TRAFFIC OPERATIONS CENTER FACILITIES

Intelligent Vehicle-Highway Systems

Denver Metro Area

Project IVH-MP 9108(1)

for the
COLORADO DEPARTMENT OF TRANSPORTATION

C-STAR

December 1992

by:
CENTENNIAL ENGINEERING, INC.
CASTLE ROCK CONSULTANTS
IBI GROUP
ABO ARCHITECTS

Denver Metro Area Traffic Operations Center

TRAFFIC OPERATIONS CENTER FACILITIES

United States, Canada, United Kingdom, Japan

Task 2 - Review State-of-the Art Facilities

Technical Memorandum #2

for the
COLORADO DEPARTMENT OF TRANSPORTATION
Project IVH-MP 9 I08(I)

December 1992

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LIST OF ACRONYMS / ABBREVIATIONS

AA	Automobile Association (UK)
AAS	Arterial Advisory Signs
ADOT	Arizona Department of Transportation
AMTICS	Advanced Mobile Traffic Information and Communications System
APID	All Purpose Incident Detection
ATIS	Advanced Traveler Information Systems
ATMS	Advanted Traffic Management Systems
BBC	British Broadcasting Corporation
BT	British Telecom
Caltrans	California Department of Transportation
CCTV	Closed Circuit Television
CDOT	Colorado Department of Transportation
CFP	Cyclic Flow Profile
CHP	California Highway Patrol
CITRAC	Centrally Integrated Traffic Control Motorway Control System
CMS	Changeable Message Sign
CSP	Colorado State Patrol
CTMS	Gardiner-Lake Shore Corridor Traffic Mangement System
EICS	External Interface Communications System
FSK	Frequency Shift Keying
FTMS	Freeway Traffic Management System
HAR	Highway Advisory Radio
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITCC	Integrated Traffic Control Center
IVHS	Intelligent Vehicle Highway Systems
LCS	Lane Control Signs
MSU	Motorway Signalling Unit
MTO	Ministry of Transportation of Ontario
OIC	Operations Information Center
OTU	Out Station Unit
RAC	Royal Automobile Club
RACS	Road Automobile Communcations System
RDS	Radio Data System
SCATS	Sydney Coordinated Adaptive Traffic System
SCOOT	Split Cycle and Offset Optimization Technique
SRC	Stathclyde Regional Council
TBU	Terminal Branch Unit
TCC	Tunnel Control Center
TMC	Traffic Message Channel
TMS	Traffic Management System

LIST OF ACRONYMS / ABBREVIATIONS

TMT	Traffic Management Team
TOC	Traffic Operations Center
TRANSCOM	Transportation Operations Coordinating Committee
TRRL	Transport and Road Research Laboratory
TSCS	Traffic Signal Control System
TSR	Traffic Situation Room
UTC	Urban Traffic Control
VDOT	Virginia Department of Transportation
VDS	Vehicle Detector Station
VDU	Visual Display Unit
VICS	Vehicle Information Communication System
VLS	Vehicle Locator System
VMS	Variable Message Sign

1.0 EXECUTIVE SUMMARY

This document examines functions, operations, organizational structures, floor layouts and institutional relationships provided by existing traffic operations centers (TOCs) in the United States, Canada, the United Kingdom and Japan. The purpose of this activity is to identify those design features achieving success, or lack thereof, at existing TOCs, incorporate the positive design variables, and eliminate the negatives, thereby benefitting the Denver area TOC design based on the experiences of operating centers.

Details concerning other TOCs' functions, responsibilities and provisions are provided to yield an understanding of how these facilities operate and what they aim to accomplish. Within subsequent sections of this document, each center's system will be compared to the operational needs and conceptual design criteria developed for the Denver TOC. These sections will identify key areas in which to examine the need and feasibility of implementing specific TOC functions in the Denver area. Since many of these centers' activities concentrate on efforts similar in nature to those of the Denver TOC, issues pertaining to their implementation and operation can be considered within the framework of the Denver TOC design. Desirable aspects of each facility will be assessed for inclusion within the Denver TOC, while those characteristics which are undesirable or not applicable will be rejected.

Chapters 2 through 5 of the text compare seven centers in the United States, two in Canada, four systems in the United Kingdom, and a general state-of-the-art discussion of Japanese centers. Two adaptive traffic control technologies are also discussed in Chapter 6. Appendix A contains the written results of a survey sent to the operators of four TOCs in the United States and Appendix B contains design drawings and floor plans from an additional five centers.

The following conclusions and recommendations for the Denver TOC are condensed from those presented in the text.

- Care should be taken in selecting the TOC building to ensure that the range of functions is not compromised by building structure. The most flexible approach would be to construct a new building to house the Denver TOC.

- Staff organization charts showing intenelationships, and proximity charts showing spacing and adjacency relationships between rooms are a good basis for designing preliminary blocking/stacking layouts.

- Ergonomic aspects of room functionality should be considered in control room layout including viewing angles and distances, acoustics, lighting, and workstation placement for effective communication.

- Graphical User Interfaces eliminate the need for two terminals (one text and one color graphics), thereby reducing the workstation equipment and serving to focus operator attention. Console equipment can also be consolidated by combining multiple computer systems to be accessed through a single terminal, incorporating video outputs into the operator interface screens, and streamlining video switching/camera control equipment by placing it flat on the console surface close at hand to the operator.

- Operator screens should be flexible and user friendly. The minimization of free-form data entry, use of pop-up menus for assistance and data specification, use of symbolism and schematic details within the graphics screens to assist in location referencing all would contribute to achieve these end results.

- Control room equipment must support functions performed by Colorado State Patrol (CSP) and Colorado Department of Transportation (CDOT), and therefore is required to present information to operators in a clear, easily comprehensible manner, and facilitate accurate and meaningful response. Some equipment such as CCTV monitors may be used simultaneously and independently for CSP and CDOT functions. It is important that the equipment is designed such that it is accessible to all users requiring it, subject to the rules of user protocol.

- Computer-to-computer links should exist between Advanced Traffic Management System (ATMS) and Advanced Traveler Information System (ATIS) functions. This will improve overall system efficiency, timeliness and accuracy.

- The BBC Travel Center is electronically linked with radio broadcast stations, police and other agencies. The Denver area TOC should include a similar electronic communications network to facilitate information sharing. The TRIS system in Ontario utilizes significant involvement with radio stations and their requirements for wording conventions and information formats.

- Several of the systems evaluated use automated faxing to disseminate information.

- The Los Angeles TOC has an incident management team and a pre-established strategy for dealing with major incidents. The incident management team provides emergency support and coordination during severe highway incidents. A similar program has been recommended for the Denver area TOC and is expected to include preplanned diversion routes.

- Several of the centers provide teletext information services to major office buildings and other outlets in the respective areas. A similar service could be advantageous to the Denver area, especially considering the adverse weather often encountered in the region. Teletext initiatives, whether interfaced with cable television or not, should be interfaced with the TOC.

- The Los Angeles TOC, among others, has served as a test bed for new technologies and transportation demonstrations. Illustrative of this is its involvement in the Pathfinder and Smart Corridor IVHS efforts. A similar role is envisioned for the Denver area TOC in support of advanced IVHS initiatives.

- The TRANSCOM project in New York/New Jersey demonstrates successful inter-jurisdictional cooperation and information sharing, a critical component of the Denver area TOC.

- The Orange County center demonstrates high levels of cooperation between the California Highway Patrol and Caltrans, increasing the effectiveness of incident management and information transfer. CDOT and CSP should strive to achieve these levels of cooperation in the Denver area center.

- There are several excellent examples detailing private sector participation in operations centers, most notably in Westchester County, New York and the Trafficmaster system in London. If the private sector is allowed to participate in the operation of the Denver area TOC, clear guidelines for such an involvement need to be developed well ahead of implementation.

Clearly, there are many variables which will ultimately need to be applied to the design of the Denver area TOC. The descriptions provided in the text are provided in an attempt to focus the reader's attention on those variables which may be the most critical.

2.0 UNITED STATES FACILITIES

2.1 Colorado Tunnel Control Centers

2.1.1. Introduction

The Colorado Department of Transportation (CDOT) currently operates two major tunnel control centers (TCCs) on I-70 west of Denver. These support the Eisenhower/Johnson Memorial Tunnels at the continental divide, and the Hanging Lakes Tunnels in Glenwood Canyon. The Eisenhower Tunnel currently supports a reversible lane operation (3 lanes eastbound, 1 lane westbound) which is initiated on weekend evenings during the ski season and on holiday weekend evenings throughout the year.

Tunnel control centers are similar to TOCs in two respects. First, they serve to collect traffic data and other relevant information for review at the control center facility. In the case of a TOC, this concerns the surrounding metropolitan area, while a TCC addresses the tunnel itself and the approaching highway sections. Second, in both cases the collected data are used as the basis for the selection and initiation of traffic management strategies. These may include, for example, incident detection, emergency vehicle dispatching, adjustment of traffic control devices and dissemination of traveler information.

These similarities between TOCs and TCCs highlight the merit of including analyses of the latter in approaching the design of the former. Lessons learned in areas such as data collection and management at tunnels may be equally applicable in metropolitan areas. In addition, examination of Colorado's two main TCCs is important in the Denver Metro Area TOC program, since all three facilities will ultimately form part of an interconnected traffic operations network. Review of the TCCs' facilities and capabilities will also provide consideration of an appropriate communications interface with the Denver TOC, which is to be undertaken as part of Task 11 of this design effort.

2.1.2 Eisenhower/Johnson Memorial Tunnels

The Eisenhower/Johnson Memorial Tunnels and associated control center were opened in 1973. The systems and approaches used at the facility largely reflect the technology of that time. Significant emphasis is placed on human involvement in the tunnel control activities, rather than automated techniques. The following sections provide an overview of the system with respect to data collection, control center features, information dissemination, and data communications.

<u>Data Collection</u> - The Eisenhower/Johnson Tunnels are 1.7 miles in length, with each tunnel divided into eleven 800-foot zones. Data collection within the tunnel is primarily undertaken on a zone-by-zone basis. Each zone contains one inductive loop per lane. These are used to count the number of vehicles passing through the tunnel. Since only single loops are used, the equipment cannot be used to measure vehicle speeds.

Each zone of each tunnel also contains a CCTV camera. One of the end zones contains two cameras to accommodate a bend in the tunnels. In addition, four CCTV cameras are used to provide coverage of the I-70 tunnel approach sections. These were originally installed for identification of placarded loads. However, CDOT tunnel personnel indicated they are most useful for identifying congestion.

All of the CCTV cameras provide color images. Tunnel personnel showed a clear preference for this option over black and white equipment. For monitoring within the tunnel, all but one of the cameras are connected back to the control center through wire link. Only one camera is currently connected using fiber optic cable, however, this will be increased in the future. Images from cameras outside of the tunnels on the I-70 approach sections are relayed back to the control center using microwave transmissions.

A third form of data collection within the tunnels concerns air quality monitoring. Carbon monoxide levels are measured at seven points in the tunnels. Data from these sensors are used to determine when the tunnel fans should be activated.

Outside of the tunnels, modulated infrared overheight sensors are used on the I-70 approach sections. These are installed one-quarter mile and one-half mile from the tunnel entrances. If the first overheight sensor is triggered, a neon exit sign is illuminated. In the event that an overheight vehicle continues to the second detector, a siren and red stop lights are activated.

Beyond these overheight sensors, there is no formal data collection for I-70 outside of the tunnels. However, the control center periodically receives weather advisories from external sources.

<u>Control Center Features</u> - A principal feature of the Eisenhower/Johnson TCC is a bank of television screens, used to display images from the CCTV cameras. Twenty-four screens are dedicated to the cameras within the tunnel. The screens are arranged in the same order as the cameras in the tunnel. Above these are two split screen televisions, used to display images from the cameras on the I-70 approach sections. The quality of these images is poor due to degradation of the microwave signal.

Beneath these televisions are a series of control panels. Each panel provides control and monitoring features for the eastbound and westbound sections of a single zone. Included within these panels are light displays which indicate lane occupancy status. If the inductive loop data reveal stopped traffic, a red light is activated. However, tunnel control personnel noted that loop inaccuracies or failures often lead to unnecessary red light warnings. Therefore, manual observation using the CCTV system is the main technique used to monitor traffic in the tunnels.

Other features of the control panels include preset message board buttons and posted speed buttons. For the message boards, twelve preset messages can be selected from the control panel. Originally, these were the only available message options. However, a system upgrade in 1987 introduced a microprocessor-based system with a menu of 50 messages, selectable by an operator. In addition, other messages can be typed into the system when required. Only the facility supervisor has the authority to generate new messages in this way.

The control center contains little in the area of data storage facilities. Traffic count data from the inductive loop system, for example, are printed out but are not retained in a computer file. However, this facility is expected to be introduced in the next system upgrade.

The system operators perform functions similar to those anticipated for the Denver TOC facility. These include monitoring traffic conditions, via both CCTV displays and inductive loop-based warnings, and setting message boards. The operators are also responsible for adjusting tunnel ventilation and addressing overheight truck incidences.

Information Dissemination - Information dissemination addresses provision of data to both travelers and public agencies associated with tunnel operations. The approaches used in each of these areas are outlined below.

For travelers, information is provided using message boards. Inside the tunnels, one message board is installed in each zone in the direction of travel. In addition, the westbound tunnel contains three message boards which face eastbound traffic. This supports the facility's reversible lane operations. The message boards use lamp matrix displays and were originally supplied by Winkomatic. However, the equipment has now been customized by CDOT's tunnel control personnel, and is maintained entirely in-house.

Beyond these in-tunnel message boards, the TCC is responsible for six variable message signs (VMSs) at various locations on I-70, between Denver and Vail. These are used to display traffic advisories and weather information. A telephone modem connection from the TCC is used to set the VMS displays.

For communication between tunnel personnel, two radio channels are used. An FM channel is used around the TCC facility and allows good communications within the tunnel. For communications on the tunnel approach sections, a UHF channel is used.

Written emergency response procedures are in place outlining roles and responsibilities in the event of a severe incident. If coordination with other groups is required, tunnel personnel contact agencies such as CDOT Region 1 dispatch in Aurora or Colorado State Patrol (CSP) using a telephone connection.

Data Communications - Although the State of Colorado owns and operates an extensive microwave communications network, the Eisenhower/Johnson TCC is not currently linked into the system. Phone lines are therefore used as the primary communications method. However, Division of Telecommunications personnel indicated that a microwave link to the tunnels is being considered, at an estimated cost of $150,000-200,000. The proposal is to use the microwave system to link telephone switchboards at Denver, Glenwood Canyon Hanging Lakes Tunnels, and Eisenhower/ Johnson

Memorial Tunnels through a Tl industry standard connection. This will simplify voice communications, and will also allow high-speed data transfer, for example compressed video images at 15-30 frames per second.

2.1.3 Hanging Lakes Tunnels

The Hanging Lakes Tunnels have recently been opened to accommodate the newly-constructed section of I-70 that runs through Glenwood Canyon, east of Glenwood Springs. The control center for these tunnels is also a new facility and contains a number of advanced elements. Details of the facility's dam collection systems, control center features, information dissemination options, and data communication capabilities are described below.

Data Collection - Like the Eisenhower/Johnson Memorial Tunnels, the Hanging Lakes Tunnels are divided into zones. Data collection is addressed on a zone-by-zone basis.

Dual inductive loop configurations are used inside the tunnels. The use of dual loops allows for calculation of vehicle speeds and lengths, as well as counting and occupancy detection. The loops are also used as the basis for automatic incident detection.

A second form of data collection involves CCTV cameras. Forty-three cameras are installed along the tunnels and approach sections, each with pan, tilt and zoom capability. Black and white video equipment was selected for this facility. Control center operators indicated the following reasons for this choice:

- Black and white viewing was felt to be better for the operators' eyes.
- Cameras are more durable.
- Night vision is better in black and white.

It should be noted that these statements, particularly concerning night vision performance, contradict feedback received on CCTV options at other facilities. In general, color equipment has been preferred.

In addition to inductive loops and CCTV cameras, carbon monoxide sensors are installed in the tunnels to measure air quality. Wind measurement sensors are also used in the tunnels.

Control Center Features - The physical layout of the Hanging Lakes TCC is similar to that at the Eisenhower/Johnson Memorial Tunnels. However, the systems used at the Hanging Lakes facility are significantly more advanced, reflecting their more recent design and implementation.

For reviewing CCTV images, a bank of televisions is installed in front of the operators' consoles. This comprises eighteen television screens, which is significantly less than the number of CCTV cameras in the system. Therefore, unless otherwise specified, a single screen will present images from several cameras, showing each image for a few seconds before moving to the adjacent camera.

The control system contains an incident detection algorithm based on the inductive loop dam. The opening of a door within the tunnel is also considered an incident. Detection of an incident causes a light to blink in the control center, corresponding to the closest CCTV camera. If there is more than one incident, the system is capable of queuing up the appropriate cameras so they can be reviewed in turn by the operators. Incident detection is semiautomatic, in that a suspected incident is identified by the system but must be confirmed by an operator.

The main features of the control system run on a VAX 4000 computer. This uses a layered operating system, controlling all features except operator interface. Operators interact with the system via DEC workstations using Windows software.

The computer system includes history software capable of storing processed data on tunnel operations. Tunnel personnel indicated that this is flexible in terms of the data that can be directed into storage files. Examples given included carbon monoxide readings, inductive loop-based data and system alarms.

Responsibilities of the system operators are again similar to those that may be found in a TOC. The operators' tasks include confirmation of incidents, monitoring CCTV screens, controlling CCTV cameras and coordinating incident response and maintenance activities. The operators also set messages on the system's CMS and VMS units, either by selecting options from a menu or typing free-form text.

Information Dissemination - The primary method used to disseminate information to travelers in the Glenwood Canyon area is message displays using VMS and changeable message sign (CMS) equipment. The system controls 20 VMS units and 20 CMS units, all of which are light emitting diode-based, manufactured by Solari. The VMS displays can be selected from a menu or generated by typing text into a computer. The CMS units can display only a limited number of preprogrammed messages.

In addition to this equipment, AM and FM radio antennas run throughout the length of the tunnels. These allow continued reception of radio broadcasts while vehicles are in the tunnel, and can therefore be used for emergency messages. PM radio also supports in-house communications, including maintenance coordination and district-wide car-to-car communication, as well as serving as a repeater for CSP.

Data Communications - The Hanging Lakes TCC is already connected into Colorado's microwave communications network, with the capability to operate eight Tl connections. The facility is linked to the Sunlight Peak station, which is part of the main Denver-Grand Junction connection. The connection to Sunlight Peak is through a channel in the 18 GHz band, capable of carrying the equivalent of 96 voice channels. Division of Communications personnel indicated that there is significant spare capacity in this link.

2.1.4 Tunnel-TOC Connections

The potential for interconnecting the Denver TOC with the two major TCCs on I-70 involves consideration of two major issues. First, what data are to be sent between these locations? Second, what communications facilities are already in place, and what additional links will be required to support this exchange of data? These questions are addressed briefly below.

With regard to data sharing, the goal should be to provide data from one facility to another only when those data are required at the receiving location. Some situations in which this could be the case include the following:

- Information on a tunnel blockage or congestion could be disseminated to adjacent control centers as the basis for travel advisories, allowing travelers more time to consider alternative options.
- Following clearance of a tunnel blockage, the adjacent control centers could be advised to expect a period of heavy traffic.
- Information on harsh weather conditions experienced at one location could be disseminated to others to support advisory messages and precautionary action.
- In the longer-term, responsibiity for monitoring and support functions, such as providing ATIS data, could be passed from one facility to the next as vehicles move along the highway. This concept is analogous to current air traffic control operations.

In the area of communications, a significant opportunity lies in the potential for use of the statewide microwave communications network. As outlined earlier, the Hanging Lakes facility is already linked into this system, while a microwave connection for the Eisenhower/Johnson facility is being considered. If this link is implemented, both centers would be connected into the main Grand Junction-Denver microwave route. This is currently being upgraded to a digital channel in the 6 GHz band, capable of carrying the equivalent of 596 voice channels.

In Denver, the main microwave station is located at CDOT Headquarters. The system here is also being upgraded from analog to digital. This will provide 28 Tl connections for data, video images and voice communications. Division of Telecommunications personnel indicated that significant spare capacity would be available in this system.

2.2 Los Angeles Traffic Operations Center

2.2.1 Introduction

The Los Angeles Traffic Operations Center (TOC) was opened in 1971 to introduce traffic surveillance and traffic management techniques to 42 miles of freeway in downtown Los Angeles. Today, the Los Angeles TOC's coverage has grown to cover the freeway network in all of Los Angeles County and part of Ventura County. The TOC utilizes advanced technologies in traffic surveillance, computer graphics and interagency communications to provide incident management and real-time congestion information.

2.2.2 TOC Operations

The Los Angeles TOC is promoted by its operators as one of the most sophisticated in th country. The TOC monitors over 264 freeway miles in the region. The TOC is managed and staffed by the California Department of Transportation (Caltrans) and provides traffic information to the California Highway Patrol (CHP), the media and directly to specially-equipped vehicles.

The TOC has implemented an incident detection and traffic management team to respond to nonrecurrent freeway congestion. It maintains an interface with the media to provide up-to-the-minute traffic reports to the public. The TOC also participated in an experiment to test the feasibility of utilizing two-way communications between the facility and equipped vehicles to monitor traffic flow and to provide real-time information to motorists. The TOC is additionally involved in a demonstration project to provide teletext traffic information to television monitors located in the lobbies of major downtown office buildings.

The Los Angeles TOC and CHP have sought to develop a strategy to rapidly detect and respond to incidents while managing the resulting congestion. When a report of a major traffic incident is received at the TOC, the traffic management team verifies the situation using the electronic surveillance and communications systems. Once an incident is verified and its severity is established, the response team proceeds with a predetermined incident management plan.

If the incident is determined to be severe enough to close two or more lanes of traffic, the TOC's Major Incident Traffic Management Team is dispatched to the site. This is comprised of CHP officers and TOC engineers. The team dispatches other emergency response agencies such as the fire department or paramedics and closes the necessary lanes of travel. The team also places changeable message signs and detour signs in key locations, while the TOC operators inform the media and provide continuous updates on the situation.

The TOC is currently preparing for a major traffic management demonstration along the Santa Monica Freeway in 1993. This demonstration will incorporate the technologies demonstrated in the Pathfinder project, which introduced in-vehicle highway navigation and motorist information systems as a means of monitoring traffic flow and providing traffic advisories. In the Pathfinder demonstration, 25 vehicles were equipped with digital mapping and two-way communications devices. The TOC obtained traffic data from the vehicles and relayed current traffic conditions back to the vehicles. The Smart Corridor demonstration will utilize these technologies in conjunction with other TOC surveillance and information systems to provide more efficient incident detection and improved traveler information.

2.2.3 Data Collection

The primary sources of data for the TOC are inductive loop sensors an CCTV . Basic d traffic flow information is gathered by in-pavement loop detectors located on both the freeway ramps and at half-mile intervals along the freeway system. These sensors count and determine the average speed of vehicles on the roadway. Field microcomputers collect these data and transfer them to the TOC computer via telephone lines.

The CCTV cameras are used to visually verify and assess the severity of incidents. The TOC has 12 CCTV cameras along the Santa Monica Freeway, one on the four-level interchange in downtown Los Angeles, one on the east Los Angeles interchange, and one on the Hollywood Freeway. The cameras constantly survey specific segments of the freeway.

The TOC utilizes a wall-sized electronic map of the region's freeway network to visually display information from the sensors. The map uses colored lights to represent traffic speeds at corresponding freeway locations. Average speeds higher than 35 mph light up in green, speeds of 25-35 mph light up in yellow and speeds below 20 mph light up in red. A flashing red light -indicates a potential incident.

When the display map shows a potential incident, TOC operators feed the information into the computer This researches the traffic conditions for the past few minutes and displays a detailed report. Traffic engineers analyze the data and pinpoint the locations where incidents have occurred.

2.2.4 Data Dissemination

The TOC disseminates traffic information to the public via commercial radio broadcasts, changeable message signs and highway advisory radio. The TOC provides traffi reports to radio stations and agencies such as Metro Traffic and LA Network (which in turn supply further broadcast media). Recent traffic reports are sent via a teletype network The TOC provides regular congestion information during rush hours and major incidents. The TOC also provides information summarizing road or lane closures for construction or maintenance. Figure 2.1 illustrates the communications network of the Los Angeles TOC.

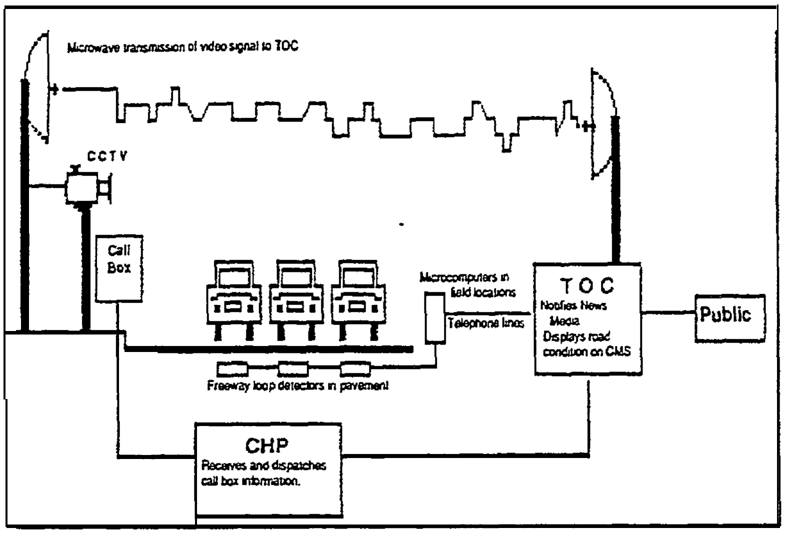


Figure 2.1 Los Angeles TOC Communications Network

The TOC operates 47 ground-mounted changeable message signs. These are located at strategic points on various freeways throughout the system. The signs are used to communicate appropriate traffic advisories indicating traffic conditions ahead. The TOC also provides information to a highway advisory radio (HAR) station that is operational on the Ventura Freeway.

The TOC's computer system contains graphics capabilities which recreate the wall-sized map display and depicts which messages are being displayed on the changeable message signs. An overview of the freeway network can be accessed on the monitors, and close-up views of traffic conditions can be accessed by computer mouse control. TOC operators can simultaneously monitor traffic conditions and changeable message signs, updating the signs based on current traffic conditions.

2.2.5 Summary

Based on this review of the Los Angeles TOC, the following issues are of interest in the design of the Denver Metro facility:

- The Los Angeles TOC has an incident management team and a pre-established strategy for dealing with major incidents. The incident management team provides emergency support and coordination during severe highway incidents. A similar program is recommended for the Denver TOC, and is expected to include preplanned diversion routes.

- The Los Angeles TOC has served as a test bed for new technologies and transportation demonstrations. Illustrative of this is its involvement in the Pathfinder and Smart Corridor efforts A similar role is envisioned for the Denver Metro Area TOC in support of advanced IVHS initiatives.

- The Los Angeles TOC provides a commuter teletext information service to major office buildings in the region. A similar service would be advantageous to the Denver Metro Area, especially considering the adverse effects of weather in the region. This is expected to be achieved through teletext and cable TV initiatives throughout the Metro Area, interfaced with the Denver TOC.

- The Los Angeles TOC's wall-sized electronic map is not representative of the technology anticipated for the Denver Metro Area TOC. A projection screen system or similar approach, capable of presenting computer-generated dynamic images as well as CCTV pictures, is preferred.

2.3 New York/New Jersey TRANSCOM

2.3.1 Introduction

The Transportation Operations Coordinating Committee (TRANSCOM) is a coalition of fourteen transportation and traffic enforcement agencies in the New York/New Jersey metropolitan area. TRANSCOM was founded to establish a focal point for interagency communication of transportation information that affects the entire region. The

TRANSCOM Operations Information Center (OIC) is at the heart of the interagency network

2.3.2 Overview

TRANSCOM'S coverage comprises a 500-square-mile area which spans the most heavily traveled roads in the New York/New Jersey area. The primary function of TRANSCOM is to coordinate information among the various agencies in the network. The TRANSCOM network encompasses state and local transportation agencies as well as transit operators, county and local police, and the media.

TRANSCOM is staffed and funded by the member agencies. The OIC relies on information from the member agencies to assess potential and ongoing traffic problems. The facility assimilates traffic information from the member agencies and utilizes a network of cameras installed at key locations to track traffic incidents and conditions on major tunnels, bridges and highways in the region.

2.3.3 Operations Information Center

The TRANSCOM OIC receives messages from over 90 agencies concerning incidents on the roadway and transit facilities in the region. It then relays that information to all agencies affected by the particular incident OIC staff members update information on existing incidents and continue to provide information until the incident has been cleared.

The TRANSCOM OIC has three primary program areas:

- Interagency notifications.
- Interagency incident management planning.
- Construction coordination.

Interagency notification is the primary responsibility of the TRANSCOM OIC. Once information is received concerning an incident or construction activity that has an impact on traffic, an OIC operator inputs this information into a database and initiates the appropriate agency notification. This notification is achieved via telephone and an alphanumeric pager network. The OIC information notification system provides emergency response requests, travel advisories and routing information. The OIC also provides weather advisories and has developed a special snow and ice emergency information network. This disseminates instantaneous notifications of reported hazards and provides hourly updates of maintenance treatments.

TRANSCOM has developed an interagency incident management planning program aimed at providing the fastest response to incidents that cause traffic delays. The program has outlined a preplanned, preapproved response to emergency situations. The incident management plan spells out detailed actions to be taken to handle traffic when a major incident closes part or all of a section of highway. An incident management plan is put together for various sections of highways and lists preapproved detour routes, road restrictions and police posts. These preapproved incident management plans are believed to significantly reduce the emergency response time for major highway incidents.

The New York/New Jersey metropolitan region roadways are continuously undergoing maintenance and repairs. TRANSCOM has developed a program of construction coordination, in which agencies responsible for construction and maintenance provide the OIC with advanced information of road repair activities. The OIC reviews all the road maintenance information and identifies instances in which two or more scheduled maintenance projects will cause alternate route roadways to be closed simultaneously. The information is also disseminated to other agencies which are affected by the activities, and is input into the incident management planning computer.

2.3.4 Data Collection and Dissemination

The TRANSCOM OIC receives messages from over 90 agencies via voice communications and its alphanumeric pager network. The primary source of incident information is police dispatch services. There are seven police agencies that preside over the TRANSCOM service area. Their dispatchers receive information from forces in the field as well as from 911 emergency calls from cellular phone users. These agencies dispatch police officers to the site and then notify the OIC. The field officers provide incident update and clearance messages to the dispatcher, who in turn communicates with the OIC. The OIC disseminates this information to other emergency response agencies or any TRANSCOM member agency affected by the incident.

The OIC is also equipped with television screens connected to video cameras at key locations along the highway. OIC operators undertake frequent observation of traffic flow on sections of the roadway which are subject to recurring congestion. This information is used in conjunction with the incident information to obtain an overall picture of the traffic environment.

The OIC communicates relevant traffic information to the public via media sources and variable message signs. TRANSCOM has a cooperative agreement with four independent traffic services. In combination, these provide access to over 70 radio stations and three television stations, as well as airborne and ground-based data collection facilities.

The OIC is also equipped to receive information from secondary dispatcher sources. New Jersey Transit buses are equipped with two-way radios and are in constant communications with their dispatcher. The dispatcher receives traffic information from the drivers and communicates it to the OIC. Conversely, the OIC directs traffic data to New Jersey Transit for relay to the drivers.

2.3.5 Summary

The following issues are of interest in the development of the Denver Metro TOC:

- TRANSCOM provides essential transportation services in the New York/New Jersey metropolitan area The most noticeable accomplishment of the TRANSCOM coalition has been to cut through the interjurisdictional red tape between agencies in the region. TRANSCOM provides a means of sharing information between all agencies concerned with traffic in the region. While this is not expected to be the primary function of the

TOC, it will certainly be an important one. To support this, a protocol of information needs should be developed and information should be disseminated based on this established protocol.

- TRANSCOM has also taken important steps in coordinating incident management tactics. However, in most instances the TRANSCOM OIC receives emergency information from a secondary source. In incident management situations, every second counts. The Denver Metro Area TOC should therefore seek to establish interjurisdictional procedures that minimize the time lag associated with incident reporting.

- The large coverage area of the TRANSCOM OIC is thought to reduce the effectiveness of the operation. In particular, incident information that is received and distributed could be more regionalized. Motorists are often required to listen to general information broadcasts when only a fraction of the information they receive is relevant. The Denver Metro TOC should therefore consider dissemination techniques that can provide motorists with selective information.

2.4 Northern Virginia Traffic Management System

2.4.1 Introduction

The Virginia Department of Transportation (VDOT)Traffic Management System (TMS) concentrates its operations within the Northern Virginia and Washington, D.C. region. The TMS services not only Virginia workers, but also D.C. commuter traffic. Approximately 40,000 vehicles travel from Virginia to Washington, D.C. every hour during the morning peak period.The goal of the VDOT TMS is to ensure the most efficient use of the three major interstate highways in the Northern Virginia region.

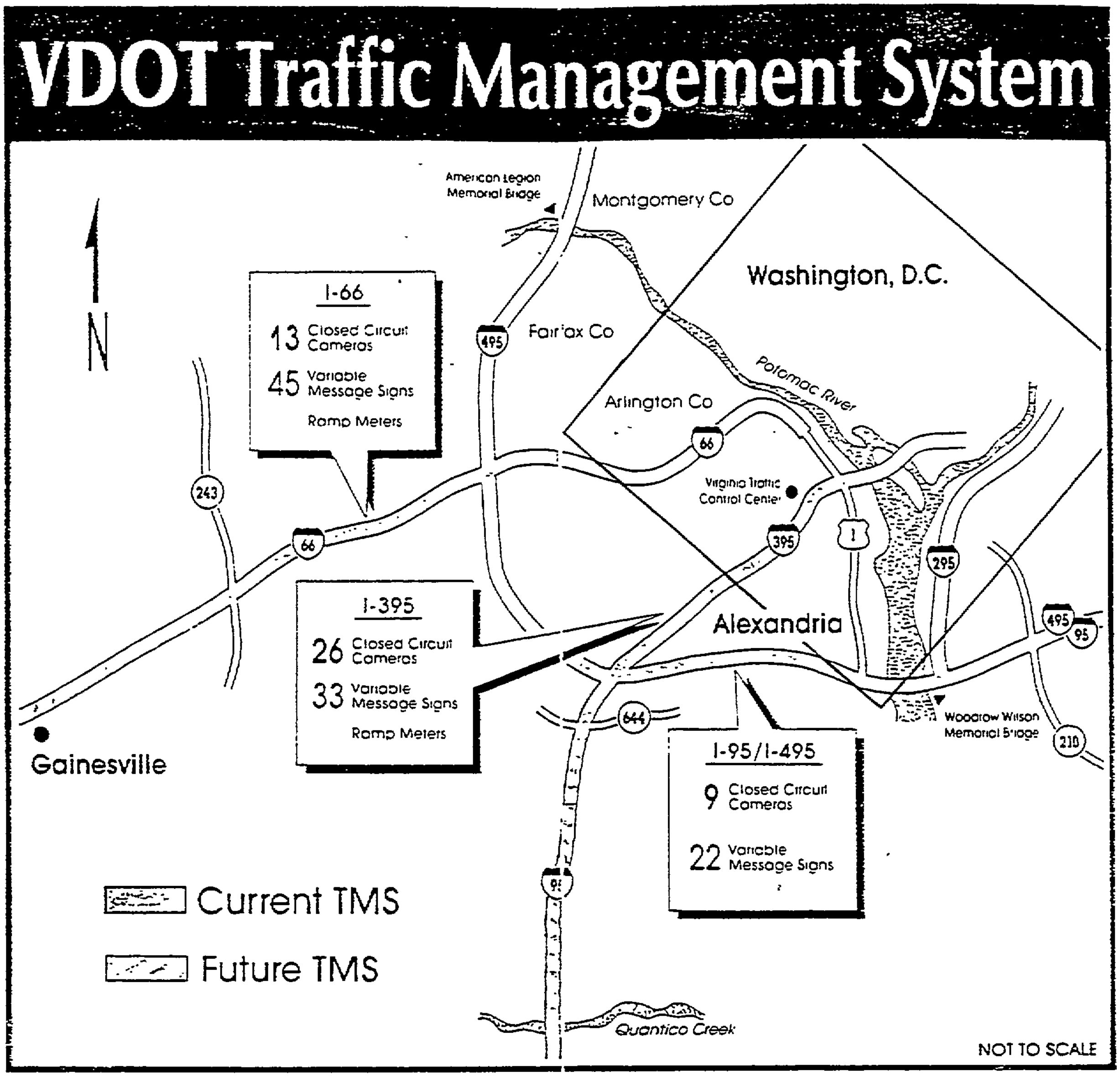
2.4.2 TMS Operations

The VDOT TMS provides computerized highway surveillance and traffic management control on 30 miles of interstate highways along I-395, I-495 and I-66. The TMS aims to achieve an efficient utilization of the interstates by detecting and helping to clear accidents or disabled vehicles and by smoothing traffic flow. The current and future TMS coverage area is illustrated in Figure 2.2.

The TMS provides early detection of incidents on the highway and alerts the appropriate emergency response agencies or tow truck services. The TMS also seeks to maintain traffic conditions through ramp metering control. Contact with VDOT's Safety Service Patrol and the State Police is maintained by the TMS to exchange relevant follow-up information. In addition, TMS operators provide traffic broadcasters with congestion updates and incident information.

Figure 2.2

VDOT TMS Coverage Area



The TMS utilizes 100 VMS units to disseminate information to motorists. These provide drivers with information regarding specific traffic conditions in the downstream highway sections. The TMS also communicates to motorists through commercial broadcast services. This includes continuous traffic information during peak travel times to radio stations and to private sector traffic information services.

2.4.4 Summary

The following issues concerning the VDOT TMS are of interest in the development of the Denver Metro Area TOC.

- The VDOT TMS does not appear to have an incident management strategy for major incidents. This is expected to be an important component of the Denver Metro Area TOC's operations.

- The VDOT TMS has a bank of TV monitors to observe traffic conditions and verify incidents. This does not seem to be the most efficient way of monitoring traffic. The Denver Metro Area TOC is seen as using graphical displays that highlight congested areas and identify the corresponding CCTV camera. This should help to reduce repetitive tasks, allowing operators to concentrate on other duties.

- The VDOT TMS relies heavily on VMS technology for information dissemination. However, experience has indicated that traffic information presented is sometimes out of date. The Denver Metro Area should include appropriate cancellation times and operator reconfirmation requirements to avoid this problem.

2.5 Orange County Traffic Operations Center

2.5.1 Introduction

The Orange County Traffic Operations Center is a joint operation between Caltrans and the California Highway Patrol (CHP). The TOC monitors the traffic flow of area highways and identifies incidents that cause traffic congestion or safety hazards. TOC operators evaluate traffic conditions and relay information to appropriate response agencies and motorists.

2.5.2 System Overview

The Orange County TOC monitors approximately 150 miles of road and more than 200 entrance ramps onto state highways. The TOC centralizes traffic information from a variety of agencies in the area. System computers continually monitor traffic flow on the highway network and identify irregular patterns of traffic which may indicate an incident. The TOC is also responsible for alerting the appropriate incident response agencies to potential incidents and for providing this information to the media.

The Orange County TOC utilizes speed detection technologies and graphical displays to identify potential mad hazards. The TOC is currently in the process of adding CCTV imaging technology to verify sensor reading and to visually monitor incidents.

Information received by the TOC is used by CHP and media broadcasters to assist in incident management and to provide motorists with advanced warnings of incidents.

2.5.3 Data Collection

Inductive loop vehicle detectors serve as the primary source of traffic information collected at the TOC. These loop detectors are in-pavement units located at half-mile intervals along the Orange County highway network. The TOC computer uses loop detectors to monitor the number and speed of vehicles on the highway. This information is displayed to the TOC operator on a graphics monitor which indicates varying speeds by presenting different colors on a map display. When a nontypical speed is detected, the computer issues a potential incident warning to the operator. TOC operators also receive incident information from law enforcement officers, media traffic reporters, highway workers and motorists with cellular phones. Cellular phone calls are made initially to CHP with appropriate information relayed to the TOC.

The TOC is currently in the process of extending its capabilities by adding CCTV cameras along the most heavily used routes of the highway network. The TOC has also begun work with the cities of Anaheim and Irvine, the University of California at Irvine, and California Polytechnic State University, San Luis Obispo, to extend the TOC's operating area to include arterial roads. The initiative will develop and test several systems aimed at collecting real-time traffic information and relaying it to motorists.

2.5.4 TOC Operations

The TOC has formed a Traffic Management Team (TMT) which responds to major incidents on the roadway. The TMT dispatches portable changeable message signs to incident sites, providing motorists with advanced warnings of lane closures or detours. The TOC also serves as the traffic information center for the region. In this capacity, the TOC receives and reports traffic information to CHP, the media, highway construction and maintenance crews, and the public. CHP maintains a dispatch presence at the TOC and continually provides the TOC with traffic information.

The TOC also provides broadcast agencies with periodic traffic information during rush hours or when major incidents occur. In addition, the TOC communicates directly to motorists through a highway advisory radio (HAR) station.

The Orange County TOC utilizes a Vehicle Locator System (VLS) to dispatch the nearest response vehicle to an incident. The VLS tracks the location of approximately 80 CHP patrol cars and 11 Caltrans vehicles. When an incident is detected the TMT can use this system to dispatch the nearest vehicle, providing support as soon as possible and helping to restore the normal flow of traffic.

2.5.5 Summary

The following issues concerning the Orange County TOC are of interest in the development of the Denver Metro Area TOC:

- The cooperation between CHP and the TOC is seen as an essential element in increasing the effectiveness of incident management and information. This supports the intent of the Denver facility to house both traffic and police resources. The Denver Metro Area TOC should also combine efforts with highway patrol and other incident response agencies to provide efficient incident response actions.

- The Orange County TOC's VLS helps to ensure the most effective response to incidents. A similar approach should be considered in the development of the Denver Metro Area TOC's incident management services.

- The Orange County facility uses HAR as one method of communicating with motorists. It is recommended that the Denver TOC should similarly operate a direct link with the HAR system, so that messages can be updated in near real-time.

- The use of portable changeable message signs in Orange County serves to support incident response activities. In the Denver Metro Area, computer systems could be used to determine the most appropriate temporary locations and messages for such resources.

- The Orange County TOC is engaged in research initiatives, in conjunction with universities and local jurisdictions, aimed at developing and testing new traffic data collection technologies. It is recommended that the Denver Metro Area TOC participate in similar efforts, potentially leading to new approaches meeting the region's unique needs.

2.6 Phoenix Freeway Management System

2.6.1 Introduction

The Arizona Department of Transportation (ADOT) has recently completed the preliminary design of a comprehensive Freeway Management System for the Greater Phoenix Area. Although coverage varies by element, the ultimate system is expected to cover some 300 route miles of urban/suburban freeways.

The current system is limited to the operation of some 35 ramp metering stations and 14 variable message signs. Wider scale implementation of the system is expected to begin in early 1993 with construction along approximately 30 miles of freeway. The control center building has been constructed and is now occupied, and it is anticipated that delivery of the computer hardware and initial software development activities will also commence in early 1993. ADOT also operates a tunnel control system along a portion of Interstate 10 which includes vehicle detection and closed circuit television camera monitoring. The central control facility, currently located at the tunnel, is expected to be relocated to the new ADOT control center by early 1993.

2.6.2 Traffic Management System

The current system is relatively limited, consisting of some 35 ramp metering stations and 14 variable message signs. The ramp metering stations utilize standard inductive loop detectors and the Model 179 rather than the Model 170 controller.

There are three types of variable message signs currently used in the system, consisting of eight flip disk type signs, four shuttered fiber optic signs, and two light emitting diode signs. Discussions with ADOT Traffic Operations staff suggested that they were most pleased with the shuttered fiber optic signs as they provided the brightest, most consistent display. The light emitting diode signs have performed well, however they sometimes suffer from color consistency and visibility problems. Both types of light emitting signs are preferred over the older flip disk ones which are no longer being considered for future applications. Specifications have been generated for new variable message signs and cover light emitting diode, shuttered fiber optic, and combination fiber/flip disk. Vendors bidding on the upcoming system expansion can propose any one of these three technologies.

In addition to the variable message signs, the immediate system expansion will include the following Traffic Management System elements:

- Inductive loop detector stations (179-based).
- Color closed circuit television cameras.
- Additional ramp metering stations.
- Interfaces to pumping stations.
- A fiber optic communications backbone.
- Operator consoles and video display equipment at the control center.

It should be noted that for the last point, computer hardware and software will not be supplied as part of the field construction contract. Instead, procurement is being undertaken separately by ADOT for the central computer hardware, central computer software, and video wall control software. Similarly, software for the Model 179 controllers used in the detector and ramp metering stations will be undertaken as a separate project.

The proposed communications system will be a fiber optic distributed node system utilizing a fully redundant counter rotating ring. Like Toronto's COMPASS system, the "ring" will be formed by installing conduit and cable on either side of the freeway, cross linking as appropriate to provide the redundant path. The decision to design a fully redundant system was a policy decision made by ADOT Traffic Operations staff based on their assessment of acceptable system loss and downtime in the event of a major cable break. It should be noted, however, that the cost of field system implementation increases significantly because of the need to trench down both sides of the freeway. This has caused some concern among ADOT's Urban Highways Division which is responsible for programming and constructing the field works.

2.6.3 Incident Response and External Interfaces

Because the current system does not include wide scale monitoring capabilities, ADOT does not presently perform incident detection and management on a real-time basis. Should a report of an incident be received by ADOT Traffic Operations staff, it is verbally passed on to the Department of Public Safety (Police) who assume responsibility for dispatching the appropriate emergency or service vehicles. In the event of a major incident, the on-site officer has the option of requesting that ADOT dispatch an incident response team to manage traffic in the immediate vicinity of the incident. In this case, a major incident is identified as one that will block at least one lane for a minimum period of one hour.

Wider scale distribution of traffic information to the public or other agencies (particularly the media) is not currently performed by the ADOT Traffic Operations staff. ADOT does maintain a Department of Public Information which is responsible for liaising with the media and other agencies, and discussions are currently underway between. Traffic Operations staff, the Public Information Department and these agencies to enhance information reporting and distribution. Enhanced or automatic information dissemination tools and techniques have not been identified as one of the early stages in the deployment of ADOT's new system. Because of funding constraints, overall system implementation has been staged over a period of time, and it is expected that such enhanced traffic information facilities will not be available for another five to ten years. Discussions with ADOT Traffic Operations staff have indicated that they would have preferred these facilities to be provided earlier, but did not have the authority to adjust the implementation program.

The new control center will include a radio dispatch console for communicating with ADOT employees in the field. Originally a separate room adjacent to the main control room had been identified for the location of this console. Current indications are that because of the small room size and need to more effectively integrate the operation of this facility with the remainder of the system, this console will be moved into the main control room and the allocated room used either for storage, kitchen or as a small office.

Highway Advisory Radio was also identified as a potential information dissemination medium. It is not clear at this point how such a system will be implemented and operated.

2.6.4 System Architecture and Software Development

The central computer system architecture will consist primarily of Sun Spare Station 10 workstations and Spare Station 490 servers connected via an Ethernet local area network. Multiple 490's will be used as communications processors to handle communications between the various field data devices and Ethernet network. Because this task is not expected to unduly load these processors, they will also be used to perform incident detection once a suitable algorithm is defmed and coded. A single, separate 490 is used as a central database processor. All system functions, with the exception of video monitoring, will be performed by the operator using the workstation. The video monitoring will be done through a separate display screen.

Control of selected system elements, notably the variable message sign system, as well as camera control and information dissemination, is expected to be performed by separate master processors. These units will be connected to the Ethernet for interfacing to both the Spare Station 10 workstations and 490 field communications processors. However, at this point it is not anticipated that the 490 database processor or any other computer will act in a supervisory function over the separate masters; operators must therefore manually implement responses for each of these separately controlled subsystems.

Procurement of the computer hardware is expected in early 1993. Once delivered and installed, it is expected that software development will focus on establishing procedures, developing modules, and testing. This will likely occur over a period of approximately one to two years, and will act as a precursor to full system software development which will occur over the following one to two years. The implications are that it will probably be 1996 or 1997 before the central computer system is fully operational.

2.6.5 Control Center

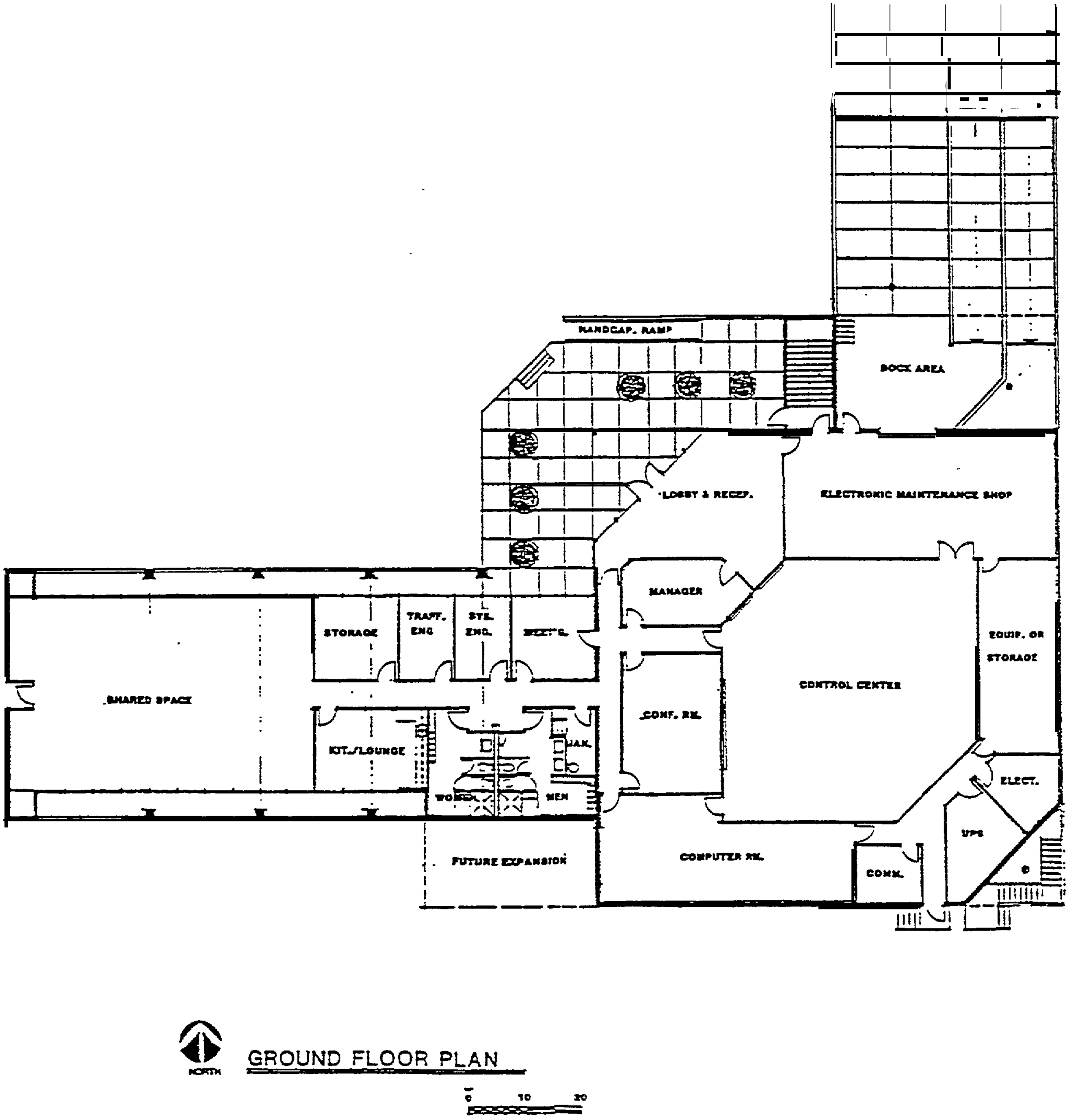
The floor plan for the new Traffic Operations Center at 2302 West Durango in Phoenix is illustrated in Figure 2.3. Equipment installation in the new facility is expected to begin in early 1993 as part of both the field construction contract and computer system equipment procurement. The facility is very attractive and highly functional. The primary control center operational area is approximately 7,000 sq. ft. and includes the following:

- Control room.
- Conference and emergency operations center directly adjacent and with viewing provided to the control room.
- Computer room.
- Electrical room.
- Uninterrupted power supply and back-up generator.
- Cable entry room.
- Electronic equipment room.
- Maintenance shop.
- Manager's office.
- Miscellaneous circulation.

There was also an additional 3,700 sq. ft. allocated for offices and general work space and 7,000 sq. ft. for basement storage.

Figure 2.3

Phoenix Traffic Operations Center Floor Plan



Discussions with Traffic Operations staff have indicated that while they are pleased with the design and layout of the new control center, there are a few areas that could have been improved upon in the design. The control room does not contain any staff facilities such as washrooms or a kitchenette. This requires that operations staff wishing to use these facilities must exit the control room and walk back into the general office space. Some retrofit work will probably be done by Traffic Operations staff to install a small kitchenette in order to minimize the time that operators are away from their posts.

One other concern was the location of the computer room. Although directly adjacent to the control room, it is separated by three moms from the electronic equipment area. Because of the need to provide a fire rated corridor between these rooms, no provisions were included in the original design for either conduit or a raised connecting floor between the two. Modifications had to be made during construction to the walls to allow cables to be routed through them between the computer room and electronic equipment room. However, this routing is rather awkward and requires that all cables must run through the control room with the attendant penalty of additional cost and installation effort.

A Halon fire extinguisher system has been installed in all moms with electrical/electronic equipment. In order to maintain compatibility with local fire codes, provisions must be included for automatic door closure and room sealing in the event of a fire. Originally this was to be done by providing electromagnetic door stops that would allow access doors to remain open during normal operations, but close automatically in the event of a tire. To reduce construction costs, a decision was made to eliminate these door stops and have all access doors closed at all times. Although this meets fire code requirements, it makes access for moving equipment in and out difficult since there is no means to prop the access doors open.

The operator consoles are fairly conventional systems furniture which have the display equipment built into a raised section on the back half of the console. Although functional and attractive, some concern was expressed by the Traffic Operations staff that this type of arrangement is somewhat inflexible and does not allow easy reconfiguration of the computer equipment to provide additional desk work space. Discussions with staff have indicated that a flat console treatment with the computers mounted under desk and monitors mounted on swing arms would be a desirable alternative.

Each operator console is expected to have two monitors; one for the workstation and the other as a detail CCTV monitor. There will also be a video wall used to display both system graphics and live video images. This video wall will consist of three major modules, a 4 W x 4 H matrix of 37” television screens in the center, flanked on either side by two matrices of 2 W x 4 H 37” monitors for CCTV display. This center display section is expected to include intelligent control to allow graphics images to be distributed across the screens as appropriate. It is not, however, planned to provide that same image spreading capability for the live video feeds.

Staffing for the new control center has yet to be finalized. The center is expected to operate on a 24 hour a day, seven day a week basis and be manned at all times. Total staff on duty at any one time is expected to be between 1 and 14, which includes the system manger, various traffic and systems engineers and technicians, system operators and clerical staff. Primary coverage is expected to be during the daytime peak periods from approximately 7:00 a.m. to 6:00 p.m.

2.6.6 Institutional Issues

Because the project is in its early stages, the majority of the institutional issues have revolved around internal coordination between ADOT divisions and departments. The four key agencies within ADOT are:

- Traffic Operations staff, responsible for the operation of the entire system;
- Urban Highways Division, responsible for the preparation of detailed design documents and implementation and administration of construction contracts;
- Purchasing Department, responsible for sole source procurement or procurement of specialized items such as the computer hardware which would not be practical under the standard competitive bid process;
- Engineering Consulting Services, which is responsible for the administration of consultant contracts.

This organization, as well as the responsibilities of the constituent agencies, was developed primarily for, and has been most successful with, the design and implementation of conventional civil engineering projects. Some concerns were raised by the Traffic Operations staff that this organization may not be the most appropriate for the design and implementation of high technology, multi-disciplinary projects such as a freeway management system. By example, the standard construction bid and award process has been found to be somewhat problematic in that ADOT does not have direct control over subcontractor vendors providing specific pieces of equipment. All contact must be through the general prime contractor who may or may not have the expertise and desire to effectively deal with issues related to specific system elements. Traffic Operations staff also indicated a desire to work more closely with the Urban Highways Division to help define the implementation schedule, consultant/contractor scope of work, etc. Some concern was raised that the current contracting and coordination process does not adequately meet the needs of this type of system.

Procurement of the computer hardware was originally to have been done through the standard competitive bid process. However, when the bid was issued, only one response was received. Because at least two responses are required under the competitive bid process, the lone bid received was rejected. Recognizing that there was only a single source for the computer hardware and in an effort to expedite equipment procurement, Traffic Operations staff then requested that the computer system be procured directly through the Purchasing Office. This is now being done and delivery of the majority of the computer hardware is expected by early 1993. Unfortunately, it has taken almost two years for this to occur which has significantly delayed the implementation of the central computer system.

Discussions with Traffic Operations Systems staff have indicated that they would prefer to have more direct control over all aspects of system implementation from preliminary design and staging development through to detailed design, equipment installation and integration. Under the current arrangements, the control center building, variable message signs, field hardware and selected central control elements, computer hardware and software are all being procured under different contracts using different procedures. No one contractor is responsible for overall system integration, consequently this responsibility will revert to the Traffic Operations staff.

The assignment of responsibility to the various procurement agencies has also made it difficult for Traffic Operations to increase their staffing level, since they have little direct involvement at this point in implementing the system. Senior operations personnel recognize the importance of having new staff brought in during the design and implementation stages, so that they can become fully familiar with all aspects of the system design and operation. This allows ADOT to have much more control of the overall system implementation and also provides them with the level of knowledge necessary to operate, maintain and upgrade the system without relying exclusively on the original system designers.

2.6.7 Summary

The Phoenix Freeway Management System promises to be an effective, modem system. The concepts and technologies used are similar to those of most current Freeway Management Systems operational elsewhere.

Based on this review of the Phoenix Freeway Management System, the following conclusions can be drawn for consideration in the design of the Denver TOC.

- Interjurisdictional issues between the various departments and divisions within ADOT have been of concern. Resolution of these issues has resulted in system implementation delays of one to two years. ADOT Traffic Operations staff is currently discussing alternatives with the other divisions and departments to help ensure that this does not occur in the future.

- Recognizmg current trends in central computer system development, ADOT is pursuing a distributed system architecture approach which will allow for easiest future expansion or enhancement.

2.7 Westchester County (NY) Commuter Central

2.7.1 Introduction

The recent CDOT TOC tour to New York and Toronto was originally planned to include a visit to the new traffic facility in Westchester County, NY. This element of the trip was cancelled because the center was in the process of opening and was therefore unable to accommodate the visit. However, a brief overview of the facility has subsequently been developed through conversations with the operator. The key aspect of interest, with regard to the Denver TOC, is the fact that the Westchester County center is operated by a private firm, serving both public and private clients. Further details are provided below.

2.7.2 System Overview

The Westchester County service is operated by a private firm, Metro Networks, which is affiliated with Metro Traffic Control. The name Commuter Central has recently been applied to the service. Westchester County is directly north of New York City. The area developed largely as a commuter community, but now includes several large companies in its own right.

The Commuter Central operation includes both public and private elements. On the public side, Commuter Central acts as a clearinghouse for information sharing between a number of agencies. These include 43 Police departments, Westchester County DOT, New York State DOT, Westchester County Department of Public Works, the TRANSCOM multi-agency group, and the local transit operator. Information is received from and provided to each of these groups. Metro Networks' staff indicated that Commuter Central does not address incident management, since this area is felt to be more appropriate for public sector responsibility.

With regard to private activities, Commuter Central seeks commercial markets for the collected data. This involves selling the data to companies, and potentially to individual motorists.

2.7.3 Control Center

The Commuter Central Control Center is a 1,200-square-feet office, configured largely as open space. It houses a large console with three working stations. Each console includes a telephone, Macintosh computer, and police radio scanner. There are also two 2-way radio units for general use, such as communications with the traffic surveillance aircraft or mobile units. A room adjacent to the Control Center is used for conferences and meetings.

2.7.4 Data Collection

The Commuter Central system collects data from a variety of sources. These include the following:

- A fixed-wing aircraft, operating for three hours during the morning peak and three hours during the evening peak.
- Mobile units owned by Metro Networks.
- Mobile units owned by other firms which provide information to Metro through cooperative agreements.
- Monitoring of radio scanners for police, fire, emergency, and medical data.
- Weather information from a commercial weather service.
- Airline and rail services data.

The Commuter Central facility is also linked to Metro's New York City Operations Center using the firm's proprietary INSTATRACK system. This allows Westchester to receive data on other locations which may be of interest, such as the tri-state area. In addition, Metro's New York facility operates a cellular dial-in system (*JAM) through an arrangement with NYNEX, and is considering a similar service in Westchester.

2.7.5 Data Dissemination

Data dissemination from Commuter Central is primarily achieved through Metro's INSTATRACK system. This uses a computer modem link to provide formatted data to the participating public agencies and subscribing firms. The customer views the data either on a computer screen, using appropriate display software, or through a teleprinter. The INSTATRACK system can be operated from each of the work stations in the Control Center.

2.7.6 Staffing

Commuter Central is currently staffed from 5:00 a.m. to 10:00 p.m. Metro Network's staff report that demand for information is currently drawn mostly from the private sector customers, requiring only daytime operations. However, the facility could function 24 hours per day, if necessary.

During its hours of operation, the facility is staffed by a minimum of one person, with two or three staff members in peak periods. Metro Networks has allocated six members of its staff to Commuter Central in total. This is soon to be supplemented with a Westchester County employee, who will be responsible for addressing interagency coordination and incident management.

2.7.7 Funding

The operation of the Commuter Central service is funded primarily by the private sector. No tax dollars are used to support the venture. Public agencies receive data free of charge, while private customers are charged for information.

Metro Networks was selected for provision of this service through an RFP process. The workscope for this effort was quite open, inviting firms to describe their proposals for service provision and funding approach. Three firms bid for the opportunity to implement and operate the Westchester County facility.

2.7.8 Summary

Based on this review of the Westchester County Commuter Central Service, the following conclusions can be drawn for consideration in the design of the Denver TOC:

- The private sector is unlikely to be suitable for activities such as interagency coordination and incident management. Public employees will need to be provided for these areas, regardless of the functions addressed by a private operator.

- A private sector operator must be capable of making a reasonable profit. Some ATIS or ATMS services which are considered desirable in the Denver Metro Area may not have immediate profit-making potential.

- If CDOT wishes to proceed with some form of officially-sanctioned private involvement in the TOC, a bid process will be required. In any case, firms that are not selected through this bid process will likely continue to offer independent traffic services. The question of private firms' rights to access data collected by public agencies arises again here.

- There is a clear distinction between the approach utilized in INFORM, where the private operator is paid by the public sector, and Westchester County, where the private operator seeks to recoup its costs through selling information. Both techniques can be considered for suitability in the Denver TOC.

3.0 CANADIAN FACILITIES

3.1 Metro Toronto Integrated Traffic Control Center

3.1.1 Introduction

The Municipality of Meto is proceeding with the construction of an Integrated Traffic Control Center (ITCC). A contract for major building renovations was awarded in December 1991, leading to occupancy in March 1993. It is expected that the consolidation of various traffic functions will improve the overall management and effectiveness of the transportation network throughout Metropolitan Toronto.

An integrated traffic control center is a unique concept, which presents special challenges in developing a design that fulfills the functional and operational requirements of the individual components, while promoting synergy of the collective elements. The approach taken involved formulating spatial requirements and proximity relationships to enhance the functionality of the ITCC and to allow for efficient day-to-day operations. In addition, the ergonomic aspects of the layout were carefully considered, to ensure an effective and comfortable working environment.

The major ITCC user groups are:

- ***Gardiner-Lake Shore Corridor Traffic Management System.*** The Gardiner-Lake Shore Corridor Traffic Management System (CTMS) will monitor and manage traffic flow along the Gardiner Expressway through Metropolitan Toronto, and along Lake Shore Boulevard, a parallel signalized arterial. The CTMS, which is scheduled to commence preliminary operations in July 1993, will make extensive use of traffic monitoring equipment and motorist information devices to improve traffic flow within the corridor. All of the CTMS equipment will be operated from the Integrated Traffic Control Center.

- ***Traffic Signal Control System.*** The Traffic Signal Control System (TSCS) operates approximately 1,700 traffic signals throughout the Metropolitan Toronto area. In addition to standard time-of-day computerized operation, TSCS has embarked on several initiatives to enhance system operation (e.g. traffic responsive signal timing).

- ***Traffic Situation Room.*** The Traffic Situation Room (TSR) will serve as a clearinghouse for traffic information throughout Metropolitan Toronto, consolidating incoming information, relaying it to the appropriate Transportation Department sections for response, and disseminating it in a standardized format to external agencies. The role of the TSR will include the development of traffic strategies for both scheduled events (e.g. construction, special events) and unscheduled events {e.g. major incidents, emergency situations). The TSR will rely on close communication and coordination with the CTMS, TSCS, Metro Transportation Maintenance, Metro Police, Toronto Transit Commission and other emergency/transportation services.

All three components require space for control functions and control support functions (i.e. housing and maintaining computer and communications equipment). In addition to control, effective integration must address office support functions for the three major user groups and other Transportation Department users.

Since the Integrated Traffic Control Center is not yet operational, it is not possible in this review to provide comments, based on actual ITCC experience, on aspects which have performed successfully and which should be avoided. However, the Traffic Operations Center (TOC) for the Denver Metropolitan Area can benefit from parallel processes for developing the ITCC and its component systems, which in turn have taken into account experiences of many diverse existing systems.

3.1.2 Advanced Traffic Management Systems Functions

3.1.2.1 TRAFFIC DATA COLLECTION

Induction Loop Detection - Induction loops were recommended for vehicle detection on the Gardiner-Lake Shore CTMS, due to their versatility, proven performance, equipment availability, and relatively low cost. Volume, occupancy and speed data may be obtained from paired induction loops, which are most appropriate for mainline freeways. Single loops, which provide only volume and occupancy data, are best suited to arterial traffic. Double loops have been installed on the Gardiner Expressway, and a combination of single and double loops on Lake Shore Boulevard and ramps in the corridor.

For the Gardiner Expressway, 600 meters was determined to be the optimal spacing for vehicle detector stations (VDS's). However, due to the restrictions imposed by the geometrics of the roadway, the presence of egress/ingress ramps and weaving sections, a consistent 600 meter spacing is not possible. As a result, the maximum VDS spacing is 700 meters while the minimum is just under 400 meters, and the average is approximately 500 meters.

On Lake Shore Boulevard, vehicle detectors were placed primarily for the purposes of queue detection, but every other station will have speed detection capability. Vehicle detectors were placed approximately 150 meters upstream of stop bars at signalized intersections, with additional detectors within these spans where spacing exceeds 800 meters. The maximum VDS spacing on Lake Shore Boulevard is 800 meters, while the minimum is approximately 250 meters, and the average approximately 450 meters.

In addition, the Traffic Signal Control Section is implementing a SCOOT (Split Cycle and Offset Optimization Technique) demonstration system for real-time adaptive traffic control. SCOOT also relies on induction loops, which are installed downstream of intersections in the SCOOT network. The Metro Toronto SCOOT system is further described in Section 2.2 of this review, and in the review that specifically addresses SCOOT systems.

Video Detection - A video vehicle detection system (likely Autoscope-2003) will be used at the Humber Bridges area, at the west end of the Gardiner-Lake Shore Corridor. This system will supplement the CTMS induction loop detectors in other parts of the corridor, and provide an opportunity for testing a local application of the video detection system. The Humber Bridges area is particularly suited to alternative detection technologies, since long term reconstruction of six bridges will result in repeated destruction of the road-bed, and therefore induction loops would not be practical. Two cameras for video vehicle detection will be installed on the structure of a nearby high-rise hotel.

Autoscope- is a wide-area vehicle detection system which uses video imaging to replace induction loops in multiple lanes and multiple directions of traffic. It accepts inputs from cameras overlooking the roadway, and the detectors are drawn graphically on a video monitor using a mouse. Different types of detectors can be selected, and the detection zones may be placed anywhere and in any orientation within the combined field of view of the cameras.

Various data are available through the Autoscope- system, for example:

- Vehicle presence.
- Vehicle passage.
- Vehicle speed.
- Flow rate.
- Volume and occupancy.
- Headway over time.
- Types of vehicles (e.g. automobiles, single-unit trucks, tractor trailers).

For the CTMS application, data which is most compatible with the induction loop detector data from other parts of the corridor will be collected and monitored.

Detection Algorithms

Incident Detection: Induction loop detectors are wired to a central computer subsystem, where incidents are identified to operators through so-called incident detection algorithms. In actuality, only the effect of an incident (i.e. the turbulence in traffic) can be detected by this system.

The following two algorithms were selected to provide incident detection along the Gardiner Expressway:

- All-Purpose Incident Detection (APID) Algorithm.
- McMaster Single Station Algorithm.

Incident detection on Lake Shore Blvd. is also required. Since an arterial incident detection algorithm has, to date, not been fully developed and evaluated, an existing algorithm will not be used on Lake Shore Boulevard. Instead, arterial detector data will be monitored, and simple comparisons between the observed variables and preset thresholds at each Vehicle Detection Station (VDS) will be made. When the variables exceed the thresholds, a congestion alarm will be sent to the CTMS operator.

Queue Detection: Traffic disturbance patterns caused by queues are distinct enough from those caused by incidents to warrant queue detection algorithms which are separate from incident detection algorithms. Therefore, two queue monitoring algorithms, are proposed for the Gardiner-Lake Shore CTMS. One of these detection algorithms reads in occupancy values for VDS's and compares them to preset threshold occupancies, determining the presence of a queue upstream or downstream of a given VDS. The other is an extension of the McMaster incident detection algorithm. This algorithm identifies congested VDS's and then determines whether the cause is recurrent congestion or an incident.

<u>CCTV Monitoring</u> - The CCTV camera subsystem is a valuable tool for unscheduled event detection, even though the main purpose of CCTV cameras is to confirm events detected by other means. Operator detection is generally the primary mode of incident detection during light-to-moderate traffic conditions, for which the existing incident detection algorithms are less effective.

Full color camera coverage will be available only on the Gardiner Expressway; however, substantial coverage (approximately 80 percent) will be available on Lake Shore Boulevard, and portions of several arterials will be viewable as well. The CCTV subsystem will provide an important source for event detection on Lake Shore Boulevard, at least until a more sophisticated arterial loop detection algorithm can be developed and implemented. CCTV cameras are spaced approximately lkm apart.

In addition to the conventional CTMS cameras, high-mounted overview cameras will be located at two locations overlooking the corridor:

- CN Tower (in conjunction with a local television station), located at the center of the corridor, and providing views of the entire corridor;

- Humber Bridges, mounted 45 stories high on the structure of a hotel in the west end of the corridor, and providing views of the west half of the corridor.

The Traffic Signal Control Section is also using CCTV cameras at isolated intersections to monitor signal timing plans. When the TSCS becomes more of a control oriented operation, CCTV monitoring of key intersections is expected to play an important role in arterial traffic control and incident management. The

TSCS control area in the Integrated Traffic Control Center can accommodate eight to sixteen CCTV monitors arranged in two to four columns.

Traffic Data Collection Summary: In terms of traffic data collection, the following points are relevant to the Denver TOC:

- While induction loop detectors have the benefits of the longest operational experience and proven performance, it is useful to integrate various new detection technologies as demonstration projects, to test how they operate in local applications;

- A high degree of integration and coordination between freeway and urban arterial traffic data collection will provide synergistic benefits to both types of systems;

- Queue detection, estimation and tracking should be considered for the Denver TOC. The extent of queue is of major interest to motorists, since it defines available diversion exits and entrances. Similarly, it is an integral part of radio traffic reports. In addition, the extent of queue is a data item that is required for deriving other information, e.g. accurate network link travel times, identified as a short-term ATMS initiative for the Denver TOC.

- Integration of overview cameras into the CCTV monitoring system would provide information on continuity of traffic conditions.

3.1.2.2 REAL-TIME TRAFFIC CONTROL

Changeable Message Signs - For the Gardiner-Lake Shore CTMS, Changeable Message Signs (CMS's) are the most effective means of providing unscheduled event information in real-time, to motorists already on the facility. Therefore, the CMS subsystem will be central to real-time traffic control. A detailed CMS response logic has been developed for different driver audiences (commuters, baseball traffic, etc.) at different time phases (e.g. incident presence, queue growth, incident clearance, etc.) of various types of scheduled and unscheduled events.

In general, the first two lines of CMS text are allocated to event and queue information, while the third line is reserved for diversion information. At the start of an unscheduled event, general information is provided about event location, number of lanes blocked, etc.

If a queue forms, CMS's will provide information on the extent of the queue to motorists upstream of the queue, so that they may review alternate route choices while an uncongested egress ramp is still available. For motorists caught in the queue, information will be provided through CMS's on the downstream limit of congestion, so they can be psychologically prepared for the length of delay, as well as on blockage clearance, so that they will be prepared for the eventual restoration of normal traffic conditions. Regardless of the event time phase, motorists immediately upstream of a brake shock wave will be given a safety message, so that they are prepared to stop in order to avoid secondary accidents.

Arterial Advisorv Signs - Arterial Advisory Signs (AAS's), located at the main arterial entrance points to the Gardiner-Lake Shore corridor, will be used for diversion and, as such, are related only indirectly to events (i.e. if a significant travel time difference is created as a result of an event). AAS's will indicate whether Gardiner Expressway or Lake Shore Blvd. provides a faster navel based on real-time traffic conditions.

Lane Control Signs - Lane Control Signs (LCS's) are planned to be implemented as the final phase of the Gardiner-Lake Shore CTMS project, and therefore will not be operational until 1996. Once the LCS subsystem has been implemented, the subsystem will provide a higher resolution motorist warning system for traffic approaching the queue end. The signs will be located at intervals of about 500 to 600 meters, and will display advised speed limits, gradually reducing vehicle speeds in order to ease the transition between free flow speeds and slow moving queue speeds. LCS's will also be used to supplement CMS event messages. For example, LCS's immediately upstream of an unscheduled event location will indicate which lanes are blocked, and will be used to clear a lane/shoulder for the passage of an emergency vehicle.

Ramp Metering, - Two on-ramps to the Gardiner Expressway are currently metered under the Traffic Signal Control System. These ramps can be closed on a time-of-day schedule basis, and also as a result of special signal timing plans on Lake Shore Boulevard. Ultimately, it is expected that the CTMS will inherit control of these ramps. In addition to time-of-day and scheduled-event control, these ramps may also be controlled during severe incidents. A possible future enhancement is the conversion of these ramp locations to ramp-metering stations, which would also allow a form of traffic-actuated control.

Real-Time Adaptive Traffic Control - Induction loop detectors have been installed downstream of selected intersections by the TSCS for the SCOOT demonstration project. SCOOT, meaning Split Cycle and offset Optimization Technique, is a computerized traffic signal control system that provides real-time traffic adaptive control on a signal cycle by signal cycle basis. The system incorporates a traffic model which predicts delays and stops caused by specific signal settings, based on actual traffic data detected and processed in the real-time model.

The Metro Toronto SCOOT Demonstration Project encompasses 75 intersections within three distinctly different operational control areas. One control area includes 42 intersections within a grid network of the central business district. Another control area includes 13 intersections along a major suburban arterial. The third control area includes 20 intersections along Lake Shore Boulevard, within the Gardiner-Lake Shore Corridor. The control areas were chosen in order to evaluate the benefits of SCOOT under various types of operating and road environment conditions. The demonstration project is scheduled to be commissioned by late 1992, with subsequent before/after survey studies to be conducted and documented.

In the future, SCOOT will function as the traffic signal interface to the Gardiner-Lake Shore Corridor Traffic Management System (CTMS). CTMS will provide input to SCOOT on suggested diversions from the freeway to the arterial, on-going freeway congestion and the on-set of freeway congestion. It is intended that a pro-active response, through additional green time required to clear traffic diverted to the arterial, will be supplied by SCOOT, if the Demonstration Project is successful.

More details on SCOOT are provided in me review on SCOOT systems.

Real-Time Traffic Control Summary - Real-time traffic control through the Gardiner-Lake Shore CTMS relies heavily on signing technologies, such as Changeable Message Signs, Arterial Advisory Signs and Lane Control Signs. These subsystems are valuable because they reach the desired audience at the appropriate location and at the appropriate time. As such, they have benefits over many Advanced Traveller Information Systems (ATIS's) which are either of a pre-trip nature (and therefore not very timely) or are unable to access a specific audience to which the information is geographically relevant Also, signing subsystems do not place the onus on the user to access information, as do many ATIS technologies, e.g. radio, telephone.

Nevertheless, signing subsystems do have drawbacks. They are costly and infrastructure dependent. Also, because they are so site-specific, there is very little room for error, including errors of omissions, if user credibility in the system is to be sustained. Therefore, in the case of the Denver TOC, the benefits and disbenefits of sign-based real-time traffic control should be carefully considered before determining to what extent variable message signing is to be used.

Other approaches to real-time traffic control, which are applicable to ITCC systems, and which are relevant to the Denver TOC include the following:

- Integrating ramp metering into traffic control operations, through automatic system prompts to change ramp meter status based on detector data and derived data on traffic conditions.

- Incorporating real-time adaptive control of traffic signals, in coordination with freeway traffic management.

3.1.3 Advanced Traveller Information System Functions

Ultimately, Advanced Traveller Information will be handled on a Metro-wide basis by the Traffic Situation Room (TSR) to be located at the Integrated Traffic Control Center (ITCC). Prior to implementing the TSR, more detailed planning is required with respect to the nature of TSR operations. Also, the operational upgrade of the TSCS to encompass more Advanced Traffic Management System (ATMS) functions, would enhance the functionality of the TSR.

In the meantime, an Advanced Traveller Information System (ATIS) is critical to the functionality of the Gardiner-Lake Shore CTMS, which will commence motorist advisory operations prior to the establishment of the TSR. Therefore, a corridor-specific system, the External Interface Communications System (EICS) is being implemented as part of the CTMS system software. The EICS will be operated by CTMS operators.

3.1.3.1 TRAFFIC SITUATION ROOM

The purpose of the Traffic Situation Room (TSR) is to act as a communication and coordination center among transportation, media and other agencies to improve the overall efficiency and operation of the transportation system in Metropolitan Toronto and beyond. The TSR will interface with the Gardiner-Lake Shore Corridor Traffic Management System, with other components of the Integrated Traffic Control Center, with various agencies located in Metropolitan Toronto, and with agencies outside Metro.

The TSR will be permanently located with the Gardiner-Lake Shore Corridor Traffic Management System (CTMS) and the Metropolitan Toronto Traffic Signal Control System (TSCS) as part of the new Integrated Traffic Control Center (ITCC). Being in close proximity to the CTMS and the TSCS, the TSR is well situated for interfacing with each of these components. The TSR will serve as a clearinghouse for information directed to the CTMS control area, and will also disseminate information on corridor scheduled and unscheduled events to external interfaces, such as emergency services and news media. Provisions also exist to provide a similar service for the TSCS component. The TSR will play a greater role in coordinating TSCS operations as the TSCS is upgraded.

In addition to CTMS related functions, the TSR will also coordinate information on traffic in Metropolitan Toronto. Input from the CTMS and TSCS will be combined with other traffic data to coordinate response to Metro traffic events. One important role of the TSR would be as a central transportation command site for major emergencies (such as a plane crash or explosion disaster) drawing on the communications infrastructure that would be already in place.

The scope of the TSR will not be limited to Metropolitan Toronto. Metro traffic conditions, incidents and events will have an impact on traffic in the surrounding municipalities, especially on cross-boundary transportation routes during periods of congestion. Under those circumstances, the TSR will be a reliable source of information and advice on the status of Metro traffic. Similarly, traffic conditions outside Metro's boundaries will affect conditions within Metro, and information on scheduled and unscheduled traffic events could be communicated to Metro through the TSR.

Three major areas where the TSR could provide a service are:

1. Communication - The TSR would receive and disseminate information on scheduled events and non-recurring events. Metro Transportation, as well as other agencies, can make use of both information on scheduled/planned events affecting the transportation system and real-time data.

2. Coordination - The TSR can play a valuable coordination role for transportation problems related to major scheduled construction activities, to major incidents and to major special events. An important aspect of TSR coordination is the central command site function for emergencies and disasters.

3. Control/Enforcement - Potentially, the TSR may have the power to enforce by-laws and to take action in the event of major incidents (e.g. have cars towed away, question street occupancies, override street closure permits, etc.) in the interest of improving traffic flow. Although the control/enforcement service may not be achievable at the outset, the TSR does provide video surveillance in conjunction with a valuable information base, so that Metro staff can more forcefully deal with illegal street use.

Figure 3.1 illustrates the coordinating, communication and potential control/enforcement relationships of the TSR with CTMS, TSCS and other transportation agencies and users.

3.1.3.2 CTMS EXTERNAL INTERFACE COMMUNICATIONS SYSTEM

An important part of the Gardiner-Lake Shore CTMS will be interfaces with external agencies, to expedite emergency response to traffic incidents, and to exchange traffic and road information that is of use to the participating agencies. These agencies might include emergency agencies, transportation agencies, the media and others. All external interfaces to the Corridor Traffic Management System will be handled through control room operators as part of the CTMS External Interface Communications System (EICS), providing a consolidated point for accessing information on accidents, incidents, congestion and maintenance/construction activities throughout the corridor.

Traffic and road information from the CTMS that could be made available to the users of the External Interface Communications System includes:

- Real-Tie Incidents - e.g.accidents, disabled vehicles, spills, emergency roadwork.

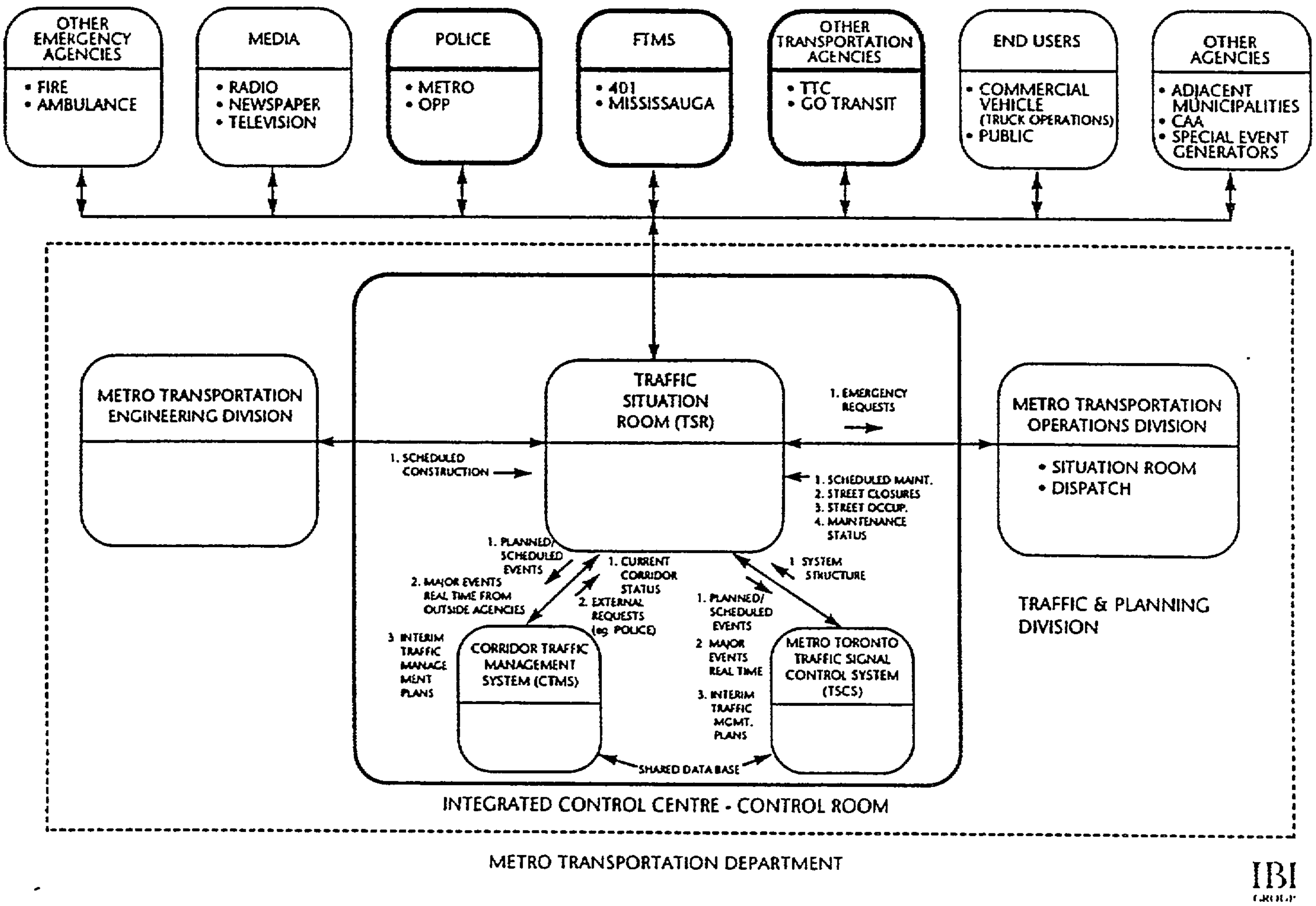
- Real-Time Traffic Conditions - e.g.traffic volumes, traffic speeds, travel time.

- Scheduled Construction/Maintenance and Special Events - e.g. road closures/detours, lane closures and disruptions, parades.

- Road Conditions - e.g. road surface conditions, visibility.

Figure 3.1

Metro Toronto Traffic Situation Room Overview



There are a number of options for information dissemination. These technologies will enable the CTMS to relay traffic information to a large cross-section of user agencies, as well as directly to the general public. Some of the options (as identified in Figure 3.2) are:

Computer Generated Fax - The External Interface Communications computer would automatically generate and send messages by fax to a list of subscribers. Fax traffic reports could be transmitted in accordance with schedules specified by each user.

Pager - Alpha-numeric pagers could be made available to user groups, to relay traffic and road information in real-time. If desired, pagers could be linked to printers, providing continuous hardcopy records of data disseminated by the system.

Remote Terminal - An interactive remote terminal would allow users to query the database directly and to generate default and customized reports. Users could be alerted to high priority bulletins through user alarms. Graphical output would be possible with this type of terminal, using location referencing through a standard coordinate system database. One application would involve pointing with a mouse at a trouble spot identified on a map and receiving text details on the nature of the traffic problem at that location.

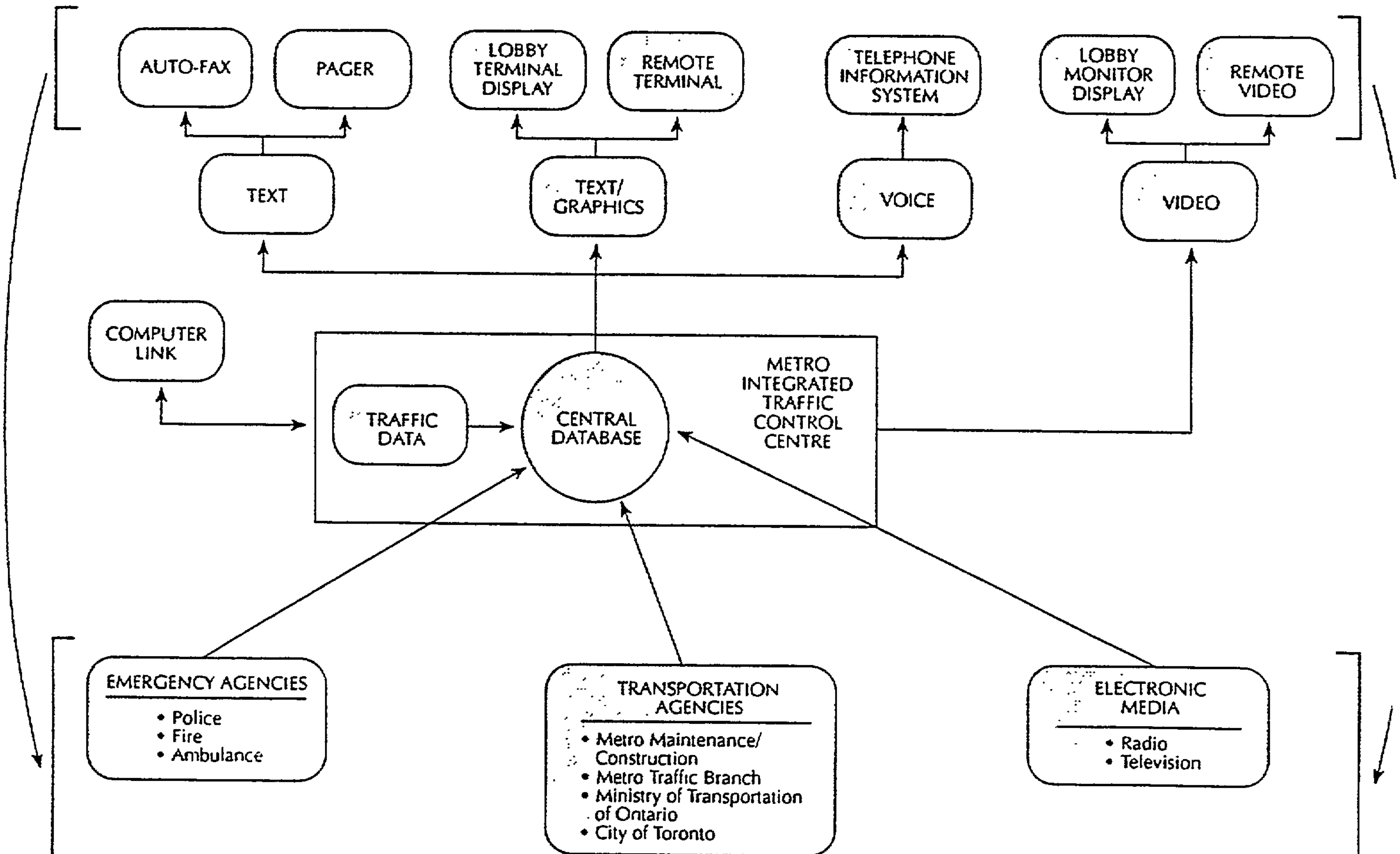
Lobby Terminal Display - Placing a remote "display-only" terminal in a public high circulation location (such as an office building lobby, shopping mall or sports stadium) would provide information on traffic conditions to motorists about to leave the location. Graphical presentation would be effective for this application, as would coupling the application with live video displays of selected locations.

Telephone Information System - The Telephone Information System would be an interactive information service delivered via telephone lines. The user could specify (by voice or by keying in numbers on a touch-tone telephone in response to vice prompts) a route or geographic area of interest. The system would then respond with an up-to-the-minute traffic report concerning the location queried.

Live Video - In conjunction with the information dissemination subsystem, CTMS-controlled live color video feeds from the Corridor's closed circuit television cameras could be provided to subscribers. The implementation offering most flexibility to the users, while still leaving CTMS in control of the output, involves a "tour" through the active cameras, showing a few seconds of output from each camera in turn. Coverage from overview cameras at the CN Tower and the Humber Bridges area will also be available through live video feed. In addition to video feeds to external agency offices, the technology would be useful in a "lobby display" application, perhaps in conjunction with the lobby terminal display option.

Figure 3.2

CTMS External Interface Communications System



Commuter-to-Commuter Link - Computer-to-computer links could be developed and installed for those users which already have operational computer systems, and wish to incorporate data from the traffic management systems.

3.1.3.3 ADVANCED TRAVELLER INFORMATION SYSTEMS FUNCTIONS SUMMARY

The following features of the ITCC Advanced Traveller Information Systems functions are pertinent to the Denver TOC:

- Area-wide interfaces work most effectively when the various external agencies have a single point of contact at the control center for receiving and/or providing traffic and road information.
- A system with a variety of dissemination technologies maximizes the exposure of end users to traffic and road information, and better addresses the diverse requirements of user groups.
- Integration of the ATIS and ATMS systems into one computer is efficient in terms of data entry, storage and processing.

3.1.4 Traffic Operations

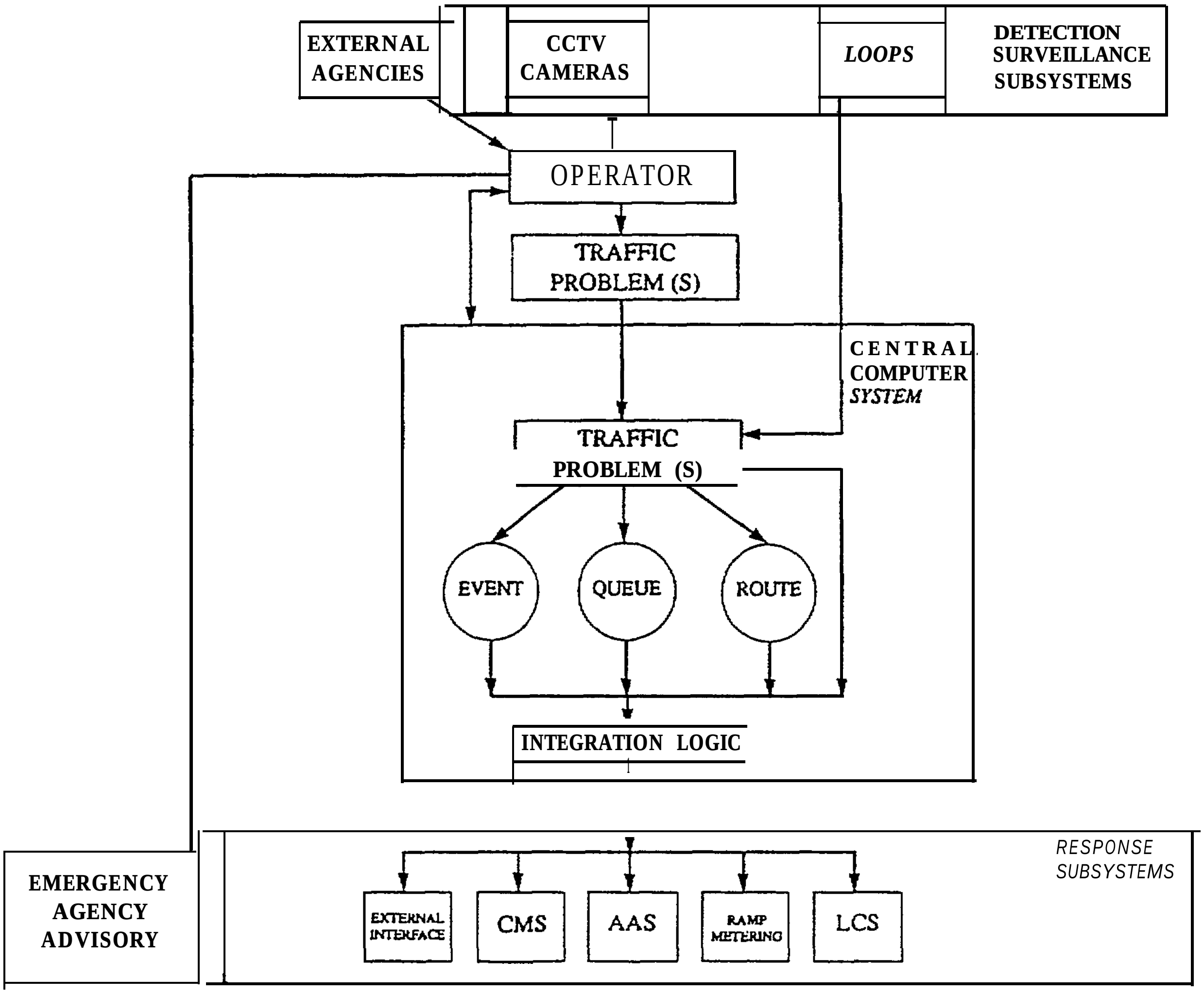
CTMS traffic operations will perform the following three basic functions:

1. Event Management - Motorists, emergency agencies and others are informed about the existence of unscheduled and scheduled traffic events, which may potentially affect traffic flow, occurring within or near the corridor. All functionality associated with detecting, confirming, clearing, monitoring and providing information on the event falls under the category Event Management.
2. Queue Management - Motorists are provided with information associated with traffic queues including queue start, queue length, and a warning that they will encounter a queue end. All functionality directed at detecting, clearing and providing information on traffic queues falls under this category.
3. Route Management - Motorists are provided with information on alternate route choices within the corridor. Any information gathering and response elements related to altering the travel characteristics of a route fall under the category of Route Management.

Figure 3.3 shows the basic traffic operations functions and the subsystems they affect.

Figure 3.3

CTMS Traffic Operations



IBI GROUP

3.1.4.1 EVENT MANAGEMENT

Unscheduled Events

Incidents: The primary mechanism for detecting incidents will be via algorithms in the central computer which use loop detector data to spot turbulence or disruptions in traffic flow. Incidents will also be detected by operators directly using the television cameras, and through reports from external sources such as the police. The CTMS operators use the CCTV system to verify an incident and provide details about its nature and precise location so that a response may be formulated. The central computer determines a response from the information it is given.

The chief method for disseminating incident information is through the Changeable Message Sign subsystem. If the incident is serious enough, the response will also include information to motorists beyond the corridor limits through external agencies such as the news media.

Immediately after an incident is detected and before it is confirmed by an operator, the system will be able to display caution messages upstream of the incident location. These are intended to give drivers approaching a problem area some waming as soon as possible after an incident is detected, since the confirmation procedure may take one or two minutes. Once the incident is confirmed, more detailed information on the nature and location of the incident will be given to upstream motorists, as well as a more urgent safety warning on the first CMS upstream of the incident. Motorists will also be informed about he status of the incident as time passes, and will be notified when the incident is cleared from the roadway.

As with all responses, operators are able to accept, reject or modify any portion of the plan before it is enacted.

Other Unscheduled Events: Other unscheduled events is a catch-all category for dealing with events which disrupt traffic or pose a safety hazard, but because of their nature cannot be treated as incidents. These include events such as hazardous weather conditions, which affect traffic operations everywhere and are not limited to specific locations, and location-specific problems which are of a long-term nature and do not require the intense response activity of an incident, such as localized flooding or broken pavement. If an "other" event is serious enough to cause traffic disruption, it will be detected and responded to as an incident.

Scheduled Events: This category includes special events (of which the CTMS has prior knowledge) which generate intense but relatively predictable traffic flows such as baseball games, and scheduled maintenance or construction work which temporarily reduces capacity.

Prior knowledge of an event allows some preparation of response elements. However, the actual behavior of traffic during the event will remain unpredictable, and specific problems will be treated as incidents. The intention here is to provide a basic advisory response, over which other responses wilt be enacted if needed.

For example, the system response for a baseball game may simply inform motorists and others about the game and suggest appropriate exits. However, if corridor traffic is adversely affected by baseball traffic, the situation will be detected and responded to as an incident.

Information about a scheduled event including its approximate starting and ending times is collected into a database which is scanned periodically by the central software. Also included in the database are details about the base response.

Before a scheduled event is set to begin, the operators are notified. Since the precise starting time of the event will usually not be known, it will usually be up to the operators to decide when the response should be set into motion. This may be determined either through a visual scan of the corridor or contact with the external agency responsible for the event.

Scheduled event responses are similar to responses for “other events” in that they simply advise motorists of the event and give way to other responses of higher priority if necessary.

3.1.4.2 QUEUE MANAGEMENT

Traffic queues form when the demand volume through a roadway section exceeds that section’s capacity. Whether the demand volume rises above roadway capacity, as during recurring congestion or special events, or whether capacity is reduced, as during incidents and maintenance activities, the queue formation process and its effect on traffic are similar. Consequently, the CTMS approach to managing queues is the same regardless of what event caused the queue to form.

The overriding concern in queue management is safety. A secondary concern of queue management is traffic flow efficiency. Finally, although not a key objective of the system, the information gathered to meet the objectives of safety and efficiency can also be used to reduce driver frustration.

A queue length determination algorithm scans for the presence of a queue and estimates the extent of the queue. Once a queue has reached a specific minimum threshold length, queue signing will begin. Periodically, the system will prompt the operator to confirm and adjust its estimate of the queue length.

The primary mechanism of the system response for queue management wilt initially be the CMS subsystem. The extent of substantial queues may also be disseminated to motorists outside the corridor using other information systems.

If the queue end is within a threshold distance of a changeable message sign, a strong warning message will appear advising of the queue ahead. Further upstream along both facilities, information about the extent of the queue will be given. As the queue grows, those who would not, or could not, divert and are caught in the queue will be advised of where the queue begins (i.e. where they may expect to resume normal speed). Both the front and back of the queues will be monitored and signed accordingly until the queue has once again dropped below the minimum threshold.

A more effective response subsystem for queue control is the Lane Control Sign system. The tighter spacing of LCS's allows better tracking and signing of the queue end, and if equipped to show suggested speeds, they can ease the shock wave by gradually lowering the speed of traffic as it approaches the queue. Both CMS's and LCS's are needed: for queue management, the LCS's are supplemented by the CMS's; for event management, and CMS's are supplemented by LCS's.

3.1.4.3 ROUTE MANAGEMENT

The objective of route management is to guide motorists through the corridor as quickly and efficiently as possible in the face of incidents, recurring congestion, scheduled events and other traffic disruptions. It achieves this through three basic approaches:

- On the demand side, an automatic, advisory capability (corridor balancing) which constantly compares travel time on both the Gardiner and Lake Shore, and suggests a route accordingly.

- On the supply side, an automatic, control capability which uses current traffic volumes to adjust corridor control systems such as traffic signal timings and ramp metering rates.

- A manually-implemented, preemptive capability which is activated at the discretion of the CTMS operators during severe incidents to maximize east-west capacity in the corridor.

The first two elements run automatically and autonomously (although operator override is always available), and result in small, incremental changes to the flow in the corridor. However, during a severe incident, such as a total blockage of the Gardiner, more drastic actions are required to keep traffic flowing.

At the operator's request, the system can enter a "severe" or preemptive mode whereby the CTMS is able to exert a greater degree of control over the corridor to maximize east-west capacity. These enhanced abilities include using SCOOT to maximize green time on the Lake Shore and prohibit or allow movements at intersections, using the ramp metering subsystem to totally close one or more on-ramps, possibly activating reversible lanes on the Lake Shore and possibly using the LCS subsystem to close a lane on the Gardiner to allow the movement of emergency vehicles.

3.1.4.4 TRAFFIC OPERATIONS SUMMARY

The Gardiner-Lake Shore Corridor Traffic Management System approach to traffic operations involves dealing directly with three basic functions of traffic operations: event management, queue management and route management. Through this compartmentalized approach, the difficulties stemming from the complex relationships between events and their traffic impacts are alleviated. For example, incidents typically result in queues which warrant diversion. However, sometimes incidents do not cause queues (e.g. under light traffic flow conditions), sometimes queues occur without incidents (e.g. recurring congestion), and sometimes queues do not warrant diversion (e.g. travel time differences are not significant). By treating each function independently, traffic operations response can be isolated to react to the specific problem area. The Denver Metro Area TOC might consider organizing traffic operations functions in a similar manner in order to increase operational efficiency and simplify software design

Other CTMS traffic operations features which could be applied to the Denver system include the following:

- System design which accepts and incorporates detection/confirmation data from various sources, e.g. algorithm detection, operator detection through CCTV camera, information from patrol vehicle, etc.

- High degree of attention to queue detection, tracking, estimation and monitoring.

- Diversion recommendations based on travel time comparisons over detectored routes.

- Including a “severe” response capability, whereby operators can pro-actively implement an extreme system-coordinated response, which goes beyond the “status quo” response typically assembled and suggested by the system.

3.1.5 Traffic Operations Center

3.1.5.1 LOCATION

The Integrated Traffic Control Center is located in North York, a municipality of Metropolitan Toronto. The ITCC location is in close proximity to the Don Valley Parkway, a major north-south Metro-owned freeway, which is intended to become the future extension of the Gardiner-Lake Shore CTMS.

The space assigned to the ITCC consists of the third, fourth and fifth stories of an existing nine-story building currently undergoing major renovations. Other building uses include the Metropolitan Toronto Police Communications Center, providing opportunities for emergency response and communications links, and offices for the Central Mapping Agency, providing opportunities for geographic data exchange. A schematic drawing of the actual ITCC design is shown in Figure 3.4.

Figure 3.4

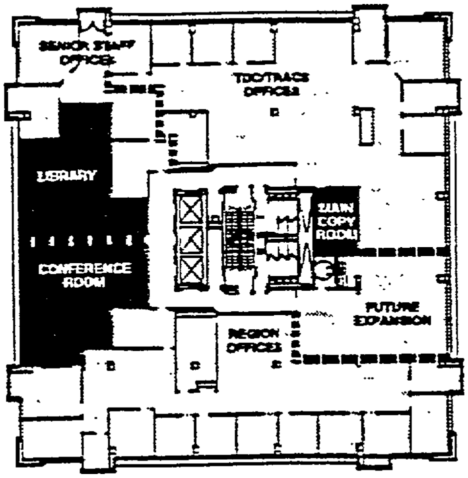
ITCC Design

Legend

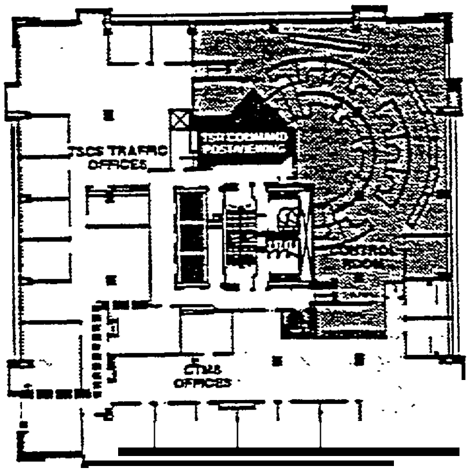
Office

Secured

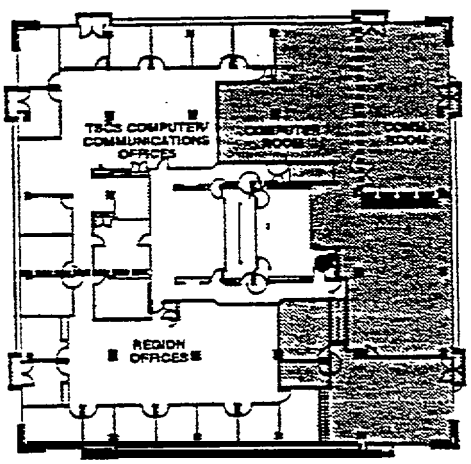
Other



6th Floor



5th Floor



4th Floor

The major limitation of the building, with respect to control center functionality, is its small floor plate (about 11,000 square feet). To maintain functional continuity, as well as unity within each user group, the control room, the TSR command post, the computer/communications room, and CTMS and TSCS staff offices ideally should be on the same floor. Since a one-story layout of these elements is impossible, a solution was obtained by locating the computer/communications room on another floor, directly beneath the control mom, maintaining proximity relationships vertically instead of horizontally. TSCS computer/communications staff offices are located on the same floor as the computer/communication room, while the TSR command post and offices for TSCS traffic operations staff and the entire CTMS staff contingent are assigned to the control room floor.

3.1.5.2 CONTROL ROOM

Hours of Oneration - The control room will operate 24 hours a day, seven days a week. Due to the layout of the control room, it is possible for one operator to operate/monitor all three control components during the night, when it may be inefficient to have more operators on duty.

Staffing/Personnel - The integrated control room has workstations for three CTMS, four TSCS and four TSR operators, as well as two additional workstations for future use. In addition, there is office space for a TSR supervisor within the control room. At the outset, and during off-peak hours, the room is not expected to he fully staffed. However, once the TSCS and the TSR have been fully integrated into the control operations, full staffing would be achieved during peak periods.

Functional Requirements

Gardiner-Lake Shore Corridor Traffic Management System: The pivotal area for CTMS operation will be the control room. In the CTMS control room, up to three operators will monitor traffic flows and will detect and confirm incidents, using incident detection algorithms, color graphics displays, closed circuit television (CCTV) monitors and external agency communications. The control room operators will also be responsible for implementing incident and congestion response plans, which could include notifying emergency agencies, activating changeable message signs and modifying traffic signal timing plans along Lake Shore Boulevard.

The primary surveillance tool will be a set of three banks of monitors showing CCTV camera output. Each operator must be able to clearly view the monitors for a given corridor section, as well as other monitors which may impact the assigned section. The placement of the monitor banks must take into account comfortable viewing distance, as well as vertical and horizontal viewing angles. Rear screen projection units placed between the monitor banks will supplement the CCTV camera output with additional visual information. All operators must he able to clearly and comfortably view the projection units.

Workstation consoles for each operator must accommodate the necessary monitoring and communications equipment (e.g. computer terminal, color graphics monitor, small CCTV monitors, camera control equipment, telephone, VCR). The equipment must be within reach, but must not obscure views of the monitor banks. Raised flooring will be required to accommodate wiring and connections to/from the monitor banks and operator consoles.

The operators must be within close proximity of each other, to provide assistance and advice, and to review response strategies for traffic events having overlapping areas of influence. Communications with other non-CTMS sections will also be important Contact with Traffic Signal Control System control staff will be required to provide CTMS operators with general traffic information on arterials near the corridor. Contact will also be required with the Traffic Situation Room, which will screen incoming calls to CTMS from external sources, organize information on scheduled maintenance/construction activities and coordinate information to be disseminated to other agencies.

Traffic Signal Control System: While operator driven monitoring and control are not yet major TSCS activities, plans are underway to introduce monitoring of critical intersections using CCTV cameras, arterial monitoring using high-mounted overview cameras, arterial incident detection, and other activities which would best be carried out by three to five operators working in a control room environment. The console equipment required for this operation, as well as the placement of the operators for constructive communication, will be similar to that required for the CTMS control room. However, the monitor bank requirements will not be as extensive. Two to four columns of CCTV monitors placed on either side of a dynamic traffic signal wall map should be sufficient to satisfy the monitoring and control requirements of TSCS.

TSCS control room operators must be able to communicate with CTMS operators, in order to obtain information on Lake Shore Boulevard traffic signals and on how neighboring arterials are expected to be impacted by corridor traffic conditions. Contact with the Traffic Situation Room will also be important, for the purposes of information communication and coordination.

Traffic Situation Room: A control room is required for two to four TSR operators, each having consoles with equipment similar to that of the CTMS and TSCS operators. TSR computer terminals should be capable of retrieving and monitoring screens from both TSCS and CTMS control operations. It is essential that the TSR operators be able to easily communicate with each other. The TSR operators should have good views of both CTMS and TSCS monitors to facilitate effective coordination.

Integrated Control Room - Due to the strong interrelationships between the CTMS, TSCS and TSR control components, it is functionally feasible to combine them into one control room (see Figure 3.5). A concentric circular layout for the room most effectively satisfies the communications and viewing requirements previously outlined. This configuration provides optimal views of the surveillance equipment that each operator relies on most, but also ensures visual access to other equipment in the room. The TSR stands on a raised surface at the hub of the control room, affording a view of all operators and surveillance/monitoring equipment, and enabling one operator to control all three components late at night. The next ring outward consists of CTMS and TSCS operator consoles, placed so that all operators are within contact range of each other, and enabling operators to survey neighboring terminals and other console equipment. All operator consoles are U-shaped, providing more direct access to equipment than would be possible with elongated consoles. The outer circle includes monitor banks, projection units and the dynamic wall map of signalized intersections.

3.1.5.3 COMPUTER/COMMUNICATIONS ROOM

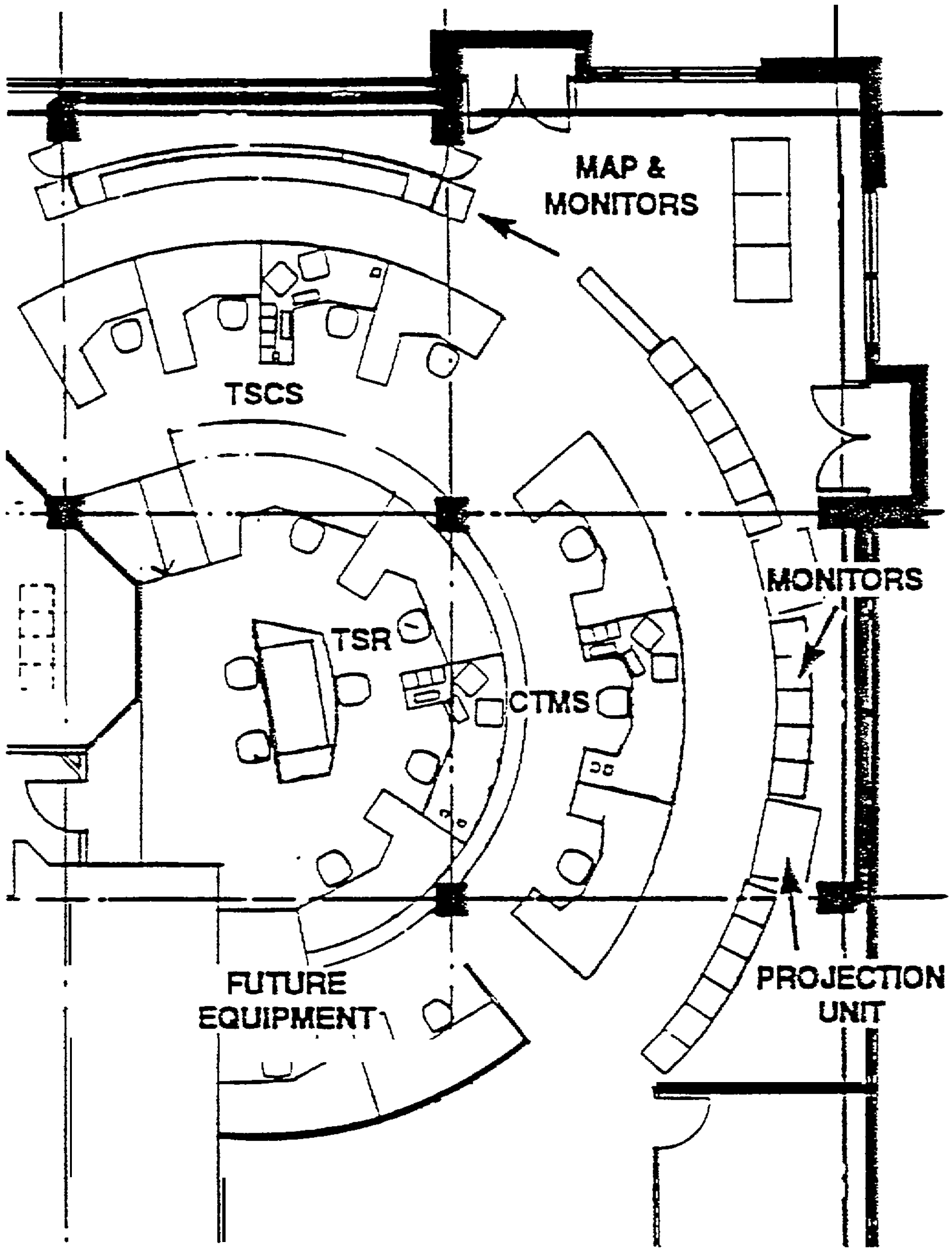
Functional Requirements - The computer room is required to accommodate all the computer equipment necessary to operate and maintain both the initial Corridor Traffic Management System as well as an expanded system. The CTMS system will consist of several DEC mini-computers (e.g. Model 3100-80) in a local area network configuration. These computers arc expected to all fit in an appropriate-sized rack. Each computer will be equipped with disk drives, tape drives and console terminals. The system will also include a server to interface to the field communications subsystem, and a high speed printer for report generation.

Space is also required for all of the computer equipment necessary to operate and maintain the Traffic Signal Control System. The existing computer equipment is currently in the process of being upgraded. It is expected that this upgrade will be completed prior to the relocation of the TSCS from the existing Control Center to the new one. The new TSCS computer system will include:

- 2 Concurrent 3280 minicomputers (tactical and strategic).
- 16 Concurrent Model 8/16 “front-end” minicomputers.
- A multiplexer board rack (note that these multiplexers may be mounted directly in the Model 8/16’s).
- Disk drives.
- Tape drives.
- Tape storage area.
- A high speed printer.
- Plotter.

Figure 3.5

Integrated Control Room



Space is also required for CTMS and TSCS head-end communications and video switching equipment. The communications room should be located near both the computer room and the control room, to minimize communications cabling. Both the computer and communications rooms should have raised floors, and must be serviced with suitable building systems (i.e. HVAC, fire/flood protection/detection, back-up power). Temporary work areas, such as for system testing, are required in both rooms.

Integrated Computer/Communications Room - The layout of the integrated computer/ communications room, including placement of equipment and furniture, is shown in Figure 3.6.

Integrating all computer/communications functions into one room provides benefits with respect to flexibility, building system efficiency and opportunities for interaction of staff from different user groups. Due to security considerations and less stringent building system requirements for communications equipment, the communications equipment is separated from the computer equipment by a temporary glass wall.

3.1.5.4 TSR COMMAND POST

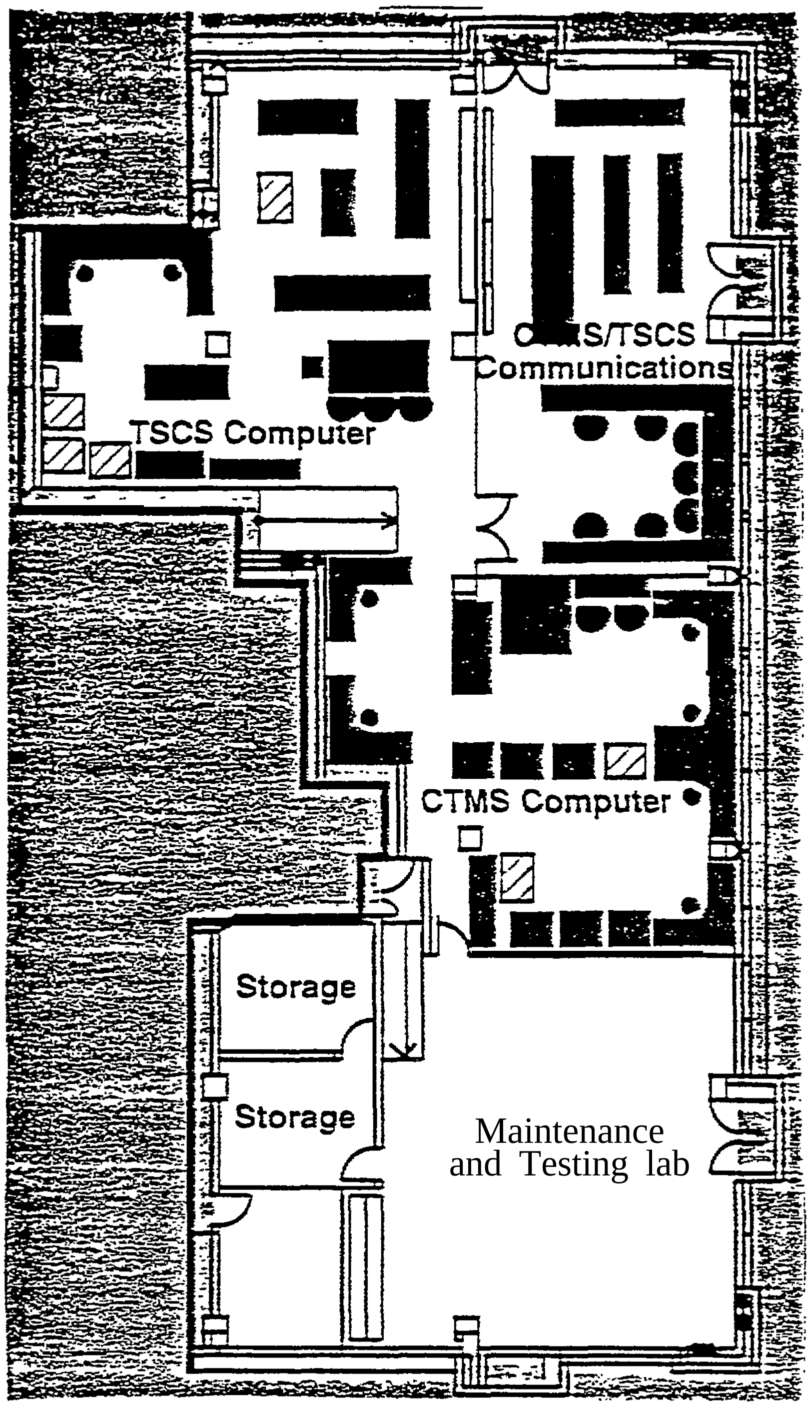
Functional Requirements - Another TSR requirement is a command post for traffic coordination during disasters and major special events, which would typically involve external participation. A room for this purpose is needed with a view into the TSR control room. It must have excellent audio-visual capabilities for communicating with the control room (including the presence of a fully equipped operators' console, linked to a projection screen, for monitoring purposes), but physical access should be restricted so that outsiders do not interfere with the work of the operators.

Integrated TSR Command Post/Viewing Room/Training Room - A room with a view into the control room, serving as a command post for disasters and major special events, is a TSR requirement. Since by definition, the room will be required only under unusual circumstances, its use will be sporadic. However, the existence of a space having strong visual and communications links with the control room presents an excellent opportunity for compatible uses that would benefit other ITCC user groups.

The TSR command post will be used as a viewing room for visitors, offering a perspective of the control room in action without causing interference to ongoing operations. The presence of a modular meeting table and sophisticated audio-visual equipment also complements the visitor viewing function. The operator workstation equipment in the room makes it a logical space for training operators. Control mom procedures and special control equipment can readily be indicated to trainees from tbis vantage point. The room will also function as setting for medium-sized meetings, for which a view of control operations might be relevant or strategic.

Figure 3.6

ITCC Computer/Communications Room



3.1.5.5 OFFICE/ANCILLARY SPACE

Functional Requirements - Offices and ancillary spaces are also be required for a number of user groups relocating to the ITCC building, including the Traffic Recording and Counting Section, Traffic Data Center, two Regional Traffic offices and Senior Staff offices.

Integrated Office/Ancillary Space - Locating staff from different user groups, but with similar work responsibilities, in close proximity provides an opportunity for interaction through sharing ideas, consolidating resources and keeping abreast of new developments in other user groups.

In addition, through integration, a number of special ancillary office functions are possible, including the following:

- Executive Conference Room: The multi-use control center supports a large scale meeting facility with sophisticated presentation capabilities, which will be available to all user groups.
- Library: The integration of a number of user groups provides an opportunity to pool library resources and to establish a central computer referencing system for more efficient tracking and retrieval.
- Seminar Room: The capability for creating large rooms for seminars and equipment demonstrations is being provided by installing temporary partitions between adjacent user group meeting rooms.

3.1.5.6 TRAFFIC OPERATIONS CENTER SUMMARY

Consolidating related traffic operations into an integrated traffic control center provides an excellent opportunity for improving overall operational functionality. The ITCC enables new possibilities for information exchange, direct and immediate communications, efficiencies in computer and communications systems, and design flexibility, yielding the benefits of synergy to participating user groups.

While the concept of integration is the primary reason for including the ITCC in the review of existing TOC's, the Denver TOC could benefit from taking into account the following issues that were dealt with during the ITCC design process:

- Care should be taken in selecting the TOC building, to ensure that the functionality is not compromised by building structure. The most flexible approach would be to construct a new building to house the Denver TOC.
- Staff organization charts showing interrelationships, and proximity charts showing spacing and adjacency relationships between rooms, are a good basis for designing preliminary blocking & tacking layouts.

- Ergonomic aspects of room functionality should be considered in control room layout, e.g. viewing angles and distances, acoustics, lighting, workstation placement for effective communication, etc.

- The use of a Graphical User Interface (GUI) eliminates the need for two terminals (one text and one color graphics), thereby reducing the workstation equipment and serving to focus operator attention.

- A “war room”, such as the TSR command post, could be used for other compatible functions, such as visitor viewing, operator training, special meetings, etc., which would benefit from adjacency to the control room and the specialized operator workstation equipment and audio-visual equipment typically located in this kind of room.

3.2 Ontario Traffic and Road Information System (TRIS)

3.2.1 Introduction

The Ministry of Transportation of Ontario (MTO) has launched a program of initiatives directed towards improving flow on MTO freeways and highways. The initiatives include Freeway Traffic Management Systems (FTMS's) such as COMPASS, as well as systems for communicating traffic and road information to the users who benefit from it. The Traffic and Road Information System (TRIS) is one of the initiatives taken by MTO to consolidate and distribute data on traffic and road conditions to the users of the road.

3.2.2 Principles of TRIS

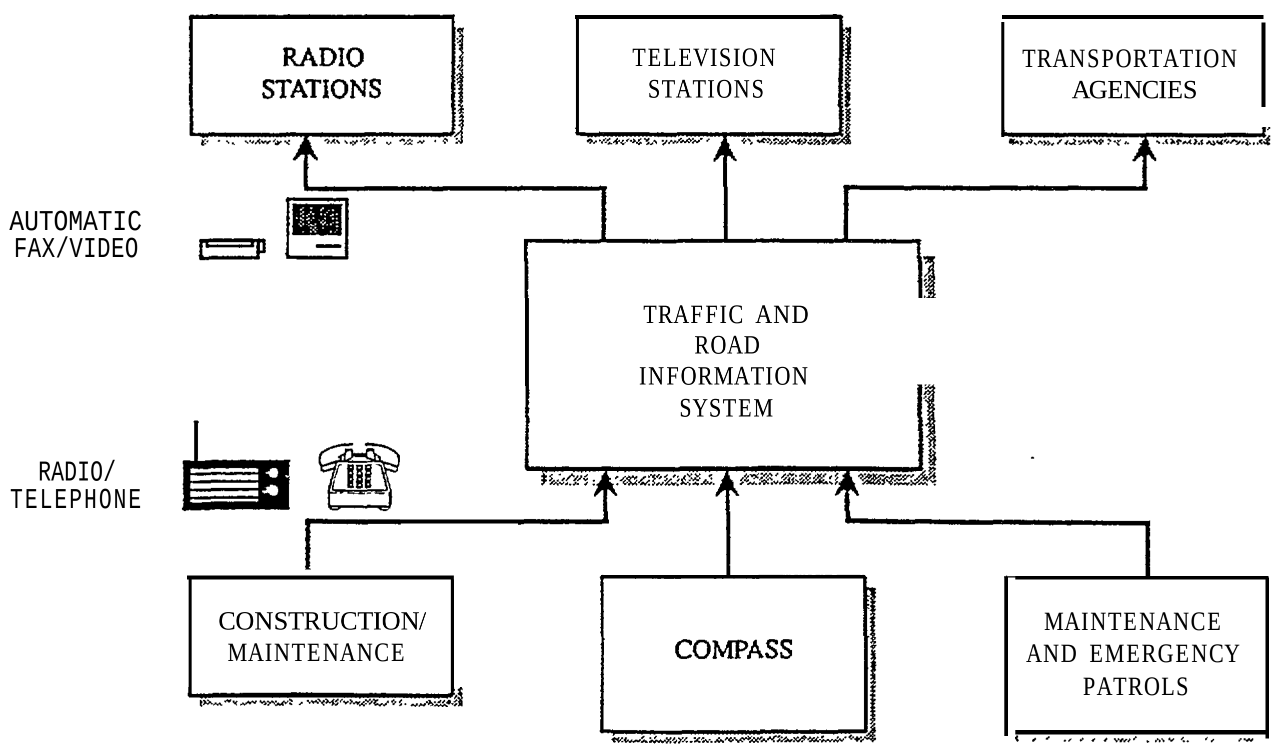
An “Interim Stage” TRIS was implemented in early 1991 as an initial mode of operation coinciding with the start up of COMPASS. Interim Stage operation is shown as a flow diagram in Figure 3.7. The main target audience of the operation is electronic media, although the system is available to a limited number of other users, primarily other sections within MTO. Under the Interim Stage, a TRIS operator working from the COMPASS control room, is responsible for collecting information on incidents and scheduled construction/maintenance. The TRIS operator completes custom designed computer screen entry forms, from which data is read into a computer database and translated by TRIS software into traffic reports. The reports are automatically faxed to subscribers of the system.

The geographic scope of the system is all provincial highways in MTO District 6, an area of about 200 square miles, which includes the Greater Toronto Area. In terms of quantity, accuracy and timeliness, however, events occurring in the COMPASS coverage area are best represented.

Figure 3.7

TRIS – Interim Stage

TRAFFIC AND ROAD INFORMATION SYSTEM - INTERIM STAGE



IBI GROUP

3.2.2.1 INFORMATION COLLECTION AND PROCESSING

The sources of information which serve as an input into TRIS consist of MTO groups responsible for producing, receiving and processing various reports. These groups provide the Radio Room, located within the COMPASS control room, with information on incidents and scheduled construction/ maintenance. The different groups include:

- Maintenance Patrols.
- Emergency Patrols.
- Maintenance Section.
- Construction Office.
- Road Information.

Since the TRIS operator is situated in the COMPASS control room, he/she not only receives information from the Radio Room, but also from the COMPASS Freeway Traffic Management System.

The product of the collection procedure is a list of details on each traffic event, including:

- Event start, update and termination times.
- Location of event.
  - Road number/name.
  - Direction of traffic flow.
  - Section type (express, collector, transfer or ramp).
  - Nearest upstream and downstream intersections/interchanges.
- Event type.
- Event severity.
- Number and ID of blocked lanes/shoulders.

These details are compiled by the TRIS operator and entered into the TRIS database through custom designed report forms on the TRIS PC screen.

Once the collected information is entered into the TRIS database, it is translated into a series of simple statements in sentence format, composed in accordance to predefined rules of syntax. The statements are sorted by event type, level of severity and logging time, and reordered to form a release.

3.2.3 Information Dissemination

The TRIS Interim Stage has three concurrent channels of dissemination:

1. Faxed messages.
2. Telephone queries to the TRIS operator.
3. Lobby monitor screens.

Fax releases are dispatched to subscribing users at the times pre-specified by each user, and/or on an occurrence basis in the case of unscheduled events. Releases assembled in the TRIS computer are faxed through the use of a PC-installed fax board, eliminating the preparation of hard copies. The receiving fax can be a "real" fax machine, or a similar PC equipped with a fax board.

To supplement information received through faxed releases, subscribers can directly call the TRIS operator. Subscribers can ask for clarification of received information, or verification of new or conflicting traffic events reported to them from other sources (e.g. cellular callers). This form of information dissemination is not encouraged. Nevertheless, radio reporters are reassured when they can have a human voice confirm the information, and continue to regularly phone TRIS operators.

Monitor screens, scrolling through text output from the latest traffic report, are being installed at selected locations (e.g. lobby of MTO Atrium Tower Building) for the purpose of providing passers-by with current traffic and road information from the Interim Stage TRIS database.

Live video feeds are also provided as a supplement to TRIS. The live video system features output from twenty-seven COMPASS video cameras, whereby ten seconds of coverage are shown from each camera in succession. Programming for live video is done through video switch hardware. All cameras are controlled by COMPASS staff, and the system does not allow media stations to request preferred coverage. Individual stations receiving the service ate responsible for setting up and maintaining their own links to the system. Currently one television station receives the feed, and while other television and radio stations are interested in receiving video images, the high cost of the communications link has been prohibitive.

3.2.4 Current and Future Initiatives

A work plan has been compiled for revising the Interim Stage TRIS, to improve the system based on the operational experience of the past two years. Some of the tasks under the work plan are already underway. Specific improvements that are part of the revision include:

- Server efficiency improvements, for more timely distribution
- Modifying the traffic report scripts to enable easier reading.

- Upgrading the existing TRIS host software.
- Developing diagnostics software to isolate failures and problems.

In addition, the Interim Stage is gradually evolving into a full system through a staged implementation. The following factors enter in the staging of TRIS:

- Phasing more user groups into the system.
- Phasing in other types of traffic and road data, e.g. traffic flow conditions, road conditions.
- Increasing the variety of operational dissemination technologies.
- Incrementing more sophisticated collection and dissemination links (e.g. evolving from manual methods to computer-to-computer communications).

Figure 3.8 presents the overall conceptual design proposed for the full TRIS system, showing the information flow from sources to users. ==The design is a synthesis of collection, processing and dissemination components.

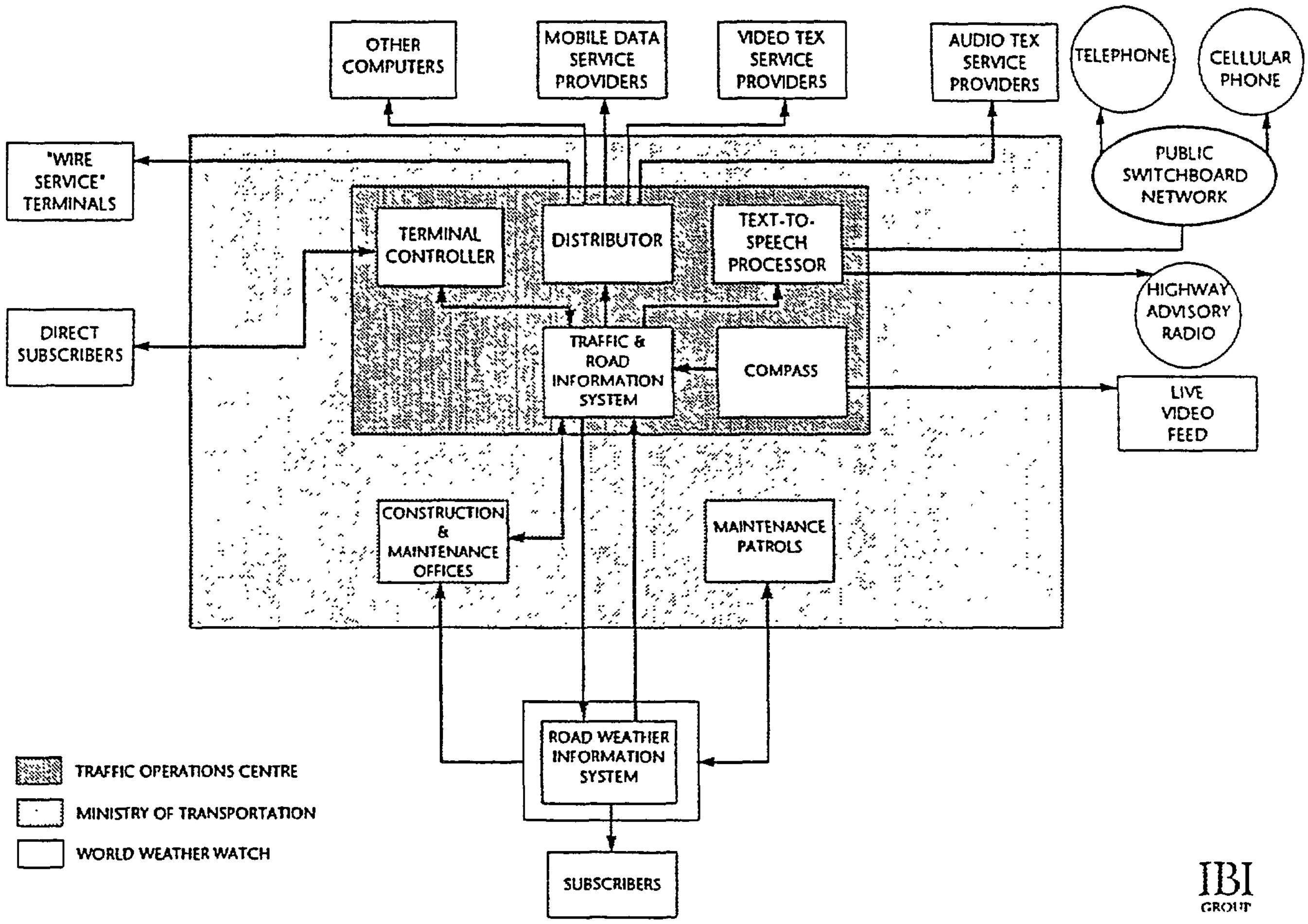
- At the center of TRIS is the platform.
- On which the database engine runs.
- That receives the processes, as necessary, information from other MTO systems and other sources.
- To which is attached the mass storage on which the database actually resides.
- That includes the controllers, distributors and other communications equipment that actually disseminate traffic and road information.

On the collection side, TRIS receives information:

- Directly from COMPASS through a serial link.
- Directly from an operator workstation at the District 6 TOC.
- From the routine construction and maintenance reports of various MTO offices, either transcribed through a data entry terminal at the TOC or entered directly from desktop computers at the source offices.
- From the Road Weather Information System (RWIS) on weather influenced road conditions.

Figure 3.8

TRIS Conceptual Design



On the dissemination side, TRIS is designed to distribute traffic and road information to a number of end users. However, all users will be reached through either:

- Interactive terminal.
- Broadcast messages.

Two dissemination methods - text-to-speech processing (for highway advisory radio and for audiotex) and computer generated fax - would be implemented on desktop computers.

The broad cross-section of technologies recommended for the full system would ensure that the system is flexible enough both to accommodate the diverse needs of users, and to maximize the exposure of individuals to traffic and road information. The multi-technology dissemination strategy would also provide good opportunities for the involvement of third party service providers, which are specialists in their areas of expertise (e.g. development of color graphics interfaces). Using third party providers would relieve MTO of the responsibility for all high level system refinements on the dissemination side, while providing the benefit of enhanced user access methods.

3.2.5 TRIS Summary

The primary users targeted for the Interim Stage of TRIS, are the media, who in turn transmit traffic and road information to motorists. Since implementing TRIS, MTO has received a positive response from the media, who have been using TRIS fax reports as a source of information for their traffic reports. In particular, radio reporters have remarked favorably upon the consistent accuracy of the information. Also, MTO has received input from the media on ways of improving TRIS. Such feedback received directly from users, is helping MTO revise its user requirements and mm TRIS into a full-fledged system. Some of the concerns shown include timeliness, format of release, and terminology of the fax reports.

Radio traffic reporters indicated that, unless reports are received within a few minutes of occurrence, they are not suitable for broadcasting. Time lags are occurring due to slow information communications, operator delays in entering the information, and queuing in the fax server. All aspects of the timeliness issue are being addressed through the TRIS Interim Stage revision project.

Feedback from radio traffic reporters has revealed that a script report format is not optimal for direct broadcasting purposes (although script format is required for other dissemination technologies, e.g. telephone information). Most traffic reporters prefer to "ad-lib" from a set of points. Therefore, they are required to re-write TRIS in point form in order to be able to create their own script text. In response to this feedback, a table format is being considered for radio fax reports.

The terminology concerns of traffic reporters include the presence of information that is superfluous for their specific needs. Reporters also object to the use of notations that, while they are easy to generate by computer, are inherently difficult for the reporters to read and the listeners to understand. For example, a numerical date is used (which does not mention the day of the week) and the time appears in twenty-four hour clock notation.

The Interim Stage implementation of TRIS is a successful initiative taken by MTO to consolidate and distribute accurate, timely, and location specific traffic and road information to users who benefit from it. Since the Interim Stage implementation, MTO has been further improving the system to meet the users' requirements as well as working towards implementing a full TRIS system. MTO's initiatives in traffic and road information are similar to some of the Advanced Traffic Information System (ATIS) functions of the Denver Metro Area IVHS program. The lessons learned from the operation of the Interim Stage TRIS, as well as the design of the "ultimate" TRIS, can be of assistance to the Denver TOC in meeting its short-term to medium-term ATIS function objectives.

In particular, the following items are of relevance to the Denver TOC:

- The capability for early implementation of ATIS functions is important with regard to the Denver TOC. A system similar to the Interim Stage TRIS for auto-fax distribution could be operational within a very short time-frame.

- The specific needs of radio stations; especially with regard to timeliness, information format and wording conventions, were determined through operational experience with the Interim Stage TRIS. The Denver TOC should take into account these requirements in the design of the ATIS elements.

- If possible computer-to-computer links should exist between the ATMS and ATIS functions. A drawback of the Interim Stage TRIS is that data output from the COMPASS computer must be manually m-entered as input into the TRIS computer, thereby compromising efficiency, timeliness and accuracy.

- In the control room, ATIS operators should be within close visual and speaking range of the ATMS operators. In the COMPASS control room, TRIS operators were relocated from the back of the room to the middle of the room, where they could more easily interact with the FTMS operators at the front of the room.

- The TRIS approach of incorporating many dissemination technologies, and using third party providers where possible, increases the exposure of traffic information to road users, and improves the presentation quality of that information.

4.0 UNITED KINGDOM FACILITIES

4.1 AA Roadwatch

4.1.1 Introduction

The Automobile Association (AA) is the primary motoring organization in the U.K. AA serves many functions similar to those of AAA, its U.S. equivalent, including provision of maps, routing advice and motorist assistance. However, AA also plays a significant role in the collection and distribution of traveler information, particularly through the Roadwatch program. It is this area that is reviewed for applicability to the Denver Metro Area TOC effort

4.1.2 AA Role

AA serves as the U.K.'s only national collation center for road traffic information. In this role, AA functions as the provider of the country's Traffic Information Center (TIC) facilities, with responsibility for collating, storing and retrieving traffic information from a variety of sources. While these activities are undertaken with the support of the government AA does not receive official government backing. However, AA's Roadwatch service acts on behalf of the police in collecting and disseminating information in a number of regions.

4.1.3 TIC Operations

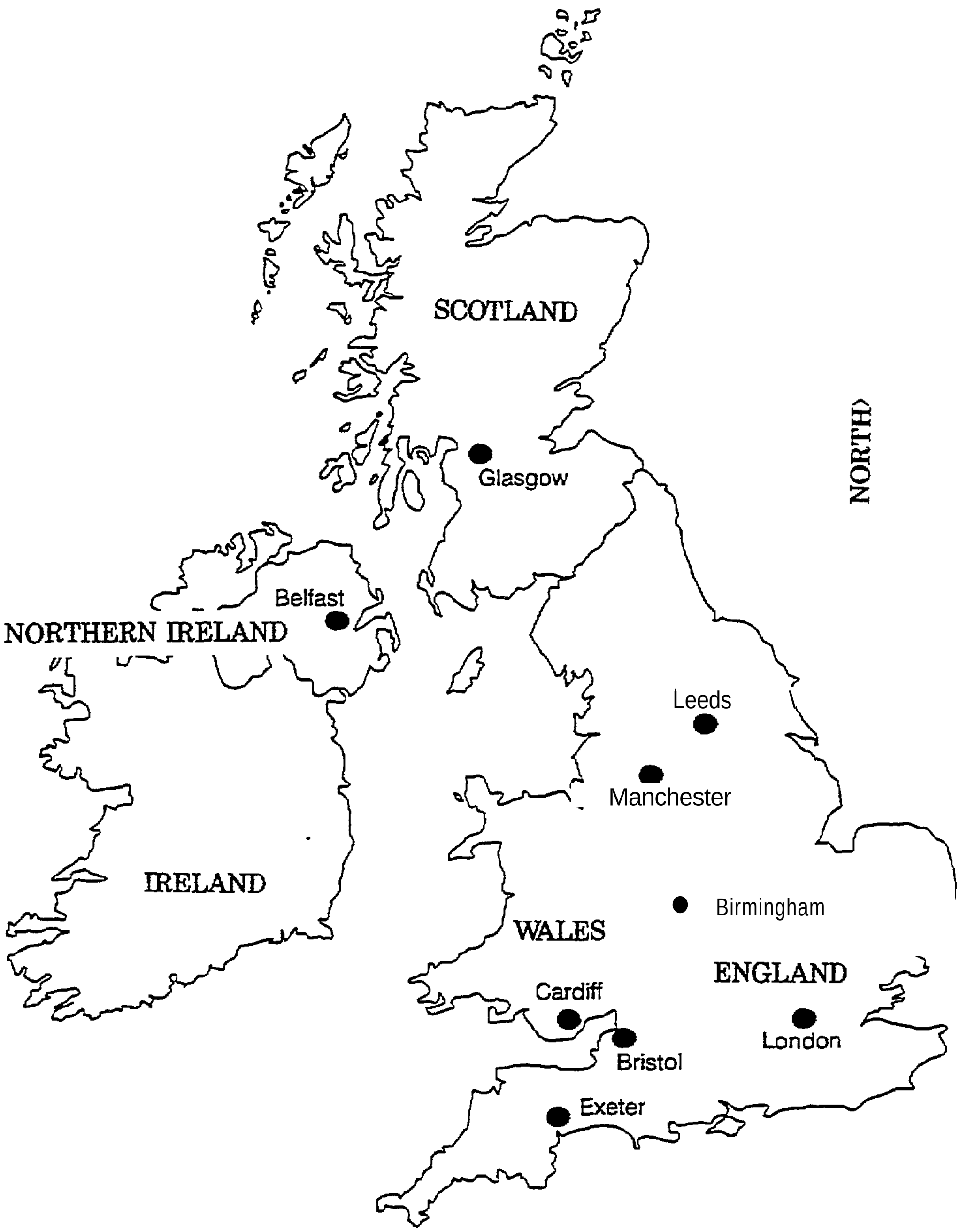
AA essentially operates as the traffic information provider for the whole of the U.K. This is achieved through a network of nine interconnected TICs. These are located in Glasgow, Belfast, Manchester, Leeds, Birmingham, Bristol, Exeter, Cardiff and London (Figure 4.1). The London TIC serves as the National Operations Center.

The distributed approach toward TIC operations in AA Roadwatch is comparable to that being considered in Colorado. In the AA system, all Roadwatch TICs operate using local area computer networks. The TICs are also interconnected via AA's corporate data network This allows information input at one location, for example Glasgow, to be simultaneously available at the neighboring facility in Manchester. The data are also relayed to the National Operations Center in London.

Conceivably, a similar approach could operate in Colorado. The C-Star strategic IVHS plan envisions a number of interconnected TOCs serving as a statewide network Formation of such a network would be initiated by establishment of data transfer procedures between the Denver TOC and the Eisenhower/Johnson Tunnel and Hanging Lakes Tunnel control centers. This would be supplemented by future TOC deployments in areas such as Colorado Springs and other locations. The Denver TOC would logically serve as the central point of this network, analogous to AA's National Operations Center in London. The distances involved in Colorado would be similar to those between TICs in the U.K.

Figure 4.1

AA Roadwatch TIC Locations



4.1.4 Roadwatch Equipment

Each TIC operates an Ethernet local area computer network running on PCs. The system is DOS-based and is written in Dataflex. This allows operators to enter and update traffic, incident and weather information. The operators can also retrieve database information for dissemination to customers. The typical regional configuration is as follows:

- 1 Novell fileserver (Compaq 386 PC).
- 1 communications service (Compaq 386 PC).
- 1 or more workstations.
- 1 or more printers.

A similar computer configuration exists at the London TIC to allow data input and updates. However, the system here is supplemented with a UNIX-based Compaq Systempro 486/420. This houses the national Roadwatch database, which is written in Dataflex.

With regard to communications, each regional TIC has custom made broadcast and line switching equipment to ensure local radio reports are broadcast effectively and clearly, plus facsimile and telex equipment. There is also a telephone system in the regions for updating a premium rate telephone service. The regional TICs are connected to each other and the National Operations Center through an X.25 wide area network.

Communications equipment at the London TIC is again similar to the regions. However, a DCE Faxbox is also connected to the UNIX processor to allow automated data extraction and faxing to a large number of external groups. These include radio stations, county councils and police forces. In addition, dial-up access is available for inquiries to the national database. The system is open so that third parties can connect into the Roadwatch database and retrieve data for their own use.

Further communications elements of Roadwatch include a data feed from the London TIC to Aircall Communications, a commercial paging company. This operates over a kilostream line owned by Aircall. Aircall uses the data received as the basis for a traffic information paging system, described below. The London TIC also contains a teletext updating terminal, and operates communications links with Trafficmaster and the Police National Computer at New Scotland yard. Figure 4.2 presents an overall schematic of the Roadwatch system.

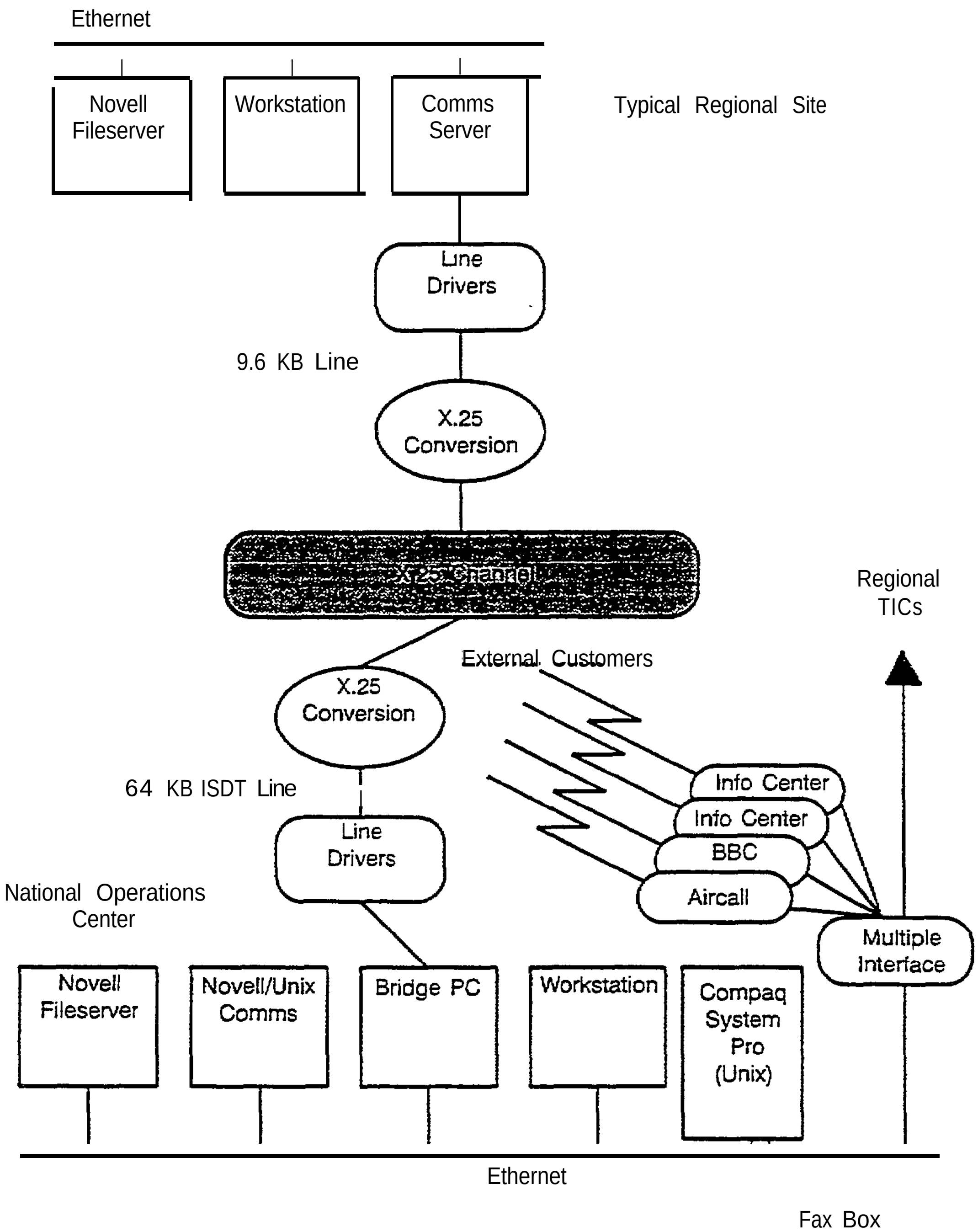
4.1.5 Data Collection

Roadwatch obtains data from a number of sources. These include the following:

- County Police Forces - private wire telephone circuits connect the TICs directly to Police control rooms. AA staff typically make 30 routine check calls per day to solicit data for dissemination. The Police also update AA on incidents using the same telephone connection. In addition, the Police originate telex messages presenting long term roadwork information.

Figure 4.2

Roadwatch Schematic



- County Councils - these update Roadwatch with regard to local roadworks. Information is received in the form of a weekly facsimile transmission with updates as necessary.

- Department of Transport - a weekly report is provided covering roadworks on motorways and other major highways nationally. This includes an advance warning service for roadworks likely to cause serious congestion. AA report that the value of this information is increased when it is supplemented through relationships with County Councils or Police Forces, who tend to be more aware of local conditions.

- M25 Police Forces - AA has a contractual arrangement with 6 Police Forces covering the M25 London Orbital Motorway. Under this contract, the Police Forces are required to advise AA of traffic delays on the motorway. This contact is via direct phone lines. AA is then responsible for informing all media contacts using a telex message. This is sent to radio, TV and newspaper media as well as other interested parties such as Trafficmaster.

- Dariford River Crossing - this is a private company operating a tunnel and bridge link across the Thames River, controlled by tolls. AA makes check calls to the facility's control room to obtain details on congestion and incidents. AA note the potential for conflict in this arrangement, since the operating company is financially dependent on toll revenues and may not find it to be in their interests to publicize delays. A similar situation may arise on the E-470 facility in Denver.

- AA Patrols - These represent a useful source of information, supplementing Police Forces and Highway Authorities. AA has approximately 3,500 patrol vehicles, each equipped with two-way radio and/or mobile telephones. Typically, 10 to 15 reports are received daily from AA patrols in each region. In Colorado, similar data can be derived from AAA activities such as the Courtesy Patrol.

- Cellular Telephones - AA has established a database of approximately 1000 mobile phone users, all of whom are individually registered with an exclusive Personal Identification Number (PIN). This PIN is quoted when the caller makes a traffic report. The number is then checked to establish that the caller is a bona fide AA member.

- Traffic Master - AA operates a data sharing arrangement with Trafficmaster. AA uses a Trafficmaster unit to review traffic speeds on the M-25, subsequently investigating the cause of any delays. In return for providing Trafficmaster with the results of this investigation, AA is permitted to use the speed data as the basis for travel advisories.

4.1.6 Data Dissemination

Data gathered from the information sources described above are disseminated in a variety of ways. The principal method is scheduled radio broadcasts. Additional approaches include teletext, conventional television, telephone information services, and direct on-line access to the AA database via networks such as Prestel.

A recent information dissemination initiative involves an arrangement between AA and Aircall Communications, a commercial paging service operator. This uses Aircall's pager network to broadcast traffic messages throughout most of the U.K. directly onto hand-held, pocket-sized, personal receivers. Aircall is reportedly offering AA Roadwatch information as a means of broadening its user base. The pager screen is quite small and typically presents information in abbreviated form, as shown by the example below:

AAR: TUE 8:24
Ml J2 ACCIDENT
BLOCKED S/BOUND C/WAY
TAKE J4 TO AVOID

Translating this into a full sentence, the message indicates that an accident at Junction 2 of the Ml motorway has blocked the southbound carriageway, and drivers are advised to exit at Junction 4 to avoid the area.

4.1.7 Funding

Funding requirements for AA Roadwatch are reportedly in excess of one million pounds per year, (approximately $1.7 million) for its 24 hours per day, seven days per week operation. AA suggests that it is unlikely that another organization would wish to fund a rival service, given the difficulties of recovering even a portion of these costs through selling information. In addition, AA notes that there are potential problems with charging for information which is originally obtained from Police Forces, Highway Authorities and County councils. Because these are public organizations, motorists expect the information to be free and in the public domain.

Despite this, AA does recover Roadwatch's operating costs through sales of data to users. This is reportedly justified on account of the value added through AA's collation and packaging of raw data. AA has also sought to maximize commercial possibilities arising from on-air accreditation via sponsorship. In addition, Roadwatch has secured BBC funding for input to the BBC Travel Center, described in this report.

4.1.8 Summary

Based on this review of the U.K.'s AA Roadwatch service, the following issues are of interest with regard to the Denver Metro Area TOC:

- AA Roadwatch represents a distributed, networked system which is likely to be similarly utilized in Colorado to link the Denver TOC with other control facilities in the state. Although it may not be required during initial operation, the Denver TOC should include the capability to support a statewide travel database.

- AA Roadwatch acts, in effect, as a national traffic information service, operating with the support of public agencies. A similar situation may develop in Denver, with private firms using data collected at the TOC as the basis for ATIS ventures. Consideration should be given to the provision of data to private firms in a fixed format, to ensure consistency of messages between competing private systems and public information outlets. Some restrictions may also need to be imposed on the extent to which private firms can draw their own conclusions or provide advice using TOC-supplied data.

- AA Roadwatch provides information to a number of public agencies by techniques such as automated faxing. The Denver TOC should include similar facilities for information dissemination in the Metro Area. The system should be open to allow easy access for users.

- AA Roadwatch collects traffic information from a variety of anecdotal sources. The Denver Metro Area TOC should seek to use similar approaches, including regular updates and advisories from local agencies. Reports from cellular telephone users and patrol or maintenance vehicles will also provide valuable data, particularly in areas of low sensor coverage density.

- AA Roadwatch feels justified in charging users for receipt of collated, packaged data from public sources. During visits to other U.S. traffic management facilities, some operators have advocated use of a similar approach in Denver as a contribution toward operating costs. A decision in this area requires consideration of who will ultimately cover the cost of this data.

  If a charge is imposed by the TOC, the cost will almost certainly be passed on from the service provider to its customers. This will increase the price of ATIS use, potentially making it unaffordable for a proportion of the public, despite their contribution to the TOC's data collection efforts through taxation. However, the amount of taxes dedicated to the TOC can be reduced through the collection of user fees.

  If data are provided free of charge by the TOC, this in turn will reduce the cost of ATIS services. ATIS will therefore be more attractive and affordable for the public. However, an increased proportion of the TOC's operating costs will be reliant on taxation.

4.2 BBC Travel Center

4.2.1 Introduction

The British Broadcasting Corporation (BBC) is the primary news and information source for the U.K. The BBC Travel Center was established to provide a more efficient means of communicating travel information to motorists. To support this endeavor, the BBC has developed a communications network with a central computer that receives traffic data from a number of sources and disseminates this information to BBC broadcasting media.

4.2.2 System Overview

The BBC Travel Center was opened in the summer of 1989, replacing the previous motoring and travel information service of the BBC. The primary objectives in establishing the Travel Center were as follows:

- To improve the quality of information.

- To speed up the dissemination of incident information.
- To implement Radio Data System (RDS) services.

To achieve these goals, the BBC developed a software program to better coordinate incoming information. An RDS information network was implemented to better communicate this information to motorists. In addition, teletext traffic services were also updated in parallel with these other enhancements.

This message generating software produces messages in a format that almost exactly matches the Traffic Message Channel (TMC) protocol, developed in the European DRIVE program for RDS and other digital communications channels. This represents an efficient way of summarizing traffic information in a concise form, suitable for visual presentation or encoded digital transmission.

4.2.3 Data Collection

Information is received by the BBC Travel Center computer electronically and manually. The Travel Center computer has three modems which receive information from travel terminals located in police control rooms and other emergency response agencies. Information is also received from a telex network and fed into a message switching system. This information is provided by the Press Association which primarily consists of radio stations in the London area. The Travel Center also receives information from meteorological services and maintenance crews. Agencies outside the BBC network provide relevant information via telephone or facsimile.

4.2.4 Data Processing

Traffic information is input into the main computer in a format that classifies the incident or problem, identifies the location and affected area, and provides an urgency measurement. The software program has a continual update mode which maintains an active warning until an all clear message is input into the computer by a Travel Center operator. These software improvements have served to standardize travel advisories and to develop message priorities which reflect the severity of traffic conditions.

4.2.5 Data Dissemination

The Travel Center has a network of data recipients which are electronically connected to the system computer. Travel terminals are installed in all police control rooms in London and in some of the surrounding areas. There are also terminals in the Press Office at London Transport and in control rooms of agencies that maintain the M25 London orbital motorway. Additionally, four local radio stations are equipped with travel screens and printers to receive information directly from the Travel Center.

The primary means of disseminating information to the public is by RDS broadcast. The Travel Center is equipped with a self-operated audio package, an RDS controller and a logging cassette deck. The information is routed to various destinations by the RDS controller matrix. The control matrix routes music and cue lines from each RDS broadcast station to individual booths at the Travel Center.

Travel advisories are issued from the Travel Center to RDS-equipped radio stations. The RDS network allows regional travel information broadcasts via the BBC's radio stations. RDS radios have features that can identify stations that provide traffic updates, turn up the volume when a message is being broadcast, or retune the radio to receive the traffic message. These features help to increase the number of travelers that receive and act on the information.

In the near future, perhaps within the next two years, the BBC is likely to start broadcasting digital messages using the RDS-TMC service. The fact that the Travel Center's existing software is already TMC-compatible will greatly support this effort.

A further method of disseminating information to the public is via teletext. A significant proportion of the U.K. population owns teletext-compatible television receivers. Teletext allows viewers to receive pretrip planning data and to select from different pages of information in accordance with individual needs.

4.2.6 Summary

The following issues concerning the BBC Travel Center are of interest in the planning of the Denver Metro Area TOC:

- The BBC Travel Center is electronically linked with radio broadcast stations, police and other agencies. The Denver Metro Area TOC should similarly consider an electronic communications network with appropriate agencies to ensure the most efficient sharing of information.

- The BBC Travel Center generates traffic messages in a TMC-compatible format. This leads to concise and consistent messages in the short-term, while supporting future upgrades to digital ATIS broadcasting. A similar approach is recommended for the Denver Metro Area TOC, minimizing the use of inconsistent free-form text messages. A copy of the TMC demonstration message generating software has been provided to CDOT, and serves as an illustration of the type of approach proposed for the TOC.

- The BBC Travel Center makes routine use of teletext, which is also being considered in Denver. Again, a standard format for message generation would support this effort, as well as a cable TV traffic information channel.

- Clearly, the Denver Metro Area TOC is not going to own and operate a chain of radio stations like the BBC. However, there is potential for the TOC to establish agreements with local radio stations and other traffic information media for dissemination of data via methods such as RDS.

4.3 Trafficmaster

4.3.1 Introduction

Trafficmaster is a commercial traffic monitoring and information system in the United Kingdom that services the Greater London area. The primary function of Trafficmaster is to provide motorists with real-time traffic information. Trafficmaster presently provides such data for motorways within a 35-mile radius of central London, and is undergoing expansion to cover additional motorways and major arterials.

4.3.2 Trafficmaster Operations

Trafficmaster provides motorists with real-time information on the speed, direction and length of congestion on the motorways. The Trafficmaster system measures low speed traffic to identify congested areas. This information is disseminated to in-vehicle portable units and superimposed on a roadmap.

Traffic speed information is collected from detectors installed at regular intervals on the motorways. The information is relayed via radio communications every three seconds to the Trafficmaster Control Center. Data are then passed on to the in-vehicle units via a commercial paging network. The paging network uses coded digital messages which enable the system to recreate the information at the appropriate point on the map display.

4.3.3 Trafficmaster Components

The Trafficmaster traffic detection network comprises over 230 infrared sensors mounted on motorway overpass bridges at approximately two-mile intervals. The detector unit illuminates two detection zones with encoded streams of infrared light. A microprocessor unit linked to the detector analyzes the light reflected back and computes the average speed. When the speed drops below a preset threshold of 25 mph the sensors relay that information to the Trafficmaster Control Center. From there, data on areas of congestion are sent out using the paging network.

The in-vehicle unit displays information on an LCD screen showing a simple map display. When new information is received, an audible warning alerts the driver and the map display shows the location and severity of the congestion. The Trafficmaster unit zooms in on the area of the map where the incident is occurring, presenting flashing messages to illustrate the location, speed and direction of the congestion. The extent of the congestion is indicated by the number of blocks flashing on the screen. Drivers can program the unit to present information on selected areas, thereby allowing them to receive only those messages that are relevant to their travel routes.

4.3.4 Trafficmaster Control Center

The Trafficmaster Control Center is the size of a large office room. The room has a large wall map that displays the network and the location of the infrared sensors. Light displays indicate whether the sensors are functioning correctly, and whether they are sending information to the Control Center.

The Control Center is typically staffed with one operator. Although traffic messages can be generated automatically, this option is not frequently used at present. Instead, the operator is responsible for transferring information from the detectors to the message generation computer. This allows incident reports to be confirmed or verified, but increases transmission delays and manual involvement requirements.

The operator is able to add additional text to the messages if more specific traffic information is required. This typically appears as abbreviated text, sometimes hard to understand, adjacent to the congestion point on the map display. The operator also maintains contact with AA Roadwatch, the U.K.'s national traffic information center. AA Roadwatch receives congestion information from Trafficmaster and in return provides Traflicmaster with reports of AA incident investigations. Trafficmaster additionally prepares a daily printout of congestion information and sells it to the Department of Transport for traffic analysis.

4.3.5 Summary

Based on this review of Trafficmaster, the following issues are of interest to the Denver Metro Area TOC:

- Trafficmaster represents an excellent example of a private sector ATIS venture unsupported by public funds or data. However, this required deployment of a private, proprietary data collection network within public right-of-way, which may be felt inappropriate in the Denver Metro Area.

- If installation of a private data collection network is permitted in the Metro Area, clear guidelines will need to be established for deployment in the public infrastructure. For example, how many companies could deploy equipment, where would it be installed, and under what terms? In particular, it is recommended that firms given this opportunity be required to provide data to the TOC free of charge (although distribution to other firms would be restricted). This is in contrast to Traflicmaster, which charges the U.K. Department of Transport for receipt of historical data.

- If private installation of data networks in the public infrastructure is not permitted, increased emphasis will need to be placed on state-funded deployment. In this case, the TOC will likely serve as an information provider to one or more commercial ATIS ventures.

- The use of digital paging for ATIS transmissions, illustrated in Trafficmaster, represents an alternative approach to radio transmissions that can be used in the Metro Area. Paging is proven and affordable, and the receivers are portable and inexpensive. A public/private partnership between the TOC and a paging firm may be considered.

- The infrared speed detectors used in Trafficmaster are one of several above-ground sensor approaches that can be used for traffic data collection. Such approaches are attractive in that they do not require road closures for installation and can be replaced or maintained easily.

4.4 CITRAC Motorway Control System Control Center

4.4.1 Introduction

The existing CITRAC (Centrally Integrated Traffic Control) Motorway Control System (CITRAC 1), for Strathclyde Region in Scotland, became operational in the early 1980's. CITRAC 1 employs three main monitoring/control elements to achieve the high level goals of reduced delay/congestion and improved safety:

- Emergency Telephone.
- Closed Circuit Television.
- Lane Control Signalling.

CITRAC 2 is a related urban traffic signal control system for Glasgow, and CITRAC 3 refers to an extended and enhanced motorway system to replace CITRAC 1. The CITRAC Motorway System Replacement project is currently in the procurement stages. In particular, the changes involved in the transition from CITRAC 1 to CITRAC 3 are of relevance to the Denver Traffic Operations Center, since those components of the system which, through experience, have operated successfully have been identified and are being retained as part of the system, while the less successful components are being modified.

The existing CITRAC motorway system is operated by both the Strathclyde Regional Council (SRC) Department of Roads and Strathclyde Police Traffic Division, from independent control centers located in separate adjacent buildings. Presently the SRC is responsible for the management and maintenance of the system, while the Police are responsible for responding to incidents and other traffic events.

4.4.2 Advanced Traffic Management System Functions

4.4.2.1 EMERGENCY TELEPHONES

All motorways within Strathclyde Region have emergency telephones sited on opposite sides of the roadway at a maximum 1.5 km interval. The Emergency Telephone System is comprised of the two independent systems of the Strathclyde Regional Council and Scottish Office Systems, separated traditionally according to the jurisdictional responsibility of the motorway on which the phones are situated.

The existing Strathclyde Regional Council System is a network of 108 emergency telephones sited at 500 to 1000m spacing between the Hillington and Baillieston Interchanges on the M8 motorway. Each telephone outstation is directly interconnected to the switchboard located within the Strathclyde Police Command and Control Center by a leased British Telecom (BT) telephone line.

The existing Scottish Office System includes the connection of 140 emergency telephones on the M8 motorway past the urban Hillington to Baillieston Interchanges as well as additional phones located on the M73, M74, M77 and M80 motorways. The system network is comprised of nine terminal branch units (TBU) to which up to 16 telephones along a particular motorway section are connected. Each TBU is connected to a terminal answering unit (TAU) located within the Strathclyde Police Command and Control Center via a leased British Telecom telephone line. There are currently 9 telephone circuits in use. On the Stepps Bypass, a 30 pair cable is being installed to provide dedicated voice communications back to a Scottish Office TBU and subsequently back to the Police Control Center via a leased BT line.

Both systems interface to central operator positions within the Strathclyde Police Command and Control Center.

4.4.2.2 CLOSED CIRCUIT TELEVISION

The Closed Circuit Television (CCTV) system is the primary tool for incident management. The objectives of the CCTV system are to provide the traffic control operators with the following capabilities:

- Identification of incidents.
- Confirmation of incidents and congestion.
- Confirmation of incident response activities.
- Assistance during the decision process for traffic diversion schemes.
- Monitoring of field devices including emergency telephones and gantries.

The present motorway CCTV system consists of 39 pole mounted black and white camera units and one roof mounted color camera unit. Cameras are situated at strategic locations to provide almost continuous coverage of the motorway network from Glasgow Airport to Baillieston. The Scottish Office installed 10 cameras in the outer limits of the motorway network which utilize fibre optic communications for video transmission. All camera installations are spaced at 500m to 1,500m along the motorway corridor.

The CCTV subsystems of the motorway control system (CITRAC 1) and the urban traffic control system (CITRAC 2) are integrated and controlled by an one video switch matrix/camera control transmitter which permits the following accessibility:

- Strathclyde Regional Council may monitor and control any CITRAC 1 motorway camera or CITRAC 2 intersection camera.
- Strathclyde Police may monitor and control any CITRAC 1 motorway camera.

Police operators assume the prime responsibility of controlling the cameras on the motorway network under the current operational procedure. Each operator has a control panel and a nine inch desk monitor. The panel enables the operator to select a camera and a monitor to observe an incident on the motorway. Push-buttons controls and a joystick on the panel provide control of camera functions including zoom, focus, pan and tilt. Images from cameras along the motorway can be automatically sequenced on a single monitor, the order of sequence and duration of display being selected by the operator.

4.4.2.3 ADVANCED TRAFFIC MANAGEMENT SYSTEM FUNCTIONS SUMMARY

Both the Emergency Telephone and the Closed Circuit Television systems have proven to be useful detection/monitoring tools for CITRAC 2. However, some changes will be implemented under CITRAC 3 to further improve the functionality of these systems.

The emergency telephone system will be upgraded to provide a more sophisticated operator interface and greater system reliability. The CCTV system will be enhanced by the gradual conversion to the use of color cameras and monitors, and geographic expansion. Operators at both the Police control center and the SRC control center will have access to the control of motorway cameras, under a set of user definable operating procedures. An interconnection between the emergency telephone system and the CCTV system will also be developed, so as to assist in the rapid identification and response to incidents.

In order to provide real-time information on traffic flows and incident locations on the motorway system, detector loops will be installed throughout the more heavily travelled urbanized sections of the network. These loops will gather traffic information such as vehicle speed, traffic volumes and lane occupancy. The CCTV subsystem will also be linked to the automatic incident detection system, to optimize operator incident confirmation.

In addition, some ancillary monitoring functions will be provided to assist operator understanding in what is happening on the road system. Such features include connections to the Meteorology Office for weather advisory, and over-height detection systems in certain bridge and tunnel locations.

Issues relating to CITRAC Advanced Traffic Management System (ATMS) functions which can be applied to the Denver Metro Area TOC are as follows:

- CCTV cameras are very useful for incident confirmation and monitoring. The functionality of the cameras are most successful when the geographic coverage is wide and continuous. Color cameras/monitors facilitate identification/tracking of incident details.

- While the emergency telephone system works well in the UK, part of this success is due to widespread public awareness and usage of the system. Therefore, a motorist learning curve is necessary prior to realizing the full benefits of this type of system.

- Several detection systems, primary and ancillary, are recommended for the Denver application. The different systems can be used to cross-check data, thereby providing a synergistic detection mechanism.

- Integration of systems (e.g. CCTV with detector loops, CCTV with emergency telephone) and of operating agencies (e.g. through shared camera control) facilitates operation and assists an integrated response.

4.4.3 Advanced Traveller Information System Functions

4.4.3.1 EXTERNAL INTERFACES

Currently, the main involvement of Police and SRC CITRAC operators in distributing traffic and road information is through contact with a traffic reporting agency called AA Roadwatch. Strathclyde Police and SRC operators telephone AA Roadwatch to relay information on traffic incidents, including information on clearance and termination. Police communications with AA Roadwatch related to specific incidents are logged by the Police Motorway Control Operators on the Command and Control terminal. AA Roadwatch in turn distributes the information to radio stations, such as BBC (which broadcasts nationwide traffic news about every fifteen minutes during peak periods) and Radio Clyde (which uses Police information as a supplement to observations made from its private company-sponsored "Eye in the Sky" helicopter). Traffic news broadcasts presented by stations receiving data from the various CITRAC operators tend to be well detailed, but are dependent upon timely broadcast.

4.4.3.2 LANE CONTROL SIGNALLING

There are currently 120 operational lane signalling gantries under control in the Glasgow area. The information provided to motorists includes advisory speed, merge and turn instructions, and a regulatory "lane closed", indication.

The lane signalling field infrastructure is composed of three major subsystems which include:

- Motorway Signalling Unit (MSU). The motorway signalling unit is a light emitting sign capable of displaying fixed speed or lane status legends (restrictions). The MSU's are mounted on overhead gantries, one per main carriageway or ramp lane. Currently there are three different types of MSU's operational in the system: incandescent bulb-matrix MSU's (manufactured by Philips) and two versions of fibre optic MSU's (manufactured by FKI Chance).

  The newer MSU's include a red "X" and are designed to meet new Department of Transport Regulations. They also include the work "END" to replace the original "0" ah-clear symbol.

  Companion to each MSU are 4 amber and 4 red flashers which operate in pairs (top and bottom pairs for the amber, left and right pairs for the red). When a restriction other than "lane closed" is in effect, the amber flashers operate as an attention-getting supplement to the legend. The "lane closed" restriction is signified on the existing MSU's by operating the red flashers alone (no legend is displayed). For the new MSU's, the red flashers will be supplemented by a continuously displayed red "X".

- Gantry. Most of the motorway signalling units are mounted at the bottom of large enclosed steel gantries (Glasgow type) that are a minirnum 5.7m above the travelled lanes. These gantries also contain standard direction signs mounted above the MSU's, and are irregularly spaced at normal direction sign locations (typically at the exit and roughly 800m and 1600m upstream of interchanges). Service access to the MSU's is from a hatchway into the gantry, located over the hard shoulder.

- Out-Station Unit (OTU). The out-station unit controls the motorway signalling units and communicates with the central computer (in-station). The out-station is mounted in the gantry, and each one can control up to 4 MSU's but can be expanded to accept a maximum of 8. Typically this results in one out-station per gantry.

The operation of the lane signalling system is governed by a set of pre-defined "ground rules" which generate a logical sequence of upstream signal displays, based upon the motorway lane configuration. Actual system operation is performed by the police from their control room via a computer terminal. The CITRAC traffic engineering staff have a separate control room with an identical terminal, but in practice do not operate the lane signalling system.

When an incident or other problem is identified, the police operator first confirms it either through CCTV surveillance or by dispatching a patrol car. Once the incident or problem has been confirmed, a command is issued through the computer terminal to implement a lane signal restriction at the gantry upstream from that location. Using the predefmed ground rules, the central computer develops an overall control plan for the immediate area and activates a countdown sequence to implement the appropriate signals. Short-term construction and maintenance work is handled in a similar manner.

Prior to clearing a restriction, the police operator dispatches a patrol car to confirm that the incident or roadworks has ended and that the reason for the restriction is over. Restrictions are not normally removed until such confirmation is received. There is no gradual removal of restrictions, they are simply turned off.

4.4.3.3 ADVANCED TRAVELLER INFORMATION SYSTEM FUNCTIONS SUMMARY

Under CITRAC 3, external interfaces, focusing on driver information, will be expanded considerably. The details of the new external interface system will be determined through a parallel project to the CITRAC Motorway Control System Replacement project.

The lane control signalling system will continue to be a part of the CITRAC Motorway Control System. The current lack of motorist credibility and compliance in lane control signalling, however, will have to be overcome through new operational approaches, which include:

- Implementing several modes of operation for increased flexibility, e.g.:
  - Automated Detection - Automatically tracks end of queue as the queue builds, displaying a general warning condition, e.g. amber flashing lights or relatively mild speed restriction.
  - General Traffic Advisory - Activated manually by operator as a general warning for known hazardous conditions.
  - Lane Use Control - Similar to current usage.
- Installing one-line variable message signs to supplement lane signalling gantries by providing additional information on the nature of the restriction.

Issues relating to CITRAC Advanced Traveller Information System (ATIS) functions which can be applied to the Denver Metro Area TOC are as follows:

- While the Denver system relies on variable message signing, rather than lane control signing, consideration might be given to lane control signing in the longer term, since this technology is better equipped for queue end response and queue control than VMS signing. VMS's, however, are preferable for descriptive information at/near the event site.
- External interfaces, directed toward driver information, are required to reach an area-wide motorist audience, complementing local signing systems such as lane control signing and variable message signing. External interfaces are also required to provide pre-trip information to motorists.

4.4.4 Incident Management

Motorway control operations in the Police control room focus on detecting, monitoring and responding to motorway incidents, as well as other events (e.g. roadwork, weather) affecting motorway safety. Operatots implement actions to increase safety at the problem site, and are not responsible for general traffic management on the motorway. Once the danger has been removed, motorway control operators are responsible for terminating the response and restoring "status quo" conditions.

Apart from monitoring incidents on CCTV monitors, the SRC does not participate in incident management.

Specifically, police perform the following incident management functions:

4.4.4.1 DETECTION/VERIFICATION

- Receive calls on incidents from patrol officers through police radio, and from motorists through the SOS emergency telephones (spaced at 1500 meter intervals along the motorway), cellular telephones and the 999 emergency telephone system (similar to the 911 emergency telephone system in North America). General emergency calls received through the 999 system are first responded to by British Telecom or Mercury, then transferred to the police control room switchboard, which in turn transfers motorway related calls to the motorway control operator.

- Visually scan CCTV monitors for incidents and unsafe road conditions due to weather (e.g. ice, rain, wind).

- Receive advance notice by teletype of planned motorway closures (e.g. for roadwork), and immediate notice by police radio that a closure is about to be implemented. Lane closures are performed by SRC road “coning crews”, which are accompanied by police escort

- Monitor emergency, operational and weather problems on the motorway by observing CCTV monitors and maintaining communications with patrol officers by police radio.

4.4.4.2 RESPONSE

- Activate police response plans to incidents using police radio. Police response plans include call-out procedures for dealing with specific types of problems, e.g. hazardous material road spills, or lane blockages which may require pushing vehicles onto the hard shoulder (Police have at their disposal a fleet of “Range Rovers” with push bumpers).

- Contact other emergency services, for example fire and ambulance, to respond to motorway incidents. These contacts are made by the motorway control operator. Police coordinate on-site response among the various emergency agencies, and maintain radio communications back to Police Headquarters.

4.4.4.3 CLEARANCE

- Make contacts to send assistance to motorists involved in breakdowns. These contacts include the Automobile Association (AA), the Royal Automobile Club (RAC), towing services (from a roster of local towing firms) and private arrangements (for example through a relative or friend of the motorist).

- Remove restrictions upon me termination of a problem. Removal of lane closure restrictions requires the presence of a police officer on site, and therefore restriction removal may occur a considerable length of time after the actual hazard has been removed.

4.4.4.4 RECOVERY

- Place speed or closure restrictions on overhead lane control signs in response to emergency, operational or weather hazards on the motorway. Emergency restrictions are used for regulating traffic at the incident site when, for example, an accident has occurred. Operational restrictions are used when a predictable situation exists, such as roadworks, and are semi-permanent. Weather restrictions are used, in general, for long sections or the total motorway control area, when hazardous conditions arise due to weather, e.g. ice, wind, etc. Primary restrictions are entered by the motorway control officer into the motorway control terminal, and the system generates secondary restrictions on the upstream gantries, as well as safe phase-in patterns, using set “ground rules”.

- Implement route diversion in conjunction with gantry control signalling. When a carriageway is totally closed, the ramp control unit will indicate a ramp closure and activate “secret” route diversion signing, directing traffic to the next open motorway on-ramp. (This system feature is rarely used by Police.)

- Activate amber flashers to mark hazards in rural areas of the motorway not covered by gantry control. The amber flasher hazard markers are located in conjunction with emergency SOS telephones, and are spaced at intervals of about 1500 meters. In addition from being activated from the control center, they can be activated in the field using a key switch.

4.4.4.5 INCIDENT MANAGEMENT SUMMARY

While the CITRAC 1 system provides effective emergency response to incidents, the focus of response is the incident location, with minimal attention to the dangerous zone at the queue end, or the effect the incident is having on the rest of the network. CITRAC 3 will remedy this problem by reinforcing the detection/verification and recovery aspects of incident response, through more active involvement of the SRC operators, and through improved communications between the Police and the SRC. SRC operators will alleviate dangerous situations at the queue end by warning motorists through variable message signs, lane control signalling, or other means, while there is still time to stop safely. Also, diversion from points upstream of the queue end will become a part of incident management recovery.

Close communications will be maintained between the two control centers to ensure that the responses initiated by the Police and the SRC are not contradictory. The agencies need to establish compatible objectives and priorities, so that their operations are complementary.

For the Denver TOC also, the issue of agency coordination, primarily between CDOT and CSP, is important. Locating the two agencies in the same control room, or integrating the staff as has been discussed, will significantly improve communications and coordination, leading to better integrated and more focused incident response.

4.4.5 Communications

4.4.5.1 DATA COMMUNICATIONS

The data communications system is used to control and monitor lane control signals located along the motorways. The communications medium is a ten-pair copper cable. Three main trunk cables are installed throughout the system to facilitate communications with the gantry sign controllers.

The lane control gantries operate in a party line fashion, with up to 32 gantry controllers on each party line. There are a total of five party lines now in use for gantry signing, two along each of the major motorway trunks and one along the Clydeside Expressway.

Each party line uses two of the copper pairs in a 4-wire communications configuration. Data is encoded using frequency shift keying (FSK) and transmitted to the gantry sign controllers at 1200 baud. Each of the 32 gantry sign controllers on each party line is polled for status every 8 seconds. The maximum message to each gantry is 32 characters.

Repeaters are located 1.5 km apart, although the system is designed to allow for 3 km spacing.

4.4.5.2 VIDEO COMMUNICATIONS

The video transmission system is comprised of a combination of coaxial and fibre optic cables. Camera control functions are remotely controlled through the use of a copper pair installed along side both the coaxial cable and fibre cables.

4.4.5.3 COMMUNICATIONS SUMMARY

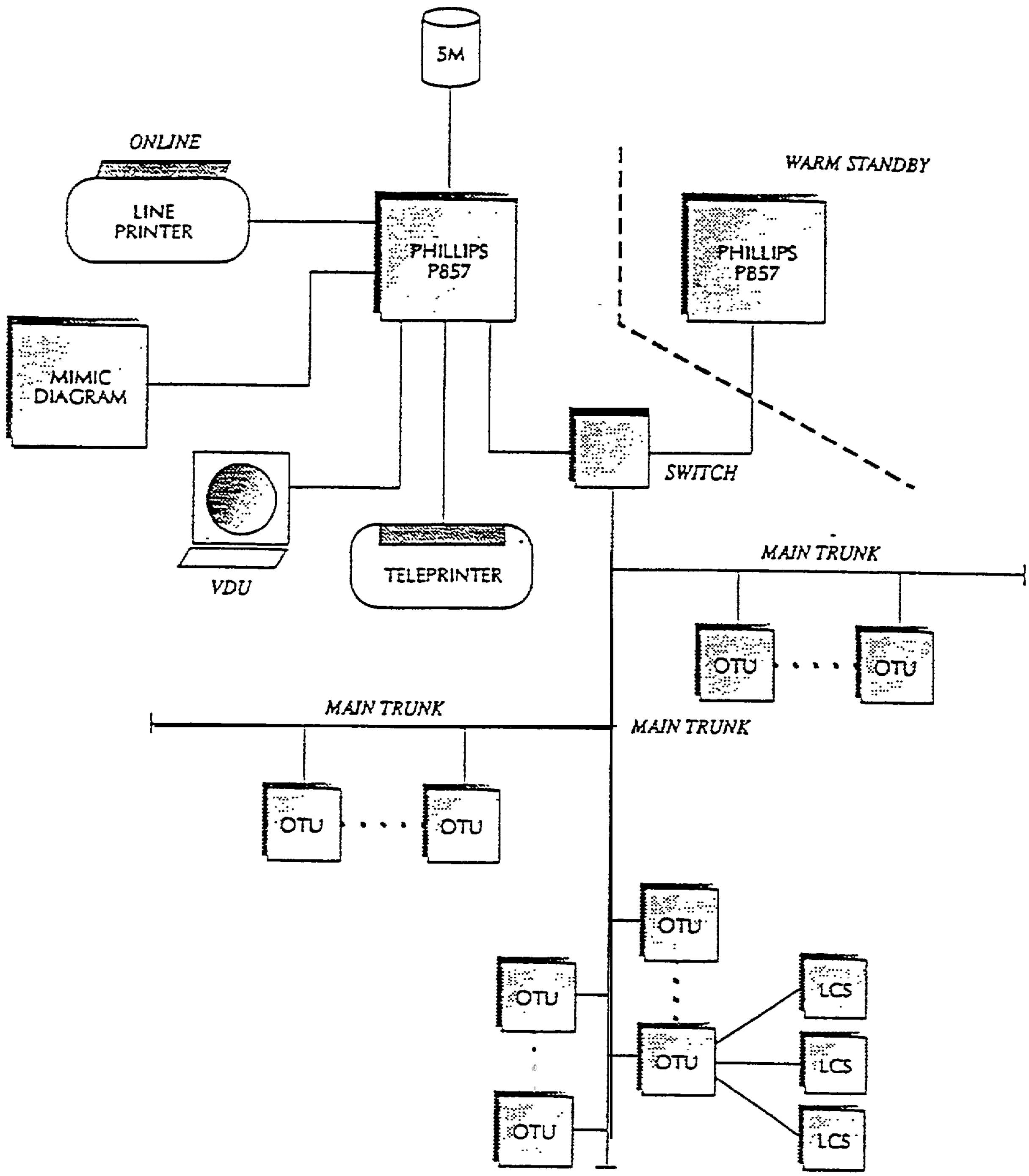
The communications system will be upgraded to provide capacity for additional field infrastructure and to maximize use of more reliable and better transmission quality fibre optic cable. It is proposed that the emergency telephone system be integrated into a fully redundant communications system with all communications employing industry standard protocols.

4.4.6 System Architecture

The central control subsystem (or in-station) of CITRAC 1 was originally operated by two Philips 16 bit 64K P857 computers each equipped with a 5MByte disk drive, control panel, and line matrix printer. The 64K capacity was extended to 96K which is the upper limit of the unit. One of the two computers operates in a warm standby mode while the other serves as the main point of operator control for the on-line system (switchover to standby is a manual procedure). Figure 4.3 provides a block diagram of the existing system architecture.

Figure 4.3

CITRAC Existing System Architecture



The central system also comprises three Visual Display Units (VDU's) used as the operator interface for control and monitoring of the CITRAC system. Four teleprinters offer backup system control capabilities and hard copy event logging facilities.

The on-line Philips computer drives LED's (one LED per gantry) on a semi-dynamic system map. The LED's provide an indication of the operation of the lane control signals mounted on the gantries along the motorway.

The in-station unit (central computer) communicates to each Out-station Unit (OTU) over a dedicated 10-pair conductor cable emanating from the control center in the form of three main trunks. The OTU's operate in a party line mode (i.e. multi-dropped) with up to 32 OTU's on a single party line. The data rate is 1200 baud and data communications conforms to a proprietary protocol developed by Philips. The overall system architecture assumes a master/slave relationships between the in-station unit and the OTU's. All communications are initiated by the in-station unit. That is, OTU's will only respond to a poll request and will never initiate a communication session.

4.4.6.1 SYSTEM ARCHITECTURE SUMMARY

As part of CITRAC 3 the existing system architecture will be replaced with the primary goal of implementing an open system which allows flexibility to add additional functionality while minimizing dependence on proprietary hardware/software. The in-station will be modular with one unit serving to provide traffic management capabilities with a second unit effecting communications with all field infrastructure. The workstations will also employ industry standard hardware.

Two types of outstations are recommended, with one unit employing industry standard processing hardware handling functions such as ramp metering, vehicle detection and lane signalling. Because of the increased memory requirements associated with Variable Message Sign Control, a distinct second VMS dedicated outstation is recommended also. All software residing within the workstation, in-station and out-station will be modular and reconfigurable. The recommended CITRAC 3 System Architecture is shown in Figure 4.4

The choice of open system architecture for CITRAC 3, driven in part by the limitations imposed by proprietary software in CITRAC 1, is also a relevant issue for the Denver TOC. Modular software design is recommended for improved organization and flexibility.

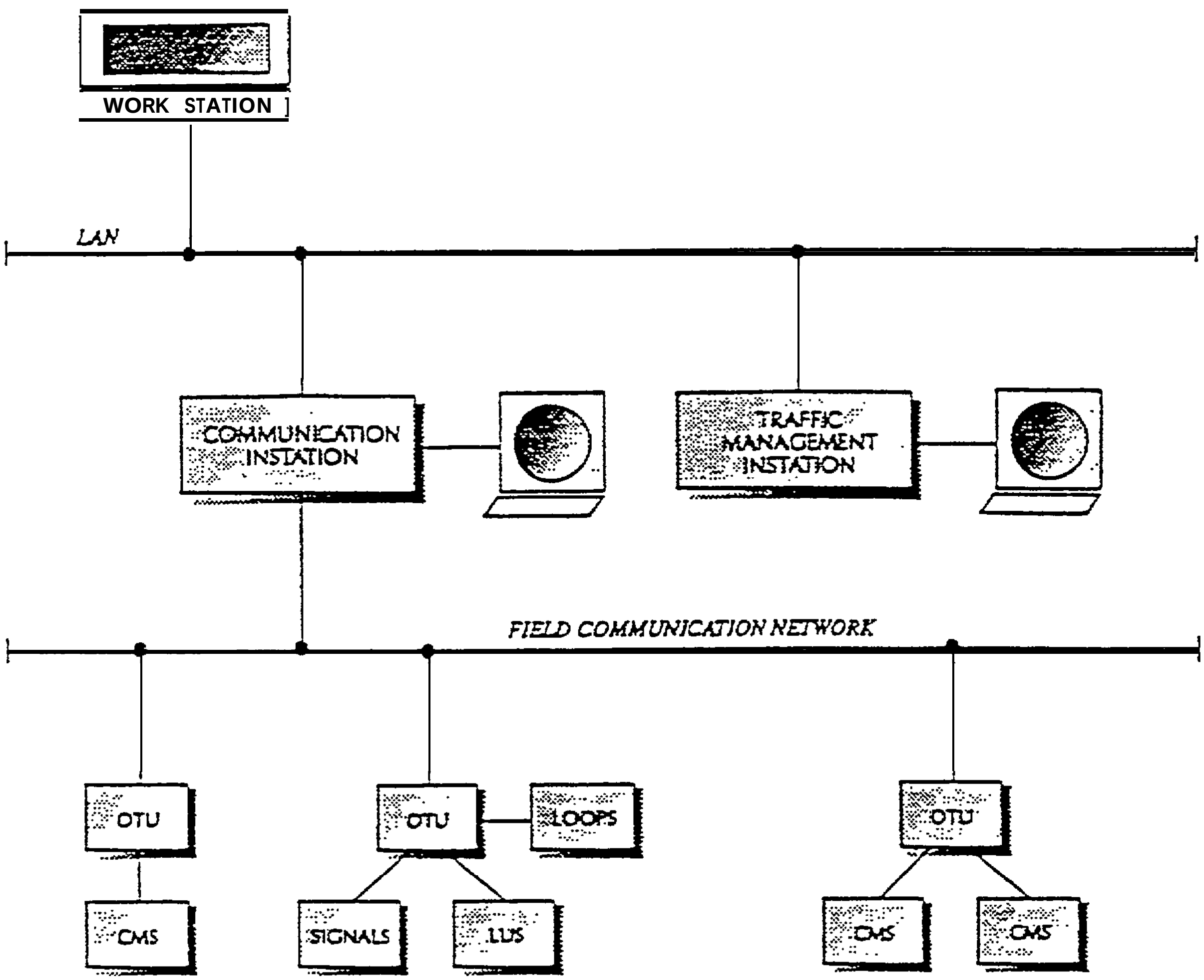
4.4.7 Traffic Operation Center

4.4.7.1 LOCATION

Located in the building housing the SRC offices, the SRC control room is also used for surveillance and control of the Glasgow Urban Traffic Control (UTC) system (CITRAC 2), which includes approximately 550 controlled intersections. The Police control room is across the street, in the Police Headquarters building.

Figure 4.4

CITRAC 3 Recommended System Architecture



The control room is the main communications center for Strathclyde Police, including overall emergency telephone response (999) and police radio dispatch, in addition to traffic related activities. Motorway computer and communications equipment is located at the SRC control center, and linked to the Police control room through a duct running beneath Holland Street.

4.4.7.2 POLICE CONTROL CENTER

Staffing - The motorway control function is a relatively minor component of overall Police control room activities, which focus on response to the 999 emergency telephone service and police radio dispatch. Accordingly, the control room has seven operator console units, as follows:

- Duty officer unit.
- Regular switchboard unit.
- Four police command and control units.
- Motorway control unit.

Each console unit can accommodate two operators, with fourteen operators comprising the fully staffed control room contingent. However, full staffing is rarely required, and the typical occupancy is about eight to ten operators. The motorway control console has one dedicated operator during peak periods (7:00 a.m. to 7:00 p.m.). At other times, police command and control operators monitor calls pertaining to motorway control, and temporarily relocate to the motorway control console to implement a response. This shared monitoring arrangement is satisfactory, since the volume of motorway calls at night is low.

All control room operators are experienced police officers, having five to ten years of active duty experience prior to working in the control room. New officers are first trained "on-the-job" in the police command and control operator position, and work in this position for about six months before being assigned to the motorway control operator position. Typically, police officers work as control room operators for about two to three years, although some staff have remained for over fifteen years.

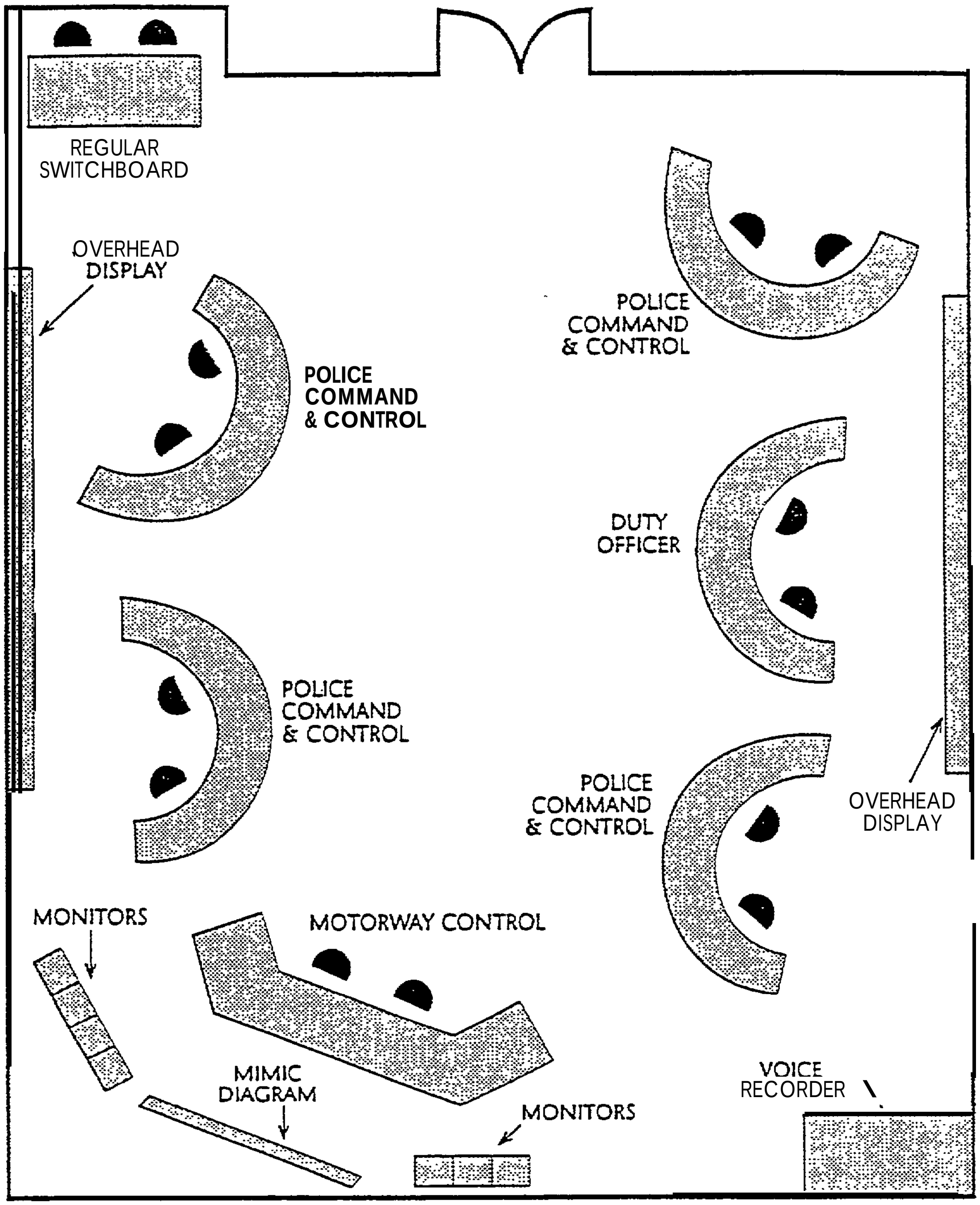
The control room operators work in four shifts. Each shift is supervised by a duty officer, who assigns specific operator duties on a rotating basis, so that all staff obtain experience in performing all operator functions.

Hours of Operation - Being the emergency communications center for Police, the Police Control Center operates 24 hours a day, seven days a week. However, as previously stated, the motorway control console is staffed with a dedicated operator only from 7:00 a.m. to 7:00 p.m. each day.

Control Room Layout - The general layout of consoles and equipment in the Police control room is illustrated in Figure 4.5.

Figure 4.5

Police Control Room Layout



NOT TO SCALE

Each of the two motorway control operator consoles contains standard equipment, in an approximate "mirror image" layout, as illustrated in Figure 4.6. The console equipment, and its operation, are described below.

- ***Motorway Control Terminal:*** A monochrome XT terminal for implementing gantry signalling control and route diversion. Gantry control involves placing speed or closure restrictions on overhead lane control signals, to notify motorists of emergency, operational or weather hazards. Primary gantry restrictions are typed in using custom commands, and the system generates appropriate response plans according to predetermined ground rules. Location information for assigning primary gantry restrictions is obtained by cross-referencing with motorway emergency telephone numbers. Simple line graphics depict the primary and secondary restrictions and count-down sequences for one motorway flow direction at a time.

- ***Telephones:*** A regular telephone is part of the console equipment.

- ***Command and Control System Terminal:*** All emergency calls received on the 999 system, as well as from other sources (e.g. police radio, motorway telephone, cellular telephone, regular telephone or CCTV monitoring) are logged onto police Command a nd Control System, which is the Police's primary event monitoring and logging system. Items recorded in the computer log include incident identifier, time, location, code and details of problem.

  In addition to the chronological log of motorway incidents stored in the Command and Control System, opera tors keep a hand-written log, complementing the computer log. The hand-written log includes contains chronological incident data, including: serial number; means of detection (telephone, radio, CCTV camera); motorway; carriageway; incident type (e.g. breakdown, accident, roadworks, etc.); type of assistance (police, Automobile Association, Royal Automobile Club, own arrangement, other). Daily and monthly summaries are prepared manually from the hand-written log and forwarded to the Scottish Office for analysis.

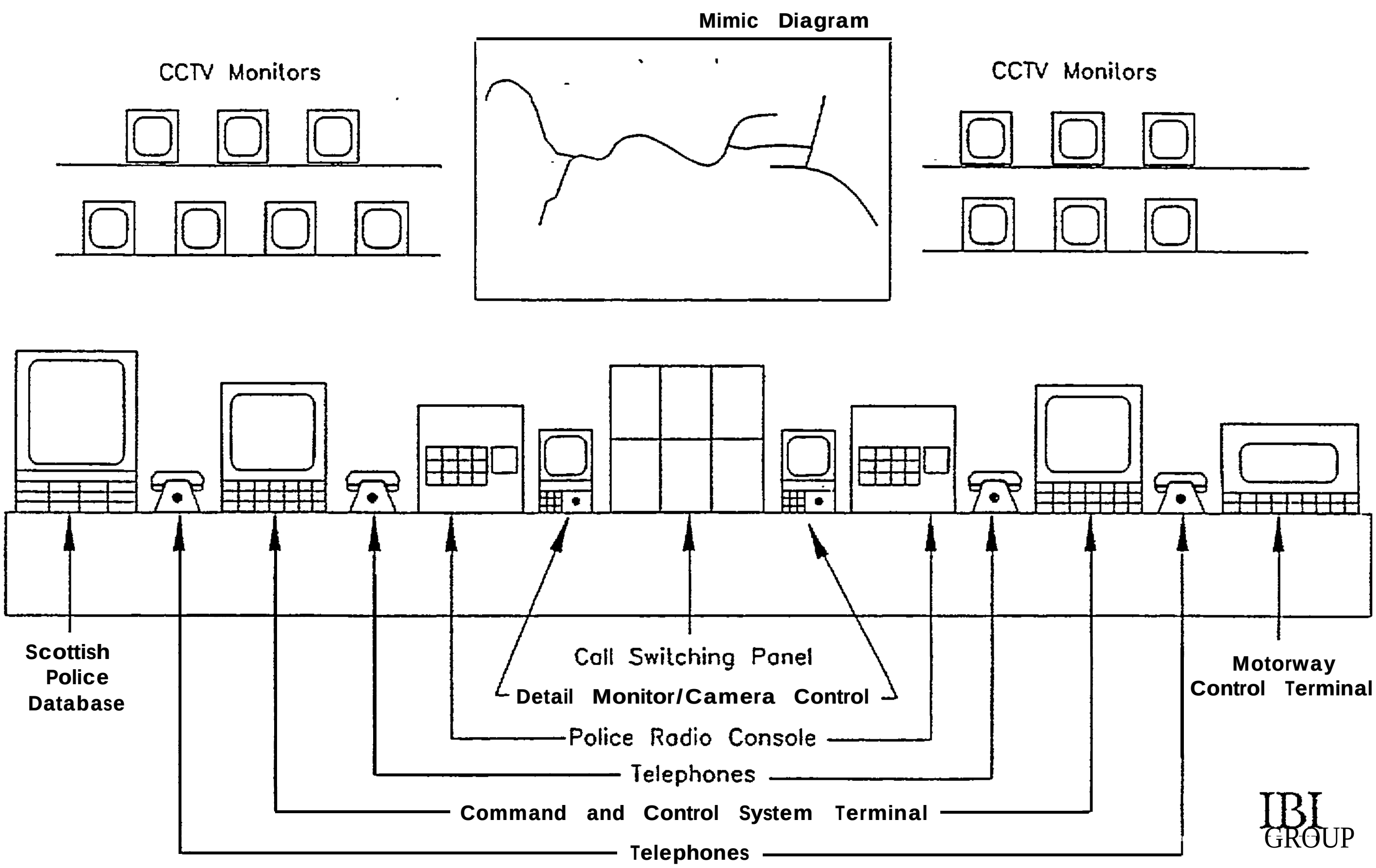
- ***Police Radio*** Console: Access panel to four operational channels - two for the Glasgow area, one each for Lanarkshire and Ayrshire districts - and one helicopter channel. Radio speakers are mounted on the ceiling, but operators are also equipped with headsets.

- ***Detail Video Monitor:*** A small (g-inch) black-and-white video monitor provides CCTV output close at hand to the operator, for the purposes of monitoring a specific incident or problem area.

- ***Camera Control Equipment:*** Equipment for selecting camera output on the large and small CCTV monitors, and for controlling the cameras through pan, tilt, zoom and focus features.

Figure 4.6

Police Control Room Operator Interface Equipment



IBI GROUP

- ***Call Switching Panel:*** Two separate banks of switches to respond to incoming calls from the rural (through Scottish Office) and urban (through Strathclyde Regional Council) parts of the motorway telephone system. An incoming call lights up a specific switch or provides a reference and sounds an alarm.

- ***Scottish Police Database Terminal:*** Only one of the two Motorway Control operator consoles has a Motorway Control Terminal. The other console is instead equipped with a Scottish Police Database terminal for data referencing, e.g. tracing license plate numbers.

Other control room equipment located near the motorway control consoles plays a role in operator interface. This equipment is described below.

- ***Mimic Diagram:*** A semi-dynamic wall map showing the motorway control area, specifying gantries, cameras and emergency telephones. The status of each device is indicated by colored LED's. The mimic diagram is frequently referred to by operators, to establish the geographic context of an incident.

- ***CCTV Monitors:*** Thirteen large monochrome video monitors arranged on shelves on either side of the mimic diagram. The monitors show selected output from thirty-eight CCTV cameras, together providing almost total coverage of the monitored sections of motorway. The monitor display is used to obtain an overview of motorway conditions.

- ***Voice Recorder:*** Equipment for recording all telephone and radio communications from all control room consoles. Recordings are retained for one month.

- ***Teleprinter:*** The teleprinter is used for printing system data, and can also be used to enter commands to restart the system, if the terminal should become locked.

4.4.7.3 SRC CONTROL CENTER

Staffing - Six SRC operator functions have been defined, as follows:

- Two for Traffic Headquarters.
- Two for the Glasgow North Area.
- Two for the Glasgow South Area.

The operators perform basic diagnostic and repair work for CITRAC 1 and 2, including first line fault diagnostics and field resets.

The SRC control room has console positions for two Urban Traffic Control (UTC) operators, and one motorway control operator. In reality, two to four staff at a time operate the UTC components, while the motorway console is typically unmanned. UTC operation requires active operator control by SRC. Motorway control, however, is primarily being performed by Strathclyde Police, in the form of its incident response activities, with SRC playing a less active role. The SRC control center also includes staff for Systems Management and Development functions (e.g. planning for system enhancements) and Traffic Engineering functions (e.g. implementing system enhancements such as the UTC user interface upgrade).

SRC is responsible for the general management and maintenance of the motorway system and the SOS system on an agency basis. Therefore, the control room activities of SRC staff center around diagnostics and monitoring, and include:

- Entering "engineer" commands into the motorway contml terminal, such as switching signal units off and on, disconnecting and reconnecting outstation transmission units, status monitoring, setting time, etc.

- Manually generating reports on incident analysis information, based on chronological event logs continuously printed out from the motorway control terminal.

Hours of Operation - The SRC control room operates from 7:00 a.m. to 7:00 p.m. Monday through Friday, and from 8:30 a.m. to 4:20 p.m. on Saturday.

Control Room Layout - The general layout of consoles and equipment in the SRC control room is illustrated in Figure 4.7.

The SRC operator interface for ClTRAC motorway control is less active than that for CITRAC urban traffic control. SRC presently plays a limited role in traffic management on the motorway. While SRC operators can technically set gantry speeds, only Police are authorized to implement lane closures and primary gantry speed restrictions associated with lane closures.

The following operator interface equipment is located at the single SRC operator console (see Figure 4.8):

- ***Motorway Control Terminal:*** A terminal identical to the one in the Police control room. SRC uses the terminal in a "read-only" mode, since only police have the authority to implement motorway incident response through gantry signalling. The terminal continuously prints a chronological event log, combining system events, device faults, gantry restrictions, communications failures, and other events. From this log, SRC operators manually generate a report on incident analysis information. No other reports of a statistical nature can be generated directly by the motorway control system.

Figure 4.7

SRC Control Room Layout

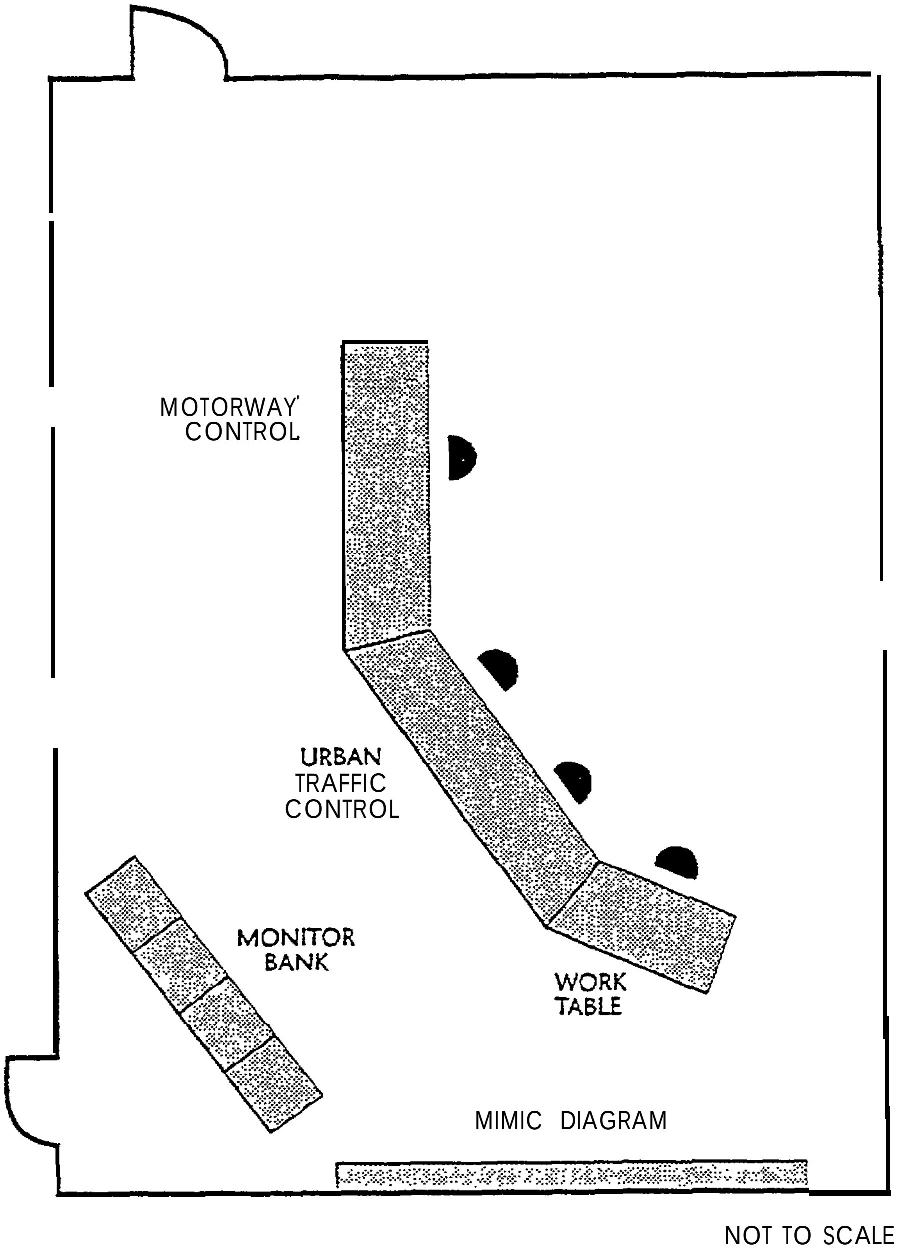
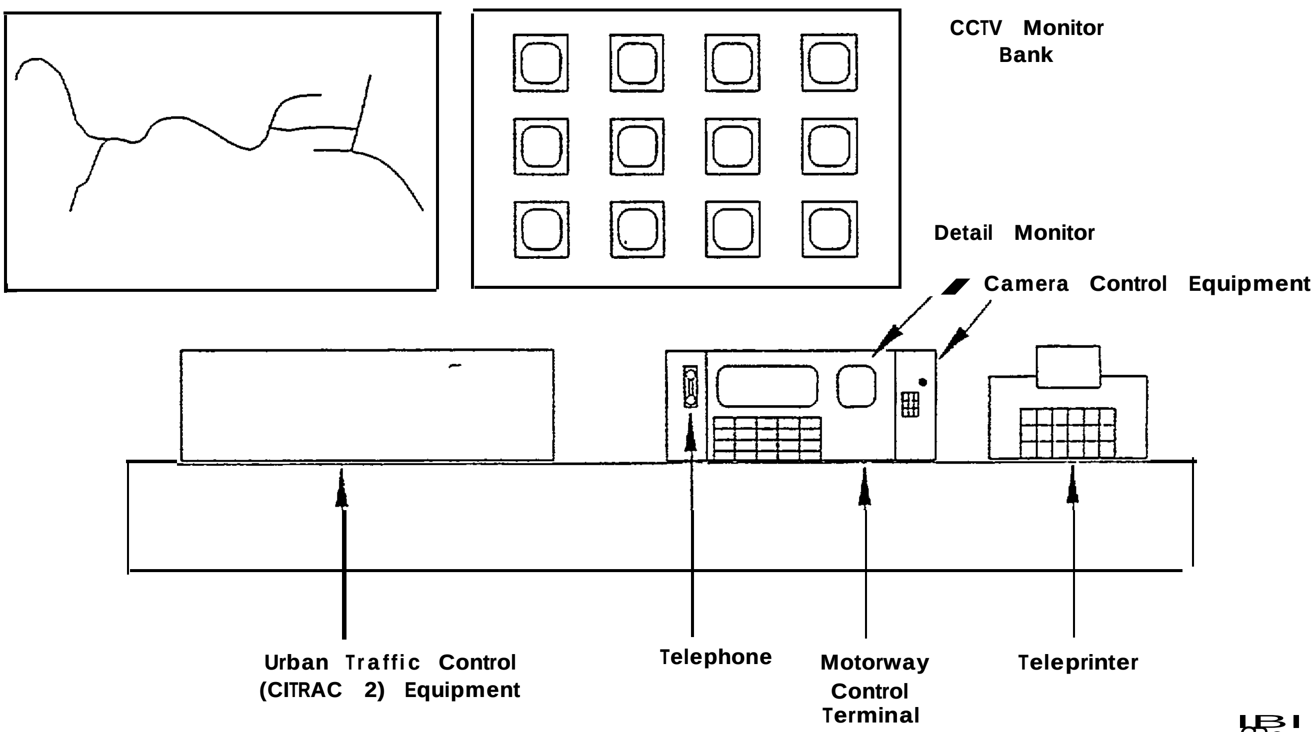


Figure *4.8*

Strathclyde Regional Council Control Room Operator Interface Equipment



- ***Camera Control Equipment:*** A video switch is provided for selecting the camera output displayed on twelve monitors (which can cover both the motorway and the urban systems), as well as the detail video monitor. SRC operators have access to motorway cameras, but due to their limited role in motorway operations, Police have priority over camera control.

- ***Teleprinter:*** For printing chronological event log produced by motorway control terminal, and for restarting the system should the terminal lock.

- ***Telephones:*** A direct line to police motorway control unit.

The SRC control room also contains a bank of twelve monitors which display selected output from thirty-eight motorway and fifteen urban black-and-white CCTV cameras. A color camera has recently been added to CITRAC. In addition, a mimic diagram, showing the status of both UTC and motorway devices by LED displays, is located near the UTC operator console.

The main user interface for the CITRAC motorway system is resident in the Police motorway control terminal, which requires user knowledge of a specific command language. The gantry line graphics on this terminal are difficult to read, provide only limited information (again in command code), and are rigidly oriented on the screen. However, a new user interface has been developed for the CITRAC 2 Urban Traffic Control system. The CITRAC 2 operator interface features a Graphical User Interface (GUI) which combines text data with mimic diagram graphics.

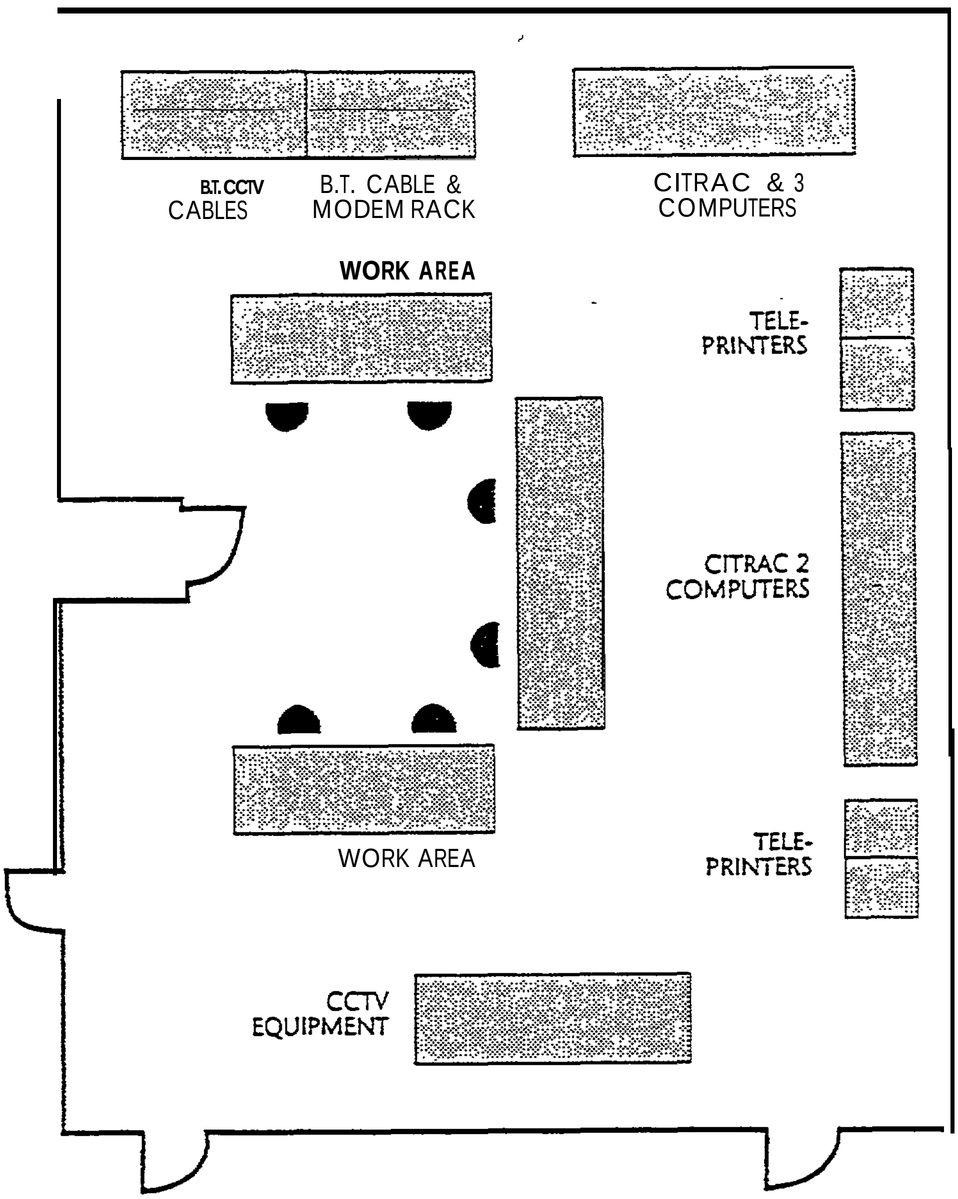
The mimic diagram part of the screen consists of a static component, showing the layout of the area, and a dynamic part, showing color-coded field equipment objects. A static zoom facility is provided, so that if the user clicks on a pre-defined "sensitive" area, a detailed picture of that area will be shown. A typical screen features pull-down menus and an alarm window. Screens are provided for alarm management, log management, parameter table management, time table management and plan management.

The CITRAC 2 operator interface improves upon motorway control user interfaces in terms of functionality, flexibility, presentation of information to the operator and ease of use. It was recommended that, as part of the system enhancements, the CITRAC 3 motorway control system incorporate some of the capabilities of the CITRAC 2 interface (e.g. GUI, windowing, pop-up menus).

<u>Computer/Communications Room</u> - The layout of the computer/communications room, also known as the equipment room, is illustrated in Figure 4.9. The major motorway control equipment housed in this room is as follows:

Figure 4.9

SRC Computer/Communications Room Layout



- ***Two Philips P857 minicomputers*** (16-bit 96K), each with 5 MByte disc drive and control panel. One computer operates on-line and the other is in warm standby, and also runs off-line simulations. A Cooke Switch is provided for the changeover of peripherals from one computer to the other.

- ***Motorway control terminal,*** identical to those in the Police and SRC control rooms.

- ***Two teleprinters*** for command inputs.

- ***Two line matrix printers,*** one connected to each computer, for system logging.

- ***CCTV processor cabinets,*** including modulators, power supplies and video matrix.

- ***Cabinets for communications circuit terminations and modem equipment.***

In addition, UTC computer equipment and communications equipment are located in this room (e.g. two computers, alarm and control processor, CCTV processor, time-lapse video recorder, etc.). Work tables with terminals and other equipment are provided for both motorway and UTC computer/communications staff.

<u>Work Room</u> - The SRC control center has a work room for testing hardware and software, including on-line testing of the computer system. Equipment typically located in this room includes:

- Traffic signal control equipment from various manufacturers for testing.
- Urban Traffic Control outstation testing equipment.
- Fault diagnostic equipment.

<u>Lecture Room</u> - A lecture mom is located on the main level of the SRC control center, adjacent to the control room. This room accommodates the numerous groups which visit the SRC control center, and features special facilities for lectures and demonstrations, including a separate projection room. The lecture room accommodates up to thirty persons.

4.4.7.4 TRAFFIC OPERATION CENTER SUMMARY

The combined Control Center functions for CITRAC were reviewed and evaluated under the CITRAC Motorway Control System Replacement project. Concerns with the existing system, which are also of relevance to the Denver Metro Area TOC, are summarized below:

Control Room Equipment and Operator Interfaces

- Information available from the CITRAC system could be presented to operators in a more effective format, so that it could readily be translated into timely and productive actions through the CITRAC motorway facilities. Specifically, motorway status could be conveyed more effectively to the operator by:

  - Incorporating audio-visual incident detection alarms into the operator interface screens.

  - Providing a flexible, high resolution color graphics system, for location based screen queries, as well as capabilities for easily building the graphics. The graphics system should include mapping at a range of scales, accessible through features such as zooming, and should be linked to the central software, so that facility device status (e.g. gantry signals) could be displayed by windowing. GIS features could also be incorporated, e.g. for geocoding devices.

  - Displaying a dynamic map based on the color graphics screen output. A dynamic map would be more flexible than a semi-static mimic diagram, and therefore would be more useful in dealing with specific situations where more detail is warranted. This type of mapping is available through technologies such as rear-screen projection.

  - Providing more detail monitors for each operator, so that incident locations, tail-back end locations and potential trouble spots can be monitored simultaneously. Autocycling might also be routinely used at the operator consoles.

- Since an operator cannot effectively use many pieces of equipment spread along a console, workstation equipment should be consolidated and centralized by:

  - Combining multiple computer systems so they could be accessed from one terminal (Police security issues could be addressed through user restrictions controlled through log-on codes).

  - Combing color graphics and text screens, e.g. through a "windows" environment, eliminating the need for a separate color graphics terminal.

  - Incorporating video output into operator interface screens.

  - Streamlining video switching/camera control equipment, and placing it flat on the console surface close at hand to the operator.

- User screen flexibility and user friendliness could be improved, in order to improve the speed, accuracy and overall efficiency of operations. A graphical user interface, integrating text and color graphics, is recommended. The following features facilitate usage:

- Minimization of free-form data entry.
- Use of pop-up menus for assistance and data specification.
- Extensive use of symbolism.
- Schematic detail in graphics screens to assist in location referencing.

- The existing procedures for logging information and retrieving it are manually intensive, and are therefore time consuming and prone to errors. Automatic generation of standardized reports, and the capability for performing variable real-time queries of the traffic database would considerably improve the operator interface.

- The operator interface screens, as well as the console and display equipment, should be structured to accommodate system growth, in terms of geographic expansion and more concentrated infrastructure, as well as integration with related systems. For example, the operator interface should be flexible enough to incorporate information from new initiatives, such as in-vehicle technology demonstrations.

- Operator interface screen design should support the security of the overall CITRAC system by ensuring that only those with authority to implement certain actions are permitted to do so. Decisions requiring a high degree of judgement, such as changing the standard wording of a variable message sign, should be restricted to an authorized group of users identifiable to the system by secured log-on codes.

<u>Control Room Operations and Layout</u>

- Control room equipment must support the functions performed by both Police and SRC operators, and therefore is required to present information to operators in a clear, easily comprehensible manner, and facilitate accurate and meaningful response. Some equipment (e.g. CCTV monitors, motorway control terminals) may be used simultaneously and independently by Police and SRC operators. It is important that the equipment is designed such that it is accessible to all requiring it, subject to rules of user protocol, and that the user status of the equipment is known to all users at all times.

- "U-shaped" consoles have been proven to be more effective than the existing elongated consoles, for accessing equipment, providing free work space, and providing clear space for viewing large display equipment (e.g. monitor banks) beyond the console equipment.

- The SRC control room layout could be improved ergonomically to support the intended functionality of the room. Under the present layout, the monitor banks are oriented toward the UTC console, creating an extremely wide viewing angle from the perspective of an operator stationed at the motorway console. These difficulties could be alleviated by either repositioning the consoles or adding additional monitors dedicated to motorway coverage. The monitors also appear to be too far from the motorway console. In addition, the wall-mounted mimic diagram is too small for an operator to be able to absorb the amount of detail depicted. A rear-screen projection unit, with capabilities for zooming in on the image, is an appropriate alternate technology for dynamic map-based displays.

5.0 JAPANESE FACILITIES

5.1 Introduction

Japan began nationwide installation of traffic control centers (TCCs) in 1971 and has implemented one of the most extensive traffic management systems in the world. This consists of traffic surveillance, signal optimization, motorist information systems and dynamic route guidance systems. TCCs in Japan have been an essential element of implementing new technologies to better manage the nation's highways.

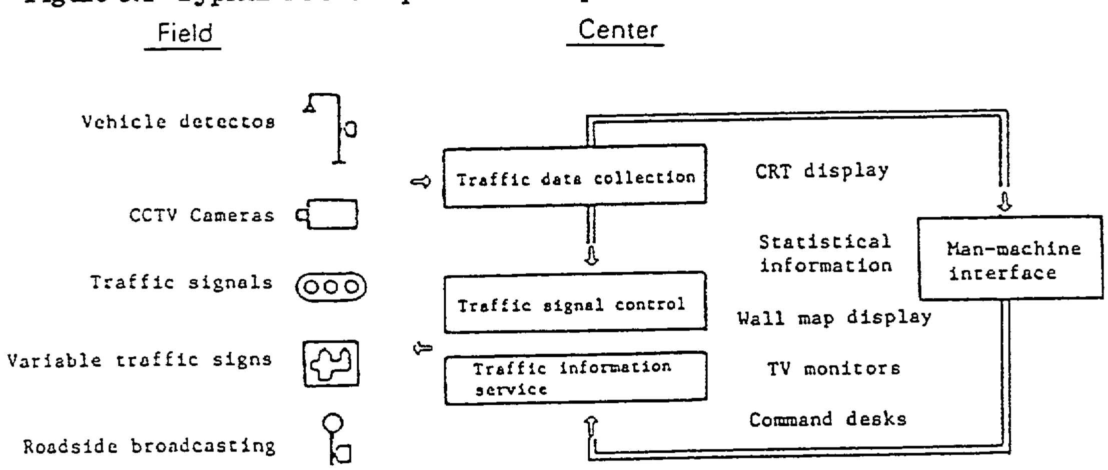
5.2 Traffic Control Center Operations

TCCs are the nerve centers of Japan's traffic management efforts. A typical TCC receives information from a variety of traffic data collection sources and operates traffic signal control and traffic information services. The TCC calculates the length of traffic lines and the degree of congestion from speed and detection devices on the roadway. Signal control algorithms are used to achieve the most efficient traffic flow. The TCC provides radio broadcast traffic information and controls variable message signs to disseminate information to motorists. In some cities, such as Tokyo and Osaka, short-range two-way communication systems are available to provide drivers with localized travel information and to use equipped vehicles as probes to measure traffic flow.

Japan's TCCs also maintain communication with the police to obtain information on incidents, and with highway construction crews to obtain information on temporary lane closures. This information is manually input into TCC computers as additional data for traffic control algorithms.

Traffic data are usually displayed on a large board in the control center. Control room operators confirm traffic congestion or incident reports by CCTV or through contact with police dispatch personnel. Emergency services are alerted and motorist advisory information is disseminated. Figure 5.1 illustrates the components of a typical TCC in Japan.

Figure 5.1 Typical TCC Components in Japan



5.3 Traffic Surveillance and Signal Optimization Systems

The core of Japan's traffic surveillance systems is vehicle detection devices. Japan's TCCs utiliie in-pavement inductive loops, overhead ultrasonic detectors and video imaging devices for traffic surveillance. These detectors are deployed primarily to support traffic-responsive signal control. A total of 132,000 intersections across Japan are signalized and approximately 41,000 of these are controlled by computer from TCCs.

Video imaging devices are located on major expressways to detect incidents and monitor traffic flow. Some systems use infrared detectors to read the license plates of vehicles and establish link travel times over major highway sections. CCTV cameras are used to visually verify incidents or traffic flow.

The vehicle detection data are transmitted, primarily via telephone lines, to the TCC. The TCC computer analyzes these data to detect incidents and establish traffic flow. This information is used in signal control algorithms for street intersections and on entrance ramps to expressways. The data are also used to develop an historical traffic database for long-term traffic management plans.

5.4 Motorist Information and Route Guidance Systems

The traffic data collected and processed within each control center are utilized in an extensive traveler information network. The Japanese Traffic Management Technology Association has implemented two major motorist information systems: the Advanced Mobile Traffic Information and Communication System (AMTICS) and the Road Automobile Communications System (RACS) which are operated through TCCs. Further details on RACS and AMTICS are provided below.

AMTICS is an integrated traffic information and navigation system. Information from TCCs in Japan is reported to the AMTICS data processing center and subsequently broadcast to vehicles. The broadcasting medium is a radio data communications system, which transmit digital information to in-vehicle microcomputers. This is connected to a navigation screen display.

The in-vehicle system provides the driver with a road network display and the vehicle's location within the network. The AMTICS system provides the driver with congestion and incident data as well as road construction and weather details. AMTICS communicates both local area and wide-area information. The driver selects the range of coverage relevant to his or her driving needs and the in-vehicle unit adjusts to receive only the appropriate transmissions.

The shortest communication broadcast is within a two-mile radius. Transmitters with a two-mile range are located throughout the region to provide the zoned communications. The local information service provides traffic information for a five-mile radius, which generally consists of information relevant to the coverage area of a single TCC. The wide-area information service combines information from a number of TCCs within a 30- to 60-mile radius.

In contrast to AMTICS, RACS operates a short-range communications system in support of its route guidance efforts. RACS was implemented as a cooperative project between Japan's Ministry of Construction, the Public Research Institute and 25 private companies. The goal was to develop an in-vehicle navigation system that receives real-time traffic information from a roadside beacon communications system.

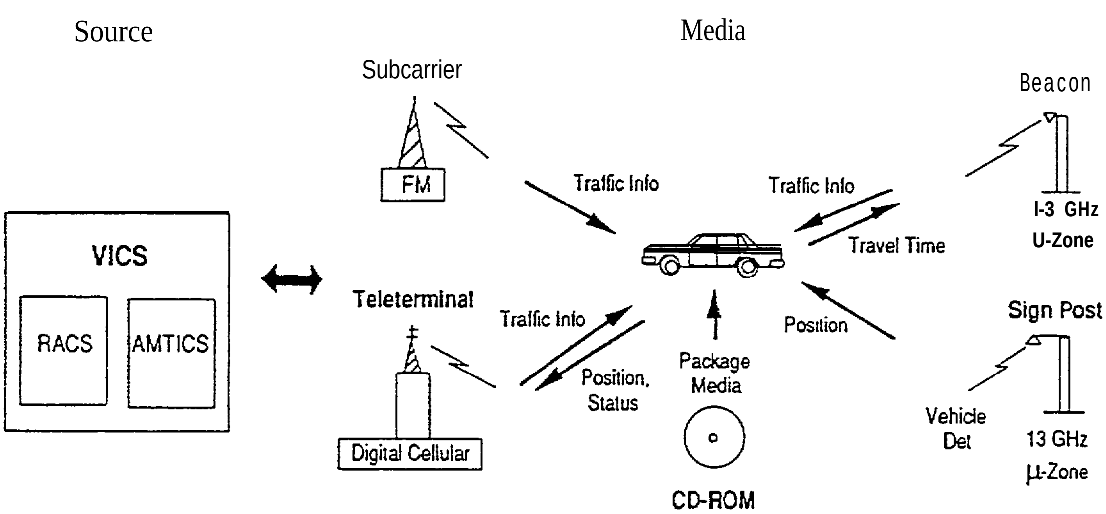
RACS utilizes location beacons, information beacons and individual communications beacons to form a dynamic information service. The location beacons assist vehicles in obtaining a map position reference by downloading location information to the in-vehicle route guidance system. The information beacons provide real-time traffic information obtained from the TCC. The individual communications beacons supports business data transmissions and individual message transfers.

The TCC serves as the information center for RACS. The communications network connects beacon stations to remote control center stations and then onto the TCC information center with fiber optic cables. The information center provides road and traffic information, processes mute guidance information and transmits these data to the roadside beacons.

RACS also provides traffic flow information by collecting ID codes and zone-passing times of vehicles between beacon locations. The travel time between beacons is used to establish real-time traffic flow with a higher accuracy than other traffic measurement methods. Ongoing RACS research is developing a system that utilizes these probe vehicles to provide information on traffic jams, accidents observed and weather abnormalities.

While AMTICS and RACS pursued different communications media, they led to almost identical in-vehicle units. This led to formation of the combined VICS (Vehicle Information Communications Systems) program. The VICS concept is illustrated in Figure 5.2.

Figure 5.2 VICS Concept



5.5 Summary

The following issues concerning Japan's TCCs are of interest in the development of the Denver Metro Area TOC:

- Japan has the most extensive traveler information networks in the world. Japan's TCCs have played a key role in facilitating the development of these communications technologies. This serves as an illustration of the potential role of the Denver facility in supporting future route guidance systems and other advanced concepts.

- While RACS and AMTICS have focused on alternative communications media, it is recommended that the Denver Metro Area TOC should not enter into the debate on this issue, which is currently being addressed in the U.S. It is anticipated that any such data broadcasts from the TOC will ultimately follow the approach to be specified through FHWA's forthcoming systems architecture study. Furthermore, it is recommended that the TOC focus more on data formats suitable for a variety of communications media than selecting the media themselves.

- In Japan, TCCs are used for traffic signal control among other applications. While this has been discussed in the Metro Area, the need to recognize the independence of the region's traffic signal control jurisdictions is clear. Nevertheless, if the necessary agreements can be put in place by DRCOG, combined signal operations from the TOC could be beneficial

6.0 ADAPTIVE CONTROL SYSTEMS

6.1 SCOOT

6.1.1 Introduction

SCOOT is an advanced implementation of computer based urban traffic control. The acronym is derived from Split, Cycle and Offset Optimization Technique. It is an adaptive traffic control strategy, researched by the Transport and Road Research Laboratory (TRRL), and developed by the U.K. government in association with three electronic companies - GEC, Plessey, and Ferranti - who now market the software. Each of these companies has also developed their own wrap around software which integrates the basic SCOOT software (known as the SCOOT kernel) with their own unique computer system interface.

Incorporation of the SCOOT kernel into advanced Urban Traffic Control (UTC) systems does not require more sophisticated and interactive control facilities. In fact, the adaptive strategy should minimize operator intervention. However, the control center facilities are an important factor in the successful integration of a SCOOT/UTC system into an overall IVHS system, such as the Denver Metro area program.

6.1.2 Principles of SCOOT

SCOOT is an adaptive signal control algorithm which can calculate timing parameters according to prevailing traffic conditions. The key functions of SCOOT are to:

- Measure Cyclic Flow Profiles (CFP's) in real-time. This allows the arrival of platoons of vehicles at a signal to be forecast.

- Update an on-line model of queues continuously. This provides an estimate of stop line congestion.

- Incrementally optimize signal settings. Split, cycle and/or offset can be adjusted by a few seconds each cycle to best address the demands on all approaches.

A basic schematic of the flow of information through SCOOT is shown in Figure 6.1.

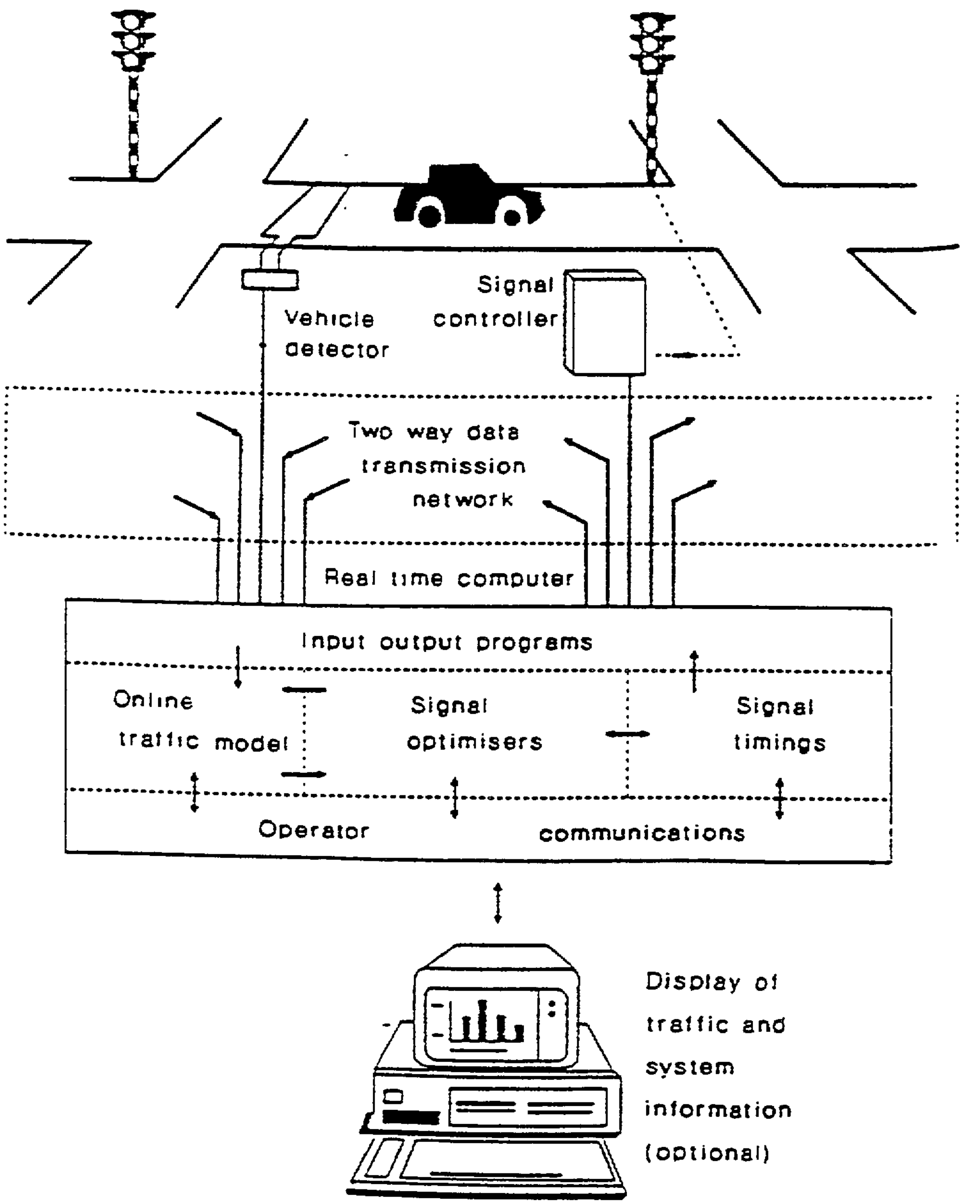
6.1.3 Traffic Data Collection

SCOOT uses vehicle detectors to measure traffic flow profiles in real-time. The detectors are placed near the upstream end of each link to measure the demand pattern of vehicles approaching the downstream signal. Information from the detector on the downstream link is also utilized to update the estimated saturation flow rate.

SCOOT detectors provide a measure. of the overall level of demand feeding into a link. Therefore, SCOOT does not rely on highly accurate counts, and requires only one loop detector on two lane approaches. Detectors are required on every signal approach for optimum SCOOT operation. Existing stop line detectors are not adequate for SCOOT.

Figure 6.1

Flow of Information in the SCOOT System



6.1.4 Real-Time Traffic Control

The traffic data is continuously processed by the SCOOT algorithm to allow signal timing to adapt in real-time to traffic changes. Therefore, SCOOT can provide many features not possible with other signal systems such as:

- An on-line model storing and updating information on flow profile, queue data, degree of saturation and congestion.
- Split optimization for relative stage durations.
- Offset optimization for coordination along a series of links.
- Cycle optimization for a region.
- Numerical and graphical output on delay, queues at green, flows, and other real-time messages for links, nodes or regions.
- Prediction and modellmg of turning traffic through stop line information on links.
- Restriction of inflow of traffic into a congested area through gating.

6.1.5 Signal Controller Requirements

SCOOT was originally conceived with fixed time controllers in mind. Recently the algorithm has been updated to allow SCOOT to work with actuated controllers. The first implementation of SCOOT with Model 170 controllers is occurring in Oxnard, California. A special 170 program to handle SCOOT requirements was created.

6.1.6 Central Hardware Requirements

SCOOT has always been implemented as part of a complete traffic signal control system from one of the three companies with rights to the package. The overall system can be configured in one or two computers as shown by Figures 6.2 and 6.3. The single computer configuration is required for all SCOOT features to be available.

The computer is a Digital Equipment VAX model with typical peripheral equipment as follows:

- Monochrome VDU terminal for command input.
- Separate printer for log print-outs.
- Optional color graphics terminal for equipment monitoring and status information displays.
- Alarm/status panel for each processor.
- wallmap Mimic Display diagram with LED status indicators.
- Optional (in lieu of wallmap) graphics video projection system for all intersections.

Figure 6.2

Dual Computer SCOOT UTC System

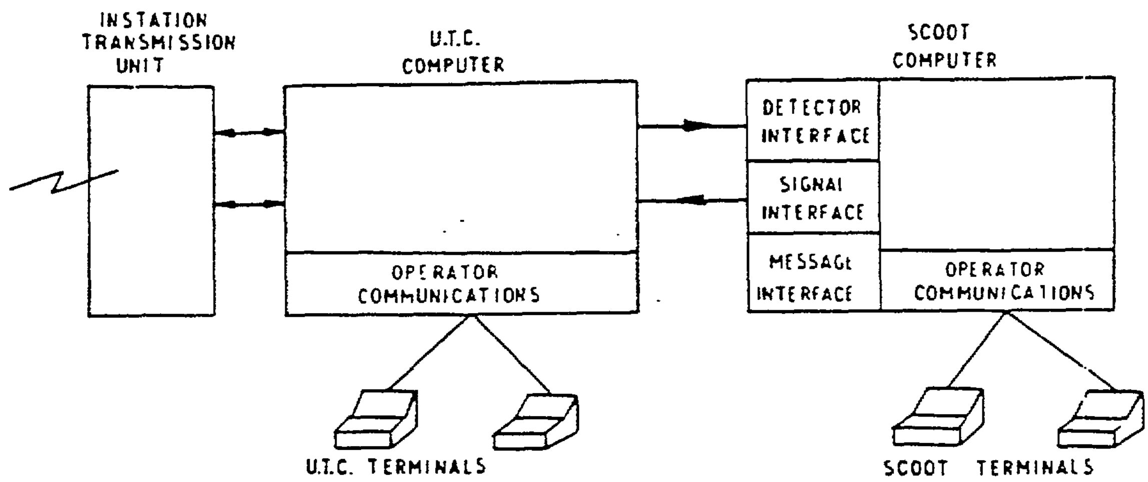
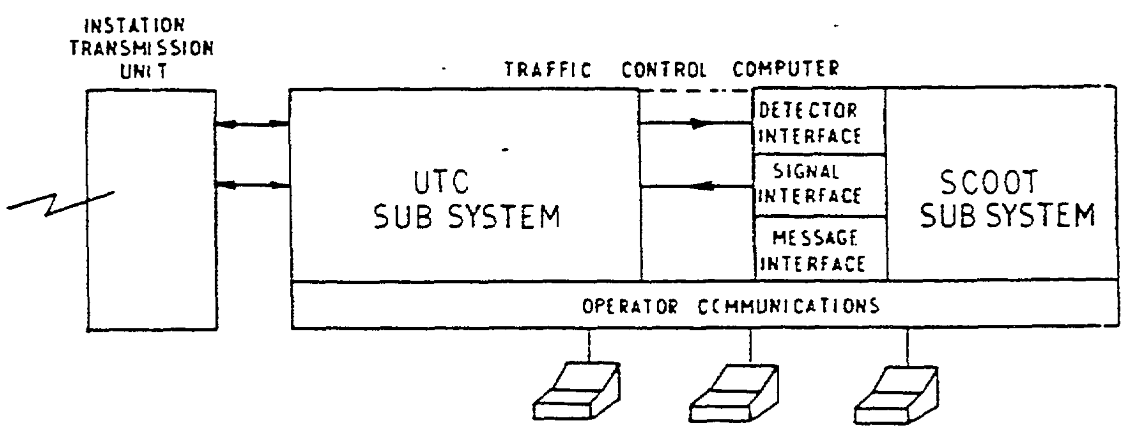


Figure 6.3

Single Computer SCOOT UTC System



Data transmission hardware for use on SCOOT systems is unique. To accommodate the communication requirements of SCOOT, Outstation Transmission Units (OTU's) have been developed by GEC, Plessey, and Ferranti.

6.1.7 SCOOT in Practice

6.1.7.1 SOUTHAMPTON, U.K.

The Southampton system was implemented by Plessey Controls Ltd. in 1984, and is based on the dual computer configuration shown by Figure 6.4.

The features of this configuration are summarized below:

- Color VDU's are used to display live update diagrams showing system operation, ranging anywhere from the whole system to individual intersections.
- Auto dial facility allows SCOOT functions to be connected temporarily via public telephone lines, wherever intersection timings are to be checked, or intersection operation is to be monitored.

6.1.7.2 METROPOLITAN TORONTO, CANADA

The implementation of SCOOT in Metropolitan Toronto is presently underway as a demonstration project which encompasses 75 intersections in three different areas. These distinctively different operational control areas were chosen in order to evaluate the benefits of SCOOT under various types of operating and road environment conditions. The areas consist of:

- 42 intersections within a grid network of the central business district.
- 20 intersections along a limited access, major arterial route that is adjacent to a major freeway system.
- 13 intersections along a major arterial with intense development and numerous accesses.

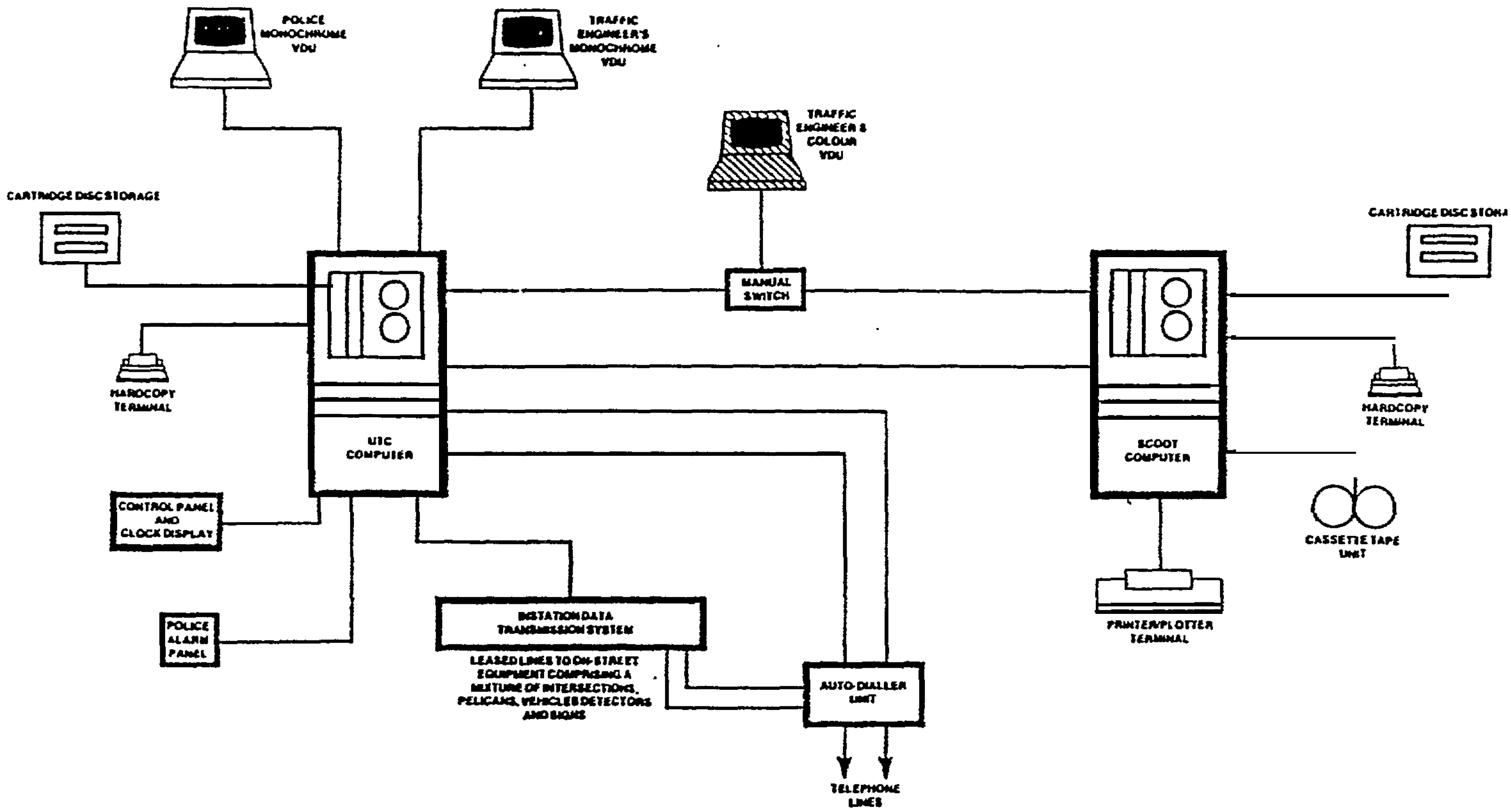
Previously, these signals were coordinated in time-of-day mode by a separate system.

<u>Central Control Hardware</u>

- MICROVAX 4000/200 computer with a capacity of 300 SCOOT intersections and 300 fixed time intersections.
- Operator interface terminals.
- Printers.

Figure 6.4

Southampton SCOOT System



- Portable computer for field validation.
- PC computer for graphics displays.

Intersection Control Hardware

- Installation of 350 detector loops (including detector amplifiers).
- Replacement of controller communications devices in each signal control cabinet.
- Controller cabinet modifications to accommodate additional loop detector amplifiers.

6.1.7.3 OXNARD, CALIFORNIA

During 1992, a small SCOOT system was implemented for 16 signals along an arterial in Oxnard. Four signals are 8-phase, four are 6-phase and the rest are two phase.

6.1.8 Summary

The real-time, adaptive capabilities of SCOOT are particularly attractive for signals within the scope of an IVHS because timing will react automatically to changes in travel patterns which result from freeway diversions and traveller information etc. However, the speed with which SCOOT reacts will be improved if it is directly interfaced with the IVHS.

One of the future functions of SCOOT will be to interface with the Gardiner-Lake Shore Corridor Traffic Management System (CTMS) currently under development in Toronto. In such an interface, the CTMS will provide input into SCOOT on suggested diversions from the freeway to the arterial, on-going freeway congestion, and on-set of freeway congestion. It is intended that a pro-active response be supplied by SCOOT to clear any traffic diverted from the freeway to the arterial.

In order to reduce the need for field equipment replacement, the opportunities to use the SCOOT kernel in conjunction with existing signal control system needs to be more fully explored.

Since the implementation of SCOOT in Toronto and Oxnard uses different control areas for evaluation purposes, the findings from these systems can provide the Denver TOC project with valuable information.

6.2 SCATS

6.2.1 Introduction

SCATS (Sydney Coordinated Adaptive Traffic System) is a computer based area traffic control system. It is a complete system consisting of hardware, software, and control strategy. Operating in real-time, it adjusts signal timings throughout the system in response to variations in traffic demand and system capacity. As with any area traffic control system, the purpose of SCATS is to optimize traffic flow on an area-wide basis, rather than on the basis of individual intersections.

Initially developed for the city of Sydney, Australia by the Department of Main Roads, SCATS has now been installed in every major city in Australia and New Zealand, as well as China, and a recent installation in Oakland County, Michigan U.S.A.

6.2.2 Principles of SCATS

SCATS operates under various modes, offering all the features of an integrated Urban Traffic Control (UTC) system. However, the normal mode, which provides adaptive traffic control is of most relevance to the Denver TOC study. Under this mode of operation, SCATS' control algorithm provides an adaptive form of signal timing by constantly deciding which of a previously defined set of splits and offsets (commonly referred to as background plans) best match the present traffic conditions.

The basic structure of SCATS can be described as modules controlling up to 120 intersections through one regional computer. At the level of the regional computer, up to 10 intersections can be defined as a sub-system, each containing one critical intersection. A group of sub-systems which are geographically related, and are desired to interact, grouped be formed into an system.

Thus, an integrated traffic signal control system operating under SCATS, may consist of several regional computers connected to a central computer which provides system level functions and operator interface.

6.2.3 Traffic Data Collection

SCATS requires all intersections to be equipped with detector loops located in each lane immediately in advance of the stop-line to perform the dual function of providing traffic flow data and vehicle actuation.

The detector requirements are based on two levels of control which effect SCATS' adaptive traffic control mode. The highest level of control is referred to as strategic control. At this level, SCATS is concerned with the determination of suitable signal timings for the systems and sub-systems, based on average prevailing traffic conditions. The lower level of control is called tactical control, where SCATS operates at the individual intersection level, within the constraints imposed by the regional computer's strategic control.

Under strategic control, inductive loop detectors are used exclusively. At this level, SCATS has the following detector requirements:

- Detectors must be 4.5 meters in length.
- Detectors must be located at the stop-line for the correct measurement of green time used by traffic.

- Detectors are required on all approaches to major intersections.
- Detectors are required on all minor intersections which are immediately upstream of major intersections.

Under tactical control, SCATS imposes the following requirements:

- Detectors must be 4.5 meters in length.
- Detectors must be located at the stop-line for differentiation between left turn, straight ahead, and right turn movements.
- Detectors should provide coverage on all lanes of an approach.
- Microwave detection may be used on approaches which require only tactical detection.

6.2.4 Real-Time Traffic Control

SCATS operates in real-time through the regional computer which analyses detector information pre-processed by intersection controllers. The algorithms in the regional computer select, in response to detected demand and capacity, the appropriate splits, offsets and cycle lengths for each sub-system and the offsets which apply between sub-systems.

Each sub-system requires a database including minimum, maximum, and geometrically optimum cycle-lengths, phase split maxima, and offset times. There are four background splits programmed for each intersection. The selection of the splits is based on the requirements of the critical intersection in each sub-system. Once per cycle, a split plan vote is calculated for each sub-system. The plan which yields the lowest degree of saturation is selected; if the same plan is selected twice in any three consecutive cycles, it is implemented. Otherwise, the plan already in effect remains in use.

6.2.5 Signal Controller Requirements

Local controllers are microprocessor based and provide for 24 detector inputs. The controllers are attached to their regional computer by a data line. SCATS controllers are manufactured in Australia by Philips and AWA Ltd. For Oakland County, the SCATS controller was modified to provide the NEMA connector standard.

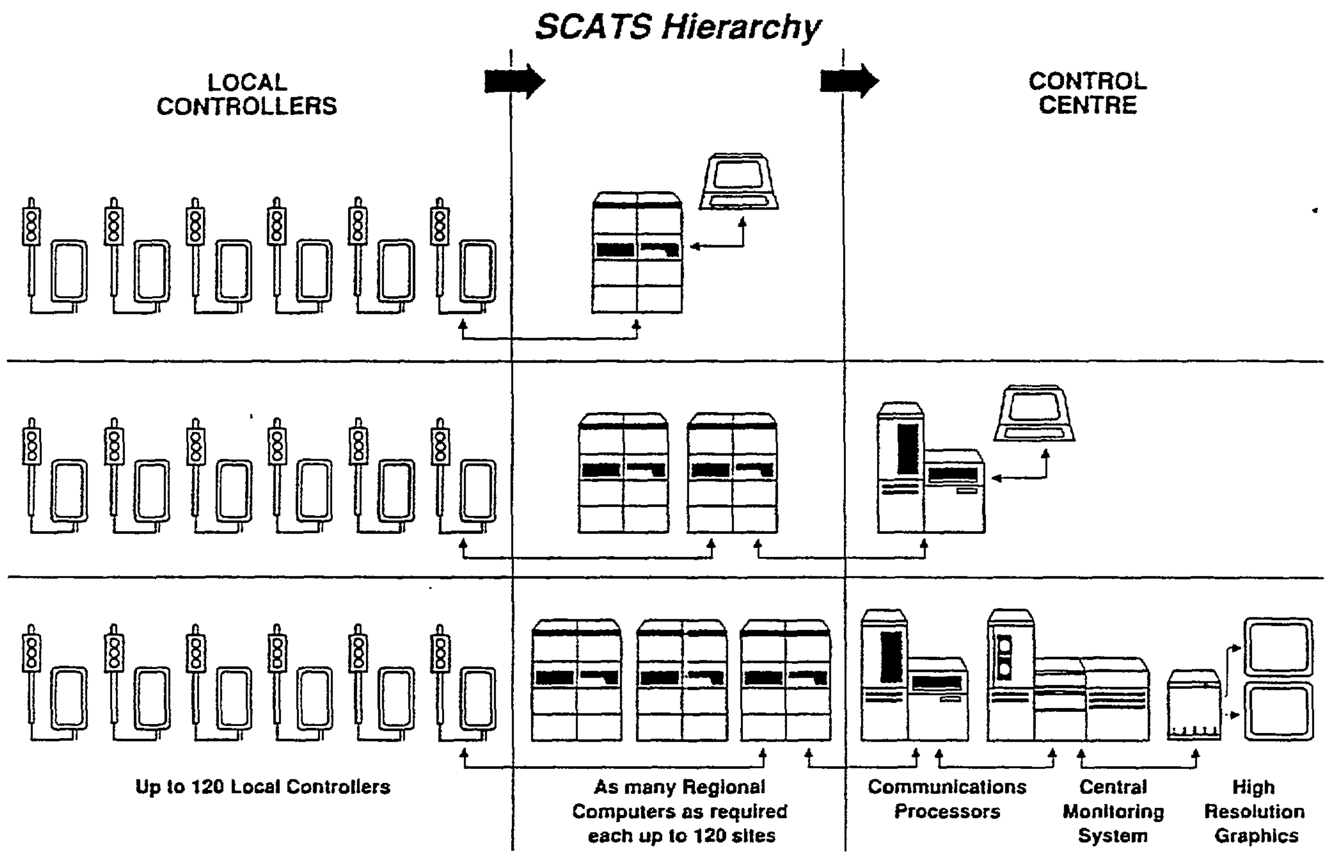
6.2.6 Hardware Requirements

The hardware configuration of SCATS is modular. System hierarchy is shown in Figure 6.5. Digital Equipment is used throughout, and the system can easily expand to suit the varying needs of different sized cities.

In its simplest form, SCATS can control up to 120 intersections with one regional computer. Through the installation of additional regional computers, the system can be expanded. When multiple regional computers are used, a control monitoring system is added to allow centralized access to regional computers.

Figure 6.5

SCATS System Hierarchy



6.2.6.1 REGIONAL COMPUTER HARDWARE

SCATS regional traffic control computers are of the PDP-11 series. The PDP-11 models range from an 11/53 for 40 intersections, to an 1 l/83 for 120 intersections. Regional computers are usually located near the center of the group of signals to be controlled, in order to minimize cost of communication lines. Although not suitable for roadside cabinet mounting, the regional computers are compact, with minimal power requirements, and can be installed in an office environment.

6.2.6.2 CENTRAL MONITORING SYSTEM COMPUTER HARDWARE

When centralized monitoring of all signals under the control of two or more regional computers is required, a central monitoring system computer is installed. This is also a PDP-11 series, usually an 11/83. The basic features of a central monitoring system computer are summarized below:

- One Webster eight channel asynchronous multiplexer is required for terminals and one for each group of eight regional computers.
- Communication is via modems operating at a speed of at least 1200 bps (but usually 4800 bps) full duplex.
- A printer terminal is required as the console terminal.
- Additional printers and VDU terminals can be connected as required.

Operator interface to SCATS can be by keyboard printer terminal, visual display unit, or by a personal computer acting as a workstation terminal. Terminal access to the system is also provided at each local controller by connecting a portable personal computer.

6.2.6.3 CENTRAL MANAGEMENT COMPUTER HARDWARE

For large systems, typically exceeding 300 or 400 signals, a VAX central management computer is recommended. The size of the VAX is determined by the number of functions which are to be supported simultaneously. A MicroVAX II is a typical minimum requirement. The functions (software packages) that can be included with the central management computer are:

- Alarm Analvsis - Two programs used to analyze the automatically stored alarm status history of every intersection in the system.
- Detector Faults - Program assisting in the management of detector loop maintenance.
- Traffic Count Analysis - Allows user to collect traffic count data based on intersection numbers, detector numbers and starting and ending times.

- System Monitor Analysis - Allows for collection of records of the cycle-by-cycle operation of any sub-system(s) in a similar manner to the Traffic Count Analysis function.

- Flexlink Plan Generation - Aids in the creation of fixed-time plans for local controllers in a system.

- Color Graphics System - Programs for generating and displaying color graphics of system operation. Four levels of color graphics displays are provided:
  - intersection display.
  - sub-system display.
  - regional display.
  - whole system display.

- Vehicle Survey Database - Set of programs for the collection and storage of traffic count, classification and weight data from permanent and temporary traffic data collection stations.

- Traffic Control System Database - Set of programs for the maintenance of complete inventory of signal control equipment.

- Traffic Signal Maintenance Svstem - On-line software which allows an authority to record and control its traffic signal maintenance activities.

- Automatic Network Travel Time Svstem - Set of programs providing for the collection and storage of travel time information within the SCATS system. Vehicles equipped with purpose designed transmitter-receivers are identified when passing nodes equipped with permanent transmitter-receivers.

6.2.7 SCATS in Practice

The initial application of the Sydney Coordinated Adaptive Traffic System, as the name suggests, was made by the Department of Main Roads in Sydney, Australia. Subsequently it has been installed throughout Australia and New Zealand. However, the first U.S. installation occurred in 1992.

6.2.7.1 OAKLAND COUNTY, MICHIGAN

The Oakland County IVHS program called FAST-TRAC is a large scale deployment of an Integrated Advanced Traffic Management System (ATMS) and Advanced Traveller Information System (ATIS). The first phase of the FAST-TRAC program, completed in June 1992, was a pilot phase which implemented SCATS and Autoscope, a video vehicle detection system developed at the University of Minnesota.

The installation of SCATS is on a small scale network consisting of 28 intersections, out of which 23 exclusively use Autoscope for vehicle detection. Not only is this the first implementation of SCATS in North America, but it is also the first adaptive traffic control system to use video image processing for vehicle detection.

The size and the placement of SCATS compatible detectors were found to have serious maintenance and reliability concerns, if loop technology was to be used. These concerns are summarized below:

- 4.5 meter loop length implies that SCATS loop detectors must typically span multiple cement pads, and survive seasonal shifting.
- Road weight restrictions in Oakland County are few, and it is common to see vehicles with as many as 40 wheels navigating the roads with enormous loads.
- Freezing and thawing cycles destroy road surfaces very quickly, and with the pouring of raw salt, survival of long detectors were in doubt.

The aforementioned problems, along with the following considerations, led to the decision of using Autoscope in the FAST-TRAC project:

- The detectors are nondestructive to the road surface, with no lane closures required to install or maintain equipment.
- The multiple detection capability offered by Autoscope can be used for queue length detection which will be used to develop the next generation of SCATS.
- The Autoscope and peripheral equipment can be installed any time of the year. Most of the installation for this initial project occurred between February to May.
- Autoscope can be used for deriving stops, delays, energy consumption and pollution levels for continuous monitoring of SCATS performance.
- The detectors can be positioned over a road surface or combination of road surfaces with no loss of performance or consistency.
- The detection performance of Autoscope has been documented to perform under all weather, lighting and range conditions that do not obscure the camera's field of view.

The major task in the preliminary engineering of the SCATS/Autoscope pilot project was to develop an interface between SCATS and Autoscope. To meet SCATS software and hardware requirements, a loop-compatible output module that meets NEMA TS/l specifications was developed, tested and deployed for Autoscope.

6.2.8 Summary

Based on the outcome from the SCATS/Autoscope phase of the FAST-TRAC program, which has been labelled in the media as a success, the Denver TOC design can gain valuable experience in integrating and customizing an adaptive traffic control system within a larger Advanced Traffic Management System.

However, controller implications are still significant.

APPENDIX A - TOC SURVEYS

The project team sent out a number of surveys to existing operation centers to obtain information on the services provided, staffing, computer operations, control room features, and facility layouts of existing TOCs. Surveys from INFORM in Long Island, NY, Seattle, Anaheim, and VDOT were returned and are included in this Appendix.

INFORM – Long Island, NY

SERVICES PROVIDED

1. Please indicate the services that the TOC provides.

	Yes	No
- ramp-metering control	✓	
- closed-loop detection	✓	
- ultrasonic detection		✓
- CCTV monitoring	✓	
- video image processing		✓
- automatic incident detection	✓	
- incident response management	✓	
- automatic link-travel time computations	✓	
- variable message sign control	✓	
- highway advisory radio control		✓
- direct modem link with other agencies	✓	
- interchange signal control and coordination		✓
- arterial signal control and coordination	✓	
- DOT maintenance dispatching Signals only	✓	
- State Patrol dispatching		✓
- emergency and courtesy patrol dispatching		✓
- emergency phone and phone call box service		✓

2. Please list any other services provided by the TOC.

Provide traffic information to media and traffic information services via computerized color-coded map which updates every minute.

STAFFING REQUIREMENTS

1. List essential personnel and staffing requirements and the functions and responsibilities of each position.

Position	No. of Staff	Functions & Responsibilities

See chart for OPERATIONS, by consultant.

MAINTENANCE is done by private contractor retained via the low bid process. The contractor uses (12) electricians daily to keep system running

State staff supervise OPERATIONS & MAINTENANCE:

1 - Traffic Operations Director
1 - Operations Supervisor
1 - Maintenance Supervisor
1 - System Modifications Engineer
2 - Traffic Signal Engineers
1 - Clerk
1 - Secretary

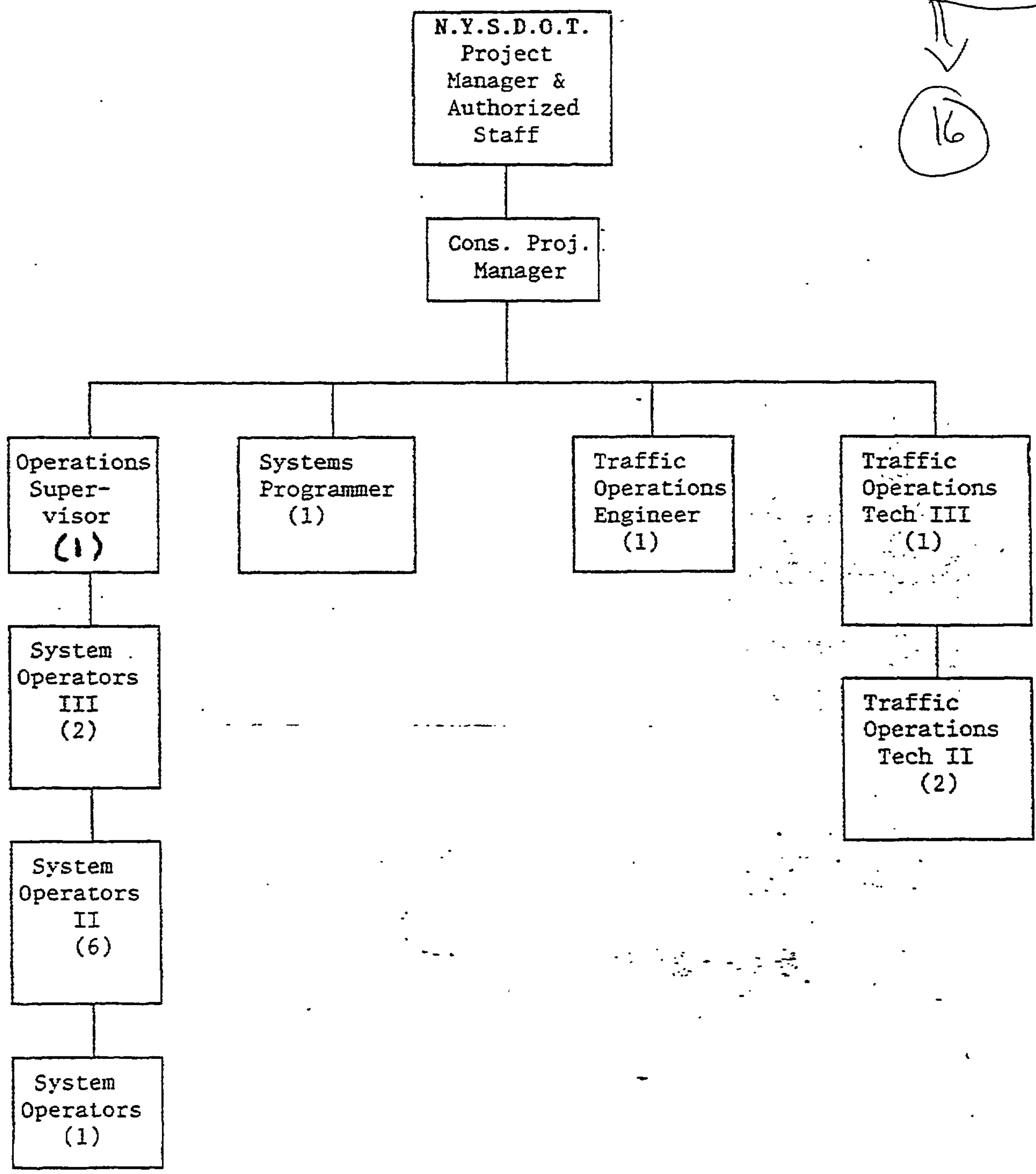
(8)

ATTACHMENT 1

INFORM TRAFFIC MANAGEMENT SYSTEM
Current Organization Chart

OPERATIONS by Consultant

16



STAFFING REQUIREMENTS (continued)

2. Please indicate peak-hour staffing requirements.

2-3 Operators
1 Operations Supervisor
1 System Programmer
1 Project Manager

w/in DC Control Center?

3. Please indicate 24-hour and off-peak staffing requirements.

2 Operators minimun at all times for 24 hours every day.

4. Please indicate training time period for each essential position.

Initially, 1 week formal training plus on-the-job training under the supervision of experienced personnel.

5. Please indicate turnover rate for each essential position.

9 Operators - Replaced 5 in 5 yrs
1 Ops. Super - Replaced 2 in 5 yrs
1 Proj. Manager - Replaced 2 in 5 yrs
1 Programmer - Replaced 1 in 4 yrs

6. Please indicate any difficult or complex problems encountered within training.

None

7. Please indicate areas in which to improve training operations.

Recommend operators get into field to become more familiar with the roadways on which they are controlling traffic.

COMPUTER OPERATIONS

1. Breakdown and identification of main traffic management supervisory computer.

- Brand name (i.e., IBM, Compaq, Toshiba, etc.)

  Perkin Elmer Model 3240 (Concurrent)
  1-Freway 1-Backup
  1-Arterial

- Type (i.e., minicomputer, networked PCs, etc.)

  Super-mini

- Operating system (i.e., multi-task like UNIX).

- Operating language (i.e., high-level like C)

  Fortran VII

- Memory storage capacity (i.e., number of Mbytes)

  2 Mbytes each computer
  1 Mbyte shared memory

2. Please indicate any support subsystem computers and associated software (i.e., operator work consoles, VMS, graphics, dispatch, etc.).

   SEVERAL SUPPORT PC'S
   SOFTWARE SPECIALLY DEVELOPED TO MANAGE:
   TRAFFIC SIGNAL REPAIR DISPATCHES
   SYSTEM INVENTORY
   SYSTEM EQUIPMENT FAILURE RECORDS

COMPUTER OPERATIONS (continued)

3. Please indicate software or algorithms currently in use.

- ramp metering

- incident detection and traffic control management – modified California

- freeway interchange control (i.e., time-of-day, stand-alone, Eagle, etc.)

- arterial and intersection control (i.e., traffic responsive, interconnected system, Econolite, etc.). UTCS usually operating in T.O.D. mode.

- other

4. Please indicate expert systems currently in use (i.e., positive incident detection generates appropriate VMS response).

VMS system automatically post messages about congestion when average speeds on sections of the instrumented highways fall below 30mph.

CONTROL ROOM FEATURES

1. Please indicate the number of operator work consoles and the appropriate staff position.

   One 25' long console accomodates 2-3 Operato

2. Please indicate the features contained on the operator work consoles.

Feature	Yes	No
- Interactive keyboard	✓	
- Ramp metering control	✓	
- CCTV switch matrix control	✓	
- Automatic incident detection alarm	✓	
- Radio panel (with DOT, State Patrol, etc.)	✓	
- Telephone panel (direct lines and/or general use)	✓	
- VMS control	✓	
- HAR control		✓
- lane control		✓
- Textual CRTs	✓	
- Graphical CRTs	✓	
- CB/mobile radio panel	✓	
- Intercom	✓	

3. Please list any other features contained on the operator work consoles.

   Police scanners, pager from other traffic center

CONTROL ROOM FEATURES (continued)

4. Please indicate the number of graphical and textual CRTs per operator work console.

7 + 2 others not on console

5. Please indicate systemwide operation display method (i.e., static wall map, projection screen TV, TV matrix, etc.).

Static Wall Map + Computer Map

6. Please indicate the following CCTV information.

- number of CCTV monitors within control center 14
- number of CCTV cameras in the field within system boundaries 25
- CCTV camera spacing in the field No pattern. CCTV has been installed as opportunities arose.
- is current CCTV coverage adequate? No, we have 9 additional CCTV sites currently under construction

7. Please indicate the following loop detector information.

- number of loop detectors in the field within system boundaries 2500
- loop detector spacing in the field One in each freeway lane at 1/2 mile intervals
- loop detector polling and data collection time interval
  Polled 60 times per sec; collected every 1/4 sec
- is current loop detector system coverage adequate? yes

8. Please indicate communication system between TOC and field equipment (i.e., fiber optic, coaxial cable, phone lines, etc.)

Principally coaxial cable & twisted pairs, some phone line and small amount of [illegible]

TOC FACILITY LAYOUT AND SIZE

1. Please indicate overall floor plan area (square feet).

   2925 SF

2. Please indicate overall control center area (square feet).

   1900 SF

3. Please indicate overall office space provided (square feet).

   1025 SF

4. Please indicate security method within TOC facility (i.e., coded ID cards, numerical code sequence, etc.).

   Numerical code

5. CRC would be very grateful if you could provide the following:

   - floor plan layout of TOC —

   - TOC control room layout —

   - operator console layout —

GENERAL OVERVIEW

1. Overall, please indicate the most usefu1 systems and functions that your TOC provides.

Traffic detection system, CCTV, police scanners & CB to gather traffic information.

Variable message signs to give current information to motorists.

Links to media via computer and use of fax machines to insure that their information about traffic conditions is accurate & timely.

Ability to control traffic signals on arterials.

2. Overall, please indicate the systems and functions that are in use all of the time.

Traffic detection - 2500 detectors
Variable Message Signs - 83
CCTV - 25 sites
Ramp meters - 60
Central control of arterial signals - 115
CB Monitors - 22 sites

GENERAL OVERVIEW (continued)

3. Please indicate the additional systems, functions, services, software, algorithms, etc., that you wish your TOC possessed.

Better information about traffic conditions on arterials and means of displaying that information in an easily usable form.

Better CCTV coverage.

MCD

Washington State DOT (Seattle TMS)

SERVICES PROVIDED

1. Please indicate the services that the TOC provides.

Service	Yes	No
- ramp-metering control	✓	
- closed-loop detection	✓	
- ultrasonic detection – TESTING ONLY, NOT IN USE YET		✓
- CCTV monitoring	✓	
- video image processing		✓
- automatic incident detection	✓	
- incident response management NOT EXPECT SYSTEM BASED	✓	
- automatic link-travel time computations		✓
- variable message sign control	✓	
- highway advisory radio control	✓	
- direct modem link with other agencies	✓	
- interchange signal control and coordination		✓
- arterial signal control and coordination		✓
- DOT maintenance dispatching	✓	
- State Patrol dispatching		✓
- emergency and courtesy patrol dispatching		✓
- emergency phone and phone call box service		✓

2. Please list any other services provided by the TOC.

RAMP METERING BOTTLENECK ALGORITHM – REDUCES METERING RATES FOR STATIONS UPSTREAM OF A PERCEIVED BOTTLENECK

STAFFING REQUIREMENTS

1. List essential personnel and staffing requirements and the functions and responsibilities of each position.

Position	No. of Staff	Functions & Responsibilities
MANAGEMENT	2	- OVERSEE OFFICE; INTERACT WITH OTHER AGENCIES
PLANNING	2	- PLAN EXPANSION OF SYSTEM; INTERACT WITH OTHER AGENCIES
DESIGN	4	- DESIGN FUTURE EXTENSION; REVIEW PLANS. INTERACT WITH PROJECT OFFICES
PROGRAMMING	4	- UPDATE SOFTWARE FOR SYSTEM, CREATE BETTER WAYS TO USE EXISTING SYSTEM
RADIO DISPATCH	6	- RESPOND TO CALLS REQUIRING D.O.T. ACTION; 24 HR OPERATION; DISPATCH FOR ENTIRE STATE AT NIGHT & HOLIDAYS; INTERACT WITH STATE PATROL INCIDENT RESPONSE
INCIDENT RESPONSE	5 PER TEAM (LOCATED SEVERAL SITES)	- PROVIDE TRAFFIC CONTROL FOR MAJOR INCIDENTS; INCLUDES PUSHING VEHICLES CLEAR, HAZ MATS, FIRES;
TRAFFIC OPERATOR	8	- OPERATE & MAINTAIN SYSTEM; SOME OPERATIONAL STUDIES; DATA COLLECTION; INTERACT WITH PUBLIC & MEDIA. SOME COMPUTER AIDED DESIGN; PROVIDE TRAFFIC REPORTS.
TUNNEL OPERATORS	10	- MONITOR TUNNELS; INCLUDING TRAFFIC FLOW, CO LEVEL CHECKS FOR INCIDENTS

STAFFING REQUIREMENTS (continued)

2. Please indicate peak-hour staffing requirements.

   ALL BUT 2 OPERATORS, 4 RADIO OPERATORS, 6 TUNNEL OPERATORS

3. Please indicate 24-hour and off-peak staffing requirements.

   1 RADIO OPERATOR 24 HRS/DAY

   1 TRAFFIC OPERATOR WEEKENDS 8⁰⁰-17⁰⁰

   2 TUNNEL OPERATORS 24 HRS/DAY

4. Please indicate training time period for each essential position.

   RADIO 3 months

   TRAFFIC - 1 MONTH + CLOSELY SUPERVISED FOR ~6 mos.

   TUNNEL - 3 MONTHS

5. Please indicate turnover rate for each essential position.

6. Please indicate any difficult or complex problems encountered within training.

   TECHNICAL OVERLOAD! NEED TO REPEAT TECHNICAL INFO. TO TRAINEES.

   CONSISTENCY - NEED TO MAKE SURE ENGINEERS TRAIN TECHNICIANS THE SAME.

7. Please indicate areas in which to improve training operations

   ADD A MANUAL OF STANDARD OPERATING PROCEDURES (SOP)

COMPUTER OPERATIONS

1. Breakdown and identification of main traffic management supervisory computer.

   - Brand name (i.e.; IBM, Compaq, Toshiba, etc.)

   - Type (i.e., minicomputer, networked PCs, etc.)

     VAX MINICOMPUTER

   - Operating system (i.e., multi-task like UNIX)

     VHS

   - Operating language (i.e., high-level like C)

   - Memory storage capacity (i.e., number of Mbytes)

     64MB MEMORY

     3.6 GB DISK SPACE

2. Please indicate any support subsystem computers and associated software (i.e., operator work consoles, VMS, graphics, dispatch, etc.).

   6 WORK CONSOLES; WINDOWS BASED SLAVES TO VAX - SOFTWARE CONTROLS THE VMS, RAMP METERING, CCTV SYSTEMS

   VAR. MSG SIGNS, NOT THE OP. SYS.

   EF JOHNSON RADIOS (800 MHz) FOR DISPATCH.

COMPUTER OPERATIONS (continued)

3. Please indicate software or algorithms currently in use.

   - ramp metering

     "BOTTLENECK" ALGORITHM DESCRIBED EARLIER, DEVELOPED IN HOUSE

   - incident detection and traffic control management

     INC. DET. - SOFTWARE DEVELOPED BY JHK

   - freeway interchange control (i.e., time-of-day, stand-alone, Eagle, etc.)

     —

   - arterial and intersection control (i.e., traffic responsive, interconnected system, Econolite, etc.).

     —

   - other

     —

4. Please indicate expert systems currently in use (i.e., positive incident detection generates appropriate VMS response).

   —

CONTROL ROOM FEATURES

1. Please indicate the number of operator work consoles and the appropriate staff position.

   6 CONSOLES: 3 FOR SURVEILLANCE, CONTROL, & DRIVER INFORMATION, 1 FOR RADIO DISPATCH, 2 FOR 2 TUNNELS (SURVEILLANCE)

2. Please indicate the features contained on the operator work consoles.

Feature	Yes	No
- Interactive keyboard MOSTLY MOUSE/JOYSTICK	✓	
- Ramp metering control	✓	
- CCTV switch matrix control	✓	
- Automatic incident detection alarm	✓	
- Radio panel (with DOT, State Patrol, etc.)	✓	
- Telephone panel (direct lines and/or general use)	✓	
- VMS control	✓	
- HAR control	✓	
- lane control		✓
- Textual CRTs 1@ EACH CONSOLE	✓	
- Graphical CRTs 2@ EACH CONSOLE	✓	
- CB/mobile radio panel		✓
- Intercom		✓

3. Please list any other features contained on the operator work consoles.

   NOT A TRUE INTERCOM, BUT 1 WAY COMMUNICATION WITH TRAFFIC REPORTERS: ABILITY TO TYPE TRAFFIC INFO (ACCIDENT, DISABLEMENT, LANES BLOCKED, ETC.) INTO CONSOLE. WHEN REPORTERS LOG IN TO GET A CONGESTION MAP, MESSAGE IS DOWNLOADED AUTOMATICALLY.

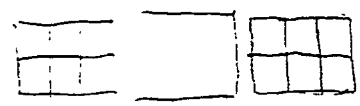
CONTROL ROOM FEATURES (continued)

4. Please indicate the number of graphical and textual CRTs per operator work console.

   2 GRAPHICAL, 1 TEXTUAL

5. Please indicate systemwide operation display method (i.e., static wall map, projection screen TV, TV matrix, etc.).

   1 PROJECTION SCREEN
   2 MATRICES →



6. Please indicate the following CCTV information.

   - number of CCTV monitors within control center

     13: 2@ 2x3, 1 PROJECTION

   - number of CCTV cameras in the field within system boundaries

     APPROX. 80 CURRENTLY. SYSTEM CAN HANDLE 256

   - CCTV camera spacing in the field

     ½ - 1 MILE

   - is current CCTV coverage adequate?

     NO - COVERAGE CENTERED ON 3 OF 5 MAJOR HIGHWAYS. EXPANSION PLANNED TO BRING CAMERA TOTAL TO OVER 200

7. Please indicate the following loop detector information.

   - number of loop detectors in the field within system boundaries

     APPROX 1200

   - loop detector spacing in the field

     ½ MILE

   - loop detector polling and data collection time interval

     170 CONTROLLER POLLS LOOP 60x/SEC
     CENTRAL COMPUTER POLLS 170 1x/SEC
     DATA COLLECTION/DISPLAY TIME INTERVAL 1x/MIN

   - is current loop detector system coverage adequate?

     NO - 4 OF 5 MAJOR HIGHWAYS COVERED CURRENTLY

8. Please indicate communication system between TOC and field equipment (i.e., fiber optic, coaxial cable, phone lines, etc.)

   FIBER OPTIC - FROM COMMUNICATION HUBS TO TOC

   COAXIAL CABLE, TWISTED PAIR } FROM EQUIPMENT TO COMM. HUB

   PHONE LINES FROM EQUIPMENT TO TOC

TOC FACILITY LAYOUT AND SIZE

1. Please indicate overall floor plan area (square feet).

SEE ATTACHED

2. Please indicate overall control center area (square feet).

SEE ATTACHED

3. Please indicate overall office space provided (square feet).

1700 SF +/-

4. Please indicate security method within TOC facility (i.e., coded ID cards, numerical code sequence, etc.).

5. CRC would be very grateful if you could provide the following:

- floor plan layout of TOC
- TOC control room layout
  ATTACHED
- operator console layout ATTACHED

GENERAL OVERVIEW

1. Overall, please indicate the most useful systems and functions that your TOC provides.

RAMP METERING

VARIABLE MESSAGE SIGNS

CCTV COVERAGE

CONGESTION MAP DOWNLOADS TO TRAFFIC REPORTERS

2. Overall, please indicate the systems and functions that are in USE all of the time.

DATA COLLECTION

INCIDENT DETECTION

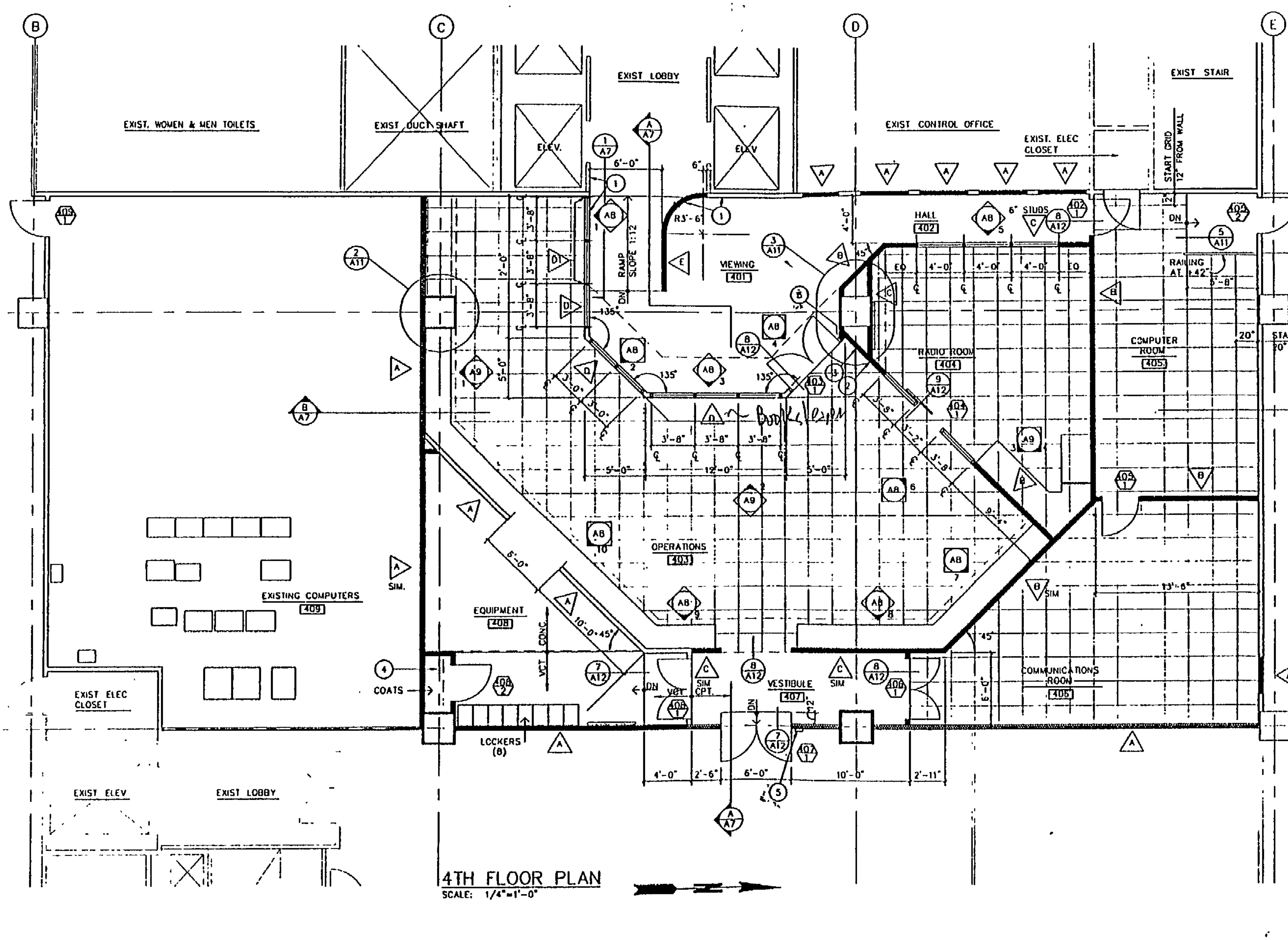
CONGESTION MAP DOWNLOADS

MAINTENANCE DISPATCH

GENERAL OVERVIEW (continued)

3. Please indicate the additional systems, functions, services, software, algorithms, etc., that you wish your TOC possessed.

EXPERT SYSTEMS SOFTWARE ALLOWING CAMERA, TO PAN TO INCIDENT, PROMPT TO PUT UP APPROPRIATE MESSAGES ON VMS & HAR.



4TH FLOOR PLAN
SCALE: 1/4"=1'-0"

CONSTRUCTION NOTES:

1. ALIGN SURFACES.
2. FIRE ALARM DISPLAY PANEL SEE ELECTRICAL DWGS
3. ELECTRICAL SWITCHES SEE ELECTRICAL DWGS
4. 12" SHELF WITH POLE
5. CARD READER LOCATION SEE ELECTRICAL DWGS

GENERAL NOTES:

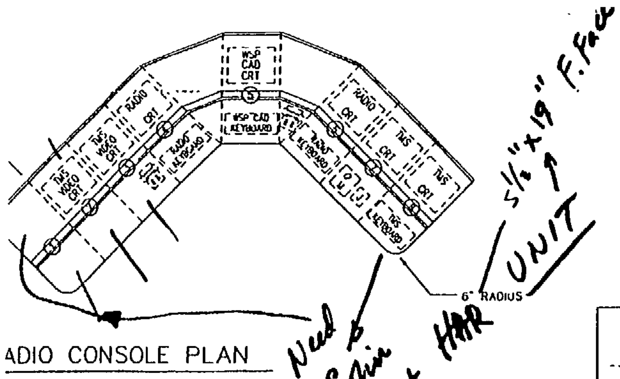
1. FOR PARTITION TYPES SEE DETAIL 1/A11
2. CONTRACTOR SHALL PATCH ALL FLOOR OPENINGS ABANDONED AS INDICATED ON THE MECH DRAWINGS SEE DETAIL 6/A11.

REGISTERED ARCHITECT
STATE OF WASHINGTON

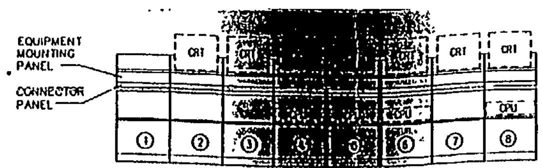
NOTE:
IF SHEET IS LESS THAN 24"X36" IT IS A REDUCED PRINT! DO NOT SCALE!

1/22/91	HEADQUARTERS SUBMITTAL	STATE	FED AID PROJ NO	HIGHWAY DIVISION	Washington State Department of Transportation	DAYTON AVENUE TRAFFIC SYSTEMS MANAGEMENT CENTER CONSTRUCTION	A4
6/11/91	FINAL SUBMITTAL	10 WASH					SHEET
		JOB NUMBER					

NOTE: CONSOLES SHALL BE SHOP FABRICATED IN AS LARGE SECTIONS AS POSSIBLE



ADIO CONSOLE PLAN

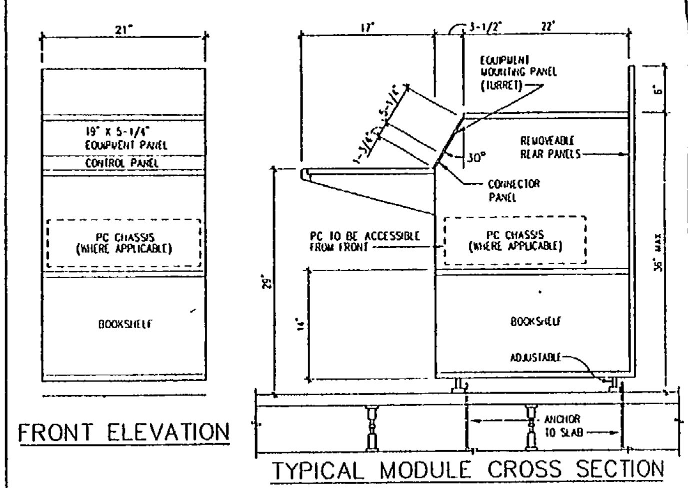


RADIO CONSOLE ELEVATION

LEGEND

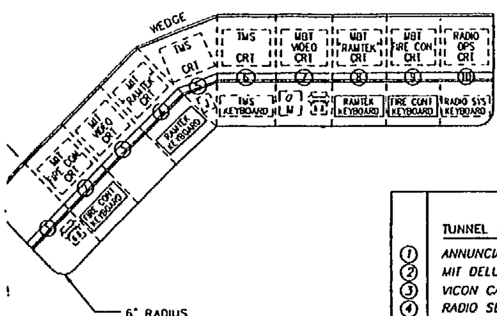
- - - -	EQUIPMENT BY OTHERS
	MOUSE
	JOYSTICK
	TELEPHONE
	KEYBOARD BY OTHERS
	KEYBOARD BY CONTR.

	RADIO TURRET EQUIPMENT	RADIO CONNECTOR PANELS
①	SNOWLINE RECORDER, CALL CHECK, VOICE RECORDER	
②	SCANNER, CALL CHECK, VIDEO SWITCH	
③	CALL CHECK RECORDER, SPEAKERS	DETAIL C
④	RADIO SPEAKER PANEL	DETAIL B
⑤	WSP CAD SPEAKER PANEL	DETAIL B
⑥	RADIO SPEAKER PANEL	DETAIL B
⑦	CALL CHECK RECORDER	DETAIL A
⑧	VOICE RECORDER	



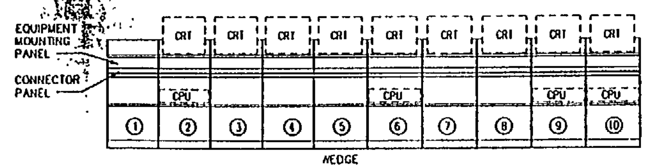
FRONT ELEVATION

TYPICAL MODULE CROSS SECTION

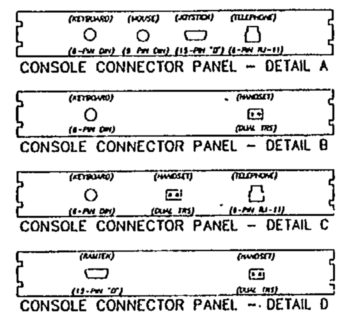


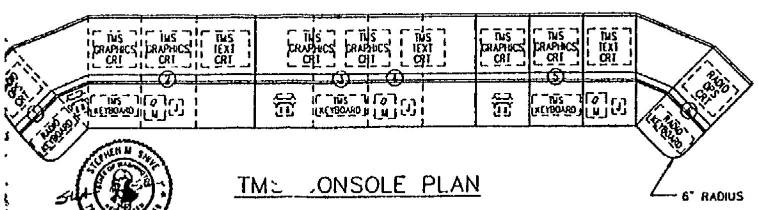
JNNEL CONSOLE PLAN

	TUNNEL TURRET EQUIPMENT	TUNNEL CONNECTOR PANELS
①	ANNUNCIATOR - MIT	DETAIL C
②	MIT DELUGE CONTROL, OPERATIONAL RADIO HANDSET	
③	VICON CAMERA CONTROL	DETAIL D
④	RADIO SEL/UNSEL SPEAKER E/W 6-POS SWITCH	
⑤	REBROADCAST HANDSET 1, REBROADCAST HANDSET 2	DETAIL A
⑥	ANNUNCIATOR - MBT	
⑦	COHU CAMERA CONTROL	
⑧	RADIO SEL/UNSEL SPEAKER E/W 6-POS SWITCH)	DETAIL D
⑨	MBT DELUGE CONTROL, OPERATIONAL RADIO HANDSET	DETAIL C
⑩	RADIO SEL/UNSEL SPEAKER - OPS.	DETAIL B



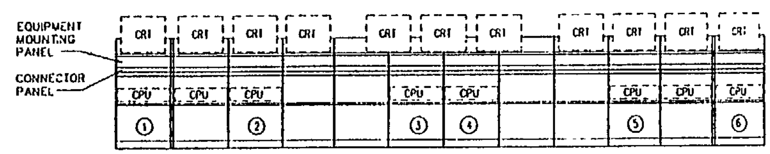
TUNNEL CONSOLE ELEVATION





TM_ _ONSOLE PLAN

	TMS TURRET EQUIPMENT	CONNECTOR PANELS
①	RADIO SEL/UNSEL SPEAKER PANEL	DETAIL B
②	PC SPEAKER PANEL	DETAIL A
③	PC SPEAKER PANEL	DETAIL A
④	SCANNER	DETAIL A
⑤	PC SPEAKER PANEL	DETAIL A
⑥	RADIO SEL/UNSEL SPEAKER PANEL	DETAIL B



TMS CONSOLE ELEVATION

ELMORE | 5/6/91 DISTRICT-WIDE SUBMITTAL | 6/10/91 HEADQUARTERS SUBMITTAL | 7/ /91 VAL . TT.

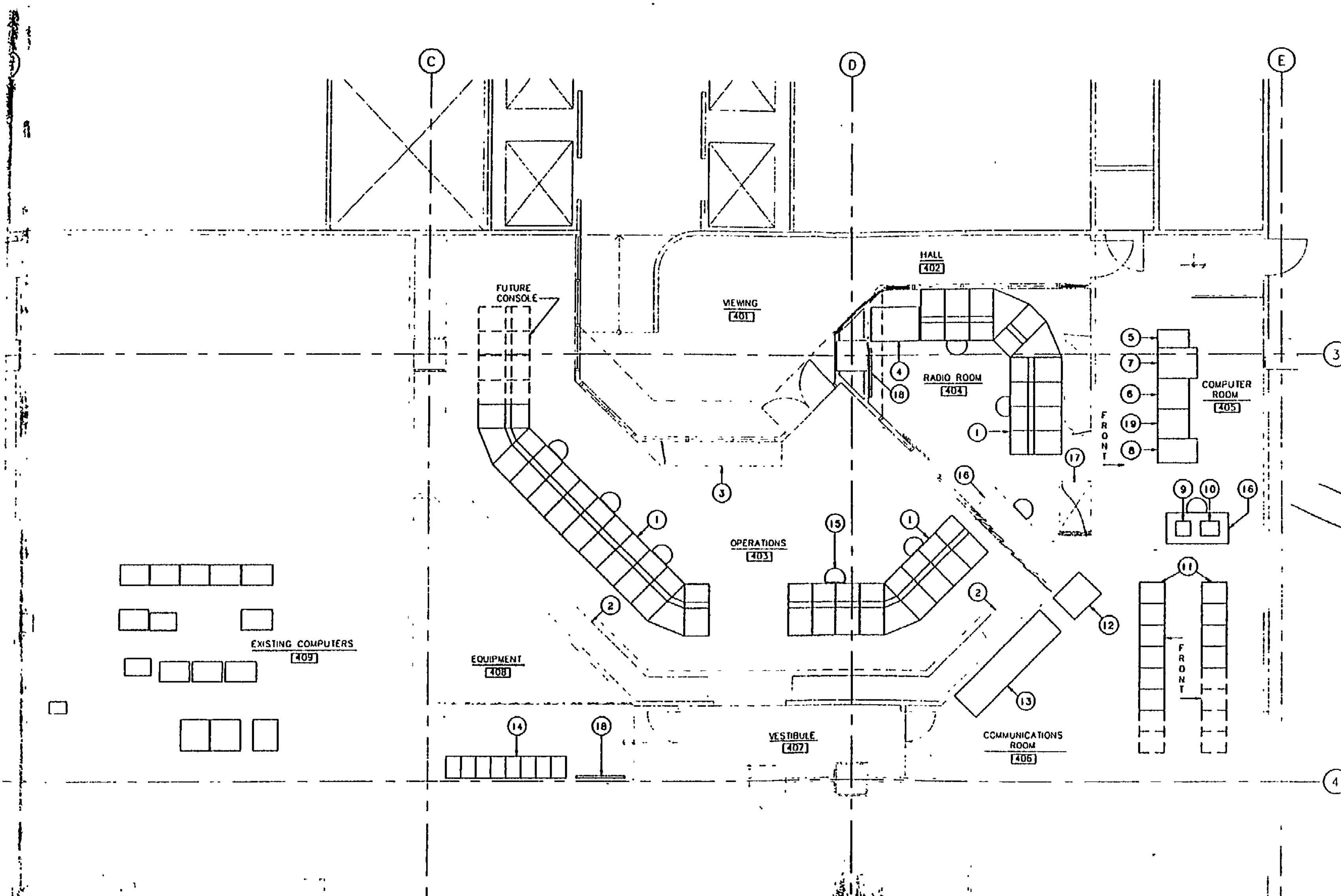
10 | WASH | I-90-1 (37C

HIGHWAY DIVISION

Washington State Department of Transportation

SR 5
DAYTON AVE. N.

D5



EQUIPMENT:

1. CONSOLE
2. MONITOR CABINETS
3. OPEN SHELVING
4. FIRE ALARM
5. TAPE DRIVE
6. CPU
7. PRINTER
8. DISK DRIVE
9. TERMINAL
10. PRINTER
11. COMMUNICATION RELAY RACKS
12. PDU
13. U P S WITH BATTERY
14. LOCKERS
15. CHAIR (9 TOTAL)
16. DESK
17. MAP FILES
18. CHALKBOARD
19. EXPANSION CABINET

4TH FLOOR CONSOLE/EQUIPMENT PLAN

SCALE: 1/4"=1'-0"

NOTE:
IF SHEET IS LESS THAN 24"X36"
IT IS A REDUCED PRINT!
DO NOT SCALE!

REGISTERED ARCHITECT
STATE OF WASHINGTON

1/22/91	HEADQUARTERS SUBMITTAL	
6/11/91	FINAL SUBMITTAL	

G. KAMI. . ANO
SHO. L. KELLUM
R. PFIFER
K. JOHNS
R. . I ENRY

REGION NO.	STATE	FED. AID PROJ. NO.	SHEET NO.	TOTAL SHEETS
10	WASH			

JOB NUMBER
91W607

I-90-1 (333)

HIGHWAY DIVISION

Washington State
Department of Transportation

FLUOR [A] ARAI/

DAYTON AVENUE
TRAFFIC SYSTEMS MANAGEMENT CENTER
CONSTRUCTION

A5

SHEET 5 OF

City of Anaheim, CA (TMC)

SERVICES PROVIDED

1. Please indicate the services that the TOC provides.

	Yes	No
- ramp-metering control		X
- closed-loop detection	X	
- ultrasonic detection		X
- CCTV monitoring	X	
- video image processing		X - Future De.
- automatic incident detection		X
- incident response management		X
- automatic link-travel time computations		X
- variable message sign control	X	
- highway advisory radio control	X	
- direct modem link with other agencies	X	
- interchange signal control and coordination	X	
- arterial signal control and coordination	X	
- DOT maintenance dispatching	X	
- State Patrol dispatching		X
- emergency and courtesy patrol dispatching		X
- emergency phone and phone call box service		X

2. Please list any other services provided by the TOC.

- Special Event Traffic Management

STAFFING REQUIREMENTS

1. List essential personnel and staffing requirements and the functions and responsibilities of each position.

Position	No. of Staff	Functions & Responsibilities
Principal Traffic Engr.	12-13, everyone below	Chief of Systems Section includes all traffic signal controls and traffic system management elements. Reports to City Transp. Manage
Assoc. Traffic Engr.-Design/Mnt.	1 Technical Aide 4 Technicians (Field)	Responsible for all systems section Design and Maintenance
ssoc. Traffic Engr. - Operations	1 Signal System Engr. 4-5 Interns/Operators	Responsible for all signal timings and TOC operations
Field Technicians	—	All maintenance of traffic signal controller equipment.
ignal Systems Engr.		Operations of System Hardwan

STAFFING REQUIREMENTS (continued)

2. Please indicate peak-hour staffing requirements.

Usually 2 of- more operators during normal weekday business hours of 7AM-6PM.

3. Please indicate 24-hour and off-peak staffing requirements.

1-2 Traffic Engineering Operators and 1 Police Supervisor during Special Event Operations in the City.

4. Please indicate training time period for each essential position.

Training not very formal. Operators can learn system within 2 weeks. Other positions get better with experience

5. Please indicate turnover rate for each essential position.

System has been in operation for about 3 years. Each essential position (Principal and 2 Associate positions) have changed once.

6. Please indicate any difficult or complex problems encountered within training.

Biggest problem is providing a Manual for Reference 0r Instruction.

7. Please indicate areas in which to improve training operations.

Having a Reference Manual.

COMPUTER OPERATIONS

1. Breakdown and identification of main traffic management supervisory computer.

   - Brand name (i.e., IBM, Compaq, Toshiba, etc.)

     Concurrent

   - Type (i.e., minicomputer, networked PCs, etc.)

     minicomputer

   - Operating system (i.e., multi-task like UNIX)

     OS/32

   - Operating language (i.e., high-level like C)

     OS/32, DOS

   - Memory storage capacity (i.e., number of Mbytes)

     Micro 3 – 2 disks, 368Mb 8Mb RAM
     3212 – 1 disk, 368Mb 8Mb RAM

2. Please indicate any support subsystem computers and associated software (i.e., operator work consoles, VMS, graphics, dispatch, etc.).

Operator work consoles: Compaq PCs
Monitors : High Resolution Multi-sync 1024x1240
Graphics : JHK Softgraf, High Res.

COMPUTER OPERATIONS (continued1

3. Please indicate software or algorithms currently in use.

- ramp metering

  None controlled by Caltrans

- incident detection and traffic control management

  UTCS -Enhanced

- freeway interchange control (i.e., time-of-day, stand-alone, Eagle, etc.)

  UTCS -Enhanced, time- of-day

- arterial and intersection control (i.e., traffic responsive, interconnected system, Econolite, etc.).

  Interconnected network with traffic responsive capabili

- other

4. Please indicate expert systems currently in use (i.e., positive incident detection generates appropriate VMS response).

None one is planned for next year.

CONTROL ROOM FEATURES

1. Please indicate the number of operator work consoles and the appropriate staff position.

   3 stations being modified to 5 stations.
   3 for Traffic Engineering Operators and 2 for local Police.

2. Please indicate the features contained on the operator work consoles.

	Yes	No
- Interactive keyboard	X	
- Ramp metering control		X
- CCTV switch matrix control	X	
- Automatic incident detection alarm		X
- Radio panel (with DOT, State Patrol, etc.)	X	
- Telephone panel (direct lines and/or general use)	X	
- VMS control	X	
- HAR control		X
- lane control		X
- Textual CRTs	X	
- Graphical CRTs	X	
- CB/mobile radio panel		X
- Intercom		X

3. Please list any other features contained on the operator work consoles.

   Projection System switching devices.

CONTROL ROOM FEATURES (continued)

4. Please indicate the number of graphical and textual CRTs per operator work console.

   1 each

5. Please indicate systemwide operation display method (i.e., static wall map, projection screen TV, TV matrix, etc.).

   Rear-view projection system

6. Please indicate the following CCTV information.

   - number of CCTV monitors within control center

     4, expanding to 8 soon.

   - number of CCTV cameras in the field within system boundaries

     9, expanding to 20+ soon.

   - CCTV camera spacing in the field

     located at major intersections.

   - is current CCTV coverage adequate?

     At major event center 75-80% coverage.

7. Please indicate the following loop detector information.

   - number of loop detectors in the field within system boundaries

     100, expanding to 200+ soon.

   - loop detector spacing in the field

     located at approach segments ~~along~~ of intersections along major arterials.

   - loop detector polling and data collection time interval

     programmable, usually about every 2 minutes.

   - is current loop detector system coverage adequate?

     approximately 20% of arterial network is covered

8. Please indicate communication system between TOC and field equipment (i.e., fiber optic, coaxial cable, phone lines, etc.)

   city owned twisted pair, planned fiber optic backbone, few leased phone lines.

TOC FACILITY LAYOUT AND SIZE

1. Please indicate overall floor plan area (square feet).

Traffic Management Center about 3000sf
Computer/Equipment Room about 400sf
3400sf

2. Please indicate overall control center area (square feet).

about 1000sf

3. Please indicate overall office space provided (square feet).

- 6 offices @ 90sf each
- 1 office @ 80sf each
- 1 office @ 130sf each

4. Please indicate security method within TOC facility (i.e., coded ID cards, numerical code sequence, etc.).

Numerical code sequence.

5. CRC would be very grateful if you could provide the following:

- floor plan layout of TOC ✓
- TOC control room layout ✓
- operator console layout ✓

GENERAL OVERVIEW

1. Overall, please indicate the most useful systems and functions that your TOC provides.

   UTCS-Enhanced Signal Control System.
   CMS Central Control.
   Graphics System.
   CCTV central control.
   Projection System
   Radio Communications to Field Personnel

2. Overall, please indicate the systems and functions that are in use all of the time.

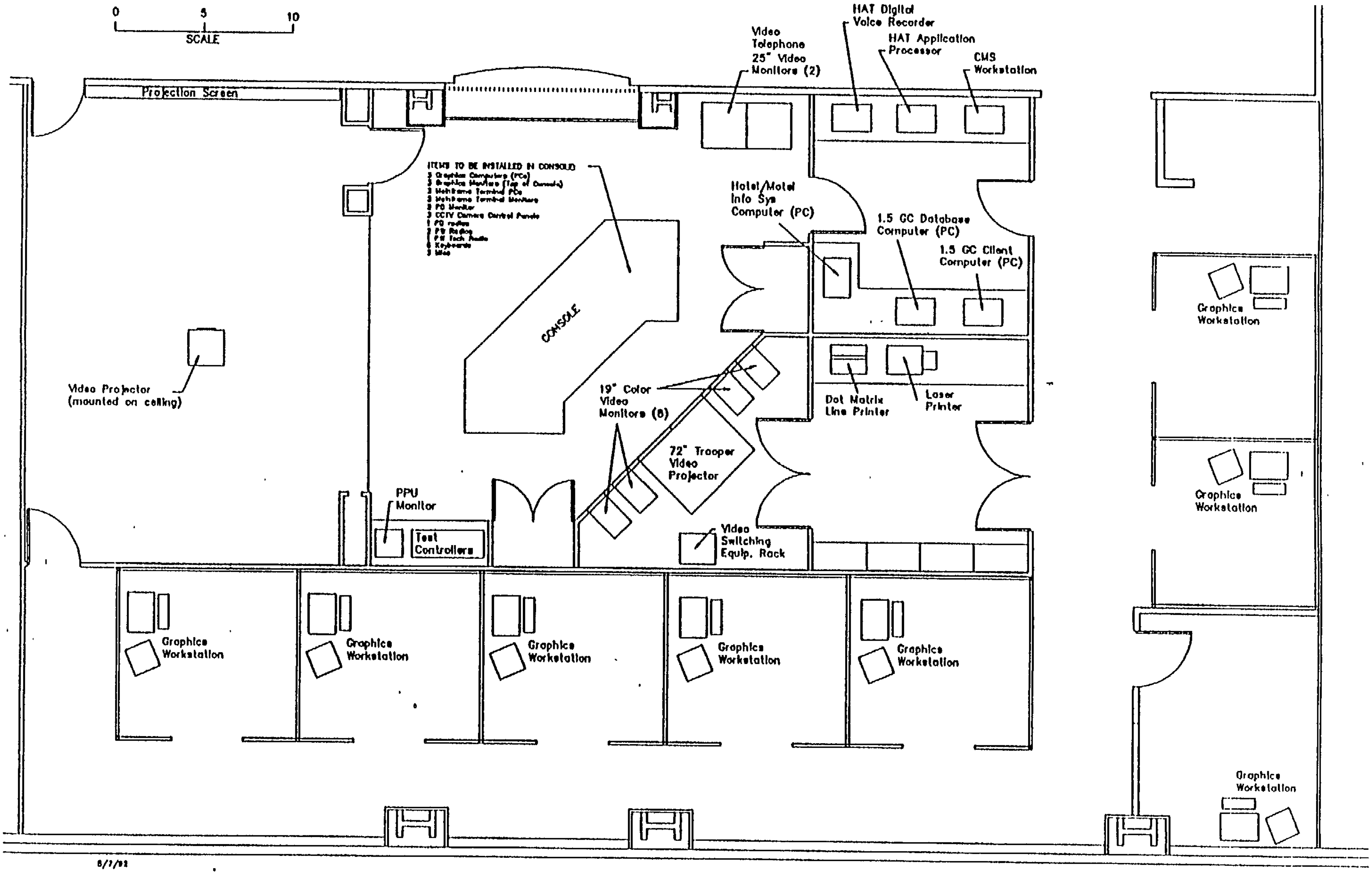
   UTCS
   CMS
   Graphics
   CCTV
   Projection System
   Radios

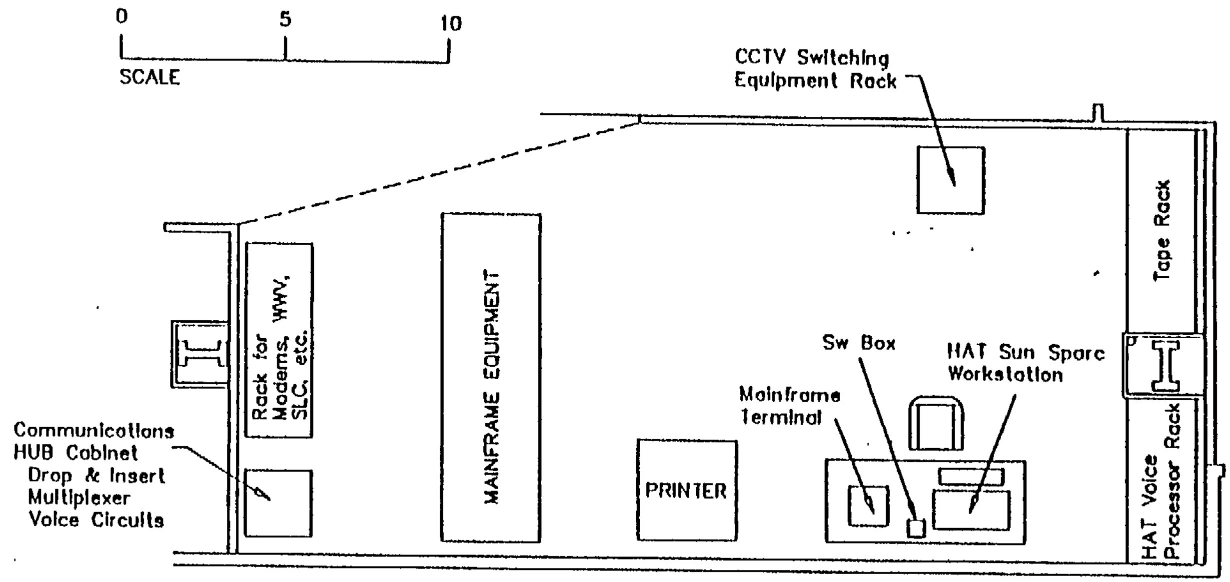
3. Please indicate the additional systems, functions, services, software, algorithms, etc., that you wish your TOC possessed.

Knowledge-based Expert System for CMS support, and HAR support.

Real-time adaptive signal control capabilities. (SCOOT)

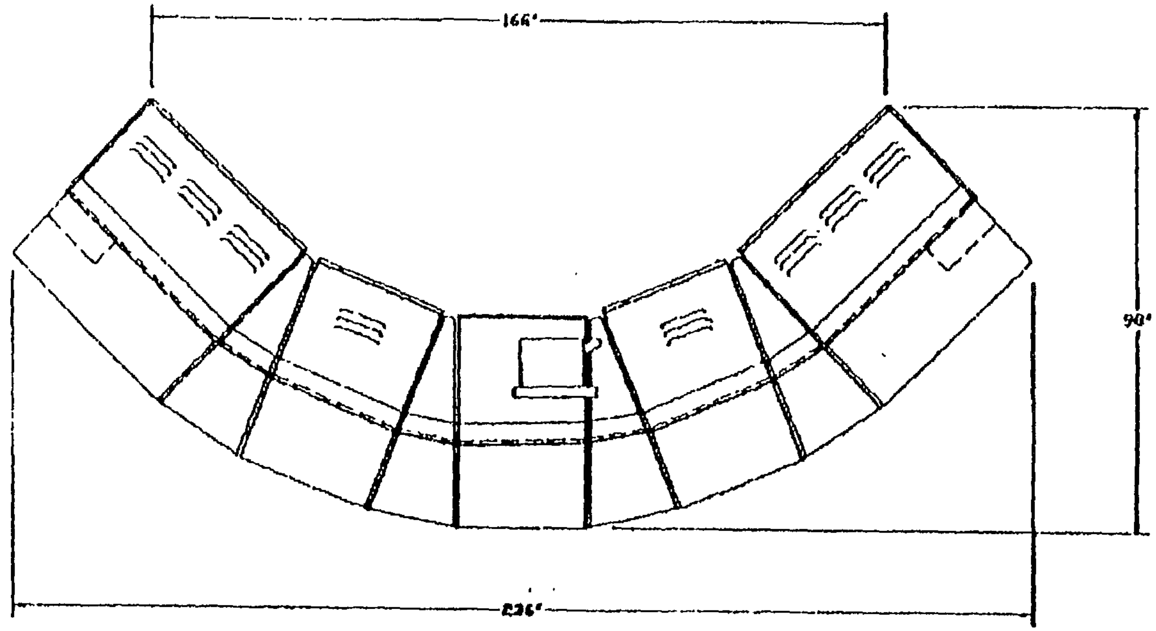
TRAFFIC MANAGEMENT CENTER



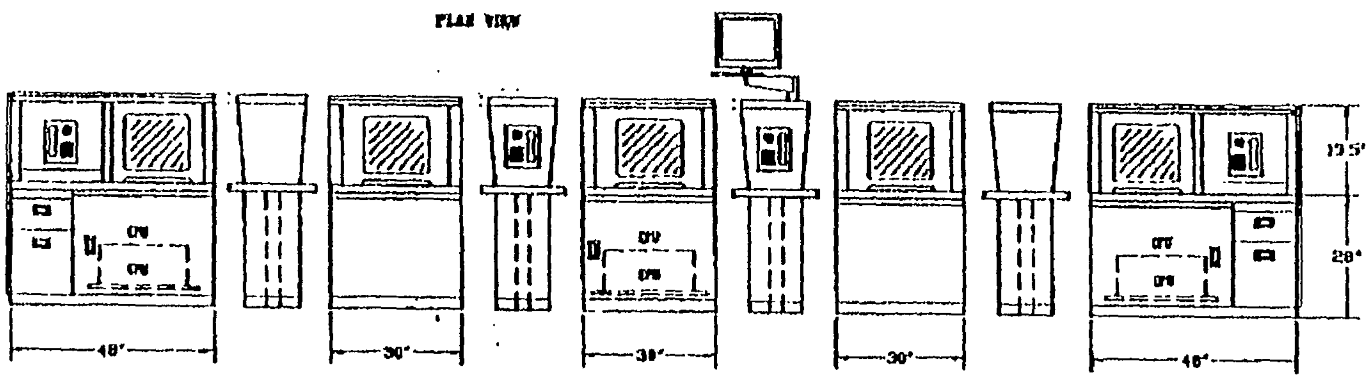


5/7/92

TRAFFIC MANAGEMENT CENTER
COMPUTER/EQUIPMENT ROOM

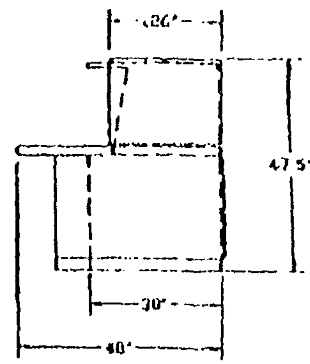


PLAN VIEW



FRONT ELEVATION

(SHOWN IN A STRAIGHT LINE FOR CLARITY)



SIDE PROFILE

NOTES:

1a FINISH FRAME AND MONITOR SECTION- TEXTURED BLACK POLYURETHANE
1b OUTER METAL COVERS- DUAL GREY
1c WORK SURFACE LAMINATE- FORMICA DOVE GREY
2 TOP PANELS TO HAVE LOUVERS AS INDICATED
3 TRANSITIONS TO BE 22.5°- MAINTAINING 24 inch DEEP WORK SURFACE

Swanson Engineering & Manufacturin	
Inglewood, CA	
Drawn by DAVID XU	Date Mar 23, 1998
Reviewed by	Date
Approved by	Date
	Scale NONE
CITY OF ANAHEIM	
TRAFFIC CONTROL CONSOLE	
Drawing Number	S-3153-LL-RR

(reduced copy - original to follow)

MCD

Virginia DOT - TMS

SEP 21 1992

SERVICES PROVIDED

1. Please indicate the services that the TOC provides. Yes No

- ramp-metering control Yes
- closed-loop detection Yes
- ultrasonic detection No
- CCTV monitoring Yes
- video image processing Yes (under Testing)
- automatic incident detection Yes
- incident response management Yes
- automatic link-travel time computations No
- variable message sign control Yes
- highway advisory radio control No
- direct modem link with other agencies No
- interchange signal control and coordination No
- arterial signal control and coordination No
- DOT maintenance dispatching Yes (only TOC maintenance)
- State Patrol dispatching Yes
- emergency and courtesy patrol dispatching Yes
- emergency phone and phone call box service No

2. Please list any other services provided by the TOC.

High Occupancy Vehicles (HOV) Lane Control.
Control of Tunnel Gas emission and the light system
Communication with media and other TOC's.
Tours and Technical seminars.

STAFFING REQUIREMENTS

1. List essential personnel and staffing requirements and the functions and responsibilities of each position.

No. of Staff		Functions & Responsibilities
2	Traffic Controller Supervisors	
5	Traffic Controllers / Full Time	
1	Traffic Controller / Part Time.	

During Weekdays we operate from 5:00 AM – 12:30 AM.
On Weekends we operate from 5:30 AM – 12:30 AM.

Staffing requirements are as follows:

1. Weekdays:
   a. 2 Controllers and one Supervisor from 5:00 AM – 1:45 pm
   b. 2 Controllers from 12:45 pm – 9:30 AM
   c. 1 Supervisor from 3:45 pm – 12:30 pm.
   d. 1 Controller From 8:00 AM – 4:45 pm.

2. Weekends:
   a. 4 part time Controller on Saturday and Sunday From 5:30 AM – 3:00 pm.
   b. 1 Controller Supervisor on Saturday and Sunday From 3:00 pm – 12:30 AM.

please see attachment for functions and responsibilities.

2. Please indicate peak-hour staffing requirements.

2 Controllers and one Supervisor are present during "Rush hour".

3. Please indicate 24-hour and off-peak staffing requirements.

please see 1.

4. Please indicate training time period for each essential position.

3 – 5 Weeks.

5. Please indicate turnover rate for each essential position.

over a period of 3 years, 3 Full time controllers and 3 part time controllers resigned.

6. Please indicate any difficult or complex problems encountered within training.

Uniformity in message display on the VMS

7. Please indicate areas in which to improve training operations.

please see General. Overview – 3

COMPUTER OPERATIONS

1. Breakdown and identification of main traffic management supervisory computer.

   - Brand name (i.e., IBM, Compaq, Toshiba, etc.)

     Perkin-Elmer 3220 mainframe Computer.

   - Type (i.e., minicomputer, networked PCs, etc.)

     Mainframe.

   - Operating system (i.e., multi-task like UNIX)

     OS/32

   - Operating language (i.e., high-level like C)

     Fortran 77

   - Memory storage capacity (i.e., number of Mbytes)

     80 MSM

2. Please indicate any support subsystem computers and associated software (i.e., operator work consoles, VMS, graphics, dispatch, etc.).

A- 2 IBM, 286 PC's, 40 MB as VMS Controllers.
B- only one recieves commands from the Perkin-Elmer.
operating language: C
Customized Software By Lake Technologies, Inc.

B. 2 CRT's for Traffic Information, VMS control ... etc.
HOV Lane control, Ramp Meter control ... etc.

3. Please indicate software or algorithms currently in use.

- ramp metering

Ramp Metering Algorithm.

- incident detection and traffic control management

Incident Detection Algorithm.

- freeway interchange control (i.e., time-of-day, stand-alone, Eagle, etc.)

None

- arterial and intersection control (i.e., traffic responsive, interconnected system, Econolite, etc.).

None.

- other

/

4. Please indicate expert systems currently in use (i.e., positive incident detection generates appropriate VMS response).

This system is connected to I-66 / I-395 signs. Messages with appropriate Milages can be displayed either Automatically or after controller's verification.

[redacted]

CONTROL ROOM FEATURES

1. Please indicate the number of operator work consoles and the appropriate staff position.

   2 CRT's and 2 PC work stations } staffed by Controllers.
   1 CCTV Console , 1 Alarm Console }

2. Please indicate the features contained on the operator work consoles. Yes No

   - Interactive keyboard yes
   - Ramp metering control yes
   - CCTV switch matrix control yes
   - Automatic incident detection alarm yes
   - Radio panel (with DOT, State Patrol, etc.) yes
   - Telephone panel (direct lines and/or general use) yes
   - VMS control yes
   - HAR control No
   - lane control (HOV lane control) yes
   - Textual CRTs yes
   - Graphical CRTs No
   - CB/mobile radio panel yes
   - Intercom No

3. Please list any other features contained on the operator work consoles.

CONTROL ROOM FEATURES (continued)

4. Please indicate the number of graphical and textual CRTs per operator work console.

   1 textual CRT, 1 PC.

5. Please indicate systemwide operation display method (i.e., static wall map, projection screen TV, TV matrix, etc.).

   Static Wall map.

6. Please indicate the following CCTV information.

   - number of CCTV monitors within control center

     48

   - number of CCTV cameras in the field within system boundaries

     48

   - CCTV camera spacing in the field

     1/2 Mile to 2 miles

   - is current CCTV coverage adequate?

     A few areas within the area covered can not be seen because of highway geometry.

7. Please indicate the following loop detector information.

   - number of loop detectors in the field within system boundaries

     550

   - loop detector spacing in the field

     1/2 mile

   - loop detector polling and data collection time interval

     1/4 second

   - is current loop detector system coverage adequate?

     Yes

8. Please indicate communication system between TOC and field equipment (i.e., fiber optic, coaxial cable, phone lines, etc.)

   All of the above are used by TOC at different locations.

[redacted]

TOC FACILITY LAYOUT AND SIZE

1. Please indicate overall floor plan area (square feet).

   60' x 60'

2. Please indicate overall control center area (square feet).

   33' x 31'

3. Please indicate overall office space provided (square feet).

   2580 □ ft

4. Please indicate security method within TOC facility (i.e., coded ID cards, numerical code sequence, etc.).

   Name Tags.

5. CRC would be very grateful if you could provide the following:

   - floor plan layout of TOC

   - TOC control room layout

   - operator console layout

GENERAL OVERVIEW

1. Overall, please indicate the most useful systems and functions that your TOC provides.

HOV Lane Control
VMS Control
Comm. with media, state police

2. Overall, please indicate the systems and functions that are in use all of the time.

VMS Control
Incident detection using the CCTV.

3. Please indicate the additional systems, functions, services, software, algorithms, etc., that you wish your TOC possessed.

* Real time alternate route identification

* Centralized Work station where all function could be performed from one computer terminal per operator.

* Automatic message selection from a message data base. This will help in the uniformity of message, display speed and time for training.

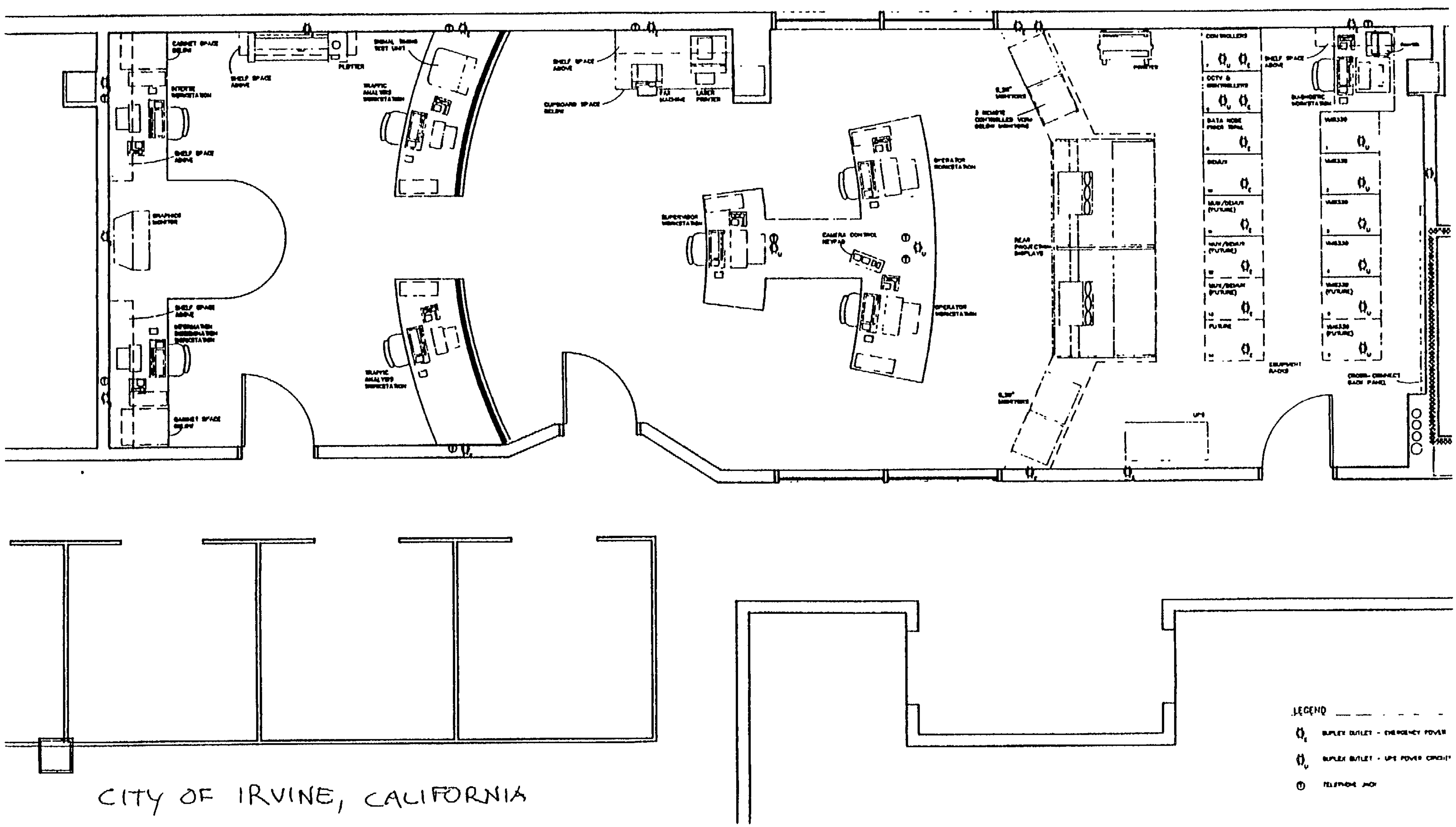
* The ability to send selective data to the maintenance department directly. This real time data will decrease down time and decrease the controllers work load.

APPENDIX B - OTHER CONTROL CENTER LAYOUTS

Layouts of several other facilities have been included for information purposes. These include centers in Irvine, CA; Toronto, Ontario (Highway 401 and ITCC centers); Mississauga, Ontario; and Riyadh, Saudi Arabia.

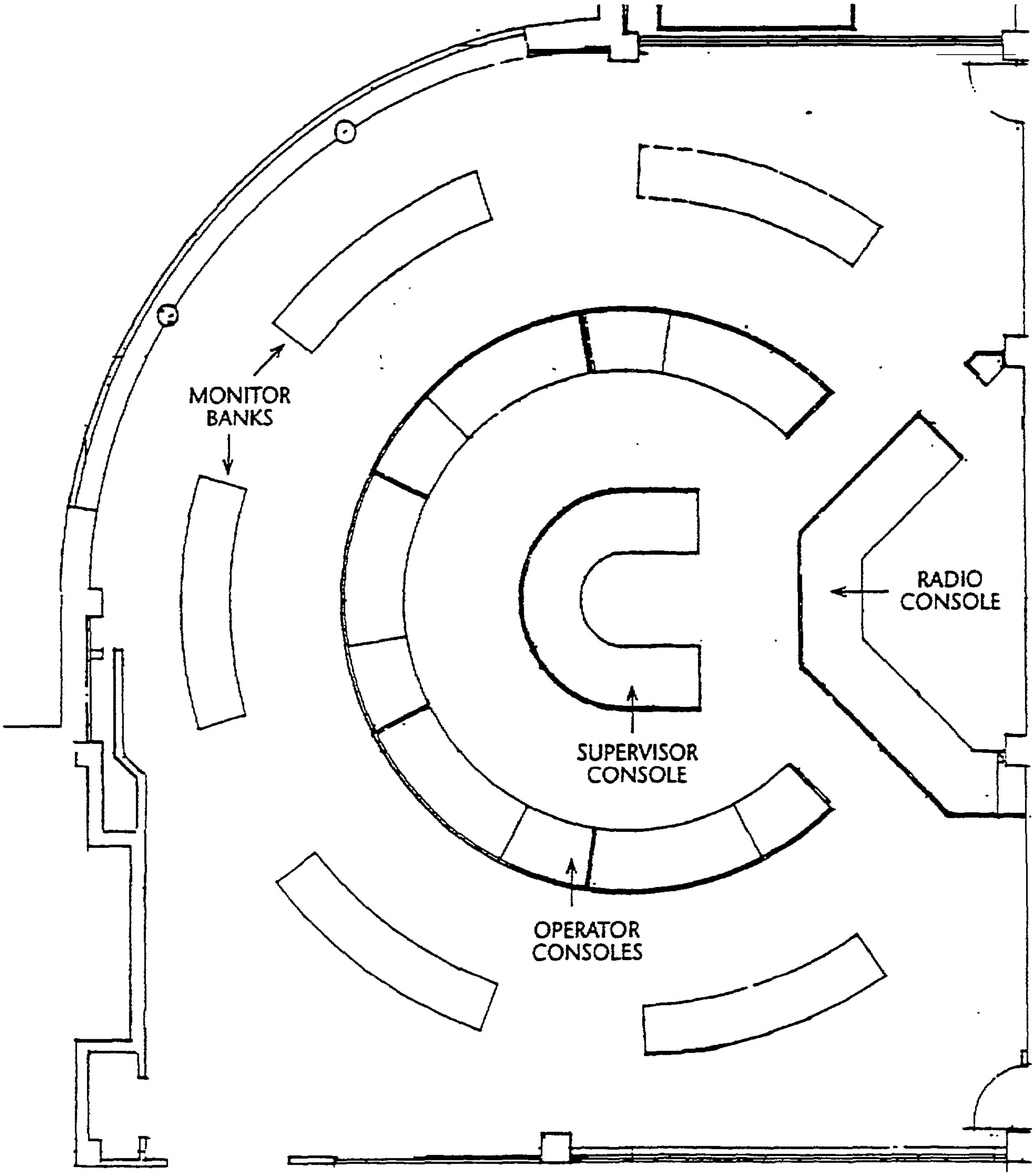
EXHIBIT 3

CONTROL CENTER
PRELIMINARY ARCHITECTURAL DESIGN

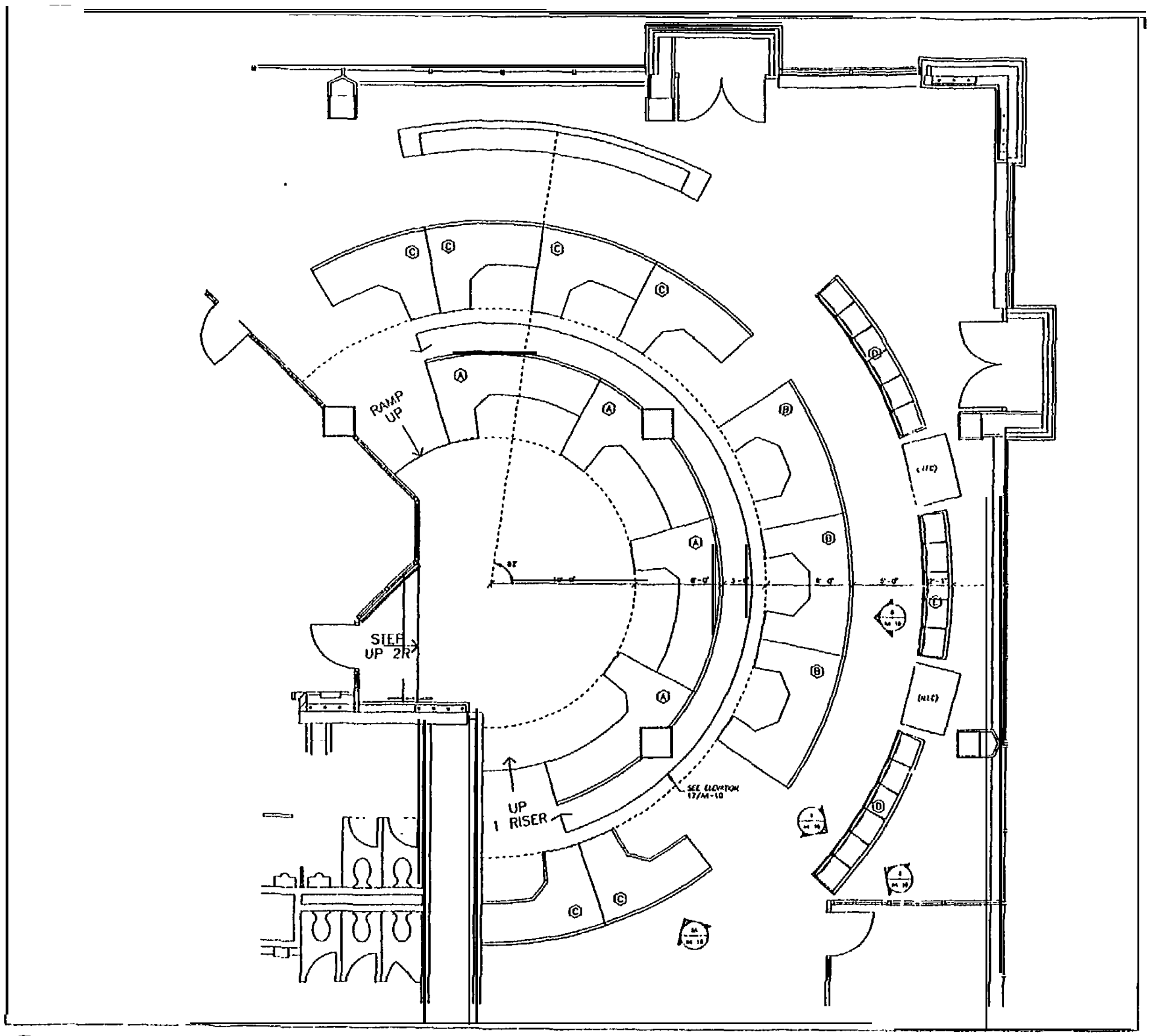


CITY OF IRVINE, CALIFORNIA

LAYOUT OF HIGHWAY 401 FREEWAY TRAFFIC MANAGEMENT SYSTEM CONTROL ROOM

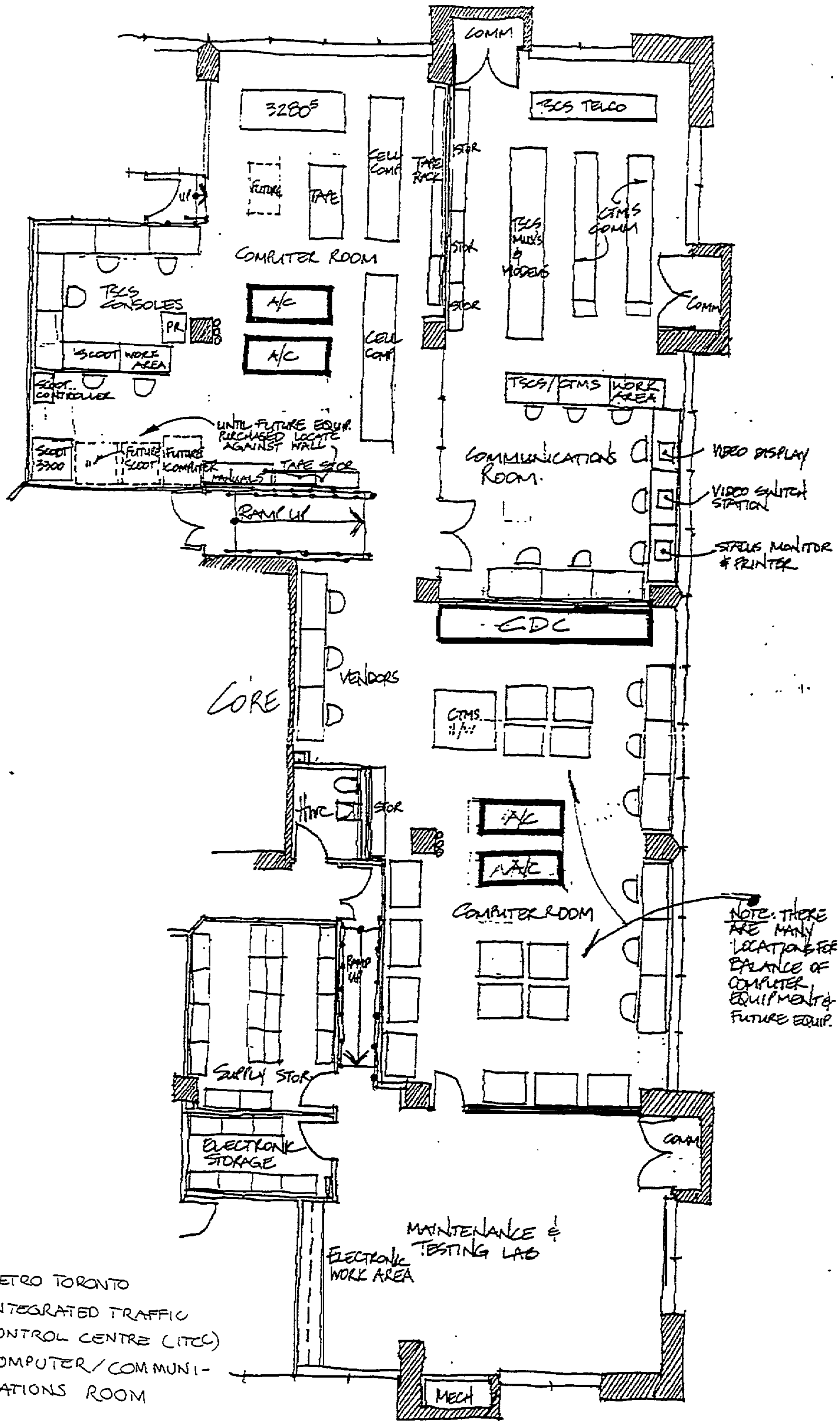


APPROXIMATE DIMENSIONS: 52 ft x 47 ft
APPROXIMATE AREA: 2,445 sq.ft.



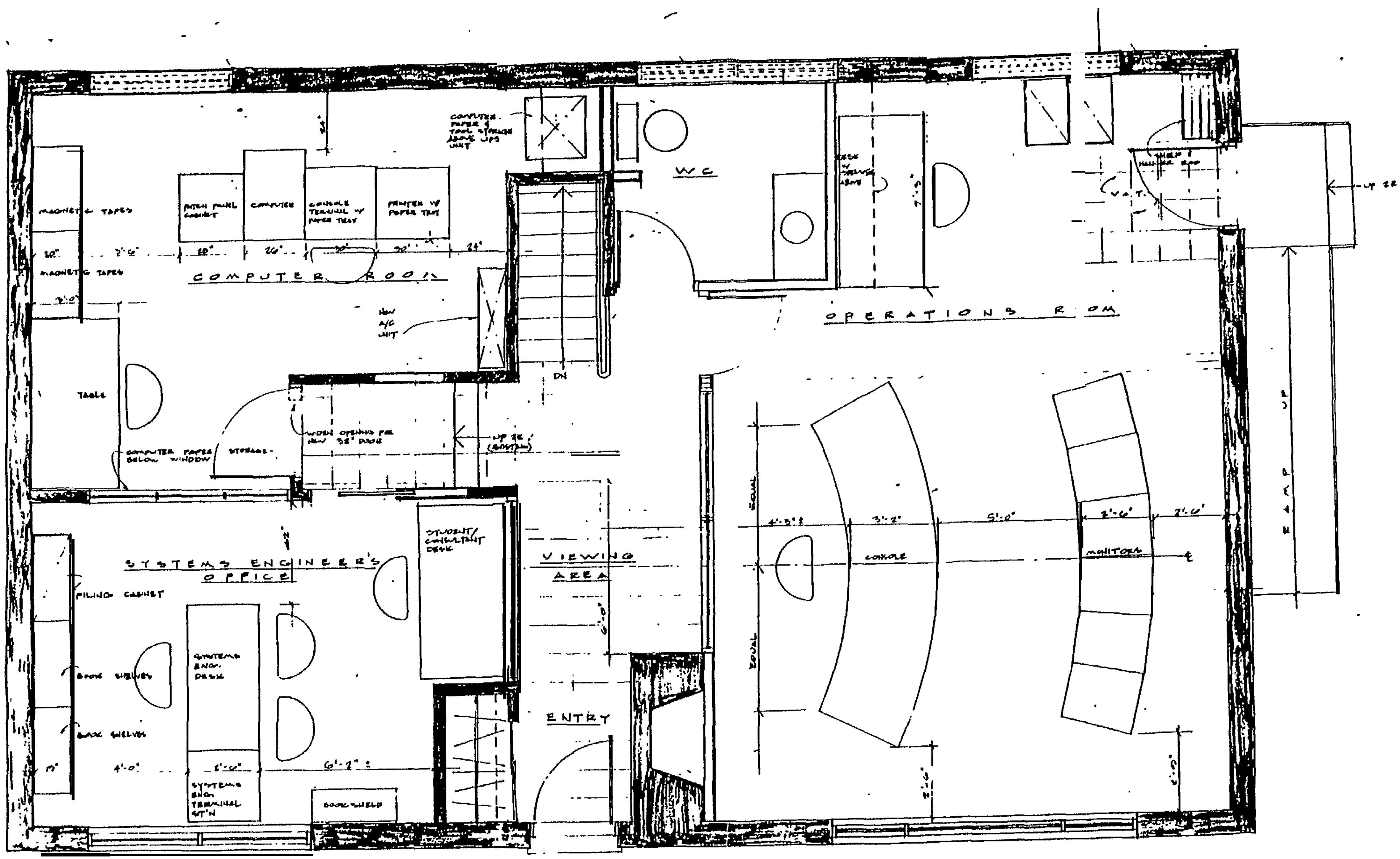
PLAN

METRO TORONTO INTEGRATED TRAFFIC CONTROL CENTRE (ITCC) - CONTROL ROOM

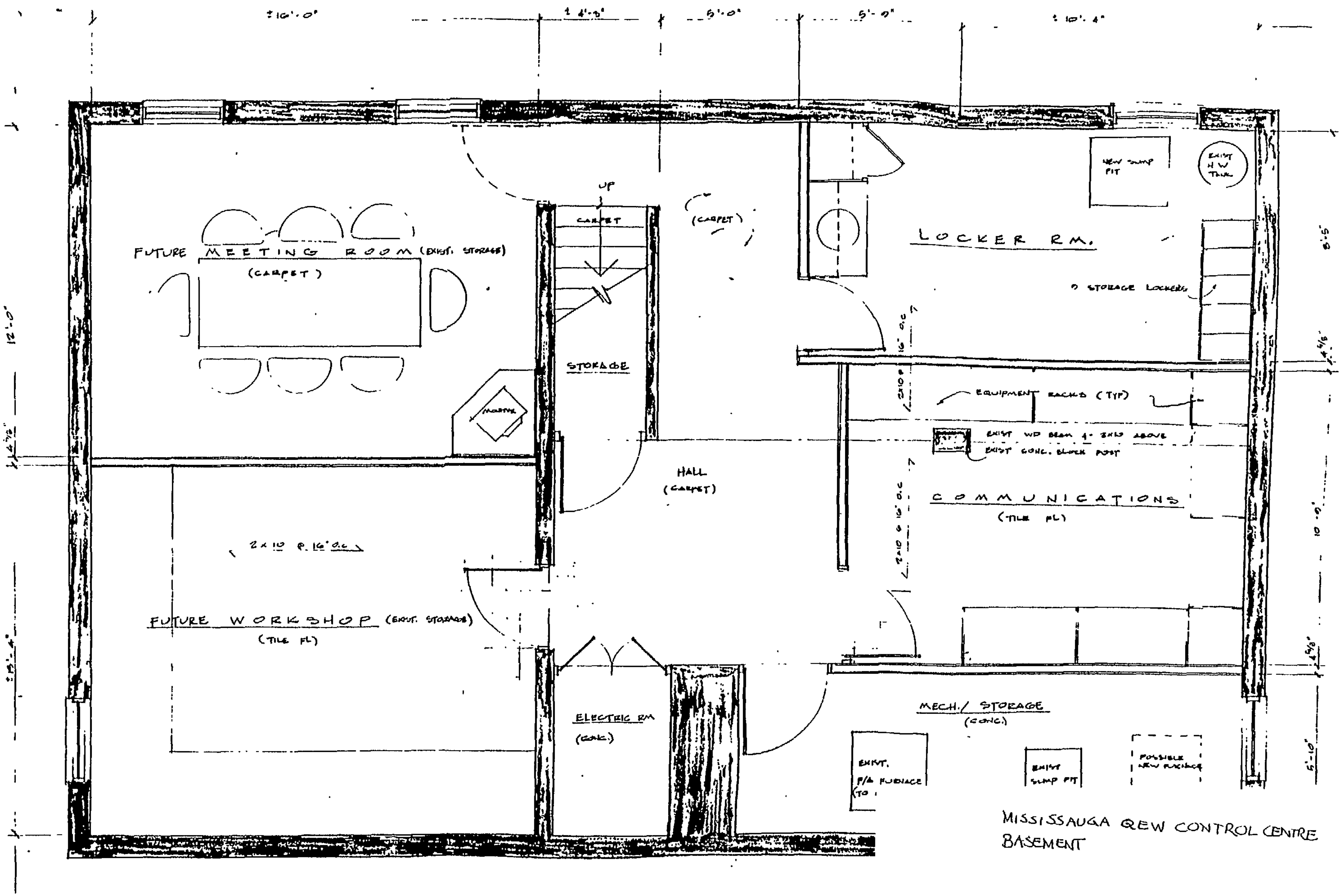


METRO TORONTO
INTEGRATED TRAFFIC
CONTROL CENTRE (ITCC)
COMPUTER/COMMUNI-
CATIONS ROOM

MAY. 22. 1992



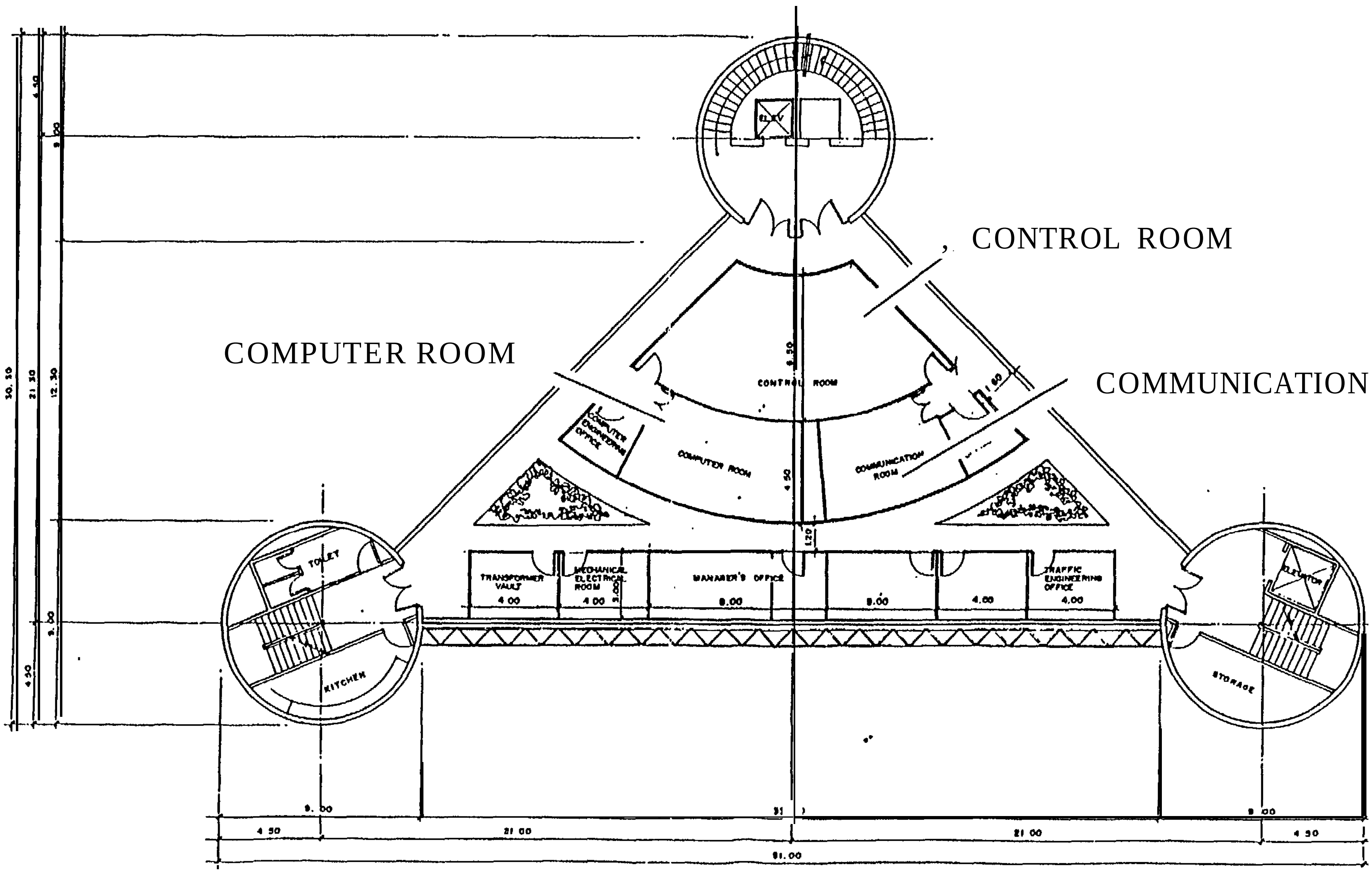
MISSISSAUGA GEW CONTROL CENTRE
GROUND FLOOR.



FUTURE MEETING ROOM (EXIST. STORAGE)
(CARPET)
STORAGE
UP
CARPET
HALL
(CARPET)
LOCKER RM.
STORAGE LOCKERS
NEW SUMP PIT
EXIST H W TANK
EQUIPMENT RACKS (TYP)
EXIST WD BEAM & 2x10 ABOVE
EXIST CONC. BLOCK POST
COMMUNICATIONS
(TILE FL)
FUTURE WORKSHOP (EXIST. STORAGE)
(TILE FL)
2x10 @ 16" O.C.
ELECTRIC RM
(CONC.)
MECH./ STORAGE
(CONC.)
EXIST. F/A FURNACE
EXIST SUMP PIT
POSSIBLE NEW FURNACE
MISSISSAUGA QEW CONTROL CENTRE
BASEMENT

ARRIYADH CONTROL CENTER

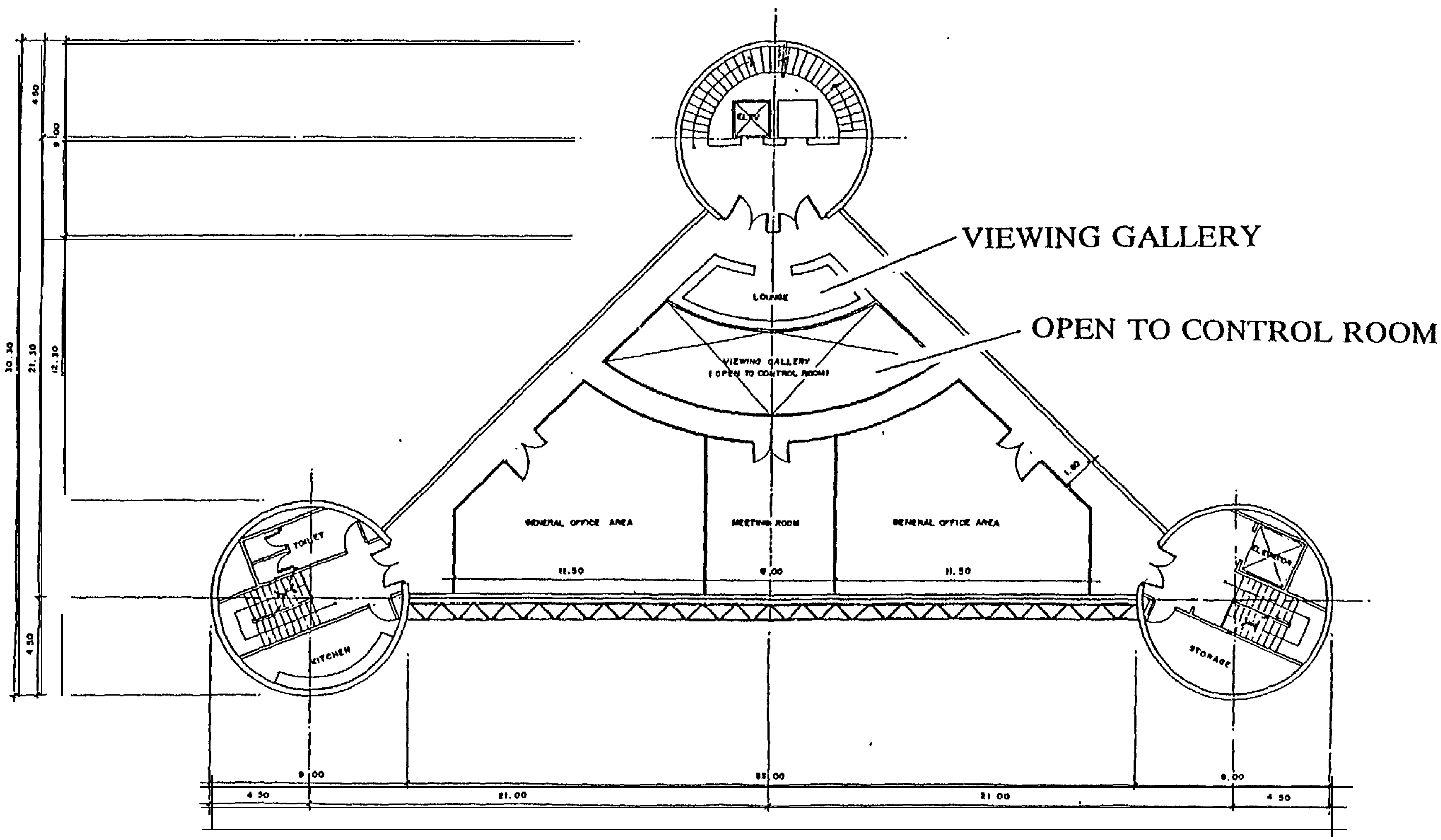
FIRST LEVEL



FIRST LEVEL

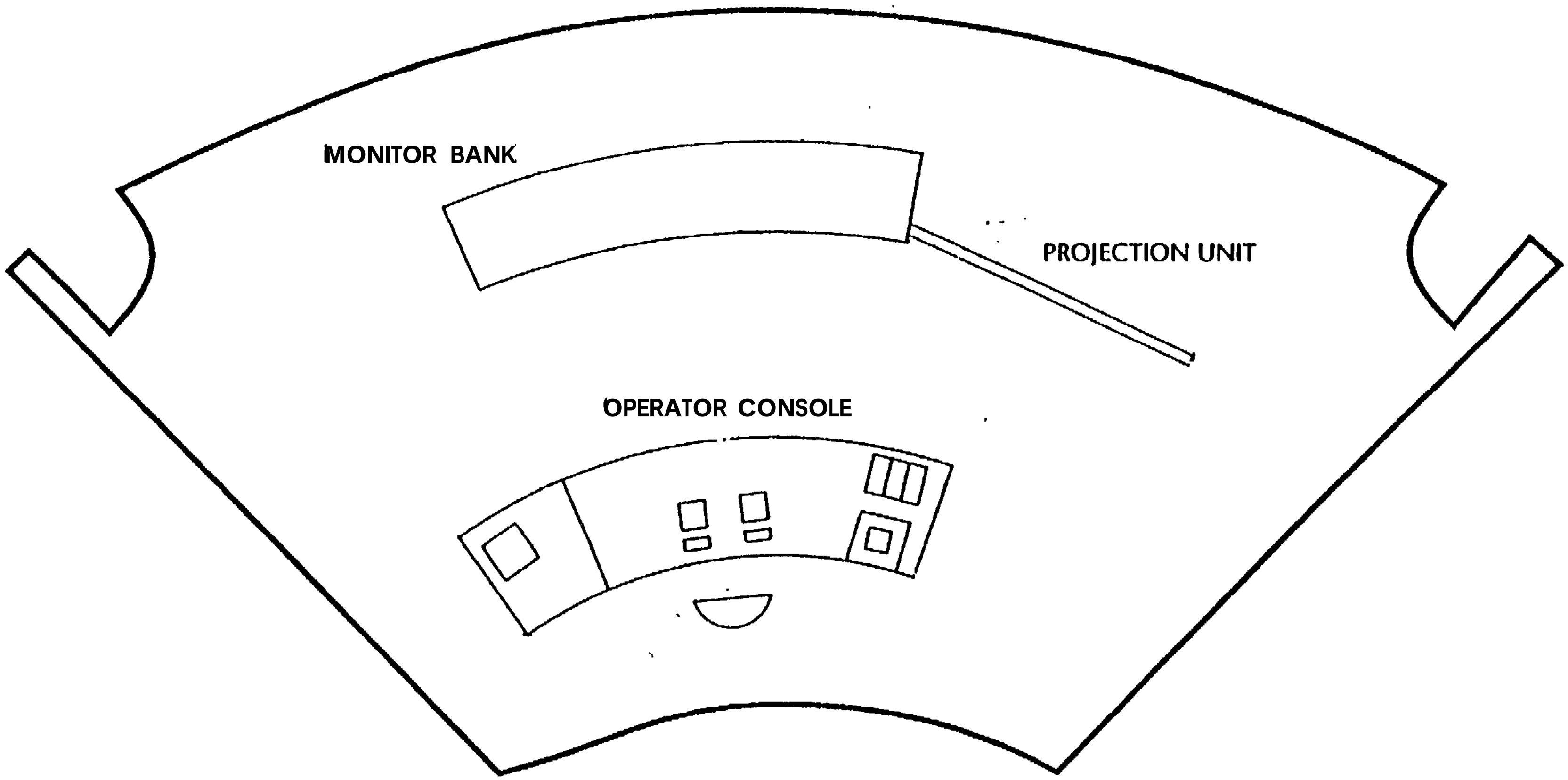
ARRIYADH CONTROL CENTER

SECOND LEVEL



SECOND LEVEL
SCALE 1:200

LAYOUT OFARRIYADH SMART CORRIDOR CONTROL ROOM



APPROXIMATE DIMENSIONS: 21 ft. x 35 ft.
APPROXIMATE AREA: 745 sq.ft.