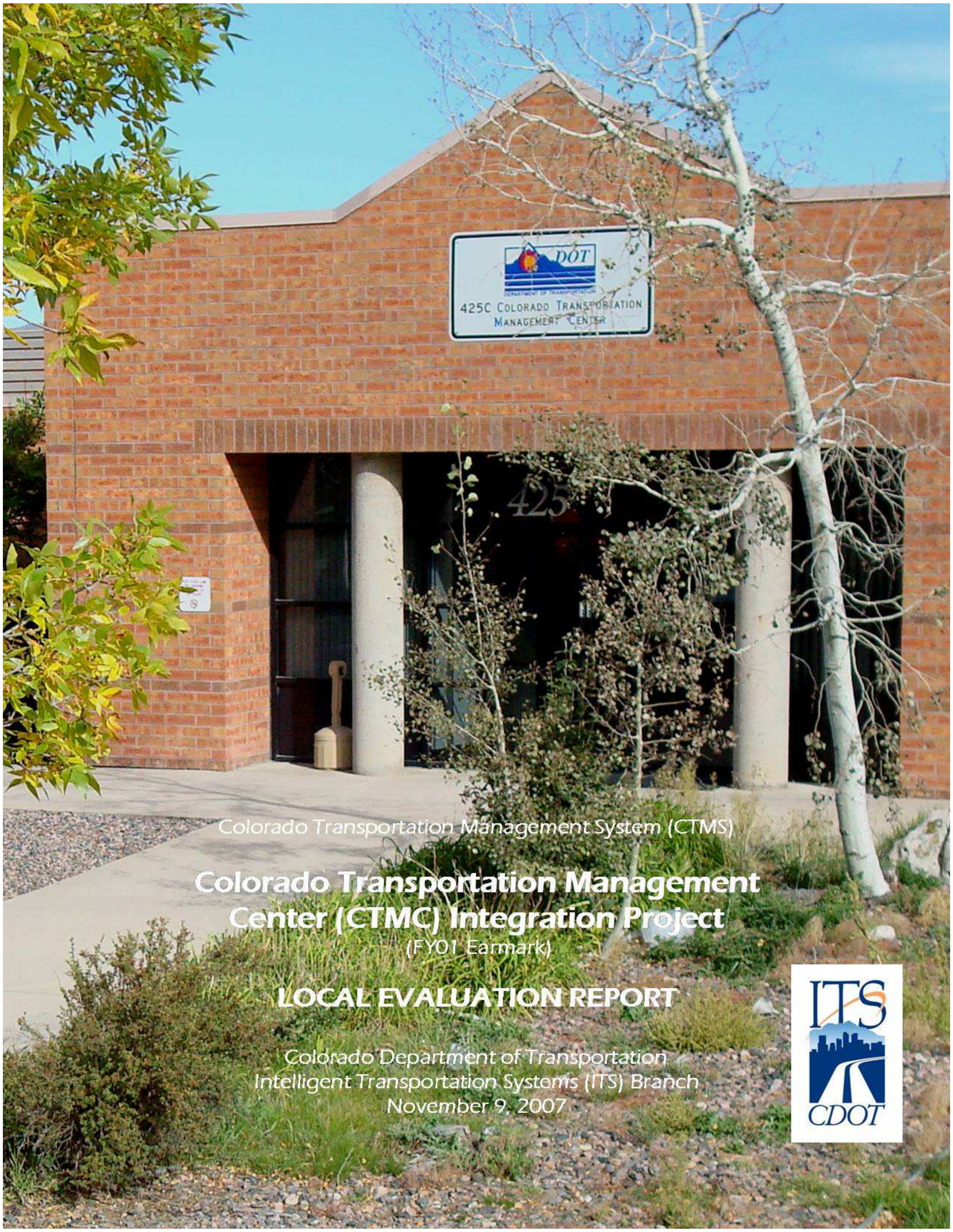

Colorado Transportation Management System (CTMS)

Colorado Transportation Management Center (CTMC) Integration Project

(FY01 Earmark)

LOCAL EVALUATION REPORT

Colorado Department of Transportation
Intelligent Transportation Systems (ITS) Branch
November 9, 2007

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16. **Abstract**

The CTMC Integration Project is the result of FY01 congressionally designated earmarks to improve transportation efficiency, promote safety, increase traffic flow, reduce emissions, improve traveler information dissemination, enhance alternate transportation modes, promote tourism and build on existing Intelligent Transportation Systems (ITS). Total project investment was $6,753,160, including $3,372,862 in federal funds and $3,380,298 of matching cash provided by CDOT.

With FHWA concurrence, the project supported work in two priority areas: 1] to support design and construction of CDOT's new CTMC facility; and 2] to develop or procure and implement a statewide "umbrella" ITS software. Award of the project funds allowed CDOT to directly address both priority areas and was therefore a critical building block for Colorado; providing critically needed facilities, hardware, software and systems integration. Project achievements included the following:

- Project funds supported planning, logistics and design for CDOT's new CTMC, including electrical, communications and computer equipment. The new building comfortably houses CDOT's operation and has capacity for substantial future growth.
- Via an RFP process, CDOT obtained the services of a Systems Integrator to develop the statewide ATMS/ATIS "umbrella" software. Work was prioritized and broken into phases with the first three software deployment iterations funded by this project, including the "core" system; and DMS, speed and travel time subsystems. Project funds supported systems engineering, software development, documentation and testing, and hardware purchases.

<u>CDOT believes the CTMC Integration Project has been a success</u>. Project goals and objectives were met. CDOT now has a state-of-the-art CTMC as well as the first three modules of its new statewide ITS management software. Behind-the-scenes deficiencies in priority ITS infrastructure were addressed; reducing demands on CDOT staff; simplifying data sharing; and boosting amount, accuracy and timeliness of data in and out of the system. The project dovetailed well with ongoing ITS initiatives, and most importantly has been an important building block and catalyst leading to greater and more visible advancements in Colorado ITS.

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Colorado Transportation Management Center (CTMC) Integration Project (FY01 Earmark)

Local Evaluation Report

November 9, 2007

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Executive Summary

The "Colorado Transportation Management Center (CTMC) Integration Project" was the result of FY01 congressionally designated earmarks intended to improve transportation efficiency; promote safety; increase traffic flow; reduce emissions; improve traveler information; enhance alternate modes; promote tourism and build on existing Intelligent Transportation Systems (ITS). Total project investment was $6,753,160; which included $3,372,862 in federal funds, and $3,380,298 of State cash match provided by the Colorado Department of Transportation (CDOT).

By 2001, Colorado's ITS Program was rapidly expanding in total number of field devices and infrastructure; operational capabilities; public agency partnerships and visibility. As a consequence, CDOT was faced with two emerging problems:

- *CDOT's interim Traffic Operations Center (ITOC) and ITS control facilities were fast becoming overcrowded.* Given an ever-increasing number of user interfaces, computers, communications, software, field devices and support equipment required to manage the CTMC, day-to-day CDOT staff was becoming overburdened. More public information officers (PIO), operators, maintenance personnel and other support contractors were brought in to address the need – and the combination of people and equipment was too much for the existing floor space to accommodate. Most CTMC workers found themselves sharing a single 10' x 12' office space with one to three others. In addition, about half of CDOT's ITS Branch staff were housed in a separate building about 10 miles away from the ITOC.

- *CDOT did not have an integrated, umbrella ITS software.* Because CDOT's ITS mission continued to grow over time, CTMC employees were responsible for an increasing number of devices and subsystems. These were not integrated, therefore multiple workstations, computers and other support equipment needed to be used for each function. Operators and PIO often found themselves moving from one workstation to the next to manage dynamic message signs (DMS), send a broadcast fax, update highway advisory radio (HAR), monitor closed circuit television cameras, answer the telephone, and so on.

CDOT thus found itself in need of new floor space to consolidate its own ITS operations and accommodate its growing functions; as well as an automated means to simplify day-to-day operations. With Federal Highway Administration (FHWA) concurrence, funds for the CTMC Integration Project were targeted directly toward these two areas. The overall intent of the CTMC Integration Project was therefore twofold:

- To support design and construction of CDOT's new CTMC facility: and

- To develop (or procure) and implement a statewide "umbrella" ITS software.

Exhibit 1 – ITOC Operations Room (September 2005)

Award of the CTMC Integration Project funds allowed CDOT to directly address both priority areas and was therefore a critical building block for Colorado; providing critically needed facilities, hardware, software and systems integration. Project achievements include the following items.

- CDOT's new CTMC is housed in a pre-existing building in Golden that was extensively remodeled to accommodate the functions required by the CDOT ITS Branch. The facility was finished in late 2005 and the CDOT employees and contractors supporting the statewide ITS operation were moved from their previous, separate locations to the new building at that time. The new CTMC has a 40,000 SF footprint; enough to comfortably house the existing operation and also provide capacity for substantial future growth. Project funds supported planning, logistics and design for the move to the new building as well as electrical, computer and communications equipment.

- Through a Request for Proposal (RFP) process, CDOT obtained the services of a Systems Integrator to lead the development of a new statewide "umbrella" software package. The umbrella is also referred to herein as the Colorado Transportation

Management System (CTMS) and as the Advanced Transportation Management System / Advanced Traveler Information System (ATMS/ATIS).

- CDOT identified a phased, prioritized program to develop the new ATMS/ATIS, and portions of the first three Iterations of the ATMS/ATIS were funded by this project. Work is currently continuing on Iteration 4 using State funds. The initial Iterations included much of the "core" system as well as a number of priority subsystems including Dynamic Message Sign (DMS) control and a new speed/travel time subsystem. Project funds supported systems engineering; software development, documentation and testing; hardware purchases; and miscellaneous communications and integration for the new system.

CDOT believes the CTMC Integration Project is a success. All project goals and objectives were met. CDOT now has a state-of-the-art CTMC facility as well as the first three functional modules of its new ITS management software. Behind-the-scenes deficiencies in ITS integration were addressed; reducing demands on CDOT ITS operators and Public Information Officers (PIO); simplifying data sharing; and boosting the amount, accuracy and timeliness of data in and out of the system. The project dovetailed well with ongoing statewide ITS activities and local initiatives. More importantly, the project was an important building block and catalyst leading to greater local support for ITS, and other visible advancements in related projects.

Exhibit 2 – ITOC Operations Room (October 2005)

1 Introduction

For Fiscal Year 2001 (FY01), Congress earmarked federal funds for specific transportation initiatives nationwide. Proposals were selected based on conformance to the following objectives:

- Support improvements to transportation efficiency;
- Promote safety;
- Increase traffic flow;
- Reduce emissions;
- Improve traveler information;
- Enhance alternate transportation modes;
- Promote tourism; and
- Build on existing Intelligent Transportation Systems (ITS).

A proposal submitted by the Colorado Department of Transportation (CDOT) for the *Colorado Transportation Management Center (CTMC) Integration Project* was assessed and found to successfully address these objectives. As a result, CDOT was awarded $3,372,862 in federal funds. An additional $3,380,298 in matching state cash yielded a total project valued at $6,753,160.

Intent of the CTMC Integration Project was twofold:

- To support design and construction of CDOT's new CTMC: and

- To develop and implement a statewide Advanced Transportation Management System (ATMS) and Advanced Traveler Information System (ATIS) "umbrella" ITS software.

Both elements had been planned by CDOT over a multiyear period starting in 1993; but efforts at the time to move forward were constrained, with the following two obstacles proving the most difficult:

- Colorado transportation agencies had been accustomed to managing transportation through "concrete and asphalt" construction; and were reticent to changing their way(s) of doing business in favor of ITS.

- There was a lack of understanding of ITS and its potential benefits among CDOT's (later) ITS partner agencies, as well as within the Department itself.

As a result, ITS in Colorado did not receive the political, managerial, and fiduciary support it might otherwise have attracted in the mid 1990's. CDOT's ITS proponents found themselves undertaking a lengthy period of education and coalition building to garner support for ITS. Eventually, this landscape changed for the better with the 1997 state-funded *Revised Model Deployment Initiative*; followed in FY98 by the first of several federal earmarks – ushering in a period of dramatic and rapid ITS growth.

By 2001 CDOT's ITS Program was quickly expanding in terms of field infrastructure; operational capabilities; public partnerships; and visibility – leading to another set of problems. The first was that CDOT's ITS mission was quickly outpacing its building facilities. The second was that extreme growth rates in number and types of ITS devices and subsystems were placing strains on CDOT's operational staff – which was required to operate ITS elements statewide using multiple software packages and workstations over a variety of occasionally inefficient communications infrastructures. The latter problem drove a need for more operators and Public Information Officers (PIO) – a dilemma for CDOT given the already full floor space and moratoriums on new State employees. Funds for the CTMC Integration Project were thus timely and sorely needed.

In the ensuing Partnership Agreement developed by CDOT and the Federal Highway Administration (FHWA), both parties concurred on the scope of work, and funds were allocated to Task Orders 1-4. The task order roster for the CTMC Integration Project was initially configured as follows:

- Task Order 1 – CTMC Facility;
- Task Order 2 – Hardware, Firmware, Databases, Operating Systems;
- Task Order 3 – ATMS and ATIS Software Integration; and
- Task Order 4 – CTMC General Integration Activities.

Exhibit 3 – CTMC Operations Room (November 2005)

Ultimately, system and software development activities under Task Orders 2-4 were found to be interdependent and overlapping on a detailed level. As a result, design and deployment efforts under Task Orders 2-4 were for all intents and purposes combined into a single activity augmented by supplemental State funds.

A condition of the Partnership Agreement was that CDOT perform a project evaluation. This document addresses that requirement by presenting a summary of the project and its outcomes.

1A Report Organization

Sections 1 and 2 provide introductory material and programmatic background. Subjects of Section 3 include the deployment team, institutional involvement, task order descriptions and intended levels of integration. Sections 4 and 5 describe the evaluation plan and a summary of findings – including two required "elected activities." Finally,

Appendix A discusses compliance of the CTMC Integration Project with the FHWA Final Rule for earmarked projects of this type.

1B Local Evaluation - Reporting Requirements

The CDOT/FHWA Partnership Agreement requires the Local Evaluation Report (LER) encompass at a minimum the following discussions:

- Description of the work completed;
- Assessment of how well the project met goals and objectives;
- Summary of lessons learned; and
- Technical and institutional issues encountered.

ITS project evaluation guidelines prepared by the United States Department of Transportation (USDOT) require two of six additional "elective" evaluation activities be undertaken as part of the LER. Each of the listed elements are identified and included in this report.

1C Abbreviations

Abbreviations are used throughout this document. Table 1 provides a list of these and their definition.

Table 1 - Abbreviations

ABBREVIATION	DEFINITION
AA	Application Area (for ITS Standards)
ATIS, ATMS	Advanced Traveler Information System, Advanced Traffic Management System
ATR	Automated Traffic Recorder (Count Station)
AVI	Automated Vehicle Identification
AVDS; AVSS	Advanced Vehicle Detection Systems; Advanced Vehicle Safety Systems
C2C, C2F, C2V/T	Center-to-Center, Center-to-Field, Center-to-Vehicle/Traveler
CAD; CCIC	Computer Aided Dispatch; Colorado Criminal Information Computer
CCTV	Closed Circuit Television
CDOT	Colorado Department of Transportation
CDMA; CDPD	Code Division Multiple Access; Cellular Digital Packet Data
CEI	Centennial Engineering, Inc. (Systems Manager)
Co-Trip	CDOT Road/Weather/Incident Information web site
CORBA	Common Object Request Broker Architecture
CP	Courtesy Patrol
CSP	Colorado State Patrol
CSTOC	Colorado Springs Traffic Operations Center
CTMC	Colorado Transportation Management Center (CDOT current statewide ITS facility in Golden)
CTMS	Colorado Transportation Management System ("umbrella" of statewide ITS projects)
DATEX	Data Exchange
DMS	Dynamic Message Sign (also VMS – Variable Message Sign)
DRCOG	Denver Regional Council of Governments (Denver area MPO)
EJB	Enterprise Java Beans
EJT	Eisenhower Johnson Tunnel
ERTS	En-Route Traffic Systems (Systems Integrator)
FHWA	Federal Highway Administration
FY	Fiscal Year
GUI	Graphical User Interface
HAR	Highway Advisory Radio
HLT	Hanging Lake Tunnel
IMP	Incident Management Program
IP	Internet Protocol
ITOC	Interim Traffic Operations Center (CDOT previous statewide facility in Lakewood)
ITS	Intelligent Transportation Systems
J2EE	Java 2 Enterprise Edition
LER	Local Evaluation Report
M&O	Management and Operation
MOE	Measures of Effectiveness
MPO	Metropolitan Planning Organization (DRCOG in and around the Denver Area)
MVC	Model View Controller
NITSA	National ITS Architecture

NTCIP	National Transportation Communications for ITS Protocol
ORD	Off Ramp Detector
PIO	Public Information Officers (CTMC employees)
RFP	Request for Proposals
RITSA	Regional ITS Architecture
RTD	Regional Transportation District
RTMS	Radar Detector
RUP	Rational Unified Process
TMC; TOC	Traffic Management Center; Traffic Operations Center
UC	Use Case
USDOT	United States Department of Transportation
XML	Extensible Markup Language

Section 2 provides more detailed project background information.

2 Contexts and Background

CDOT has concluded or is continuing work on multiple projects using federal ITS discretionary funding and matching state funds – all considered part of the State's Colorado Transportation Management System (CTMS) Program. The first was the I-25 Truck Safety Improvements in FY98, a project which is complete, encompassed statewide deployment and integration; and built on existing ITS systems and architectures. Another earmark in FY00 was for Southeast Corridor and CTMS Integration, a companion to the $1.67B Transportation Expansion (T-REX) project along I-25 in Denver. There were two FY01 earmarks – the first for this project and a second for I-70 West Integration (also known as "Trip-70" to CDOT staff). The latter deployed devices, wire-line and wireless communications infrastructure and developed portions of a speed and travel time subsystem for the I-70 mountain corridor. The fifth and sixth were combined into a single project to install a fiber optic backbone communications system and limited ITS infrastructure along I-70 West; while the seventh installs ramp meters at selected locations – also along I-70 West. Table 2 lists the federally earmarked projects. Status of the Local Evaluation Report (LER) is listed for each.

Table 2 – Earmarked ITS Projects in Colorado

YEAR	NAME [STATUS]	VALUE	PRIMARY WORK AREAS
FY98	I-25 Truck Safety Improvements [COMPLETE; LER 12/2004]	$11,250,000	POE automation; operations; web; ATR; DMS; HAR; integration; communications; speed maps; event management; road/weather; kiosks
FY00	SEC and CTMS Integration [COMPLETE; LER late 2007]	$3,940,688	Agency, transit, public safety integration; low and high-speed communications; road/weather
FY01	I-70 West Integration ("Trip-70") [COMPLETE; LER 6/2006]	$1,191,734	Speed subsystem; web upgrades and road/weather integration; communications; C2C with EJT/HLT
FY01	**CTMC Integration [COMPLETE; LER attached]**	**$6,753,160**	**New command and control software; equipment upgrades; support for CTMC relocation**
FY03-04	I-70 West Corridor Mgmt. I [COMPLETE; LER 11/2006]	$11,760,000	Fiber installation from Denver to Frisco; POE automation; Beaver Tail Tunnel localized ATMS
FY05	I-70 West Corridor Mgmt. II [COMPLETE; LER by others]	$2,500,000	Field deployment including ramp meters at critical locations; travel time sensors in existing gaps
	CTMS Earmark Total*	**$37,395,582**	

** CDOT total ITS program expenditures exceed the totals shown. Additional investment of State and Local Agency funding outside of these earmarked projects does not appear in Table 2.*

As described, the focus of the work under this earmark was in two areas – supporting CDOT's relocation to a new management and control facility; and supporting CDOT's development efforts for a new Advanced Transportation Management System / Advanced Traveler Information System (ATMS/ATIS) umbrella software system to manage ITS operations statewide.

2A Late 1990's ITS Configuration

Before 2001, earlier earmarked projects and other federally-funded, state-funded, and privately-funded initiatives allowed CDOT to establish initial data exchange with selected (priority) transportation management centers across Colorado. Thus, the configuration of the statewide system in 2001 was generally as depicted in Exhibit 4. The

ITOC (referred to in the Exhibit as the CTMC), was linked to CDOT tunnel control centers at the Eisenhower Johnson Tunnel (EJT) and Hanging Lake Tunnel (HLT) along I-70; as well as to the City of Colorado Springs via a combination of microwave (pre-2000) and T-1 communications (after 2000). Data exchange in and around the Denver area was facilitated by installation of a backbone fiber optic ring, constructed by one of CDOT's "Shared Resources" private partners. In exchange for access to certain portions of State highway rights-of-way, CDOT was provided with long-term use of portions of the backbone. Those public agencies and CDOT facilities immediately along the fiber alignment were connected at that time. Thus, the Regional Transportation District (RTD), the City & County of Denver, and the City of Lakewood were part of the original Denver-area ring; which also included connection to CDOT Headquarters, CDOT Region 6, and two CDOT nodes controlling operation of the High Occupancy Vehicle (HOV) lanes along I-25 and US-36.

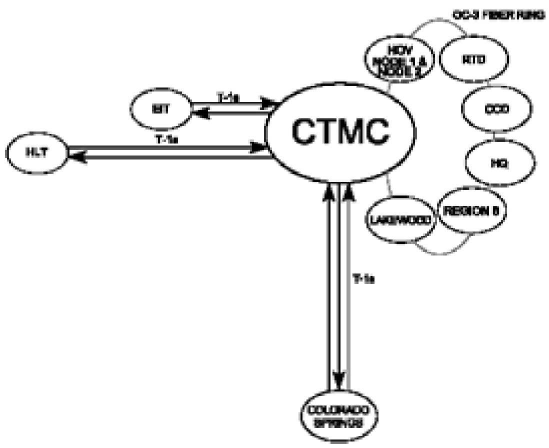

Exhibit 4 – Pre-Project Statewide ITS Framework

Through day-to-day practice at the time, CDOT began to see the potential efficiencies of exchanging transportation and incident information with agency partners and the general public; but also the benefits of using the CTMC, Colorado Springs and HLT facilities as the framework for the long-term statewide ITS. Later Shared Resources projects eventually linked the CTMC with Colorado Springs via fiber optics along I-25; and the CTMC with the Kansas State Line via I-70. Finally, the FY98, FY00 and FY03-04 Earmarks helped extend and enhance the Denver area fiber ring and also constructed a new fiber backbone on I-70 west of Denver. The latter project extends to Frisco; thus although it does not yet extend to HLT, the EJT has been physically linked with the CTMC at present.

2B CDOT Vision for Statewide System

CDOT's long-term vision for statewide ITS deployment in Colorado includes use of a three-tiered command and control architecture in a "hub and spoke" configuration as shown in Exhibit 5. The first tier includes center-to-center (C2C) interfaces and/or integration for requirements ranging from simple data exchange to interoperability with other regional nodes. The second provides similar function, but at the *regional* level, between the major/regional node and local agencies. The third tier is the center to field (C2F) level.

The top tier is therefore the *statewide* level, and is proposed to ultimately include three Transportation Management Centers – the CTMC, the Hanging Lake Tunnel (HLT) Control Center and the Colorado Springs Traffic Operations Center (CSTOC) – to form the three-hub system core depicted in red.

The CTMC would retain its role as the overall statewide center but ultimately distribute geographic functionality to HLT and CSTOC, which would serve as statewide level hubs for distribution of data and function in their own areas. Each of the three centers will serve as a hub responsible for collecting and disseminating statewide and regional information to about one-third of the State with CSTOC responsible for southeast Colorado; HLT for western Colorado; and CTMC for central, eastern and northeast Colorado in addition to its statewide mission as the focal point for statewide traveler information dissemination. In the long-term, CDOT would like to achieve interoperability between the three centers via deployment of the same software or extremely powerful levels of systems integration. In the short-term, CDOT is working in this direction through the provision of functional interfaces allowing data exchange.

The second level is the *regional* level and is best visualized as one of the three "hub" facilities and its "spoke" connections to the control centers of other partner agencies in its sphere of influence. The purpose of this level of control is information exchange on a regional, rather than statewide scale. For example, the CTMC as the central area node has already established limited information exchange with other local control centers including Denver, Lakewood, RTD, Englewood and other transportation, enforcement and emergency response entities. Centers such as these compile transportation data in their jurisdiction which can be packaged and sent to the CTMC.

Many such hub-agency links have been implemented over time, and long-term regional interoperability will likely be pursued with several partners, although intensive levels of integration would not be needed or desired with all. Prior to pursuing longer-term interoperability with specific regional partners, CDOT will establish initial functional interfaces to allow data exchange – mostly for video images.

The third tier is the *local* level and refers to the communications between roadway ITS devices and the individual centers. Both regional and statewide hubs will physically connect to field devices.

The CTMC and the ATMS/ATIS software provide two of three elements critical to the ITS framework needed to allow CDOT to migrate toward its long-term vision. The third element is communications, and although not a key aspect of this project, CDOT has made considerable progress in this area through the construction of portions of a statewide high-speed network. For example, a high-speed fiber ring is in place in the Denver area; with high-speed fiber "spokes" installed from the CTMC south along I-25 through Colorado Springs to Pueblo; east along I-70 to Kansas and west along I-70 to Frisco. An extension of the latter line to Vail is under design; as is a new backbone along I-25 north from Denver through Fort Collins to Cheyenne, WY.

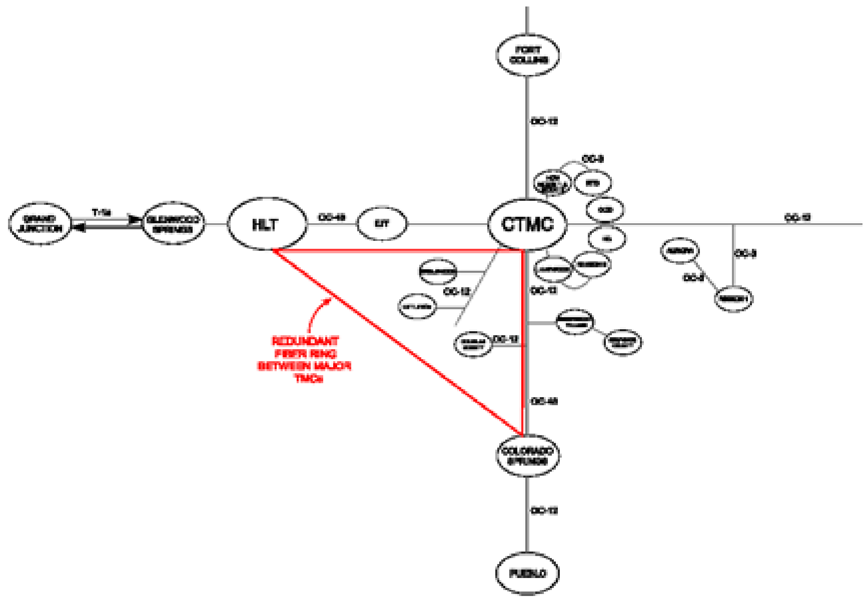

Exhibit 5 – Future Statewide Network Configuration

2C New CTMC

CDOT's vision for the statewide system was developed in the 1990's. Because the key element of the Colorado ITS framework was the new CTMC as the primary geographic and functional node; CDOT had long recognized the need for a new facility to accommodate its envisioned staff, computing and communication resources. The new CTMC is therefore the culmination of years of effort dating to Colorado's first ITS studies in 1991.

Need for this facility was identified as early as 1993, when the CDOT ITS Branch was first formed around two State employees. Shortly thereafter, the ITOC was established, initially housed in a few successive one- and two-room office locations near CDOT Headquarters in southeast Denver. In 1995, the facility was moved to its "interim" Lakewood location, where it shared part of an office floor with the dispatch unit of the Colorado State Patrol (CSP). In parallel and also at approximately the same time, the Colorado Transportation Commission established a sub-committee to guide development of the ITS Branch at a policy level and to plan for a new, future CTMC facility.

As agency and public demand for additional traveler information and management increased in the mid to late 1990's, so did the number of ITS field devices and functions supported, operated and maintained by the ITS Branch. As a result, the number of ITS Branch and contract employees also grew.

Due to limitations on available floor space at the Lakewood facility – which was only 3,340 SF – CDOT was forced to split ITS Branch forces into planning and operations categories and assign personnel in these classifications into separate office spaces. Thus, ITS planning personnel not deemed critical to day-to-day operations mission of the ITOC were housed in an additional 3,000 SF in south Denver, about 12 miles away.

By the late 1990's, the ITOC had developed into a 24/7 facility, with the operations arm typically staffed by operators and Public Information Officers (PIO). Primary operator activities included incident management coordination; dispatching courtesy patrols; and updating DMS based on input from PIO or external government or enforcement agencies, typically CDOT Maintenance, Colorado State Patrol, or the Denver Police Department. Primary PIO activities included monitoring current conditions; updating the road report system (via automated fax and emerging Internet technologies); and responding to inquiries from the media (radio, television, newspapers, etc.) and the public, including commercial truckers.

Exhibit 6 – CTMC Operations Room (October 2007)

The ITOC included separate work environments for Operators and PIO, although the work stations were close enough to allow coordinated activities between these personnel during major incidents or weather events. Over time, the ITOC lost its "interim" label, remaining at the Lakewood site until late 2005.

Prior to 2003, CDOT had been unable to identify and secure State funds to construct a new building or modify an existing facility to house the CTMC. This situation changed in 2003, when the project became economically feasible as part of a large-scale consolidation and relocation of CDOT employees in the Denver area. Thus, CDOT made the determination that the CTMC would be constructed as part of a rehabilitated building in Golden that would also house personnel from the CDOT Regions in a separate part of the same building.

2D New ATMS/ATIS Software

This subsection describes CDOT's vision and intent for the new ATMS/ATIS software package. A detailed description of specific elements actually deployed in this project appears in other sections of this document. The ATMS/ATIS is envisioned as an umbrella management, control and operating system enabling the multiple functions provided by the CTMC to be accomplished through a single, integrated software platform and a set of common user interfaces. Through the first few Iterations (the nomenclature for the phases of ATMS/ATIS implementation), the new system is already yielding significantly more powerful levels of automation; greater operator efficiencies; more accurate and timely information for CDOT use and quicker dissemination to the general public; and a better mechanism from which to link to and integrate with the control systems of partner transportation, enforcement and emergency response agencies, and other ITS stakeholders. The initial phases of the new ATMS/ATIS have already proven to be a vast improvement over the non-integrated, disparate systems in place before the project.

Generally, the ATMS/ATIS can be thought of as similar to personal computer program managers such as Windows ™ in which a single piece of master or umbrella software provides security and organizes files, programs and applications – allowing user access to all functions the work station can accomplish through one piece of integrated software. The ATMS/ATIS provides these administrative functions and takes the concept further by providing additional computing power, data manipulation and transfer and common user interfaces under the umbrella.

The new software is providing considerable benefits for CDOT ITS Operations staff and PIO by allowing system access via common interfaces without requiring staff to change workstations or software; facilitating communications and data exchange with outside systems; and automating many of the functions previously accomplished manually. The ATMS/ATIS ultimately allows much more cohesive, efficient and coordinated management of the CTMC. Prior to this project, the internal ITS functions provided by the CTMC and its operators were for the most part not integrated. Because of this, operators and PIO were regularly required to move from one desk-top computer to the next or one software package to the next in the course of their day-to-day duties. In addition, several of these functions were not previously automated and required significant levels of operator input or intervention to achieve the desired results.

The intent of this deployment has always been to accomplish the system build-out in phases. This is primarily due to insufficient funding available to construct the complete build-out system at one time – but also because CDOT's experience has shown that smaller 6-9 month deployment packages seem to allow for the most efficient and logical software development and deployment. Therefore, at the project outset, CDOT determined it would be best served by identifying the high level "look and feel" of the ultimate ATMS/ATIS; and then developing an implementation plan to deploy the highest priority system elements first. To that end, the first step in the process consisted of a workshop to begin planning efforts for the ATMS/ATIS. Objectives of that activity were to: 1] document functions currently (at that time) accomplished by the ITOC; and 2] to document immediate, intermediate and future needs of the system – in effect describing the build-out condition.

Exhibit 7 graphically represents the results of these early workshops. At the time, system elements shown in red in the exhibit were identified to be high priorities; those in yellow to be medium priorities; and those in green to be the lowest or longest-term priorities.

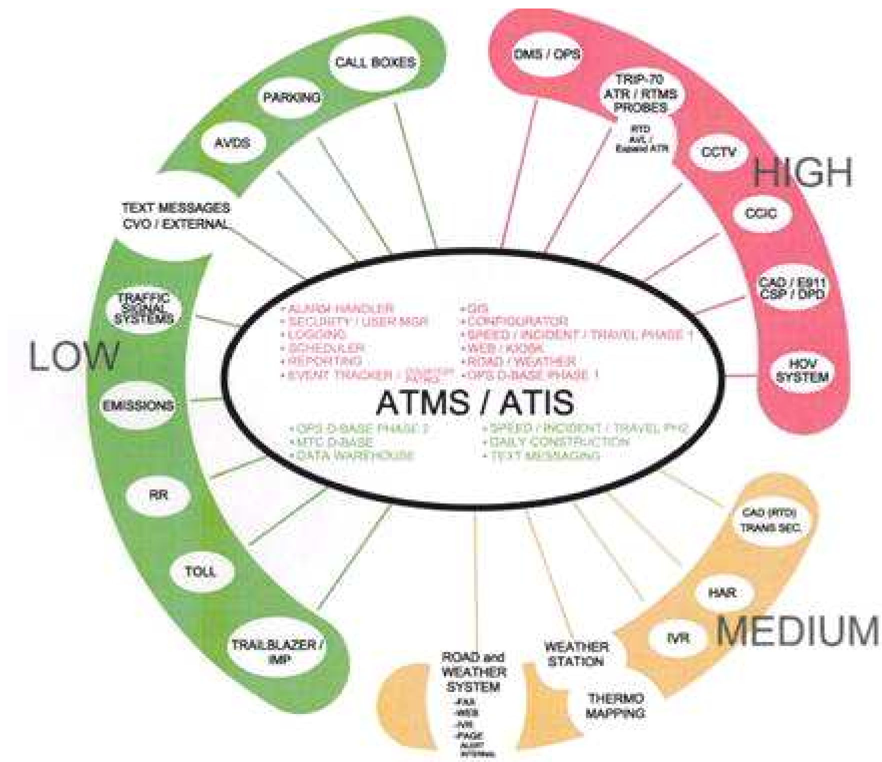

Exhibit 7 – ATMS/ATIS Priorities (2002 Version)

The "core" portion of the ultimate ATMS/ATIS was identified as the highest priority – thus those portions of the system related to day-to-day activities like logging in and out, security, passwords, adding new users, creating a graphical user interface, viewing alarms, and so on were identified to be the highest of the "high" priorities, along with the command, control, library and other support modules addressing DMS.

Portions of the "core" determined to be less important (for example, management and archiving of data) were planned to be deferred until Iteration 2 (or later phases), along with drivers and related modules addressing speed and travel time – which was deemed to be the next priority.

Section 3 provides more detail about project management configuration, institutional involvement, task order breakdown and work descriptions and levels and types of integration.

3 Project Detail

Just prior to 2001, CDOT and its previous Systems Integrator ("Integrator") made a mutual decision to discontinue their contact. For a few years thereafter, most of the ongoing ITS work previously assigned to the Integrator was instead completed by CDOT's Program/Systems Manager ("Manager"), CDOT's ITS Operations Contractor, CDOT's ITS Maintenance Contractor, or CDOT employees.

At the outset of this project, CDOT recognized it would need the expertise and services of a new Integrator to take the lead role in software development for the ATMS/ATIS. Thus, one of the early action items following award of the funds for this contract was a Request for Proposal (RFP) process to procure these services. The new Integrator thus became the primary agent in the development of the ATMS/ATIS, with support services provided as required by the other referenced parties.

3A Project Management

CDOT and its partners formed a team for the CTMC Integration Project in a similar configuration to that used in previous Colorado ITS activities.

In addition to CDOT and participating agencies; the deployment team included the participation of the following private sector groups: 1] the Integrator; 2] the Manager; 3] the Operations Contractor; and 4] the Maintenance Contractor.

Within the CDOT ITS program, the Integrator's role generally encompasses design and construction, procurement, software development and integration. The Manager provides technical oversight, completes portions of selected task orders, and otherwise assists CDOT with coordinating, managing and reporting aspects of the program, including evaluation, as well as other administrative duties. The Operations Contractor provides staffing for the CTMC control center as well as other technical staff. The Maintenance Contractor's role is self-explanatory. Table 3 identifies the project management team most directly involved with day-to-day CTMC Integration Project activities.

Table 3 – CTMC Integration Project Management Team

ORGANIZATION & ROLE	NAME	PHONE
FHWA Oversight and Management	Rick Santos	720-963-3009
CDOT ITS Branch Manager	Ken DePinto	303-512-5820
CDOT Project Manager 2001-2005	Frank Kinder**	303-757-9428
CDOT Task Leader New CTMC / Project Manager 2005-Presen	John Nelson	303-512-5838
CDOT Task Leader Communications and C2C	Bob Wycoff*	n/a
CDOT Task Leader ATMS/ATIS Development and Integration	John Williams	303-512-5823
CDOT Task Leader Operations	Rod Mead	303-512-5822
Network Design and Deployment – Centennial Engineering▲	Bill Kascek	303-512-5839
Assistant Project Manager – Frankie Friend & Associates■■	Cary Weiss	303-512-5853
ITS Maintenance – EnRoute Traffic Systems■	Lee Novotny	303-356-8009
Software Development Task Leader – EnRoute Traffic Systems■	Pawan Kharbanda	303-478-2991
Program/Systems Manager – Centennial Engineering▲	Steve Sabinash	720-279-7250

** Deceased*
*** No longer with CDOT ITS Branch*
■*Integrator and Maintenance Contractor was EnRoute Traffic Systems, Inc. (ERTS)*
■■*Operations Contractor was Frankie Friend & Associates*
▲*Program/System Manager was Centennial Engineering, Inc.*

CDOT determined the Manager would continue to provide technical and administrative assistance during this project in part, by developing scopes of work, estimates and schedules for each task order. These were reviewed by a committee of CDOT, FHWA, the Integrator, and the Operations and Maintenance Contractors as applicable, as well as affected local agencies. Upon approval by the referenced parties, individual task orders were activated.

3B Institutional Involvement

CDOT worked closely with internal and external stakeholders and partners throughout the CTMC Project – although perhaps to a lesser extent than other earmark projects due to the somewhat "internal" and CDOT-specific nature of the work required under this earmark. Table 4 lists those stakeholders involved at least sporadically throughout the development of the project.

Table 4 – CTMC Integration Project Stakeholders

ORGANIZATION	NAME	PHONE
CDOT Executive Director / Chief Engineer's Offices	Peggy Catlin	303-757-9203
CDOT Region 1 – Traffic & Safety Office	Ken DePinto*	303-757-9122
CDOT Region 3 – Traffic & Safety Office	Jim Nall	970-248-7213
CDOT Region 6 – Traffic & Safety Office	Ali Imansepahi**	303-757-9511
City of Colorado Springs	John Merritt	719-661-6214
Colorado State Patrol – Lakewood Office – Dispatch	Capt. Chris Meredith	303-239-4501
Denver (City & County) – Police Department	Ed Connors	303-640-2011
Denver (City & County) – Transportation Operations	Matt Wager	720-865-4061
Denver International Airport	Rick Busch	303-342-2200
Denver Regional Council of Governments	Steve Rudy	303-480-6747
City of Lakewood	Dave Baskett	303-987-7980
Regional Transportation District	Dave Shelley	303-299-2408
T-REX Project (CDOT Representative)	Gary Gonzales	303-357-8575

**now ITS Branch Manager*
***now with CDOT ITS Branch*

As applicable, project stakeholders were involved in all phases of work related to their jurisdictions or areas of interest. Such involvement began during scoping and continued throughout the work. Further discussion of institutional involvement and related issues is provided later in this document.

3C Task Order Breakdown and Work Descriptions

CDOT and FHWA began scope negotiation following award. The project was originally configured to include four (4) task orders as described in the funding application and Partnership Agreement. CTMC Integration Project task orders are briefly highlighted in Table 5. Project funds allocated to each and a brief work description are included in the Table. Detailed descriptions follow.

Table 5 – CTMC Integration Project Task Order Overview

NO	TASK ORDER NAME	VALUE	BRIEF DESCRIPTION
1	New CTMC Facility	$1,503,050	Funds devoted to the new CTMC building
2	ATMS/ATIS Hardware, Firmware, Database and Operating Systems	$1,031,890	Primarily those items "supporting" ATMS/ATIS software development – servers, training, etc.
3	ATMS/ATIS Software Integration	$2,961,415	Primarily ATMS/ATIS software development
4	ATMS/ATIS General Integration	$1,256,805	Primarily ATMS/ATIS software development
	TOTAL	**$6,753,160**	

The CTMC Integration Project task orders continued and in some cases culminated efforts started much earlier through several state- and federally funded projects including Colorado's 1997 Revised Model Deployment Initiative and the FY98 and FY01 (Trip-70) earmarks. The two "products" of the CTMC Integration Project – namely the new CTMC and the new ATMS/ATIS, were both years in the making. Initial planning work for the new CTMC began in 1992. Similar planning efforts for the ATMS/ATIS started in earnest in 1995.

Due the number of active ITS projects in Colorado by 2001, CTMC Integration Project activities overlapped and supported parallel efforts already underway in other projects. For example, the function and architecture of CDOT's speed and travel time subsystem was developed during the Trip-70 project – while CDOT was investigating alternatives to vehicle probes along the I-70 mountain corridor. The Trip-70 project then funded and installed the speed sampling units (primarily radar detectors) and toll tag readers used to obtain the surveillance data used as inputs for that subsystem. The FY03-04 combined earmark funded installation of a fiber optic backbone along I-70

– ultimately used to bring the I-70 speed and travel time data back to the CTMC. Finally, the CTMC Integration Project funded the development of the system "logic" and software during ATMS/ATIS Iterations 2 and 3. Eventually, additional State funds were used to provide the field trials, testing and before/after studies needed to successfully debug and fine tune the overall subsystem.

3C.1 Task Order 1; New CTMC

This task order was used to help plan and support the CDOT ITS Branch's move to the new CTMC in late 2005. As described, the new CTMC was warranted for two reasons: 1] to provide adequate floor space to house CDOT's day-to-day statewide transportation management and traveler information dissemination operations; and 2] to allow consolidation of ITS Branch professional staff at a single location.

Work undertaken in Task Order 1 was split into three sub-tasks as CDOT conducted detailed planning for a non-specific new site; identified the proposed location; and then planned and designed in detail for the new CTMC. A brief overview of this work is provided in Table 6.

Table 6 – Task Order 1 Work Breakdown Summary

#	SUB-TASK VALUE	WORK DESCRIPTION
1A	$137,000	2003 transition planning and gap analysis; non-specific new CTMC location
1B	$140,050	2005 CTMC computer room transition, hardware, rack, network, cabling, electrical, telephone, communications, miscellaneous design assistance
1C	$1,225,000	2005 new CTMC building project management, design, coordination, inspection
All	**$1,503,050**	**Task Order 1 Totals**

In 1994, CDOT established the Interim Traffic Operations Center (ITOC) at 700 Kipling Street in Lakewood. Because the ITS Branch had only a few employees in 1994 and immediately thereafter, 700 Kipling served its purpose well as the ITOC for many years. Gradually, CDOT's ITS Program slowly gained momentum and grew in function, budget and needed professional staff. Due to the limited (3,340 SF) capacity of the 700 Kipling offices, CDOT was eventually forced to house about half the ITS Branch staff in a second building about 12 miles away. At that point, due to the need for ITS staff to work together, frequent and inefficient back-and-forth travel was required. In addition, state and contract employees at 700 Kipling were generally forced to share office space with one or two other individuals. By the time the CTMC Integration Project funds were awarded, CDOT was clearly in need of new building facilities to house ITS operations.

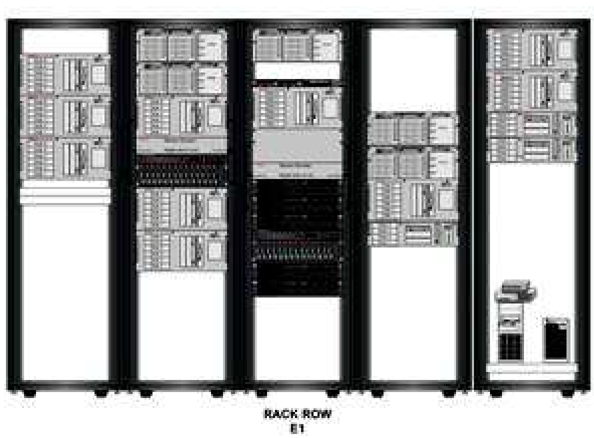

Exhibit 8 – 700 Kipling Inventory Example – Rack Elevation

At the project outset, a new (second) Lakewood site for the CTMC had been tentatively identified but had not been approved by CDOT management. The first portion of Task Order 1 funds were therefore broken out into Task 1A to help CDOT develop a transition plan and gap analysis for a move to a generic location with the tentative site somewhat "in mind." This work consisted of the following three elements:

- Inventory and assessment of ITOC hardware, communications, networks, functions, systems and other assets (see Exhibit 8);
- Definition and analysis of the desired future environment; and
- Strategic plan(s) required to achieve the latter.

The product of Task 1A was a "Network Inventory and Assessment" report dated March 2003. Shortly thereafter, CDOT management determined not to further pursue the second Lakewood site due to its identification of a potential alternative site in Golden – which was eventually selected as the location of the new CTMC. Thus, the asset inventory and transition activities undertaken as Task 1A were timely, and formed the basis for the 2005 move to the new Golden facility.

Once CDOT made the determination to construct the new CTMC at the Golden site, a number of design and coordination activities were undertaken to prepare the facility for CDOT occupation. Remaining Task Order 1 funds were therefore divided as follows:

- Task 1B funds were used for design and coordination assistance specific to the proposed computer room (including electrical, cabling, hardware and structural elements), telephones, and various computers, servers, switches, routers, other hardware components and network equipment throughout the facility. Exhibits 9 and 10 depict the types of design work undertaken.

- Task 1C funds were used for design and construction management assistance directly related to construction of the building facility. Task 1C funds were transferred directly to the appropriate departments within CDOT at the direction of the Executive Director. Generally, the funds supported project management, design reviews, design and construction project coordination, various logistics and planning activities, and construction management, materials testing and inspection.

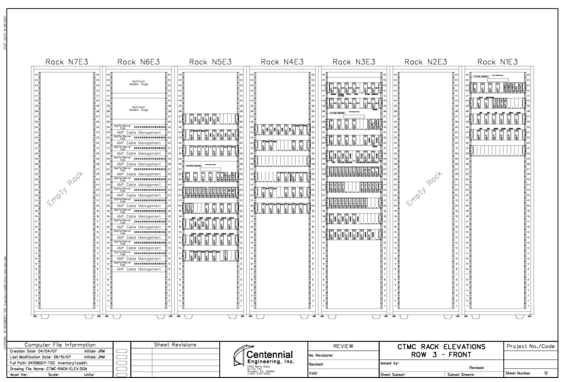

Exhibit 9 – Sample Rack Layout; New CTMC

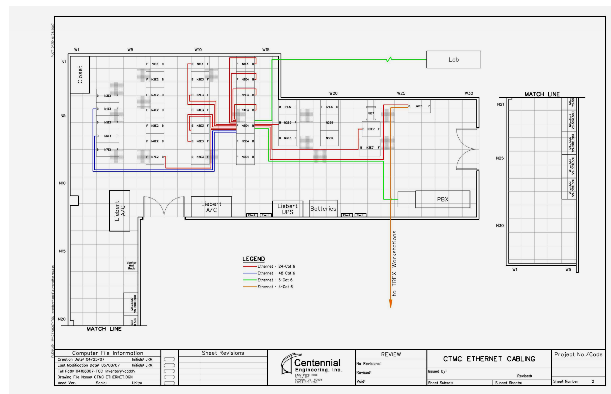

Exhibit 10 – Ethernet Layout; New CTMC

Task 1A and 1B work was completed by the Manager with assistance as required from CDOT staff, the ITS Maintenance Contractor and the Integrator. Task 1C work was completed by CDOT.

Exhibit 11 – New CTMC Building; 425C Corporate Circle, Golden

3C.2 Task Orders 2, 3 and 4: New ATMS/ATIS

For convenience, Task Orders 2, 3 and 4 have been combined for discussion as a single work activity. Because these three task orders were for hardware, software integration and "general" integration, work often overlapped the complimentary areas and was at times difficult to differentiate. For example, selected hardware procurement took place under all three task orders; and development of the ATMS/ATIS software was split between the three task orders as well. In addition, much of the project was completed as a "design to cost" activity. Needed "core" ATMS/ATIS features that could not be accommodated under a given software implementation phase ("Iteration") were, with FHWA approval, deferred or completed under another Task Order. The eventual and approximate distribution of the cash portion of the project between Task Orders 2, 3 and 4 is provided in Table 7.

Table 7 – Work Detail Task Orders 2-4

WORK ITEM / TASK ORDER	TASK ORDER 2 – HARDWARE, FIRMWARE, DATABASE, OPERATING SYSTEMS	TASK ORDER – ATMS/ATIS SOFTWARE INTEGRATIOI	TASK ORDER – ATMS/ATIS GENERAL INTEGRATIOI	ACTIVITY TOTAL
Integrator RFP Development	-	-	$65,000	$65,000
Architecture/Overall System Design	-	$955,000	-	$955,000
[General] Test and Documentation	$405,852	-	-	$405,852
Iteration 1 Management/Administration	-	-	$326,827	$326,827
Iteration 1 Software Development	-	$1,112,914	-	$1,112,914
Iteration 2 Management/Administration	-	-	$211,181	$211,181
Iteration 2 Software Development	-	$893,501	-	$893,501
Iteration 3 All Tasks (Partial)	-	-	$472,313	$472,313
[General] Network Administration	-	-	$69,476	$69,476
[General] Software Coding I	-	-	$62,900	$62,900
[General] Software Coding II	-	-	$49,108	$49,108
Video Wall	$346,932	-	-	$346,932
Miscellaneous Items I*	$155,998	-	-	$155,998
Miscellaneous Items II**	$121,306	-	-	$121,306
Total Project Investment	**$1,031,890**	**$2,961,415**	**$1,256,805**	**$5,250,110**

** miscellaneous items include (among others) off-the-shelf software; leased (Oracle) software; software licenses; office supplies; safety materials; operator and/or PIO workstations; other technical support and training.*
*** miscellaneous items include (among others) Cisco consoles; DigiPort server; Smart Array; VM Ware; books and reference materials; flat panel monitor(s); ArcIMS; laptops; Legato training; Java software and training*

The CTMC Integration Project essentially provided construction of the first three Iterations – or build phases – of the ATMS/ATIS. Additional Colorado funds not listed in Table 7 were also contributed toward the system development effort. For example, the table does not list additional State funds that were allocated to Iteration 3 and Iteration 4 (the latter is not part of this project); nor Colorado's purchase and implementation of the Rational Unified Process (RUP) Suite Product Family, used to frame and guide the ATMS/ATIS software development and systems engineering effort.

3C.2.1 Task Orders 2, 3 and 4: ATMS/ATIS System Overview

CDOT began planning the new ATMS/ATIS in the late 1990's well before the start of this earmark but accelerated such efforts following award. Early, high-level planning activities identified those elements of the ATMS/ATIS envisioned to be critical pieces of the long-term, statewide transportation system. As the look and feel of the build-out ATMS/ATIS began to emerge, CDOT was able to document its priorities in a Top Level Iteration Plan, the purpose of which was to organize the proposed elements in order of importance; and then further group these into deployments of deliverable components.

A list of the prioritized functional components of the ATMS/ATIS is provided in Appendix B. Generally, Iteration 1 built a substantial portion of the system "core" and also developed the DMS functional module, which was determined by CDOT to be the highest system priority. Thus, Iteration 1 included (but was not limited to) software development including the following items:

- Login and logout.
- Manage, edit and add system users.
- Change passwords.

- Navigate desktop and search map.
- Find, control, view, clear, add, manage, configure, remove DMS.
- DMS message library, spell check, banned words directory.
- Test and poll DMS.
- Configure communications pool and port;
- View and add alarms.
- Log and view user activity.

Iteration 2 completed selected elements of the core and DMS modules; but the major component of the second Iteration was the development of the speed and travel time subsystem. Iteration 2 included (but was not limited to) software development in the following areas.

- Enhance DMS polling, clear, test, configure.
- Add new/additional alarms.
- Enhance login, navigate desktop.
- View snapshot, routes, segments.
- Add, view, configure, remove and poll radar detector.
- Add, view, configure, remove and poll toll tag reader (AVI reader).
- Add, view, configure, remove and poll ramp meter.
- Add or edit communications pools and ports.
- Post trip travel time on DMS.
- Manage, edit "intelligent tasks" (e.g. calculation of speed and travel time).
- Get device (radar detector, toll tag reader, ramp meter) data.
- Process data.
- Calculate segment speed, congestion, travel time.
- Manage, publish, archive data.
- Create, publish, view reports.

Exhibit 12 – CTMC Control Room

Finally, Iteration 3 increased the functionality of the existing system pieces and modules and added incremental system functions and capabilities. Iteration 3 included (but was not limited to) software development in the following areas.

- Enhance login, logout.
- Manage "events."
- Add event timeline(s) and logs.
- Enhance navigation of workspace.

- Add, view and search project (i.e. road closures in this example).
- View, fax and e-mail reports.
- Add, view, search and edit Courtesy Patrol incidents and reports.
- Add, configure, remove off-ramp detector.
- Control blank-out sign.
- View camera tour.

Generally, new hardware that was needed was purchased by the Integrator, who was also responsible for subsequent installation and testing. Software development and integration work was completed by the Integrator with assistance and significant coordination as required from CDOT staff; and minor coordination as required from the Manager and the ITS operations contractor.

The Integrator is continuing its work in Iteration 4, which is further enhancing previous functionality and providing new modules and subsystems. These latest efforts are being provided using State funds.

Brief overviews of the DMS subsystem (Iterations 1-2) and the Speed and Travel Time subsystems (Iterations 2-3) are provided in the following sections.

3C.2.2 DMS Subsystem

In addition to constructing the "core" of the ATMS/ATIS, the first two Iterations developed the DMS subsystem. Essentially, this software provided CDOT with the following features or capabilities:

- Operator control of DMS (sign on/off and display of messages) via single user interface;
- Line and/or character matrix at deployment (full matrix to be provided in the future);
- Multiple panels (up to three) in a single message and flashing capability;
- Selection of upper/lower case letters and punctuation;
- Adjustment and selection of fonts;
- Left, center and right justification of messages;
- Sign response plans based on operator input (e.g. chain law sequences);
- Communications with NTCIP- and non-NTCIP-compliant signs;
- Alarms for communications and device failures;
- Test messaging;
- Message library;
- Spell checker;
- "Not allowed" words list;
- Call multiple signs simultaneously;
- Tabulation and logging of maintenance data;
- User-requested timer option with pop-up display to remind operator that allowed time has expired;
- Sign diagnostics provided for maintenance personnel;
- DMS status reporting for DMS capable of providing such information;
- Display current messages and device status on GUI;
- Display device locations by icon on the appropriate map layers;
- Priority/protocol lists for DMS access/control by different level of user;
- Deliver DMS data to ATMS/ATIS database for web publication;
- Configuration of existing/new signs to include communication type, polling rate, modem selection, size, number of text lines, number of pixels and so on; and
- Store 3 months of operations logs.

3C.2.3 Speed/Travel Time Subsystem

In addition to continuing the construction of the ATMS/ATIS "core" and enhancing the previous DMS modules, Iteration 2 and 3 developed a new speed and travel time subsystem. Essentially, this software provided CDOT with the following features or capabilities:

- Select and pull common/required data from multiple types of count stations and surveillance devices. Link simultaneously to multiple devices that will provide information yielding speeds or leading to the development of travel time information.
- Select and pull common data for speed algorithms – CDOT and the Integrator investigated, selected and deployed the Virginia Tech algorithm used for such applications.

- Get volume and occupancy data as available from Automated Traffic Recorders (ATR), off ramp detectors (ORD) and CDOT's existing Ramp Metering System;
- Get speed and volume data as available from side-fired radar (RTMS) surveillance devices
- Get volume data from toll-tag reading devices (AVI readers);
- Integrate traffic data into Oracle database;
- Use data to calculate estimates of congestion, corridor segment speeds and estimate travel times;
- Internal data flows provided as required between sub-modules to support travel time algorithm;
- Operator capability to request travel times based on multiple and configurable points/cities of origin/destination;
- Data used to generate/support speed maps using definable, configurable segments;
- Display speed and travel time data to operator/PIO and make available for Co-Trip website;
- Make travel time data available for DMS and post such data in the field;
- Manage, add, configure, view, remove ATR, ORD, ramp meters, RTMS and AVI readers;
- Archive, manage and publish data; and
- Create, publish and view reports.

Exhibit 13 shows graphical representation of a test of the travel time subsystem between two sampling points along a Denver-area highway. Note the significant increase in travel time during the PM Peak.

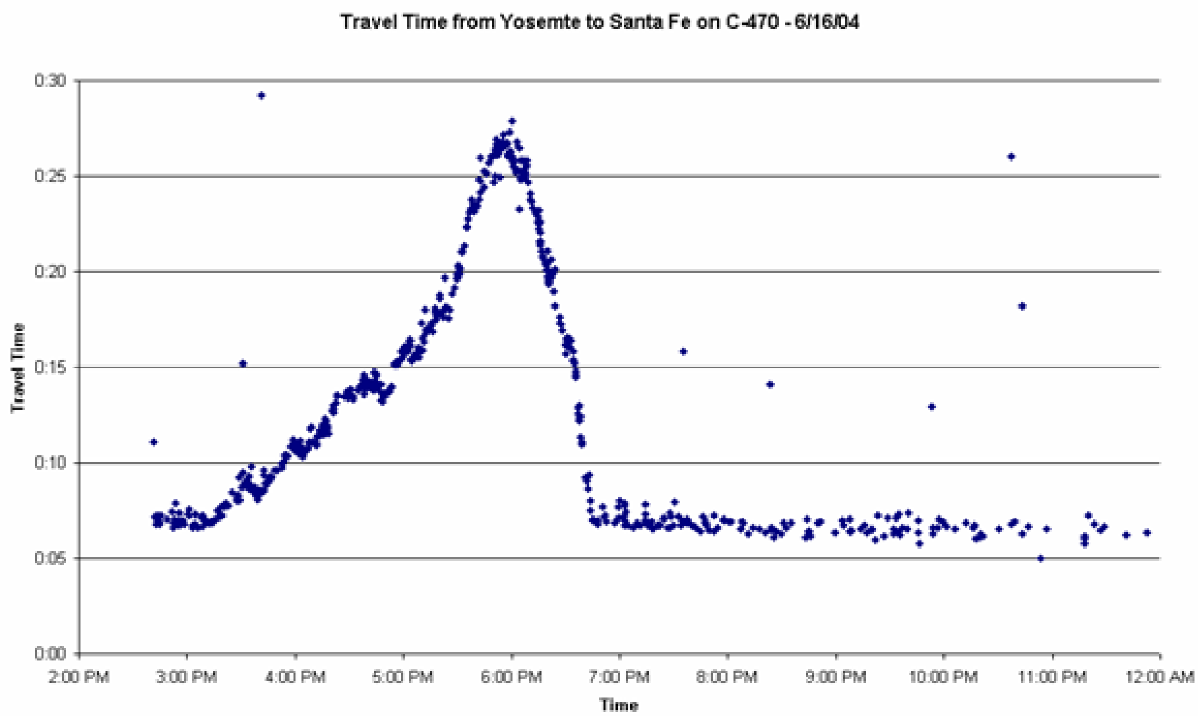

Exhibit 13 – Travel Time Subsystem Test Using AVI Readers

3D Levels and Types of Integration

That portion of the CTMC Integration Project addressing the new building was not intended as an integration activity – however, development of the first three Iterations of the ATMS/ATIS addressed CDOT systems integration on a "global" scale at three levels: 1] system-wide; 2] at the subsystem level; and 3] at the center-to-field (C2F) level.

- *System-Wide*. Development of the "core" of the ATMS/ATIS in Iterations 1 and 2 created the framework for CDOT's future statewide ITS. Basic structures and functions including architecture; administration; logging in and out; security; alarms; basic system navigation; mapping, displays and interfaces; and so on are critical building blocks for a successful system.

- *Subsystem Level*. At the subsystem level, CDOT constructed completely new subsystems to manage both DMS and the new Speed and Travel Time modules. Both were developed as integral parts of the emerging core ATMS/ATIS and yielded significant device management and time saving improvements for CTMC operators and PIO. New subsystems will be developed in Iterations 4 and beyond as funding becomes available.

- *C2F Level*. Finally, CDOT developed new C2F integration capabilities by establishing ATMS/ATIS functionality with DMS, ATR, ramp meters, radar detectors and AVI readers. CDOT is now able to (among other functions) add, delete, configure, poll and collect data from these devices; as well as communicating with multiple devices simultaneously. As CDOT continues to build the ATMS/ATIS through Iteration 4 and beyond, additional device modules will be developed and brought on line.

Section 4 describes the evaluation plan for the project, including goals and objectives, hypotheses, measures of effectiveness, and a description of the additional elective activities.

4 Evaluation Plan

As described in the Local Evaluation Reporting Requirements, the following measures, where applicable, are to be quantitatively assessed as part of this report:

- Reduction of crashes;
- Reduction of fatalities;
- Increased throughput – people and goods;
- Reduction of congestion-related delay;
- Improved customer satisfaction;
- Savings in cost to the public and private sectors; and
- Energy and emissions impacts.

Technical levels of success for ITS initiatives are difficult to quantify – especially for projects like this, which have large integration components (including a new building) but little physical field deployment. This is because there is no proven algorithm to relate items like crash reduction or emissions to ITS software development, or an activity such as ITS communications enhancement. FHWA continues to collect data toward identifying correlations between ITS elements and "hard" measures of effectiveness (MOE), but significant work remains to be done.

Proven algorithms to relate MOE to ITS integration are unavailable and qualitative measures easier to identify. Because most of the CTMC Integration Project relates to software development, this project is yet another that will not directly yield hard MOE in the desired categories.

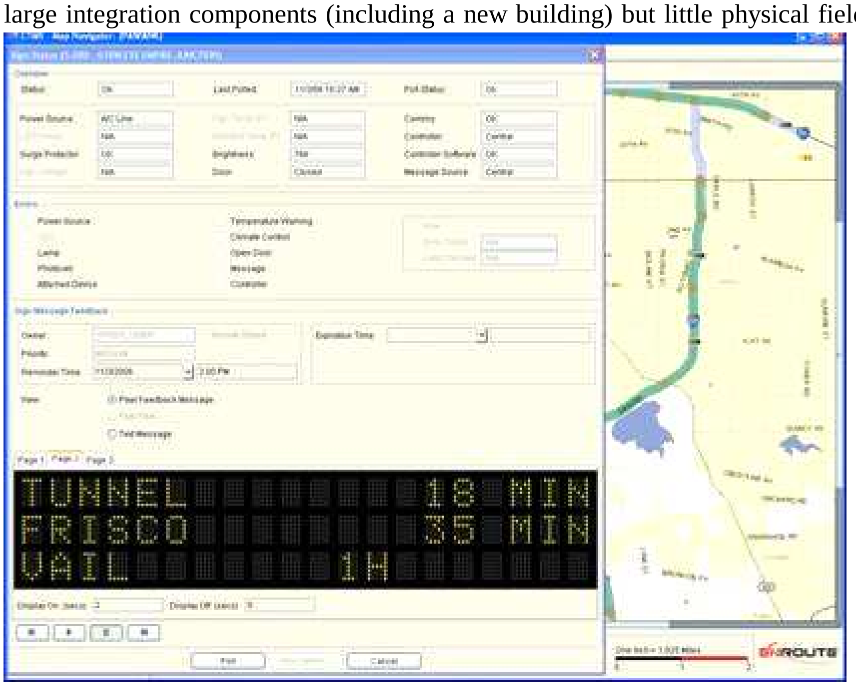

Exhibit 14 – Test Screen; DMS/Travel Time Subsystems Integration

Primary CDOT goals for the CTMC Integration Project were: 1] that CDOT address deficiencies in ITS infrastructure, integration, communications and operating systems and; 2] that the project be perceived as a "success story" to help continue building support and momentum for the Colorado ITS Program. Considering the subjectivity inherent in evaluating ITS projects, and given the desire for a "success story," CDOT determined at an early stage to take an institutional approach to local evaluation. In addition to the technical evaluation – measured by enhanced capabilities such as systems integration and improved inter-agency data exchange; the evaluation was directed to investigate managerial and administrative performance. In addition, two elective activities are part of the evaluation, discussed in a later Section.

4A Goals and Objectives

In parallel with this project, CDOT continued ongoing strategic planning for statewide deployment of ITS. As part of that activity, broad goals have been identified for the Colorado ITS Program. These include:

- *Improve productivity.* Maximize productivity of the transportation system by using ITS to increase throughput of passengers and vehicles – effectively increasing capacity. Use ITS to manage and fine tune system operation in response to demand and in the event of incidents that interrupt normal operations.

- *Increase mobility*. Provide travel choices and increase efficiency by access to comprehensive, reliable, timely traveler information. Allow travelers to make informed decisions about their trip prior to and during travel. Enable travelers and businesses to efficiently choose mode and route based on near real-time data. This spreads volume between modes and over time, reduces costs of doing business and enhances quality of life.

- *Increase safety.* Enable faster response to incidents and reduce incidents by active management. Secondary benefits are realized from broadcasting alternate routes allowing travelers to avoid incidents and congestion with alternates developed as part of IMP. ITS technologies enhance public safety by monitoring operations, managing traffic affected by special events, and providing travel related weather advisories.

- *Enhance inter-modal connectivity and inter-jurisdictional coordination*. Promote and support seamless inter-modal transportation connectivity and Colorado ITS systems. Manage information as a resource that will enhance inter-modal connectivity between services of public and private transportation providers.

These goals frame development of an ATMS/ATIS that allows integration and interface of existing legacy and future systems; one in which data is managed as an asset of value to system users and transportation providers. CDOT's role is to provide statewide leadership by deploying enabling infrastructure, developing partnerships, establishing policies and procedures with stakeholders to ensure integration and easy access to data, and by advocating those ITS investments that have a strong business case.

CDOT's overall ITS program addresses all four of the programmatic ITS goals in addition to other high-level goals not listed herein. The CTMC Integration Project, being a subset of the former, directly supported the fourth program goal, and indirectly addressed the other areas. Ultimately, the CTMC Integration Project was developed with two specific goals in mind:

- Address Colorado ITS infrastructure deficiencies; and
- Create/build an ITS success story in Colorado.

Because the CDOT ITS strategic planning goals had yet to be developed at the project outset, these two goals were identified as appropriate targets for this work. To that end, objectives were identified to help guide development of the CTMC Integration Project, including the following:

- Automate processes towards minimizing burdens on State staff;
- Provide enhanced functionality;
- Improve the dissemination of traveler information;
- Enhance availability of data for partner agencies;
- Enhance existing corridor incident management capabilities; and
- Improve amount, accuracy and timeliness of data flows into and out of the system.

4B Hypotheses

Based on the listed goals and objectives, CDOT developed hypotheses upon which to build evaluation of the CTMC Integration Project. As might be expected, these focus tightly on elements of primary interest to CDOT staff within the ITS Branch. The hypotheses were as follows:

- <u>Hypothesis 1</u>. At project conclusion, CDOT capabilities to collect, compile and disseminate traveler information statewide will be enhanced.

- Hypothesis 2. At project conclusion, CDOT will have maintained ITS partnerships with external agencies. CDOT capabilities to exchange data with agency partners will be enhanced.

- Hypothesis 3. At project conclusion, CDOT will have taken advantage of synergies created by the project as a catalyst for widespread ITS deployment through other projects and funding sources, in effect using the CTMC Integration Project as a springboard from which to promote ITS as a Colorado "success story."

Evaluation is thus based on a combination of high-level programmatic goals, as well as more microscopic goals and objectives identified for this project. Changes in operational factors such as delay reduction or movement of goods are unavailable and are not the focus of the evaluation.

4C Measures of Effectiveness (MOE)

CDOT prepared a list of MOE based on the three hypotheses to judge success of the CTMC Integration Project from a system-wide perspective as well as at the more detailed task order level. These were:

- Hypothesis 1 – Traveler Information. Goals addressed include: 1] improving infrastructure deficiencies; 2] automating processes; 3] enhancing functionality; 4] improving traveler information dissemination; 5] improving incident management; and 6] improving amount, accuracy and timeliness of data flows. Most CTMC Integration Project activities are in this category through development of the ATMS/ATIS; and outcomes are difficult to measure. In any case, project-specific MOE include: 1] magnitude of the improvement; 2] why the improvement is important; 3] how the improvement enhanced data quality or flow; and 4] how the improvement enhanced functionality. For integration and/or enhanced subsystem tasks, MOE include: 1] functions provided; 2] purpose; and 3] subsequent reduction in CTMC (or other public employee) operator demands.

- Hypothesis 2 – Data Exchange and Partnerships. Goals addressed include enhancing data availability for partners as well as preserving existing partnerships. Measures include: 1] whether existing partnerships were maintained; 2] number of new partnerships developed (if any); and 3] identifying the types of cooperation or data exchange achieved. Evaluation criteria are subjective – such as quality and perceived levels of cooperation, and potential for future exchange due to system development; but are addressed nonetheless.

- Hypothesis 3 – Intangibles. Goals addressed include creating and/or building an ITS success story. MOE regarding whether the CTMC Integration Project is a success story are qualitative and again subjective but primarily relate to how well the project met the goals and objectives outlined at the project outset.

4D Additional Elective Activities

CDOT determined the following two elective activities (from the FHWA-suggested list for local evaluation) would also be part of this report:

- *Institutional issues associated with achieving cooperation among public sector agencies should be provided as well as documentation of how these were overcome.*

- *A brief "Lessons Learned" report should also be provided that describes the technical and institutional issues encountered by CDOT during the project.*

Both elective activities coincide well with the latter two project hypotheses identified previously and are described in detail herein.

Section 5 describes the project outcome and findings, including the results of the additional elective activities.

5 Evaluation Findings

CDOT believes the CTMC Integration Project has been a success. Goals and objectives were met or surpassed. Deficiencies in ITS infrastructure, functionality, automation, information dissemination, data sharing; and amount, accuracy and timeliness of data were addressed. The project dovetailed with related activities but most importantly was an important building block and catalyst for the Colorado ITS program. Momentum generated by the earmarked ITS projects – including this one – has allowed CDOT to develop order-of-magnitude improvements in devices; data collection and dissemination; communications; interfaces with partners; and operations, maintenance and program management.

The following sections illustrate how the CTMC Integration Project met the established goals and objectives, discuss the task orders and overall project in terms of MOE, and identify institutional issues encountered and lessons learned (the latter representing the two additional "elective" evaluation activities).

5A CTMC Integration Project Outcome

A summary of how the project-specific goals and objectives were addressed by individual task orders within the CTMC Integration Project are listed in Table 8.

Table 8 – Project Goals and Objectives Met By Task Order

#	TASK ORDER / GOALS & OBJECTIVES MET? (REFERENCE GOALS & OBJECTIVES LIST BELOW TAI	A	B	C	D	E	F	G	H
1	New CTMC Facility	Yes	Yes						
2	ATMS/ATIS Hardware, Firmware, Database and Operating Systems	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
3	ATMS/ATIS Software Integration	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
4	ATMS/ATIS General Integration	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	OVERALL PROJECT	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**

Table 8 Goals and Objectives List (from Section 4A):
A - Address ITS infrastructure deficiencies.
B - Create an ITS "success story" in Colorado.
C - Automate processes to minimize burdens on state or partner agency employees.
D - Provide enhanced functionality
E - Improve dissemination of traveler information
F - Enhance availability of data for partner agencies
G - Enhance incident management capabilities
H - Improve amount, accuracy and timeliness of data flows into and out of the system

Goals and objectives were met. Pre-project deficiencies in infrastructure; functionality; automation; traveler information dissemination; sharing of data; and amount, accuracy and timeliness of data were addressed across the CTMC Integration Project task orders.

The following sections discuss project results within context of the three evaluation categories developed using the goals, objectives and hypotheses. Because it is difficult to quantify integration activities in terms of the FHWA-suggested MOE for traffic operations, relative success of the project will instead be assessed and discussed qualitatively.

5A.1 Test/Evaluation of Hypothesis 1 – Traveler Information

Hypothesis 1 proposes that "*CDOT capabilities to collect, compile and disseminate traveler information statewide will be enhanced.*"

No new field devices to collect or disseminate traveler information were included in the CTMC Integration Project; yet CDOT's efforts were extremely successful in addressing Hypothesis 1. Capabilities to collect data for traveler information was enhanced in ATMS/ATIS Iterations 2-3 by development of the central subsystem used to manage data coming from existing ATR, ramp meters, radar detectors and AVI readers; and use it for speed and travel time information dissemination. Capabilities to compile data were enhanced by internal; subsystems developed by the Integrator to collect, organize, manipulate, interpret and otherwise manage data to identify near-real-time speeds and travel times. Finally, capabilities to disseminate this information were improved by an order of magnitude by developing the DMS subsystem in Iterations 1-2.

These boosts to operational efficiency were for the most part completely behind the scenes and accomplished through the new ATMS/ATIS. Improvements were realized in several areas including response capability; efficiency; and messaging as described below. All three of the discussed areas are somewhat related.

- *Response*. The Integrator designed and deployed a completely new DMS subsystem using a single user interface. Prior to this work, CDOT ITS operators and PIO were required to deploy DMS messages using multiple user interfaces specific to different manufacturers, with these often hosted on separate desk-top computers. At the time, CDOT also had no modem bank to facilitate simultaneous call-up of multiple DMS. Regional DMS messaging for a wide-area emergency – such as an Amber Alert – was therefore slow and cumbersome. Using the Amber Alert example, over 90 minutes was often required to for a CDOT operator to send the required messages to a regional family of DMS – a process now reduced to a matter of a few minutes. Thus, the ATMS/ATIS yielded much greater and immediate response capability through the operational assistance provided to CTMC staff. Indirectly, CDOT is also seeing a higher percentage of DMS on-line at all times; which also facilitates response capability. The latter condition has been realized because CDOT maintenance forces have better and more up-to-date information to work with as provided by better device polling and reporting capabilities available through the new system.

- *Efficiency*. Common user interfaces and vastly increased speeds of message dissemination to multiple DMS save operator time and effort in the control room. Better maintenance of devices and speed of message dissemination benefits the traveling public and enforcement agencies – particularly in the case of a wide area alert or emergency.

- *Messaging*. As part of the Integrator's work, message libraries were created so the operator would not need to re-type commonly-used, repetitive messages. A spell checker and banned words list were included in the subsystem to help the operator avoid errors and mistakes. In addition, the travel time information currently posted to DMS in selected corridors is a completely new set of information provided by CDOT through this project. During an "event (for example chain law conditions) different messages can be sent to multiple DMS almost instantly using a few keystrokes.

Traveler information was therefore improved statewide by collection of new data in real-time (travel time subsystem); availability of new information unavailable prior to the project (travel time subsystem); better timeliness of information (efficiencies of the ATMS/ATIS); better dependability of devices (through improved maintenance reporting); and better speed/responsiveness in posting messages (through t6he DMS subsystem).

The CTMC Integration Project therefore succeeded in addressing Hypothesis 1.

5A.2 Test/Evaluation of Hypothesis 2 – Data Exchange and Partnerships

Hypothesis 2 proposes that "*CDOT will have maintained ITS partnerships with external agencies. CDOT capabilities to exchange data with agency partners will be enhanced.*"

CDOT first established a "bare-bones" Denver area multi-agency ITS partnership about 10 years ago to pursue federal funding via the FHWA sponsored Model Deployment program. Although Colorado was unsuccessful in that effort, CDOT was able to partially fund the intended Model Deployment activities using State money and the original partnership was maintained in part, to oversee those efforts. Agency participation in this group gradually increased over time to coordinate the efforts of the earmarked Colorado projects.

By 2001, a solid and permanent working partnership was successfully established, and the group was further expanded to address the (FY00) T-REX project and develop Regional ITS architectures. Separate but strong partnerships developed in several Colorado regions – including southeast, northeast and western Colorado; the Denver metropolitan area and another along the I-70 mountain corridor. By 2007, it can be said with certainty that Colorado has many such local, regional or corridor-specific ITS partnerships in place.

CDOT is also in the process of deploying additional Denver-area ITS and communications infrastructure using DRCOG-allocated funds for FY05-FY12; and continues to provide local leadership in pursuit and implementation of ITS initiatives statewide. Leading and otherwise participating in these activities has provided CDOT with numerous opportunities to cultivate and strengthen the multi-agency ITS partnerships and these remain intact as of the date of this document.

The referenced earmarks have funded improvements to data exchange through: 1] enhancing communications between multiple data concentration points; and 2] providing numerous data exchange connections between CDOT and local agencies in Denver and statewide. Over time, CDOT continues to establish connections to additional new agencies.

CDOT has been extremely successful in this area in parallel and related initiatives but success was limited in this project because most of the work was internal to the CTMC and therefore transparent to CDOT's partners. On the other hand, the basis has been set for future center-to-center (C2C) interfacing between CDOT and its partners at the *system* level. Prior to this project, CDOT could not work toward actual C2C interfaces because it did not have a system to interface with. That shortcoming has now been addressed.

In any case, CDOT has maintained ITS partnerships over the past five years and entered into many new ones – several with enforcement and emergency response agencies. Prior to this work, many of these partners were relative novices in ITS, therefore CDOT's chance to actively work with these individuals as new systems were brought on line provided an excellent opportunity to educate these parties about ITS and exchange information and points of view. Ultimately, the CTMC Integration Project laid the groundwork for future, integrated data exchange; not only with new local agencies, but at more extensive levels over time with CDOT's statewide nodes at Hanging Lake and Colorado Springs..

The CTMC Integration Project can therefore be considered a success in addressing Hypothesis 2.

5A.3 Test/Evaluation of Hypothesis 3 – Intangibles

Hypothesis 3 proposes that "*CDOT will have taken advantage of the synergies created by the project as a catalyst for statewide, widespread ITS deployment through other projects and funding sources, in effect using the CTMC Integration Project as a springboard from which to promote ITS as a Colorado success story*."

Previous needs in internal infrastructure; amount, type and flow of data; communications; and overall functionality have been addressed by the project. Because the CTMC is the ITS "nexus" of Colorado, it has always acted as a catalyst to attract the interest and attention of agencies that had not expressed prior interest in ITS. The new CTMC and ATMS/ATIS have not changed this condition but magnified it. Local agencies statewide look to CDOT as their leader and mentor when considering ITS initiatives. This is probably best demonstrated by the increase over the years in the size of the ITS partnership and level of inter-agency support for the statewide ITS program. ITS initiatives were a difficult "sell" as recently as five years ago. Champions of the CDOT ITS program should feel a strong level of vindication upon seeing the levels of support for ITS increase dramatically across Colorado in a short period of time.

Exhibit 15 – CTMC Maintenance Workshop

The CTMC Integration project can therefore be considered a success in addressing Hypothesis 3.

5B Elective Activity #1 – Institutional Issues

As its first elective activity for the local evaluation report, CDOT has chosen to recount selected institutional issues encountered during the project. Institutional issues can best be described as those items that are not technical in nature that needed to be overcome or otherwise addressed to achieve success in the CTMC Integration Project. These include items such as in-house expertise, coordination with stakeholders, partnerships, and organizational structures and processes. These items are discussed in additional detail in this section.

5B.1 Deployment Team Expertise

Installation, operation and maintenance of ITS systems requires personnel with specialized technical skills including expertise in non-traditional civil engineering areas such as computer networks, communications, computer hardware and peripheral equipment, electronics, the Internet, software development, databases, and protocols to allow these elements to interact. At the beginning of the series of federal earmarked projects in 1998, CDOT had only one task manager who was well-versed in these areas with only limited similar experience among the rest of the ITS Branch staff.

Fortunately, over a relatively short time, CDOT was able to greatly enhance its expertise in networking, hardware, electronics, the Internet, software development and databases – allowing CDOT to complete a high percentage of the parallel earmarked projects in-house. These capabilities also proved beneficial to CDOT following procurement of the Integrator; as the ITS Branch was able to proactively direct and support their efforts to develop the ATMS/ATIS. By the conclusion of the CTMC Integration Project, the CDOT ITS Branch had greatly increased its internal technical skill sets in these categories by adding several full-time and/or contract employees who supported the ongoing work.

Many non-traditional Department of Transportation tasks such as communications and network architectures; web site development; database enhancements; development of device drivers; electronics set-up and installation for cameras, switchers and multiplexers; and so on were thus successfully completed as a team effort between CDOT and the Integrator. As a result, CDOT has come to the conclusion that non-traditional in-house skill sets are an indispensable resource most definitely required for success in complex ITS projects.

5B.2 Coordination with Stakeholders and Agency Partnerships

CDOT was fortunate the CTMC Integration Project was fourth in the lineup of earmarked projects because an extensive multi-agency partnership was already in place. The existing partnerships had previously established the names of contact persons and lines of communication and outlined the parameters of working together to achieve common ITS goals. These elements were reinforced via a number of Letters of Agreement, Memoranda of Understanding and Intergovernmental Agreements. Those partnerships were maintained over the course of the project through parallel but separate projects which include but are not limited to:

- Other earmarked ITS projects from FY98, FY00, FY01, and FY03-FY05.
- Development of Regional ITS Architectures (RITSA).
- Ongoing work for the deployment of ITS using DRCOG-administered FY05-FY12 funds.

Exhibit 16 – CTMC Trail Ridge Conference Room

The number of statewide partnerships developed in this and parallel projects is probably too numerous to itemize completely but includes the following broad categories of participants.

- Police and Sheriff's Agencies: Breckenridge, Broomfield, Clear Creek County, Colorado State Patrol, Denver, Dillon, Eagle County, Empire, Englewood, Frisco, Georgetown, Golden, Greenwood Village, Idaho Springs, Jefferson County, Silverthorne, Summit County, and Vail.

- Transportation and Public Works Agencies: Arapahoe County, Aurora, Boulder, Broomfield, Clear Creek County, Denver, Dillon, Douglas County, DRCOG, Eagle County, Englewood, E470 Public Highway Authority, Frisco, Georgetown, Golden, Greenwood Village, Idaho Springs, Jefferson County, Lakewood, Littleton, Northwest Parkway Public Highway Authority, RTD, Silver Plume, Silverthorne, Summit County, Thornton, Vail, and Westminster.

- Fire and Emergency Response Agencies: Clear Creek Ambulance, Copper Mountain Fire, Eagle County Ambulance, Evergreen Fire/Ambulance, Foothills Fire/Rescue, Genesee Fire/Rescue, Highlands Fire/Rescue, Lake Dillon Fire, Lower Blue Fire, Red White & Blue Fire, North Metro Fire/Rescue, South Metro Fire/Rescue, Summit County Ambulance, Pleasant View Fire, Vail Fire, West Metro Fire/Rescue.

- Emergency Management Services: Colorado Office of Emergency Management (OEM) – Dry Creek and Camp George West Centers; Eagle County, Summit County, Clear Creek County, Jefferson County.

- Other Federal and State Government: Colorado Department of Revenue, DRCOG, FHWA, US Forest Service, US Bureau of Land Management,

Establishing such partnerships was by no means easy ten years ago. Issues overcome during the coalition building phase included: 1] educating the partners on ITS in general; 2] selling the participants on the need for, and benefits of ITS; 3] laying the groundwork for a team – rather than individual agency – approach; and 4] developing interpersonal relationships based on trust between partners. As a result, CDOT partnerships have grown over time and remain intact to the present day.

Due to the nature of this earmark as somewhat "internal" to CDOT, outside agency participation was primarily limited to peer review activities and status meetings.

In past instances where local agency involvement is required, participation typically has included reviewing the initial scope of services; attending the kick-off meeting; attending regular project technical or coordination meetings; working with CDOT on day-to-day coordination; and providing support services, technical review or installation with their own employees.

CDOT's conclusion is that inter-agency partnerships are valuable resources to the ITS Program. Not only do such working relationships facilitate successful day-to-day operation, but open talk and interactions help form a solid foundation from which to build future ITS initiatives. Recurring communications with partners – even though they may not be actively involved at the moment – also helps maintain an atmosphere of cooperation, good fellowship and agreement.

5B.3 Modular Project Structure

Previous ITS projects were subdivided into a number of smaller work activities, or task orders. The CTMC Integration Project also used a similar modular structure, with the actual software deployment work instead broken into Iterations – defined as shorter 9-12 month build phases. Although this is not the traditional format for most CDOT projects, the task order and/or phased subdivision of the CTMC Integration Project provided a number of apparent advantages. These included:

- *Better cost tracking of all labor and direct expenses on a by-Iteration basis*. Because each work task was broken out separately, it was easier for the CDOT management team to identify areas incurring a potential over-run, as well as areas not incurring sufficient labor to meet schedules. Overall, the task order system (for non-software work) was deemed superior in tracking and controlling costs and will generally be retained for future ITS projects. The use of phased software development modules or iterations will be similarly retained.

- *Better schedule tracking on a task basis*. Because schedules were reported on bi-weekly at a minimum, it was easy for the CDOT management team to identify areas encountering schedule difficulties. Again, the task order and/or iteration system was deemed superior in identifying critical scheduling issues as they arose.

- *Better subdivision of CDOT management responsibilities*. Because CDOT assigned a number of task managers to the project, it had more "eyes and ears" available to actively monitor progress of the work across multiple task areas.

- *Modular aspect of the deployment*. In the previous Colorado ITS projects, a single large deployment was tasked for delivery at one time. This system ultimately led to major disagreement and controversy between CDOT and its contractor at that time; followed by non-delivery of a functional system. The modular aspect of ITS delivery yielded by the task order system allowed the work to be better organized and helped ensure delivery and acceptance of the required product on budget. There have been no similar disagreements or controversies with the current Integrator specific to development of the ATMS/ATIS.

CDOT's conclusion is that breaking large ATMS/ATIS projects into smaller, individual task orders and/or Iterations is a positive means to maintain control over most elements of large-scale ITS projects.

5C Elective Activity #2 – Lessons Learned

As its second elective activity for the local evaluation, CDOT has chosen to summarize its experiences on the project in a lessons learned format.

5C.1 Administrative Items

Conclusions apparent at the completion of the CTMC Integration Project include the following:

- *In-house expertise in ITS specialty areas is beneficial*. CDOT believes that had it had the current levels of in-house expertise throughout the duration of the ITS Program, some difficulties at the outset could have been lessened or avoided. Addition of these skill sets ultimately allowed CDOT to subdivide technical responsibilities for completion of multiple task orders between several capable and knowledgeable individuals – rather than one or two "thinly spread" individuals. CDOT believes in-house skills in ITS-related technical areas are an indispensable resource definitely required for success in complex ITS projects.

- *Although task order project configuration is not necessarily more efficient for a contractor (if one is involved), it provides a better mechanism for the owner to track progress and control schedules and costs*. Task order and/or phased software iteration configuration provided much better control than did previous ITS projects that dictated delivery of one large product at the end of the schedule. A small amount of additional time is required on part of the owner in a task order environment to better monitor and manage progress on a greater number of total activities. Task order and/or software iteration configuration has been kept for later and ongoing Colorado earmarked ITS projects as applicable.

- *Open communications are critical to success*. Frequent communications engender trust and are critical to success in a complex systems engineering project environment.

- *Economies of scale can be realized*. For example, on other earmarked projects including local agency participation, the agency contributed to the project in terms of purchasing, in-kind services, assistance in obtaining related services or contracts, or the provision of ancillary materials. The result of such partnership was deployment with a total value exceeding that originally planned. These partnerships have helped set the basis for additional coordinated work in the future with current and new partners and also set the basis and example for such participation with new agencies as part of future projects.

5C.2 Systems Engineering

Although these items are discussed in more detail in Appendix A, the application of systems engineering principles benefited CDOT in a number of ways. Lessons learned include the following:

- *Alternatives Assessment*. Early evaluation of proposed ATMS/ATIS architecture requirements revealed an area of potential risk in the communications architecture component of the system. To mitigate risk and better understand the issues, several architecture prototypes were constructed and compared. The basic choice was between two Common Object Request Broker (CORBA) architectures and two Java-based architectures, one using Extensible Markup Language (XML). The four prototypes were evaluated based on CDOT-generated architecture goals of: 1] scalability; 2] maintainability; 3] availability; 4] prevalence; 5] ease of implementation; and 6] standards. Based on the results of this assessment, CDOT determined the architecture would be Java-XML based.

- *Risk Management.* CDOT applied risk management principles during the CTMC Integration Project as outlined in the Risk Management Plan developed at the project outset. The plan allowed CDOT to identify possible risks, assign probabilities and priorities to each, and track these throughout development of the ATMS/ATIS. The document allowed CDOT to address individual risks proactively – before they impacted schedule and projected costs.

- *Requirements.* System requirements were developed at two levels. Initially, high-level requirements were developed by CDOT to provide the Integrator with enough information to identify CDOT's intent. Once the Integrator began work on a given module, extremely detailed requirements were developed to address specific functionality. For example, a high level requirement might say that the system "shall have a communications layer dedicated for communicating with field devices which is implemented or managed by a communications server." A detailed requirement might say that, "communications ports use baud speeds of 2400, 4800, 9600, 19200, 32400, 57600, 115200 and more; with data bits of 8, 7 or 6, parity of none, odd or even and stop bits of 1, 1.5 or 2."

- *Standards and Testing.* CDOT used the Manager to provide independent tests for portions of the Integrator's work. Tests were undertaken to determine whether the specific module(s) functioned as intended. Once the Manager provided a written report summarizing the test results, CDOT and the Integrator developed a prioritized list of issues to be addressed immediately; as well as other items to be addressed on a non-priority basis. All such items found to be missing or otherwise incomplete were addressed and adjusted accordingly by the Integrator prior to final acceptance.

These and other lessons learned in systems engineering are described in Appendix A. Appendix B provides a detailed summary of the ATMS/ATIS work completed in each system Iteration.

End Local Evaluation Report

Colorado Transportation Management Center (CTMC) Integration Project (FY01 Earmark)

Local Evaluation Report

Appendix A: Compliance with FHWA Final Rule

The FHWA Final Rule and FTA Policy for Applying the National ITS Architecture (NITSA) at the Regional Level requires ITS projects implemented with Highway Trust Fund monies conform to the NITSA and ITS standards. Regional Architecture conformance is a condition of FHWA acceptance for major ITS projects, defined as "*any ITS project that implements part of a regional ITS initiative that is multi-jurisdictional, multi-modal, or otherwise affects regional ITS integration*." The CTMC Integration Project applies, thus the Rule calls for three conditions to be met: 1] demonstration of compliance with regional architecture(s); 2] use of systems engineering; and 3] use of appropriate ITS standards. This appendix describes how the CTMC Integration Project complies with the Rule.

Colorado has several Regional Architectures finished and information from these is used to demonstrate compliance. Systems engineering was used in varying intensities depending on the specific activity as applicable – to an extensive level relating to development of the ATMS/ATIS and to a minimal extent pertaining to the new CTMC building. Finally, ITS standards were used as applicable. CDOT has a rough standards framework in place for use project-by-project and is considering developing a Standards Plan to govern statewide ITS deployment.

A1 First Condition - Regional Architecture Compliance

Prior to 2001, Colorado had no Regional ITS Architectures (RITSA) developed; and CDOT used the National ITS Architecture (NITSA) as needed to frame statewide ITS planning discussions. By the 2001 outset of this project, the Denver area was working on Colorado's first RITSA, a document that was completed and published in December, 2001. A number of additional RITSA and project-specific architectures are now finished, superseding the National Architecture previously used as a guide by CDOT. Generally, given the statewide mission of the CTMC, four RITSA apply here, which cover a significant portion of the state. These are:

- The Denver RITSA (2001); which generally covers the Denver Regional Council of Governments (DRCOG) planning area;
- The Region 4 RITSA (2004); which was developed for northeastern Colorado excluding the Denver area;
- The Southeastern Colorado RITSA (2006); which applies to the area south of Denver and east of the Continental Divide; and
- The Western Colorado RITSA (2007); which encompasses the area west of the Continental Divide.

Exhibit A1 – CTMC Operator/PIO Work Station

Project architectures were also initially developed for the I-25/US-50 project in Pueblo and T-REX; but these were superseded by the Southeastern, and Denver RITSA, respectively. A fifth "statewide" RITSA is also currently under development – although the intent of the latter document is to compliment, rather than supersede the four existing RITSA. The Statewide Architecture will be completed in 2007, and the Denver and Region 4 RITSA are also scheduled to be updated prior to the end of 2007.

For the purposes of this report, the Denver RITSA will be used to demonstrate compliance; as it is the largest and most comprehensive of these – in other words it includes the most stakeholders, functionality, user services, and market packages and so on.

CDOT realizes the importance of building its statewide system using RITSA guidelines. In fact, all of the Colorado RITSA documents identify functions already provided by CDOT as cornerstones of the specific regional transportation systems. For example, each RITSA calls out market packages like Road Weather Information, Incident Management, Network Surveillance, Commercial Vehicle Operations and Traffic Information Dissemination as core elements – services already provided by CDOT and its state and local agency partners.

Future RITSA functions were also identified. For example, the Denver RITSA calls out ITS Data Mart, Multi-Modal Coordination, and Railroad Operations Coordination as market packages and subsystems to be accommodated in the future although they are not currently deployed.

CDOT's initial planning efforts for development of the ATMS/ATIS used the Denver RITSA as a *reference*. Thus, all Market Packages proposed in the Denver RITSA are included in the ATMS/ATIS – although it is recognized that many of these are the primary responsibility of partners, or are otherwise long-term initiatives. On a larger scale beyond this project, CDOT uses its library of RITSA documents as a guide in its strategic planning activities for statewide ITS deployment.

Compliance will be demonstrated by a brief overview of Colorado architectures at the macroscopic (statewide) and microscopic (local) levels. A common thread throughout all Colorado RITSA is a series of core strategies for ITS deployment statewide. These are identified in Table A1.

Table A1 – Colorado Regional Architectures; Common Core Services and Strategies

COLORADO STATEWIDE CORE ITS SERVICES	STRATEGIES DEVELOPED IN RITSA PLANNING
Traffic Management	Establish active traffic management in priority corridors.
Traveler Information	Continue statewide deployment of devices to collect pre-trip and en-route travel planning information. Develop the ATIS and disseminate statewide traveler information.
Incident Management	Use real-time road data to assist in incident response. Use active traffic management to reduce congestion arising from incidents. Provide traveler information about incidents.
ITS Maintenance	Establish a statewide ITS maintenance planning, replacement, budgeting process.
ITS Planning and Project Prioritization	Conduct statewide ITS planning and provide leadership for deploying statewide ITS enabling infrastructure. Use performance measures to evaluate ITS. Institutionalize ITS into the statewide and regional planning processes.
Enabling Infrastructure	Deploy ITS enabling infrastructure statewide.
Project Delivery Support	Establish statewide ITS device procurement specifications/guidelines. Establish guidelines for device inspection/acceptance. Establish statewide design standards for ITS systems/devices.

The CTMC Integration Project complies with RITSA strategies at the statewide level. The two CTMC Integration Project "products" – namely the CTMC building and the ATMS/ATIS – directly support CDOT's ITS mission; providing the two most important items needed to carry the State's ITS program forward through the next decade and beyond. Four of the seven statewide core ITS services (Traffic Management, Traveler Information, Incident Management and Enabling Infrastructure) are directly addressed by the project and enhancements in these areas will continue to be realized as CDOT builds additional new functionality into the ATMS/ATIS over time. ITS Maintenance, ITS Planning and Project Prioritization, and Project Delivery Support are being addressed by CDOT as part of separate initiatives. At present, the initial improvements in the core service areas generally lie in efficiencies created for CTMC staff as a result of the new building or the new ATMS/ATIS.

At a microscopic level, use of the Denver RITSA meets the conditions outlined in the FHWA Final Rule. During high-level requirements development undertaken early in this project, CDOT configured the build-out ATMS/ATIS to match the recommendations of the Denver RITSA – an activity that continues over time as the statewide CTMS develops. The Denver RITSA also provides the framework needed to achieve institutional agreement and technical integration of ITS projects. Scopes of work for the CTMC Integration Project task orders were developed using the guidance of these documents as a configuration resource. Following scoping, task orders were submitted to FHWA to demonstrate compliance, meeting the conditions of the interim rule in effect prior to April 2001 and the Final Rule thereafter.

Table A2 identifies market packages selected for inclusion in Colorado's long-term ATMS/ATIS. Numeric identification of the market packages is from the current NITSA and several market packages were combined in the table for convenience. Many new market packages were identified since 2001 and are now considered elements of the NITSA – these will be evaluated for inclusion (or not) in the Denver RITSA as part of a 2007 update activity. All architecture elements identified for inclusion in the 2001 RITSA were included in the ATMS/ATIS plan; although some modules were intended to be the responsibility of other parties or were otherwise long-term in nature. Some current market packages (for example ATMS 19: Speed Monitoring) were not part of the 2001 NITSA but have been included in the interim and deployed as part of the current ATMS/ATIS – thus these market packages will likely be added to the 2007 Denver RITSA.

Table A2 – CTMC Integration Project ITS Architecture and Denver Area RITSA Market Packages

NITSA ID	MARKET PACKAGE*	INCLUDED IN DENVER RITSA (2001)?	INCLUDED IN ATMS/ATIS?
AD 01 / 02	ITS Data Mart / Warehouse	Yes	Yes [1][5]
AD 03	ITS Virtual Data Warehouse	No [2]	Consider [1][3]
APTS (All)	Advanced Public Transportation Systems (10 Market Packages)	Yes	Yes [1][5]
ATIS 01 / 02	Broadcast / Interactive Traveler Information	Yes	Yes [5]
ATIS 03 / 04	Autonomous / Dynamic Route Guidance	No	Consider [4]
ATIS 05 / 07	ISP-based Trip Planning/Route Guidance / Yellow Pages and Reservation	No	Consider [1][3]
ATIS 06	Transportation Operations Data Sharing	No	Yes [5]
ATIS 08	Dynamic Ridesharing	Yes [1]	Yes [1]
ATIS 09 / 10	In Vehicle Signing / Vehicle Infrastructure Integration Traveler Information	No	No [6]
ATMS 01 / 02	Network / Traffic Probe Surveillance	Yes	Yes [5]
ATMS 03 / 04	Surface Street / Freeway Control	Yes	Yes [5]
ATMS 05 / 06	HOV Lane Management / Traffic Information Dissemination	Yes	Yes [5]
ATMS 07 / 08	Regional Traffic Management / Traffic Incident Management System	Yes	Yes [5]
ATMS 09	Traffic Forecast and Demand Management	No	No [1]
ATMS 10 / 11	Electronic Toll Collection / Emissions Monitoring and Management	Yes	Yes [5]
ATMS 12	Roadside Lighting System Control	No	Consider [3]
ATMS 13	Standard Railroad Crossing	Yes	Yes [1][4]
ATMS 14	Advanced Railroad Grade Crossing	No	Consider [3]
ATMS 15	Railroad Operations Coordination	Yes	Yes [1][4]
ATMS 16 / 17	Parking Facility / Regional Parking Management	Yes	Yes [1][4]
ATMS 18	Reversible Lane Management	Yes	Yes [1][4]
ATMS 19	Speed Monitoring	No [2]	Consider [5]
ATMS 20	Drawbridge Management	No [2]	No
ATMS 21	Roadway Closure Management	No [2]	Consider [5]
AVSS (All)	Advanced Vehicle Safety Systems (12 Market Packages)	No	No [4][6]
CVO (All)	Commercial Vehicle Operations (13 Market Packages)	Yes	Yes [1][5]
EM 01 / 02	Emergency Call Taking and Dispatch / Emergency Routing	Yes	Yes [1][5]
EM 03	Mayday and Alarms Support	No	No [6]
EM 04	Roadway Service Patrols	No [2]	Yes [5]
EM 05	Transportation Infrastructure Protection	No [2]	Yes [5]
EM 06 / 07	Wide Area Alert / Early Warning System	No [2]	Yes [5]
EM 08	Disaster Response and Recovery	No[2]	Consider [3]
EM 09	Evacuation and Reentry Management	No [2]	Consider [3]
EM 10	Disaster Traveler Information	No [2]	Consider [3]
MC 01 / 02	Maintenance/Construction Vehicle & Equipment Tracking / Maintenance	No[2]	No
MC 03	Road Weather Data Collection	Yes[7]	Yes [5]
MC 04	Weather Information Processing and Distribution	Yes[7]	Yes [5]
MC 05	Roadway Automated Treatment	No [2]	Consider [3]
MC 06	Winter Maintenance	No [2]	Consider [3][5]
MC 07 / 10	Roadway Maintenance & Construction / Activity Coordination	No [2]	Consider [3][5]
MC 08 / 09	Work Zone Management / Safety Monitoring	No [2]	Consider [3]
MC 11	Environmental Probe Surveillance	Yes[7]	Yes [5]
MC 12	Infrastructure Monitoring	No[2]	Consider [3]

[1] included in ATMS/ATIS build out but primary responsibilities by outside agencies; ATMS/ATIS expected to link via C2C or device drive
[2] not a recognized Market Package in 2001
[3] Market Package under consideration in 2007 Denver RITSA update
[4] long-term deployment profile
[5] activity (or aspects thereof) already underway
[6] no in-vehicle initiatives included in Colorado architectures at this time

[7] previous Market Package ATIS 18 [Road Weather Surveillance System]

Due to funding levels, not all market packages identified in the Denver architectures are accommodated by this project. A few work activities trace to multiple RITSA market packages, while others are addressed by one or two. The CTMC Integration Project is therefore perhaps not the best "fit" with the approved RITSA architectures due to its focus on building infrastructure, software development and integration. Still, the project is a subset of the larger CTMS, which includes other earmarked projects from FY98 through the present; and which ultimately accommodates the entire list of market packages identified during development of the architectures.

Exhibit A2 – New CTMC Control Room

As part of the CTMS, market packages of applicable RITSA have been accounted for in planning and requirements development for the new ATMS/ATIS command and control system, currently continuing through the early deployment stages. Generally, the project focus on software and integration means the project has helped form the technical and structural basis for larger, more visible successes in later projects, while only indirectly referencing specific market packages. In any case, CDOT feels the CTMC Integration Project traces well to the Colorado RITSA. Additional documentation describing the RITSA and architecture traceability in the overall CTMS program – specifically within the ATMS/ATIS – is available from CDOT under separate cover.

A2 Second Condition – Systems Engineering Approach

A "system" is an aggregation of end products and enabling products to achieve a purpose. Systems engineering is a structured mechanism in complex project development with checks and balances to: 1] reduce risk; 2] control costs and schedules; 3] satisfy needs; 4] improve quality; and 5] meet regulations and rules. Systems engineering defines ways of doing things, tools, techniques and a structured way of thinking to implement complex projects.

The Rule requires the deployment team to address the following items (lettered A-C for convenience):

- A] Identify alternatives at each step of building the system.
- B] Evaluate alternatives based on cost, political or technical considerations and customer needs.
- C] Consider what risks exist throughout the process and plan for their management.

In addition, for ITS projects, the Rule requires the systems engineering analysis include the following activities and items (lettered D-J for convenience):

- D] Identification of portions of the Regional ITS Architecture being implemented.
- E] Identification of participating agencies' roles and responsibilities.
- F] Requirements definitions.
- G] Analysis of alternative system configurations and technology options to meet the requirements.
- H] Procurement options.
- I] Identification of applicable ITS standards and testing procedures.
- J] Procedures and resources necessary for operations and management of the system.

The following sections demonstrate how CDOT has met the Second Condition for the CTMC Integration Project. Some of the following discussions are framed in the context of the overall CTMS.

A2.1 CDOT Compliance with Second Condition – Program-Wide Systems Engineering

CDOT continues developing the statewide ATMS/ATIS started in the FY01 CTMC Integration Project. Work is being conducted using the Rational Unified Process (RUP) – which provides recommendations and guidelines for software development projects of significant magnitude and complexity. The effort is being undertaken by CDOT using inputs solicited from a technical task force and resulted in a number of guiding documents; all of which apply to the overall Colorado ITS deployment program. These include: 1] Vision Statement; 2] Top Level Iteration Plan; 3] Software Architecture Guidelines; 4] Risk Management Plan; 5] Change Management Plan; 6] Software Development Plan; 7] Detailed Iteration Plan; 8] Product Acceptance Plan; and 9] other miscellaneous use cases, requirements, project standards and documents. These documents set the systems engineering framework for ongoing and future ITS development and deployment in Colorado at the statewide level. Additional documents to provide supplemental guidance in systems engineering continue to be developed over time.

A2.2 CDOT Compliance with Second Condition – Alternatives Assessment

CDOT has completed alternatives assessment during the CTMC Integration Project in accordance with the following Federal Rule requirements:

- A] Identify alternatives at each step of building the system.
- B] Evaluate alternatives based on cost, technical and political considerations.
- G] Analyze alternative system configurations and technology options to meet requirements.

Alternatives assessment is a cornerstone to systems engineering success – particularly in design. It outlines strengths and weaknesses of proposed and alternate systems; evaluates institutional compatibility; estimates initial and life cycle costs; evaluates against constraints; and helps in evaluating technical and operational feasibility. Alternatives analysis is the “bridge” between requirements and specifications (which define the “how” aspect of functionality deliberately ignored in requirements development). Often, specification development and preliminary design efforts are concurrent. Based on past events in Colorado ITS program history, CDOT is unwilling to proceed with system design without close analysis and evaluation of alternatives. Due to constrained budgets, value engineering was applied throughout planning, design and implementation to help identify the best means to achieve the desired final system products.

The CTMC Integration Project featured alternatives analysis as appropriate and when the system development was approaching critical decision points. For example, development of the speed map component in Iteration 2 was based on a comparison of “best practices” including the local T-REX project, Seattle and San Francisco; the travel time component was based on an evaluation of several alternatives prior to selecting the Virginia Tech algorithm; and the software architecture included an evaluation of alternatives including Data Exchange (DATEX), Common Object Request Broker Architecture (CORBA) and Extensible Markup Language (XML).

Exhibit A3 – CTMC Equipment Warehouse

A2.2.1 Project Alternatives Analysis Example – Software Architecture Assessment

Early evaluation of proposed ATMS/ATIS architecture requirements revealed an area of potential risk in the communications architecture component. To mitigate this risk and better understand the issues, several architecture prototypes were constructed. The basic choice was between CORBA based architecture or Java 2 Enterprise Edition (J2EE)/XML based architecture for communication. Ultimately, the J2EE-XML architecture was selected.

The ATMS/ATIS project architecture is based on open standards and existing production systems architectures. Most ATMS/ATIS architectural elements are standard, such as J2EE, Enterprise Java Beans (EJB), and Oracle. The communication architecture component that supports interaction between the ATMS/ATIS and field devices had the most uncertainty. CORBA and J2EE both offered potential solutions, so prototypes were developed to better understand each of the alternatives. The prototypes were evaluated based on CDOT-generated architecture goals:

- *Scalability:* To evaluate potential of the system to grow and support future needs.
- *Maintainability:* To analyze maintainability of the system in the future with respect to technology evolution and the introduction of new features and requirements.

- *Availability:* To evaluate the availability of support products involved in the overall architecture and the availability of programmers required to implement the architecture.
- *Prevalence:* To check the prevalence of the technology choices in US and other state-held DOT's.
- *Ease of Implementation:* To study the ease of implementing the architecture.
- *Standards:* To study the support available for the standards.

CDOT also checked the alternatives against the following project-specific goals:

- Use three tier (or n-tier) application architecture;
- Manage all application communication using Model View Controller (MVC) pattern;
- Place as much of the application as possible in the Application Server Container; and
- Let the application layer manage communication between architectural components.

Based on the results of the assessment, CDOT determined the communications architecture of the ATMS/ATIS was to be J2EE-XML based. Table A3 depicts the scoring of the alternatives.

Table A3 – Communications Architecture Alternatives Scoring Summary

METRICS*	MODEL 1: CORBA - VISINOTIFY	MODEL 2: CORBA - JMS	MODEL 3: JMS - MDBS	MODEL 4: J2EE - XML
Cost	3	4	6	6
In-house expertise	2	3	7	7
Complexity	3	3	5	6
Scalability	5	5	5	6
Network Overheads	3	3	6	6
Portability	3	3	6	8
Vendors required	7	7	8	8
Vendor support	7	6	7	8
Standards acceptance (ITS/ IT)	5	5	4	6
Support Asynchronous Comm.	5	5	6	6
Risk	3	3	5	6
Ease of Implementation	3	3	5	6
Availability of programmers	3	3	7	7
Conjecture of future	4	4	5	6
Total Score	**56**	**57**	**82**	**92**

*Each category scored 0-10 based on agreed-upon criteria between CDOT, Integrator and other technical stakeholders

A2.3 CDOT Compliance with Second Condition – Risk Management

CDOT addressed risk management during the CTMC Integration Project in accordance with the following Federal Rule requirement:

- C] Consider what risks exist throughout the process and plan for their management.

When problems occur in system development they can have profound impact to costs and schedule. CDOT believes a key to avoid common or unforeseen risks lies in planning. Sources of "generic" risk in systems engineering generally lie in one of the following areas:

- Technology;
- People;
- Physical environment;
- Political environment; and
- Contracting.

In addition, frequent risks in ITS projects include: 1] personnel shortfalls; 2] unrealistic schedules and/or budgets; 3] functions and/or user interface incorrect; 4] gold-plating; 5] requirements changes (scope creep); 6] component shortcomings; 7] external dependencies (subcontractors, partners, etc.); 8] real-time performance shortfalls; and 9] unrealistic requirements. CDOT has hands-on experience addressing nearly all of these risks in past ITS projects and knows that when developing a risk management program to "plan" for these occurrences, it is important to remember no one can ensure the risks cannot occur. One can however, plan to reduce their probability and implement procedures to address risks as they happen.

Mitigation of risk scenarios is accomplished by establishing a tracking and monitoring plan that is carried through the project during meetings of the management team. Important considerations in plan set-up include identifying "symptoms" of generic and ITS-specific risks; and defining the frequency with which the symptoms are checked. When risks are identified, the plan provides resolution measures – an agenda of actions for identified risks. These are achievable and describe anticipated results. Keys to success are awareness of risks; understanding their impact; planning for mitigation; monitoring performance; executing the plan; and obtaining stakeholder/partner buy-in.

Changes to major ITS projects in design are inevitable. Uncontrolled small changes can have major impact to costs and schedules. Events that cause change requests include: errors in components; external factors such as legislation; technology advances; new capabilities requested by users; and "improved" solutions proposed by the technical team.

Because changes are inevitable and can be frequent if not controlled, it is essential to establish a technical "baseline," controlling how changes are made, and communicating approved changes to the development team. Such a mechanism is Configuration Management. Generally, four activities are involved:

- *Definition*. The baseline configuration is the starting point or definition of the system and includes all elements – hardware, interconnections, software, documentation and test procedures.
- *Status accounting*. This activity keeps track of the status of configuration-controlled items.
- *Change control*. This activity restricts changes to only those that are essential and affordable.
- *Audits*. These are undertaken periodically to double-check that configuration management processes are adequate.

Items subject to configuration management include: requirements; interface control documents; design documents; hardware technical data packages; manuals; test plans, test procedures and test reports; and training materials. These strategies were used extensively in the CTMC Integration Project – during which CDOT established a Configuration Control Board to help limit scope creep caused by requests for changes. The Board reviewed all proposed changes for impacts and prioritized them – identifying those to be implemented as well as those to be postponed or deferred.

Exhibit A4 – CTMC Computer Room Equipment Racks

The board included managers (CDOT, Integrator, and Manager), a key user representative, a senior manager with funding responsibility and the configuration manager; and met periodically to address proposed changes. The Configuration Control Board helped identify and track risks with the following focus areas included:

- Risks related to managing system requirements.
- Risks related to system development life cycle management.
- Risks related to managing customer (user) requirements.
- Risks related to technical and support personnel.
- External risks.
- Risks related to development methods and tools.

Controlling the impact of change can perhaps best be accomplished by building in increments. If not possible, when changes occur, configuration management can allow changes to be deferred to later "versions" (a principle used in the overall CTMS project) – as well as forcing justification for changes, even minor ones.

A2.3.1 Project Risk Management Example – Risk Management Plan

CDOT applied risk management principles during the CTMC Integration Project, as outlined in the Risk Management Plan developed at the project outset. Table A4 summarizes those risks identified by the project team, their priorities and their probabilities as envisioned prior to the beginning of the ATMS/ATIS development process.

Table A4 – Risk Prioritization

PRIORITY	RISK ID #	DESCRIPTION	PROBABILITY	SCORE
1	R15	Budget	High (>70%)	5
1	R18	Resources	High (>70%)	5
1	R19	Schedule	High (>70%)	4
1	R16	External Constraints	High (>70%)	4
1	R17	Politics	High (>70%)	4
1	R22	Technology Integration	High (>70%)	4
2	R23	Move to a New Facility (occurred October 2005)	High (>70%)	3
2	R11	Cooperation	Medium	4
2	R8	Quality of Requirements	Low (<30%)	4
2	R9	Measurability of Customer Requirements	Low (<30%)	4
3	R3	Availability of Requirements Management Tools	Medium	3
3	R5	Critical Phase Reviews	Medium	3
3	R20	Insufficient Funds for Development Tools	Medium	3
3	R2	Volatility of System Requirements	Medium	3
4	R1	Complexity of Managing System Requirements	Medium	2
4	R4	Integrity and Maintainability of System Development Life Cycle Documents	Medium	2
4	R6	Development Model	Medium	2
4	R7	Formality and Manageability of Customer Requirements	Medium	2
4	R13	Development Experience and Technical Knowledge	Low (<30%)	2
4	R14	Training	Low (<30%)	2
4	R21	Technical Skills for Development Methods and Tools	Low (<30%)	2
5	R10	Communication	Low (<30%)	1
5	R12	CDOT-Internal Domain Knowledge	Low (<30%)	1
		Risk Assessment (Guidelines used for Risk Scoring): *0 – No known risk exists* *1 – Risks are inconveniences without serious impact* *2 – Risks threaten minor impact to process or product* *3 – Risks may disrupt the process or degrade the product* *4 – Serious risk to a major part of the project exists* *5 – Risk exposure threatens failure of the project*		

Ultimately and in hindsight, the greatest amount of risk and delay was probably introduced through the CDOT-internal process required to approve and purchase the system development tools – particularly the Rational Suite Product Family that was eventually purchased to help frame, optimize and simplify the software development process.

A2.4 CDOT Compliance with Second Condition – Regional Architecture Implications

The FHWA Rule requires CDOT complete the following activities as part of the CTMC Integration Project:

- D] Identify the portions of the Regional ITS Architecture being implemented.

The Rule requires such identification and because the high-level ATMS/ATIS requirements were developed using the Denver RITSA as a guide, all new modules and subsystems are by definition part of the RITSA. CTMC

Integration Project activities were compared to the Denver RITSA to verify architecture compatibility. See Section A1 of this Appendix for additional information.

A2.5 CDOT Compliance with Second Condition – Roles and Responsibilities

The FHWA Rule requires CDOT complete the following activities as part of the CTMC Integration Project:

- E] Identify participating agency roles and responsibilities.

CDOT has relied on the support and cooperation of many local agency partners statewide throughout initiation and development of its statewide CTMS Program. Such roles and responsibilities for participation within the Program were identified early in the CTMS systems engineering process – predating the CTMC Integration Project – through development of Operational Concepts. Because CDOT is familiar with systems engineering in ITS deployment as a result of using similar approaches on previous projects, the initial Operational Concepts development was relatively straightforward as it was applied to this project – primarily because the initial Iterations of deployment were all internal to CDOT. Thus, although CDOT maintains data exchange capabilities with many agencies statewide, their participation in the CTMC Integration Project was limited during the initial deployment phases because the required work hereunder established internal CDOT "core" systems, and then worked to develop two modules (for DMS and speed/travel time) that interface to devices along CDOT-owned freeways.

Generally, these agencies will again become directly involved as the CTMC is developed further. Thus, earlier work to develop Operational Concepts will be revisited at that time. Generally, Operational Concepts define the following at a high level:

- Deployment strategy;
- Activities to be performed;
- Organizational relationships and responsibilities;
- Information flows;
- Message priorities;
- Archiving needs;
- Administration (including access and security);
- Definition of critical parameters;
- Determination of preferred life cycle; and
- Definition of operating environment(s).

Operational Concepts are usually one of the first tasks undertaken in an integration activity for good reason – they define relationships between systems and organizations. An agency or partnership of agencies cannot successfully build a system until the processes it supports have been defined.

Operational Concepts are an important first step in "traceability" – in which a numbering system is developed to allow concepts to migrate to requirements, then specifications and later, tests. Traceability ensures important and desired aspects of the systems are not overlooked or forgotten later. CDOT has existing Operational Concepts documents for a number of interfaces –and although a few of these are somewhat dated, CDOT feels they provide a solid foundation on which to proceed. Ultimately, modifications or updates to these Operational Concepts documents are required and will be undertaken at a later date as additional center-to-center (C2C) functionality is developed as part of the build-out ATMS/ATIS.

A2.6 CDOT Compliance with Second Condition – Requirements

The Federal Rule requires that CDOT complete the following activities as part of the CTMC Integration Project:

- F] Requirements definitions.

System Requirements define "what" a system does – not "how" it is accomplished. CDOT has had success developing requirements with a hierarchy – beginning with high-level requirements and developing those in ever-increasing detail. Requirements are written to address multiple aspects of a system such as functions, performance and interfaces – as well as enabling requirements such as speed, testing, deployment and support. Characteristics of good requirements are that they are: clear and unambiguous; complete; measurable; consistent between each other; achievable; testable; and in line with user, owner and developer expectations.

To ensure requirements are complete, consistent, concise and correct, CDOT typically institutes a series of requirements "walk-through" meetings. These are held at initial development, at each evolutionary phase and whenever multiple requirements are changed. Participants include CDOT, affected partners, the project managers of participating entities and the system developer. Purpose of the walk-through is to clarify; ensure common understanding; agree on constraints; prioritize (and eliminate unnecessary requirements); and discuss changes since the last walk-through.

At the project start-up, CDOT completed definition of high-level (non-detailed) requirements for the ATMS/ATIS; while extremely detailed requirements were completed by the Integrator for those portions of the system being deployed. The latter are reviewed via walk-through reviews before proceeding to the build stage of software development. Such requirements were developed for all deployed components of CDOT's current system.

A2.6.1 Project Requirements Example – Communications Server

The following section provides an excerpt from the detailed requirements developed by the Integrator for Colorado's ATMS/ATIS. Function of the ATMS/ATIS communications server was selected as an example to illustrate the levels of detail and investigation typically required to create comprehensive, detailed system requirements. Many more such requirements were written by the Integrator.

Communications Server

The Communications Layer is responsible for the communications to devices and is implemented by a "Communications Server." It knows how to connect to devices in a scalable manner (reusing connections across multiple requests to the same device, pooling connections, etc.) and it also knows how to transform an instruction from an object format to a device-specific protocol and vice versa.

The Communications Layer does not perform business or validation logic and acts simply as a worker, communicating to devices that it has been told to interact with. The Services Layer is the "brains" behind determination of which instructions to execute and when to run them, for instance, now or in the future via the Scheduler. The Communications Layer cannot be run in the Enterprise Java Beans (EJB) Container. It requires threading, asynchronous protocol event handling. Throughout the communications server specifications, the terms for jobs, instructions, tasks, messages and request/reply have been used interchangeably.

1. *Communication servers are post-loaded after startup of the Java 2 Enterprise Edition (J2EE) application server. The check is made whether another instance of communication server is running or not.*
2. *Communication servers are clustered (master active – slave active environment) to provide fail over and load balancing features. Fail over is automated without human intervention.*
3. *In the clustered environment the Jboss Instance is restarted if any of the services fail.*
4. *Communications servers handle all instructions, request and response through the message queues.*
5. *The system connects to a configurable series of serial communications ports. This set is reloaded without requiring reboot of the system.*
6. *Communications to devices handle asynchrony, not holding up the requestor until a device handles the instruction.*
7. *The system handles connection to devices hooked into dial-up modems, fiber optic lines, serial RS-232/RS-435, wireless, and Internet Protocol (IP) sockets.*
8. *The system initializes itself on startup, performing operations such as connection pooling and device lookups before receiving requests from the application.*
9. *The system uses smart connection pooling dependent upon the device. For instance, a device connected to a fiber optic line uses a local cached connection.*
10. *Communication ports use baud speeds of 2400, 4800, 9600, 19200, 32400, 57600, 115200 and more, with data bits of 8, 7 or 6, parity of none, odd or even and stop bits of 1, 1.5 or 2. Default is 9600-8-none-1 and with flow control set to none.*
11. *The system supports addition or removal of modem banks without downtime.*
12. *The system loads known devices from one source common to all communication servers.*
13. *The system reloads the device configuration without requiring reboot of the system. In other words the communication server supports dynamic configuration change of the devices.*

14. *The dial-up communication takes about 30 seconds to dial the number and accomplish initial handshake with the remote modem. On fiber it takes less than about 5 seconds to accomplish the handshake.*
15. *The system times out and closes the serial port if it fails to receive a response in the specified time. This timeout period is configurable and modifiable without requiring a system reboot.*
16. *Modem initialization string is user configurable without reboot. The default initialization string is ATE0V1.*

A2.7 CDOT Compliance with Second Condition – Procurement

The Federal Rule requires CDOT investigate the following as part of the CTMC Integration Project – specifically intended to focus on software.

- H] Procurement options.

Based on past experience, CDOT realizes software development will not be a perfect process, nor is there a magic formula available to cure all software and system development shortcomings. Because CDOT participated in a previous and somewhat unsuccessful large-scale ITS software development project in the late 1990's, it has learned some valuable lessons in this regard. Consequently, CDOT has identified a number of guiding principles to consider in systems and software development activities such as the CTMC Integration Project.

Software acquisition is collaborative. This principle extends beyond organizational boundaries to include multiple parties. The Integrator's role is especially critical, as it is the single party generally best-suited to evaluate cost and schedule ramifications of seemingly innocuous requirements. No single public agency or individual has the skill needed to evaluate all aspects of a large-scale software development. Required skill sets include hardware, software and systems engineering, contracting and legal expertise. Individuals with some of these skills can bring different perspectives to a problem along with their expertise. Partner agencies are potentially valuable participants who can provide additional advice. CDOT was fortunate to increase the systems engineering skills of its staff by an order of magnitude between the late 1990's project and this one.

Exhibit A5 – New CTMC Building Entrance

Historically, because most previous CDOT projects dealt with construction, CDOT has a mind-set that tends toward rigid conformance to specifications. In software development, a "give and take" approach is a better norm as there are often design changes whether the participants are prepared for these or not.

CDOT recognizes requirements evolve over a project; thus CDOT may not get everything it wants as an outcome because trade-offs need to be made with costs and schedules. Deviations from requirements can be a positive – encouraging Integrator innovation and yielding a best value acquisition. Conversely, too much flexibility is not beneficial as requirements "creep" must be avoided. Configuration management principles should be applied to achieve balance. CDOT is also aware of the risk of trying to accomplish too many things at once. Although ambitious plans are desirable, growth is best achieved one step at a time. Small development pieces facilitate low costs and short, less complex, manageable schedules. In CDOT's experience, 9-12 month software module development schedules yield logistically reasonable deployment packages.

CDOT philosophy for its umbrella ATMS/ATIS software was that Iteration 1 took a number of existing capabilities already provided and made them "work" over a period of about 9-12 months Iterations 2 and 3 addressed more existing capabilities while adding a number of "new" capabilities; with each phase also sized and scheduled over an approximate 9-12 month period.

Additional Iterations for functions not yet provided were prioritized and programmed for later addition over 5-7 phases using State funds.

A2.7.1 Project Procurement Example – Integrator Request for Proposals

In 2003, CDOT began developing a Request for Proposals (RFP) to obtain the services of a new Integrator to design, deploy and test the proposed ATMS/ATIS. The RFP was released late that year. Respondents were directed to submit a proposal in strict conformance with a specified format to facilitate ease of evaluation by the selection committee. Proposals were evaluated based on attention to the following elements:

- Response Team Capabilities and Representative Projects;
- Key Employees, Roles and Responsibilities;
- Work Location;
- Hourly Rates;
- Project Understanding and Critical Issues;
- Project Approach;
- Systems Engineering;
- ITS Standards;
- ITS Architecture;
- Management Plan;
- Cost Control, Schedule Control and Quality Control; and
- Benefits.

Proposals were received from three highly capable and qualified system integration teams. After a detailed and extensive review process, the selection committee chose En Route Traffic Systems (ERTS) as its new Integrator.

A2.8 CDOT Compliance with Second Condition – Standards and Testing

The Federal Rule requires CDOT complete the following as part of the CTMC Integration Project:

- I] Identification of applicable ITS standards and test procedures.

Although standards are discussed separately, a brief discussion of testing for this project follows. Verification of whether requirements have been met is accomplished through tests. Acceptance lies in three areas – validation, verification and quality assurance. Validation requires analysis of whether the system matches user needs – in other words was the right system built? Verification checks whether the system has met requirements – in other words was the system built right? Quality assurance evaluates if the correct development procedures were followed – in other words was the system built the right way?

Acceptance is achieved through testing at various points in development and consists of unit tests; subsystem tests; integration tests; pre-staging tests; and acceptance tests. The first three take place in development to verify operability at key steps of assembly. They determine operation of individual units, subsystems (collections of individual units performing a defined function), and integration (a collection of subsystems performing together). Hardware tests of these components take place visually but are also tested for functionality and conformance with environmental requirements. Similar software tests are performed by programming staff. Pre-staging tests are performed to ensure modules, subsystems and/or overall systems are "ready." Acceptance testing is undertaken prior to CDOT assuming ownership.

Exhibit A6 – New CTMC Video Wall (Back)

Acceptance testing includes functional tests, performance tests (including throughput, storage and "stress" or peak testing), failure mode tests and operability. Prior to testing, CDOT and the integrator typically develop a comprehensive test plan to define parameters of the test program. Test plans might therefore include:

- Test procedures;
- Expected results;
- Test data sheets;
- Schedules;
- Test conditions and settings;
- Testing team identified;
- Requirements traceability matrix; and
- Problem reporting, tracking and resolution processes.

The final test generally requires an observation period consisting of a predetermined number of days of trouble free operation. Applicable portions of the task orders comprising this project were developed to include a test plan. All items were tested in accordance with specific test plans outlined in that task order (or via previous projects).

A2.8.1 Project Standards and Testing Example - Iteration Two

CDOT used the services of the Systems Manager to provide independent tests for portions of the Integrator's work. Tests were undertaken to determine whether the specific module(s) functioned as intended. The examples listed in Table A5 are excerpted from the Manager's product acceptance test for Iteration 2 of the ATMS/ATIS.

Table A5 – Iteration 2 Product Acceptance Test (Excerpts)

USE CASE	USE CASE NAME	COMMENT
I2.5.70	Add AVI Reader	Basic Flow #6 – There is no place to input a "z" value if using the latitude and longitude option
I2.5.61	Configure RTMS	Basic Flow #13 states "The system displays the following: … all OK or Degraded Comm Pools…"; this text was not provided
I2.2.83	View Snapshot	Basic Flow #12 states "user zooms in on the snapshot viewer"; zoom functionality not provided
I2.2.91	View RTMS Status	Basic Flow #6 states "Offline status devices are shown grey"; status of "OK" was shaded grey

Table A5 is shown for the purpose of listing a few examples only. Additional comments were also provided for the same Use Cases shown as well as other Use Cases not listed in the table. Once the Manager provided a written report summarizing the test results, CDOT and the Integrator developed a prioritized list of issues to be addressed immediately; as well as other items to be addressed on a non-priority basis.

In any case, all such items found to be missing or otherwise incomplete were addressed and adjusted accordingly by the Integrator prior to final acceptance.

A2.9 CDOT Compliance with Second Condition - Management and Operation (M&O)

The Federal Rule requires CDOT attention to the following item as part of the CTMC Integration Project.

- J] Procedures and resources required for management and operation (M&O) of the system.

CDOT is aware that proper M&O procedures through the life cycle of the system are essential to success. Because of this, CDOT has restrained the department's ITS program growth to a certain extent over the past five years to allow planning and funding to catch up with ongoing deployment. CDOT has identified and implemented management principles in this area as follows:

- Maintain multi-agency/multi-disciplinary coordination of activities. This establishes strong, effective work relationships. Techniques include establishing steering committees; traffic management teams; incident/emergency response teams; and periodic agency briefings. These are used to coordinate and develop management strategies and operational plans. CDOT has strong regional partnerships that established the foundation for this project, preceding work and other ongoing efforts.

- Encourage partnerships when appropriate for ITS activities. CDOT always considers partnerships to share or acquire infrastructure and other resources. Current such partnerships include over 40 participants statewide.

- Ensure system reliability. Steady operation must be maintained to gain confidence of management, agencies and the public. Options for reliability include: actions in design, procurement, implementation and day-to-day operation; specifications and acceptance testing; and careful selection of Integrator and hardware. CDOT will continue to monitor reliability as a key aspect of the new system as it develops, and diagnostics are a key element. Initial indications are that the new ATMS/ATIS is vastly superior from a reliability standpoint versus the preceding conglomeration of stand-alone modules and subsystems.

- Conduct regular M&O briefings with agency personnel. CDOT already completes such briefings internally.

- Establish performance requirements and criteria to manage and operate ITS; and monitor, measure and report system performance and benefits. Possible Measures of Effectiveness (MOE) include: delay, throughput, air quality, malfunction response times, incident response times, safety and customer satisfaction. Performance requirements are being developed.

Key operational issues to be applied include:

- Develop and maintain operations plans, manuals and documentation. The Integrator is developing an extensive library of documentation as a deliverable for all ATMS/ATIS development activities.

- Develop and maintain operations manuals to define the critical functions of the system. As new subsystems and modules are brought on-line, such documentation is being, and will continue to be developed by the Integrator.

- Develop policies and procedures for incident management. CDOT has Incident Management Plans (IMP) for ten corridors. The policies and procedures developed in those plans form the framework for such policies and procedures statewide. Additional corridors are under consideration for IMP development.

- Develop protocols for operating ITS devices of other agencies. These are being developed in parallel projects.

A3 Third Condition – Use of Appropriate ITS Standards

Industry-consensus ITS standards define how transportation system components interconnect and interact within the framework of the NITSA. They specify how technologies, products and components interconnect and inter-operate among different systems so that information can be shared automatically. There are currently over 120 approved and emerging ITS standards – all developed by public and private stakeholder organizations in a process supported by FHWA. Many are approved and published while others are progressing and will be adopted soon, thus as of now it makes sense to use standards in ITS design and implementation. This approach has little risk and facilitates future integration opportunities.

Exhibit A7 – CTMC Weather Monitor

There are a series of standards that define terms, data elements, message sets, and foundation standards that cut across many Market Packages. Several (e.g. the NTCIP family) were and continue to be used in the CTMC Integration project. These form the basis for interoperability by defining common terms and information elements. Baseline standards are critical for deploying a wide range of market packages because they establish common vocabularies of data elements and message structures that allow regional ITS applications to exchange data and information. Adopting common vocabulary is of particular importance for exchange of data between the developing ATMS/ATIS and the various external transit, traffic and emergency management systems.

A3.1 CDOT Compliance with Third Condition – Exchange of Video Images

National ITS Standards have not directly addressed exchanging video data due to the extensive standards and conventions that exist. Colorado has developed an ad-hoc “standard” to enable such exchange. CDOT worked with regional agencies to install a SONET-based high-speed ITS communications backbone. As part of this effort, CDOT deployed Nortel communications multiplexers that allow video and data to be sent over the network, and also identified Panasonic CCTV cameras and switchers as the statewide equipment standard. CDOT is providing local agencies with this equipment as part of ongoing projects. Use of common equipment eases integration and facilitates sharing of video images. Development of the ad-hoc standard was completed under three task orders in the FY98 earmark project. The referenced installations also operate using a common software platform.

A3.2 CDOT Compliance with Third Condition – CDOT Standards Plan

As part of ongoing programmatic work, CDOT continues its process of developing Standards Plans to apply program-wide. A summary of initial work is provided below. Standards Application Areas (AA) are 19 deployment categories focusing on specific ITS services – each containing references to the NITSA. Categories identified for inclusion in the context of the overall CDOT ITS Program are described below.

A3.2.1 Standards Application Areas

AA identified as part of the *short-term* standards plan and rationale for inclusion are described in additional detail below. The numbering scheme matches that provided by FHWA in the standards guidance documentation. An asterisk [*] indicates that standards within this AA were used in the CTMC Integration Project.

- 1] Data Collection/Monitoring*: Interfaces between a management center or data archive and roadway devices that collect traffic data over time.
- 2] Dynamic Message Signs*: Information exchange between a control center and DMS in the field.
- 3] Environmental Monitoring: Information exchange between a control center and roadway equipment that monitors environmental conditions – commonly those being part of a RWIS.
- 6] Vehicle Sensors*: Interface between a control center and roadway equipment that senses traffic parameters.
- 7] Video Surveillance: Interface between a control center and video surveillance equipment located on the roadside.
- 9] Incident Management: Interfaces that support coordination/exchange of incident-related information between allied agencies. Such interfaces are planned (or already in place) statewide.
- 11] Traffic Management: Interface between a traffic management subsystem and other internal/external centers.
- 13] Traveler Information (C2C): Interface between a creator of traveler information data and other centers using the data.
- 16] Traveler information (Center to Vehicle/Traveler – C2V/T)*: Interfaces between centers that provide traveler information and travelers (either pre-trip or en-route).
- 17] Toll/Fee Collection. Interface between a toll collection or parking facility and a vehicle for electronic fee collection. CDOT already uses High Occupancy Toll (HOT) lanes on I-25 and two regional toll highways also intersect I-25.

Exhibit A8 – CTMC Control Room Viewed from Media Room

The remaining application areas are part of the long-term Standards Plan and will not be immediately applied for use statewide.

- 4] Ramp Metering (note volume/speed/occupancy data from ramp meters currently used as input to travel time subsystem).
- 5] Traffic Signals.

- 8] Data Archival (note CTMC archives DMS and limited travel time data but does not provide such services for other agencies).
- 10] Rail Coordination.
- 12] Transit Management.
- 14] Mayday.
- 15] Transit Vehicle Communications.
- 18] Signal Priority.
- 19] Highway Rail Interface.

These AA will remain the responsibilities of the CDOT Regions, outside agencies, are not currently planned, or are currently planned but anticipated to be part of the longer-term program for ITS deployment in Colorado.

A3.2.2 Standards Selection Process

Standards selection will consist of a four-step process and the same logical flow applies whether applied to a specific project or program-wide.

- Step 1. The short- and long-term AA are verified and the AA list for the overall program developed.

- Step 2. An initial list is developed including all FHWA-recommended standards from the appropriate AA.

- Step 3. Unsuitable standards from the initial list are eliminated as a "first cut." For example, many listed standards address in-vehicle navigation systems, which CDOT does not intend to accommodate in the short-term; or transit-vehicle communication, which CDOT will leave to the discretion of the transit-operating agency. In these cases the referenced standard is eliminated from the list or deferred until such time as CDOT begins developing such systems. The "first cut" therefore eliminates or defers non-applicable standards by inspection.

- Step 4. Standards surviving Step 3 require further investigation to determine potential applicability. Standards determined to apply are retained and deployed as part of the most applicable ongoing, current or planned project.

End Appendix A

Colorado Transportation Management Center (CTMC) Integration Project (FY01 Earmark)

Local Evaluation Report

Appendix B: ATMS/ATIS Work Summary by Software Iteration

CDOT began planning the new ATMS/ATIS in the late 1990's well before the start of this earmark; but accelerated such efforts after the award. An early high-level planning activity identified elements of the ATMS/ATIS envisioned to be critical pieces of the long-term, statewide system. The Denver Regional ITS Architecture (RITSA) provided CDOT with a comprehensive list of market packages to be included as proposed system modules (*e.g. "The system should provide the capability for CDOT operators to control highway advisory radio equipment."*). In parallel, high-level functional requirements were developed for the system as a whole (e.g. *"The system should include an alarm handler."*). These were further discussed to determine if the various functional elements under discussion should be part of the "core" system or be otherwise linked to using device drivers. As the look and feel of the build-out ATMS/ATIS began to emerge, CDOT documented its priorities in a Top Level Iteration Plan, the purpose of which was to organize the proposed elements into order of importance, and then further group these into deployments of deliverable components.

The highest priority components identified in 2003 are listed in Table B1. The *actual* components deployed during the three software iterations to date are individually identified by the Use Case abstracts in Sections B1-B3.

Table B1 – High Priority Functional Components (as defined in 2003)

FUNCTIONAL COMPONENT	PRIORITY [1]	RISK [2]	SOURCE [3]	ITERATION [4]
Alarm Handler	1.1	L	internal	1 [partial]
Dynamic Message Signs (DMS)	1.1	M	internal	1 [partial]
Radar/Speed Detectors (RTMS)	1.2	L	internal	2
Security/User Manager	1.2	L	internal	1 [partial]
Automated Traffic Recorders (ATR)	1.3	H	subcontract	2
Logging	1.3	L	internal	1 [partial]
Mapping / Graphical User Interface (GUI)	1.4	M	external interface	1 [partial]
"Configure" Element	1.5	H	subcontract	1 [partial]
Core Architecture Framework	not assigned	not assigned	internal	1
Scheduler	1.5	M	internal	2
Courtesy Patrol	1.5	L	internal	2 or 3
Web	1.5	M	internal	2 or 3
Highway Advisory Radio (HAR)	1.4	M	subcontract	2
Reporting	1.5	L	internal	2
Kiosks	1.5	L	internal	3
Operations Database	1.5	M	internal	2
Scripting	1.6	H	internal	2
Computer Aided Dispatch (CAD) -E911 Interfaces	1.6	L / H	external interface	2
Regional Transportation District (RTD) Interface	1.6	M	external interface	2
Road Weather Core System	1.5	L	internal	2 or 3
Weather Station Interface	1.5	H	subcontract	3
Speed/Incidents/Travel Time Phase 1	1.5	M	internal	3
Closed Circuit Television (CCTV)	1.6	H	subcontract	3
Colorado State Patrol Interface (CCIC)	1.6	L	external interface	3

[1] In this instance, the LOWER the number, the higher the priority
[2] Risks are low, medium and high (L, M, H)
[3] Planned "source" in 2003; most activities eventually completed by Integrator
[4] Planned/proposed deployment iteration as of mid-2003; see Use Cases for actual elements completed by iteration

Medium and lower priority functional components identified in 2003 are listed in Table B2. *Actual* components deployed in the three software iterations to date are individually identified by the Use Case abstracts in Sections B1-B3

Table B2 – Lower Priority Functional Components (as defined in 2003)

FUNCTIONAL COMPONENT	PRIORITY [1]	RISK [2]	SOURCE [3]	ITERATION [4]
Probes*	2.1	H	internal	TBD
Transit Security	2.2	L	internal	TBD
"Trip-70" Interfaces	2.2	H	internal	TBD
Road Weather System Phase 2	2.2	L	internal	TBD
Telephone Hot Lines	2.3	H	internal	TBD
Thermo-graphic Mapping	2.3	M	internal	TBD
HOV Subsystem	2.5	H	internal	TBD
Trailblazers	3.1	M	internal	TBD
Toll Collection Interfaces	3.1	M	internal	TBD
Railroad Interfaces	3.1	M	internal	TBD
Emissions Interfaces	3.1	M	internal	TBD
Traffic Signal System Interfaces	3.1	M	internal	TBD
CVO/External Interfaces	3.1	M	internal	TBD
Advanced Vehicle Detection Systems (AVDS)	3.1	M	internal	TBD
Parking Interfaces	3.1	M	internal	TBD
Call Boxes	3.1	M	internal	TBD
Operations Database Phase 2	3.1	M	internal	TBD
Speed/Incidents/Travel Time Phase 2	3.1	M	internal	TBD
Daily Construction	3.1	M	internal	TBD
Text Messaging	3.1	M	internal	TBD
[1] In this instance, the LOWER the number, the higher the priority [2] Risks are low, medium, high (L, M, H) [3] Planned "source" in 2003; most activities (to date) completed by Integrator [4] Planned/proposed deployment iteration as of mid-2003; see Use Cases for actual elements completed by iteration				

** In-vehicle probes had been a mid to high priority along I-70 in the mountain corridor; but the configuration of this subsystem was changed as part of the I-70 West Integration Project ("Trip-70") to one using a combination of toll transponders, count stations and ramp meters to evaluate speeds and develop projected travel times between points along I-70 West. See the Trip-70 Local Evaluation Report for additional information. The core portions of this system – in which the Virginia Tech algorithm was used to predict travel times based on surveillance data – is part of Iteration 2.*

The software development work completed in ATMS/ATIS Iterations 1-3 (those iterations in which the federal funding for this project were a contributor) is outlined and briefly described in the following sections, with "Use Cases" used to describe the work accomplished. A Use Case is defined as a description or technique used in software and systems engineering to capture the functional requirements of a system; and to describe how to achieve a goal or task. As will be illustrated below, a Use Case may be related to multiple system features and/or functions.

Use Cases describe the interaction between a primary "actor" (the initiator of the interaction) and the system itself, represented as a sequence of simple steps. In Colorado's case, all were written by the Integrator in substantially more detail than that represented herein – the documents developed for each Use Case are several pages in length.

B1 Work Completed in Software Iteration 1

At the conclusion of Iteration 1, Colorado's ATMS/ATIS was able to accomplish the following activities. The abbreviated Use Case (UC) abstracts provided are intended to yield a "snapshot" of the system at the conclusion of the first three development phases.

- *1. Iteration1 ("I1") UC 1.00 Login to System.* A user logs into the system using this UC. User name and password are required to login. All attempts are logged. Repeated failed attempts from the same computer (IP address) of greater than 10 will generate an alarm.

- *2. I1 UC 1.10 Logout of System.* A user is able to log out of the system using this UC. Logout closes the client.

- *3. I1 UC 1.30 Manage Users.* This is a base UC that defines the conditions needed to access manage user tasks.

- *4. I1 UC 1.31 Add New User.* An administrator adds a new user to the system; sets the password (using change password) and sets the roles. The administrator selects all elements (username, password, name, email, phone, group, role, status, etc.). A user can have only one role. Hierarchy of roles is: 1] administrator; 2] maintenance; 3] operator/PIO. An e-mail is sent to the user whose account has just been created. All account details will be in the e-mail.

- *5. I1 UC 1.32 Edit User.* Thus UC assigns the group the user belongs to, assigning and removing global and regional roles, and disabling or enabling the user. There is an administrative account that cannot be locked out – password can be changed on this account. Username cannot be changed on any created account. Account changes are e-mailed to the user.

- *6. I1 UC 1.33 Change Password.* An administrator may change a user's password. A password must be >8 characters and contain alphanumeric characters, no special characters and is case-sensitive. A password change is e-mailed to the user.

- *7. I1 UC 2.00 Navigate Desktop.* This UC defines the elements, menus, icons, toolbars, zoom presets, default tool and map in the graphical user interface (GUI) based on role. The standard desktop for the Client GUI has 2 screens. Screen 1 is left and is the main map navigator which displays layers, file menu, and map view. Screen 2 is right, and is the status console, containing windows for alarms, logging, etc. Task-based windows (e.g. view DMS, etc.) always open in Screen 1, but can be moved (to Screen 2 or other position in Screen 1). This UC focuses on behavior and functionality in Screen 1. Windows in Screen 2 are defined in their own UC. Layers include: background image, counties, state boundary, CDOT Regions, maintenance sections, highways, cities, mile markers, and maintenance patrols. At startup, the client displays a "loading" message identifying the data or module being loaded. Available functionality depends on the role of the logged-in user. Devices are shown using different icons with status indicated by color or symbol. Device attributes may drive icon type displayed (such as reminder timestamp for DMS). Toolbars include zoom in/out, full extent or fit to screen, arrow, pan, rubber band (rectangle/free form), find, and refresh view. When a user moves their mouse over a device (DMS), the system displays the following: sign ID (highway, direction or mile marker), common name, message text and last polled timestamp.

- *8. I1 UC 2.10 Search Map.* The user may type a text string, select layers and find a device, icon or element. Foe example, the user could find a particular mile marker by entering the exact mile point. The desktop will highlight the icon, if found. The find screen will also display the search results and allow the user to go to the device, icon or element on the desktop.

- *9. I1 UC 2.20 Find DMS.* A user scrolls and zooms to a particular section of the map, drags over with a mouse and selects a set of DMS. The system automatically displays a list of DMS. The user is able to make a selection of DMS using two types of rubber bands – rectangle and free form. The user is able to find a DMS using the Search/Find Device UC. If the user clicks on a single DMS, a menu is displayed (add message, clear sign, configure DMS, set brightness, poll DMS, etc.).

- *10. I1 UC 3.00 Control DMS.* This is the base UC that provides access to view DMS, add message to one or more DMS, adjust brightness, clear DMS message to one or more DMS, poll DMS and test DMS pixels.

- *11. I1 UC 3.15 View DMS.* The system displays the list of selected DMS. Elements displayed include sign ID/common name, message text, status, last poll time, reminder time, message expiration time, check box. Text of each row (i.e. DMS) will be in a color determined by the status (blue=OK, red=failure, yellow=degraded, maintenance needed, etc.). The system displays buttons to poll DMS, activate message, clear sign, view status, refresh view, etc.

- *12. I1 UC 3.20 Add Message to One or More DMS.* A user may select one or more DMS, type a message, add/remove DMS and send the message. Line and character matrices are supported. Messages have high, medium and low priorities. An override flag is provided. For the administrator, an additional flag allows only other administrators to delete this job (if not yet run). Upon sending a message, the system will prompt the user that "additional/secondary DMS" may need messages. It will display related highways to all DMS that the message was just posted to. Message validation includes: spell check, check for banned words, message length check, and message priority check against current message. Errors generated when trying to post the sign (once accepted by the system) are displayed in the error handling window. Two fonts are provided (standard and compressed).

- *13. I1 UC 3.25 Use Message Library.* Select a stored message when adding a message to one or multiple DMS. Libraries include: chain law messages, amber alert messages, lanes closures, others. A message within a library will have a display order, sequence number, and message priority.

- *14. I1 UC 3.26 Check for Banned Words.* This UC checks for any banned words in the message text before it is submitted to the queue for posting to one or more DMS. All banned words are entered from the DB layer (no GUI access will be provided).

- *15. I1 UC 3.27 Check Spelling.* This UC uses a third party spell checker to verify spellings of words in a message before it is sent to one or more DMS.

- *16. I1 UC 3.30 Adjust Brightness.* This UC allows the operator to adjust brightness on one or more DMS.

- *17. I1 UC 3.40 Clear DMS Message.* A user is able to manually blank one or more DMS using this UC. Upon receiving this task, the system removes the current message on the DMS and displays a blank message.

- *18. I1 UC 3.50 Poll DMS.* The system polls all DMS automatically at a designated time. A user of the system is also able to poll one or more DMS manually at any time to check its status.

- *19. I1 UC 3.51 Text DMS Pixels.* From the poll DMS screen a user can manually execute a pixel test for a particular DMS. The results are populated on the screen and provide the user with a view of pixels that are OK, stuck on, stuck off, etc.

- *20. I1 UC 4.10 Issue Device Instruction.* This UC is used by all other UC that generate instructions (e.g. add message to DMS). This UC defines the business rules around how instructions get inserted into the queue and run. In the event the DMS has a task (message) with a high priority and the new message to be inserted is lower priority, the system will not override the first message (unless override is set to "true"). This event will be logged. In the case of a tie, the newer message replaces the older message.

- *21. I1 UC 4.20 View Device Instruction State.* A user can view all instructions currently in queue and those scheduled to run. Instructions could be a message to be set on a DMS, poll a DMS, adjust brightness, etc. The UC defines the criteria for viewing the jobs (i.e. by status, by time, by user, by device, any filters/sort criteria). The following attributes of an instruction are displayed: device ID, instruction ID, task, start time, priority, status, and owner. The completed, cancelled or failed jobs are not displayed in this view (as they are done).

- *22. I1 UC 4.30 Remove Instruction from Queue.* A user can only cancel their instruction(s) in the queue that are in "pending" state. An administrator can cancel instructions from a user within their security group and is in "pending" state.

- *23. I1 UC 5.00 Manage DMS.* This is the base UC that provides access to manage DMS tasks. Only the administrator and maintenance users will be given access. They will be able to accomplish the following: add DMS, configure communications pool, configure communications port, read from sign, configure DMS and remove DMS.

- *24. I1 UC 5.10 Add DMS.* Only maintenance and administrators can add a new DMS. An add device wizard will walk the user thought the steps required to add the new DMS device. The UC uses the Read from Sign and Configure DMS UC.

- *25. I1 UC 5.11 Configure Communications Pool.* Only an administrator can add, edit or delete a communications pool. A communications pool is a collection of one or more communications ports for accessing devices.

- *26. I1 UC 5.12 Configure Communications Port.* Only an administrator can add or edit a communications port. A communications port is the physical port a device is connected to or accessed by. It cannot be deleted; instead it can only be enabled or disabled. A communications port must be associated with a communications pool in order for it to be used.

- *27. I1 UC 5.20 Read from Sign.* This UC allows for data to be read from a DMS.

- *28. I1 UC 5.30 Configure DMS.* This UC allows maintenance or administrator to get and view sign configuration data. A read from sign function is performed to get latest data. The application saves this information. Some business data (e.g. common name, mile marker, etc.) is changeable in the CTMS database. No data is saved to the sign from this UC (this applies to configuration data). DMS status can be changed between new, maintenance, disabled, active. Data elements that differ in the system when compared to the database are displayed red. Data elements that do not differ are displayed blue.

- *29. I1 UC 5.40 Remove DMS.* An administrator or maintenance can remove a DMS from the system. The DMS status is set to offline. It is not physically deleted from the system. Only DMS that have the status "disabled" can be deleted.

- *30. I1 UC 6.00 View Alarms.* Unacknowledged alarms are broadcast to system users. The following are displayed: alarm type/description; device ID; alarm ID; generated ID; comments; close time; last updated time; owner; status (acknowledged or not). A user can acknowledge an alarm but alarms can only be acknowledged once. Upon acknowledgement, the information is broadcast to other users (so they know who is working on the alarm). View can be filtered/sorted by several columns (owner, status, device ID, and alarm type). At start up all unacknowledged alarms are displayed. At logout, all alarms are cleared from this window. A button to clear all acknowledged alarms from the alarms window is provided.

- *31 I1 UC 6.10 Add Alarm.* When a task fails an alarm is generated. The system auto-creates/broadcasts new alarms.

- *32 I1 UC 7.00 Generate Fax Log.* A user can request the system generate fax logs. The system automatically determines which fax logs to generate based on changes to the state and messages on the DMS since the time of the last report.

- *33 I1 UC 7.10 Generate Equipment Failure Report.* This system-generated report lists DMS in need of service.

- *34 I1 UC 8.10 Log User Activity.* The system logs major user activity and defines steps in logging the data . These include log in; log out; add user; edit user; change password; add message; adjust brightness; blank sign; poll sign; test DMS pixels; remove instruction from queue; add sign; configure communications pool; configure communications port; read from sign; configure sign; remove sign; view alarms; generate fax log,; and generate equipment failure report.

- *35. I1 UC 8.20 View Logged Activity.* User activity logged to the system can be viewed. As new tasks are done and logged, the system broadcasts this information to all CTMS clients.

- *36 I1 UC 9.00 Integrate with Co-Trip Website.* This UC defines the automated processes that inform the Co-Trip website of the current status of the DMS. Additional elements such as DMS status, new, removed and location changes of DMS are incorporated in this interface.

B2 Work Completed in Software Iteration 2

At the conclusion of Iteration 2, Colorado's ATMS/ATIS was able to accomplish the following activities in addition to those listed under Iteration 1. The abbreviated Use Case (UC) abstracts provided are intended to yield a "snapshot" of the system at the conclusion of the first three development phases.

Exhibit B1 – New CTMC Video Wall

As part of the Iteration 2, CDOT enhanced the functionality of some of the earlier core system functions. Items that were improved in Iteration 2 that were previously listed as Use Cases in iteration 1 include the following activities:

- *I1 UC 1.00 Login to System:* support multiple logins.
- *I1 UC 2.00 Navigate Desktop:* adjust client profile.
- *I1 UC 3.15 View DMS:* control and select.
- *I1 UC 3.20 Add Message to One or More DMS:* message expiration; add pixel feedback to editor; if one DMS selected, show current/old message, other leave blank; reminder message is now an alarm.
- *I1 UC 3.30 Adjust Brightness:* add driver for temporary DMS make/model.
- *I1 UC 3.40 Clear DMS Message:* add driver for temporary DMS make/model.
- *I1 UC 3.50 Poll DMS:* add driver for temporary DMS make/model.
- *I1 UC 3.51 Test DMS Pixels:* add pixel legend; add to activate message (show broken pixels).
- *I1 UC 4.10 Issue Device Instruction:* add new instructions.
- *I1 UC 4.20 View Device Instruction Queue:* sort filters; make consistent with current client.
- *I1 UC 5.10 Add DMS:* add driver for temporary DMS make/model.
- *I1 UC 5.11 Configure Communications Pool:* incorporate Manage Communications UC.
- *I1 UC 5.12 Configure Communications Port:* incorporate Manage Communications UC.
- *I1 UC 5.20 Read from Sign:* add driver for temporary DMS make/model.
- *I1 UC 5.30 Configure DMS:* add driver for temporary DMS make/model; adjust various settings.
- *I1 UC 5.40 Remove DMS:* add driver for temporary DMS make/model.
- *I1 UC 6.00 View Alarms:* revise; add filters; make consistent with View Logs and View Instructions.
- *I1 UC 6.10 Add Alarm:* various revisions.
- *I1 UC 7.10 Generate Fax Log:* users can now select the report and which groups to send it to.
- *I1 UC 8.20 View Logged Activity:* add filters.

New Use Cases addressed in Iteration 2 include the following:

- *1. Iteration 2 ("I2") UC 2.30 Status Console.* Defines windows and filters/sorting behavior. This UC is extended by view instruction queue UC, view logs UC, and view alarms UC that contain data element details and broadcast behavior specifics.

- *2. I2 UC 2.83 View Snapshot.* This UC provides the ability for the user to get a quick look at a particular speed node and view the devices on that node or segment. This includes the input and output devices and cameras. Any related routes will be displayed as well. A tabbed view on this window will organize most of this information. A summary map may also be provided.

- *3. I2 UC 2.84 View Routes.* Routes are listed with speed information. Routes are pre-defined. Trip travel time for routes is displayed here. Similar data is displayed under view device UC.

- *4. I2 UC 2.85 View Segments.* Details regarding congestion/volume/speed for the segments are defined here. Similar data is displayed under view device UC.

- *5. I2 UC 2.90 View Device.* Additional devices show up in tabs. Routes, nodes and segments appear in individual tabs.

- *6. I2 UC 2.91 View RTMS.* List of RTMS is provided with detailed speed and congestion data.

- *7. I2 UC 2.92 View Ramp Meter.* List of ramp metering devices is provided with detailed speed and congestion data.

- *8. I2 UC 2.93 View AVI Reader.* View device.

- *9. I2 UC 3.60 Post Trip Travel Time on DMS.* This UC defines frequency and how a Trip Travel time message is automatically posted on a DMS. The following attributes are defined: segment; distances from/to; average speed. The system will post the message automatically on a DMS every 3 minutes. Time range of the messages is as follows: 1] minimum duration < 4 minutes; 2] from 4-20 minutes, use 2 minute ranges; 3] from 20-30 minutes, use 3 minute ranges; and 4] maximum duration > 30 minutes. The UC provides the ability to disable or enable a DMS and to receive and post speed messages. Automated messages are only posted to DMS so configured to receive them. Speed messages are treated separately from user defined messages.

- *10. I2 UC 5.13 Manage Communications.* This UC allows users to access communications pool and communications ports.

- *11. I2 UC 5.14 Add Communications Pool.* This UC allows the user to add a communications pool.

- *12. I2 UC 5.15 Edit Communications Pool.* This UC allows the user to edit an existing communications pool.

- *13. I2 UC 5.16 Add Communications Port.* This UC allows the user to add communications ports.

- *14. I2 UC 5.17 Edit Communications Port.* This UC allows the user to edit existing communications ports.

- *15. I2 UC 5.50 Add RTMS.* This UC defines steps and data needed to add an RTMS (side-fired radar speed reader) device.

- *16. I2 UC 5.51 Configure RTMS.* This UC extends the add device UC. It allows users to configure RTMS including disabling them temporarily. The communications data and business data (such as common name, mile marker, etc.) will be changeable in the CTMS database. The device can be temporarily disabled as well. No device configuration on actual device.

- *17. I2 UC 5.52 Remove RTMS.* Administrator or maintenance can remove a device from the system. The device status is set to offline. It is not physically deleted from the system.

- *18. I2 UC 5.60 Add Ramp Meter.* This UC defines the steps and data elements needed to add a ramp meter.

- *19. I2 UC 5.61 Configure Ramp Meter.* This UC extends the add device UC. It allows users to configure ramp meters including disabling them temporarily. The communications data and business data (such as common name, mile marker, etc.) will be changeable in the CTMS database. The device can be temporarily disabled as well. No device configuration on actual device.

- *20. I2 UC 5.62 Remove Ramp Meter.* Administrator or maintenance can remove a device from the system. The device status is set to offline. It is not physically deleted from the system.

- *21. I2 UC 5.70 Add AVI Reader.* This UC defines the steps and data elements needed to add an AVI (automated vehicle identification or toll tag) reader device.

- *22. I2 UC 5.71 Configure AVI Reader.* This UC extends the add device UC. It allows users to configure AVI readers including disabling them temporarily. The communications data and business data (such as common name, mile marker, etc.) will be changeable in the CTMS database. The device can be temporarily disabled as well. No device configuration on actual device.

- *23. I2 UC 5.72 Remove AVI Reader.* Administrator or maintenance can remove a device from the system. The device status is set to offline. It is not physically deleted from the system.

- *24. I2 UC 9.10 View Speed, Travel Time, Congestion in Co-Trip.* This UC allows the user to view speed information on the web client. This could include point speed, congestion map (by speed, by occupancy) and travel times. This may be similar to the View Snapshot UC.

- *25. I2 UC 10.00 Manage Intelligent Tasks.* This is the base UC for "tasks," i.e. management/deletion of intelligent tasks.

- *26. I2 UC 10.10 Create Intelligent Tasks.* This UC allows the user to save a task.

- *27. I2 UC 10.20 Execute Intelligent Tasks.* This UC allows interactive tasking.

- *28. I2 UC 10.30 Edit Intelligent Tasks.* This UC allows the user to modify a few elements.

- *29. I2 UC 11.00 Reports.* This is a web based solution for up to five reports placed on the web site. Functions include query of the log table for data with available information including device ID, create data, user ID, message, and status.

- *30. I2 UC 20.00 Get Device Data.* This base UC is extended by the device specific data gathering UC. The CTMS gets data from devices or it goes to the specific devices (or interfaces to the devices) and collects the data.

- *31. I2 UC 20.10 Get RTMS Data.* This UC describes RTMS data collection. Three types of connections are supported: 1] directly connecting to the RTMS and requesting poll data (volume, speed, occupancy) from it; 2] getting flat file, database layer or raw data from the T-REX system; and 3] getting data directly from the RTMS and polling via fiber. The CTMS will request RTMS data every 60 seconds directly from the devices. The data collected from the T-REX RTMS will be real-time. For RTMS connected via Smart Box (cell phone), the Smart Box will transmit data to the CTMS every 60 seconds.

- *32. I2 UC 20.15 Poll RTMS.* The system performs a self-test when a problem is indicated within the Get RTMS Data function.

- *33. I2 UC 20.20 Get Ramp Meter Data.* The CTMS will connect to the ramp metering computer and get data through a database layer connection. The CTMS will not connect directly to a loop or ATR for this iteration (as there is currently no device driver developed for this application). Data from the ramp meter system will be collected in real-time.

- *34. I2 UC 20.30 Get AVI Data.* AVI readers will be configured to report collected data every 60 seconds. The CTMS will maintain a direct connection with these devices and receive this information when sent (every 60 seconds).

- *35. I2 UC 20.40 Manage AVI Pairs.* This UC allows the user to manage AVI source and destination pairs. This activity is essential to process AVI matches and calculate travel time / speed for the segments.

- *36. I2 UC 30.00 Process Data.* This set of UC will define the business rules, algorithm and processes required to calculate an estimated speed for roadway segments. It will also define congestion.

- *37. I2 UC 30.10 Calculate Segment Speed.* This UC defines how speed will be calculated (estimated) based on the data input sources. It will define when to use what data (i.e. if the coverage is not 100%) on any segment. The UC will define how often this speed will be calculated and how it is made available for publishing (i.e. to the CTMS application and web servers, etc.). At least 60% of the devices on a segment must be reporting good data for the segment to display a speed. Speed status color codes are red, yellow, green, gray (no data or offline). Speed is calculated every 2 minutes. Speeds are posted to the DMS every 3 minutes. Device specific algorithms and behavior is described in more detail in the UC.

- *38. I2 UC 30.20 Calculate Segment Congestion.* This UC defines how congestion is calculated. The algorithm and what data sets to discard are defined in this UC. Device-specific business rules are described in the UC.

- *39. I2 UC 30.30 Calculate Route Travel Time.* This UC defines the list of routes, attributes and how to calculate speed and travel time based on the zones and segments in each route.

- *40. I2 UC 40.00 Manage Data.* This is the UC that describes how data (mostly speed/travel time information) is handled.

- *41. I2 UC 40.10 Publish Data.* Well defined data elements /structures are made available for access via other systems (say via XML interface). UC also describes making data available for replication on Co-Trip.

- *42. I2 UC 40.20 Archive Data.* The UC defines what data (by task, by device) gets archived and how often this activity occurs. The duration of data in the system as well as the duration of the archived data in the system is defined. The goal is to store archived "report" data to support planning, accountability and other historical needs.

Exhibit B2 – New CTMC; 425C Corporate Circle

- *43. I2 UC 40.30 Create and Publish Reports.* The UC defines all the reports that are going to be available to the users of the CTMS. Any other reports that may be available to the website are defined in this UC. Specifics of data elements, queries and other details (recipients – CTMS users and outside entities) are defined; as are where the reports get published (web, e-mail, etc.) and how often they are created.

- *44. I2 UC 40.40 View Reports.* Pre-defined reports are presented to the user, who can run reports permitted by system security.

B3 Work Completed in Software Iteration 3

At the conclusion of Iteration 3, Colorado's ATMS/ATIS was able to accomplish the following activities in addition to those listed under Iterations 1-2. The abbreviated Use Case (UC) abstracts provided are intended to yield a "snapshot" of the system at the conclusion of the first three development phases. New Use Cases addressed in Iteration 2 include the following:

- *1. Iteration 3("I3") UC 1.00 Manage Events.* This is the base UC that describes the common data elements across all event types and the relationship and behavior of events.

- *2. I3 UC 1.10 Workspace Login.* This UC allows a user to login to the application from a web page. If a user is already logged in and starts the Workspace, the user is automatically logged in and will have to launch the workspace from CTMS.

- *3. I3 UC 1.20 Workspace Logout.* This UC allows a user to log out of the application from a web page. It also defines timeout for a session.

- *4. I3 UC 1.30 Forgot Password.* If a user forgets their password, the system will send them their password, provided they enter their username and e-mail correctly.

- *5. I3 UC 1.40 Add Event Timeline.* This UC adds specific timelines for a given event.

- *6. I3 UC 1.45 Event Action Log.* This UC allows for the logging of actions for a given event. This is meant to mean user activity specific to that event.

- *7. I3 UC 2.01 Navigate Workspace.* This UC defines the working area for users – a tabbed approach for each content type (closures, road weather conditions, road report) will be used. The currently open daily/weekly closures are displayed. All projects pending approval are listed. Functions also included are: create/edit closures (projects), add work orders and get to the search lane closures/projects function.

- *8. I3 UC 2.02 Generate Page Numbers.* This UC defines how page numbers are provided to the user and their behavior (next, previous, first, end, etc.). The UC for Search/Navigate Workspace will use this UC.

- *9. I3 UC 2.10 Add Project.* The list of open projects and the details of particular projects are defined.

- *10. I3 UC 2.20 View Project.* This UC allows a user to view project details including updates.

- *11. I3 UC 2.25 Search Project.* This UC defines basic structured querying that will allow users to search for closures. The query is form based with some free-form input and the results are displayed in html format as well.

- *12. I3 UC 2.28 View Project in CTMS.* A layer is provided showing the various open (in the system) lane closures. The user clicks on a closure and the CTMS client will display a detailed version of the view project UC. The View device UC will display the list view of the projects selected. Refer to the UC for view project and view work order for details.

- *13. I3 UC 2.30 Edit Project.* This function allows a user to edit an existing project.

- *14. I3 UC 2.40 Approve Project.* A created project is approved through this UC.

- *15. I3 UC 2.50 Reject Project.* A created project can be rejected through this UC. If rejected, an e-mail will be sent to the project creator and the project will be physically deleted.

- *16. I3 UC 2.60 Close Project.* The user is allowed to manually close a current (open, hold, other states) project. When a project reaches is expiration date/time, the system will close it as well.

- *17. I3 UC 2.70 Add Project Work Update.* The user can add a new work order to a project. By default, when a project is created, a work order is created for it. Lane closure information is placed here.

- *18. I3 UC 2.75 Edit Project Work Update.* This UC allow s the user to edit or delete an existing work order.

- *19. I3 UC 2.80 View Reports.* Predefined detailed reports (all templates) can be viewed and printed. Projects are listed by highway in each report.

- *20. I3 UC 2.81 Fax Reports.* This UC allows the user to manually select and send a report to a fax group. Development of this UC has been deferred until Iteration 4.

- *21. I3 UC 2.82 E-mail Reports.* This UC allows the user to manually select and send a report to an e-mail group. The intent is to allow the user to develop or obtain a PDF version of the report as an attachment to a distribution list. Development of this UC has been deferred until Iteration 4.

- *22. I3 UC 3.01 View Courtesy Patrol (CP) Incidents.* This UC allows the system to show open/waiting to clear CP incidents.

- *23. I3 UC 3.10 Add CP Incident.* This UC creates a CP incident.

- *24. I3 UC 3.25 Search CP Incidents.* The user can search for CP incidents.

- *25. I3 UC 3.28 View CP Incidents in CTMS.* Not-cleared CP incidents are displayed on the map in CTMS.

- *26. I3 UC 3.30 Edit CP Incident.* The user may update data related to a CP incident except for creation time and incident ID.

- *27. I3 UC 3.40 Manage Cross Road.* This UC allows the system to list all known cross roads and their intersecting highways. Users are allowed to add, delete or edit crossroads.

- *28. I3 UC 3.41 Add Cross Road.* The user may add a cross road (related to known highways).

- *29. I3 UC 3.42 Edit / Delete Cross Road.* This UC allows a user to edit or delete a cross road.

- *30. I3 UC 3.80 View CP Reports.* The user has access to predefined CP reports.
- *31. I4 UC 2.10 View Closure.* This UC describes how the user views the closures workspace.
- *32. I4 UC 2.20 Add Closure.* The user may add a road closure.
- *33. I3 UC 5.90 Add Off Ramp Detector (ORD).* The user may add an ORD to the CTMS.
- *34. I3 UC 5.91 Configure ORD.* The UC allows the user to configure an ORD device (only the view in the CTMS).
- *35. I3 UC 5.92 Remove ORD.* The UC describes how an ORD may be removed.
- *36. I3 UC 5.93 Get ORD Data.* The user may obtain data from an ORD device.
- *37. I3 UC 5.95 View ORD.* The user may view data from an ORD.
- *38. I3 UC 6.10 Control Blank Out Sign.* The user may turn the display on or off for a given blank-out sign.
- *39. I3 UC 7.10 View Camera Tour.* The user may view available cameras "tours" and related routes.

Exhibit B3 – Building Sign above Entryway

End Appendix B