GUIDELINES FOR DESIGNING AND IMPLEMENTING TRAFFIC CONTROL SYSTEMS FOR SMALL- AND MEDIUM-SIZED CITIES IN IDAHO

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Executive Summary

The State of Idaho Intelligent Transportation Systems Strategic Plan identified traffic signal upgrades and signal integration projects as high-priority projects for major cities throughout Idaho. There is a need to determine the merits of different signal control alternatives and to precisely quantify the magnitude of the incremental benefits that might be achieved through changing the signal control system to a more advanced centralized or closed loop systems. The objective of this research report is to provide the Idaho Transportation Department (ITD) staff with guidelines on how to select the most appropriate signal control system for situations encountered in Idaho cities and how to design, procure and operate advanced control systems such as closed-loop and centralized control systems.

The report documents the characteristics of traffic signal systems in different Idaho cities as well as the resources available for ITD staff in different districts. It includes a review of the state of the traffic signal control industry covering both hardware and software. The report provides developmental guidelines pertaining to the concepts of operations for signal integration projects and includes a case study for a signal integration project followed by an example of setting and managing closed-loop software. A summary of the workshop that presents guidelines for designing and implementing traffic control systems for small and medium-sized cities is presented in Appendix C.

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1.0 Introduction

In order to achieve the strategic goals of reducing congestion, improving safety on the state highway system and maintaining both operational and capital costs at minimum levels, Idaho Transportation Department (ITD) is investing in the deployment of Intelligent Transportation System (ITS) signal integration projects in a number of cities throughout the state. Because the traffic signal technology and associated capabilities are so dynamic, there are few, if any, design or process criteria and standards to guide implementation of such projects. It is difficult for traffic engineers to determine what type of traffic signal control system, supporting software, communication and detection systems they need. In addition, the implementations of such systems are often faced with many technical difficulties, especially with the limited technical resources available for the staff designing, implementing and operating the signal control systems. In order to make the best decision on the most appropriate system to achieve the strategic goals, there is a need to develop guidelines and specifications that help ITD staff and city engineers make decisions about the optimal type of different traffic control systems and to successfully procure, manage and operate such systems.

The State of Idaho Intelligent Transportation Systems Strategic Plan identified traffic signal upgrade and the development of centralized signal control systems as short-term high-priority projects for major cities throughout Idaho. However, in some instances, a closed loop system or even a traditional master-based system might be a viable alternative to centralized control. Thus, there is a need to determine the merits of these signal control systems and to precisely quantify the magnitude of the incremental benefits that might be achieved through changing the signal control system to a more advanced centralized or closed loop systems. The objective of this research report is to provide ITD staff with guidelines on how to select the most appropriate signal control system for situations encountered in Idaho cities and how to design, procure and operate advanced control systems such as closed-loop and centralized control systems.

The report is organized in six sections. After the introduction, section 2 documents the characteristics of traffic signal systems in different Idaho cities as well as resources available for ITD staff in different districts. Section 3 includes a review of the state of the traffic signal control industry covering both hardware and software. Section 4 provides guidelines on the development of concept of operations for signal integration projects. Section 5 includes a case study for a signal integration project followed by section 6 which includes an example of closed-loop software.

2.0 Existing Resources

2.1 Current Characteristics of Traffic Control Systems in Idaho Cities

The purpose of this part of the report is to summarize the characteristics of the traffic signal systems in major cities in Idaho. The characteristics of the traffic networks of 14 major cities in Idaho are summarized in Table 1 and presented in Appendix A.

Table 1. Traffic Network Characteristics for Major Idaho Cities

No.	CITY	Total number of intersections*	Number of intersections in the CBD	Number of intersections in other areas	Population**
1	Sand Point	7	6	1	7,167
2	Mountain Home	8	4	4	11,531
3	Chubbuck	9	2	7	10,002
4	Blackfoot	10	6	4	10,552
5	Rexburg	11	6	5	17,558
6	Moscow	13 (15)	8	6	21,674
7	Post Falls	14	5	9	18,738
8	Burley	15	9	6	9,375
9	Twin Falls	18 (32)	8	10	35,633
10	Caldwell	20	9	11	29,466
11	Coeur D’ Alene	29	17	12	36,259
12	Pocatello	30 (53)	13	17	51,242
13	Idaho Falls	35	17	18	51,096
14	Nampa	37	12	25	60,259

* ITD owned signals
** Population as of July 2002.

2.2 Traffic Signal Modeling Software

Traffic models can be classified into two categories based on the type of analysis they can perform: optimization models and simulation models. Optimization model are used to develop optimal signal control plans for intersections, corridors and networks. Optimization could be done using mathematical techniques, hill-climb simulation iterations or other advanced techniques such as genetic algorithms or neural networks. These may include capacity calculations, cycle length, splits optimization and coordination/offset plans. Some optimization models can also be used for optimizing ramp metering rates for freeway ramp control. The most common optimization models for traffic signal design include SYNCHRO, TRANSYT and PASSER.

SYNCHRO is a complete software package for modeling and optimizing traffic signal timings. Key features include intersection capacity analysis, optimization of cycle lengths, splits and offsets. SYNCHRO has some advantageous features such as easy data entry, complete and flexible optimization and graphical reports and Time-Space diagrams. TRANSYT is a traffic signal timing optimization software package for traffic networks and arterial streets. TRANSYT combines an optimization process (including genetic algorithm, hill-climb and multi-period optimization) with a macro-simulation model (including queue spillback, platoon dispersion and actuated control simulation). PASSER, another example of optimization software, computes cycle length and phase sequencing and splits that minimize average delay per vehicle for a pre-timed interchange. PASSER uses a deterministic, macroscopic time-scan optimization model. It can also determine splits and offsets for interchange signals along a frontage road, but in this case bandwidth is the performance objective.

Traffic simulation, however, is the process of modeling traffic events and traffic interactions on transportation facilities over a period of time. Simulation models employ mathematical techniques to predict system performance based on individual traffic events in space and time and reflect the random nature of traffic. Traffic simulation models widely used by transportation professions include CORSIM, VISSIM and Simtraffic. The characteristics of different traffic optimization/simulation models and their data input requirements are presented in Tables 2 and 3.

Table 2. Capabilities of Different Simulation and Optimization Models

Software Tool	ANALYZE									OPTIMIZE				SIMULATE							
	Freeways	Interchanges	Networks	Corridors	Links	Stop-controlled	Actuated signalized	Fixed-time signalized	Roundabouts	Network Cycle Lengths	Network Offsets	Intersection Offsets	Splits	Freeways	Interchanges	Networks	Corridors	Stop-controlled	Actuated signalized	Fixed-time signalized	Roundabouts
Synchro	■	■	■	■	■	■	■	■	■	■	■	■	■								
Transyt 7F		■	■	■	■	■	■	■	■	■	■	■	■								
Passer			■	■	■		■	■		■	■	■	■								
SimTraffic														■	■	■	■	■	■	■	■
Corsim	■	■	■		■		■	■						■	■	■	■		■	■	

Table 3. Input Requirements for Different Simulation and Optimization Models

Software Tool	Analysis Level	GEOMETRY					TRAFFIC FLOW					SIGNAL TIMING							
		Number of Lanes	Lane Canalizations	Lane Widths	Lane Alignment	Turn Pockets	Volumes	Free Flow Speed	Saturation Flow	Mean Startup Delay	Peak Hour Factor	Control Type	Min. Green	Max. Green	Yellow Time	All-Red	Vehicle Extension	Offsets	Cycle Length
Synchro	Macroscopic	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Transyt 7F	Macroscopic	■	■	■	■	■	■	■				■			■	■			■
Passer	Macroscopic	■	■	■	■	■	■	■				■			■	■			■
Corsim	Microscopic	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Simtraffic	Microscopic	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

2.3 Resources Available for ITD Staff

A survey tool (Appendix B) was used to interview ITD staff to establish typical ITD district level traffic engineering staff resources and those at ITD headquarters. This was essential in order to determine the feasible amount and type of work that ITD can be expected to do for a given traffic signal system. Staff resources are measured using information such as personnel qualifications and availability at the districts and at headquarters. This step was also important to determine the resource requirements for each type of traffic signal control in the following areas: design, installation, operation and maintenance. Resources are assigned to categories such as human resources, equipment, hardware, software, buildings, power and fees. Findings from the survey are summarized in Table 4.

Results from the survey indicated that MUTCD and ITD design manuals are the resources used the most by ITD staff. They are also the resources ITD staff is most familiar with. Few traffic modeling software are available for ITD staff, however, the staff familiarity with these models and their weekly usage ranked lower than all other resources. The survey results showed that district engineers spend, on average, more than 76% of their time on general management tasks, with less than 10% of their time dedicated to training or modeling activities.

Table 4. Summary of Resources Available to ITD Staff

Resources/ Tools	Availability	Familiarity						Uses/Week						
		Excellent	Very Good	Good	Poor	None	Index	≥ 4	3	2	1	< 1	None	Index
Synchro	50%				5	1	11					1	5	7
CORSIM	0%			1	1	4	9						6	6
Transyt 7F	17%					6	6						6	6
CORSIM (HILS)	0%			1		5	8						6	6
HCS or HiCap	83%		1	3	1	1	16			1	2	1	2	14
VISSIM	17%			1		5	8		1				5	10
ITD Traffic Manual	100%		1	4	1		18		1	1	2	2		19
HCM 2000	83%		1	2	2	1	15				2	3	1	13
ITE Traffic Ctrl. Sys. Hndbk.	67%		1	2		3	13				1	2	3	10
FHWA Traffic Ctrl. Sys. Hndbk.	17%				2	4	8					1	5	7
MUTCD	100%	1	1	4			21	3	1	1	1			30
AASHTO	100%		1	3	1		15			1	2	2		14

3.0 Characteristics of Traffic Control Systems

3.1 Overview

To justify the investment, the decision to change traffic signal control hardware and software must be based on user needs. The needs will determine what software features are required and whether a change in traffic signal control hardware is required to support those features. The traffic signal control hardware and software are closely related because certain software functions are dependent on the traffic signal control hardware capability. For example, if there is a need for more inputs and outputs than the current cabinet configurations can support, then a modification to traffic signal controller hardware and cabinets would be required to accept and process the additional inputs. Several questions need to be raised before starting the planning process for any traffic signal system.

1. How many of the current State of Idaho traffic signal control needs can be performed by existing traffic signal systems?
2. What are the limitations of the existing traffic signal control systems?
3. What percentage of intersections require operations and control capabilities beyond the current software and hardware capability?
4. What future transportation management and operations applications should the agency be preparing for?
5. If a change to the traffic signal control software specification is required, does this require a change in the hardware (controller and cabinet) specification?

The traffic signal control system user needs were developed based on input from engineers, signal technicians, maintenance staff and transportation data personnel. The user needs include both operational (i.e. local and coordinated signal timing) and functional (i.e. hardware and user interface) needs. Figure 1 illustrates the steps used to develop the needs and functional requirements.

Figure 1. Process to identify needs and define functional requirements

3.2 Advanced Traffic Signal Systems – Potential Benefits

The expectations to manage traffic in real-time in an effort to reduce congestion, improve safety and provide reliable travel times are increasing. The following are identified as key elements for the success of new signal integration projects:

1. Minimize equipment downtime: with tight operations budgets, there is a need to operate the traffic signals more efficiently with existing staff levels and budgets. Reducing the time between a fault and maintenance identification and repair such as a failed detector, controller in flash, etc., can restore intersection efficiency quickly and provide better service to the public.
2. Improve and enhance traffic signal operations and safety: the ability to remotely access the traffic signal system and adjust signal timings can minimize delay and improve intersection efficiency. Other advanced features, such as the ability to use more vehicle phases and the ability to program detector functions by input provide system operators with more tools to operate complex intersections efficiently.
3. Support advanced operations – Initiatives such as Vehicle Infrastructure Integration (VII) and additional volume and occupancy detection will require more processing power and additional capabilities beyond the existing control capabilities.
4. Support Advanced Traveler Information Systems (ATIS) applications: provide delay, travel time and congestion and incident information to the public.

3.3 Traffic Signal System Hardware: Current Technology

The purpose of this section is to summarize the state of the traffic signal control system industry and to provide the stakeholders with a background on current industry capabilities and standards. Two primary types of traffic signal controllers have dominated the market for the past thirty years: the NEMA standard controllers and the Model 170E controllers. These two standards were developed along somewhat parallel paths, but the equipment has very different physical characteristics. NEMA controllers use A, B, C and D connectors, and the Model 170E uses a C1 connector. Model 2070, while designed for a 170 type cabinet, can be installed in an existing or NEMA type cabinet without wiring modifications using an added NEMA interface. Four types of controllers are currently available in the US market:

1. NEMA-based Controllers (Currently used in the State of Idaho)
2. Model 170 Controllers
3. Model 2070 Controllers
4. Advanced Traffic Controllers (ATC)

3.3.1 Model 2070 Controllers

Specifications for the Model 2070 controller were originally developed by Caltrans and have been modified several times since the original version. The specifications for the Model 2070 controller are provided as part of the Caltrans Transportation Electrical Equipment Specifications (TEES), so the version of Model 2070 specification will often be referred to as TEES followed by the year of the specification (e.g. TEES 2002). The ATC Joint Committee (JC) modified the Caltrans TEES 1999 specification for Model 2070 controllers to be non-agency specific. The ATC JC specification for the Model 2070 controller is referred to as the ATC 2070. While ATC 2070 was developed as an open architecture application, it should be noted that not all Model 2070 local traffic signal software works on every Model 2070 hardware.

The Model 2070 specification identifies several configuration options to accommodate various user needs. The current Model 2070 standard defines several separate controller unit configurations:

a) 2070 Versions – These are mated to the 170 cabinet family and have a C1 and C11 connector for the input and output interface. The version includes:
    a. 2070V Unit – Full unit with VME cage assembly mated to the 170 and ITS cabinet family.

   b. 2070L Unit – Lite unit mated to the 170 and ITS cabinet family.
   c. 2070LC Unit – Lite unit mated to the ITS cabinet only.

b) 2070 NEMA (N) Versions – These are mated to the NEMA style cabinets and have the base module with A, B, C and D connectors.
   a. 2070VN1 Unit – Full unit with VME cage assembly mated to the TS1 cabinet family.
   b. 2070LN1 Unit – Lite unit mated to the TS1 cabinet family.
   c. 2070VN2 Unit – Full unit mated to the TS2 Type 1 cabinet family.
   d. 2070VLN2 Unit - Lite unit mated to the TS2 Type 1 cabinet family.

The 2070 L unit is referred to as the 2070 “Lite” version which comes equipped without the VME cage assembly. The 2070N comes equipped with a NEMA interface module with the standard A, B, C and D connectors for connection to a NEMA-style cabinet. The 2070 unit can come equipped with or without the VME cage assembly (2070-5). The VME cage assembly was originally intended to provide an interface with a worldwide standard of hardware that could support other applications operating on the 2070 controller in addition to the traffic signal control application. The “lite” versions of the controllers do not have the VME cage assembly and have the option for a 3.5 amp power supply (2070-4B) in lieu of the 10 amp power supply (2070-4A) used by the full 2070 versions.

3.3.2 Advanced Transportation Controller (ATC)

The ATC standard promises a traffic signal controller modeled after the personal computer (PC) industry. The intent is for the ATC controller to provide a field hardened computer that is capable of operating multiple software applications including traffic signal control, count stations, dynamic messages signs and others. The current ATC controller standard and ATC Application Programming Interface (API) standard are being developed and have not been approved.

3.3.3 Controller Communication Capabilities

The characteristics of communication port functions in different controller types are summarized in Table 5.

NEMA TS2 Type 1 and Type 2

- Port 1 Connector -- a High Speed data channel connecting the controller unit, monitor, detectors and back panel.
- Port 2 Connector -- a RS-232 (EIA/TIA Standard DTE Interface) in 25-pin configuration supporting baud rates from 1200 to 19200 bps. Used to interface with a Personal Computer, Printer or a like controller unit.
- Port 3 Connector -- Used for On-Street Communications and available in the following forms:
- 1200 Baud FSK Modem (2-wire or 4-wire)
- Fiber Optic Modem with two ports supporting baud rates from 1200 to 19200 bps.
- Port 4 Connector--- Used for On-Street Communications and available in the following forms:
- 1200 Baud FSK Modem (2-wire or 4-wire)
- Fiber Optic Modem with two ports supporting baud rates from 1200 to 19200 bps.

The TS 2 Type 2 Actuated Controller Unit includes all the features of the Type 1 and adds the following:

- MSA, MSB, and MSC connectors for data exchange with the Terminals and Facilities. This provides a degree of downward compatibility with NEMA TS 1 counterparts.
- 37-pin "D" connector for backward compatibility with TS 1 counterpart.

2070 Communication ports

- Slot A1 2070-7X or 2070-6x communication card (/SP3 AND /SP4)
- Slot A2 2070-7x or 2070-6x communication cards (/SP1 AND /SP2)
- Slot A3 2070-2A or 2070-2B Field I/O card
- Slot A4 Covered by 2070-2A and reserved for future use

- Slot A5 2070-1A Transition Board or 2070-1B CPU card
- VME Chassis 2070-1A CPU card (VME position I)
-

Table 5. Controller Communications: Port Functions

	Port	Type
NEMA TS2	Port 1 Port 2: Port 3: Port 4: MS Connector: Port A Port B Port C Port D	High Speed RS-485 Serial Port (SDLC(Synchronous Data Link Control) RS-232C-25 pin Terminal Port (TERM) RS-232 – 9 pin (Telemetry Interface Port (TLM)) RS-232 – 25 pin (Telemetry Interface Port (TLM)) 55-pin (Plug) 55-pin (Socket) 61-pin (Socket) 37-pin
NEMA TS1	Port 1 Port 2: Port 3: Port 4: MS Connector: Port A Port B Port C Port D	RS232 A RS232 B MODEM Connector Communication Inputs 55-pin (Plug) 55-pin (Socket) 61-pin (Socket) 37-pin

3.4 Traffic Signal System: Control Alternatives

Traffic signal system can be defined as a set of traffic signals that are coordinated. The most common traffic signal control systems are classified as Time-Based Coordination (TBC) Systems, Master-Based Coordination Systems, Closed-Loop Systems and Centralized signal control systems in terms of control flexibility and coordination capability. Each control system has its own different characteristics.

3.4.1 Time-Based Coordination Systems (TBC)

The Time-Based Coordination Systems (TBC) means a control system in which each local controller correspondingly assigned for each intersection operates independently without master controllers; there are no communication systems and interconnections required between controllers of the system.

The coordination is achieved through offsets and time-synchronization based upon the timing plans and schedule plans. Time and date control the system regardless of demand. The timing plan of each intersection including cycle lengths, phase, offsets and splits are predetermined; Schedule plans of each intersection such as year, week and day of week schedules are also predetermined. Time-synchronization is achieved via new controllers that use GPS clock synchronization to maintain.

The TBC system is a simple control system in which basic coordination can be programmed. The cost is relatively low because there is no equipment cost for communication network and less maintenance cost. However, the cost of modifying the system is significant, and the system doesn't have capabilities of system monitoring, data archiving and responding to unexpected traffic conditions. The clock in each controller must be periodically maintained in synch with each other for coordination. Timing plans and schedules must be updated when traffic volumes and patterns change.

3.4.2 Master-Based Coordination Systems

Master-based control system is composed of a central monitor and master-based subsystems. One set of Local controllers at signalized intersections are interconnected as a subsystem, in which master controller is assigned for the intersection with the most critical volume. Communication system including interconnections between intersections and links between each master controller and the central monitor are required. Communication control software (dial-in to the master) is typically included in the system.

Coordination of Master-Based Coordination System is achieved through offsets and time-synchronization controlled by a master controller for individual subsystem. The system can be monitored effectively. The cost of modifying the system is minimal, and there is no additional cost for communication control software. However, the system doesn't have the capabilities of data archiving, coordination among subsystems and employing responsive or adaptive system.

3.4.3 Closed Loop Systems

Closed Loop is a method of interconnecting several local controllers of signalized intersections with a master; the central system can connect with the masters via modem or phone line, while local controllers composing of a subsystem communicate with the master via fiber optic cables, electrical cables or twisted pair wire, sending back information regarding their operations. It is common to assign one master controller for each subsystem. These allow an operator, through a central office computer, to monitor on-street masters and subsystems for proper operation as well as the ability to change timing functions.

Closed-Loop Systems require a communication system for interconnections between intersections and links between each master and the center. Control software is typically included in the system. System detectors are additionally needed to determine the traffic demand level. Closed Loop Systems are similar to Master-Based Coordination Systems; its Coordination is achieved through offsets and time-synchronization controlled by a master controller for each subsystem. The system can be monitored effectively, and the system has capabilities of easy access maintenance, data archiving, conducting possible coordination among subsystems and employing both responsive and adaptive systems. The cost of modifying the system is minimal. However, there is an additional cost for control software ranging from $40,000 to $80,000 for employing responsive and adaptive system. The predefined and static subsystems might not coordinate well together.

3.4.4 Centralized System

Centralized System is a computer control system in which the central computer, central communication facilities and display equipment are all situated at the same single location, and the center interconnects and communicates directly with each local controller. From this center, an operator can coordinate and control traffic signals and related traffic control functions throughout the whole area.

Centralized Systems require a communication system for links between each intersection and the center. Direct communication is required between each intersection and the center. There are no masters required; the subsystem can be defined dynamically, therefore the local controllers of local signalized intersections can easily be moved in and out of systems as traffic volume and patterns change; in addition, changes in traffic patterns can be quickly identified from the center. Centralized Systems are similar to Closed-Loop systems; it's coordination is achieved through offsets and time-synchronization managed by the central control software. The system can be monitored effectively, and the system has capabilities of good data archiving, good coordination among intersections and employing both responsive and adaptive system. The cost of modifying the system is minimal. However, an extensive communication network between each intersection and the center is required; there is an additional cost for control software ranging from $80,000 to $400,000 for employing responsive and adaptive systems. Typically a sub-component of ATMS software is required.

3.4.5 Characteristics of Different Traffic Control Systems

In general, each traffic signal control system is designed to maximize traffic flow efficiency and public safety, accurately monitor traffic flows, make appropriate traffic control decisions in a timely manner and reduce fuel consumption and environmental impact of stop-and-go traffic through improvements to traffic flow efficiency. An efficient traffic signal system should have the ability to optimize available capacity on surface streets through continuous adjustment of traffic control and coordination parameters. Another function of traffic signal control systems is to monitor equipment for faults or malfunctions that may affect the system's or controller's ability to properly control traffic flow through an intersection. Such malfunctions might include a signal head indicator failure, detector failure, conflict in signal indications, a broken communications link or a power failure in a field device. The objective of monitoring is to identify system and equipment operational problems and initiate corrective actions and repair responses to return the equipment to its proper operating condition as quickly as possible in order to keep traffic flow interruptions to a minimum.

When distinguishing between traffic control systems, two factors should be taken into consideration: 1) the way coordination between signals is achieved, and 2) the way a control plan selection is being done. Coordination between signals can be achieved through one the following methods:

1. Time-based coordination. In this method, no interconnect between intersections or a master controller is needed, coordination is achieved through time synchronization between different intersections.
2. Interconnected time-base coordinated with field master. This method has two level distributed controls: master and local controllers. Field master based systems are often implemented by field microprocessors computers that serve as on-street masters controllers.
3. Closed loop systems with Field masters. This method has three level distributed controls: PC with control algorithm in the closed-loop software, master and local controllers.
4. Centralized control systems. This method has two level distributed controls: PC with control algorithm in the centralized control software and local controllers.

Plan selection can be done using one of the following four methods:

1. Manual plan selection
2. Time of day control
3. Responsive systems
4. Adaptive systems

Field master based systems are often implemented by field microprocessor computers that serve as on-street master controllers. Adding a computer, with software that runs specific signal control algorithm to the field master system would upgrade the signal system operation to “closed-loop” operations. Closed-loop systems provide two-way communication between the intersection signal controller and its master controller. The master controller communicates to the traffic operation center. The central computer provides the capability to monitor traffic conditions and change timing plans and other control parameters by downloading this information to the field master controller then to local controllers. The master controller could be located at an intersection or at a central location such as traffic operation center. In addition to traffic plan commands, the master controller sends time synchronization signals to the intersection controllers.

Closed-loop system can determine proper system detection function by checking detector information with historical traffic information in its database or a preset algorithm which notes continuous detector response over a given time period. With many closed-loop systems, the operator can override either the time-of-day or traffic responsive plan and select another timing plan. Intersection controllers maintain several traffic control plans, which the master controller can select. In centralized computerized systems, the ability to make control decisions and to issue control commands is placed at one location, typically at the traffic operation center. This control system employs, in contrast to the field master and closed-loop systems, a non-distributed control operation.

In responsive systems, the traffic flow information collected by surveillance equipment allows master controllers or control software (closed-loop or central control software) to process detector data and select the cycle length, split and offset setting on the field controllers from a group of signal timing plans configured in the local controller. Adaptive systems, however, are more sophisticated. Traffic flow information coming from detectors are being used to predict future traffic demands at the network then use these future demands predicted to develop optimal control plans at the network and local intersection levels. These control plans are then uploaded to the local controllers. Adaptive control logic is available only in centralized control software.

3.5 Standard-Based Traffic Signal Systems

3.5.1 ITS Standards: An Overview

ITS Standards are documented guidelines or rules specifying the interconnections among elements and the performance required of technologies and products to be used in ITS installations. Standards describe in detail what types of interfaces should exist between ITS components and how the components will exchange information and work together to deliver certain user services. Standards define, for example, data elements and message sets used by devices and systems or certain physical characteristics of a particular device. Communication protocols are collections of rules for moving data elements and messages between devices and systems within the context or framework established by the National ITS Architecture. Section 520.6(e) of TEA-21 explicitly requires that all ITS projects funded through the Highway Trust Fund “conform to the national architecture, applicable standards or provisional standards, and protocols.”

Figure 2 shows as example of the integration of a signal project (the Moscow ITS project) within the Idaho regional ITS architecture.

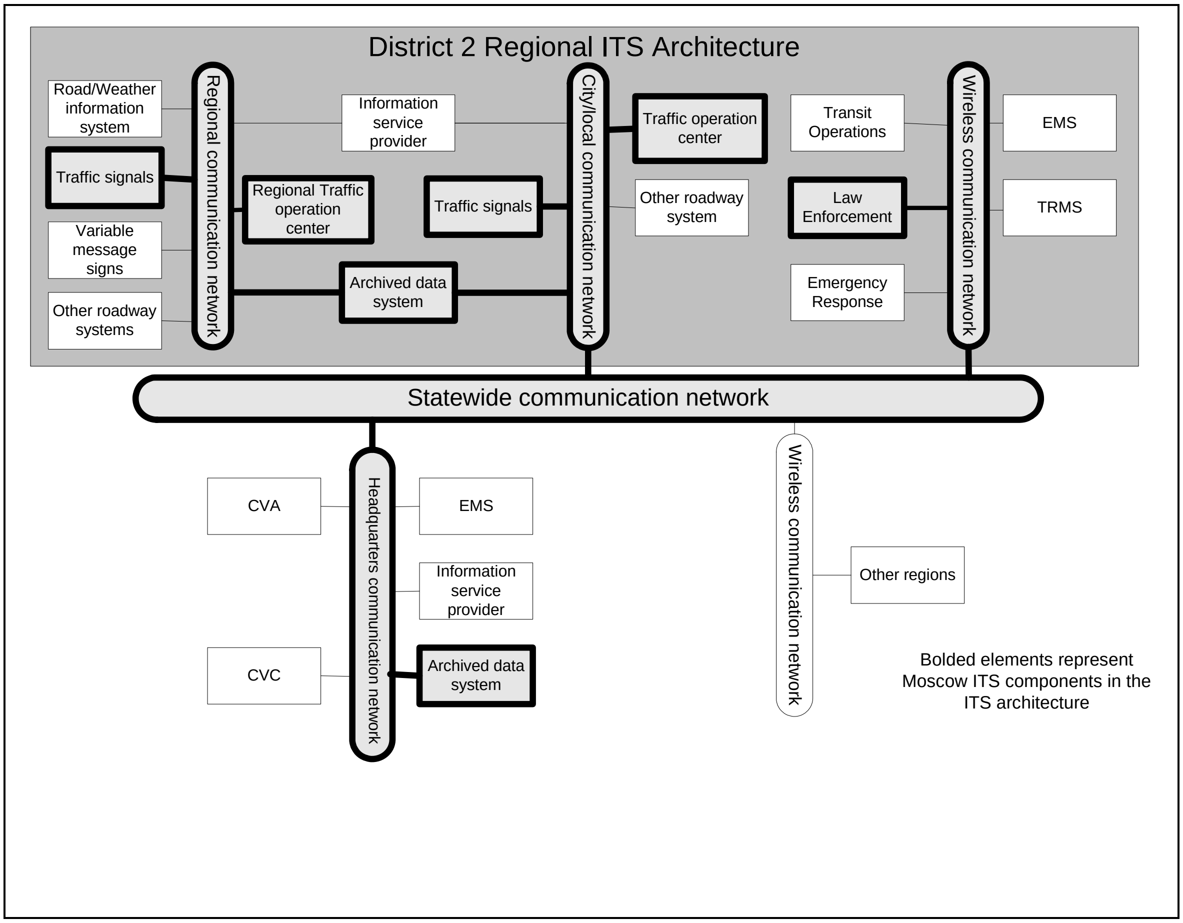


Figure 2. Integrating Signal Integration Projects within regional architecture

3.5.2 National ITS Architecture

The national ITS architecture provides a framework for planning, defining and integrating intelligent transportation systems, including signal integration projects. It reflects the contributions of a broad cross-section of the ITS community (transportation practitioners, systems engineers, system developers, technology specialists, consultants, etc.). The architecture is a national consensus on the course that ITS development should take in the United State, defining the functions (e.g., gather traffic information or request a route) required for ITS, the physical entities or subsystems where these functions reside (e.g., the roadside or the vehicle) and the information and data flows that connect these functions and physical subsystems into an integrated system.

The Architecture describes the required interfaces descriptively; it is a reference framework. There are many different ways to design an architecture-defined interface. To provide the desired interoperability, consensus standards are needed. No matter how complete an architectural master plan may be, standardized parts are needed to carry out the plan consistently.

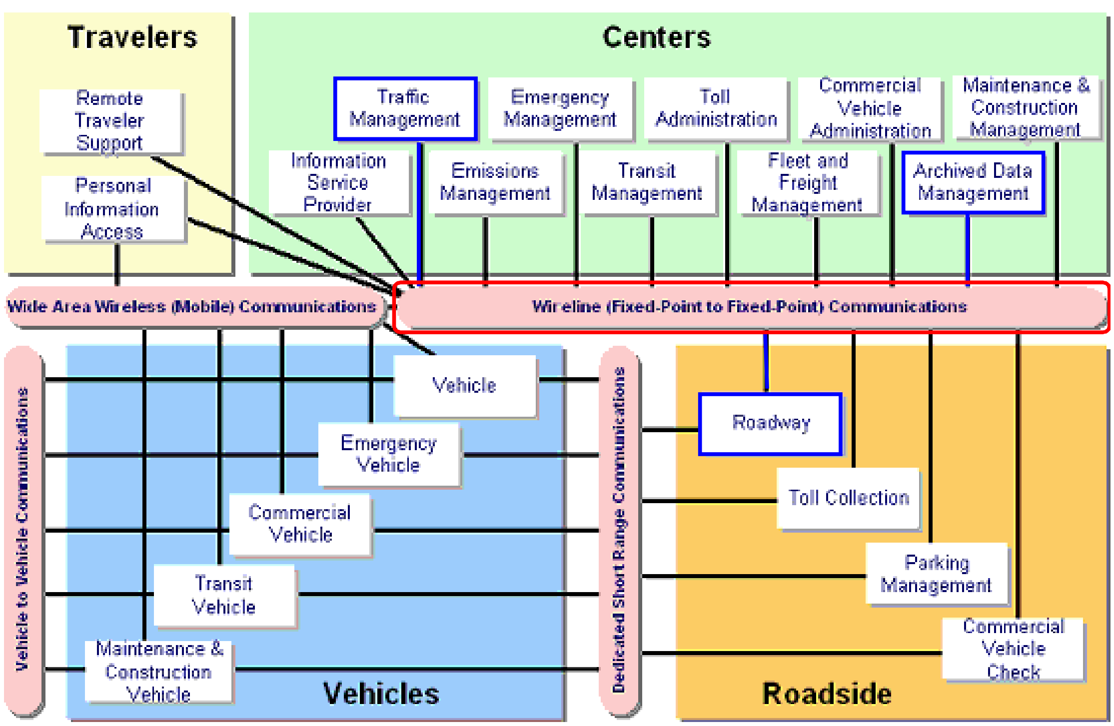


Figure 3. Physical Entities of National ITS Architecture Related to Traffic Signal Project

ITS standards can be categorized into three sets of standards: hardware/software standards, human factors standards and the communication standards.

3.5.2.1 Hardware / software standards

Hardware/software standards define the standards for physical devices such as controller (Controller Housing, CPU Assembly, Communication Modules, etc.) and cabinets (Input Assembly, Output Assembly, Power Distribution Assembly, etc.). They also define the standards for the software that control those physical devices (Applications, Application Program Interface, Operation System, etc.) Examples of the Hardware/software standards are:

1. NEMA TS2-1998 traffic controller assembly with NTCIP requirements
2. Standard practice for installation of fiber optic cables
3. ITS cabinet subsystem definitions
4. Advanced Transportation Controller (ATC)

3.5.2.2 Human factors standards

Human factors standards define how to design ITS systems safely for humans and provide consistent operating characteristics and control/interface design. The Society of Automotive Engineers (SAE) has developed series of standards for in-vehicle system.

3.5.2.3 Communication standards

Communication standards allow different systems to speak with each other in a common language, using common data elements, well-defined data structures or ”messages” and well-understood protocols or rules for data exchange and sharing. Communication protocols define sets of rules for moving data and associated messages. Figure 4 and Figure 5 show a typical NTCIP communication framework for a traffic signal system and a closed-loop signal system, respectively.

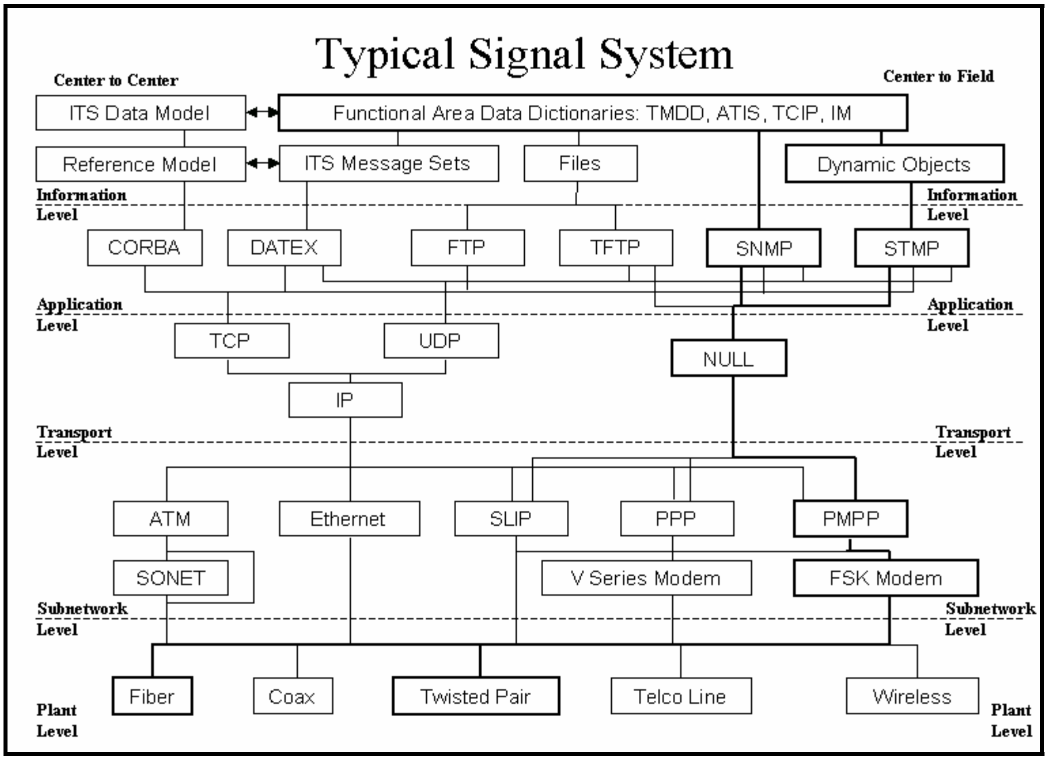


Figure 4. NTCIP Communication Framework for a Traffic Signal System

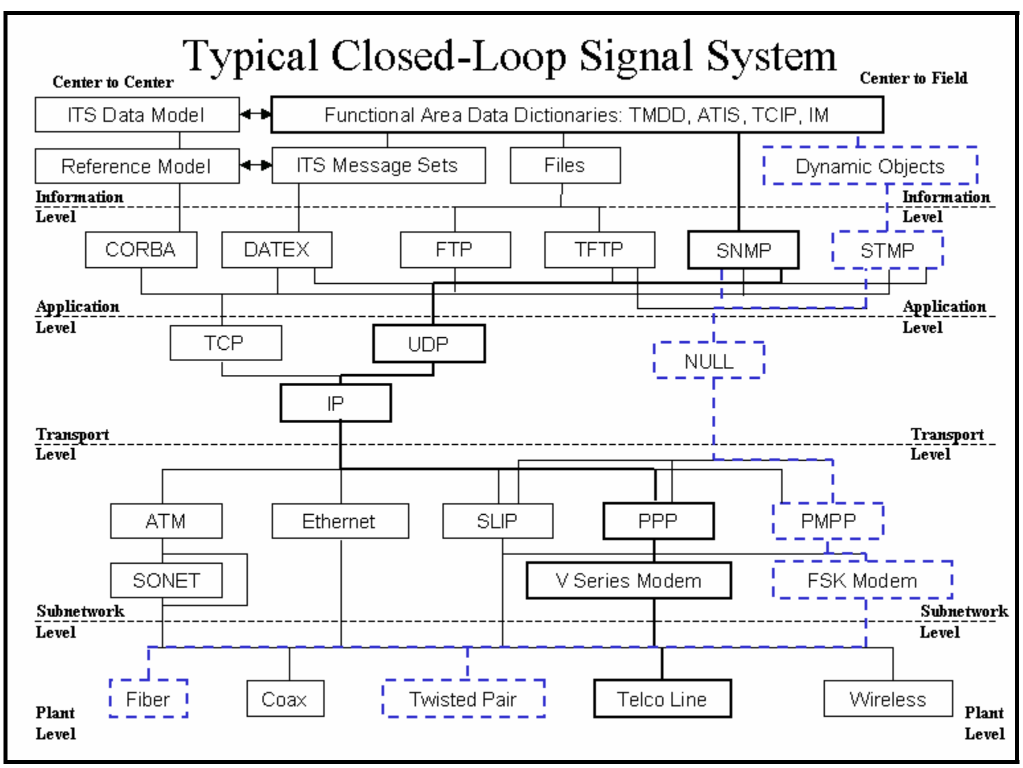


Figure 5. NTCIP Communication Framework for a Closed-Loop Signal System

3.5.3 National Transportation Communications for ITS Protocol (NTCIP) Standards

The National Transportation Communications for ITS Protocol (NTCIP) defines a common set of rules for communicating (called protocols) and the vocabulary (called objects and data definitions) to allow electronic devices from different manufacturers to operate with each other as a common system. The NTCIP 1202 standard defines the objects for Actuated Traffic Signal Controller Units. The NTCIP 1202 standard contains the bare minimum list of controller features, and the majority of objects in the NTCIP 1202 standard (version 1 and 2) are optional. To claim conformance, a vendor only needs to implement the objects that are listed as mandatory in the NTCIP 1202 standard. The NTCIP standard is separated into “Conformance Groups” that are used to specify a collection of related managed objects. Each conformance group is designated as either mandatory or optional, and the objects within the group are also designated as either Mandatory or Optional. Table 6 lists communication standards related to traffic signal systems.

Table 6. NTCIP Standards Related to Traffic Signal Systems

Standard Number and Title	Development Status
NTCIP 1101: Simple Transportation Management Framework (STMF)	Published
NTCIP 1102: Octet Encoding Rules (OER) Base Protocol	Approved
NTCIP 1103: Transportation Management Protocols (TMP)	Approved
NTCIP 1201: Global Object Definitions	Approved
NTCIP 1202: Object Definitions for Actuated Traffic Signal Controller (ASC) Units	Approved
NTCIP 1209: Data Element Definitions for Transportation Sensor Systems (TSS)	Under Development
NTCIP 1210: Field Management Stations (FMS) – Part 1: Object Definitions for Signal System Masters	Under Development
NTCIP 1211: Object Definitions for Signal Control and Prioritization (SCP)	Approved
NTCIP 2101: Point to Multi-Point Protocol Using RS-232 Subnetwork Profile	Published
NTCIP 2102: Point to Multi-Point Protocol Using FSK Subnetwork Profile	Published
NTCIP 2103: Point to Multi-Point Protocol Over RS-232 Subnetwork Profile	In Ballot
NTCIP 2104: Ethernet Subnetwork Profile	Published
NTCIP 2201: Transportation Transport Profile	Published
NTCIP 2202: Internet (TCP/IP and UDP/IP) Transport Profile	Published
NTCIP 2301: Simple Transportation Management Framework (STMF) Application Profile	Under Development
NTCIP 2302: Trivial File Transfer Protocol (TFTP) Application Profile	Published
NTCIP 2303: File Transfer Protocol (FTP) Application Profile	Published
NTCIP 8003: Profile Framework	Published
NTCIP 9001: NTCIP Guide	Under Development
ITE 9603-1: Application Programming Interface (API) Standard for the Advanced Transportation Controller (ATC)	Under Development
ITE 9603-2: Advanced Transportation Controller (ATC) Cabinet	Under Development
ITE 9603-3: Advanced Transportation Controller (ATC)	In Ballot
SAE J2266: Location Referencing Message Specification (LRMS)	Published

4.0 Traffic Control Systems: Concept of Operation

4.1 Overview

What is the concept of an operations report and why is it an important part of this project? The concept of an operations report describes several important elements of the project. It describes the system that will be designed or upgraded. It defines what functions the system will accomplish, and the processes by which the system will accomplish these functions. And it identifies the stakeholders who have some responsibility for the design, operation and/or maintenance of the system.

Guidance for the preparation of this report comes from the report: Transportation Management Center-Concepts of Operation, Implementation Guide, prepared for the Federal Highway Administration and the Federal Transit Administration in December 1999. Two excerpts from the FHWA/FTA report are particularly relevant:

> In its simplest definition, a concept of operations for a [system] defines what the [system] accomplishes, and how it goes about accomplishing it. Thus, it defines functions (what is accomplished) and processes (how they are accomplished). The concept of operations ideally addresses both operations and maintenance of the [system], and the resources for which it is responsible. It describes the interactions that occur within the [system], and between the [system] and its partners (firms and agencies) and customers (motorists, media, etc.) in managing transportation. As a tool developed primarily in the planning stage, it often works at a summary level. It is not intended to serve as an operations manual, although it may follow a similar outline.
>
> The concept of operations is often the first detailed examination of the idea for implementing a system. It will provide guidance and direction to help ensure that the subsequent procurements result in the type of facility and systems that best serve the agency's needs, and which represent an effective utilization of limited budgetary funds. It will also assure that the operational needs of the [system] are consistent with the resources and policies of the responsible agencies. Thus, a path can be laid for successful operations and maintenance, realizing the maximum possible benefit from the investment.

This guide can be obtained from the U.S. Department of Transportation's ITS electronic document library.

4.2 Concept of Operations: Systems engineering approach

Systems engineering involves the transformation of an operational need into a description of system performance parameters and a preferred system configuration. This is done through the use of an iterative process of functional analysis, synthesis, definition, design, testing and evaluation. The systems engineering approach seeks to maximize efficiency and effectiveness through employing a continuous and iterative process that incorporates the feedback actions necessary to ensure convergence to the most optimal solution. Systems engineering will be used in the development of this project and the design of its various components.

There are several systems engineering models that can be used. The V^{++} model was selected as the systems engineering approach that will be employed in the development of the Moscow ITS project and in the development of this concept of operation report. The V^{++} model is a three-dimensional systems development model that includes decomposition, verification and resolution processes.

Figure 6 presents the V^{++} model that was adapted for use during the Moscow ITS project and for the development of this concept of operations report. It shows the tasks that will be completed as part of the project represented on the left side of the V. The required testing and validation for each task are represented on the right side of the V. This shows the feedback process inherent in the systems engineering approach and the importance of testing and validating each part of the project.

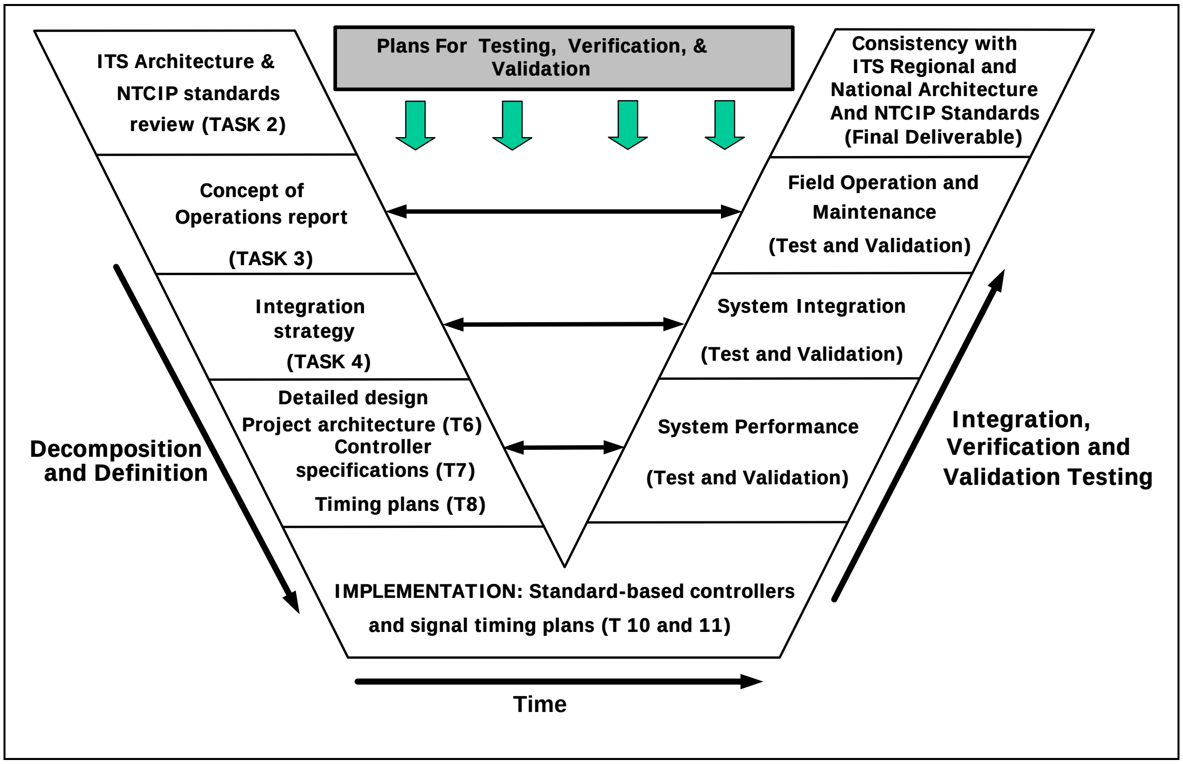


Figure 6. A systems engineering approach for a Signal Integration Project

4.3 Concept of Operations: Defining System Requirements

4.3.1 Identifying Project stakeholders

A stakeholder is someone who has a share or an interest in an endeavor or enterprise. For signal integration project, the endeavor or enterprise is the traffic signal system and its associated devices that are located within the traffic signal system. A possible list of stakeholders includes: FHWA, the city and county at which the signal system is located, Idaho Department of Administration-Division of Information Technology who operates the statewide microwave communication network, private communications service providers such as local Internet service providers may be utilized as communication links, and railroad operators have an interest in improving railroad crossing operations and safety.

4.3.2 Identifying stakeholder needs and proposed system requirements

Once stakeholders are identified, their need should be reviewed and coordinated. The following functional and operational needs are identified by the signal integration project stakeholders:

- A traffic signal system that safely and effectively moves people and vehicles through and within the City of Moscow.
- A traffic signal system that can be integrated with ITD’s regional architecture and national ITS standards.
- A traffic signal system that is flexible and can be expanded to meet future needs.
- A traffic signal system that adapts to changing traffic conditions and responds to special events and to pedestrian and bicycle flows.
- A traffic signal system that can be easily and remotely maintained.
- A communications infrastructure that provides links between signalized intersections with the central traffic operations centers and to the city’s operations center.
- A roadway sensor or detection system that monitors traffic signal system performance and changing traffic flow conditions and provides continuous system evaluation and diagnostics.
- A data archiving system that collects, aggregates and archives traffic flow and signal timing data.
- A surveillance system that provides real-time monitoring of the city traffic signal network.
- Highway/rail intersections that use signal preemption and interconnects

These operational and functional needs are then translated into system requirements. Table 7 lists the system requirements as defined for the City of Moscow Signal Integration project.

Table 7. System requirements as identified by primary project stakeholders

System Requirements	Agency responsible	Stakeholders
A traffic signal system [controllers and cabinets] that: ▪ Responds to varying traffic conditions and provides progressive traffic flow between intersections ▪ Responds to special events and to pedestrian and bicycle flows ▪ Communicates equipment status to ITD and the city ▪ Is integrated into the regional architecture and is consistent with national standards ▪ Is NTCIP compliant ▪ Is flexible and expandable to meet future needs ▪ Provides secure and reliable signal system operations ▪ Is maintainable with access to replaceable parts ▪ Improves railroad crossing safety and operations	ITD	FHWA ITD City of Moscow Railroad operators
A field data collection and surveillance system that: ▪ Collects traffic flow and signal timing data ▪ Provides traffic flow data to users	ITD	ITD City of Moscow
A data archiving system that: ▪ Archives traffic flow and signal timing data	ITD	ITD City of Moscow
A surveillance system that: • Transmits real time CCVT images to the traffic operation center	ITD	ITD City of Moscow

4.3.3 Documenting existing conditions

This step includes a documentation of existing conditions. This should include signal control hardware (controller and cabinets), detection devices and interconnect. This step should also include a documentation of system performance measures using field travel-time and delay studies.

4.3.4 Identifying available resources

This step includes identifying resources available for the signal integration project. Resources include items such as communication networks available both public (state, regional and local) and private. Resources should also include current and future road improvement and transportation projects in the area.

4.3.5 Defining system components, functions and requirements

Based on the system requirements identified for the project and the functional and operational needs of the project stakeholders, system requirements can be identified and documented. System requirements for a typical signal integration project include:

a) Traffic Signal System
   - Traffic controllers that are:
     - Defined by open (NTCIP) standards
     - Compliant with the NTCIP and other relevant ITS standards (as identified in task 2 of this project)
     - Supported by Windows-based software
     - Actuated and traffic responsive
     - Interconnected for progressed traffic flow
     - Connected to District 2 traffic operation center for support, management and maintenance
   - Cabinets that:
     - Are suitable for ITS applications
     - Allow for serial bus communication
     - Connected to District 2 traffic operations center

b) Field data collection and surveillance system that:
   - Collects all field detection data from loop and video detectors
   - Communicates real-time CCTV images to the traffic operation center and the City of Moscow Police

c) Data archiving system that:
   - Aggregates and archives all field data in a format that is usable by ITD and others
   - Provides traffic flow and signal operation data on a regular basis to ITD headquarters, City of Moscow and NIATT.

d) Communication infrastructure that is:
   - Capable of supporting NTCIP communication standards

- o Capable of communicating field object status and detection data to ITD District 2 traffic operation center, City of Moscow traffic operation center and UI traffic controller laboratory
- o Reliable and secure.

4.3.6 Identifying devices in the system and operational facility needs

Once the system requirements are defined, devices proposed for inclusion in the system can be identified. The proposed devices should include local traffic controllers, master controllers, control centers, detection devices, surveillance cameras, and communications system components. An example of a proposed list for the City of Moscow signal integration project is shown in Table 8.

Table 8. Proposed devices, communication linkages, and facilities

	Device	Description	Number of Devices
Devices in the system	Local controllers/cabinets	NTCIP compliant controllers and cabinets	12-15
	Master controllers/cabinets	NTCIP compliant mater controllers and cabinets	0-3
	Detection systems at signalized intersections	Improve detection capabilities at intersection. Add loop/video detection to CBD intersections	15
	CCTV surveillance cameras	CCTV dome cameras at three locations	3
	Data archiving system	Data and video servers, storage capacity, data aggregation and archiving capacity, data analysis capacity	1
Communication	Devices/system/linkages between each of the 15 intersections and ITD District 2 traffic operation center	NTCIP Center-to-Field communication standards	
	Communication between ITD District 2 traffic operation center and the City of Moscow Traffic operation center	NTCIP Center-to-Center communication standards	
	Communication between ITD District 2 traffic operation center and UI traffic controller laboratory	NTCIP Center-to-Center communication standards	
	Communication between ITD District 2 traffic operation center and ITD Traffic facility and the City of Moscow Police	NTCIP Center-to-Center communication standards	
Centers	ITD District 2 traffic operation	Located in ITD District 2 headquarters in Lewiston, Idaho	1
	City of Moscow traffic operation center	Located in the city of Moscow, Moscow, Idaho.	1

4.3.7 Defining interagency coordination and integration

This task addresses the interagency coordination required during two stages of the project: the implementation and operational stages based on stakeholders needs and responsibilities identified in earlier steps.

4.3.8 Defining system integration and testing plan

This task addresses the integration and testing required for different components of the traffic signal system. This should include initial testing and acceptance of different system devices and communication links. It also includes identifying required system reliability and safety and defining system accessibility and security hierarchy levels. Issues such as field access to the controllers and cabinets, remote access to different field devices and authorization to modify device settings should be addressed at this stage.

4.3.9 Defining system integration with legacy systems

The operation of the legacy systems that are not part of the project shall be examined under the proposed configuration of the new proposed system to ensure integration and interoperability between legacy system and new proposed system. In case there is any conflict between the standards-based equipment with the legacy system, action should be taken to upgrade the legacy system to be standard-compliant.

5.0 Potential Benefits of Signal Integration Projects: A Case Study

This section includes a case study to access the potential benefits of signal integration projects for small and medium size cities.

5.1 Modeling the Operations of Traffic Signal Systems

5.1.1 City of Moscow

a) Master-based case design—fixed time coordination and actuated-coordination will be considered.
   - Scenario 1: Zone A, master intersection: Line & SH8
   - Scenario 2: Zone B
     - Alternative1: Zone B, master intersection: A& Jackson,
     - Alternative2: Zone B, master intersection: 6th & Washington
   - Scenario 3: Zone C, master intersection: SH8&US 95

b) Closed-Loop case design—fixed time coordination and actuated-coordination will be considered.
   - Scenario 1: Zone A, master controller 1 needed;
   - Scenario 2: Zone B, master controller 2 needed;
   - Scenario 3: Zone C, master controller 3 needed;
   - Scenario 4: Zone B plus SH8 & US 95, Sweet & 95, master controller 4 needed;
   - One central monitor that connects master controller 1, 2, 3and 4 needed.

c) Centralized signal system—Fixed time coordination and actuated-coordination signal design will be considered.
   - Scenario 1: peak hour period (morning and afternoon): interconnect Zone A, B, C
   - Scenario 2: non-peak hour period: interconnect intersections on US 95 North to 3rd St. West, farther to SH8 West, including: Sweet St.& US95, H8&US95, 6th& Washington, 3rd&Washington, 3rd & Main, 3rd&Jackson, SH8& Line, SH 8& Farm and SH8 &Warbonet.

- Scenario 3: non-peak hour period: interconnect US 95 south intersections: A&Jackson, 3rd&Jackson, 6th&Jackson and US 96 north intersections: Sweet&US 95, SH8&US95, 6th&Washington, 3rd&Washington.

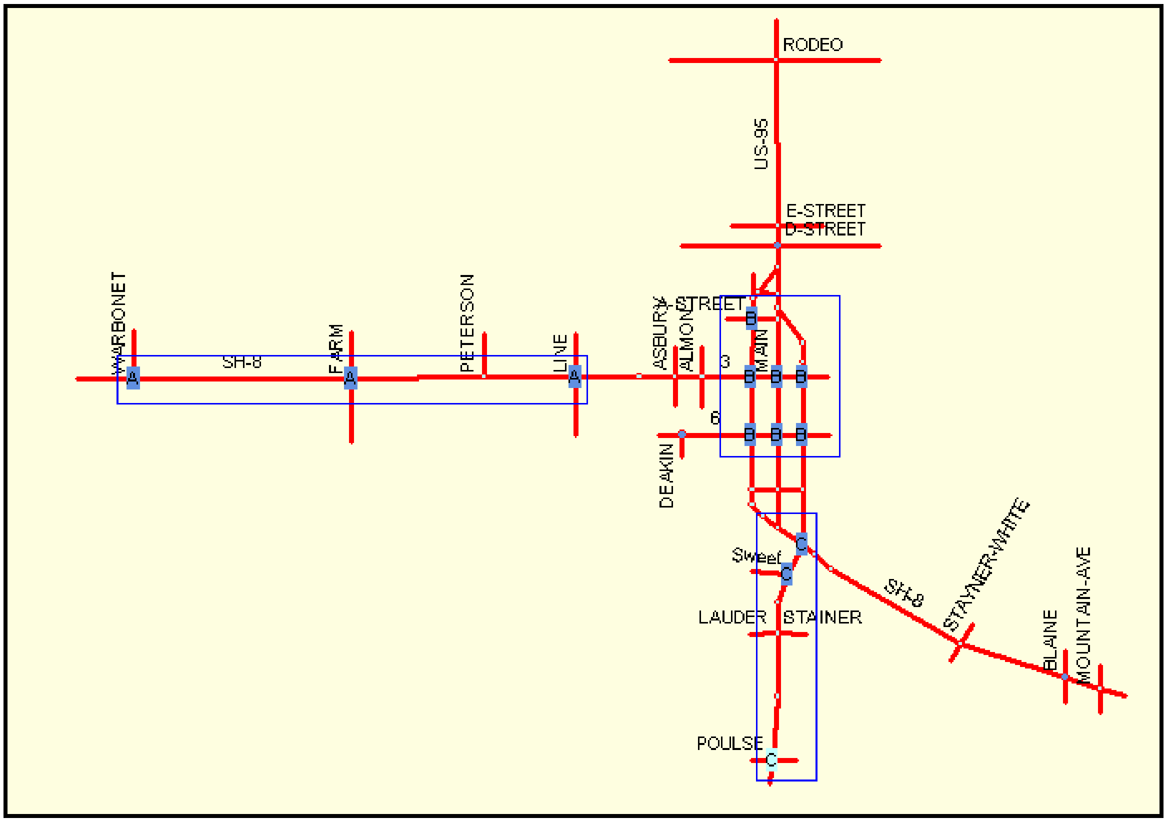


Figure 7. City of Moscow Traffic Signal System

5.1.2 City of Twin Falls

a) Master-based design—fixed and actuated-coordination will be considered.
- Scenario 1: Zone A, master intersection: Eastland Dr.& Kimberly Rd.
- Scenario 2: Zone B, master intersection: Eastland Dr.& Elizabeth Blvd.
- Scenario 3: Zone C, master intersection: Blue Lakes Blvd.& Falls Ave.
- Scenario 4: Zone D, master intersection: Eastland Dr.& Bridgeview Blvd.
- Scenario 5: Zone E, master intersection: Washington St.& 6th Ave. N.
- Scenario 6: Zone F, master intersection: Morrison St.& Addison Ave.

b) Closed Loop case design-- fixed-coordination and actuated-coordination will be considered.

- Scenario 1: Zone A, master controller 1 needed;
- Scenario 2: Zone B, master controller 2 needed;
- Scenario 3: Zone C, master controller 3 needed;
- Scenario 4: Zone D, master controller 4 needed
- Scenario 5: Zone E, master controller 5 needed;
- Scenario 6: Zone F, master controller 6 needed;
- One central monitor that connects master controller 1, 2, 3, 4, 5 needed.

c) Centralized signal system-- Fixed-coordination and actuated-coordination signal design will be considered.

- Scenario 1: peak hour period (morning and afternoon): interconnect subsystem 1, 2 and 3.
  - Subsystem 1: intersections on Eastland Dr. and Kimberly, including Kimberly & Blue, Kimberly& Locust, Kimberly & Eastland Dr., Elizabeth Blvd.& Eastland Dr., Addison & Eastland, Filer & Eastland, and Falls & Eastland.
  - Subsystem 2: intersections on Blue and Locust, including Addison& Blue, Heybum & Blue, Filer& Blue, and Falls& Blue, Addison& Locust, Filer& Locust, and Falls& Locust.
  - Subsystem 3: Zone E.
- Scenario 2: non-peak hour period: interconnect Zone B, C and Zone E
- Scenario 3: non-peak hour period: interconnect Zone A, B, C, D, E and F

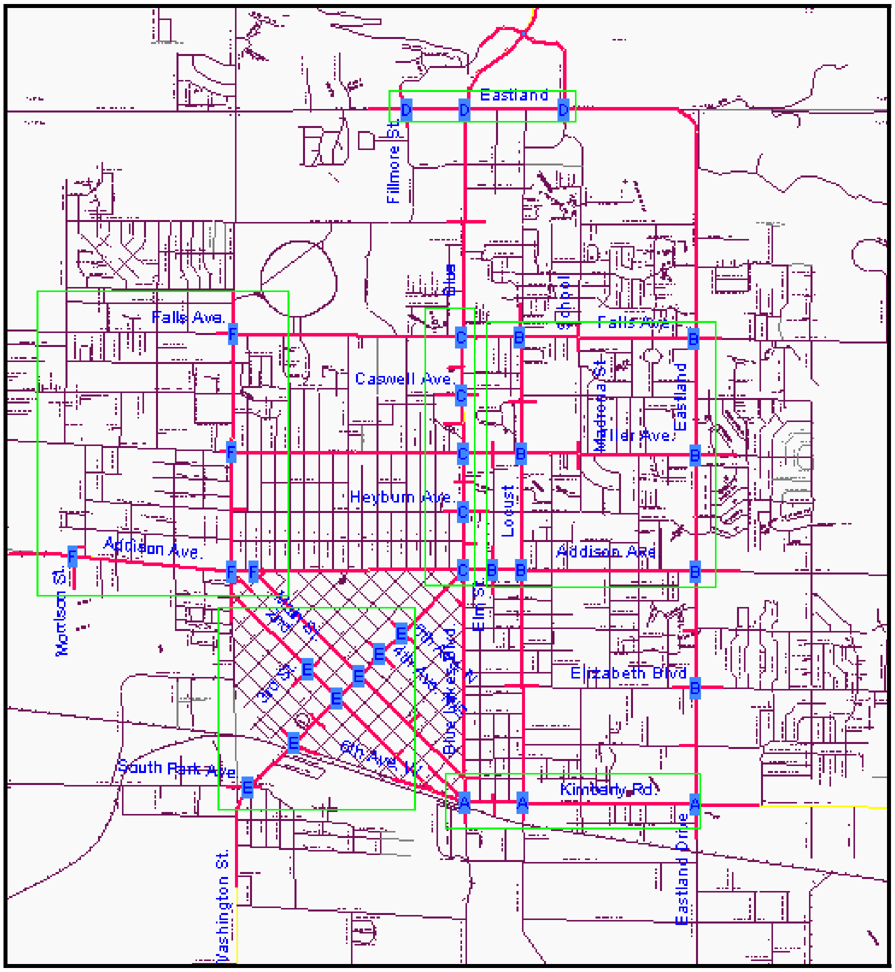


Figure 8. City of Twin Falls Traffic Signal System

5.1.3 City of Pocatello

a) Master-based case design—fixed-coordination and actuated-coordination will be considered.

- Scenario 1: Zone A, master intersection: Fred Meyer & Warren
- Scenario 2: Zone B, master intersection: Fred Meyer & Pole Line
- Scenario 3: Zone C, master intersection: Chubbuck & Yellowstone
- Scenario 4: Zone D, master intersection: Fred Meyer & I-15 NB On
- Scenario 5: Zone E, master intersection: Clark& I-15 NB On

b) Closed Loop case design-- fixed-coordination and actuated-coordination will be considered.

- Scenario 1: Zone A, master controller 1 needed;
- Scenario 2: Zone B, master controller 2 needed;

- Scenario 3: Zone C, master controller 3 needed;
- Scenario 4: Zone D, master controller 4 needed;
- Scenario 5: Zone E, master controller 5 needed;
- One central monitor that connects master controller 1, 2, 3, 4 and 5 needed.

c) Centralized signal system-- Fixed-coordination and actuated-coordination signal design will be considered.

- Scenario 1: peak hour period (morning and afternoon): interconnect subsystem 1, 2 and 3.
    - Subsystem 1: Zone A
    - Subsystem 2: Zone B
    - Subsystem 3: Zone C
- Scenario 2: non-peak hour period: interconnect subsystem 4 (Zone D) and subsystem 5 (Zone E)
- Scenario 3: non-peak hour period: All subsystem operates individually

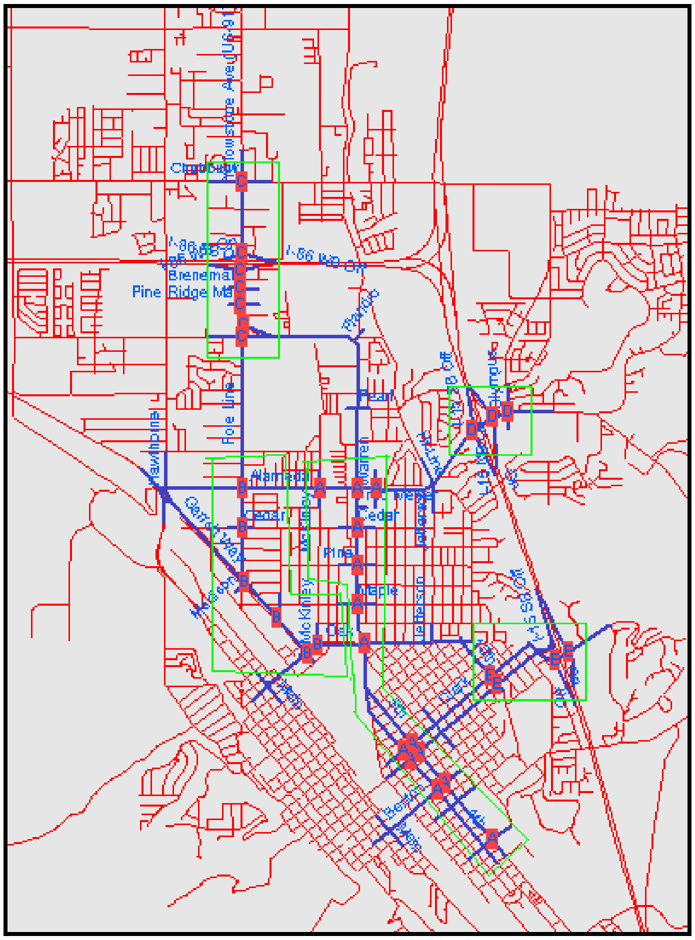


Figure 9. City of Pocatello Traffic Signal System

5.2 Signal Integration Projects: Accessing Potential Benefits

5.2.1 Overview

This section presents the results of a cost/benefit analysis conducted as part of the city of Moscow ITS signal integration project. The city of Moscow is a small-size city located in the North Idaho region. The results of the cost/benefit analysis show that the potential delay reduction benefits resulting from advanced control features included in signal integration projects, such as responsive or adaptive control, may not be the primary benefit of these projects. Some of these delay reduction benefits could still be achieved through less advanced control systems. Institutional benefits such as the ability to continuously monitor system devices, the ability to troubleshoot some of the device problems from the control center and the ability to monitor the network performance through CCVT cameras seem to be the primary benefits of such signal integration projects.

Idaho Transportation Department (ITD) has recognized that there is a wide range of transportation problems that must be addressed throughout the state, particularly in the state's small rural towns. A statewide planning effort was initiated in 1999 to evaluate the potential of advanced technologies to help address transportation related needs and to develop a statewide Intelligent Transportation System master plan. The statewide plan recognizes that, while important new traffic technologies are being applied to larger urban areas, there has been little effort to date to apply these technologies to improving traffic problems in smaller towns. Further, there has historically been little technical expertise available in these small towns to provide basic traffic signal-timing analysis and operational improvements.

The statewide ITS plan identified traffic signal control systems and highway-railroad intersections as two of the most important ITS categories applicable to Idaho's rural towns. The plan suggested the following strategies for consideration in future projects: signal coordination, signal systems interconnection, actuation, signal hardware improvements, improved detection components and enhanced rail crossing integration. The statewide ITS plan recommended a high priority project to address traffic flow problems in the city of Moscow, Idaho.

The city currently has a total of sixteen intersections, shown in Figure 10. Seven of the intersections (in the downtown area) are interconnected through twisted pairs of copper lines. These intersections operate on a fixed time mode as there are no detection capabilities at these intersections. Three intersections on the west side of the city are interconnected through 6-strand fiber optic cables. The remaining 6 intersections are operating on isolated actuated mode with no interconnection. Of the 9 intersections that have detection, two intersections only use video-detection, while the other seven intersections use inductive-loop detectors.

A signal integration project for the city started in 2001, with a total budget of $1,634,459. The project has the following three major objectives:

1. Deploy a standards-based traffic signal controller system that could be used as a test for the implementation of NTCIP standards in a small-town traffic control system.
2. Connect all signals in the city's traffic signal system to the district and the city operational management centers through fiber optic communication network.
3. Develop a data archiving system to collect and archive traffic flow and system performance data.

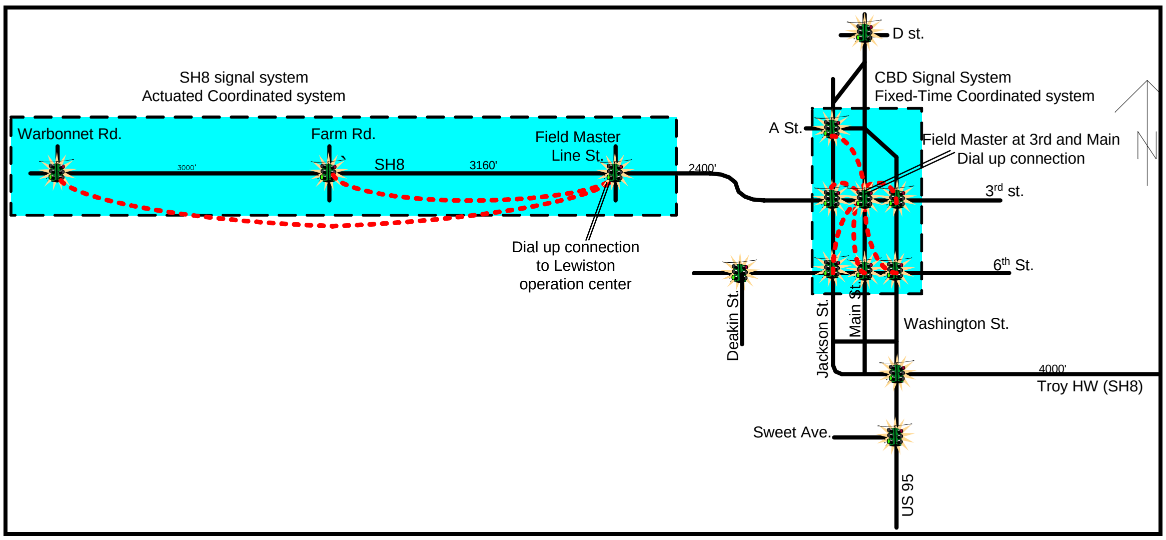


Figure 10. City of Moscow traffic signal system

5.2.2 Traffic signal system functional specification and system requirements

In general, each traffic signal control system is designed to maximize traffic flow efficiency and public safety, accurately monitor traffic flows, make appropriate traffic control decisions in a timely manner and reduce fuel consumption and environmental impact of stop-and-go traffic through improvements to traffic flow efficiency. An efficient traffic signal system should have the ability to optimize available capacity on surface streets through continuous adjustments of traffic control and coordination parameters. Another function of traffic signal control systems is to monitor equipment for faults or malfunctions that may affect the system's or controller's ability to properly control traffic flow through an intersection. Such malfunctions might include a signal head indicator failure, detector failure, conflict in signal indications, a broken communications link or a power failure in a field device. The objective of monitoring is to identify system and equipment operational problems and initiate corrective actions and repair responses to return the equipment to its proper operating condition as quickly as possible in order to keep traffic flow interruptions to a minimum.

Most transportation needs and problems are identified through the planning process. Both current and future needs should be identified. Transportation agencies go through a variety of steps and processes in developing and deploying transportation improvement projects. In the Moscow ITS signal integration project, and before finalizing the concept of operation, the functional specifications and the system requirements for the project, the potential benefits of several components of the project were examined and their relative cost/ benefit ratios were evaluated. These components and their potential benefits are presented in Table 1 and discussed in the following sections.

1) Install detection systems at the seven intersections in the downtown area. Installing these detection system will allow for changing the operations at the downtown network from fixed-time based control to actuated control. A hardware-in-the-loop simulation (HILS) VISSIM model for the network was used to assess the potential delay reduction benefits from such change. Four time periods were considered in the analysis: morning peak, afternoon peak, noon-peak, and non-peak periods.
2) Install system detectors at strategic locations in the network. These system detectors will allow for the implementation of area-wide responsive control. Benefits of such system were examined using the HILS model for the downtown network and the three intersections in the west side under special event data.
3) Install redundant fiber optic communication system. This redundant system will ensure that communication between the operation centers and intersections are available all the time, even if there is a cut in part or damage in one or more of the fiber optic links. This option was compared against the case when communications between the operation center and the field devices are lost until

the fiber link cut is repaired (typically one-two weeks). The potential benefits of this component were assessed qualitatively through interviews with different traffic system operations.

4) Centralized-control software: adaptive control logic. One of the benefits of having centralized control software is to have the ability to deploy adaptive advanced control logics in the network. To assess the potential benefits of these components, a literature review was conducted to document the potential benefits of adaptive control logics for small and medium size networks.
5) Centralized-control software: dynamic subsystems definition. Another benefit of centralized control software is the flexibility in defining subsystems. Unlike closed-loop software, where the definition of subsystems is static and can not be changed, centralized control software allows operators to define subsystems dynamically. Potential delay reduction benefits of such dynamic definition of subsystems within the network were evaluated using a Syncrho model for the network.
6) Closed-loop software: continuous device monitoring. The potential benefits of this component were assessed qualitatively through interviews with different traffic system operations.
7) Closed-loop software: continuous traffic flow monitoring through detector data. The potential benefits of this component were assessed qualitatively through interviews with different traffic system operations.
8) Closed-loop software: data archiving. The potential benefits of this component were assessed qualitatively through interviews with different traffic system operations.
9) CCTV cameras: continuous traffic flow monitoring through network surveillance. The potential benefits of this component were assessed qualitatively through interviews with different traffic system operations.

The functional specifications of the project were defined based on the priority listed in Table 8. The project’s functional requirement, system components and communication scheme are presented in Figure 12.

The Results of the cost/benefit analysis shows that the potential delay reduction benefits resulting from advanced control features included in signal integration projects, such as responsive or adaptive control, may not be the primary benefit of these projects. Some of these delay reduction benefits could still be achieved through less advanced control systems. Institutional benefits, such as the ability to continuously monitor system devices, the ability to troubleshoot some of the device problems from the control center and the ability to monitor the network performance through CCVT cameras, seem to be the primary benefits of such signal integration projects.

Table 9. Cost/benefit analysis and priority ranking for some project components

Project Component	Measure	Potential Benefits	Potential Cost	Priority
Detection systems at the seven downtown intersections	Quantitative	Low	Moderate	Low
System detectors at strategic locations in the network	Quantitative	Moderate	Low*	Moderate
Redundant fiber optic communication system	Qualitative	Low	High	Low
Centralized-control software: adaptive control logic	Quantitative	Low	High	Low
Centralized-control software: dynamic subsystems definition	Quantitative	Moderate	High	Low
Closed-loop software: continuous device monitoring	Qualitative	High	Moderate	High
Closed-loop software: continuous traffic flow monitoring through detector data	Qualitative	High	Moderate	High
Closed-loop software: data archiving	Qualitative	moderate	Moderate	High
CCTV cameras: continuous traffic flow monitoring through network surveillance	Qualitative	High	Moderate	High

*system detectors will be installed during pavement resurfacing projects

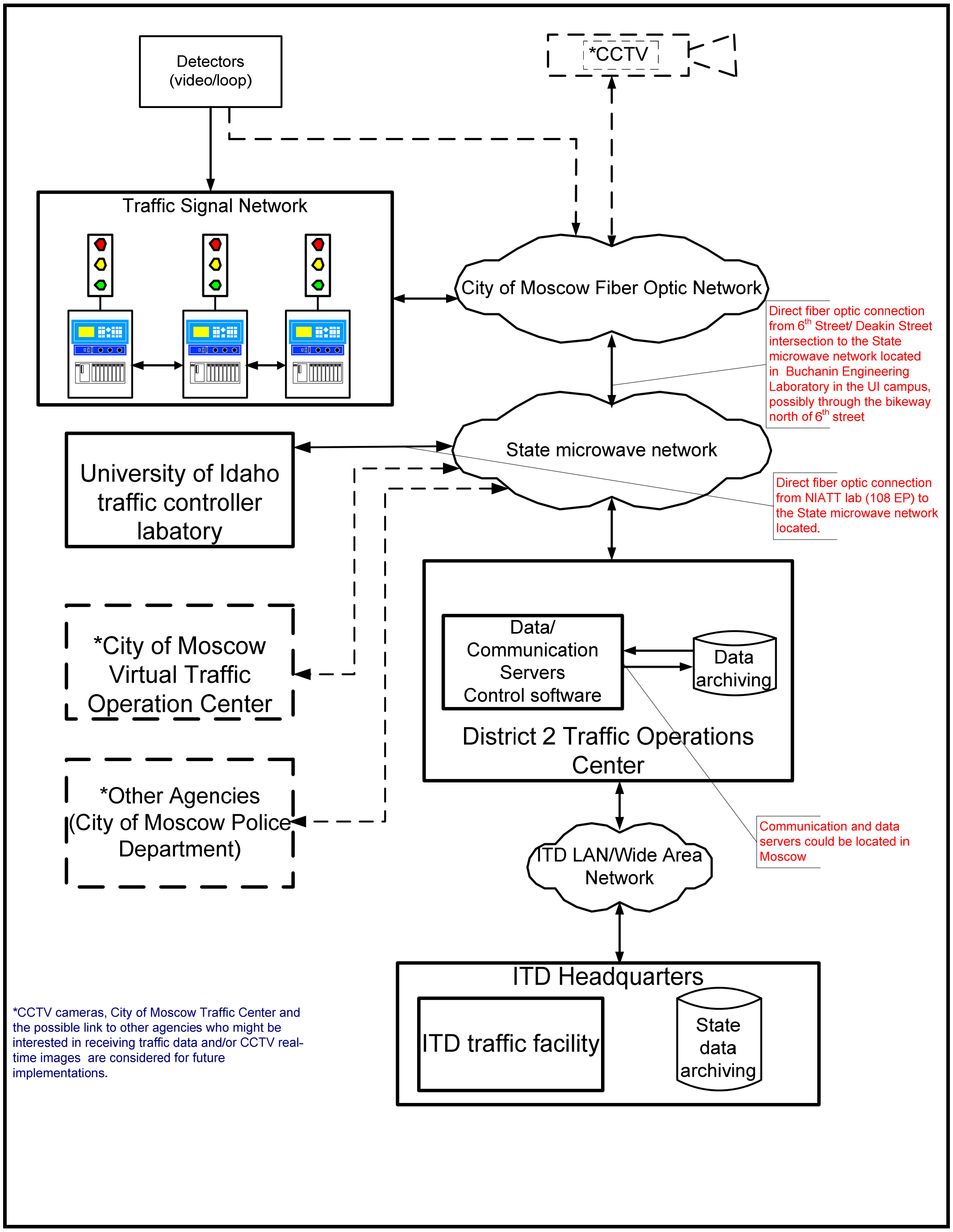


Figure 11. City of Moscow ITS Project – project components and communication schemes

6.0 Managing Software-Based Traffic Control System (Closed-Loop Software)

This section includes a case study of managing and operating closed-loop control software. The software used in this case study is Econolite Aries closed-loop system software.

Adding new zones (defining subsystems) using Aries

1. In the “Aries Zone Manager” window, right click “Zones” and select “Add Zone”. “Add Zone Node” window appears.
2. The window defaults to the next unused zone number, which you may overwrite as necessary.
3. Enter the “Telephone Number” if the zone is connected via a modem. Add any applicable dialing prefixes or long distance codes. Insert spaces, hyphens and parentheses. Insert a comma for a dialing pause or leave blank in case of direct connect.
4. Enter “Bank 1” in the “Zone Name”. This also can be the name of the street for an arterial with multiple intersections.
5. Click in the field for “Zone Type” and make a selection from the pull-down menu.
6. Click on the field for “Bit Rate” and make a selection from the pull-down menu. The normal choice should be 2400 bps. Use 1200 bps or 300 bps for older, slower modems in the field. This does not apply to Intersection Monitor II, ASC-8000 or ASC/2 direct zones.
7. Enter the “Access Code” for any “Zone Master” where an access code is required for security purposes.
8. Check the box “Create New Master Data File”. This creates a data file for that zone on the Aries computer.
9. Click “OK”. The “Data Rate Selection” window appears. Enter the same bit rate as entered previously, typically 2400 or 1200 bps.
10. Click “OK” to complete data entry for the first zone “Bank 1” (Figure 13).
11. Repeat 1-10 to create Zone 2, 3 and 4 for subsystem Bank 2, Bank 3 and Bank 4.

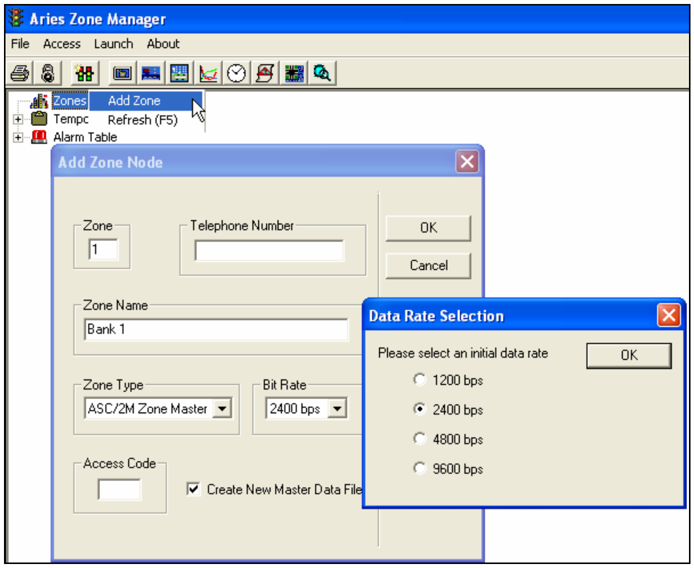


Figure 12. Zone definition

Editing a Previously Entered Zone

1. Select the "Aries Zone Manager" window.
2. Right-click "Zone 1" and select "Edit Zone Properties" from the pull-down menu.
3. The "Edit Zone Node" window appears. Make the necessary changes and click "OK" to accept them or "Cancel" to end the operation (Figure 14).
4. Repeat 2-3 to edit other Zones if necessary.

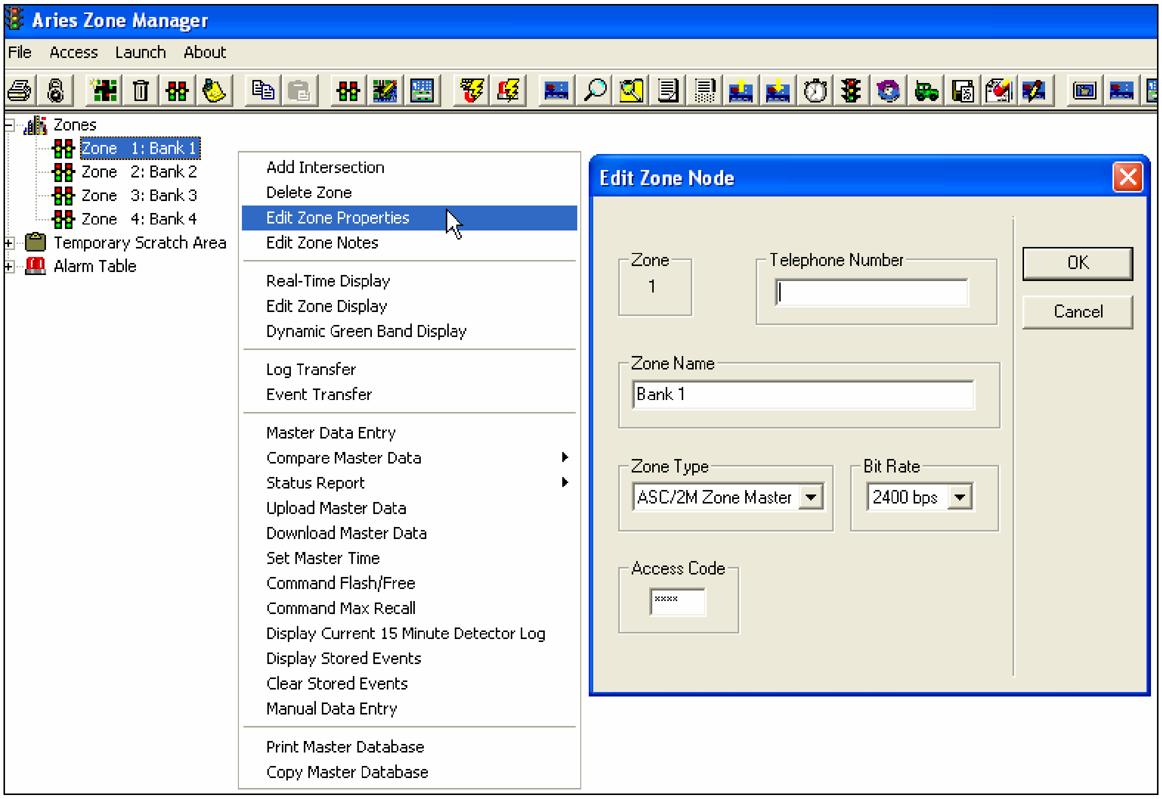


Figure 13. Edit a Zone

Adding Intersections to a Zone

1. In the "Aries Zone Manager" window, right-click the "Zone 1".
2. Select "Add Intersection" and supply the data change "Access Code". The "Add Intersection Node" window appears, suggesting the next available number for the intersection.
3. In the "Intersection Name" field, enter "TC1". If street names are used, normally two street names separated by an "&."
4. In the "Controller Type" data field, select a controller from the pull-down menu. Choices are ASC2 for the ASC/2 series, ASC for the ASC-8000 series. Press "OK".
5. Depending on the type of controller selected, a controller sub type window appears prompting you to select a controller sub-type. In case of the ASC/2, this refers to NEMA TS2 type (Type 1 or Type 2) and the size of the EEPROM data module (8K or 32K). "TS2 Type 2" includes TS1 emulation (Figure 7-17).

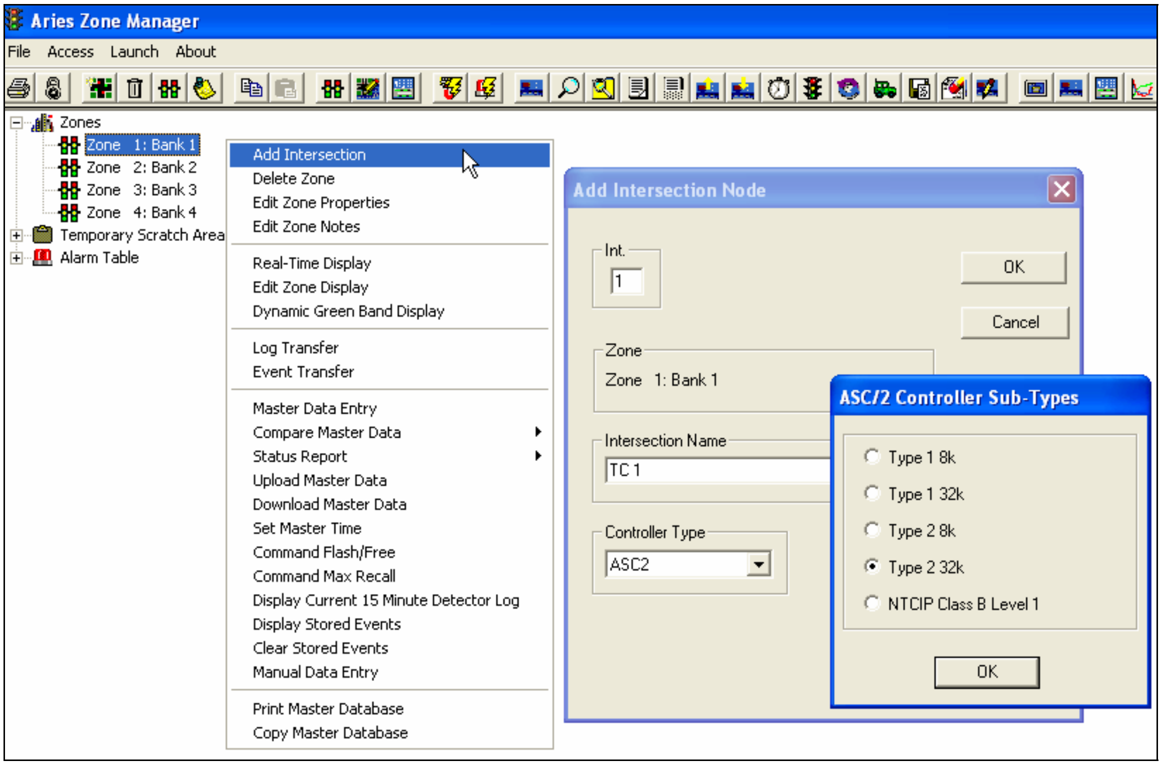


Figure 14. Add an Intersection

6. Repeat 1-5 above to add other intersections to Zone 1 and Zone 2-4 (Figure 15).

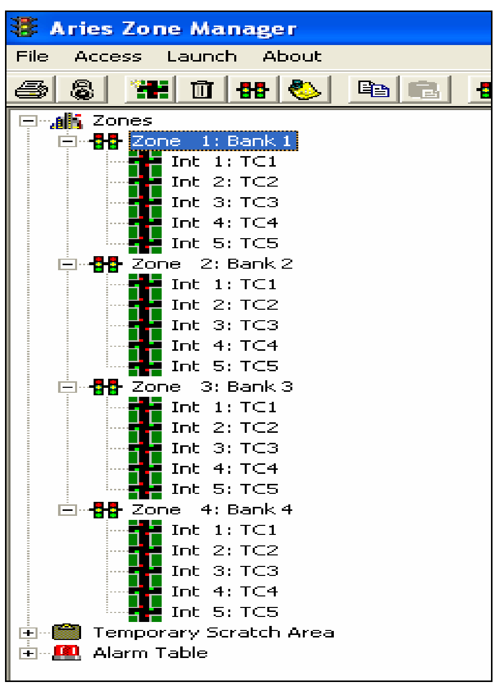


Figure 15. Twenty Intersections Added

Setting up Communication

To set up communication:

1. In "Aries Zone Manager", click "Launch", then "Communication Server". "Aries Communications Server" window appears (Figure 16).

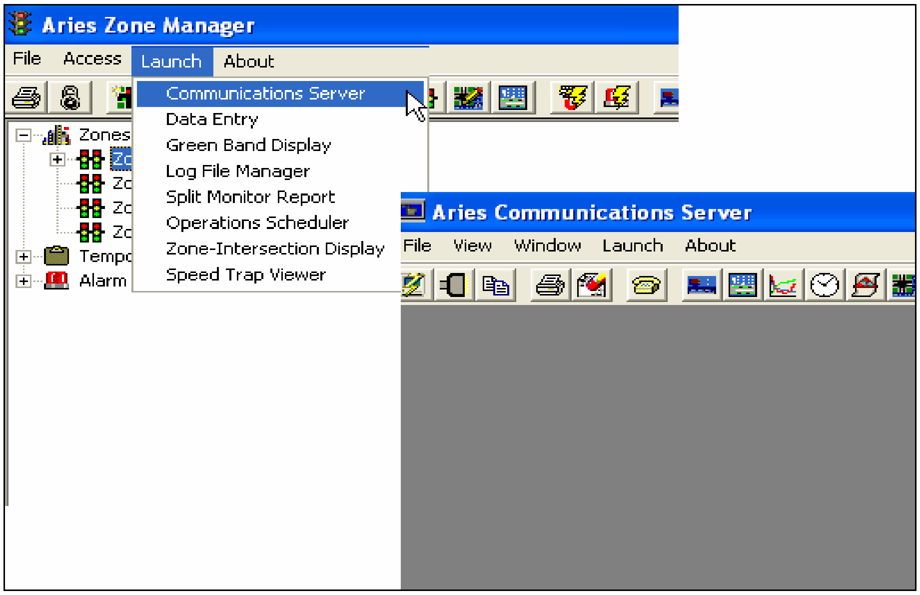


Figure 16. Open Aries Communications Server

2. In "Aries Communications Server", click "File", then select "Setup", next select "Channel", "Channel Configuration" window appears (Figure 17).

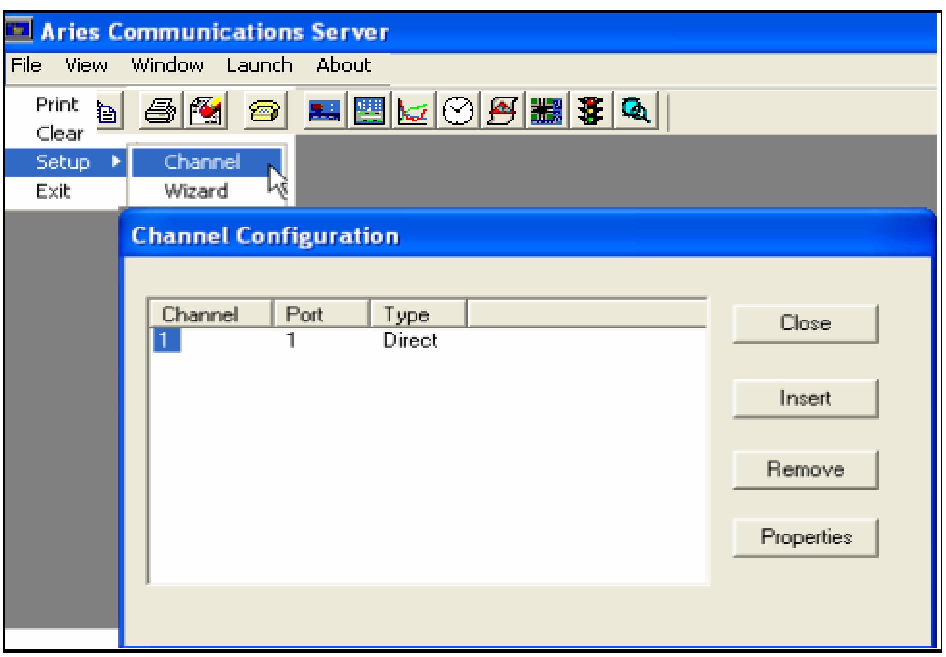


Figure 17. Channel Configuration

3. In the “Channel Configuration”, if there is no existing channel, click “Insert” to add a new one. If a channel already existed, click “Properties” to edit.
4. In “Channel 1 Configuration”, click “Port” in the menu.
5. For “Port Number”, enter the number corresponding to serial port on the computer.
6. For “Bite Rate”, select “19,200” for direct connection.
7. For “Data Bits”, check the box for “7”.
8. For “Parity”, check the box for “Even”.
9. For “Stop Bits”, check the box for “1”.
10. In “Channel 1 Configuration”, click “Options” in the menu.
11. For “Communication Type”, select “Direct”.
12. For “Inactivity Period”, input “1”.
13. For “Mode”, select “Any”.
14. Check the box for “Zone Number Verification”.
15. Click “Apply”, and then click “OK” to dismiss “Channel 1 Configuration” (Figure 18).

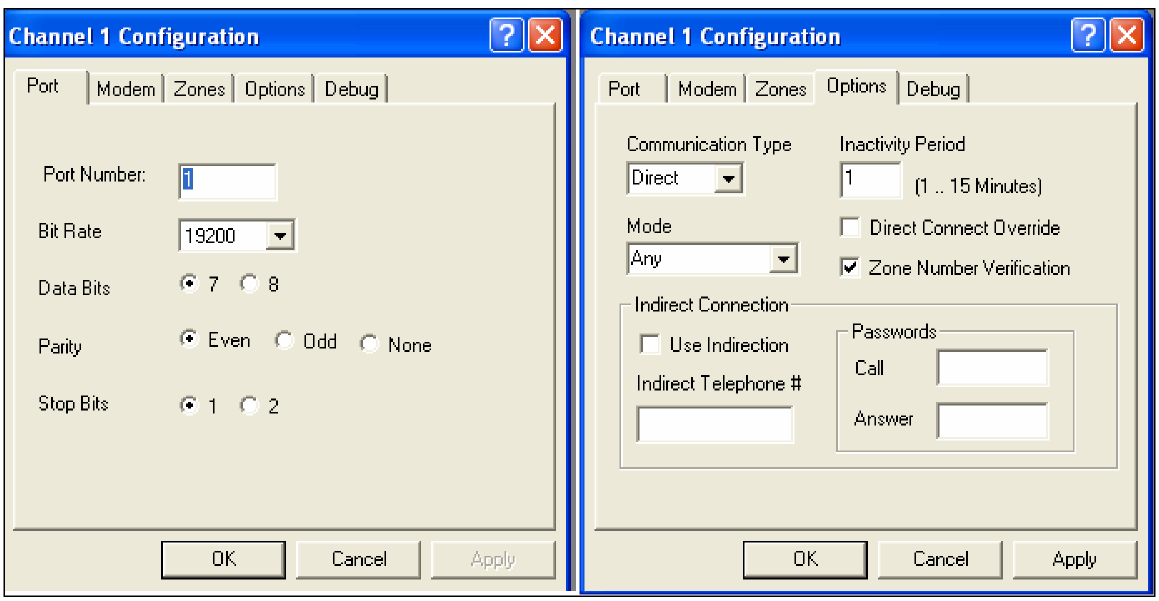


Figure 18. Channel 1 Configuration

Verifying Communication

To verify the communication for the Master and each local controller:

1. In “Aries Zone Manager”, right-click “Bank 1”, and then select “Compare Master Data”, and next select “Byte Compare”.
2. “Operation Progress Messages” window appears. Click “Start” to conduct “Byte Compare” for Zone 1.
3. Repeat 1-2 to verify communication for Bank 2, 3 and 4 (Figure 19).
4. In “Aries Zone Manager”, right-click “TC1” under “Bank 1”, then select “Compare Local Controller Data”, and next select “Quick Compare”.

5. “Operation Progress Messages” window appears. Click “Start” to conduct “Quick Compare” for Zone 1, Intersection 1.
6. Repeat 4-5 to verify communication for other local controllers (Figure 20).

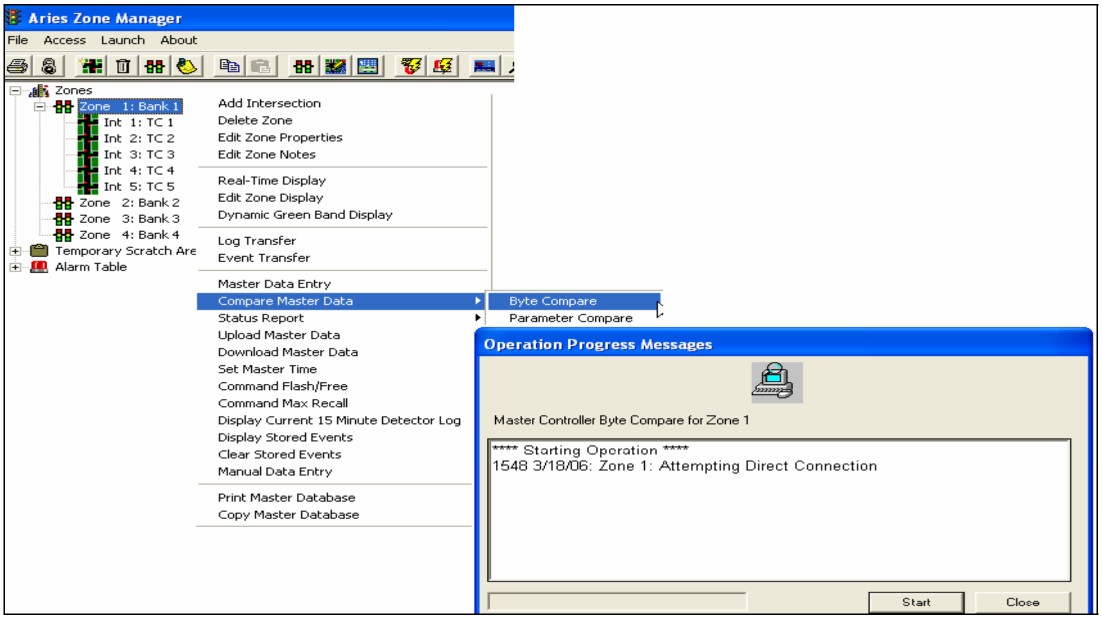


Figure 19. Verifying Communication for Master

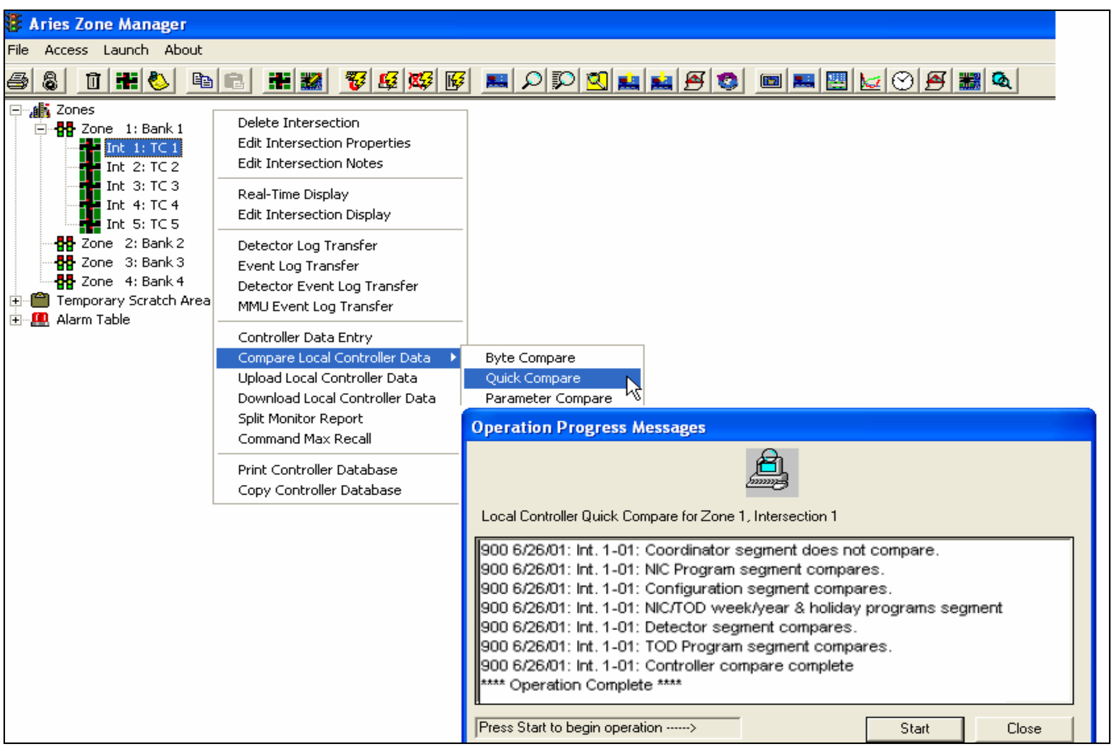


Figure 20. Verifying Communication for Local Controller

Uploading Master Data

To upload master data:

1. In the “Aries Zone Manager” window, right-click the desired zone.
2. Select “Upload Master Data” and press “Start” to begin the operation.
3. The message “Upload Complete”. “SAVE, COMPARE OR CANCEL” appears.
4. Select “Save” if this was your first upload to save the 2-kilobyte file on disk. The “Compare” option allows you to compare the uploaded data with data from a previously saved master data file for that zone. “Cancel” ends the operation (Figure 21).

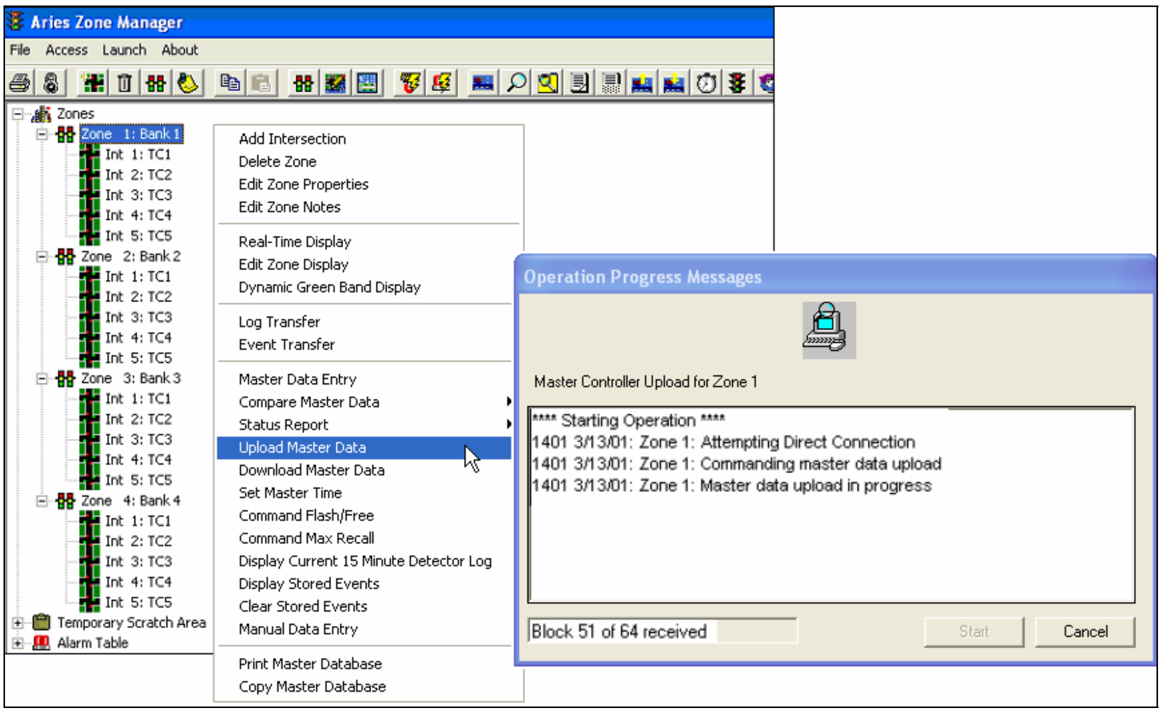


Figure 21. Upload Master Data

Editing Master Data

To edit the master data that you have uploaded:

1. In the “Aries Zone Manager” window, right-click on the desired zone.
2. Then select “Master Data Entry”.
3. Enter the “Data Entry” access code, defined earlier, to prevent unauthorized data modification. The “Aries Data Entry” window appears.
4. In “Aries Data Entry” window, click on the topic selection index on the left side of the window and then make data change if necessary. Below are two sample topics with different data entry sub-screens.

    1) In “Aries Data Entry-Bank 1”, click “System Parameters”. On the right of the index, a set of data entries of “General”, “SD diagnostics”, “Nominal Speed”, and “Version” appears.

- General.

Master Number: enter the corresponding number for Master.

Cycle length Cycle X: Local controller coordination plans are entered here. If four coordination plans are being used, the first four entries need to be modified, so that the local controllers can be coordinated (Figure 22).

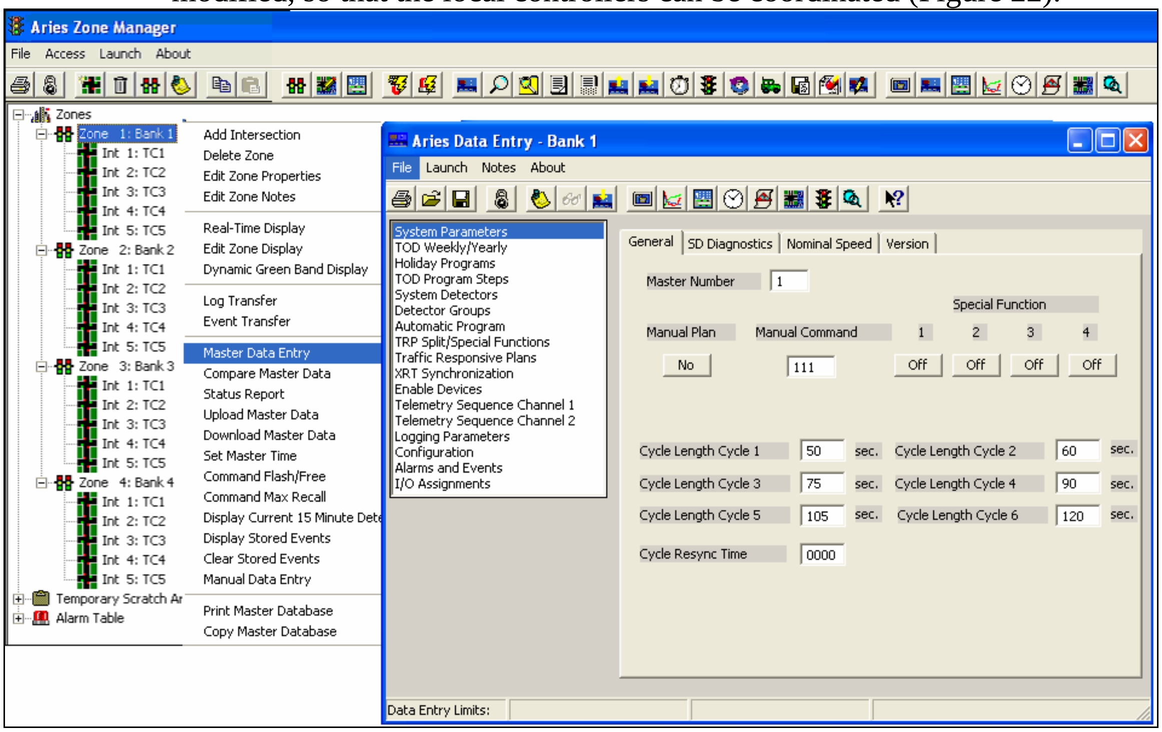


Figure 22. Editing System Parameters for Master

2) In “Aries Data Entry-Bank 1”, click “TOD Weekly/Yearly”. On the right of the index, a set of data entries of “Weekly” and “Yearly” appears.
   - Weekly. TOD can be programmed on a certain day of the week. For example, program 1 runs Monday through Friday and program 2 runs on Saturday and Sunday (Figure 23).

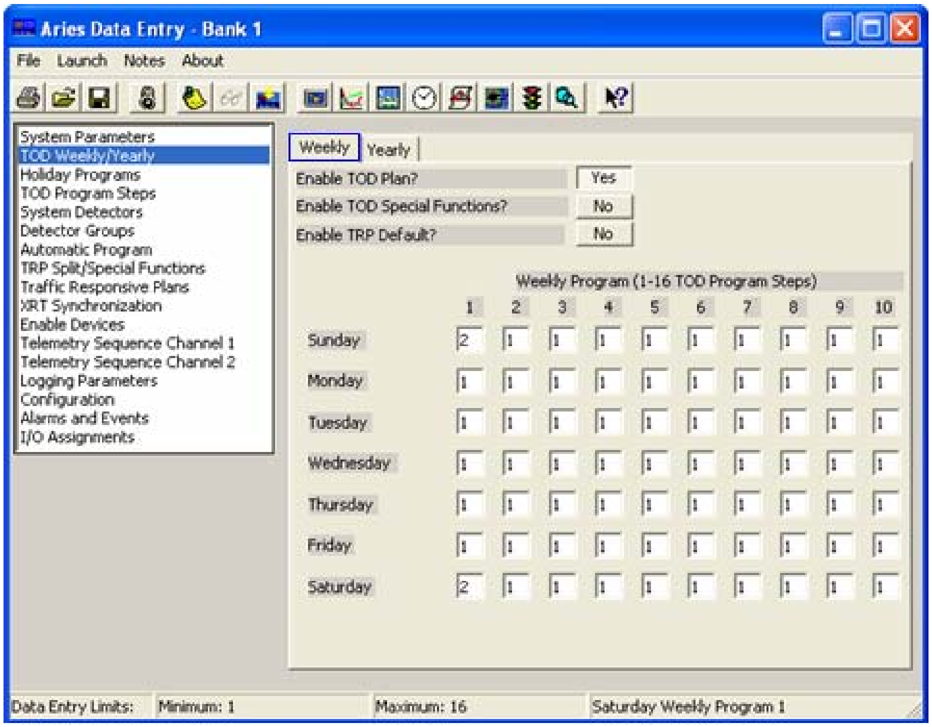


Figure 23. Editing TOD Weekly (/Yearly) Plan for Master

- Yearly. TOD can be programmed based on a certain week of year (Figure 24).

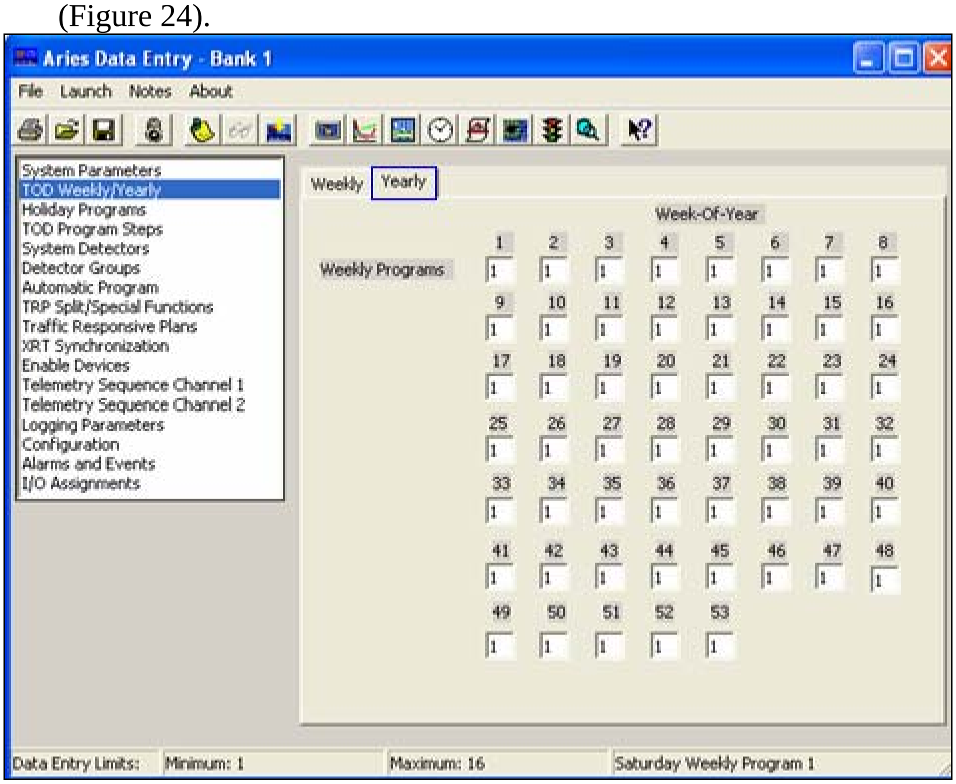


Figure 24. Editing TOD (Weekly/) Yearly Plan for Master

5. Make data change for other topics index if necessary. Save the data and close the window.

Comparing Master Data

To compare the master data in the computer and in the equipment in the field:

1. From the “Aries Zone Manager” window, right-click the “Zone”.
2. Select “Compare Master Data”, then “Parameter Compare”.
3. In the “Operation Progress Messages” window, click the “Start” button. The Aries system compares the disk file to the uploaded file.
4. The “Aries Data Entry for Zone” window appears and shows any discrepancy in two one-line fields at the bottom. Use the “Back” and “Next” buttons of the window to cycle between multiple discrepancy messages (Figure 25).

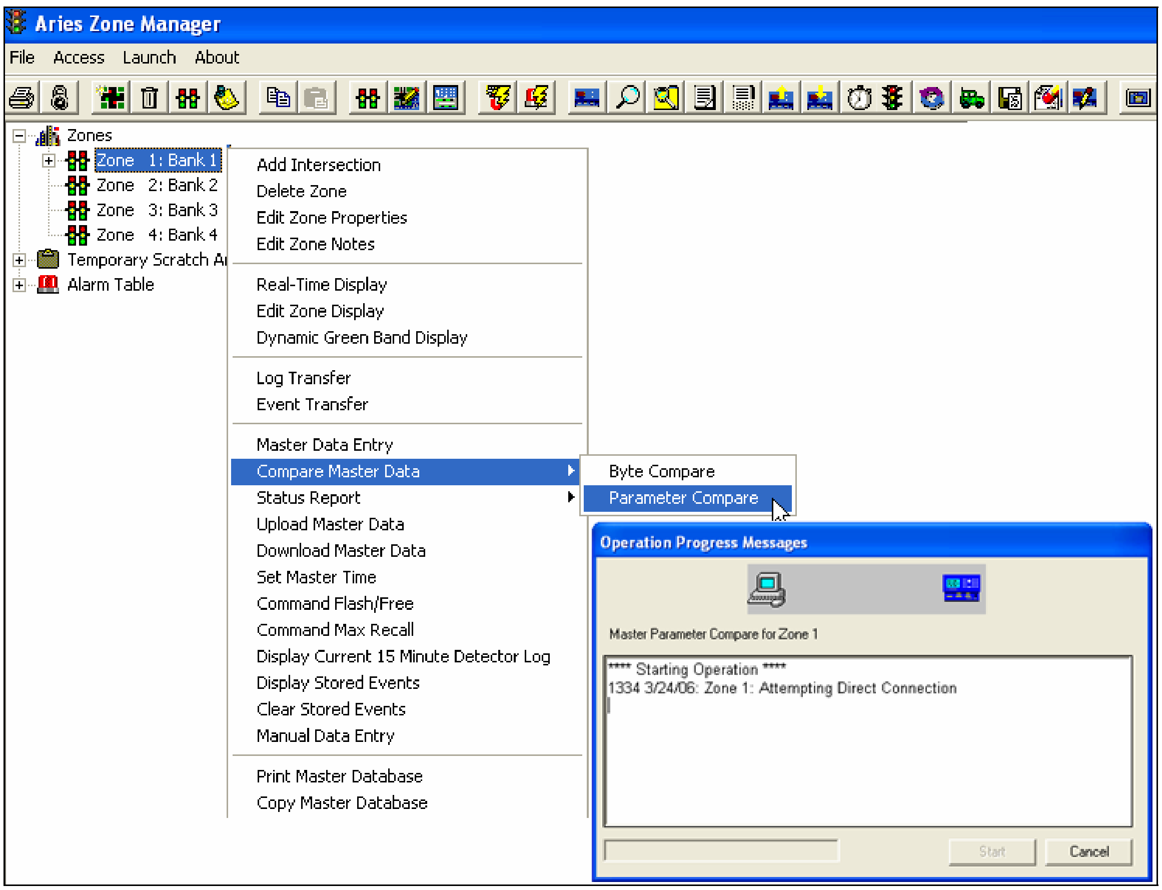


Figure 25. Comparing Master Data

Downloading Master Data

To download the edited master data:

1. In the “Aries Zone Manager” window, right-click the desired Zone.
2. Select “Download Master Data” and press “Start” to begin the operation. The master download operation is completed when the message ‘**** Operation Complete ****’ appears.

3. Close the window. A compare operation at this time shows the disk files and the field files match (Figure 26).

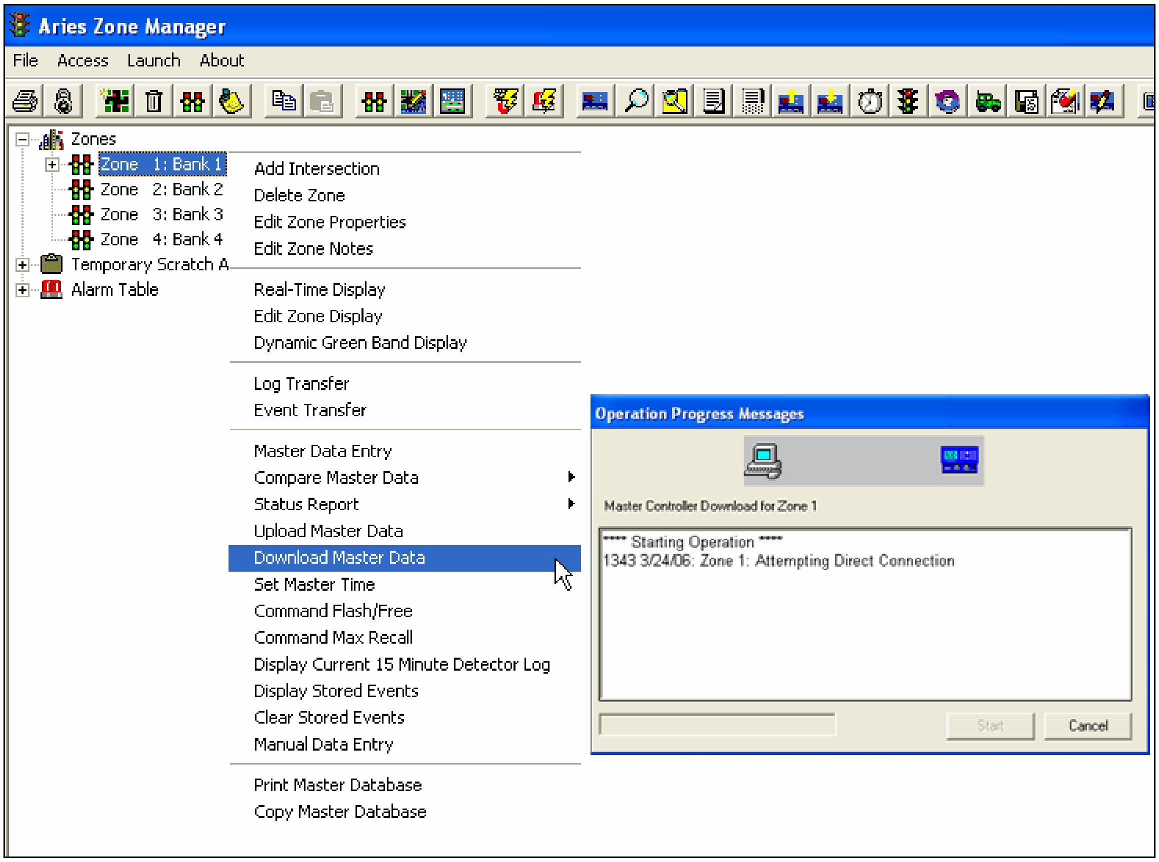


Figure 26. Downloading Master Data

Uploading Local Controller Data

To upload controller data:

1. In the "Aries Zone Manager" window, right-click the desired intersection.
2. Click "Upload Local Controller Data".
3. When prompted to select the segments to upload, select only the segments that you need. A full upload from a controller through a zone master can take up to 15 minutes.
4. Press "Start". When you upload controller data from an intersection for the first time, the message, "Configuration does not match" appears. This is normal. Choose "Proceed".
5. When the upload is complete, select "Save" to store the uploaded data in the appropriate directory on disk (Figure 27).

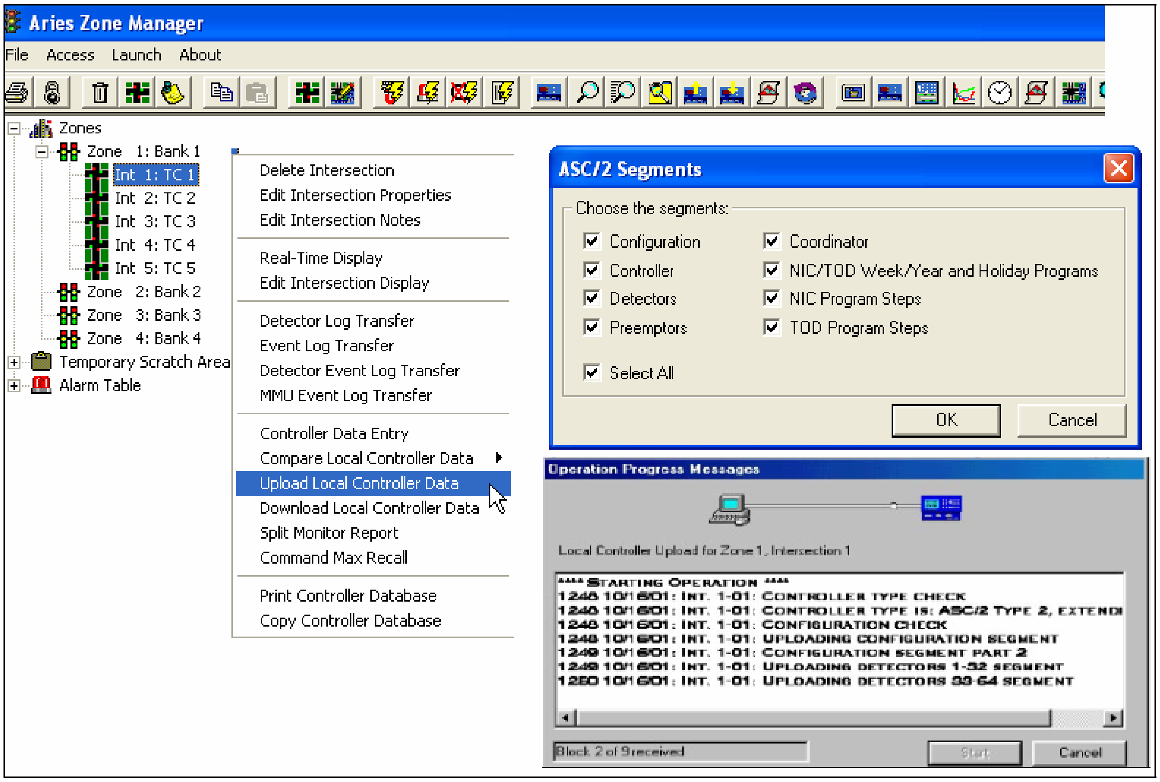


Figure 27. Uploading Local Controller Data

Editing ASC/2 Local Controller Data

To edit ASC/2 controller data:

1. In the “Aries Zone Manager” window, right-click the intersection and click “Controller Data Entry”. Enter the “Data Entry Access Code”.
2. The “Aries Data Entry” screen appears. On the left hand side of the screen, there is a topic selection index. Clicking on each topic presents you with a different data entry sub-screen, located to the right of the index. Below are two sample topics with different data entry sub-screens (Figure 28).

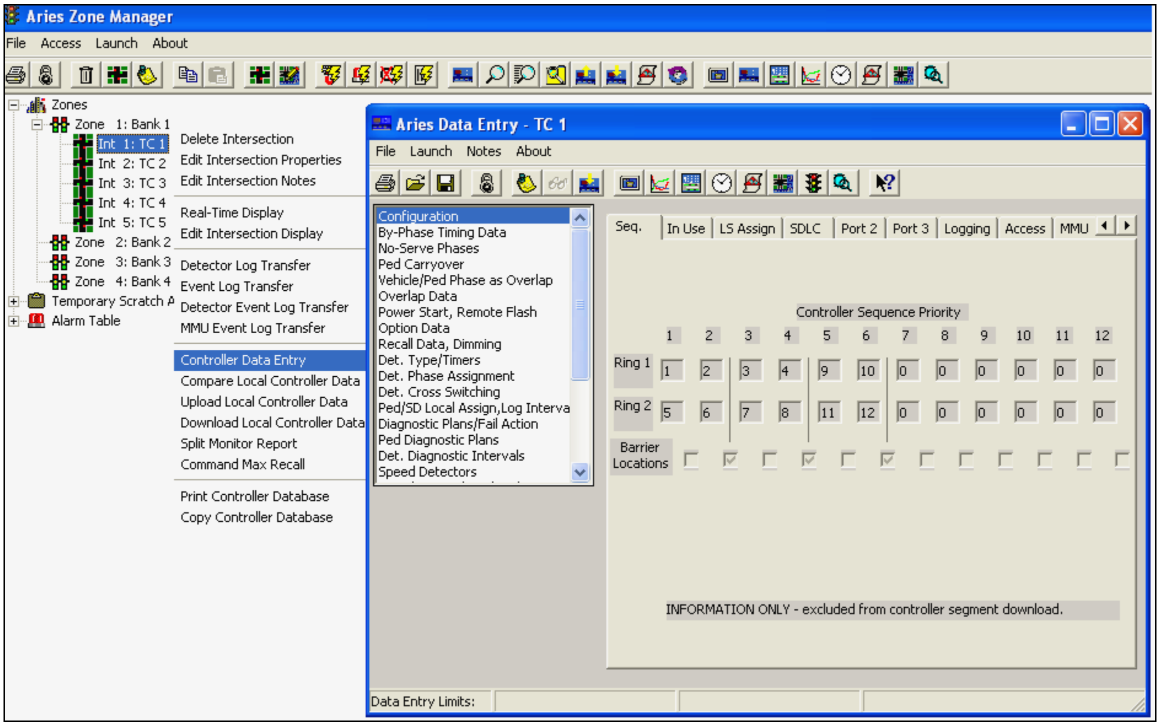


Figure 28. Editing ASC/2 Local Controller Data

1) <u>Configuration</u>. In “Aries Data Entry” window, click “Configuration”. On the right of the index, a set of data entries of “Seq.”, “In Use”, “LS Assign”, “SDLC”, “Port 2”, “Port 3”, “Logging”, “Access”, “MMU” and “Vision” appears.

   - <u>Seq.</u>

   Select ring phase assignment, order of rotation and concurrent group barrier position to define controller phase sequence (Figure 29).

Figure 29. Editing Seq. of Configuration for Local Controller

- <u>In Use</u>

Indicates phases including overlaps to be active and define the direction for each phase. Exclusive Ped. means phases timing only pedestrian intervals without concurrent vehicle movement (Figure 30).

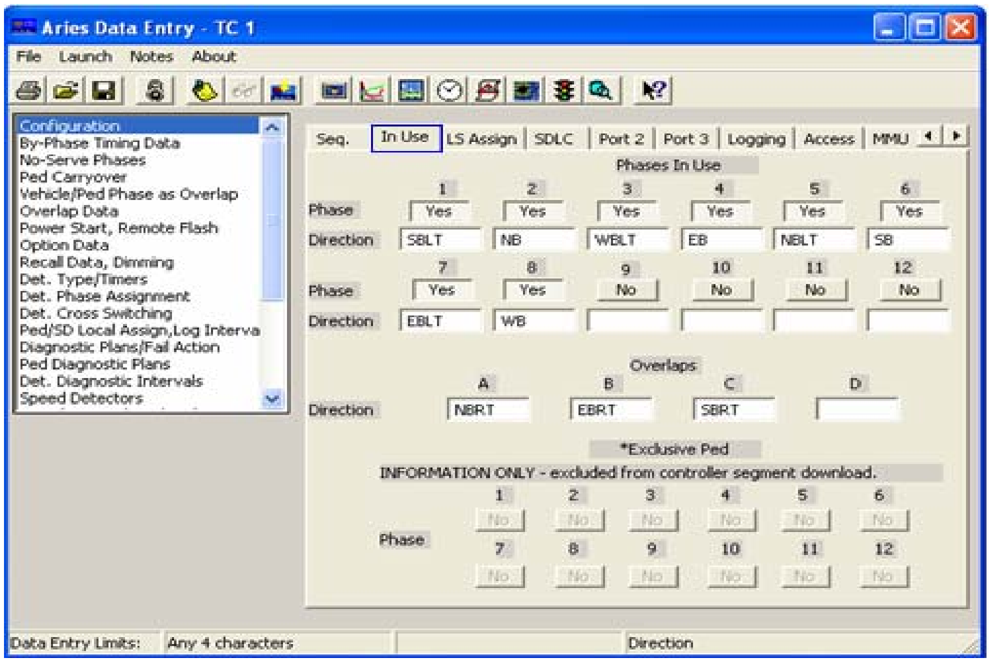


Figure 30. Editing In Use of Configuration for Local Controller

- <u>LA Assign</u>

Assigns phases 1-12 and overlaps A-D to MMU channels and loads switches 1-16. Numbers 13, 14, 15 and 16 correspond to overlaps A, B, C and D, respectively. Pedestrian phases must be identified (Figure 31).

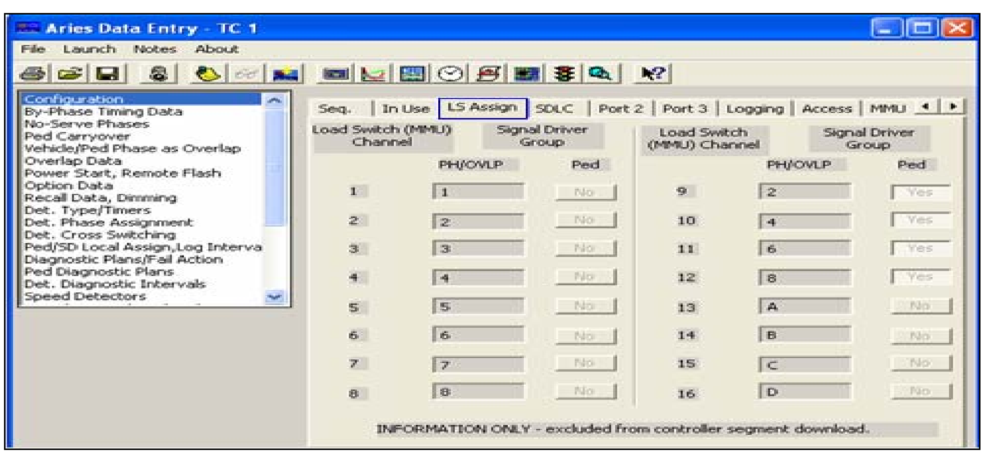


Figure 31. Editing LS Ass. of Configuration for Local Controller

- <u>SDLC</u>

Enable BIU used by terminals and facilities.
Enable BIUs used by detector rack by all detector interface functions.
Enable Type 2 controller to operate as Type 1.
Disable MMU readback capabilities for Type 2 operation.
Enable interface to test case for bench top diagnostics.
Enable peer to peer communication. This enables communications between devices external to traffic control system via the controller.
Define peer to peer device address. Communications addresses can be set for up to ten external devices attached to SDLC (Figure 32).

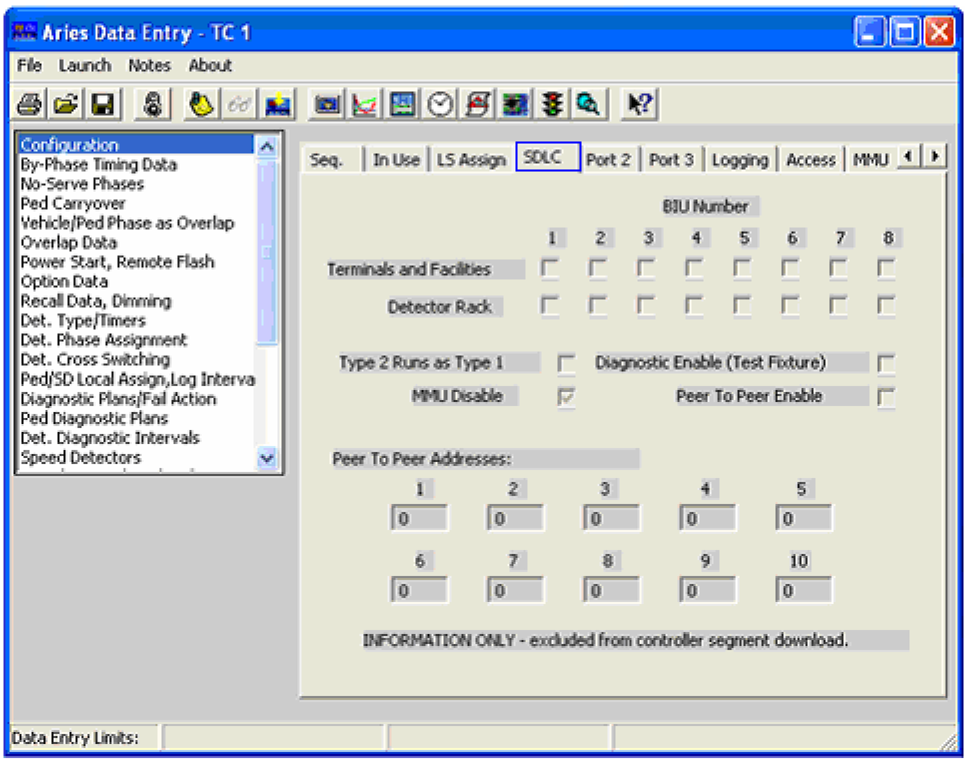


Figure 32. Editing SDLC of Configuration for Local Controller

- <u>Port 2</u>

Toggles Terminal for Port 2 Protocol
Select terminal data rate (1200, 2400, 4800, 9600, or 19.2k).
Specify word length, parity and stop bit (7, E, 1 or 8, N, 1).
Define AB3418 protocol parameters.
Enable port 2(Figure 33).

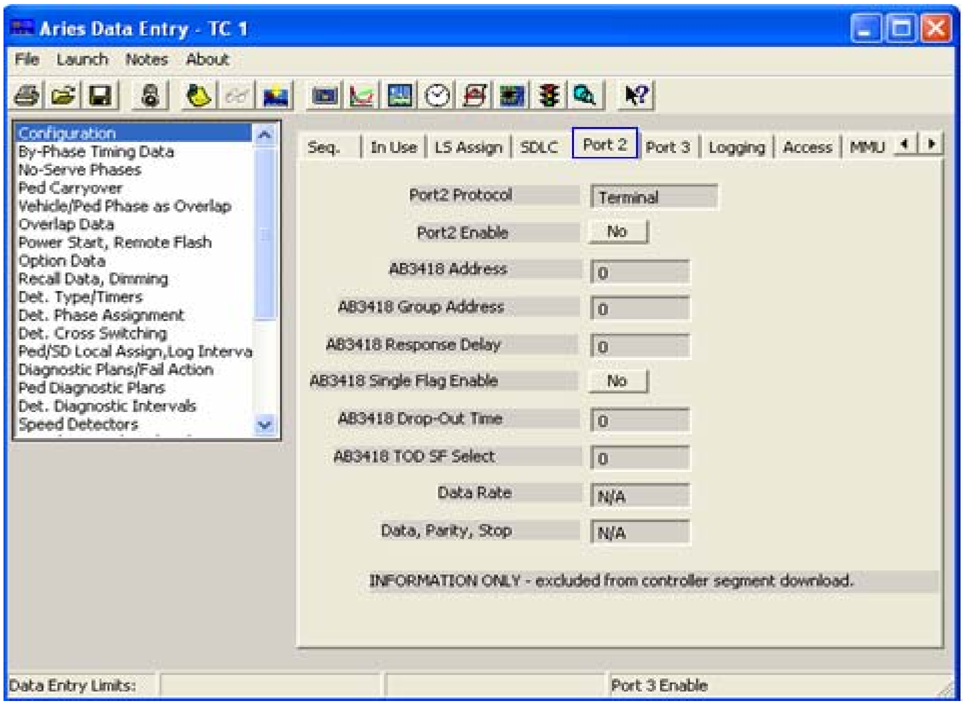


Figure 33. Editing Port 2 of Configuration for Local Controller

- <u>Port 3</u>

Assign telemetry address to local controllers (1-5).
Assign a unique address number 1-24 to groups of local system detectors to allow a zone master to access system detectors 9-16 as defined by the controller.
Set a telemetry response delay.
Define AB3418 Address (0-65535).
Define AB 3418 Group Address (0-65535 except 63).
Define AB3418 Response Delay (0-71 msec).
Define AB3418 Drop-Out Time (0-64800 sec).
Define Data, Parity, Stop (8, 0, 1; 8, N, 1; 8, E, 1; 7, E, 1).
Enable port 3 (Figure 34).

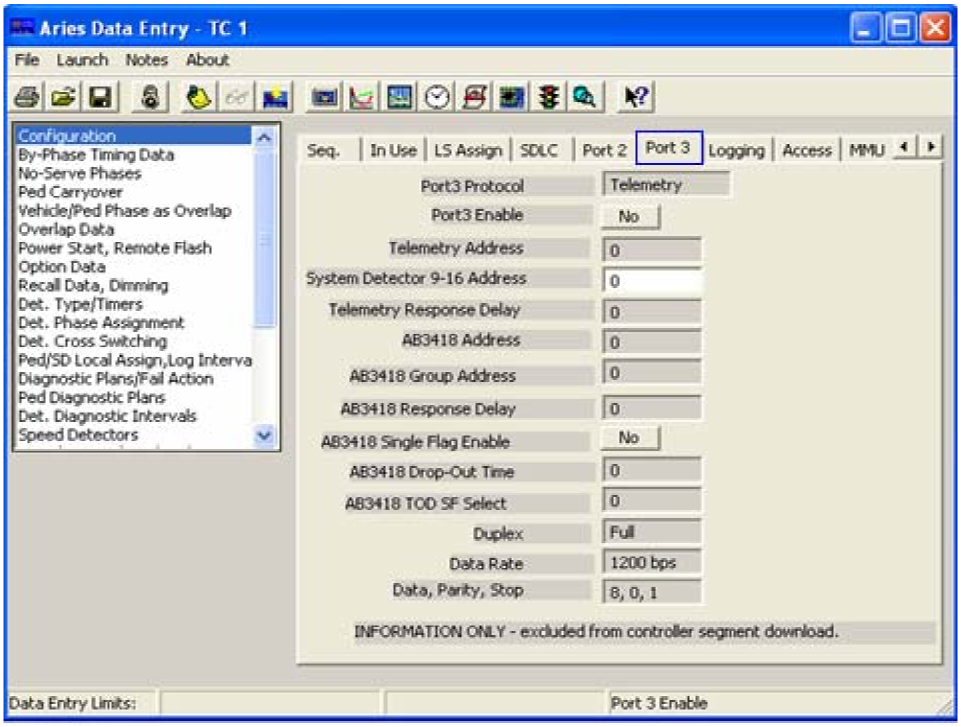


Figure 34. Editing Port 3 of Configuration for Local Controller

- Logging. Enable real-time logging of various events (Figure 35).

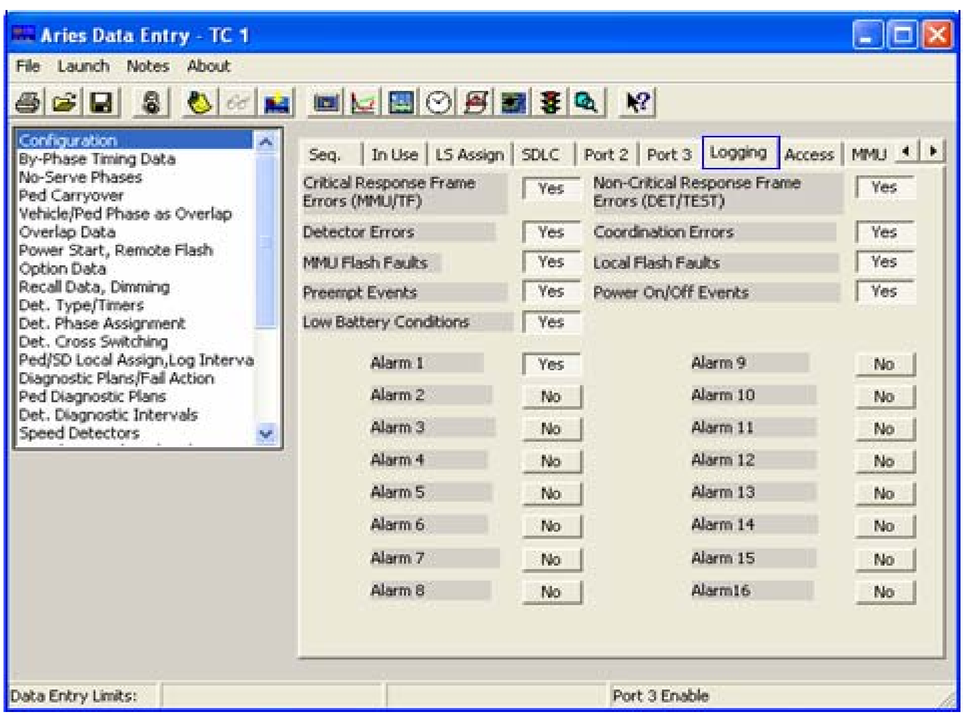


Figure 35. Editing Logging of Configuration for Local Controller

2) Coordination Patterns. In “Aries Data Entry”, click “Coordination Patterns”.
   - Select Coordinator Pattern. Patterns can be selected from 1-64.
   - Cycle length (30-255 seconds).
   - COS (Cycle/Offset/Split) is another way of referring to the coordination plan. Three plans with different cycle lengths, offsets and splits can be expressed as 1/1/1, 2/2/2 and 3/3/3.
   - Offset is typically entered in seconds.
   - Splits are entered in percentages or in seconds.
   - Coordinated Phases are usually the main street through phases.
   - Vehicle Max Recall is enabled on all phases that have no detection (Figure 36).

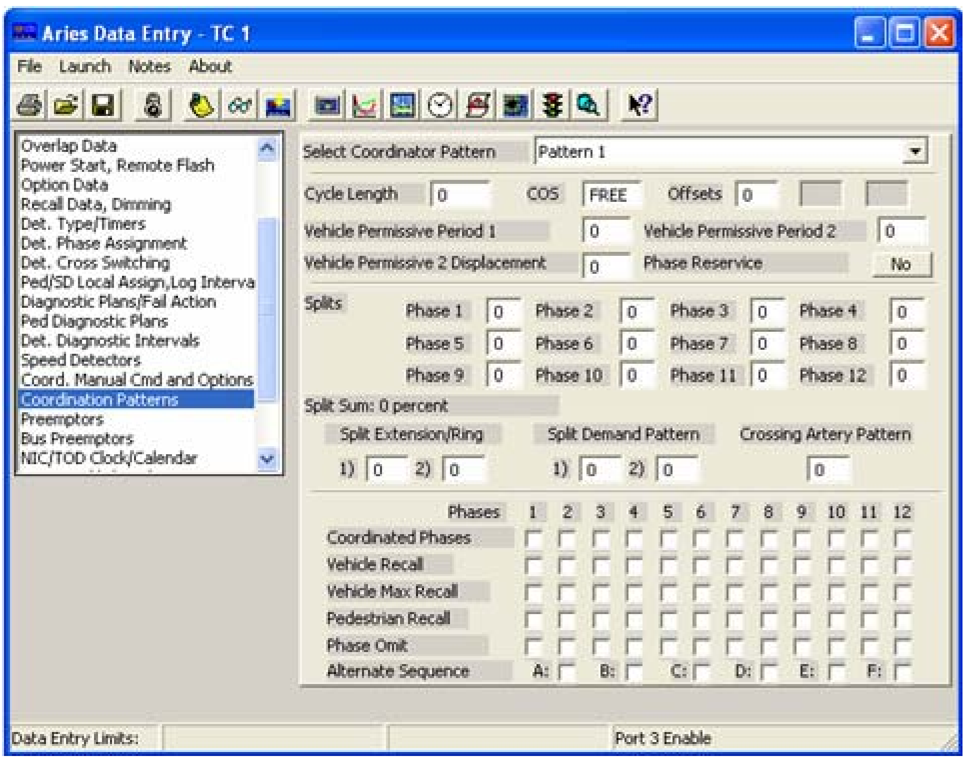


Figure 36. Editing Coordination Patterns for Local Controller

3. Make data changes for other topics index if necessary. Click “Save Data File” under the “File” pull-down menu.

Comparing ASC/2 Local Controller Data

To compare ASC/2 file and local controller data:

1. In “the Aries Zone Manager” window, right-click the desired intersection and click on “Compare Local Controller Data”. There are three options to choose from:
   - “Byte Compare” provides pass/fail indication by segment (or topic) by comparing the data one byte at a time.

- "Quick Compare" also provides pass/fail indication by segment, but in much less time by limiting the comparison to 16-bit CRC results.
- "Parameter Compare" identifies the specific elements that differ.

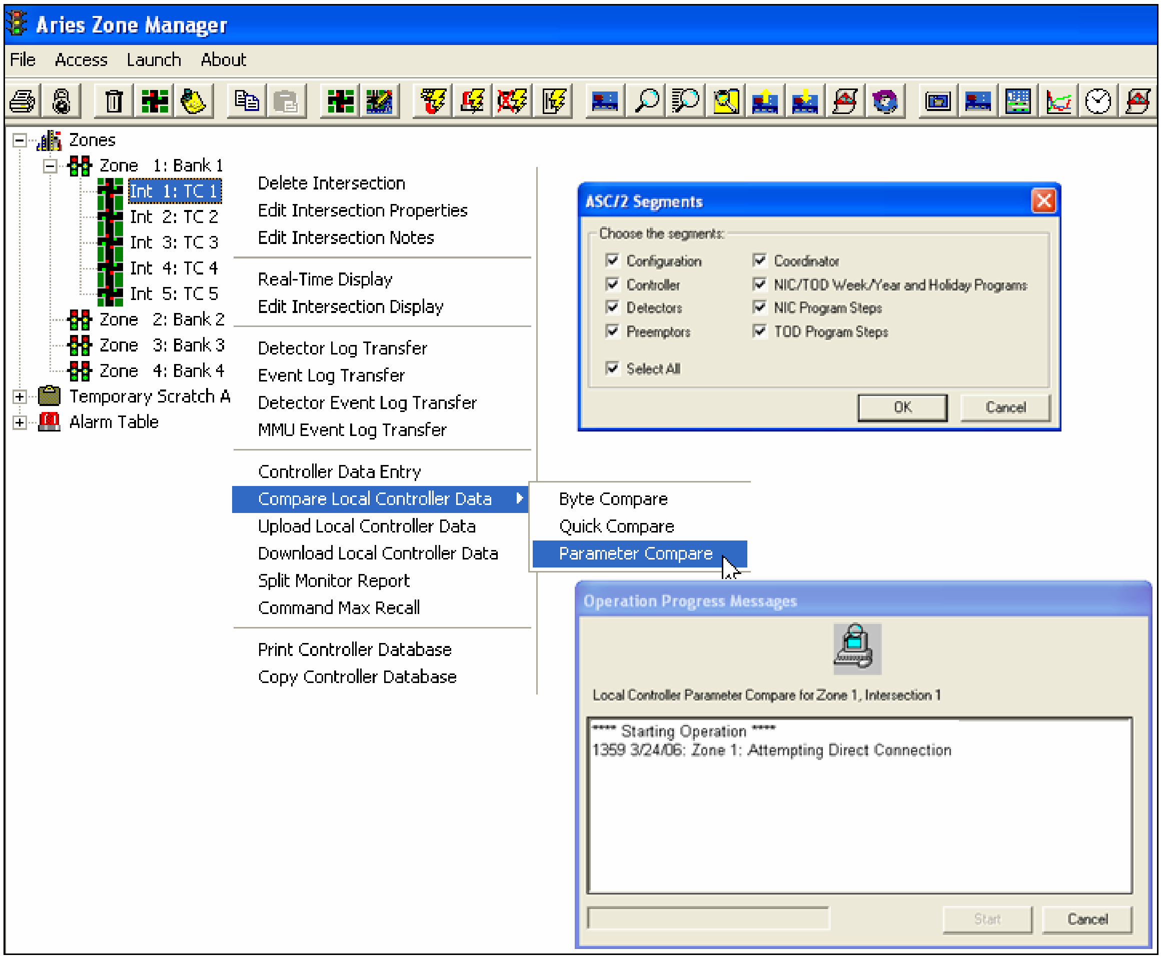


Figure 37. Comparing Local Controller Data

2. Select "Parameter Compare". Select the segments to be compared. Selecting fewer segments saves time. Press "Start" to begin the upload of data from the ASC/2 controller.
3. At the "Aries Data Entry" screen, the two fields at the bottom of the screen list any differences between the uploaded controller data and file data. Click "Next" to move to the next difference. Click "Back" to return to the previous difference.
4. Make any database changes using the "Aries Data Entry" screen. Select "Save" under the "File" pull-down menu to save any changes to disk. Begin a download operation to enter the file data into the ASC/2 controller (Figure 37).

Downloading Local Controller Data

To download controller data:

1. In the “Aries Zone Manager” window, right-click the desired intersection and click “Download Local Controller Data”. A dialog box appears, allowing you to choose the segments to be downloaded.
2. Choose either all the segments or certain ones to download. Select only the segments you need to download, thus speeding up the download process and saveing time (Figure 38).

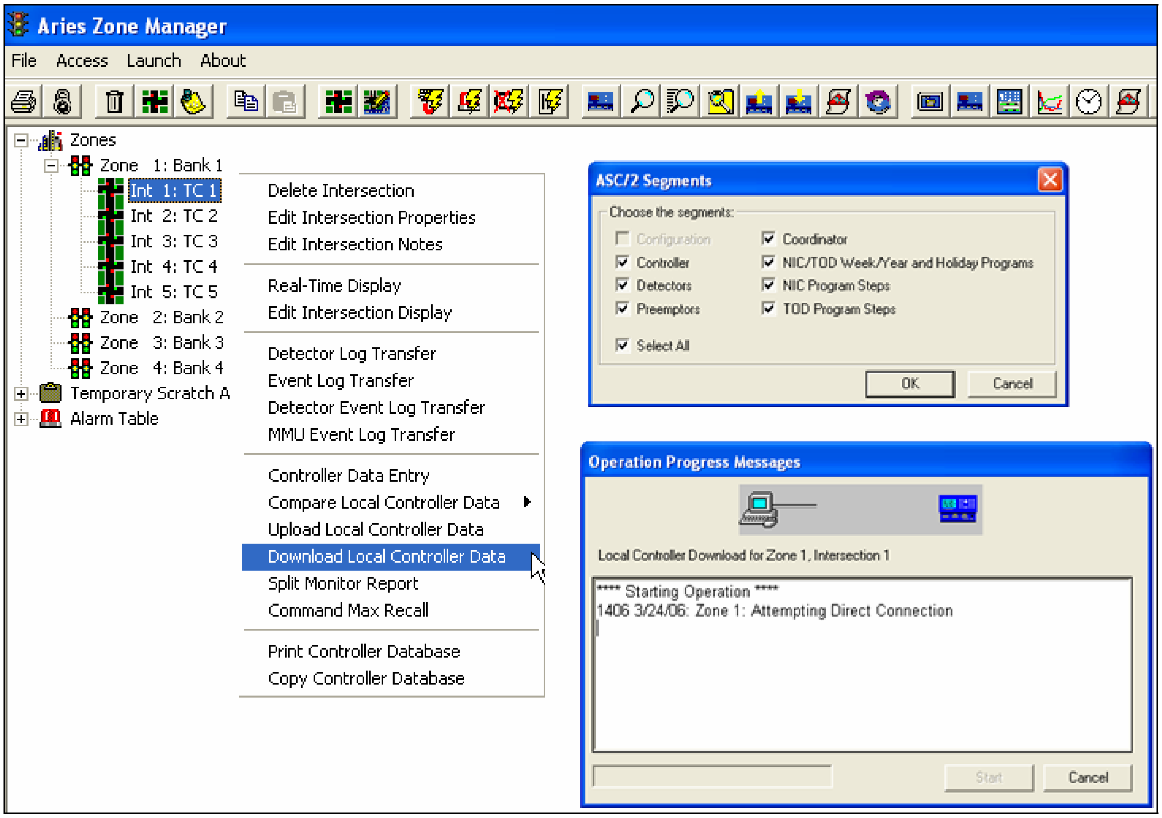


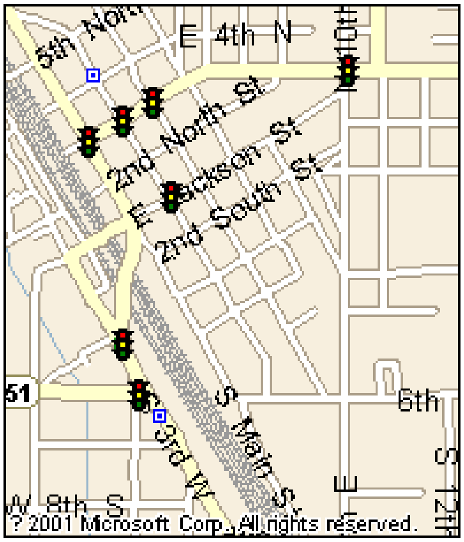
Figure 38. Downloading Local Controller Data

APPENDIX A: CHARACTERISTICS OF TRAFFIC CONTROL SYSTEMS IN IDAHO CITIES

1- SANDPOINT

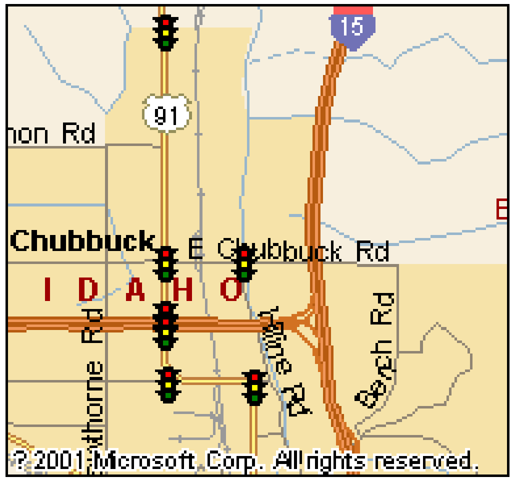
Signal No.	Location	Major Mile Post	Controller Make	Controller Model	Installation Date
13200001	1st. & PINE	474.24	TCT	LMD8000	1/31/1997
13200002	2nd. & CEDAR	474.51	TCT	LMD8000	9/17/1993
13200003	5th. & CEDAR	474.72	TCT	LMD8000	9/17/1993
13200004	5th. & LARCH	475.00	PEEK	LMD8000	1/31/1997
13200005	5th. & PINE	474.50	TCT	LMD8000	1/31/1997
13200006	US-2 & DIVISION ST.	27.71	TCT	LMD8000	12/20/1994
13200007	US-2 & BOYER AVE.	28.33	TCT	LMD8000	12/28/1994

2- MOUNTAIN HOME



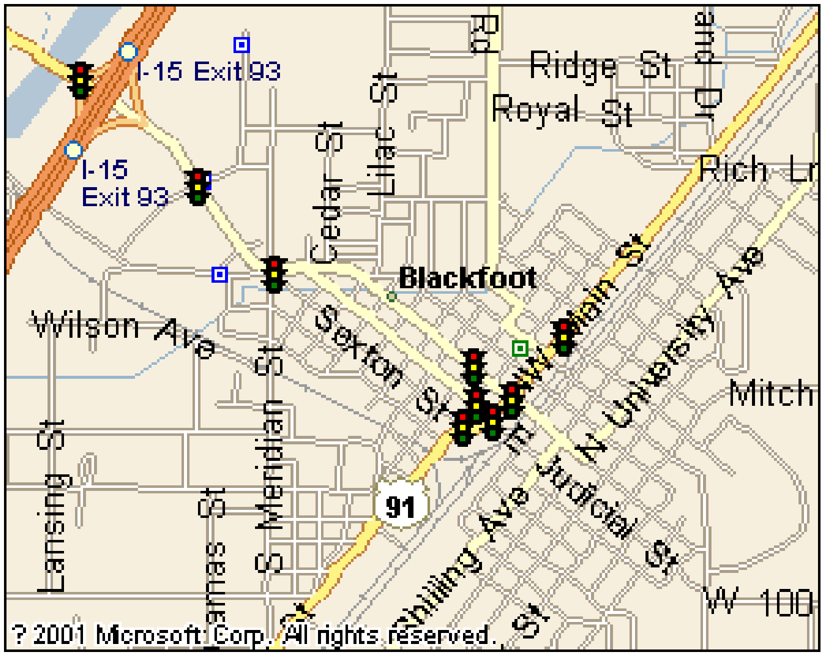
Signal No.	Location	Major Mile Post	Controller Make	Controller Model	Installation Date
	Airbase(SH51) & 5th W		TCT	LMD8000	
	SH51 & 5th W Tmp Cstrc.Traf. Cntrl.		TCT	LC8000	
	Airbase(SH51) & 3rd W		TCT	LMD8000	
	2nd E (I84B) & Jackson		TCT	LC8000	
32730001	10th & American Legion	93.08	TCT	LC8000	
32730002	US-30 & SH-51	4.54	TCT	LC8000	
32730003	3rd & American Legion	93.66	TCT	LC8000	
32730004	2nd & American Legion	4.06	Peek	LMD8000	

3- CHUBBUCK



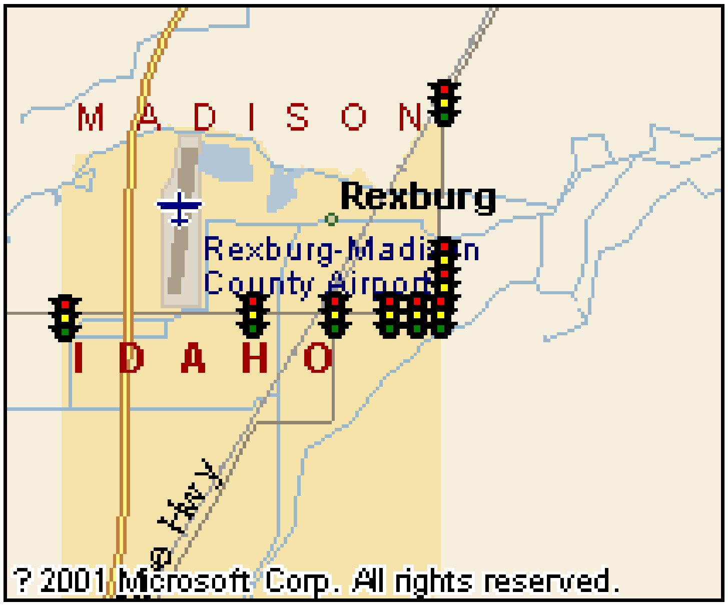
Signal No.	Location	Major Mile Post	Controller Make	Controller Model	Installation Date
51800001	Yellowstone & Poleine	79.66	TCT	LC800	
51800002	Yellowstone & Pineridge Mall	79.69	TCT	LC800	
51800003	Yellowstone & Breneman	79.86			
51800004	Yellowstone & I-86 E/B Offramp	79.98			
51800005	Yellowstone & I-86 W/B Offramp	80.09			
51800006	Yellowstone & Chubbuck Rd.	80.57			
51800007	Hwy 91 & Tyhee Rd (Flasher)	82.57			
	S. Rmp (EB off/on) Chubbuck IC				8/12/2002
	Chubbuck & Hiline				9/22/2000

4-BLACKFOOT



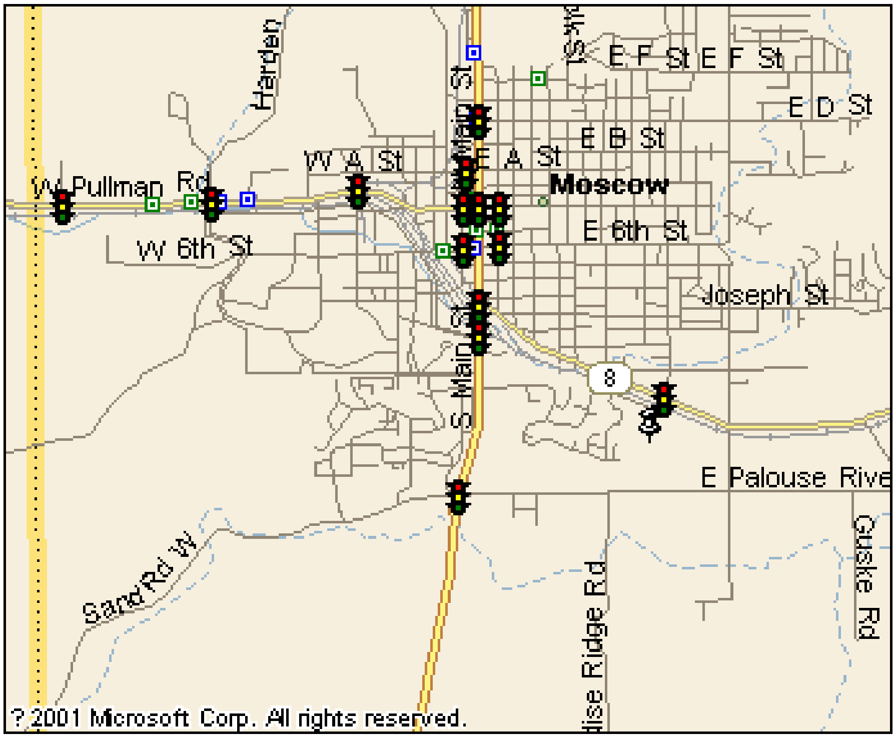
Signal No.	Location	Major Mile Post	Controller Make	Controller Model	Installation Date
51620001	Hwy 30 & Lund/Bancroft (Flasher)	378.43			
51650001	Hwy 91 & Alice	100.89			
51650002	Hwy 91 & Judicial	3.70			
51650003	Broadway & Judicial	3.74			
51650004	Hwy 91 & W. Bridge	3.66			
51650005	Broadway & W. Bridge	3.73			
51650006	Ash & W. Bridge	3.79			
51650007	Meridian & W. Bridge	4.33			
51650008	Parkway & Bergener	4.60			
51650009	I15 SB Off & Hwy 26	4.80			
51650010	W. Main & Broadway (Flasher)	3.46			
	I15 & US 26 Temp (Bridge out)				11/20/2000

5-REXBURG



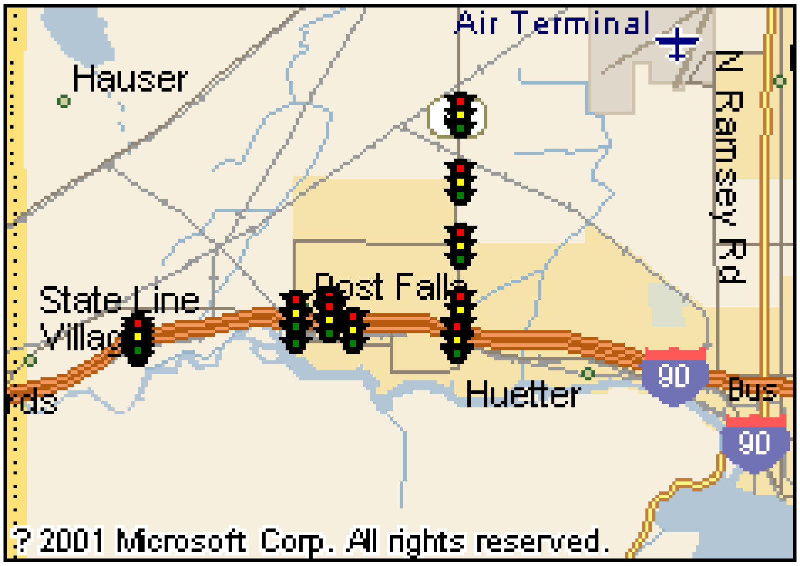
Signal No.	Location	Major Mile Post	Controller Make	Controller Model	Installation Date
63080001	MAIN & 5TH WEST	78.86			
63080002	MAIN & 2ND WEST	79.29			
63080003	MAIN & CENTER	334.48			
63080004	MAIN & 1ST EAST	334.62			
63080005	MAIN & 2ND EAST	334.77			
63080006	2ND EAST & 1ST NORTH	334.92			
63080007	2ND EAST & MT. RIVER RD	335.52			
63080008	SH-33 & SALEM ROAD	335.82			
	SH33(2nd E) & 2nd N				5/22/2001
	SH33 (2nd E) & Walmart				8/15/2002
	SH 33 & 2000W				

6-MOSCOW



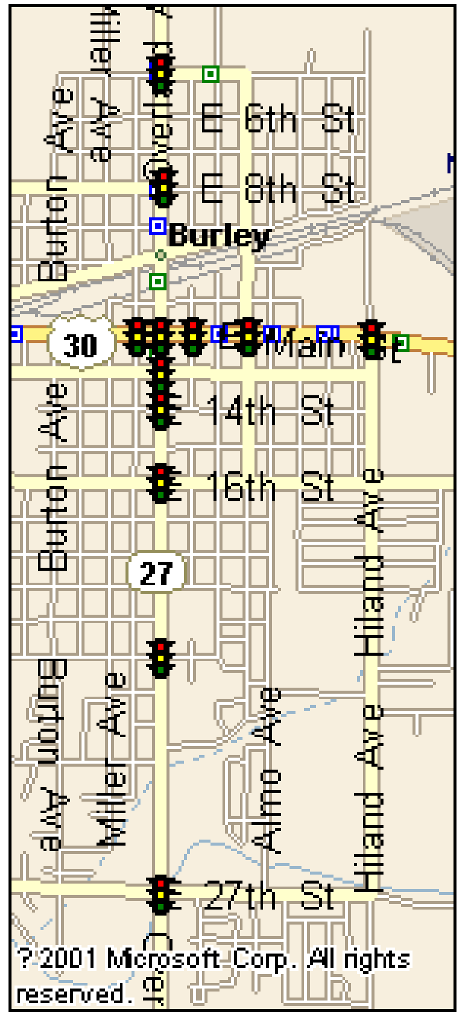
Signal No.	Location	Major Mile Post	Controller Make	Controller Model	Installation Date
22720001	US-95 & Sweet Ave.	344.76	TCT	LMD8000	9/17/1993
22720002	US-95 & SH-8	344.91	TCT	LC8000	
22720003	US-95 & D St.	345.63	TCT	LMD8000	12/28/1994
22720004	6th St. & Jackson	0.19	TCT	LC8000	
22720005	3rd St. & Jackson	0.35	TCT	LC8000	
22720006	A St. & Jackson	0.50	TCT	LC8000	
22720007	6th St. & Washington	345.20	TCT	LC8000	
22720008	3rd St. & Washington	345.35	TCT	LC8000	
22720009	SH-8 & Warbonnet	0.12	TCT	LMD8000	12/28/1994
22720010	SH-8 & Perimeter Dr.	0.73	TCT	LMD8000	12/28/1994
22720011	SH-8 & Line St.	1.33	TCT	LMD8000	8/1/1995
22720012	Main & 3rd St.	1.86	TCT	LC8000	
22720013	SH-8 & Blaine	3.07	TCT	LMD8000	9/17/1993
	US 95 & Palouse Rv. Drive				

7-POST FALLS



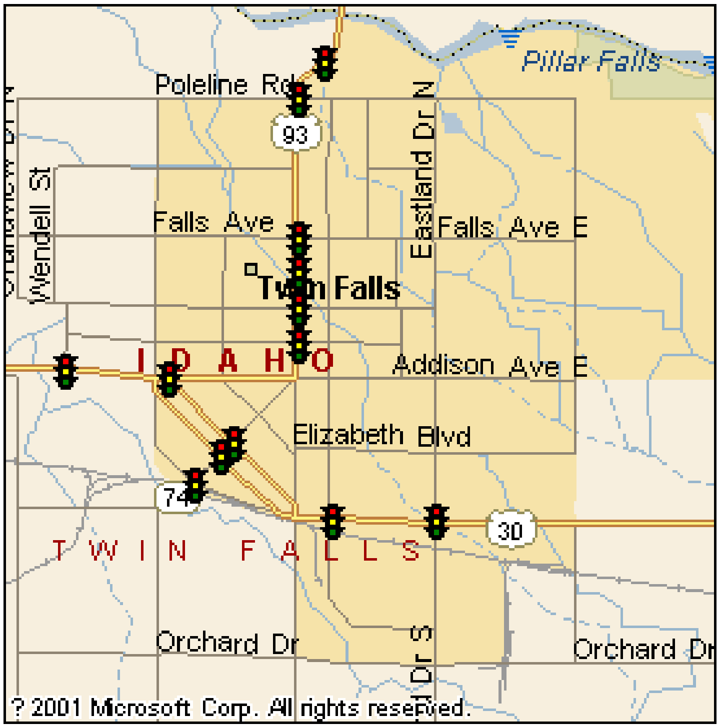
Signal No.	Location	Major Mile Post	Controller Make	Controller Model	Installation Date
13020001	I-90 & PLEASANT VIEW E.B.	2.05	TCT	LC8000	
13020002	I-90 & PLEASANT VIEW W.B.	2.11	TCT	LC8000	
13020003	I-90 & SELTICE WAY E.B.	6.77	TCT	LMD8000	8/1/1995
13020004	SELTICE WAY & SPOKANE ST.	4.72	TCT	LC8000	
13020005	SELTICE WAY & IDAHO ST.	5.25	TCT	LC8000	
13020006	SH-41 & SELTICE WAY	0.00	TCT	LMD8000	8/1/1995
13020007	SH-41 & I-90 W.B. OFF	0.17	TCT	LMD8000	8/1/1995
13020008	SH-41 & MULLAN AVE.	0.44	TCT	LMD8000	9/17/1993
13020009	SPOKANE ST. & I-90 E.B. OFF	0.12	TCT	LC8000	
13020010	SPOKANE ST. & I-90 W.B. OFF	0.20	TCT	LC8000	
13020011	SH-41 & PRAIRIE AVE.	2.45	TCT	LMD8000	9/17/1993
13020012	SH-41 & HAYDEN AVE.	3.45	TCT	LMD8000	12/28/1994

8-BURLEY



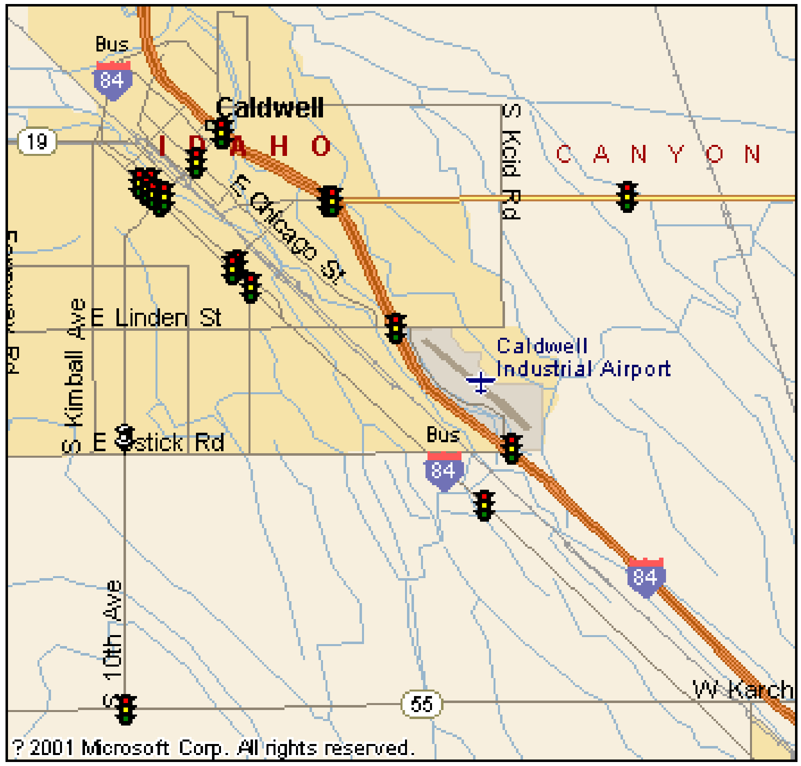
Signal No.	Location	Major Mile Post	Controller Make	Controller Model	Installation Date
41720001	OVERLAND & 21ST	21.03			
41720002	OVERLAND & 16TH	21.44			
41720003	OVERLAND & 14TH	21.62			
41720004	OVERLAND & 13TH	21.71			
41720005	OVERLAND & 8TH	22.16			
41720006	OVERLAND & ALFRESCO	23.59			
41720007	MAIN & OVERLAND	257.56			
41720008	MAIN & ALBION	257.62			
41720009	MAIN & NORMAL	257.76			
41720010	MAIN & HIGHLAND	258			
41720011	MAIN & OAKLEY	257.49			
41720012	MAIN & Y-DELL	258.5			
41720013	OVERLAND & 5TH	22.44			
41720014	OVERLAND & 27TH	20.44			
	Overland (SH27) & 7th				4/6/2001

9-TWIN FALLS



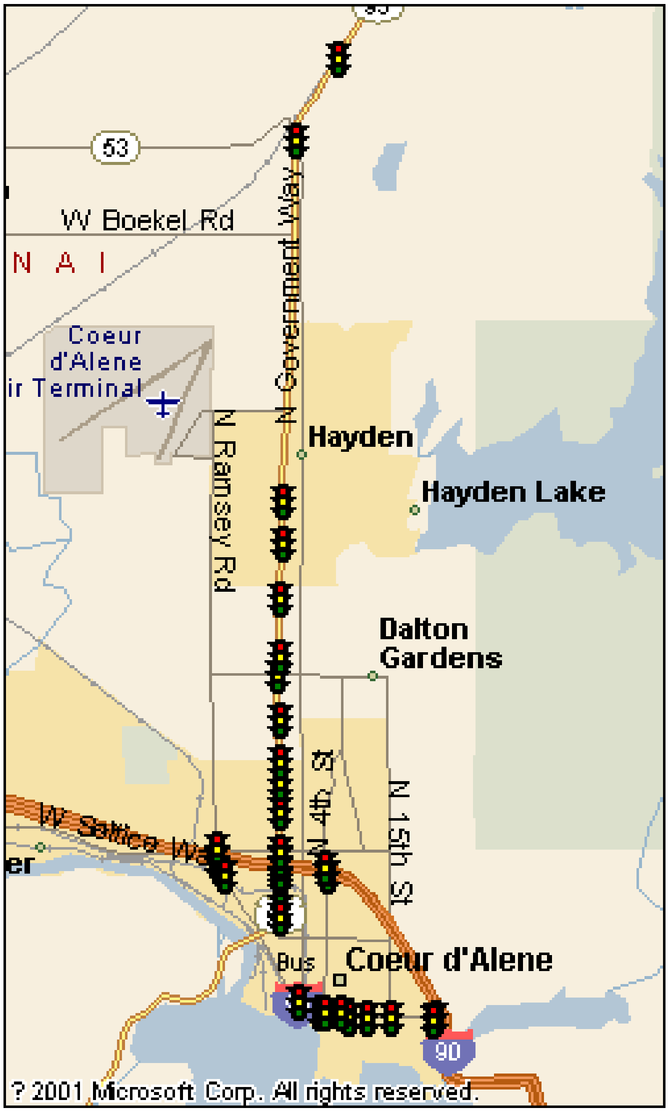
Signal No.	Location	Major Mile Post	Controller Make	Controller Model	Installation Date
43370001	SHOSHONE ST. & 2ND AVE N/E	217.93			
43370002	SHOSHONE ST. & 2ND ST. S/W	217.86			
43370003	6TH & SHOSHONE MINIDOKA	7.38			
43370004	WASH. SOUTH PARK / RUMAGE	7.14			
43370005	3RD AVE. & 2ND AVE S/W	217.77			
43370006	NORTH 5 POINTS	47.47			
43370007	BLUE LAKES & HAYBURN AVE	47.71			
43370008	BLUE LAKES & FALLS AVE	48.47			
43370009	BLUE LAKES & CASWELL AVE	48.22			
43370010	BLUE LAKES &N FILER AVE	47.96			
43370011	2ND AVE & ADDISON AVE. N.	46.45			
43370012	WEST 5 POINTS	217.22			
43370013	EAST 5 JPOINTS	218.66			
43370014	KIMBERLY & LOCUST AVE.	218.92			
43370015	KIMBERLY & EASTLAND DR.	219.67			
43370016	BLUE LAKES & POLE LINE RD.	49.45			
43370017	ADDISON MORRISON MARTIN	216.05			
	Blue Lakes (US93) & Bridgeview				4/25/2002
	SH46 & Idaho (Main)				8/10/2001

10-CALDWELL



Signal No.	Location	Major Mile Post	Controller Make	Controller Model	Installation Date
31740001	10th & Blaine	50.05	TCT	LC8000	
31740002	Kimball & Blaine	20.40	Crouse Hinds	LC8000	
31740003	7th & Cleveland	20.31	TCT	LC8000	
31740004	Kimball & Cleveland	20.38	TCT	LC8000	
31740005	9th & Cleveland	20.45	TCT	LC8000	
31740006	10th & Cleveland	50.08	TCT	LC8000	
31740007	21st & Blaine	50.85	TCT	LMD8000	
31740008	21st & Cleveland	50.88	TCT	LMD8000	
31740009	US-20-26 & Middleton Rd.	27.25	TCT	LMD8000	
31740010	SH-55 & 10th	11.62	TCT	LMD8000	
31740011	I-84B (US-30) & Ustick	53.01	TCT	LMD8000	
31740012	I-84B (US-30) & Happyday	53.79	TCT	LMD8000	
31740013	I-84 & 10th Ave. North	28.01	TCT	LC8000	
31740014	I-84 & 10th Ave. South	28.01	TCT	LC8000	
31740015	I-84B (US-30) & Linden	51.56	TCT	LC8000	
	N-C Blvd (I84B) & Wal-Mart		TCT	LC8000	
	I-84 & Franklin/US 20 Int EB Off		Crouse Hinds	LC8000	
	I-84 & Franklin/US 20 Int WB Off		TCT	LC8000	
	Cleveland & Indiana		TCT	LC8000	
	10th & Chicago (off system)		TCT	LC8000	

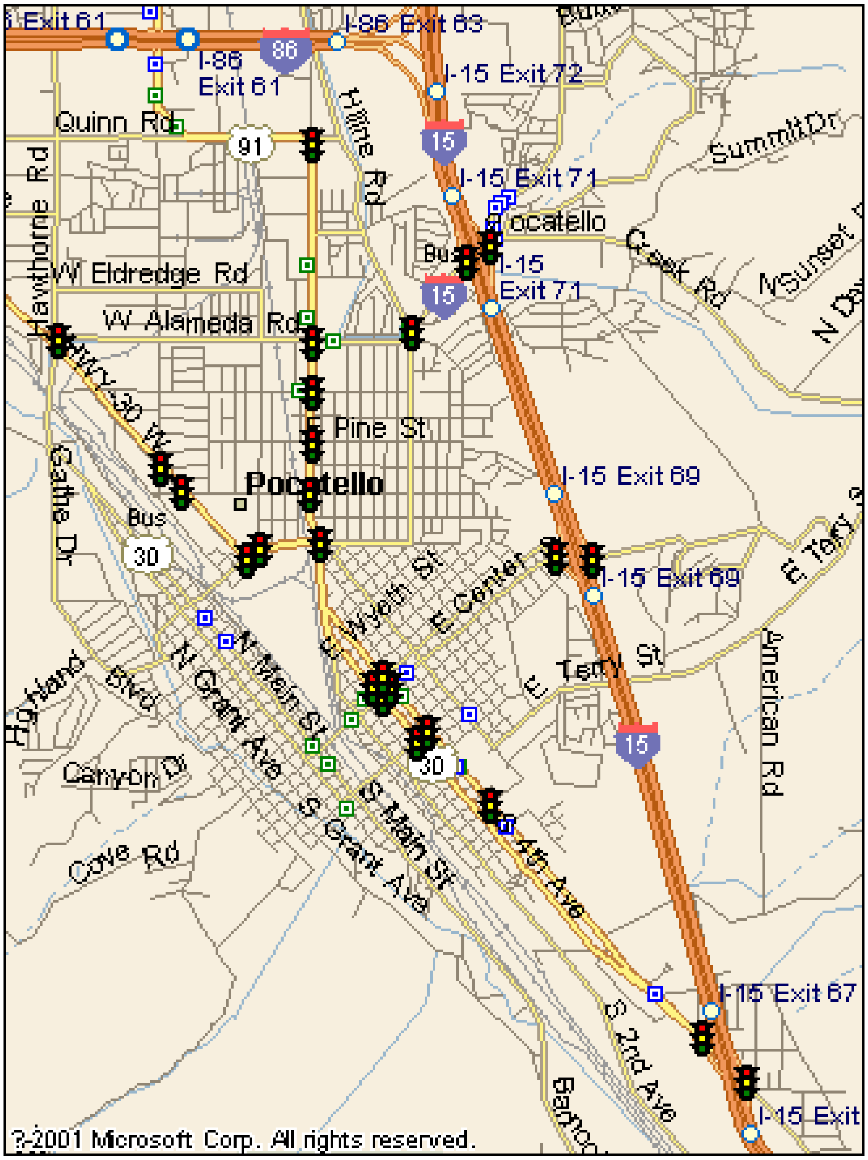
11- COEUR D'ALENE



11- COEUR D'ALENE

Signal No.	Location	Major Mile Post	Controller Make	Controller Model	Installation Date
11840001	US-95 & LACROSS	430.01			
11840002	US-95 & IRONWOOD	430.35	CROUSE HINDS	LC8000	
11840003	US-95 & I-90 E.B. OFF RAMP	430.57	TCT	LC8000	
11840004	US-95 & I-90 W.B. OFF RAMP	430.68	TCT	LC8000	
11840005	US-95 & APPLEWAY	430.76	TCT	LC8000	
11840006	US-95 & NEIDER AVE.	431.21	TCT	LC8000	
11840007	US-95 & BOSANKO AVE.	431.53	TCT	LC8000	
11840008	US-95 & KATHLEEN AVE.	431.78	TCT	LC8000	
11840009	US-95 & DALTON AVE.	432.28	TCT	LC8000	
11840010	US-95 & HANLEY AVE.	432.78	TCT	LC8000	
11840011	US-95 & CANFIELD AVE.	433.00	TCT	LC8000	
11840012	US-95 & PRAIRIE AVE.	433.79	TCT	LC8000	
11840013	US-95 & SH-53	437.01	TCT	LMD8000	8/1/1995
11840014	US-95 & GARWOOD	438.01	TCT	LMD8000	8/1/1995
11840015	I-90 & 4th. ST. E.B. OFF	12.55	TCT	LC8000	
11840016	I-90 & 4th. ST. W.B. OFF	12.56	TCT	LC8000	
11840017	I-90 & SHERMAN W.B. OFF	14.78	TCT	LC8000	
11840018	N.W.BLVD. & APPLEWAY	0.00	TCT	LMD8000	8/1/1995
11840019	N.W.BLVD. & I-90 E.B.OFF	0.12	TCT	LMD8000	8/1/1995
11840020	N.W.BLVD. & IRONWOOD DRV.	0.26	TCT	LMD8000	8/1/1995
11840021	N.W.BLVD. & GOVT. WAY	2.00	TCT	LMD8000	9/17/1993
11840022	N.W.BLVD. & LAKESIDE AVE.	2.10	TCT	LMD8000	6/9/1993
11840023	SHERMAN AVE. & 8th.	2.66	TCT	LMD8000	6/9/1993
11840024	SHERMAN AVE. & 11th.	2.88	PEEK	LMD8000	8/1/1995
11840025	SHERMAN AVE. & 15th.	3.15	PEEK	LMD8000	8/1/1995
11840026	SHERMAN AVE. & 23rd.	3.67	TCT	LC8000	
11840027	LAKESIDE & 3rd.	2.30	TCT	LMD8000	6/9/1993
11840028	LAKESIDE & 4th.	2.37	TCT	LMD8000	6/9/1993
11840029	LAKESIDE & 7th.	2.57	TCT	LMD8000	6/9/1993

12-POCATELO


I-86 Exit 63
I-86
Exit 61
I-15 Exit 72
Quinn Rd
91
Hiline Rd
Summit Dr
I-15 Exit 71
Pocatello
Hawthorne Rd
W Eldredge Rd
I-15
Exit 71
W Alameda Rd
Pine St
Pocatello
I-15 Exit 69
Bus
30
E Center
I-15 Exit 69
E Terry St
American Rd
N Main St
N Grant Ave
E Terry St
Highland Blvd
Canyon Dr
Cove Rd
S Main St
S Grant Ave
4th Ave
S 2nd Ave
I-15 Exit 67
I-15 Exit
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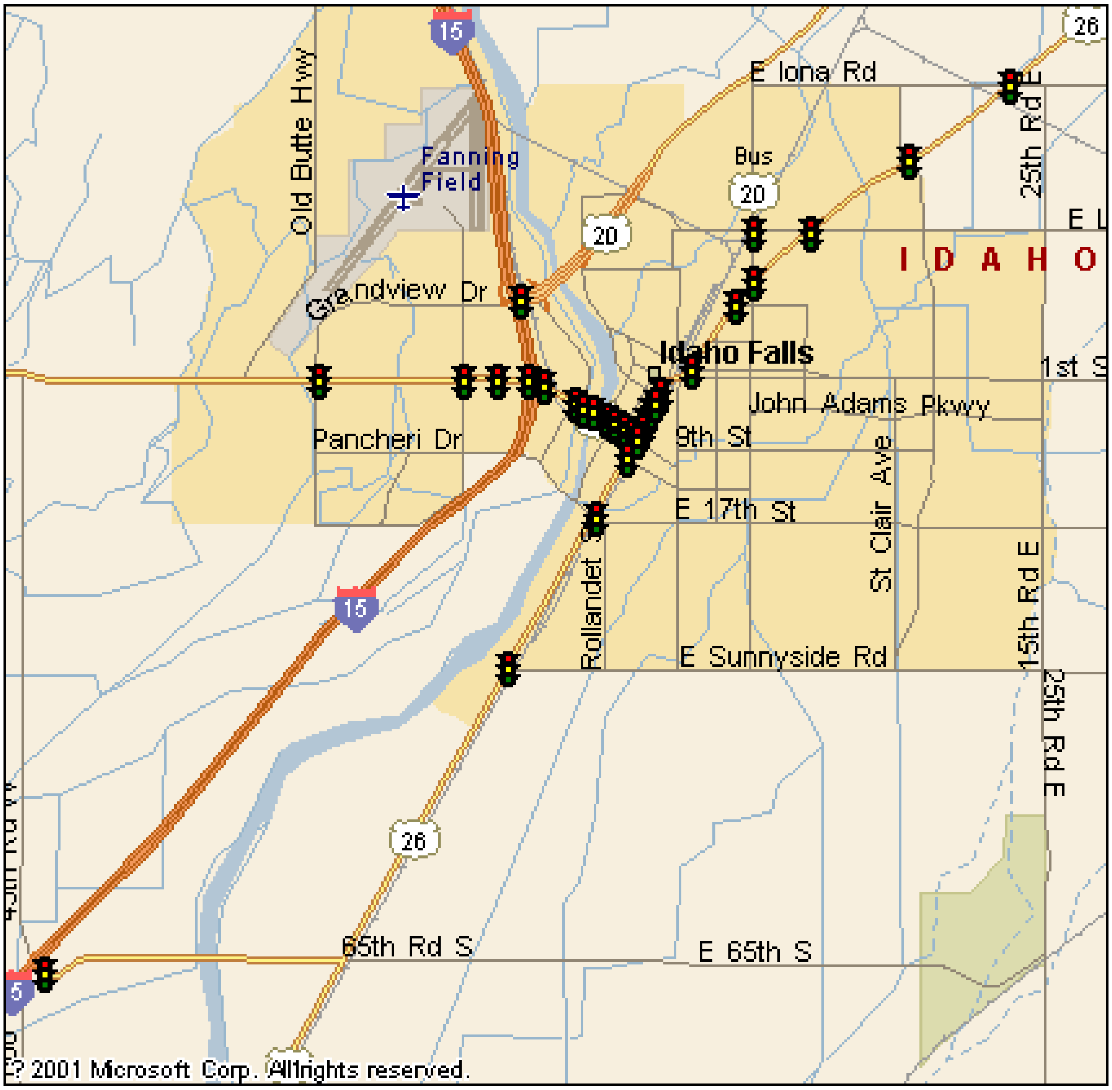
12-POCATELLO

Signal No.	Location	Major Mile Post	Controller Make	Controller Model	Installation Date
53000001	Yellowstone & Flandro	78.82			
53000002	Hawthorne & Garrett Way	334.01			
53000003	Poleline & Garrett Way	334.08			
53000004	Moreland & Garrett Way	334.77			
53000005	Gould & Garrett Way	335.39			
53000006	Gould & McKinley	335.49			
53000007	4th & Benton	2.35			
53000008	4th & Center	2.62			
53000009	4th & Clark	2.69			
53000010	5ht & Humbolt	1.87			
53000011	5th & Renton	2.34			
53000012	5th & Center	2.61			
53000013	5th & Clark	2.69			
53000014	Yellowstone & Oak	3.45			
53000015	Yellowstone & Maple	3.73			
53000016	Yellowstone & Pine	3.98			
53000017	Yellowstone & Cedar	4.22			
53000018	Yellowstone & Alemeda	4.48			
53000019	Jefferson & Alemeda	4.98			
53000020	I15 SB & Pocatello Crk	5.42			
53000021	I15 NB & Pocatello Crk	5.57			
53000022	I15 NB & Clark St	69.38			
53000023	I15 SB & Clark St	69.4			
53000024	Hwy 30 East of Simplot (Flasher)	331.91			
53000025	I86 EB by Airport (Flasher)	55.87			
53000026	I86 WB East of Simplot (Flasher)	59.09			
	Alameda & Warren				11/15/2000
	Alameda & Hawthorne				2005?
	I15 NB (Exit 67) & 5th				2003
	I15 SB (Exit 67) & 5th				2003

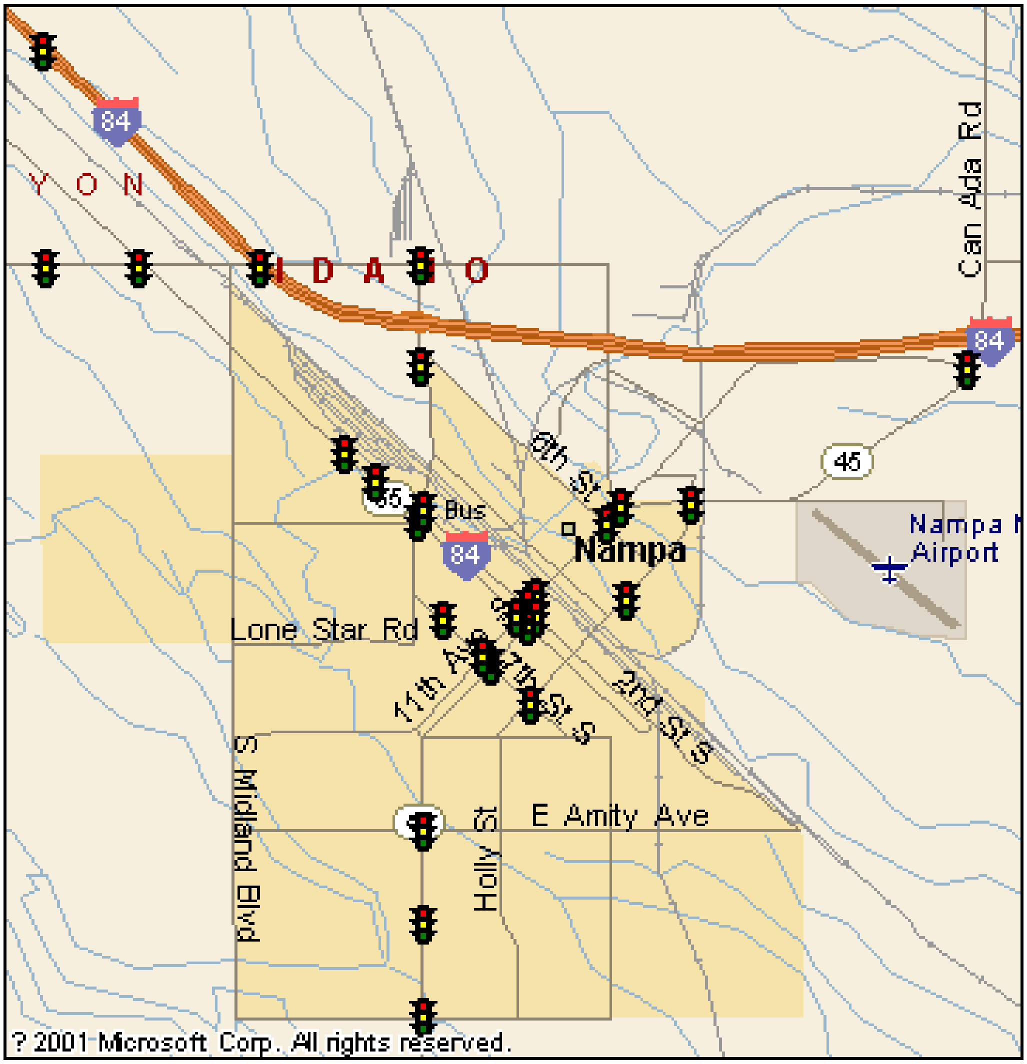
13- IDAHO FALLS



13- IDAHO FALLS

Signal No.	Location	Major Mile Post	Controller Make	Controller Model	Installation Date
62370001	BROADWAY & BELLIN	305.53	TCT	LC8000	
62370002	BROADWAY & SKYLINE	306.51	TCT	LC8000	
62370003	BROADWAY & SATURN	306.75	TCT	LC8000	
62370004	BRDWAY & IC 118 SB OFF/ON	306.90	TCT	LC8000	
62370005	GRANDVW & IC 119 NB OFF/ON	306.90	TCT	LMD8000	
62370007	HOLMES & ANDERSON	2.62	TCT	LC8000	
62370008	YELLOWSTONE & A	333.11	TCT	LC8000	
62370009	YELLOWSTONE & B	333.18	TCT	LC8000	
62370011	YELLOWSTONE & D	333.31	TCT	LC8000	
62370012	YELLOWSTONE & E	333.39	TCT	LC8000	
62370013	NORTHGATE & LOMAX	333.66	TCT	LC8000	
62370014	NORTHGATE & ELVA/HIGBY	334.19	TCT	LC8000	
62370015	NORTHGATE & HOLMES	334.37	TCT	LC8000	
62370016	YELLOWSTONE & LINCOLN	334.91	TCT	LMD8000	
62370018	YELLOWSTONE & SUNNYSIDE	4.53	TCT	LC8000	
62370019	YELLOWSTONE & 17TH	5.71	TCT	LMD8000	
62370020	YELLOWSTONE & CLIFF	6.16	TCT	LC8000	
62370021	YELLOWSTONE & BROADWAY	6.32	TCT	LMD8000	
62370022	BROADWAY & SHOUPE	6.38	TCT	LC8000	
62370023	BROADWAY & PARK	6.45	TCT	LC8000	
62370024	BROADWAY & CAPITOL	6.51	TCT	LC8000	
62370025	BROADWAY & MEMORIAL	6.58	TCT	LC8000	
62370026	BROADWAY & RIVER PARKWAY	6.68	TCT	LC8000	
62370027	BROADWAY & LINDSAY	6.77	TCT	LC8000	
62370028	BROADWAY & UTAH	6.85	TCT	LMD8000	
62370029	BRD WAY & IC 118 NB OFF/ON	7.13	TCT	LC8000	
	I15B & US91-65th-Riviera				3/12/2002
	US 26 and SH 43/35th St. East				3/25/2003
	Hitt Rd & US26				7/3/2001
	Broadway & I15 NB(E)				10/9/2002
	Broadway & I15 SB(W)				10/9/2002
62370006	LEWISVILLE & IC 310 OFF/ON	1.47	TCT	LC8000	
62370017	YELLOWSTONE & WOODRUFF	335.75	TCT	LC8000	

14 -NAMPA


84
Y O N
I D A H O
Can Ada Rd
84
45
6th St
55
Bus
84
Nampa
Nampa
Airport
Lone Star Rd
11th Ave
2nd St S
S Midland Blvd
Holly St
E Amity Ave
? 2001 Microsoft Corp. All rights reserved.

14 -NAMPA

Signal No.	Location	Major Mile Post	Controller Make	Controller Model	Installation Date
32780001	I-84B (US-30) & Karcher Rd.	55.94	TCT	LC8000	
32780002	1st & 11th South	58.82	Crouse Hinds	LC8000	
32780003	6th & 11th North	59.35	TCT	LC8000	
32780004	3rd & Nampa Blvd.	57.94	TCT	LC8000	
32780005	2nd & Nampa Blvd.	57.87	TCT	LC8000	
32780006	7th & 12th (SH- 45)	27.29	Crouse Hinds	LC8000	
32780007	Lake Lowell & 12th (SH-45)	26.26	TCT	LC8000	
32780008	Greenhurst & 12th (SH-45)	25.26	TCT	LC8000	
32780009	I-84 & Garrity Blvd.	38.01	TCT	LC8000	
32780010	Iowa & 12th (SH-45)	25.7	TCT	LC8000	
32780011	I-84 & Nampa Blvd. North	35.01	Eagle Signal	EF122	
32780012	I-84 & Nampa Blvd. South	35.01			
32780013	I-84B (US-30) & Canyon	57.63			
32780014	I-84B (US-30) & Midland	56.58			
32780015	I-84B (US-30) & SHOPKO	55.59			
32780016	SH-55 (Karcher)& Middleton	15.63			
32780017	I-84B (US-30) & Middleton	55.19			
32780018	2nd & 11th South	58.74			
32780019	2nd & 12th (SH-45)	27.65			
32780020	3rd & 12th (SH- 45)	27.58			
32780021	3rd & 11th South	58.67			
32780022	Karcher Rd. & Cassia St.	16			
	16th Ave N & 3rd St N				
	Northside & Karcher				
	SH45 (12th) & 7th				
	Nampa/Caldwell Blvd. & Orchard				
	Garrity Interchange WB Off/On				
	Garrity Interchange EB Off/On				
	Garrity & Flamingo				
	Garrity & 16th Ave N				
	Nampa Blvd & 6th St Ext				
	7th St S & 16th Av S OS				
	Garrity/Can-Ada & Franklin OS				
	7th St S & 11th Ave S OS				
	Garrity & 11th Ave N				
	7th Ave & 7th St				
	Garrity (I84B) & Kings Rd				

APPENDIX B: EXISTING RESOURCES—STAFF SURVEY

Research Project Background and Goal
The Idaho Transportation Department has contracted with a research team at the University of Idaho to develop a set of guidelines for traffic control systems. Several versions of guidelines from various agencies exist and each offers a valuable perspective in the area of traffic signal systems. Unfortunately, existing guidelines overlook many issues that are extremely important to small and medium sized cities. To better address these issues, the goal of this project is to establish a set of guidelines that will help bridge the gap between available traffic control technologies, anticipated traffic conditions, traffic operations goals, and the realities with which transportation departments have to live.

Purpose of This Survey
This survey will help determine the realities as they relate to human resources, giving an accurate picture of the human resources available at ITD to work with traffic control systems. Specifically, the research team needs information describing the number of personnel serving in key positions, the experience of these personnel, and their familiarity with traffic engineering software packages and reference materials. Please accept the appreciation of the research team and the ITD advisory committee members for taking the time to complete the survey and to assist us in improving the operations and safety of the Idaho transportation system.

Part A: Human Resources Available
District Traffic Engineer
Years in current position
Years of experience related to traffic signal systems

In your opinion, what are the three most important technical qualifications for someone working in the area of traffic signal systems

1)
2)
3)

On an average working week (40 hours), how many hours do you spend on each of the following tasks:

Day-to-day management operation
Field work
Signal Retiming/update of existing traffic signals
New traffic signal projects
Training/Education
Other Tasks

Traffic Signal Technicians
Number of traffic signal technicians positions in the district

Number of filled positions

On an average working week (40 hours), how many hours does a traffic signal technicians spend on each of the following tasks:

- Field work
- Day-to-day management operation
- Signal Retiming/update of existing traffic signals
- New traffic signal projects
- Training/Education
- Other Tasks

Are there any technical support resources available for the traffic section in the following areas?

Computer support (software)
Computer support (hardware)
Network Administrator (software)
Communication specialists

<u>Part B: Design Manuals, References and Software [Availability, Familiarity and Frequency of use]</u>

<u>1. SYNCRHO</u>

Software/reference availability [☐available☐not available]

What is the level of your familiarity with the software/reference?

☐Excellent ☐Very Good ☐Good ☐Poor ☐None

On an average week how many times do you use the software/reference?

☐Four or More ☐Three ☐Two ☐One ☐None

<u>2. CORSIM</u>

Software/reference availability [☐available☐not available]

What is the level of your familiarity with the software/reference?☐Excellent ☐Very Good ☐Good ☐Poor ☐None

On an average week how many times do you use the software/reference?

☐Four or More ☐Three ☐Two ☐One ☐None

<u>3. TRANSYT 7F</u>

Software/reference availability [☐available☐not available]

What is the level of your familiarity with the software/reference?

☐Excellent ☐Very Good ☐Good ☐Poor ☐None

On an average week how many times do you use the software/reference?

☐Four or More ☐Three ☐Two ☐One ☐None

<u>4. CORSIM (Hardware-in-the-loop-Simulation)</u>

Software/reference availability [☐available☐not available]

What is the level of your familiarity with the software/reference?

☐Excellent ☐Very Good ☐Good ☐Poor ☐None

On an average week how many times do you use the software/reference?

☐Four or More ☐Three ☐Two ☐One ☐None

<u>5. Intersection Capacity Software (HCS, HiCAP)</u>

Software/reference availability [☐available☐not available]

What is the level of your familiarity with the software/reference?

☐Excellent ☐Very Good ☐Good ☐Poor ☐None

On an average week how many times do you use the software/reference?

☐Four or More ☐Three ☐Two ☐One ☐None

<u>6. VISSIM</u>

Software/reference availability [☐available☐not available]

What is the level of your familiarity with the software/reference?
☐Excellent ☐Very Good ☐Good ☐Poor ☐None

On an average week how many times do you use the software/reference?
☐Four or More ☐Three ☐Two ☐One ☐None

7. ITD design Manual
Software/reference availability [☐available☐not available]

What is the level of your familiarity with the software/reference?
☐Excellent ☐Very Good ☐Good ☐Poor ☐None

On an average week how many times do you use the software/reference?
☐Four or More ☐Three ☐Two ☐One ☐None

8. HCM2000
Software/reference availability [☐available☐not available]

What is the level of your familiarity with the software/reference?
☐Excellent ☐Very Good ☐Good ☐Poor ☐None

On an average week how many times do you use the software/reference?
☐Four or More ☐Three ☐Two ☐One ☐None

9. ITE Traffic Signal Systems Handbook
Software/reference availability [☐available☐not available]

What is the level of your familiarity with the software/reference?
☐Excellent ☐Very Good ☐Good ☐Poor ☐None

On an average week how many times do you use the software/reference?
☐Four or More ☐Three ☐Two ☐One ☐None

10. FHWA Traffic Control Systems Handbook
Software/reference availability [☐available☐not available]

What is the level of your familiarity with the software/reference?
☐Excellent ☐Very Good ☐Good ☐Poor ☐None

On an average week how many times do you use the software/reference?
☐Four or More ☐Three ☐Two ☐One ☐None

11. Other Handbooks [Please specify]
Software/reference availability [☐available☐not available]

What is the level of your familiarity with the software/reference?
☐Excellent ☐Very Good ☐Good ☐Poor ☐None

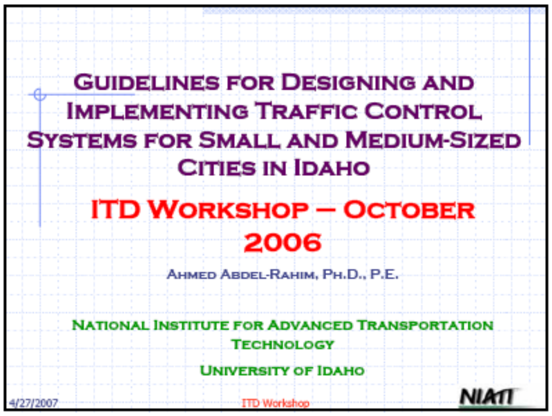
On an average week how many times do you use the software/reference?
☐Four or More ☐Three ☐Two ☐One ☐None

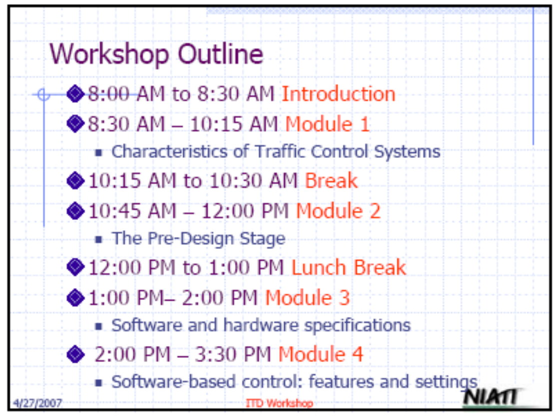
12. Other Handbooks [Please specify]
Software/reference availability [☐available☐not available]

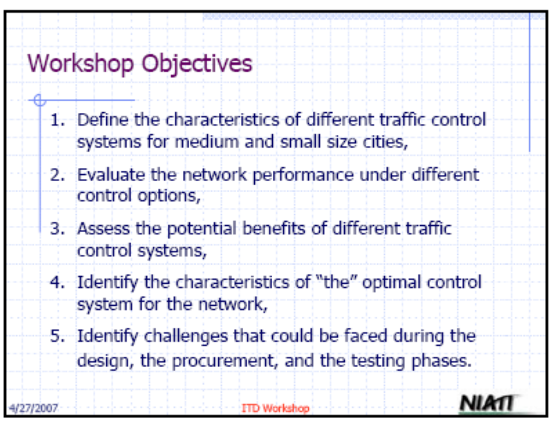
What is the level of your familiarity with the software/reference?
☐Excellent ☐Very Good ☐Good ☐Poor ☐None

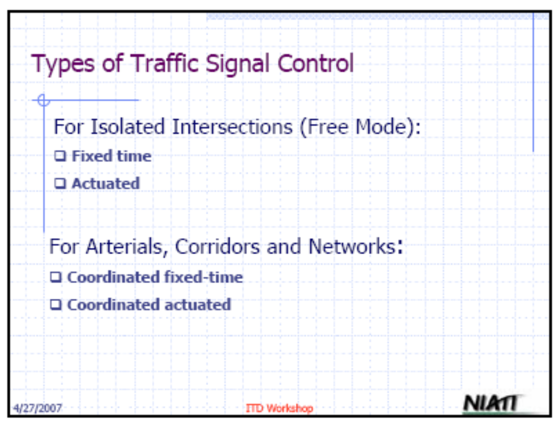
On an average week how many times do you use the software/reference?
☐Four or More ☐Three ☐Two ☐One ☐None

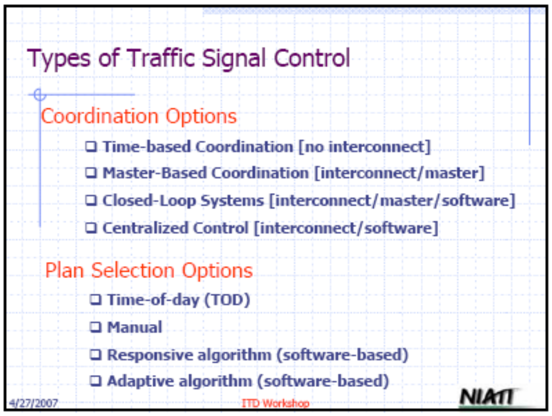
APPENDIX C: TRAFFIC SIGNAL SYSTEM WORKSHOP










Types of Traffic Signal Control
Coordination Options
Time-based Coordination [no interconnect]
Master-Based Coordination [interconnect/master]
Closed-Loop Systems [interconnect/master/software]
Centralized Control [interconnect/software]
Plan Selection Options
Time-of-day (TOD)
Manual
Responsive algorithm (software-based)
Adaptive algorithm (software-based)
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Optimal signal timing plan?
What do you exactly mean by that?
Users' prospective ["I am stopping for too long compared to vehicles in the major street. That's not fair and not optimal"]
System operators' prospective [minimize system wide delay, travel time, cost, and users' complains]
Environmental advocates' prospective [minimize vehicle-related emissions]
Politicians prospective ["whatever makes people (voters) happy is, for me, optimal"]
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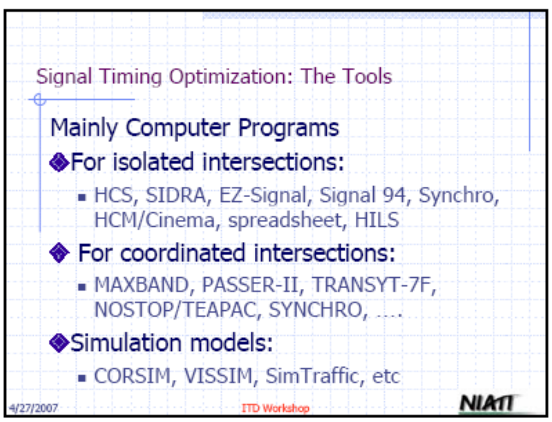
Signal Timing Optimization: The Tools
Mainly Computer Programs
For isolated intersections:
HCS, SIDRA, EZ-Signal, Signal 94, Synchro, HCM/Cinema, spreadsheet, HILS
For coordinated intersections:
MAXBAND, PASSER-II, TRANSYT-7F, NOSTOP/TEAPAC, SYNCHRO, ….
Simulation models:
CORSIM, VISSIM, SimTraffic, etc
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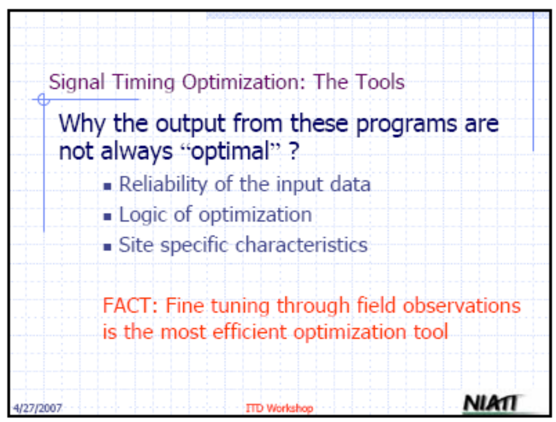
Signal Timing Optimization: The Tools
Why the output from these programs are not always "optimal" ?
Reliability of the input data
Logic of optimization
Site specific characteristics
FACT: Fine tuning through field observations is the most efficient optimization tool
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Modeling Tools - Applications

Software Tool	ANALYZE: Freeways	Interchanges	Networks	Corridors	Links	Stop-controlled	Actuated signalized	Fixed-time signalized	Roundabouts	OPTIMIZE: Network Cycle Lengths	Network Offsets	Intersection Offsets	Splits	SIMULATE: Freeways	Interchanges	Networks	Corridors	Stop-controlled	Actuated signalized	Fixed-time signalized	Roundabouts
HCS	X			X		X	X	X													
Synchro	X	X	X	X	X	X	X	X	X	X	X	X	X								
Transyt 7F			X	X	X		X	X		X	X	X	X								
Passer II				X			X	X		X	X	X	X								
Passer III		X								X	X	X	X								
Passer IV			X		X		X	X		X	X	X	X								
SimTraffic														X	X	X	X	X	X	X	X
Corsim	X	X	X		X		X	X						X	X	X	X		X	X	
Vissim	X	X	X	X	X	X	X	X	X					X	X	X	X	X	X	X	X

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Modeling Tools – data need

Software Tool	Level of Analysis	GEOMETRY: Number of Lanes	Lane Channelization	Lane Widths	Lane Alignment	Turn Pockets	TRAFFIC FLOW: Volumes	Free Flow Speed	Saturation Flow	Mean Startup Delay	Peak Hour Factor	SIGNAL TIMING: Control Type	Min Green	Max Green	Yellow Time	All-Red	Vehicle Extension	Offsets	Cycle Length
HCS	Macroscopic	X	X	X	X	X	X	X	X	X	X	X			X	X	X		X
Synchro	Macroscopic	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Transyt 7F	Macroscopic	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Passer II	Macroscopic	X		X	X		X	X	X			X	X		X	X		X	X
Passer III	Macroscopic	X		X	X		X	X	X			X	X		X	X		X	X
Passer IV	Macroscopic	X		X	X		X	X	X			X	X		X	X		X	X
Corsim	Microscopic	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Simtraffic	Microscopic	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Vissim	Microscopic	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X

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Modeling Tools – ITD Resources

Resources/ Tools	Availability	Familiarity: Excellent	Very Good	Good	Fair	None	Index	Uses/Week: ≥4	3	2	1	<1	None	Index
Synchro	50%				5	1	11					1	5	7
CORSIM	0%			1	1	4	9						6	6
Transyt 7F	17%					6	6						6	6
CORSIM (NL6)	0%			1		5	8						6	6
HCS or HiCap	83%		1	3	1	1	16			1	2	1	2	14
VISSIM	17%			1		5	8		1				5	10
ITD Traffic Manual	100%		1	4	1		18		1	1	2	2		19
HCM 2000	83%		1	2	2	1	15				2	3	1	13
ITE Traffic Ctrl. Sys. Hndbk.	67%		1	2		3	13				1	2	3	10
FHWA Traffic Ctrl. Sys. Hndbk.	17%				2	4	9					1	5	7
MUTCD	100%	1	1	4			21	3	1	1	1			30
AASHTO	100%		1	3	1		16			1	2	2		14

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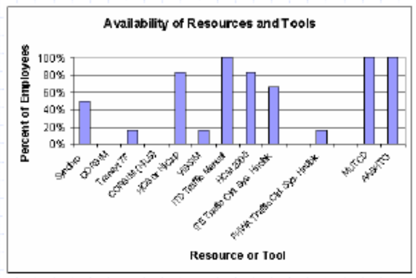
Modeling Tools – ITD Resources



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Traffic Signal System Functionalities

- Provide optimal signal control (users)
- Provide continuous monitoring and evaluation (institutional)
- Maintainable, manageable and accessible (institutional)
- Detect malfunctions/problems (detectors, phase failures, etc.)

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The Pre-Design Stage

- Identify network characteristics and possible improvements
  1. Optimal number of control Plans
  2. Optimal number of subsystems [coordination decisions]
  3. Long versus short cycle length
  4. Fixed time versus actuation decisions

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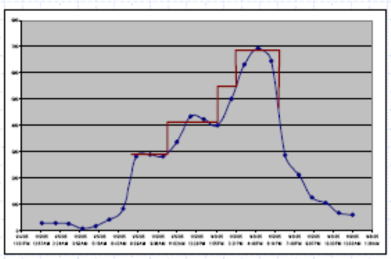
The Pre-Design Stage: Identify the Operational Characteristics of the Network

Optimal Number of Control Plans



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Case Study A: Optimal Number of Control Plans for the City of Moscow

- Data sources:
  - ATR stations
  - Tube counts
- Issues to consider
  - Major movements (priorities)
  - Seasonal variation
  - Entry volumes versus mid-block volumes (data archiving)

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Case Study A: Optimal Number of Control Plans for the City of Moscow (15-minute)

- Steps for the analysis
  1. Identify data used in the analysis (days and stations)
  2. Plot 24-hour volume for each day at each station (highlight the data then click on the graph icon)
  3. Start at the most critical station, identify optimal TOD plans
  4. Examine and modify the TOD plans obtained in (3) with other stations/days
  5. Determine optimal number of control plans and the duration of each plan.
  6. Determine need for special event plans

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Case Study A: Optimal Number of Control Plans for the City of Moscow (15-minute)

- Issues to think about
  1. Validity of the output (what if we used two different days for the analysis?)
  2. System detectors concept
  3. Disutility during transition periods
  4. Design hourly volumes for each of the control plans

Lesson 1: Availability of volume and turning percentage data is the #1 factors for successful implementation

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Case Study B: Optimal Number of Subsystems in the city of Moscow (30-minute)

- Each set of coordinated signals in one subsystem
- Three different groups:
  1. Definitely isolated (free-mode)
  2. Definitely coordinated
  3. Possibly coordinated [need to examine the potential benefit from coordination]

Issue to consider: are subsystems the same in all TOD plans?

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Case Study B: Optimal Number of Subsystems in the city of Moscow (30-minute)

- Steps for the analysis
  1. Identify questions to be answered
  2. Identify scenarios to be tested based
  3. Use one of the analysis tools (either Corsim or Synchro) to answer the set of questions identified in 1
  4. Document the output of the analysis.

Lesson 2: Keep updated models for your cities

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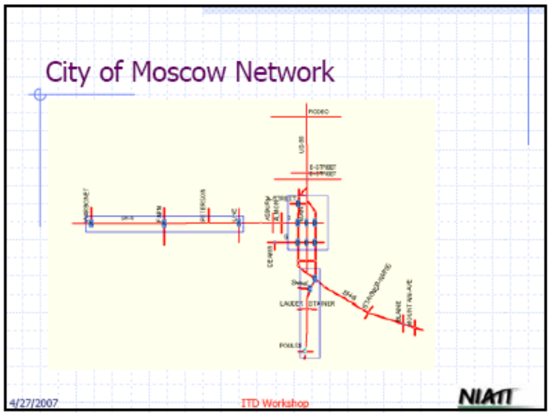
City of Moscow Network
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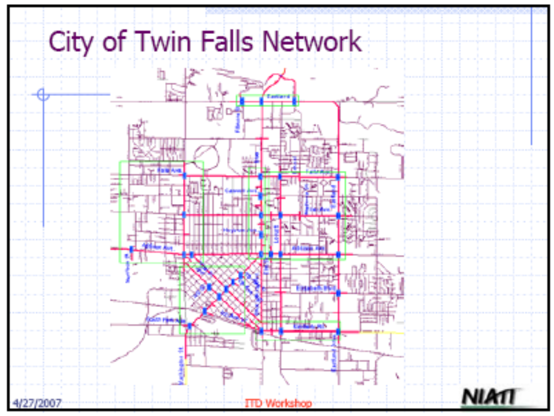
City of Twin Falls Network
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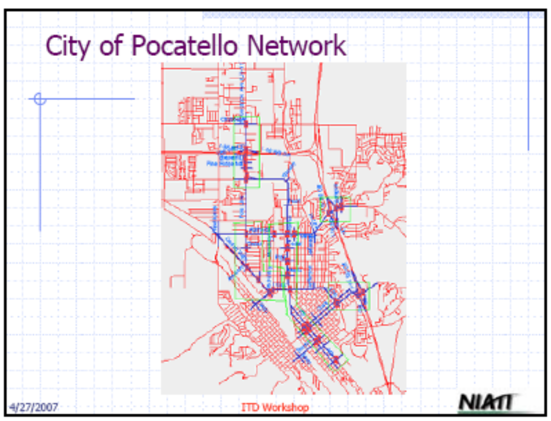
City of Pocatello Network
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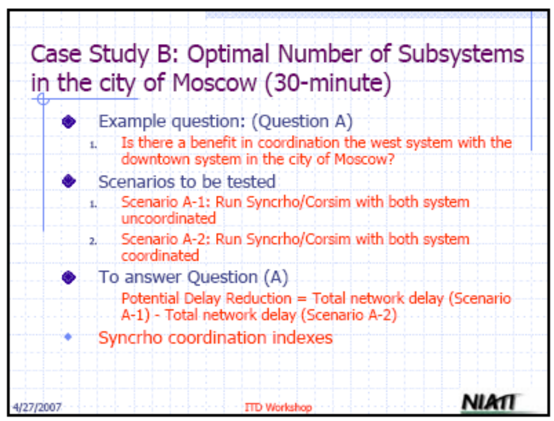
Case Study B: Optimal Number of Subsystems in the city of Moscow (30-minute)
Example question: (Question A)
1. Is there a benefit in coordination the west system with the downtown system in the city of Moscow?
Scenarios to be tested
1. Scenario A-1: Run Syncrho/Corsim with both system uncoordinated
2. Scenario A-2: Run Syncrho/Corsim with both system coordinated
To answer Question (A)
Potential Delay Reduction = Total network delay (Scenario A-1) - Total network delay (Scenario A-2)
Syncrho coordination indexes
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Case Study C: Are we getting the best we can from existing system (30-minute)

- Can features that already exist in the current system (i.e. coordinated actuated, volume/density, etc.) improve the network operations?

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Characteristics of different Control Systems : Time-based coordination

- Coordination is achieved through offsets and time-synchronization
- Work very effectively with new controllers that uses GPS clock synchronization
- No communication system required
- No masters
- The cost of modifying the system is significant
- No system monitoring or data archiving capabilities

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Characteristics of different Control Systems : Master-based coordination

- Coordination is achieved through offsets and time-synchronization controlled by a master controller for each subsystem
- The system typically includes a communication software [dial-in to the master]
- Communication system required [interconnect between intersections and a link between each master and the center]
- One master for each subsystem

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Characteristics of different Control Systems : Master-based coordination

- The cost of modifying the system is minimal
- Good system monitoring
- No data archiving capabilities
- No coordination among subsystems
- No responsive or adaptive system
- No additional cost for a control software

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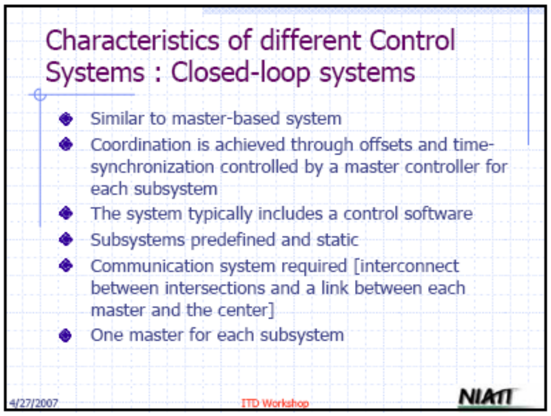
Characteristics of different Control Systems : Closed-loop systems
Similar to master-based system
Coordination is achieved through offsets and time-synchronization controlled by a master controller for each subsystem
The system typically includes a control software
Subsystems predefined and static
Communication system required [interconnect between intersections and a link between each master and the center]
One master for each subsystem
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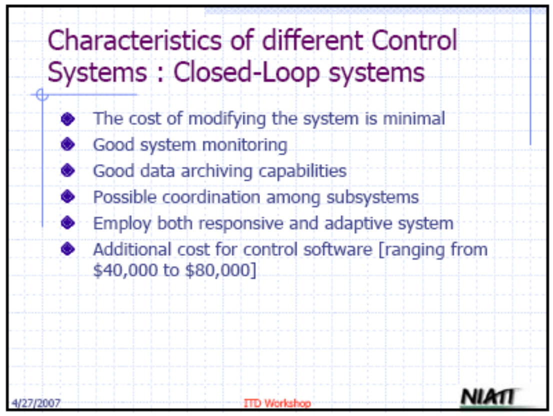
Characteristics of different Control Systems : Closed-Loop systems
The cost of modifying the system is minimal
Good system monitoring
Good data archiving capabilities
Possible coordination among subsystems
Employ both responsive and adaptive system
Additional cost for control software [ranging from $40,000 to $80,000]
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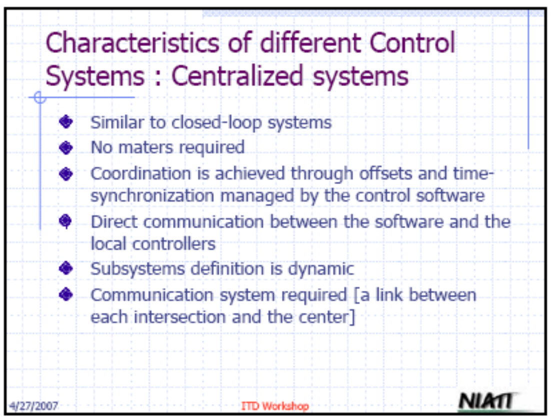
Characteristics of different Control Systems : Centralized systems
Similar to closed-loop systems
No maters required
Coordination is achieved through offsets and time-synchronization managed by the control software
Direct communication between the software and the local controllers
Subsystems definition is dynamic
Communication system required [a link between each intersection and the center]
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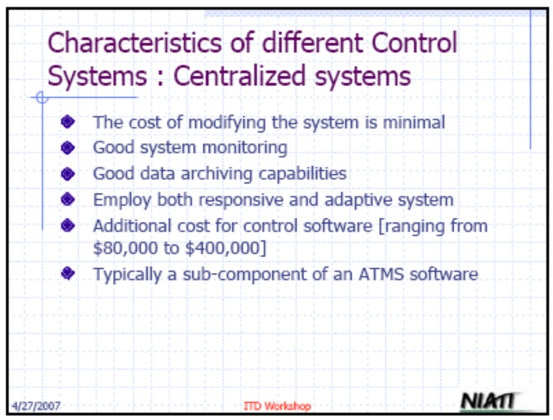
Characteristics of different Control Systems : Centralized systems
The cost of modifying the system is minimal
Good system monitoring
Good data archiving capabilities
Employ both responsive and adaptive system
Additional cost for control software [ranging from $80,000 to $400,000]
Typically a sub-component of an ATMS software
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Characteristics of different Control Systems

Types	Closed Loop	Centralized
Definition	Local controllers connect to Master controller via fiber optic cable Master controller connects to central monitor via modem or phone line Central monitor can monitor operations of master and local controllers System detectors are needed	Computer system (including Master computer, communications, console, display) communicate directly with each local controller Coordinate and control traffic signal and traffic control throughout the area
Signal Flexibility	Predetermine timing plans and schedule (year, week and day schedule) System detector controls system signal based on demand Traffic Responsive OVERRIDE: Schedule traffic responsive in the predetermined schedule Time of Day OVERRIDE: Schedule time based coordination, but allow traffic responsive to take over if demand is present	Locals can easily be moved in and out of systems as traffic patterns change Changes in traffic patterns can be quickly identified Traffic signal equipment problems can be recognized and managed more efficiently The timing between traffic signals can be more easily coordinated
Advantage	TBC and TRP Coordination (system clock) System maintenance access (24/7) Data collection Remote Monitoring Data Logging	TBC and TRP Coordination (central clock) Remote Monitoring Data Logging System Structure Control

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Example of a closed-loop Software: Aries

- Windows based data management and monitoring system
- Graphical user interface(point-and-click selection of zone,intersection and functions)
- Multitasking operation (system operation,system monitor and scheduler)
- Multiple communication ports (up to 16 communications ports)
- Distributed network support (handle all communication tasks,perform from any workstation)
- Operation scheduler (multiple operations repeat at intervals in min/hr/days/months/years)
- Manual commands (initiated-manual operations)
- Split monitor report (split utilization display,program start time and duration,etc.)

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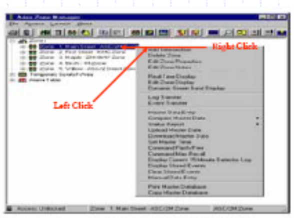
Aries Zone Manager

- Manage zone and intersection information via right click on zone or intersection icon.
- Define or perform necessary operations accordingly via left click on pop-up manus



Aries Zone Manager menu

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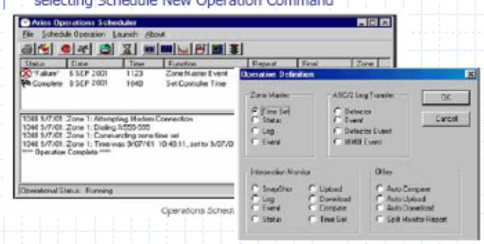
Operations Scheduler

- Schedule zone and intersection operation to take place at a define time and data
- Scheduling an operation by clicking the application window and selecting Schedule New Operation Command



Operations Schedul

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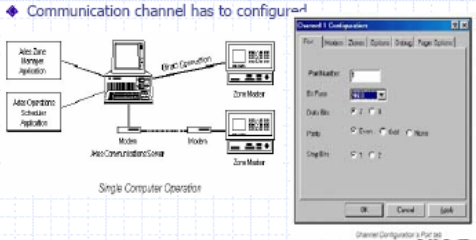
Aries Communications Server

- Data connection with the remote device, communicating with remote device,and then directing any data back to the requesting application
- Communication channel has to configured



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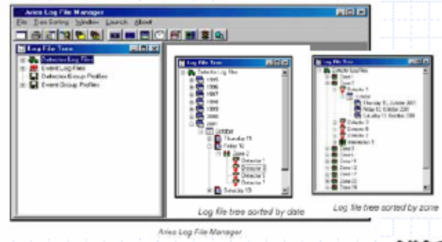
Aries Log File Manager

- Maintain and view log and event files that are obtained from a master or intersection controller, sorted by date or zone



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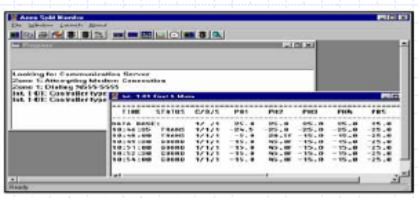
Map Display and Report Capability

- Real-time zone map display and intersection display
- Dynamic Green Band Display
- Split Monitor Report: show split usage overtime
- Status,Event Report
- Detector log data in table or plot format
- Zone Master Speed Trap Viewer



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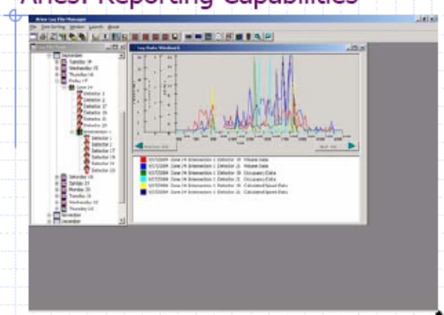
Aries: Reporting Capabilities



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Example of a centralized software: Icons

- Advanced Traffic Management System that provides a centralized integrated platform for traffic signal control, information management and graphical data display
- Full-featured, object-oriented Graphical User Interface with intersection specific objects designed for centralized management and control of signalized intersections.
- Compatible with ATC Controller such as Model 2070 as well as NEMA TS-1/TS-2
- Capable of controlling, receiving status and detector data from, and uploading and downloading local controller parameters to and from each intersection

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System Configuration

- Define and configurate system and system elements
- Define mandatory and optional parameters for:
  - A system
  - A zone
  - A section
  - A signal
  - A detector
  - A link
  - A master
  - A CCTV
- Configuration by selecting System Settings/specific configuration for:
  - Event mapping
  - Preempt
  - Time drift
  - Event log monitor

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Traffic Signal Operations

- System setup and configuration (communication sever, system configuration editor, and map graphics Files need to be configured)
  - Add controller to communications server
  - Add intersection using system configuration editor
  - Add intersection to graphics display
- Monitor
  - Graphic (display phase,overlap, ped status,communication , detector etc.)
  - Information(display parent, controller type, location and agency)
  - Timing(display desired method,coordination,offset,cycle,flash,time etc)
  - Alarm(flash list label and other list label)
  - Phase data(phase, overlap,preempt/priority, special functions)
- Control
  - Manual override
  - TOD Schedule
  - Holiday Assignment
  - Traffic Responsive

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System Report

- System Status (entity,primary_name, secondary_name, status)
- Communication Status(entity, primary_name, secondary_name, status)
- Event Log (system ID, Device description, Device ID,Timestamp, Event description, number)
- Alarm Report(Alarm ID, System#, time, Sent to, Alarm type)
- Stuck Preempt Events Report(Signal#, Event description,Preempt time,Duration)

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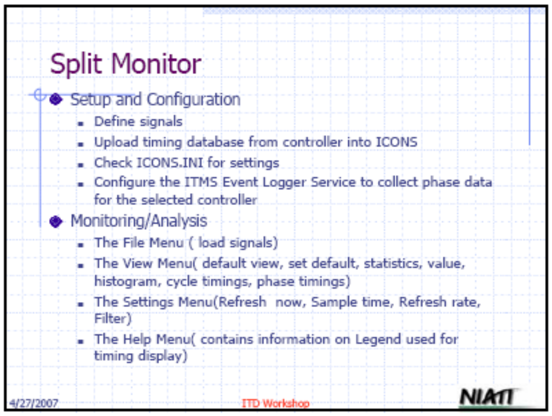
Split Monitor
Setup and Configuration
Define signals
Upload timing database from controller into ICONS
Check ICONS.INI for settings
Configure the ITMS Event Logger Service to collect phase data for the selected controller
Monitoring/Analysis
The File Menu (load signals)
The View Menu(default view, set default, statistics, value, histogram, cycle timings, phase timings)
The Settings Menu(Refresh now, Sample time, Refresh rate, Filter)
The Help Menu(contains information on Legend used for timing display)
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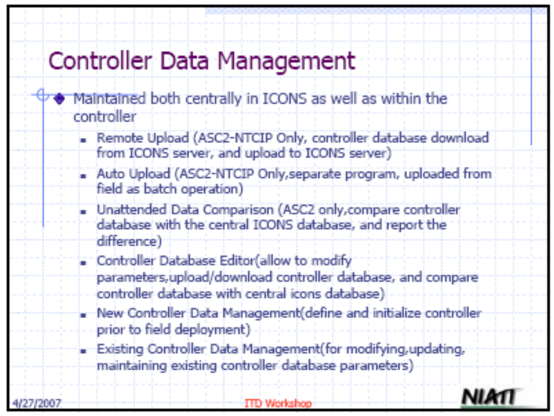
Controller Data Management
Maintained both centrally in ICONS as well as within the controller
Remote Upload (ASC2-NTCIP Only, controller database download from ICONS server, and upload to ICONS server)
Auto Upload (ASC2-NTCIP Only,separate program, uploaded from field as batch operation)
Unattended Data Comparison (ASC2 only,compare controller database with the central ICONS database, and report the difference)
Controller Database Editor(allow to modify parameters,upload/download controller database, and compare controller database with central icons database)
New Controller Data Management(define and initialize controller prior to field deployment)
Existing Controller Data Management(for modifying,updating, maintaining existing controller database parameters)
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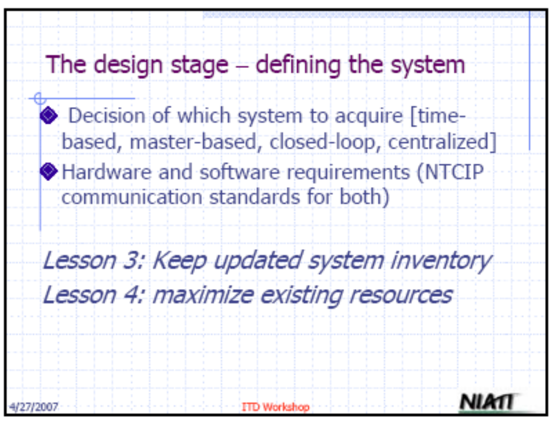
The design stage – defining the system
Decision of which system to acquire [time-based, master-based, closed-loop, centralized]
Hardware and software requirements (NTCIP communication standards for both)
Lesson 3: Keep updated system inventory
Lesson 4: maximize existing resources
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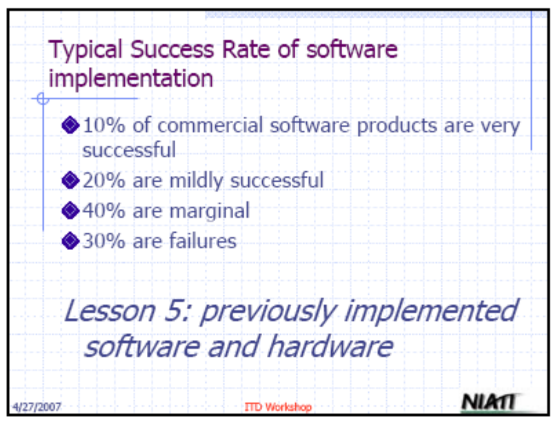
Typical Success Rate of software implementation
10% of commercial software products are very successful
20% are mildly successful
40% are marginal
30% are failures
Lesson 5: previously implemented software and hardware
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Why Use the Standards

- Employing the standards is better than ignoring the standards - even though they are changing and may not yet fully interoperate
- Early use of standards can be more costly, but the long term benefits will improve future interoperability & extensibility.
- Use of standards is critical to developing regional ITS deployment strategies.

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Current Status

49 Published	Available for Purchase
33 Approved	Passed all necessary ballots and approved by SDO(s) but not yet published
16 In Ballot	Being voted upon by committee, others
13 Under Development	Being Drafted by committee

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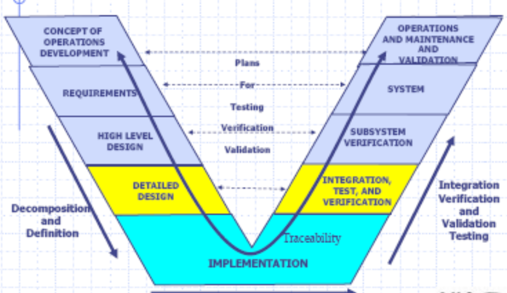
The FHWA's Systems Engineering Model



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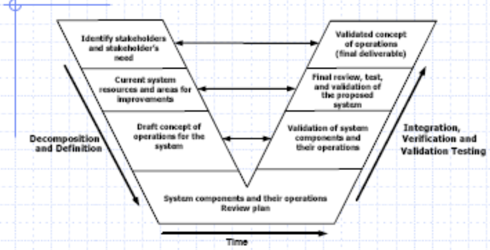
Moscow ITS model



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What have we learned?

- Defining the system is not a trivial task
- It will not happen overnight
- More products and alternatives are becoming available
- Additional help is needed throughout different design and implementation stages

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Open Issues

- Defining functionality
- Conformance definition
- Interoperability testing
- Testing deployments
- Standards Maintenance
- Proprietary Implementations
- Standards Allow Customization

Lesson 6: Functionality-based Concept of Operation

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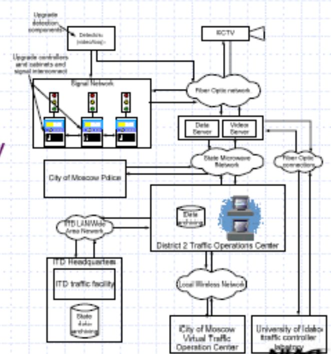
Moscow ITS Functionality Concept



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Options

- Proprietary solution
- NTCIP with proprietary additions
- NTCIP without any additions

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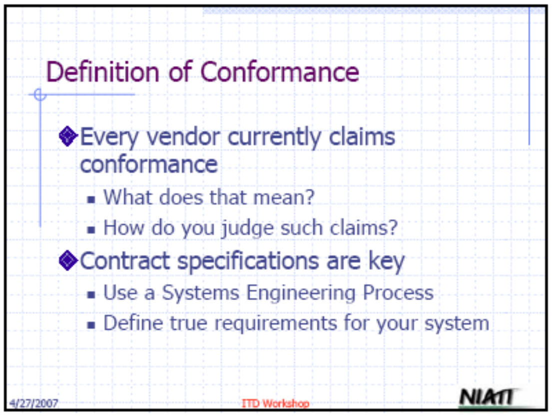
Definition of Conformance
Every vendor currently claims conformance
What does that mean?
How do you judge such claims?
Contract specifications are key
Use a Systems Engineering Process
Define true requirements for your system
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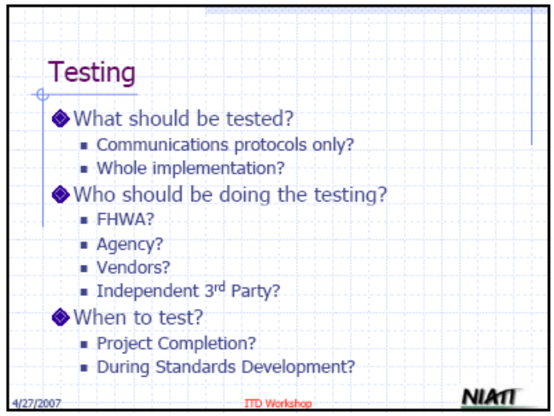
Testing
What should be tested?
Communications protocols only?
Whole implementation?
Who should be doing the testing?
FHWA?
Agency?
Vendors?
Independent 3rd Party?
When to test?
Project Completion?
During Standards Development?
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