

Final Report

California ATMS Testbed

PHASE III: Operational Research Implementation

**Volume II
Technical Report**

submitted to:

California Department of Transportation
Office of Technology Applications
Division of Research & Innovation
c/o Transportation Management Center
6681 Marine Way
Irvine, Ca 92618

submitted by:

Institute of Transportation Studies
University of California, Irvine
October 2006

TABLE OF CONTENTS

ORGANIZATION OF THE REPORT..... III

TESTBED RESOURCES 1

1.1 INTRODUCTION..... 2

1.2 TESTBED FACILITY AND SUPPORTING INFRASTRUCTURE 2

 1.2.1 *Testbed Laboratories* 3

 1.2.2 *Data Streams* 4

 1.2.3 *Surveillance* 4

 1.2.4 *Wireless Data Capabilities and Real-time Vehicle Tracking*..... 5

 1.2.5 *Travel Behavior Monitoring* 6

 1.2.6 *Microscopic Simulation* 6

 1.2.7 *Mobile Surveillance* 7

 1.2.8 *Mobile Transportation Management Capability* 8

 1.2.9 *Testbed Resource Web Access* 8

1.3 TESTBED ARCHITECTURE 8

1.4 TESTBED LABORATORY FUNCTIONALITY 11

TESTBED DEPLOYMENT 15

2.1 FULL DEPLOYMENT OF THE TRAFFIC DETECTOR AND SURVEILLANCE SUB-TESTBED (TDS²) 16

2.2 TESTBED ATMS TRAINING AND DEVELOPMENT ENVIRONMENT 18

2.3 CALTRANS DISTRICT 12 REAL-TIME DATA INTERTIE 23

2.4 CITY OF ANAHEIM REAL-TIME DATA INTERTIE 26

2.5 CITY OF IRVINE REAL-TIME DATA INTERTIE 29

2.6 ATMS TESTBED RESOURCE WEBSITE 31

TESTBED RESEARCH AND DEVELOPMENT 36

3.1 DEVELOPMENT AND DEPLOYMENT OF CORRIDOR MANAGEMENT PROTOTYPE 37

3.2 DISTRIBUTED PARAMICS DEVELOPMENT 39

3.3 INCORPORATION OF WIRELESS ATMS TECHNOLOGIES WITHIN THE TESTBED 44

3.4 REAL-TIME ADAPTIVE SYSTEMWIDE RAMP METERING AND SIGNAL CONTROL 46

3.5 IMPLEMENTATION OF A TOOL FOR MEASURING ITS IMPACTS ON FREEWAY SAFETY PERFORMANCE 49

ATMS TESTBED FINAL REPORT: Volume II - Technical Report OCTOBER 2006

TESTBED MANAGEMENT, TECHNICAL ASSISTANCE, AND MAINTENANCE.....51

4.1 TECHNICAL ASSISTANCE TO CALTRANS, CCIT, AND PARTNERS.....52

4.2 ATMS TESTBED LABORATORY DEVELOPMENT AND MAINTENANCE53

4.3 TESTBED MANAGEMENT54

ORGANIZATION OF THE REPORT

This report summarizes research and development that has been conducted to position the Testbed to support prototype deployment and evaluation of Advanced Transportation Management Systems (ATMS) products and services. The various elements contained in the report generally involve both research and development; funding for the research aspects reported herein was provided by the Caltrans Division of Research and Innovation (DRI) under the Partners for Advanced Transit & Highways (PATH) research program with Testbed support funding for those aspects of the research that involve development and management of the ATMS Testbed infrastructure to support the research agenda of the Caltrans Division of Research and Innovation (DRI). This joint effort targeted research activities that, with Testbed support, might lead to candidate products for deployment. In that sense, the research funded under this agreement has been in support of the Advanced Transportation Management and Information System (ATMIS) research program of DRI, PATH, California Center for Innovative Transportation (CCIT), and other such organizations.

The work accomplished under this agreement is divided among four basic categories:

1. Testbed Resources
2. Testbed Deployment
 - 2.1 Full Deployment of the Traffic Detector and Surveillance Sub-Testbed (TDS²)
 - 2.2 Testbed ATMS Training and Development Environment
 - 2.3 Caltrans District 12 Real-time Data Intertie
 - 2.4 City of Anaheim Real-time Data Intertie
 - 2.5 City of Irvine Real-time Data Intertie
 - 2.6 Testbed Website
3. Testbed Research and Development
 - 3.1 Development of Corridor Management Prototype
 - 3.2 Distributed Paramics Development
 - 3.3 Incorporation of Wireless ATMIS Technologies within the Testbed
 - 3.4 Development of Real-time Adaptive Systemwide Ramp Metering and Signal Control
 - 3.5 Freeway Safety Analysis
4. Testbed Management, Technical Assistance, and Maintenance
 - 4.1 Technical Assistance to Caltrans, CCIT, and Partners
 - 4.2 Maintenance of Testbed Laboratories and Field Operations
 - 4.3 Testbed Management

They are summarized in the following sections; the Testbed Research and Development Activities are discussed in detail in the set of accompanying Testbed Technical Reports.

PART 1

TESTBED RESOURCES

1.1 Introduction

The ATMS Testbed Program was initiated in early 1991 to provide an instrumented, multi-jurisdictional, multi-agency transportation operations environment linked to university laboratories for real-world development, testing and evaluation of near-term technologies and applications, and to serve as an ongoing testing ground for California and national Intelligent Transportation Systems (ITS) efforts. Located in Orange County, California, and under the direction of the University of California, Irvine (UCI) Institute of Transportation Studies, the Testbed is intended to:

- accelerate deployment through advanced technology research;
- demonstrate the readiness of advanced systems;
- implement and evaluate operations of an integrated multi-jurisdictional, multi-agency transportation operations system.

The Testbed is based on real-time, computer-assisted traffic management and communication. The transportation operations system that forms the backbone of the Testbed is structured to provide intelligent computer-assisted decision support to traffic management personnel by integrating network-wide traffic information (both surface street and freeway) in a real-time environment. The Testbed currently either has, or is developing, direct links to three traffic operations centers (TMC), Caltrans District 12 TMC, City of Anaheim TMC, and City of Irvine Transportation Research and Analysis Center that provide real-time data links from area freeways and major arterials directly to dedicated Testbed research laboratories located at UCI.

The broad mission of the Testbed Program is to work toward overcoming institutional, technical and philosophical barriers to introducing innovative technologies into the management of complex transportation systems. Working together with CCIT, California PATH and the Testbed Partners, the Testbed Research Implementation and Prototype Development Program is designed to establish an intermediary link between basic research in ATMS/ATIS technologies and their full deployment.

1.2 Testbed Facility and Supporting Infrastructure

The Testbed covers the entire freeway system in Orange County and two contiguous sub-areas comprising an arterial system that includes most of the major decision points for freeway travelers in the region. The City of Anaheim sub-area encompasses the City's major special event traffic generators and is centered about two of its designated "smart streets," Harbor Boulevard and Katella Avenue. This sub-area is ideal for network-wide applications of advanced technologies in traffic management. The City of Irvine sub-area provides freeway access to many business and office complexes on both sides of the 1-5 freeway and is ideal for corridor-level integration of real-time communication and control in traffic management.

A comprehensive testing and evaluation system has been established to support activities in the Testbed. The system has been developed to interface with existing traffic surveillance and control components and provide a common integrated real-time traffic database for ATMS research conducted within the Testbed. The system design is built upon a wide-area communications network backbone linking the Cities of Anaheim and Irvine Transportation

Management Centers (TMCs) to the California Department of Transportation's District 12 TMC and with the ATMS Research Laboratories at the UCI Institute of Transportation Studies. The communications network is configured to permit easy future expansion to accommodate appropriate private/public sector research implementation projects that may be conducted within the Testbed.

The Testbed has the following main components:

1. Testbed Labs
2. Data Streams
 - a. Historical
 - b. Real-time
3. Surveillance
 - a. Freeway
 - b. Arterial
4. Wireless Data Capabilities and Real-time Vehicle Tracking
5. Travel Behavior Monitoring
6. Microscopic Simulation
7. Mobile Surveillance
8. Mobile Transportation Management Capability
9. Testbed Resource Web Access

1.2.1 Testbed Laboratories

The Testbed laboratories form a computerized research environment connected to the real world transportation system. The laboratories are a testing ground for the development of particular ATMS *modules* and of integrated ATMS *applications*. The goal is for the Testbed laboratories to have a complete simulation of the transportation systems that are part of the Testbed. The Paramics (parallel microsimulation) traffic model is the core simulation for the Testbed laboratories. It can simulate all of the existing and currently envisioned traffic measurement and control devices associated with ATMS.

The Testbed Real-time Integrated Control and Evaluation Prototype System (TRICEPS) was developed as an implementation platform to provide plug and play capabilities for the testing and evaluation of a range of ATMS modules. TRICEPS permits modules to be configured for various ATMS applications and run in simulated, real-time, and integrated modes. Any particular ATMS application thus can be implemented by being connected to both simulated and real-world transportation systems so that overall effectiveness can be first assessed in the laboratory and then evaluated in the field.

A key module implemented for use with TRICEPS is the real-time multi-agent incident management system Coordinated Adaptive Real-Time Expert System for Incident management in Urban Systems (CARTESIUS). Traffic management in urban corridors is complicated by jurisdictional as well as operational problems. Corridor traffic demand increasingly requires

coordinated management that optimizes corridor traffic while preserving the various levels of authority, data control, and decision-making power. CARTESIUS approaches this problem by employing advanced cooperation and conflict resolution methodologies for coordinated traffic management operations among multiple agents. The Testbed includes this broadly defined ATMIS application centered on the CARTESIUS traffic management system, deployed within the TRICEPS implementation and evaluation platform, and linked to a transportation system modeled by the Paradyn (the hybrid Paramics and Dynasmart) simulator. This work has been extensively tested using laboratory simulation with positive outcomes.

1.2.2 Data Streams

Historical

Currently, historical freeway data (all Caltrans District 12 systems) is available. These data are accessed via command line executables. Users request data with the following information:

- freeway id (405, 55, 133, etc)
- direction (N,S,W,E)
- start and end postmiles
- start and end times

Data is available in the following format:

- vds id & timestamp
- lane & loop count
- volume, occupancy, status

and can be placed on an ftp site for download.

Real-time

Real-time freeway data in the form of 30-second loop counts and occupancy are available only on the Testbed lab PTL? network via a CORBA interface. These data come directly from the Caltrans District 12 FEP. Users wishing to access these data must do so on-site; IDL's? will be supplied to the researcher so they can build client applications with stubs for the CORBA functions.

Real-time arterial data from the City of Anaheim are in the form of raw loop data (sampled every 250 milliseconds) from the City's integrated SCOOT control system using Advanced Transportation Controller (ATC) Model 2070 controllers.

Real-time CCTV from all major intersections in the City of Irvine (with full pan-tilt-zoom capability) is available in the Testbed labs. Real-time loop data along Alton Parkway and its connectors to I-405 are also available.

1.2.3 Surveillance

A detector test site has been constructed comprising: in-pavement, overhead- and side-mount detection capability at two locations on I-405: Sand Canyon Avenue and Laguna Canyon Road.

The overhead mounts include “ground truth” video cameras over each lane, connected to a bank of VCRs and to an automated video image capture and re-identification system.

There are double loops in all traffic lanes. All loop data are available at the UCI-ITS lab, or via DSL connection through a local webserver.

Advanced IST detector cards have been installed at 18 locations along I-405 from the “El Toro Y” to SR 55 that permit a host of surveillance initiatives, including vehicle re-identification and O-D estimation techniques, to be tested and evaluated.

1.2.4 Wireless Data Capabilities and Real-time Vehicle Tracking

The Wireless Testbed effort is intended to extend the Testbed research capabilities to make use of new, wireless data collection and transmission technologies. The Testbed currently has the capability of real-time vehicle tracking using a series of Extensible Data Collection Units (Tracer EDCU), employing 12-channel Garmin GPS 35 TracPak, with communications providing web-based CDPD 2-way wireless data transfer. These units are portable, self actuating, and powered from a standard DC outlet (e.g., cigar lighter) in the vehicle. The units are coupled to OpenMap GIS for analysis and display, and can be integrated with the REACT! computer assisted survey instrument (CASI). Any number of vehicles may be outfitted with this device and driven simultaneously, allowing for multiple data streams consisting of position, speed, and other GPS-based information. These units have applications to:

- Traffic Monitoring / Vehicle Probes
- Route Choice Studies
- Travel Behavior Surveys with REACT!
- Extensions to Route Guidance

The units can reliably collect information and transmit that data back to the database. A web-based front end has been developed to display the data collected. This web functionality includes monitoring the position of any given EDCU in real time, and displaying any number of past data collection trips separately or in a single map. Other more generic database gateways have also been implemented, including an XML interface which responds to data queries with validated XML documents, and a simple form-based file uploading interface to enable data to be uploaded directly.

The main thrust of work has been to integrate the EDCUs into the larger Testbed. The specific tasks related to this include:

- Integrating GPS record-based data with other Testbed data streams;
- Developing and implementing path-based data analysis algorithms; and
- Developing and implementing automatic mapping algorithms.

A second, more exploratory direction of the Wireless Testbed effort has been to decentralize the data processing tools, leveraging both wide area and local area wireless connectivity. The second generation EDCUs (EDCU-2) are equipped with an improved, wide area augmentation system (WAAS) capable GPS antenna, which provide better than 3 meter RMS accuracy. The EDCU- 2 units are also equipped with a local area 802.11b WiFi card. These new EDCUs can be used to

explore modes and methods for sharing precise GPS information amongst vehicles within a platoon, and between vehicles in opposing platoons.

1.2.5 Travel Behavior Monitoring

A comprehensive activity/travel survey instrument, REACT!, is available in the form of a self-administered web-based data access and data submission of household level processing of travel and activity diaries. This instrument has an integrated GIS feature to facilitate data entry & geocoding, and extensive on-line help via a graphic user interface. It can be integrated with the GPS units in TRACER for use as a memory jogger, and/or to ascertain routing behavior.

1.2.6 Microscopic Simulation

Paramics is the primary microscopic simulation currently used by Caltrans; the Testbed has been the primary developer of APIs (Application Programming Interfaces) that have made it possible for Caltrans Divisions of Traffic Operations and Planning to apply the Paramics simulator for realistic California freeway and surface street networks. Specifically, Testbed researchers have developed over 30 APIs related to such key elements as ramp metering and actuated signal control based on Type 170 controllers, queue detection, routing, 30-sec loop output, and evaluation of ramp metering algorithms. The APIs developed at UCI are especially suitable for path-level computations across sub-network simulations and it significantly enhances the ATMIS and DTA simulation options for Caltrans, to use these capabilities within distributed frameworks. Testbed researchers have used Paramics to assist Caltrans in its TOPS evaluation and have put on workshops to train Caltrans Planning and Operations staff in the use of Paramics and other microsimulation tools. Coded Testbed networks include:

- Orange County (Caltrans District 12) freeway system (detailed)
- City of Irvine “Golden Triangle” (detailed)
- City of Anaheim convention area (coarse)

Work currently underway is focused on developing procedures to enhance the ability of Paramics to better handle large networks in real-time through distributed network modeling approaches. Other work involves the development of an integrated ramp-metering design and evaluation platform with Paramics simulation. The ramp metering evaluation tool employs the testing and evaluation of a metering algorithm and its design based on performance measures obtained from simulation. A library of metering algorithms either currently or potentially applied in California is being included in this platform. These algorithms include District 3, 6, 8, and 11’s SDRMS, and District 7 and 12’s SATMS, as well as some adaptive metering strategies (e.g., ALINEA, and SWARM) that potentially can be applied. The platform will have intuitive graphical interfaces in order to facilitate Caltrans practitioners. Compared to field tests, the platform provides a quick and cost-effective way to conduct ramp-metering studies in the microscopic simulation environment. The platform can be used to analyze and improve the current metering operations, to test a new algorithm, to fine-tune parameters of an algorithm, to evaluate various aspects of performance of a metering strategy, and to conduct a series of deeper level analysis of the performance of the algorithm.

A listing of key APIs designed to aid in simulation studies is given below:

- Full-actuated signal control
 - eight-phase, dual-ring, concurrent controller logic (Type 170)
- Actuated signal coordination
 - additional force-off logic, background cycle length, and sync phase yield to full-actuated signal API
- Time-based ramp control
 - can interface with external ramp metering algorithms
- Intersection delay calculation
 - stop delay, control delay, incomplete / running delay at each time step, queue length, travel time
- MYSQL database interface
 - store the simulation outputs to either ASCII files or database
 - store intermediate simulation results for queries by other external APIs
- Loop data aggregator
 - emulates the outputs of real-world data collection from inductive loops
 - raw data or smoothed
 - aggregated loop data (including volume, occupancy, speed) can be output to ASCII files or MYSQL database
- Ramp metering algorithms
 - local traffic-responsive algorithms:
 - fixed-time
 - demand-capacity
 - occupancy control
 - ALINEA
 - coordinated algorithms:
 - BOTTLENECK algorithm (Washington State)
 - ZONE algorithm (Minnesota)
- Measures of Effectiveness (MOEs)
 - total system travel time
 - total traffic throughput of the mainline freeway
 - mainline average travel time
 - average on-ramp waiting time and average queue length
 - travel time for vehicles between specific OD pairs

1.2.7 Mobile Surveillance

A prototype mobile surveillance unit is available, featuring:

- wireless Communication
- acoustic detector system for wireless ramp metering
- RTMS detector system for collecting mainline traffic data
- low voltage LED signal head
- solar powered system

1.2.8 Mobile Transportation Management Capability

A “Mobile TMC” (MTMC) has been developed, featuring:

- Surveillance
 - mast-mounted pan, tilt, and zoom surveillance camera
 - receive & transmit compressed video to D12 TMC
 - RTMS detector system for collecting mainline traffic data
- Wireless Communication
 - voice & video conference with personnel in D12 TMC.
 - operate D12 ATMS from within MTMC
- Ramp Control
 - relay ramp metering trailer 170 controller data to the D12 TMC from remote locations.
 - detection via mast-mounted RTMS vehicle detection system connected to on-board 170 controller connected to D12 FEP
 - Acoustic detector system for wireless ramp metering
 - Solar-powered low Voltage LED signal head.

1.2.9 Testbed Resource Web Access

Access to Testbed research, testing and evaluation resources is provided via an integrated website. The web page features a real-time graphical user interface whereby researchers and Caltrans staff can download information (both historical and real-time) from Testbed data collection services (e.g., real-time freeway and arterial loop data and signal status, probe vehicle information, video surveillance, detector testbed data, etc.), as well as coded networks, various API's and other software tools developed under the Testbed using a browser for query. The web page is available on the Testbed network as well as via the Caltrans Wide Area Network.

1.3 Testbed Architecture

A general goal of the Testbed is to develop and maintain an implementation platform that gives Testbed researchers “plug and play” capabilities with ATMIS modules and sub-systems. The idea is to be able to create ATMIS applications by substituting in different modules, or reconfiguring how data is distributed between modules. At the same time, we wish to be able to connect a particular ATMIS application to both simulated and real-world data so that we can prove its effectiveness and then evaluate it in the field. This concept has been implemented in the form of TRICEPS (**T**estbed **R**eal-time **I**ntegrated **C**ontrol and **E**valuation **P**rototype **S**ystem), which consists of the control subsystem of the Testbed Workbench ATMS and a set of evaluation tools. TRICEPS is structured to interface both with real-time data provided through the Testbed's ATM real-time data interface as well as with simulation data provided by the Testbed's traffic simulation software (Figure 1-1). The architecture of TRICEPS allows for the introduction of a full range of control and management techniques, not limited to those already implemented into the TRICEPS.

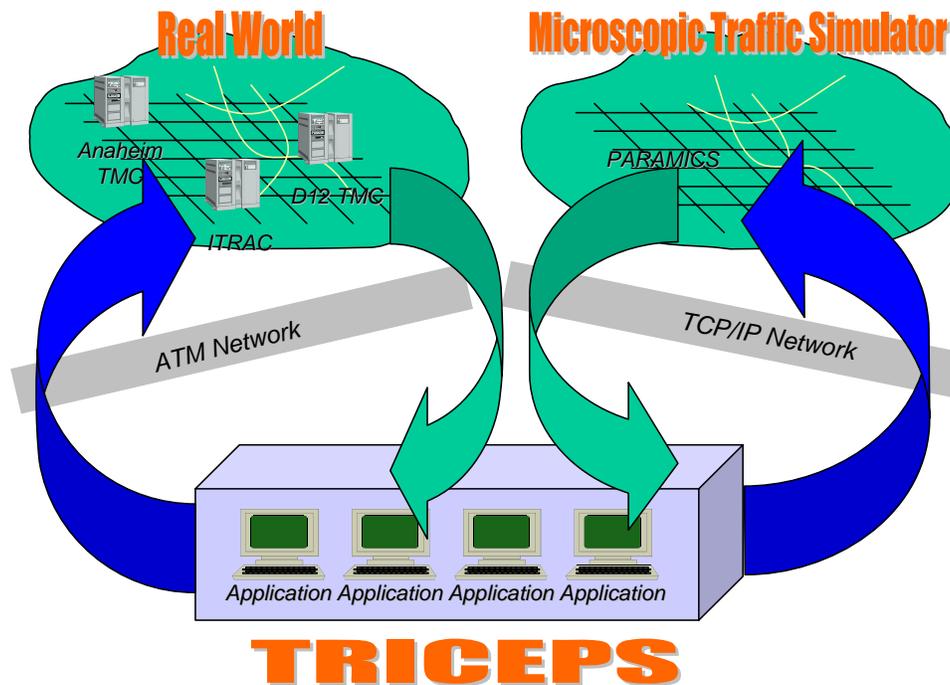


Figure 1-1. Testbed Laboratory Environment

A communications architecture has been developed to permit direct interaction with selected Testbed field devices to test and evaluate alternative ATMS designs. The real-time data retrieval subsystem has been designed to interface directly with the Caltrans District 12 Front End Processor (FEP), utilizing the ATMS Testbed server (Nemesis) which provides a bridge between the system and CORBA compliant objects, with communication with the Caltrans District 12 FEP provided over the Testbed Private Local Area Network (LAN). Under this architecture, the functionality of both the information format, as well as such operational procedures and control capabilities as ramp metering, is not limited to procedures supported by the ATMS, but rather can support the testing and evaluation of ATMS component designs that are not configured in accordance with the existing ATMS specifications, as well as the testing of alternative ATMS subsequent module designs themselves – both essential ingredients in the successful development of the Testbed research environment that renders the UCI ATMS Testbed Intertie to function in a dedicated, independent environment that is functionally isolated from the Caltrans District 12 operating system. Similar communications systems are currently being implemented for subsystems within the cities of Anaheim and Irvine.

A schematic of the ATMS Testbed communications network is provided in Figure 1-2.

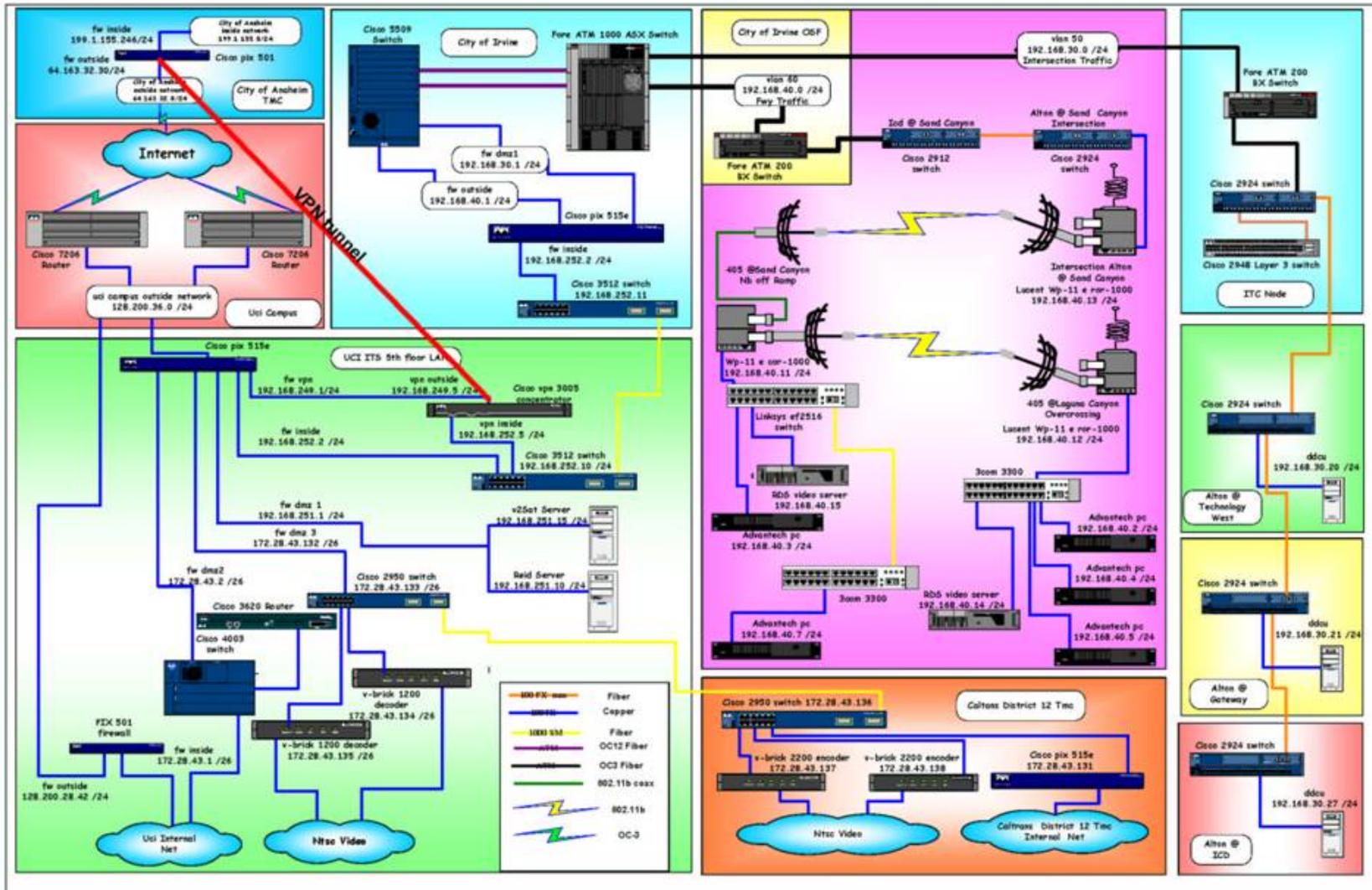


Figure 1-2 Testbed Communications Network

1.4 Testbed Laboratory Functionality

Testbed laboratory functionality can be divided into six basic categories:

1. real-world transportation system infrastructure
2. transportation system simulation
3. core TMC modules and subsystems
4. transportation system datasets and configuration data.
5. implementation architecture.
6. Testbed laboratory management.

These functional elements relate to each other as shown in Figure 1-3. Data from the real world are passed to a simulated system environment and to an integrated ATMIS application built from core ATMIS modules and realized using an implementation platform consisting of communications and presentation (data mapping) layers. The laboratory is managed by a meta-application that configures the application and selects the datasets (which are mapped representations of the system infrastructure) that are to be used.

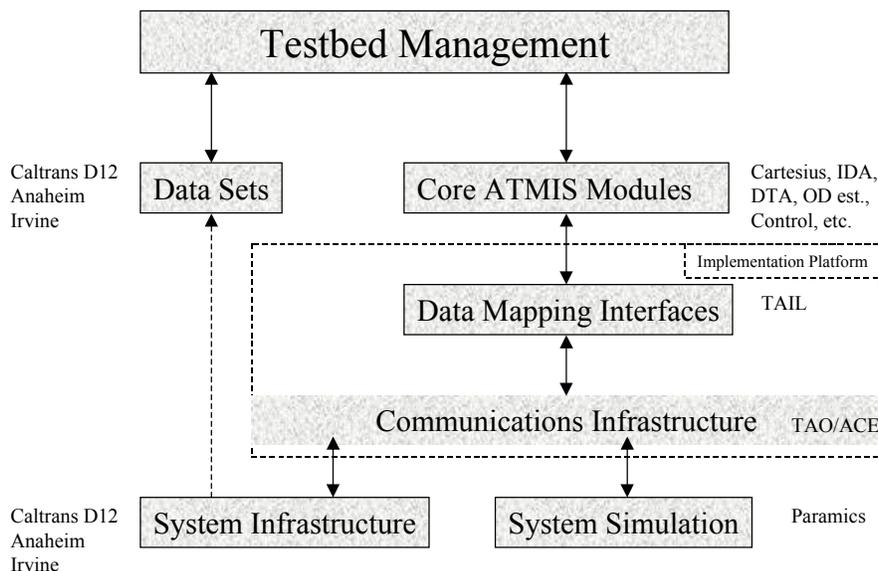


Figure 1-3. Testbed Laboratory Architecture

Research in the Testbed is centered on data collection, analysis, and on the development, testing, and implementation of ATMIS applications consisting of integrated ATMIS modules that can be roughly broken down into five categories:

1. data analysis
2. state estimation
3. management

- 4. prediction and evaluation
- 5. control

The general flow of information through an ATMIS application utilizing each of these module categories is shown in Figure 1-4.

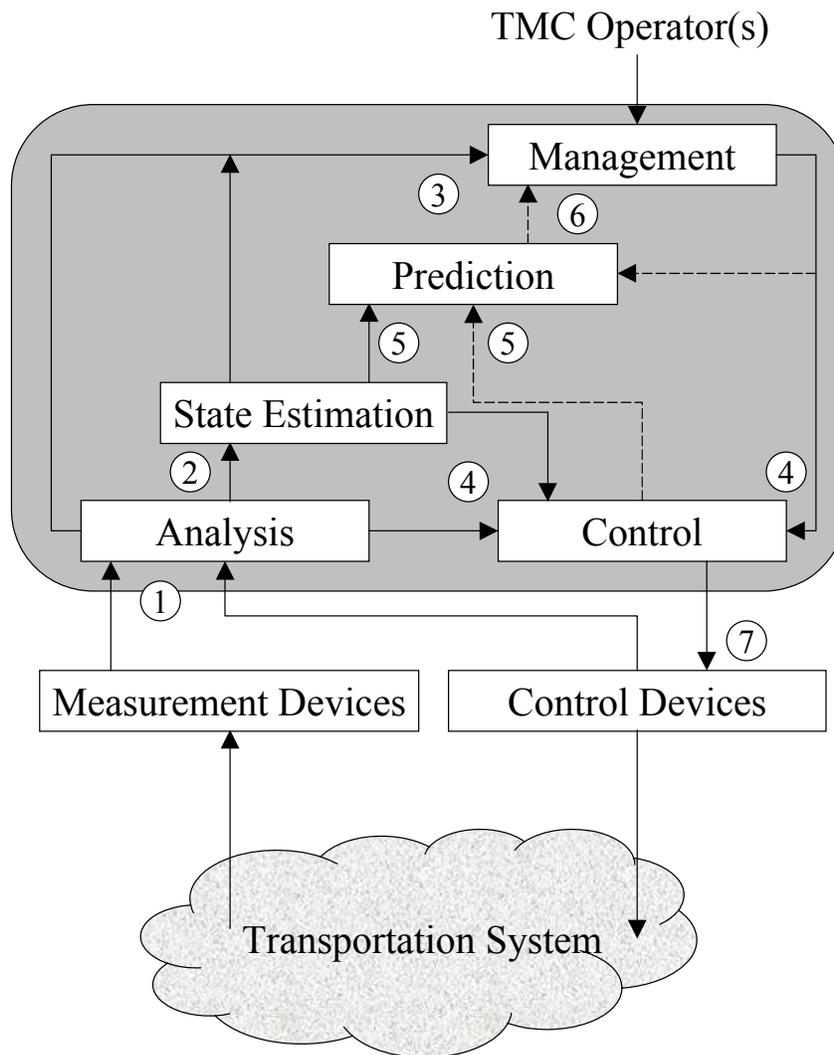


Figure 1-4. Testbed Laboratory ATMIS Application Modules

Field measurements and control status are passed to the analysis modules (1) which process the raw data. These data are used by state estimation modules (2) that attempt to infer higher-level state characteristics. The management modules use both low and high level state estimations to determine management strategies (3) which are then used in conjunction with the state estimations by control modules (4) to determine control actions. These actions are passed along with current state estimations to the predictions modules (5) which evaluate potential control for re-consideration by the management modules (6). Once an acceptable operational strategy has

been determined, the control actions are introduced into the system (7). The diagram below provides a graphical picture of the system described above.

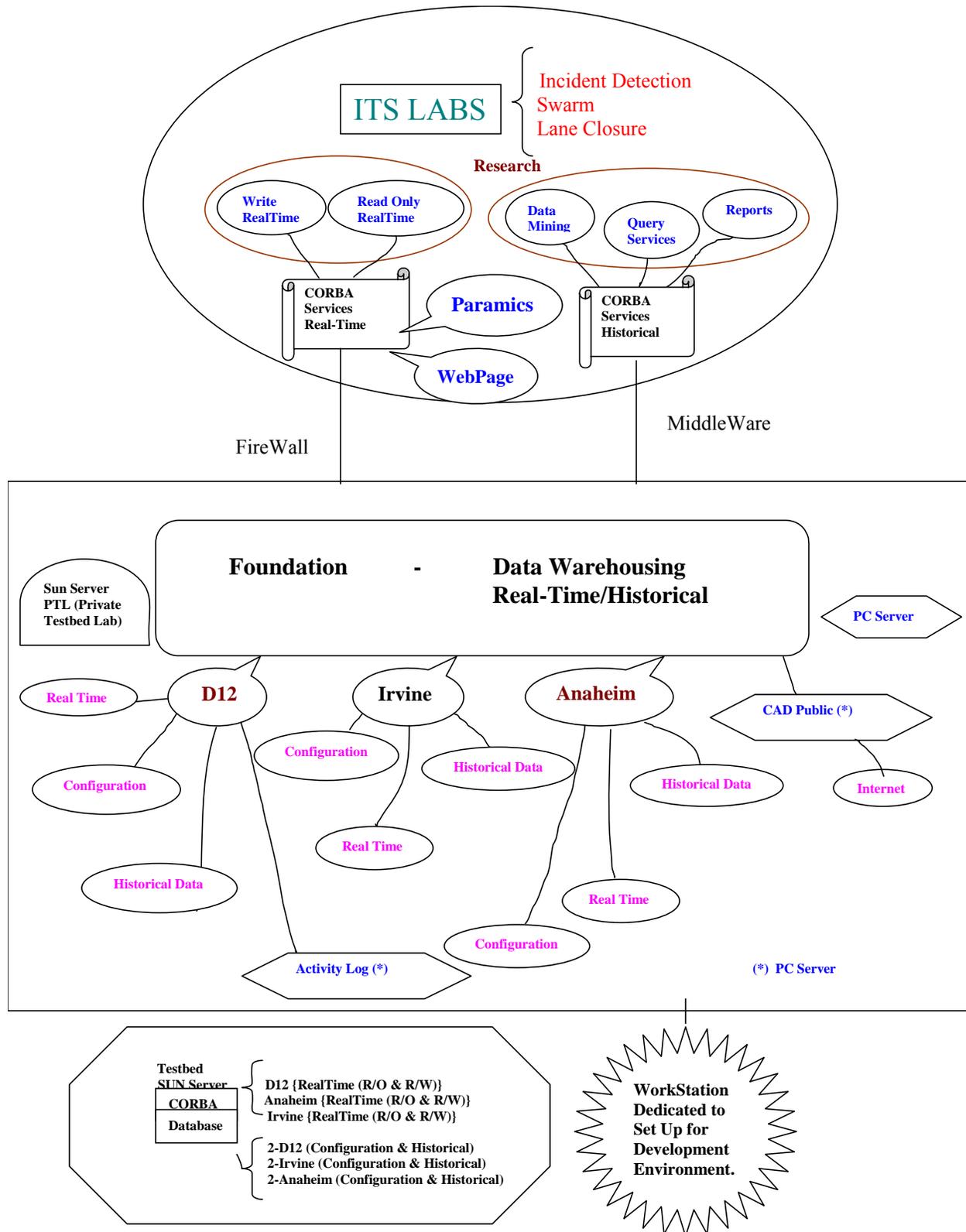


Figure 1-5 Functional Summary

PART 2

TESTBED DEPLOYMENT

2.1 Full Deployment of the Traffic Detector and Surveillance Sub-Testbed (TDS²)

To fully exploit the benefits of the new generation of Intelligent Transportation Systems now under development, including applications for homeland security, more accurate and appropriate real-time traffic data need to be collected from the urban highway transportation network and communicated to traffic management centers, traffic operations personnel, travelers, and other agencies.

To address this need, there has recently been substantial interest in Europe and the United States, and particularly in California, in implementing vehicle reidentification systems. Interest has initially focused on using the extensive existing inductive loop infrastructure in California, while recognizing that such emerging technologies as video and laser detectors, the Global Positioning System of satellites, automatic vehicle identification systems involving on-board vehicle sensors/tags/transponders, and wireless vehicle-to-vehicle and vehicle-to-roadside communications, may transition into practice in the future. However, a non-intrusive and anonymous vehicle tracking surveillance technology that could utilize the extensive inductive loop detector infrastructure already installed on freeways and arterial streets in California would be highly advantageous for performance measurement (for at least the next decade or two). In addition, regardless of the traffic sensor technologies used, Caltrans has identified real-time travel time and origin-destination (OD) information as particularly important outputs of any traffic surveillance system.

To assist in identifying and evaluating detector technologies for ITS deployment, the Testbed initiated development and construction of a Traffic Detector and Surveillance Sub-Testbed (TDS²) within the Testbed. The overall purpose of the Traffic Detector/ Surveillance Sub-Testbed is to provide a real-world laboratory for the development and evaluation of emerging traffic detection technologies relative to: appropriateness for ITS operations and performance measurement, data quality and consistency, ease of use, ease of installation, and overall cost.

The first phase of the development of TDS² focused on the installation of “ground truth” sensing equipment and attendant communications infrastructure at two contiguous sites along the I-405 freeway within the Testbed —at I-405 and Laguna Canyon Road, and at I-405 and Sand Canyon Avenue. At these sites, “ground truth” video cameras were installed over each lane of traffic, connected to a bank of VCRs and to an automated video image capture and re-identification system. Data from these systems are transferred to the UCI Testbed Laboratories via a combination of SSR and F/O cable. This facility has already proved extremely useful in the testing and evaluation of overhead-mounted detectors (laser), side-mounted detectors (OMRON Vision Sensor Detector, RTMS radar sensor detector, Pan-Tilt-Zoom Webcam, Spread Spectrum Radio), and in-pavement detectors (enhanced double loop, High-resolution Detector Blade).

Work under this component continued the development of a real-world corridor-level testbed facility that would permit field testing and evaluation of advanced traffic sensor, detection and surveillance technologies to enhance the ability of Caltrans to deploy such technologies as well as advanced systems for improved traffic management and control of California's freeways and signalized arterials.

In its current configuration, TDS² comprises a fully-instrumented facility for the testing and evaluation of advanced detectors—one that has been utilized extensively (with considerable success) by Caltrans staff to evaluate several alternative detection technologies. With the completion of the current phase of construction, an 8 km corridor comprising both a freeway (I-405 NB) and adjacent arterial (Alton Parkway, both directions, including 18 intersections) has been fully instrumented to provide real-time data streams detailing traffic movement through the corridor; in addition to providing raw loop data for all detectors on all approaches, the arterial subsystem is instrumented to furnish real-time status information of the signal displays at each of 18 intersections. The freeway locations have the latest-generation IST detector cards installed along both the freeway mainline as well as on the associated on- and off-ramps; these installations provide data for signature analysis associated with the Caltrans REID vehicle reidentification development. For the arterial sites, 2070 controllers and associated detection software (ACTRA) have been deployed at the 18 intersections and are planned to be outfitted with IST detector cards and blade sensors. Software elements of the project included modification and enhancement of existing field to central server communications and real-time data base and web-site access, deployment and evaluation of advanced vehicle reidentification methods for anonymous real-time tracking of individual vehicles, real-time travel time and performance measurement, real-time management and control, and potentially homeland security applications.

In order for TDS² to be extended to a fully-instrumented facility for the testing and evaluation of detection designed to yield such link- and path-based real-time information in support of ATMS deployment as journey travel times, origin-destination demand, and routing choices, the following enhancements are suggested:

1. Installation of advanced IST detector cards at all detector stations along the Alton Parkway segments of the TDS² corridor, together with any software development required to implement the arterial version of REID.
2. Installation of video (or other) ground-truth system at key points in the TDS² corridor—minimally at the entry/exit points to the combined freeway/arterial network.

With these enhancements, the point-to-point or section-based vehicle travel time and Origin/Destination (O/D) information that are essential parameters for many ITS functions can be accurately ascertained by re-identifying detected feature vectors which are correlated with individual vehicles between sites. Development and verification of this technology would provide an inexpensive, and anonymous, alternative to vehicle tracing (i.e., probe vehicles).

V2SAT

TDS² serves as the principal laboratory for the development and testing of V2SAT. Funds to accomplish work, equipment procurement, and construction required to permit Caltrans to perform a preliminary evaluation of V2SAT Phase 2B algorithms were provided by the Testbed. This included the configuration, calibration, and optimization of the V2SAT system, and support of testing of this system and other experimental detection means in the testbed. Computer vision algorithms were adapted and refined for the specific location and environment. Loragen engineers worked on-site in Irvine with Caltrans and UCI Testbed personnel in support of all testbed activities.

2.2 Testbed ATMS Training and Development Environment

Work under this element is designed to bring operational capability to the TMC Simulation Laboratory, and to establish the associated networking that will link the simulator to the ATMS Testbed Laboratories. As part of this effort, a foundation has been laid for the evolution of an ATMS development environment that will support isolated, independent testing and evaluating ATMS products prior to their deployment in a district operating environment, as well as to provide operator training using the latest version of the ATMS software in a simulated environment.

The work has established a stable network in support of the ITS Test Center and TMC Simulator that provides connectivity to the Testbed's real-time data streams (field and simulated). The network has been designed to isolate network traffic depending on the nature of services needed or open communication among different subnets. Resulting from the effort, a simulation environment is in place that features:

1. a "live" connection to Caltrans field traffic control systems including vehicle detector stations, dynamic message signs, and camera stations;
2. a "virtual" (through simulation) connection to Caltrans field traffic control systems including vehicle detector stations, dynamic message signs, and camera stations;
3. an ATMSV2 Graphical User Interface (GUI) with geographic map depicting freeways and field element icons for displaying traffic status by levels of speeds, volumes, or occupancies at vehicle detector stations, and simulated status for dynamic message signs, and camera stations;
4. connection of ATMSV2 software to Paramics for simulation of real-time operation.

It provides a real-world testing environment for ATMS modifications and enhancements before being ported to an operating TMC. Both existing and proposed operational transportation management system software (such as the Caltrans ATMS Version 2) potentially can be tested and evaluated in a full ATMS setting by utilizing the capability afforded by the Testbed ATMS microscopic traffic simulator (Paramics) and the Testbed's access to both historical and real-time field data from the Caltrans District 12 system, and the Cities of Anaheim and Irvine. The ITS Test Center has the dual functionality of interacting both with actual, real-time or "playback" field data as well as with specific operational scenarios developed from loop-simulated data generated by the Paramics real-time microscopic traffic model.

In a joint effort among the Testbed, Cal Poly, and Caltrans Division of Traffic Operations work has been conducted to develop a realistic training environment for Caltrans TMC operations based on a simulation version of ATMSV2 that has been developed by NET specifically for use by the Testbed in support of Caltrans' TMC operator training program. The ATMSV2 Simulation (ATMSSIM) is based on the port of District 7's ATMSV2 with 7.2 functionality to District 11 using upgraded COTS software. The ATMSSIM functionality includes:

1. ATMS Map Graphical User Interface
 - Map and map manipulation tools
 - Field device icons (CMS, CCTV, VDS, RMS)

- CCTV Control Dialogs
- CMS Control Dialogs
- VDS/RMS Display Dialogs

2. Data Integrity

- Real-time traffic data calculation
- Failure Management
- Data Normalization

The ATMSSIM software includes:

1. Orange County specific data and map,
2. On/Off control mechanism for failure management and data normalization for VDS and RMS interface,
3. CMS and CCTV interfaces,
4. Ability to receive raw data from two sources: a) Caltrans District 12 FEP, and 2) FEP-simulated pre-recorded data from Paramics. These interfaces are identical.

An overview of the ATMSSIM software is provided in the diagram in Figure 2.1-1 below.

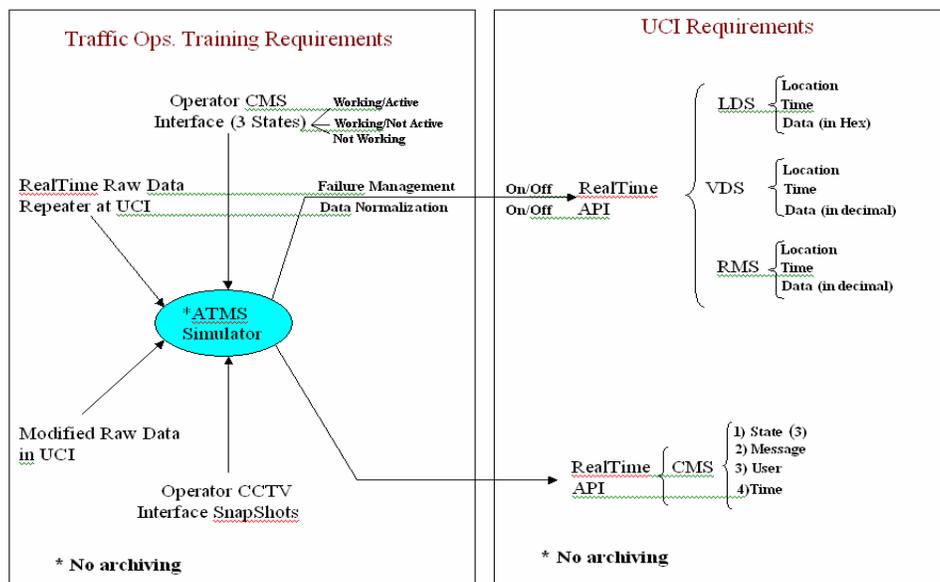


Figure 2.1-1 Traffic Operations Training and Testbed Simulator

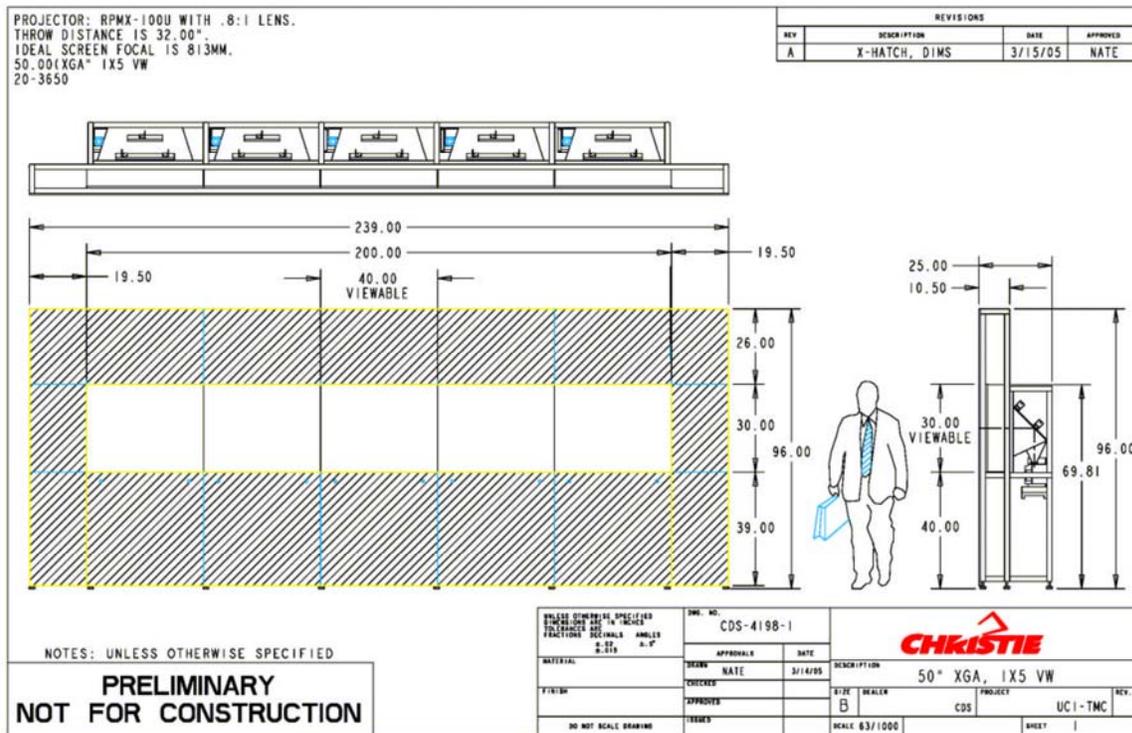
With this system, the Caltrans TMC Operator Training will be transitioned from the current Cal Poly training facility to the Testbed facility at UCI. The work proposed here is both in support of Caltrans’ operator training efforts as well as in the development of a true testing environment for ATMS upgrades and enhancements.

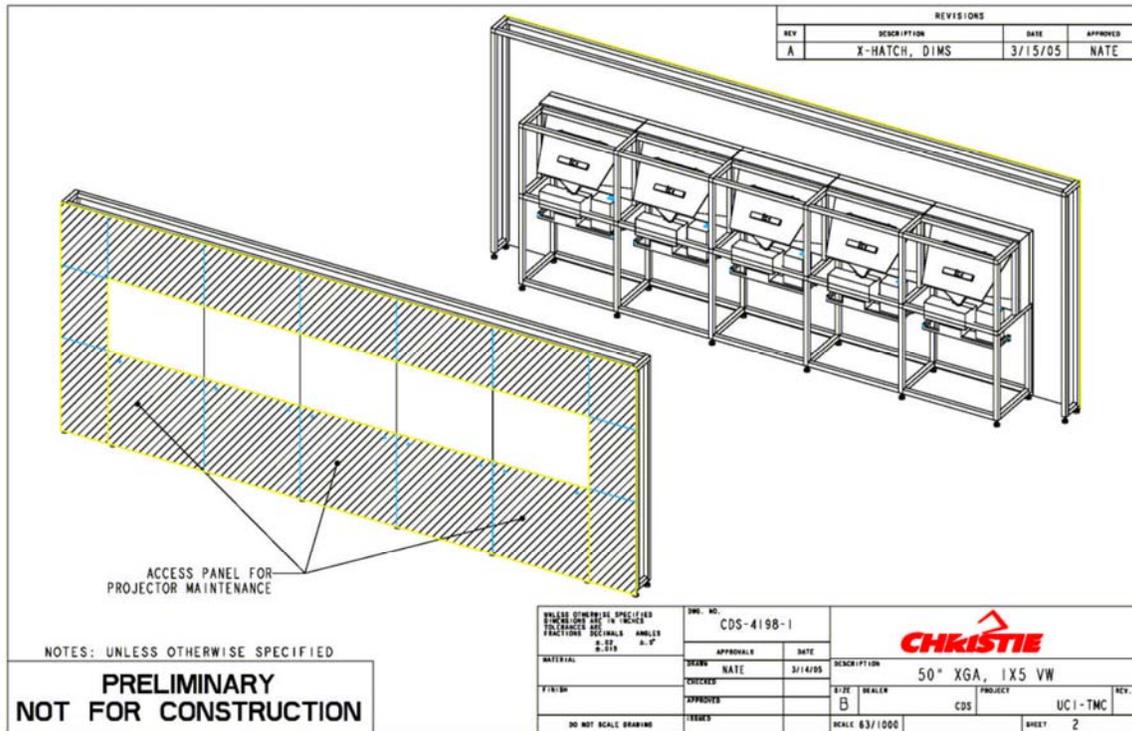
Display System: Display Wall System

To support training operations, the Testbed has installed a free-standing, Display Wall System, custom designed and built by Christie Digital Systems Group. The structure consists of (5) five display modules in a 1 high by 5 wide configuration, with a faux wall surround. The display

modules are comprised of 50" diagonal, 4 by 3 aspect ratio screens. The over all dimensions of the display screen is approximately 200" long x 30" high and 25" deep. The screens are 1/4" thick acrylic neutral gray diffusion screens with optical coating that provides good contrast, uniformity and color rendition with wide viewing cone to deliver a sharp image with uniform image brightness and color balance from center to corner of each screen and between screens.

Front access panels allow for easy front access to the projectors, to perform routine maintenance and service on the projectors (changing lamps and dust filters). The Display Wall is mounted on heavy retractable slides so it can be moved in the unlikely case that a projector needs to be removed or some part of the system needs to be replaced. Routine maintenance of the projectors will be done through the front access panels. A schematic of the design is displayed in the figures below.





The Display Wall System includes (5) Christie Digital XGA DLP projectors. These projectors are designed for 24/7 operation and include low geometry distortion, excellent color uniformity, advanced color wheel system and integrated 6-axis adjustment system. The major electronics modules boast >30,000 MTBF and the 100W/120W UHP lamp averages 6000-8000 hours.

To allow for maintenance the projectors are mounted below the screens using mirrors to fold the image. Cabinet doors across the bottom of the structure allow access to the projectors without moving the structure. The aluminum framed structure sits against the front wall of the room and is finished top to bottom and side to side with a black laminate faux wall. A video processor combines all (5) projectors to display as one large “desktop”.

Display Wall Processor: The system features a Christie Digital FRC 5100 Display Wall Processor, designed for 24/7 operation as an integral part of the video wall, capable of driving ultra high resolution tiled wall displays of virtually unlimited local or network-based software applications, real-time video inputs and multiple RGB Inputs. The processor can be controlled through a touch panel, RS-232 and IP with software on local workstations. A complete suite of software is included for...

- Intuitive, user-friendly interface for wall configuration and application display
- Seamless integration of multiple live video and RGB input sources
- Real-time networked mouse and keyboard control
- Comprehensive client-server display wall administration software
- Multi-tiered advanced security mechanisms
- Native Microsoft® Windows XP/2000® platform
- Full-featured X server software package included for X Windows applications

The processor hardware is configured to accept (20) video feeds and (4) RGB sources. A VGA and a Composite video feed are routed to adjacent rooms for viewing. A Crestron TPS-5000 connected via Ethernet to the Caltrans Pro2, switches the camera inputs at the matrix switcher. A Crestron Pro2 CPU provides control of local TMC equipment. The Crestron TPS-5000 is connected to the TMC Pro2 to perform the following:

- Existing matrix switcher control at Caltrans District 12 via Ethernet.
- Display Wall Processor control of presets and input selection.
- Projector control.

2.3 Caltrans District 12 Real-time Data Intertie

The current data intertie is configured based on a system architecture that, to the extent possible, renders the UCI ATMS Testbed Intertie to function in a dedicated, independent environment that is functionally isolated from the Caltrans District 12 operating system. Specific care has been given to adopting a design that will ensure that the UCI ATMS Testbed Intertie remains operational, with minimal revision, as the Caltrans District 12 ATMS is upgraded or is otherwise changed.

The real-time data retrieval subsystem has been designed to interface directly with the Caltrans District 12 Front End Processor (FEP). The FEP system includes a dedicated computer that collects data from traffic controllers via modems and interfaces with the outside world via TCP/IP network connection. It acts as a small central repository for the data collected from all of the traffic controllers that are connected to it. As it has limited memory it cannot hold large quantities of data, but does have the ability to respond to requests from a remote computer that wants to receive a copy of the traffic controller data that it collects. During normal operation the FEP continuously polls the traffic controllers and stores the returned data internally, together with diagnostic information regarding the communication link, timestamps, etc. This information is held in a small internal buffer and the oldest data is overwritten by the newest as the data arrives.

In order to retrieve this internally stored data we have provided a RECEIVER program that runs on a separate workstation under the Solaris 7 operating system (a version of UNIX). It communicates with the FEP via a standard TCP/IP network (such as a LAN or the Internet), and thus can be running on a workstation that geographically is quite distant from the FEP. This program instructs the FEP to send whatever traffic controller data that it has stored in RAM, together with diagnostic information, back to the RECEIVER program. The RECEIVER program then formats this information in a human readable way and outputs it to a stream (e.g., console or disk file).

Under the current Testbed integration with D12's ATMS and SATMS-170 controllers, the Testbed Labs at UCI receives the same type of data feed from the D12 FEP that the D12 Advanced Traffic Management System (ATMS) receives. This data stream is a real-time data feed of 30-second "poll-data" from all of D12's SATMS 170 controllers. The network connection between D12 FEP and the UCI Testbed private network is restricted by the D12 firewall to permit transmission only *from* the D12 FEP *to* the UCI Testbed Labs; transmissions *to* the D12 FEP *from* the UCI Testbed Labs are strictly prohibited.

The real-time data feed from the D12 FEP is received by machine *Nemesis* at UCI Testbed Labs; the data is then stored in a database and made available for distribution to various real-time research and development activities. The diagram in Figure 2.3-1 outlines the current configuration.

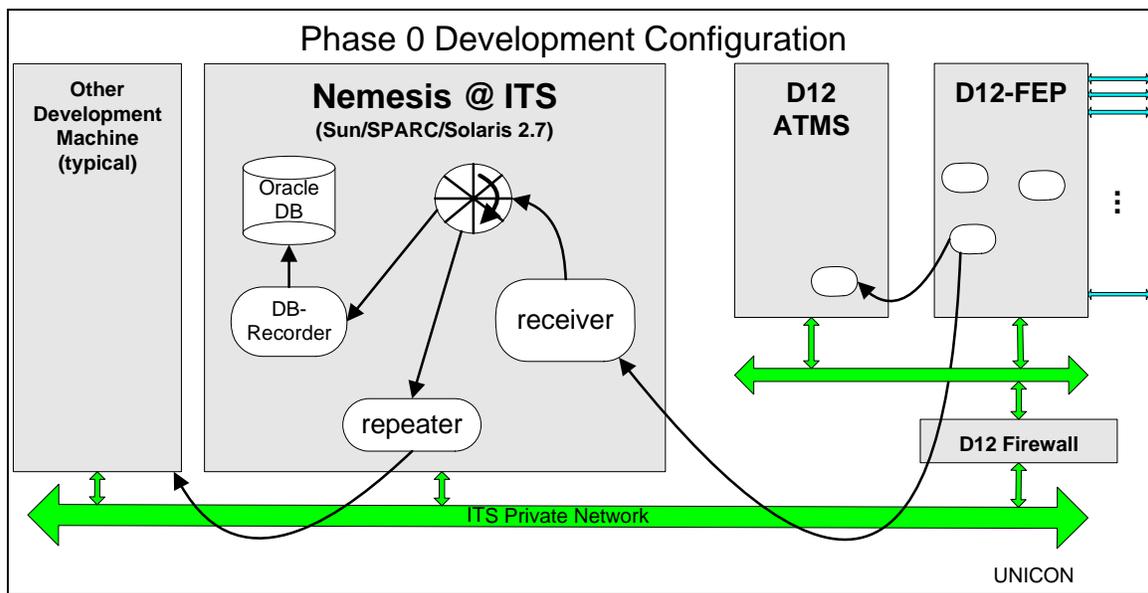


Figure 2.3-1. Current (Phase-0) Configuration

Several enhancements to this basic system were implemented. First, high speed switching and firewall equipment was procured and installed that established a secure gigabit Ethernet data link between the two sites. Data from the Front End Processor (FEP) sent from the TMC to ITS over a T-1 line was rerouted over the new fiber link. Two simultaneous video feeds across the fiber link from the TMC to ITS were established through the procurement. Configuration and installation of MPEG encoding and decoding equipment were completed to allow UCI/ITS to obtain video feeds from the Caltrans TMC cameras and to visually verify traffic conditions. Second, a touch screen panel that will be used as the physical interface for UCI/ITS to select the traffic feeds from the Caltrans TMC was installed and configured.

Mobile TMC

Performance specifications for both the Mobile TMC and the Mobile Ramp Meter were developed, allowing procurement of additional units to support Caltrans traffic operations. The Mobile TMC was developed and has been maintained for Caltrans Division of Research and Innovation (DRI) between 1994 and 2004 as part of the ATMS Testbed. The previously developed Mobile Ramp Metering (MRM) system was modified and integrated to operate in the field with the Mobile TMC. The Mobile TMC and the MRM are capable of operating in conjunction with the Caltrans District 12 TMC or independent of it. These two systems provide on-site traffic data collection, video surveillance, and management functions to support Caltrans TMC operations.

The following tasks were completed relative to standardizing their continued use:

1. Developed a performance specification for the Mobile TMC subsystems:
 - Satellite and wide-area data communications, including automatic-deploy satellite antenna, satellite modems, and network routing equipment.

- Data communications to the Mobile Ramp Meter to support video and 170 controller data collection.
 - Computer, networking, display, and backup power supplies.
 - Video surveillance, compression, and decompression.
 - Vehicle detection and processing via on-board Front-End Processor (FEP) and mini-ATMS.
 - Electric power generation and distribution.
 - Vehicle climate controls.
 - Wiring and system interconnects.
 - Instrumentation mast and controls.
 - Voice radios and communications.
 - Vehicle safety lights.
 - Mini-kitchen and bathroom, including water and waste systems.
2. Developed a performance and equipment specification for the MRM subsystems:
- Data communications to the Mobile TMC to support video and 170 controller data transmission.
 - Wireless data communications to the Caltrans District 12 TMC to support transmission of 170 30-second data transmission to the D12 Front End Processor.
 - Vehicle detection and ramp metering via the RTMS traffic sensor, 170 controller and cabinet equipment, passage and demand sensors, and portable signal poles with lights.
 - Video surveillance, compression, and decompression.
 - Solar and generator electric power generation, battery storage, and distribution.
 - Wiring and system interconnects.
 - Instrumentation mast.
 - Trailer specifics, wheels and axels, and jacks.

A series of enhancements to the Mobile TMC were also made. A video encoder was purchased and installed in the Mobile TMC vehicle; a video decoder was purchased and installed in the Caltrans District 12 TMC facility. Baxall codecs will allow relay of video from the Mobile TMC to the District 12 TMC over the Mobile TMC's satellite communications link. A 5.5kw Onan generator was purchased and installed in the Mobile TMC to power all AC electrical equipment on board the Mobile TMC, including on board computers and satellite communications system.

2.4 City of Anaheim Real-time Data Intertie

The City of Anaheim (COA) has played an active role in the development of the California ATMS Testbed. A key operational element of the Testbed is the TMC located in the City of Anaheim and used to manage the flow of traffic in the Anaheim portion of the Testbed. Both for the purposes of managing traffic within the Southern California Priority Corridor as well as to extend the capabilities of the Testbed for the purposes of research validation of active “network-level” control in a real-time environment, an intertie between the Anaheim TMC and the UCI ATMS Testbed Laboratories has been developed to exchange real-time data with other Testbed partners, enabling research into network-level control and traveler information systems, utilizing real-time traffic information for input into the various models and algorithms, and also providing closed-loop control capability of the field devices for validation of the technologies under development.

The Testbed Partners have identified that a capability for active transportation control research implementation should be focused around Anaheim’s traffic generators (e.g., Disneyland, the Arrowhead Pond of Anaheim, the Edison Field and the Convention Center). This focus area has events year round and generates complex and often unpredictable traffic patterns that will benefit from advanced traffic control research. In 1989, the City implemented a Traffic Management Center (TMC) and began a series of ITS installations including closed circuit television cameras (CCTV) and changeable message signs (CMS) to better manage traffic congestion during peak periods and special events. The continuous stream of special events managed in a well-equipped ITS facility presents a unique opportunity for researchers to collect real-time traffic data.

In 1997, the City integrated SCOOT to test adaptive control for traffic congestion and began deployment of Advanced Transportation Controller (ATC) Model 2070 throughout the City. In 1998, the City adopted a transition plan into open systems architecture and implemented a Real-Time Information Gateway (RTIG) in 1999 that provides traffic systems access in a networked environment. In 2000, the City upgraded its entire CMS network to be NTCIP compliant.

Work in this phase focused on two critical requirements for the intertie: the first is to enable the City’s traffic control system to disseminate the information in the proper format at the requested frequency; the second is to enable the City’s traffic signal controllers to return the proper information to the traffic control system.

The City has successfully updated its SCOOT system to enable ATC Model 2070 controllers to be integrated into SCOOT with a more robust protocol to accommodate real-time traffic information exchange to the TMC. However, SCOOT does not have a built-in ability to distribute real-time data. ASTRID, a SCOOT data collection feature, is capable of outputting certain formatted data in 15-minute increments. As such, the ASTRID data are neither real-time nor in the format or resolution required for research purposes. SCOOT is already capable of monitoring detector operations in real-time in 0.25 seconds increments. It relies on the CCU and the SCS to receive and interpret the real-time data from the City’s existing T1 controllers and ATC Model 2070 controllers, respectively. Although the SCOOT system should have the database query capability for data dissemination, the CCU and the SCS should be the mechanism for data transport.

Work under this element developed the framework for establishing SCOOT real-time control capabilities from the UCI ATMS Laboratories. It will result in development and implementation of an interface for remote control access of the COA SCOOT system field elements, providing the capability for closed-loop control, based on industry-standard communication technologies.

The following diagram outlines the COA TMC system configuration.

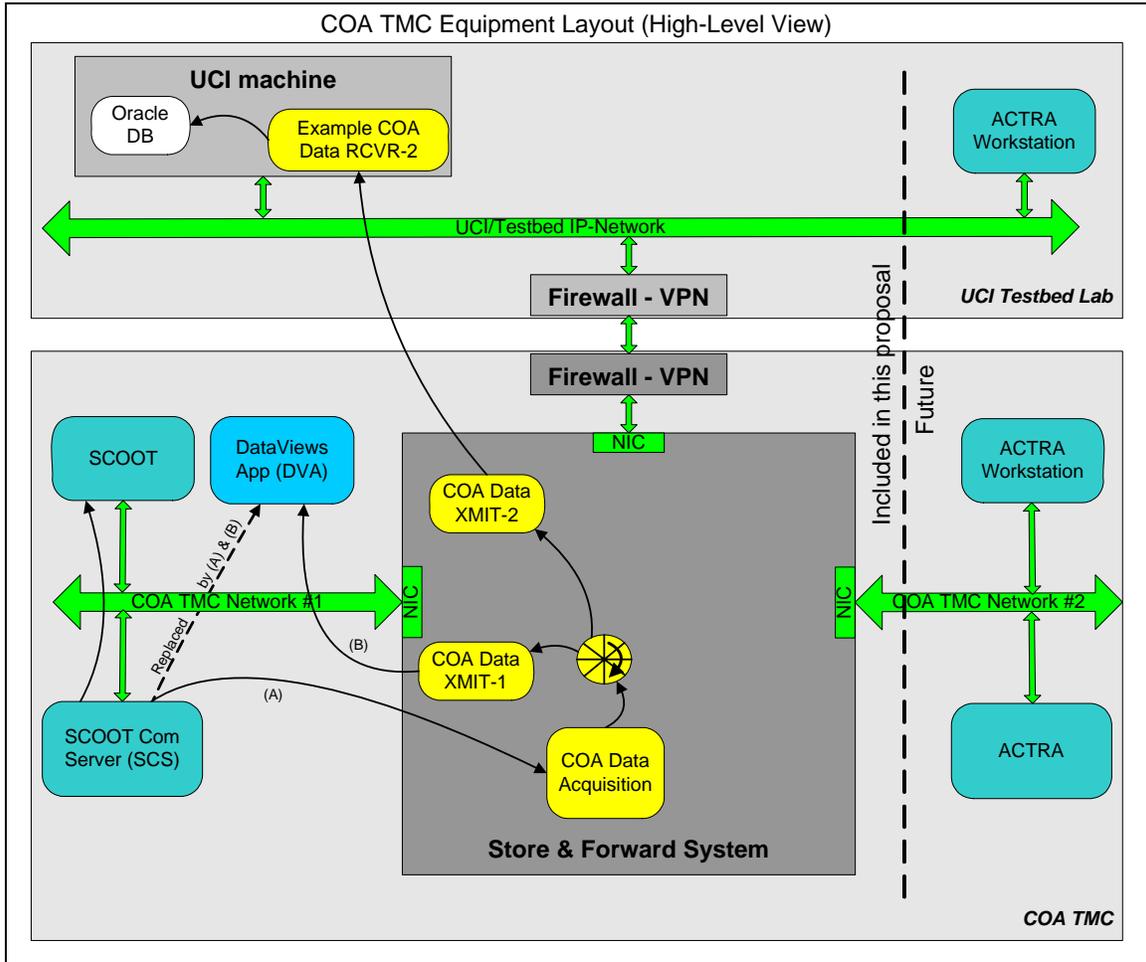


Figure 2.4-1 - COA TMC Layout with new Testbed equipment installed

Arrows in the above diagram reflect data flows related to Testbed data acquisition. The SCS is currently capable of delivering data to two network nodes. Currently node-1 is the SCOOT system and node-2 is the COA Data Views Application (DVA) system. The approach taken was to redirect SCS node-2 to the Testbed SAF system. SAF system software would then be responsible for storing the data locally and forwarding the SCS data back to the COA DVA system (via XMIT-1) and also forwarding the SCS data to machine 'Nemesis' at UCI (via XMIT-2).

The above diagram shows the various components and the normal operational data flow. The new Testbed hardware that was installed at the COA TMC is shown in a **dark-gray** color. The following components are shown:

- The ***Store-and-Forward*** (SAF) system is a rack-mounted mini-server that is configured with two network adapters. This system runs the ***Store-and-Forward*** (SAF) application components.
- The ***Firewall-VPN box*** provides network security for the SAF system and indirectly for the COA TMC.
- DSL supports the Testbed access to the SAF system within the COA TMC.

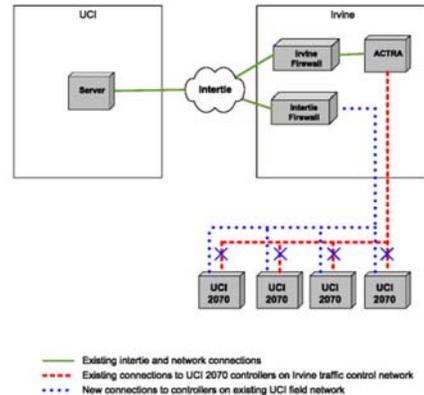
As the COA TMC real-time traffic data is acquired by the SAF system it is stored locally in a circular buffer located in a shared memory data structure (SMDS). Once the data are stored in the SMDS they are then retransmitted to the COA DVA machine as well as to a machine at UCI. The local buffering on the SAF system allows the data acquisition process to proceed without concern for the speed of outgoing transmission processes. It also allows multiple transmitting agents to operate completely independently and without side effects. The design allows for the continuous recording of data locally and the reliable forwarding of data to the COA DVA system even if the network link to UCI should go offline. The storage requirement on the SAF system is minimally only a few seconds. This minimal interval provides sufficient storage to prevent a loss of data during typical momentary networking delays; however, this buffer area has been sized to accommodate several days of COA TMC data. In this way an extended network downtime can be tolerated without an actual loss of data—data would just continue to be stored locally until the network link is restored (up to the limit of the buffer used). This allows Testbed management a reasonable amount of time to notice a networking problem and arrange for link repair prior to a loss of data. Once the link is restored, the SAF system software would simply forward the data stored locally over to system Nemesis at UCI as fast as the network link will allow.

On the UCI side of the connection, a COA TMC data reception application RCVR-2 has been developed to accept the COA TMC real-time data stream as it arrives from the SAF system. This application stores the data in the existing Testbed Oracle database for distribution on the Testbed website.

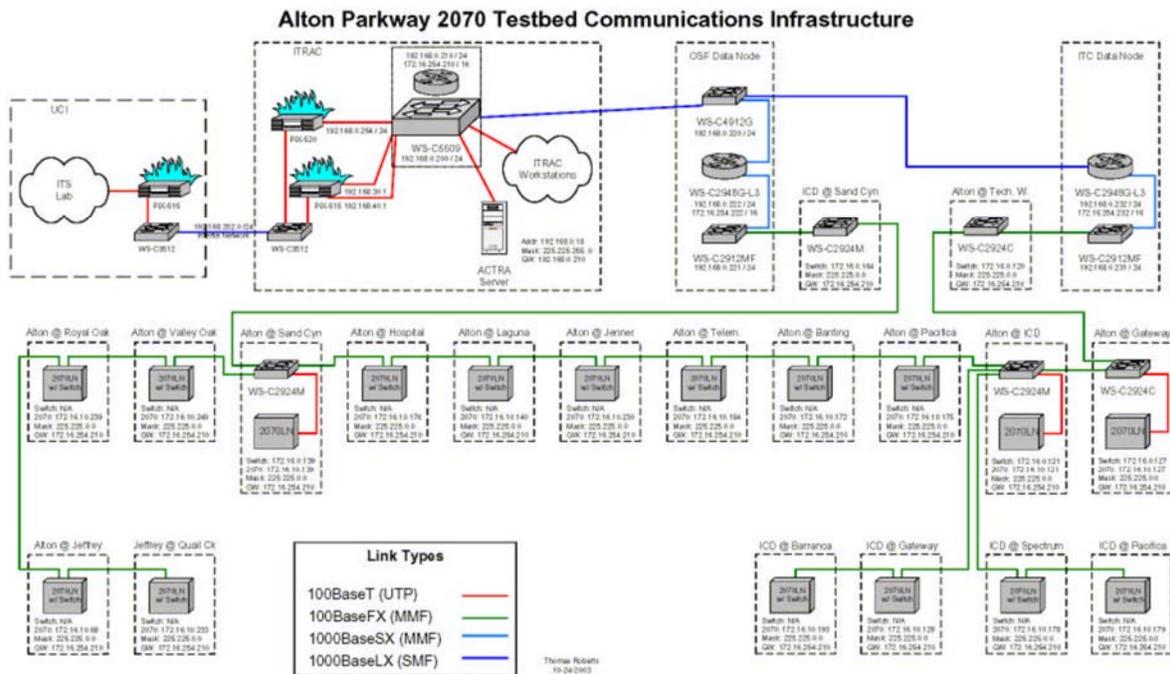
2.5 City of Irvine Real-time Data Intertie

A state-of-the-art Siemens ACTRA Central Traffic Control System and eighteen 2070NL intersection controllers with SE-PAC firmware was installed along an 18-intersection adaptive control testbed in the City of Irvine (COI) that supplies real-time traffic data to the UCI ATMS Testbed laboratories utilizing single mode fiber optic communication operating over 4 communication channels. The Eagle ACTRA system provides detection and adaptive control capabilities utilizing existing Ethernet communications.

The communications architecture for the complete systems is designed to isolate the Testbed functions from the COI's traffic system, thus allowing researchers to interact with the traffic system without the possibility of disrupting normal city operations.



A diagram of the preliminary communications infrastructure is provided below. The actual implementation in the field involved some modifications to that shown in the diagram, most notably: on the Cisco 4912G backbone, all the ATM links have been changed to Gig-E single mode (1000 SM) between sites and Gig-E multi mode (1000 MM) between switches within the ITRAC, OSF and ITC sites. A one Gig-E single mode link has been added from the OSF to the



ITC to complete the gigabit ring. All of the controllers on Irvine Center Drive now connect to

Ethernet switches at each site, not to each other; the switches are tied together with multimode fiber.

Input Acquisition Software (IAS) was developed to enable transmission of all detector inputs and signal displays to the UCI Testbed laboratories. The 2070 controller and its corresponding field I/O module (which is the 2070-8 for the purposes of this document) are really two separate computers. They each have their own memory, CPU, and firmware. The job of the field I/O module is to interpret serial data coming from the controller via a synchronous serial link ten times a second and set the state of the hardware outputs to whatever the traffic program in the 2070 wants them to be. Conversely the field I/O module reads the state of the hardware inputs ten times a second and reports these back to the main 2070 CPU over a synchronous serial link. None of the inputs or outputs have any meaning to the 2070 hardware, only to a traffic program running in the 2070.

The IAS replaces the SE-PAC traffic software with another program (not a traffic control program) that simply looks at the serial data stream coming back from the 2070-8 NEMA base every tenth of a second, picks out the input status bits (either on or off) and reports these back to a host program via a UDP packet. This approach is very elegant because the host can see the state of all of the inputs into the 2070-8 NEMA base for every 10th second of time. The host may then archive or process the data as desired. The software supports the following:

- Allow communications via Ethernet using the UDP protocol on port 20000.
- Allow the user to remotely query the date and time of the unit.
- Allow the user to remotely set the date and time of the unit
- Allow the user to specify a rate at which the state of the filtered input bits on the - 8 NEMA base are transmitted to the user.
- Periodically send the user the state of the filtered input bits on the -8 NEMA base at the specified rate.

2.6 ATMS Testbed Resource Website

Access to the resources of the ATMS Testbed are provided through a Testbed website. The website has a real-time graphical user interface for freeway and traffic information from the physical testbed, as well as access to historical databases using a browser for query. The website was developed and is maintained by the ATMS Testbed staff.

Through the website, the ATMS Testbed can provide university researchers, Caltrans staff, and public and private sector partners with a “virtual gateway” both to the traffic data streams (real-time and historical) generated in the testbed as well as the analysis tools (e.g., Paramics APIs) developed by Testbed researchers. Examples of some of the data currently available on the Testbed website are given below.

As described in detail above, the ATMS Testbed maintains a rich complement of both real-time and historical data generated within the Testbed. These data are being made available to researchers through the ATMS Testbed website (Figure 2.6-1).



Figure 2.6-1. ATMS Testbed Website Homepage

Through the website, members (researchers, Caltrans, public and private sector partners) can obtain access to the various resources maintained by the Testbed, under varying levels of access privilege. For example, information pertaining to the Traffic Detector and Surveillance Sub-Testbed (TDS²) can be accessed through a “pull-down” menu (Figure 2.6-2),

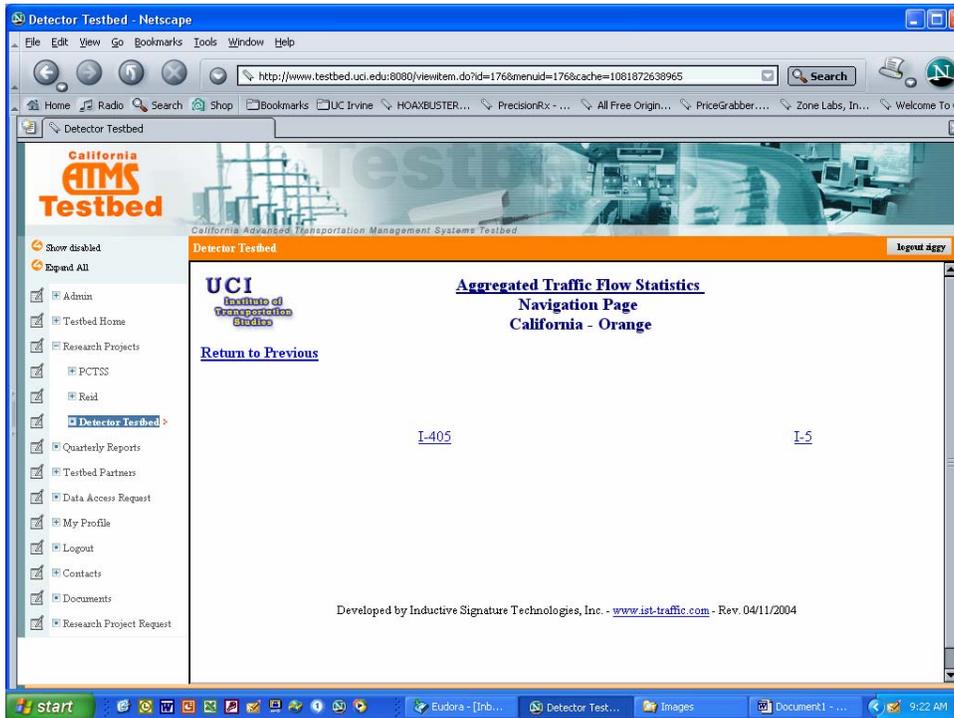


Figure 2.6-2. Traffic Detector and Surveillance Sub-Testbed Page

from which either historical data, either raw (Figure 2.6-3) or statistical (Figure 2.6-4) can be retrieved.

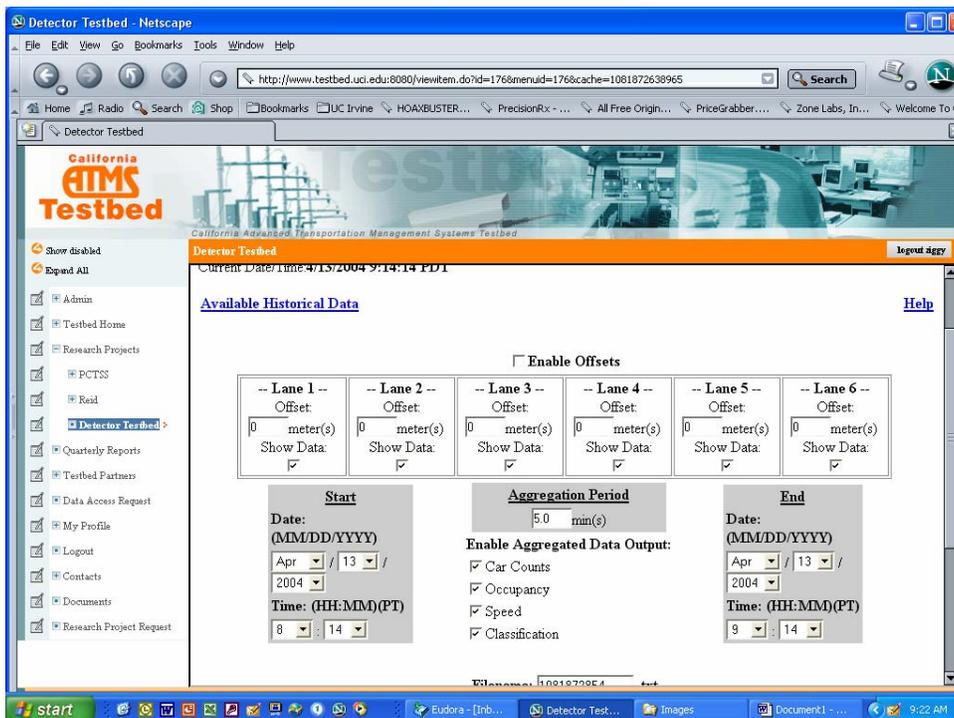


Figure 2.6-3. Traffic Detector and Surveillance Sub-Testbed Historical Data

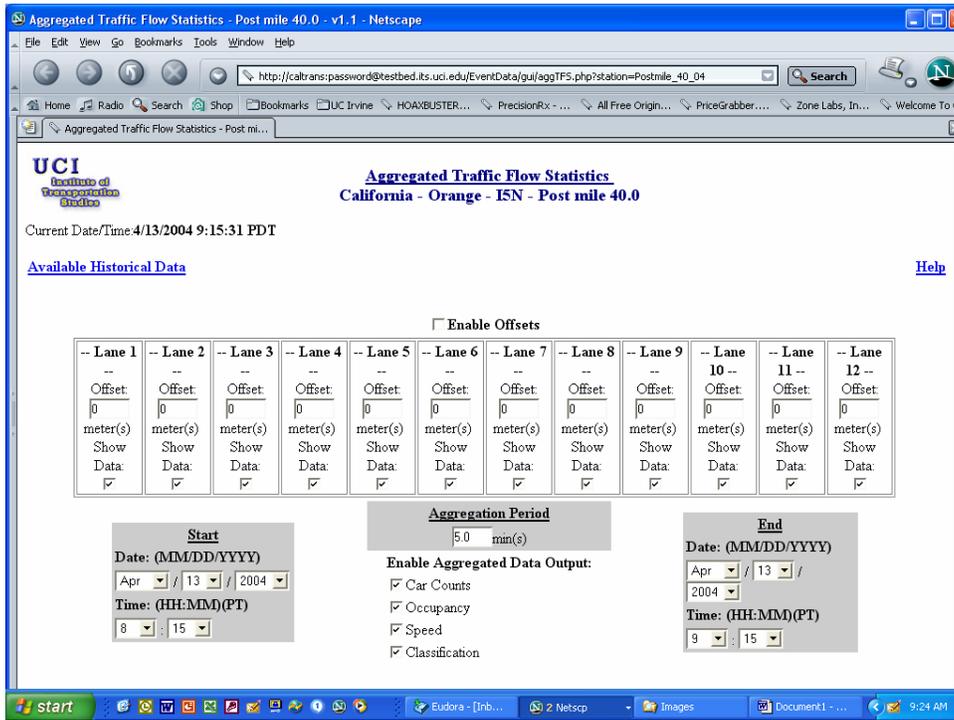


Figure 2.6-4. Traffic Detector and Surveillance Sub-Testbed Statistics

Utilizing vehicle re-identification systems developed jointly by PATH and the Testbed (Figure 2.6-5) real-time section data can be obtained both for arterial and freeway networks within the Testbed (Figure 2.6-6).

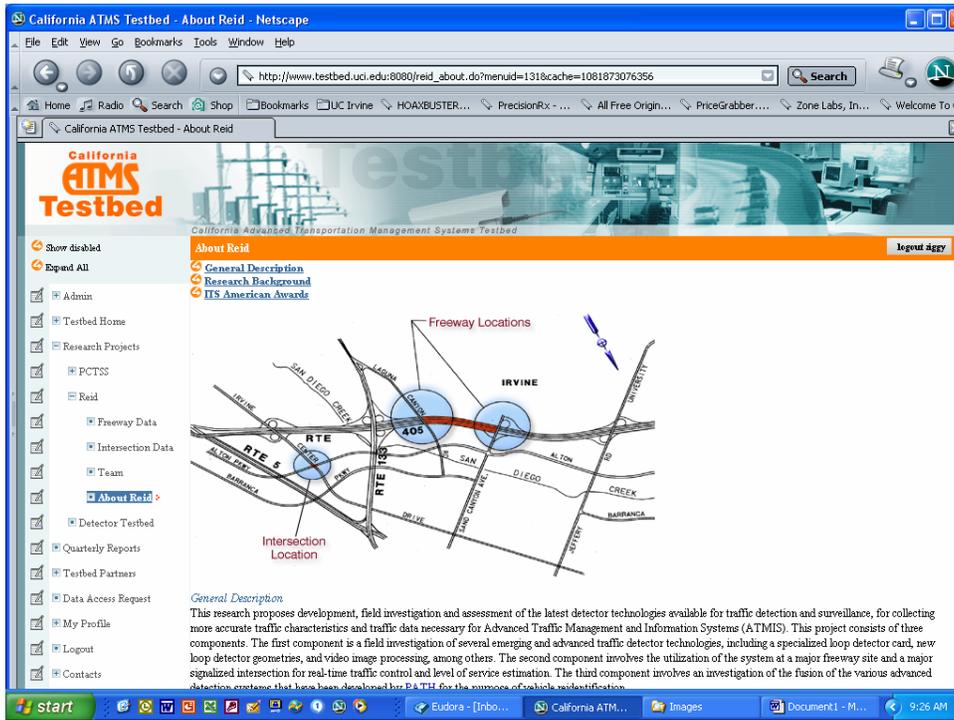


Figure 2.6-5. REID System

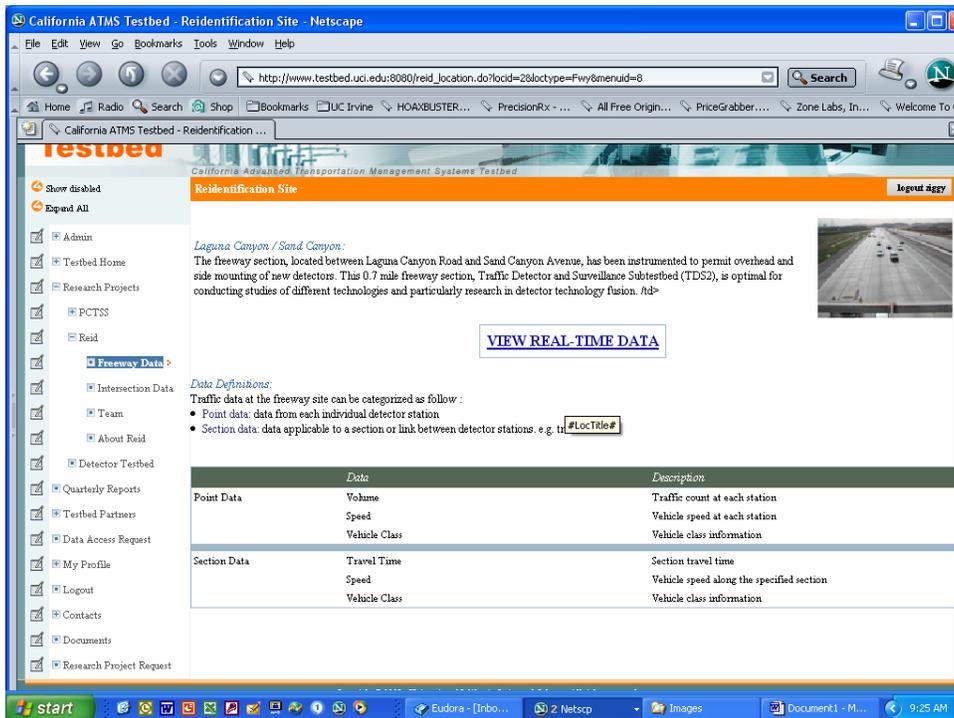


Figure 2.6-6. Real-time Section-related Data

The full complement of resources (e.g., data streams, streaming video, software packages) available at the ATMS Testbed are incorporated in the Testbed web page in a manner that

provides “virtual” access to these resources. The web page has a real-time graphical user interface for Orange County freeways and traffic information from the cities of Irvine and Anaheim, access to historical database using a browser for query, and IP streaming video. The web page is available on the Testbed network as well as via the Caltrans Wide Area Network.

The website has been developed and will be maintained by the ATMS Testbed staff. As new resources are developed, they will be incorporated into the website in a manner that will facilitate their use by Caltrans staff, researchers, and Testbed Partners.

PART 3

TESTBED RESEARCH AND DEVELOPMENT

3.1 Development and Deployment of Corridor Management Prototype

A central ATMIS capability is a timely and efficient response to non-recurring congestion. The complexity of traffic in urban corridors requires substantial interaction between the various agencies that share responsibilities for corridor management. Coordinated response to congestion phenomena between these agencies avoids the implementation of responses that may be conflicting and therefore counter-productive.

The problems of transportation management in urban areas are complicated by jurisdictional as well as operational problems. The spatial and administrative organization of transportation management agencies in metropolitan networks requires a coordinated solution effort that preserves the different levels of authority, guarantees privileged data control, and in general reflects the inherent distribution of the decision-making power. A coordinated response to congestion avoids the implementation of operations that may otherwise conflict, and therefore be counterproductive. The Testbed functionality in this broadly defined ATMIS application is centered on the real-time multi-agent incident management system CARTESIUS (Coordinated Adaptive Real-Time Expert System for Incident management in Urban Systems), deployed within the Testbed Real-time Integrated Control and Evaluation Prototype System (TRICEPS). CARTESIUS approaches this problem by employing advanced cooperation and conflict resolution methodologies for coordinated traffic management operations among multiple agents. This system is at the cutting edge of the application of agent technology to traffic management and has been tested extensively using laboratory simulation with positive outcomes reported across the scenarios evaluated. To date, however, it has not been deployed in the field.

In an ongoing joint Testbed/PATH project, TRICEPS/CARTESIUS is in the process of being field tested in two evaluation modes. In the first mode, the system processes real-time data coming from sensors in the field and provides advisory management strategies and control actions for the consideration of Caltrans District 12 (Caltrans D12) and City of Irvine Traffic Management Center (ITRAC) personnel. The second evaluation mode involves usability and stress testing of the TRICEPS/ CARTESIUS system with the CARTESIUS agents remotely connected to the Paradyn traffic simulator at the UCI Testbed laboratories, where Transportation Management Center (TMC) operators/personnel will be asked to respond to the scenarios using CARTESIUS to implement control strategies in Paradyn. Tasks scheduled to be completed include: deploying the current version of TRICEPS and CARTESIUS in both the Caltrans D12 and ITRAC TMCs; linking with the Paradyn simulator at UCI and real-time data feeds from UCI or Caltrans D12; developing field test scenarios and evaluation protocols; and conducting and evaluating the field tests. Full documentation of the experiments and the results, as well as the implemented software platform, will include Operator Guides and a Final Report.

In work performed under the Testbed, TRICEPS/CARTESIUS will be deployed in its real-time, interactive, mode in the in the TDS² corridor. The deployment will utilize dynamic O-D patterns and travel times derived from the REID system described above to assess alternative routing of vehicles through the corridor. Signal timing recommendations selected with the aid of TRICEPS/CARTESIUS will be implemented through the ACTRA system already deployed by the Testbed along Alton Parkway; ramp meter settings will be implemented based on enhancements to the Caltrans D12 Testbed intertie described in a later section.

The product of this work will be deployment of a multi-jurisdictional, multi-agent traffic management decision support system using an extensible implementation architecture. The deployment will utilize the products of current and prior Testbed research and evaluate their use in practical settings. The field deployment of TRICEPS/CARTESIUS will produce a functional multi-agent, multi-jurisdictional traffic management system for the real-world transportation corridor that is part of the Testbed. This system will coordinate management strategies between Caltrans D12 and the City of Irvine. The TRICEPS/CARTESIUS system is a mature research project utilizing agent technology to implement strategies that “coordinate freeway and arterial operations among multiple agencies.” The work conducted here will produce a pilot deployment of this system in a specific real-world setting. This will permit further evaluation of both the performance of the architecture as well as provide feedback on the practical usability of the system from the operators' perspectives.

Because CARTESIUS will be deployed in the Irvine I-405 transportation corridor, it also addresses the following important areas:

1. *Assessments of impacts of application of technologies:* The impact of TRICEPS and CARTESIUS on various non-recurrent congestion scenarios in Irvine corridor will be assessed.
2. *Studies of institutional coordination issues:* The efficacy of CARTESIUS mediated inter-jurisdictional coordination of traffic management strategies between the City of Irvine and Caltrans D12 will be evaluated. Recommendations for improving the coordination model of the system will be made that are both specific to the Irvine corridor and that are generally applicable to multi-jurisdictional settings.
3. *Post-deployment evaluations of effectiveness:* While full evaluation of the deployment will likely require longer-term calibration of the system and subsequent monitoring, preliminary evaluations of its performance will be produced and used to feed further fine-tuning of the deployment.

Because of the safety, legal, and institutional issues involved with moving research into full deployment, we have included stages in the development that provide a middle ground between research and practitioners by establishing the ability to engage in TMC-in-the-simulation-loop experiments. We hope this will provide an important prototype for moving research into practice.

3.2 Distributed Paramics Development

The application of high-performance distributed traffic simulation is an important element in Caltrans' strategic planning toward the development of a real world transportation environment, helping it to alleviate the congestion problems experienced in the state of California. In the transportation simulation field, there is some general agreement that micro-simulation, i.e., a computational resolution down to the level of individual travelers, is now a viable alternative and may be the only answer to a wide variety of problems. A traffic simulator for dynamic traffic management plays two distinct roles: as an off-line evaluation / design tool and as an on-line control / guidance tool. Both roles demand fast simulator to fulfill their tasks. The need for parallel or distributed simulation approaches can be understood from examining the need for computational speed-ups, availability of options towards that, and then at the need to distribute the effort to develop network simulation contexts and data sets, as below.

1. **Off-line Planning:** Many types of localized traffic jams, which can only be produced on the micro-simulation level, affect people's modal and route choice. Furthermore, the environmental impacts of highway design alternatives are almost entirely dependent on the details of such congestion phenomena. The traditional planning models based on simple link travel time functions are proven to show unacceptably erroneous emission impact and many planning studies have ended up even in court litigation on this count. Integrated planning using microscopic modeling already requires efficient simulations of large networks of the kind needed for planning exercises. The simulation may have to loop several times back and forth between a route planning and a micro-simulation, thus producing a need to execute the micro-simulation several times instead of only once until a result is achieved.
2. **Online Control/Guidance and Emergency modeling:** Online simulation applications such as prediction for traffic control require the model to run much faster than real time, especially in the case of computationally-intensive modeling for real-time operations such as rerouting around accident sites. This is even more important if modeling is to be used for bigger emergencies requiring area-wide evacuations, etc.
3. **Monte Carlo Analysis:** The apparent global stochasticity of traffic is captured in most modern simulation approaches. In order to generate credible results, multiple simulation runs are a must. There is a potential danger of analysts not repeating the simulations enough times, and using spurious results in making potentially costly decisions. Once again, the speed of simulations becomes critical.

For comprehensive traffic solutions for route-level and area-wide congestion amelioration, the analysis network sizes are often several miles or tens of miles in length and breadth. That is, networks of even 20 or 30 times the size/area of current (local) analysis networks need to be simulated. Furthermore, for online analysis of multiple solutions, we need another order of magnitude speed-up in the operations. Even a Moore's law extrapolation would require more than a decade for such a 100-fold increase in computational capabilities on single computers. This implies that harnessing additional processors in parallel and decomposing the problem domain into sub-domains is an option of promise, and perhaps the only solution.

In addition to the above issues, decomposed and distributed simulation schemes are a requirement in incrementally developing network data sets and debugging the simulation cases in any operational computer environment that a large state agency such as Caltrans would contemplate. For example, it is nearly impossible to develop a network data set for all of Los Angeles basin or the San Francisco bay area without significant decomposition of simulation efforts across analysts and modeling personnel. The effort could well have to be across different analysis offices at Caltrans districts or headquarters. Ensuring the integrity of the data sets will also require techniques that would allow smaller sub-areas to be tested with larger areas that they are part of, with the flow-through traffic modeled properly. To effectively “stitch” together sub-network data sets and to test their integrity distributed simulations are required. In other words, the capabilities developed for faster simulations will also yield capabilities for managing the simulation data set environment better. No effective framework with such comprehensive approaches to modeling practical networks exists in the traffic analysis community as yet. This is an added practical reason to develop abilities to set up simulation frameworks across robust distribution platforms such as CORBA.

Research is being conducted under the auspices of both PATH and the Testbed to develop a distributed version of Paramics that will satisfy these concerns. This work is ongoing and will carry through the next two years; a summary of the work is provided below.

In the distributed simulation environment being developed, the targeted large network is divided into sub-networks, and each sub-network is simulated on a separate desktop PC. Therefore, the general distributed architecture includes: 1) a “controller” simulator running the "master network," and 2) several sub-network simulators. Although the controller may have various tasks related to coordinating the traffic simulation itself, the essential task from a computational architecture standpoint is the synchronization of the time in each sub-network, either at every simulation time-step or at specified time intervals. To synchronize the simulation time, the controller has the ability to start and stop the sub-network simulation at any time. In addition, such information as boundary zones and their corresponding ownerships are established in the controller computer.

During a simulation run, the controller and simulators communicate over the distributed platform. The sub-network simulators act as slaves to the controller. During a time step of simulation or certain time interval, a simulator executes a non-blocking loop (asynchronous communication) while waiting for a new request from the controller. A request is simply a message associated with a specific task. When the request arrives into a sub-network simulator, it starts with an execution of the corresponding sequential code. When the request task is completed, a notification is sent back to the controller. When all simulators are “checked in”, the simulation master clock advances by one step and broadcasts the new times to every simulator in the system. Each simulator then proceeds until it reaches the master clock time. A pictorial description of the scheme used for distributed processing is shown in Figure 3.2-1. The communication between the simulators and controller is through the CORBA distributed platform.

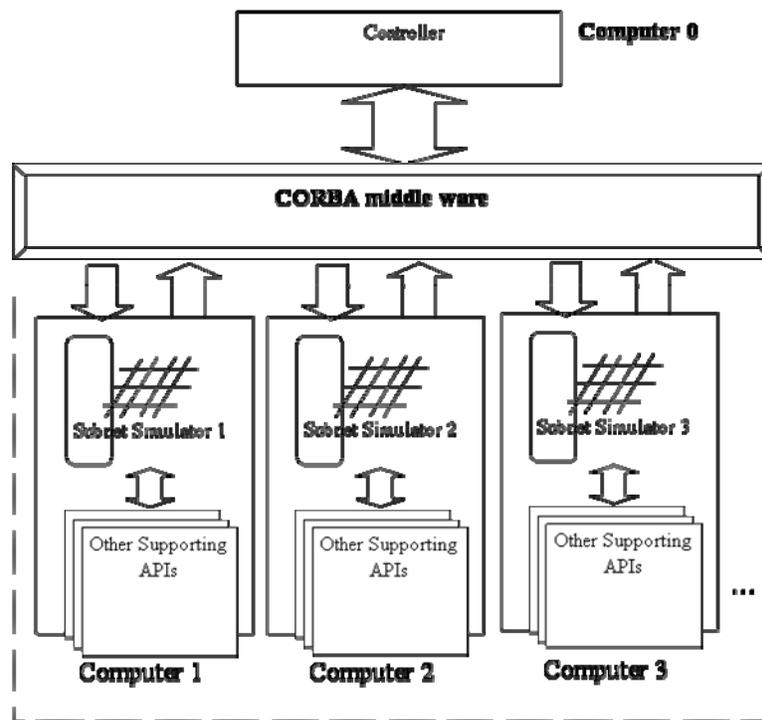


Figure 3.2-1. General Distributed Architecture

Since synchronous communication is used among simulators and controller, each simulator can only run as fast as the slowest; proper and balanced decomposition of the network is critical to the overall performance. Because the total computational requirement for a microscopic traffic simulation is dominated by the number of vehicles in the network at any time, the ideal division of network is to create N regions that each have exactly V/N vehicles, where V is total number of vehicles in the simulation and N is the target number of processors. The speed-up performance of the simulation in distributed processing is also dependent on the communication to computation overhead: if there are a large number of communication operations for each computational operation, the overall process will reduce in speed. In order to minimize the communication to computation overhead, distributed simulations require methodological decomposition of the large network to find a subdivision where there are as few boundaries as possible and the computational load is spread evenly across the processors.

In the current work, two alternative designs for the controller-simulator architecture are being developed: 1) light controller and heavy simulators, and 2) heavy controller and light simulators.

Light Controller and Heavy Simulators

The light controller and heavy simulator design is the simplest form of distributed simulation. In this case, each sub-network simulator has its own origin-destination demand matrix and its own route tables, but its simulation clock time is synchronized by the controller. In other words, if the time synchronization from the controller is removed, each sub-network simulator should be

able to perform its simulation independently. The only task for the controller is to synchronize the time clock for each sub-network.

Communication between processors is required when an object (a vehicle) moves from one sub-network to another. A message is sent from the originating simulator to the receiving simulator describing the object, and the “ownership” of the objects is thus transferred. Once the transfer is confirmed, the vehicle object disappears at the destination zone of the originating sub-network, and the corresponding vehicle will be generated from the origin zone in the receiving sub-network. The destination of the transferred vehicle is set randomly in the receiving sub-network, but the probability of selecting a particular destination zone is equal to the ratio of origin-destination demand with total demand generated from the origin zone. Once the destination of the transferred vehicle is selected, the transferred vehicle will be taken as one of the vehicles generated from this particular O-D demand.

This design features easy implementation since the vehicle routing has been taken care by the individual simulator. On the other hand, since each simulator knows only the local traffic condition in the sub-network, without knowing the big picture of the large network, this design may suffer from the unpractical or unrealistic routes taken by some vehicles. Therefore the congestion pattern from the simulation may be distorted from reality.

Details of this approach are contained in Testbed Technical Reports **TTR3-06** and **TTR3-07**.

Heavy Controller and light Simulators

The design with a heavy controller and light simulators is at the other end of the spectrum, compared to the previous design. In this case, not only will the controller synchronize the time clock of simulators but also contain the global abstract network, global O-D matrix and global routing table. The global abstract network is a simplified network from the original large network, and used only for routing purposes. The controller will control the vehicle generation in the sub-networks and the individual vehicles' paths. The local traffic condition in the sub-networks will be reported back to the controller and used in the dynamic update of the global routing table. When a vehicle comes to the boundary of the originating sub-network, the controller will notify the receiving network to generate an identical vehicle, and continue to route the vehicle to the destination. Here, each sub-network simulator is only used to update the individual vehicle's location according to the car-following, lane-changing and gap-acceptance models, which are the most time-consuming parts in microscopic simulation.

The benefit from this design is that vehicle's origin-destination and its path are all controlled at the global level, as opposed to the local level in the previous design. In this aspect, the heavy controller and light simulators design is similar to the simulation over single processor in term of routing, with the distinction of updating vehicle's location over distributed processors. But the communication load between the controller and simulators is also significant higher than that of previous design, which may slow down the simulation.

The heuristic routing approach could be taken to reduce the communication overhead. In this case, the controller will still have the global abstract network, global O-D matrix and global routing table. Each simulator also has its own local routing table. When a vehicle is generated in the sub-network, if its origin and destination belong to different sub-network, its temporary destination in the originating sub-network will be determined from the global routing table, but

its path in the originating sub-network will be determined locally from the local routing table. Therefore, instead of routing every individual vehicle at the global level, the revised design allows a vehicle's route calculated at the local level. Significant communication overhead will be reduced in this case. However, this heuristic approach does not solve the routing problem in the first approach completely in that the vehicle's temporary destination determined from the global routing table may be changed in the dynamic assignment case.

Both designs use CORBA as the general infrastructure for communication in the distributed simulation environment. From a non-technical viewpoint, one of the compelling reasons for employing CORBA is that it has significant and growing support and momentum from industrial users. Most of the capabilities involved in the methodological development can only be implemented with the appropriate CORBA-based test platform. It should be noted that simultaneous work is underway by UCI Testbed researchers for Paramics implementation using the same CORBA platform for a prototype distributed system, which may be fine-tuned for commercial purposes by Quadstone. The API coding for proper implementation of Paramics in a CORBA environment is a significant effort undertaken by PATH research engineers at UCI in this task. The platform is being coded with the later tasks in mind, specifically the prototype testing of comprehensive large network modeling framework in year 2 of the current work.

For early testing, the relatively large Orange County Testbed network recently fine-tuned at UCI is being used. This network is one of the largest networks coded in Paramics, with as many as 100,000 vehicles being present at any given time. Options to develop larger networks for subsequent simulations will depend on hierarchical network disaggregation/aggregation schemes and sub-network boundary interfacing techniques developed.

Based on the above condensed conceptualization of dynamic transportation network management, we have identified a set of improvements to Paramics that will substantially enhance its use Advanced Traffic Management and Information Systems (ATMIS) applications.

3.3 Incorporation of Wireless ATMIS Technologies within the Testbed

Work has been completed in the Testbed that is intended to extend the Testbed research capabilities to make use of new, wireless data collection and transmission technologies. The core technology available to the Wireless Testbed project at this time is the Extensible Data Collection Unit (EDCU). The EDCU is an in-vehicle device that collects GPS data, and transmits that data wirelessly, using a Cellular Digital Packet Data (CDPD) modem, to a central database in near real time. Any number of vehicles may be outfitted with this device and driven simultaneously, allowing for multiple data streams consisting of position, speed, and other GPS-based information.

Much of the work to date for the Wireless Testbed has gone into developing the most important functions of the EDCU and the supporting database software. The units can reliably collect information and transmit that data back to the database. A web-based front-end has been developed to display that collected data. This web functionality includes monitoring the position of any given EDCU in real time, and displaying any number of past data collection trips separately or in a single map. Other more generic database gateways have also been implemented, including an XML interface which responds to data queries with validated XML documents, and a simple form-based file uploading interface to enable data to be uploaded directly.

The main thrust of the work has been to integrate the EDCUs into the larger Testbed. The specific tasks related to this include:

1. integrating GPS record-based data with other Testbed data streams;
2. developing and implementing path-based data analysis algorithms; and
3. developing and implementing automatic mapping algorithms.

The GPS sequences collected by the EDCUs can be used in many ways by Testbed projects, from real-time monitoring of traffic flow variables to dynamic revision and augmentation of the shape points describing traffic network links. Further, the existence of a large and growing body of travel data prompt new research initiatives. For example, we recently began cooperating with an artificial intelligence research group within UCI's School of Information and Computer Sciences who are interested in developing algorithms and techniques to "learn" travel behavior so as to be able to predict future behavior within minutes of the start of a trip.

The existing EDCUs are not new and are beginning to show their age in many ways. The CDPD technology upon which they rely rapidly becoming obsolete. We have actively addressed this issue in two ways. First, we have upgraded some units to newer wireless modems that provide data access speeds comparable to a regular 56Kbps dialup modem. We have also integrated 802.11b (WiFi) antennas into the EDCU to provide **free** wireless communications capability over a local area at tested speeds of up to 4 Mbps. The original GPS antennas included with the EDCU have a positional accuracy of 15 meters, while the newest antennas have a positional accuracy of 3 meters, attributable to the wide area augmentation system (WAAS).

Although the EDCU is no longer a cutting edge piece of hardware, it has proven itself to be a very useful tool. Four of the units were used for extended periods of time with no driver interaction whatsoever, relying strictly upon the wireless link to collect data for months on end.

One unit was in use continuously for over a year. The EDCU can be programmed quite easily to run new software, since the underlying operating system is Linux. And the basic functions of collecting and transmitting GPS data can continue to be performed by the EDCU, leaving other devices free to perform other tasks. For example, a current project we are performing uses Java code that requires more processing power than the EDCU can provide. So we have installed the processor-hungry applications on laptops, and have linked each laptop via an ethernet cable to an EDCU to provide GPS services as well as central monitoring services over the wireless link.

While the EDCU contains wide area and local area wireless technologies, there are many technologies that may require future equipment purchases. For example, the FCC recently finalized rules for the DSRC ITS band. While we have yet to see any consumer-grade devices that use this new slice of spectrum, cards and devices should be coming on the market soon, and it would be interesting to be able to compare this technology to others such as 802.11b. At the other end of the scale, the ZigBee Alliance and other, similar groups are promoting very simple communications protocols for very simple devices. Their idea is that a large network of these cheap, small devices will be more powerful and flexible than sparse networks of expensive devices. These micro devices are far smaller than our EDCU, but have less processing power and much smaller bandwidth.

Despite these limitations to the EDCU, it remains a sufficient platform for most of our current needs—not having immediate access to any particular technology is not a limiting factor because we are interested in *applications* that *use* the technologies, rather than the technologies themselves.

Details of the Testbed efforts to incorporate and test wireless technologies in transportation systems management are contained in Testbed Technical Reports **TTR3-01**, **TTR3-02**, **TTR3-03**, **TTR3-05**, **TTR3-08**, **TTR3-09**, **TTR3-10**, and **TTR3-11**.

3.4 Real-time Adaptive Systemwide Ramp Metering and Signal Control

In support of Caltrans' ramp metering deployment efforts, an evaluation platform based on PARAMICS simulation is being developed jointly by the Testbed and PATH. The ramp metering design tool handles how to implement a metering algorithm within a target freeway corridor. The ramp metering evaluation tool employs the testing and evaluation of a metering algorithm and its design based on performance measures obtained from simulation. A library of metering algorithms either currently or potentially applied in California is included in this platform. These algorithms include District 3, 6, 8, and 11's SDRMS, and District 7 and 12's SATMS, as well as some adaptive metering strategies (e.g., ALINEA, and SWARM) that potentially can be applied. The platform has intuitive graphical interfaces in order to facilitate Caltrans practitioners.

Compared to field tests, the platform should provide a quick and cost-effective way to conduct ramp-metering studies in the microscopic simulation environment. The platform can be used to analyze and improve current metering operations, to test a new algorithm, to fine-tune parameters of an algorithm, to evaluate various aspects of performance of a metering strategy, and to conduct a series of deeper level analysis of the performance of the algorithm.

In addition, the platform can serve as a training environment for Caltrans personnel to gain experience with various metering algorithms, especially those coordinated metering algorithms that are characterized by many parameters and complicated control logic. This platform can guide Caltrans personnel on how to successfully manipulate the various aspects of the ramp-metering systems, including initializing parameters, fine tuning of parameters, performance analyses, and hypothetical "what if" simulated testing.

The overall framework of the platform is shown in Figure 3.4-1. The input data of PARAMICS simulation are network geometries, traffic control data, and traffic demand data estimated from real-world loop data. The platform has four main modules, and each module is made up of several components. The components within the red dotted box represent the newly-developed modules. The light green module is the core module, including two functional tools, design and evaluation. The bright green module is the graphical interface module through which users can access these tools. The blue module is metering algorithm module that consists of a library of Caltrans' metering algorithms (implemented as PARAMICS plug-ins). The pink module is the supporting module, which includes several PARAMICS API plug-ins used to support various metering algorithms and measurement data collection from the simulation world.

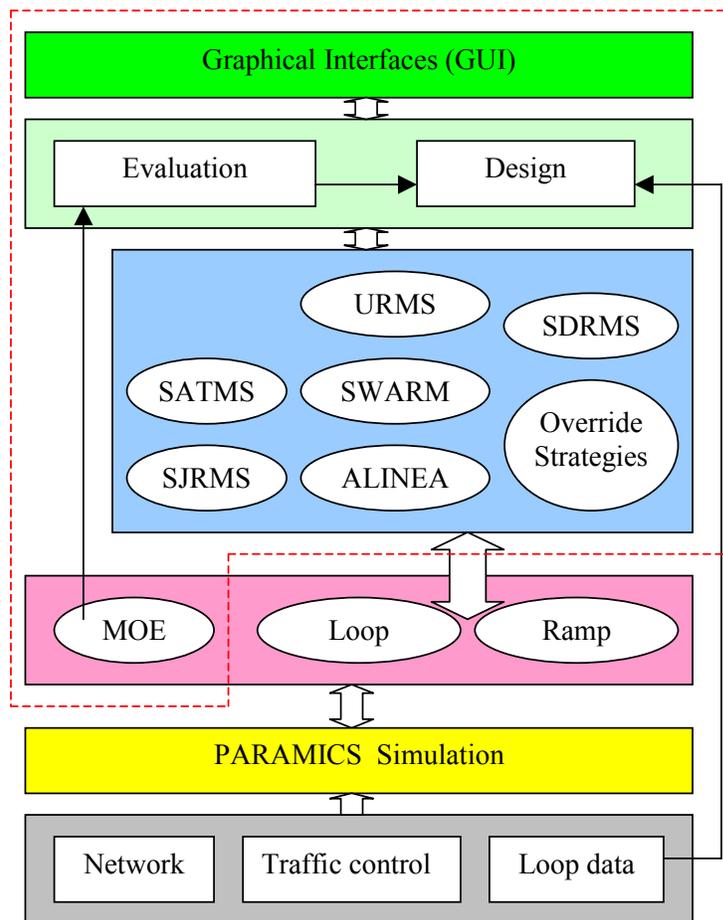


Figure 3.4-1. Framework of the ramp-metering evaluation platform

The latest web-based programming technologies have been used to implement the platform; the web pages containing the GUI have been developed using HTML and JavaScript; the core module of the platform is implemented in Java language, which has strong capabilities of the development of graphical interfaces; XML (eXtensible Markup Language) is used for data exchange between the core module and two PARAMICS plug-ins modules, including metering algorithm module and supporting modules.

A series of performance measures for evaluating various aspects of ramp metering can be extracted, including the following time-dependent measures:

1. Average mainline travel speed / travel time and its standard deviation
2. Total delay at an on-ramp
3. On-ramp queue length
4. Time percentage of queue spillback to the local streets at an on-ramp
5. Travel time from an on-ramp to downstream end of freeway and its standard deviation

The evaluation tool of the ramp-metering platform employs the evaluation of the metering design of a metering algorithm, and various traffic operational aspects of the ramp metering control. It links a specific ramp metering study, such as a study of freeway mainline efficiency, with required performance measures. Examples of these ramp-metering studies include freeway mainline efficiency, on-ramp delay, and equity analysis of a metered freeway corridor. As a result, the applications of the evaluation tool are:

1. Investigate whether metering has been operated correctly and efficiently
2. Analyze, evaluate and improve the current metering operations
3. Test new algorithm and fine-tune parameters

These studies can be done based on trial-and-error method and selected performance measures. Through the GUI, users can thus dynamically observe the performances of various aspects of metering control graphically.

3.5 Implementation of a Tool for Measuring ITS Impacts on Freeway Safety Performance

Reduced congestion and smoothed traffic flow are likely to improve safety, as well as reduce psychological stress on drivers. Using data from the Testbed, we have begun to document the relationship between safety and improved traffic flow. Recent developments indicate that the time is right to refine and implement analytical tools that can be used in real-time monitoring of the safety level of the traffic flow on any instrumented segment of freeway. As opposed to tools that measure freeway performance in terms of throughput or travel time, the data indicate that the key elements of traffic flow affecting safety are not only mean volume and speed, but also variations in volume and speed. We further determined that it is important to capture variations in speed and flows separately across freeway lanes, and that such information is useful in differentiating types of crashes.

The objective of this joint effort between the Testbed and PATH is to implement a real-time tool for safety analysis. The overall project goal is to calibrate and verify a tool that translates traffic flow, as measured by ubiquitous single loop detectors, into safety performance in terms of expected numbers of crashes by type of crash per exposed vehicle mile of travel. This tool can be used in monitoring the safety performance of freeway operations and to evaluate and document improvements to safety arising from such ITS deployment as system-wide ramp metering (SWARM), freeway service patrol (FSP) and other incident response measures, and driver information. By quantifying the safety benefits accrued from smooth and efficient traffic operations, Caltrans should be able to incorporate safety measures in assessment of performance gains resulting from ITS deployment. Another application will be to forecast the safety implications of proposed projects by evaluating the levels of safety implied by traffic simulation model outputs. The safety aspects of costs and benefits can be assessed by comparing the levels of safety estimated by the tool for traffic flows before and after implementation of a treatment, such as a component of an intelligent transportation system (ITS) or infrastructure project. It can also be used to forecast the safety consequences of doing nothing. It is meant to complement performance measurement systems that focus on travel times and delay (PeMS, 2005).

In work conducted thus far, we lay the groundwork for the development of a performance tool that gauges the level of safety of any type of traffic flow on a California freeway. The inputs to this tool are data from single loop detectors, so the tool can be implemented wherever such data are monitored or simulated. Our analyses are based on loop detector data for each of the freeway lanes for a short period of time preceding each of over 1,700 accidents in our case study. This case study covers the six major freeways in Orange County for a six-month period in 2001. The results have uncovered an extensive set of statistical parameters that capture those aspects of traffic flow that are strongly related to accident potential.

In this work we recognize that loop detector data at a specific time and place cannot be converted to speed, because it is not possible to know effective vehicle length at such a detailed level (that is, the mix of long and short vehicles is unknown at a specific place for a short period of time). Consequently, we avoid using any direct speed or density measures among the parameters. These parameters include not only central tendencies (means and medians), but variations, and

measures of systematic and synchronized traits that capture patterns in short period of loop detector data. Such patterns include breakdown from free flow to congested operations or recovery back to free flow, and differences in traffic conditions across lanes. We demonstrate that the parameters can account for speed and density, even though these are not used directly. Moreover, the parameters account for important differences among the types of accidents that occur under different type of traffic flow. Details of these findings are contained in Testbed Technical Report **TTR3-04**.

In work underway, the goal is to test the model's ability to distinguish locations and conditions with high accident rates from those with low accident rates. Because the methodology does not depend directly on specific geometric characteristics, but rather is based on the traffic conditions arising from both roadway layout and demand, the goal is to demonstrate that the tool can be readily transferred to any urban freeway that is fully instrumented with loop detectors without the need for extensive calibration. Once validated, code will be developed to deploy the model, first as a stand-alone on the Testbed website using data from the Caltrans District 12 FEP as input. Eventually the tool could provide the safety element of a performance measurement system such as PeMS.

PART 4

**TESTBED MANAGEMENT, TECHNICAL ASSISTANCE, AND
MAINTENANCE**

4.1 Technical Assistance to Caltrans, CCIT, and Partners

The purpose of this element is twofold: 1) to provide a continuing capability for Caltrans to analyze and measure the expected net benefits of ATMS projects proposed by Caltrans, typically by applying a microscopic simulation approach to evaluation of traffic improvement projects, and 2) to provide technical assistance to Caltrans, CCIT, and Testbed Partners in their use of Testbed resources.

Work conducted under this element focused on providing an “on demand” environment for Caltrans’ strategic planning exercises involving both ATMIS as well as capital improvement projects, using the analysis capabilities of Paramics, the physical testbed and the rest of the Testbed Workbench applications. In addition, human resource capability was maintained to service “on demand” requests for such analyses and evaluations.

Under this element, the UCI Testbed Team provided assistance in four broad categories:

1. On-Call Direct Support of Paramics
2. Technical Guidance on Microsimulation
3. Microsimulation Research-related Support
4. Technical Support of Use of Testbed Resources

The UCI Testbed team provided technical support for APIs developed by Testbed personnel on an on-call basis. Due to PARAMICS new builds and updated versions, the released APIs needed occasional maintenance to ensure full PARAMICS compatibility.

As different scenarios that could not be handled by current API versions were identified by Caltrans, an assessment was made by the project team to define necessary API modifications and these enhancements then programmed. For any modified or new APIs developed as part of this task, both source code and technical documentation were provided to Caltrans

Microscopic simulation models have the capability to evaluate transportation facility plans and design alternatives as well as traffic operation strategies. However, lack of appropriate guidance and/or direction may lead to inappropriate use of and inaccurate results from these models. It is anticipated that, as Caltrans' districts use microsimulation models with increasing frequency, a standardized guidance and evaluation process would facilitate model application and analysis, as well as the comparative interpretation of model results. The UCI Testbed team provided Caltrans with guidance and evaluation for simulation studies relative to traffic modeling and microsimulation.

On request, the UCI Testbed team evaluated Caltrans on-going simulation studies, and provided input to guidelines for application of microsimulation models upon request. It is anticipated that experience gained with the current microsimulation applications in California will contribute significantly to the development of guidelines.

As expected, there is increasing demand to utilize Testbed resources in support of deployments within the Testbed. The Testbed team maintained a capability to technically support such deployments.

4.2 ATMS Testbed Laboratory Development and Maintenance

The UCI Institute of Transportation Studies is responsible for the overall development and management of the ATMS Testbed Laboratories. Acting on behalf of the Caltrans Division of Research and Innovation, it continued to:

- develop necessary software enhancements to bring prototype Testbed model simulation systems to full operational capability.
- develop protocols for “plug and play” operation.
- develop Application Program Interfaces (API’s) for research and prototype deployments conducted within the Testbed.
- develop and coordinate an equipment and software upgrade and replacement program to keep Testbed capabilities within current industry standards.
- incorporate and integrate appropriate simulation/modeling advancements emanating from associated Caltrans research programs and other national/international efforts within the Testbed modeling environment.
- maintain and manage the Testbed Communications Network, including security provisions.

4.3 Testbed Management

The UCI Institute of Transportation Studies is responsible for the overall management of Testbed operations. Acting on behalf of the Caltrans Division of Research and Innovation, it continued to:

- develop and maintain the Testbed facilities in a manner that facilitates the overall goals of Caltrans DRI, CCIT, and the Testbed Program.
- establish and coordinate the activities of the various management committees charged with overseeing Testbed operations.
- act as liaison between CCIT, PATH researchers, private and public sector users and the Testbed operating agencies that comprise the Testbed partnership.
- identify and coordinate enhancements to the Testbed that serve its basic functions.
- coordinate and assist in the procurement of hardware/software necessary for the conduct of deployments within the Testbed.
- develop and execute a strategic plan for realizing the maximum potential from Testbed activities.
- represent the interests of the Testbed at national and international forums.
- manage the Testbed Communications network.
- supervise and coordinate the activities of Testbed researchers assigned to the Testbed Program.
- act as Caltrans agent in all such other Testbed activities not specifically delegated.