COORDINATED HIGHWAYS ACTION RESPONSE TEAM
STATE HIGHWAY ADMINISTRATION

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1 INTRODUCTION

1.1 Purpose

This document presents the architecture of the Coordinated Highways Action Response Team (CHART) Advanced Traffic Management System (ATMS). The architecture of the CHART ATMS is presented as a number of different "views", with each view representing a different perspective of the system.

1.2 Views Descriptions

Each view is described in Table 1-1. In addition, there are various appendices, described in Table 1-2.

Table 1-1. CHART ATMS Architecture Document Views

View Name	Description	Typical Stakeholders	Section
Feature List View	Provides a brief high-level overview of the CHART ATMS and describes the features available in the system	Representatives from other agencies interested in CHART ATMS's capabilities, as well as operators, support personnel, developers, and managers	2
Functional View	Describes basic CHART ATMS functionality and some key operational concepts that drove how the functionality has been implemented	Developers, managers and officials from other organizations, looking to interface with or build a system like the CHART ATMS	3
System View	Shows system components and how they connect to each other	System administrators, software developers and architects and others interested in the system-level architecture	4
Interface View	Describes the CHART ATMS external interfaces	Representatives from other agencies interested in CHART ATMS's capabilities, specifically software and system architects who may be looking to interface with CHART ATMS	5
Data View	Describes how data moves into, out of, and around the CHART ATMS	CHART ATMS database administrators (DBAs), management, developers, and stakeholders of connected systems	6
Deployment View	Describes the various CHART ATMS deployment configurations	Operations & Maintenance personnel, network engineers	7

View Name	Description	Typical Stakeholders	Section
Subsystem View	Describes CHART ATMS software/ hardware subsystems and Commercial Off-The-Shelf (COTS) products	Developers, configuration managers, and management	8
Standards View	Describes the standards used by the CHART ATMS	Management, CHART ATMS developers, and those looking to interface with the CHART ATMS	9
Business Architecture View	Describes the CHART ATMS from a business process perspective	Business Area Architecture (BAA) process participants, those interested in CHART's business plan and its mapping to CHART capabilities	10
System Maintenance View	Describes Operations and Maintenance aspects of the CHART ATMS	System administrators, software and system architects, others interested in CHART ATMS maintenance tasks	11

Table 1-2. CHART ATMS Architecture Document Appendices

Appendix	Description
A	Design studies performed during the development of the CHART ATMS
B	Major prototypes created during the development of the CHART ATMS
C	Database entity-relationship (ER) diagrams describing the design of the CHART ATMS database
D	Release history of the CHART ATMS

1.3 Applicable Documents

Relevant documents associated with the system architecture are listed in the Table 1-3 below.

Table 1-3. Document References

Requirements and Vision
CHART II System Requirements, May 5, 2000, M361-RS-002R2.
CHART II Business Area Architecture Report, August 23, 2000, M361-BA-005.
CHART Video Software Requirements, June 2005
CHART R2B3 Requirements, October 2006
CHART Business Area Architecture, January 2007, W01-BA-001
CHART R3B1 Updated Software Requirements Revision 2, January 2008, W009-WS-001R2

CHART Business Area Architecture Revision 1, January 2008, W01-BA-001R1
CHART R3B2 Updated Software Requirements Revision 3, September 2008, W011-RS-002R3
CHART Business Area Architecture Revision 2, October 2008, W01-BA-001R2
CHART R3B3 Updated Software Requirements Revision 2, November 2009, WO15-RS-001R2
CHART Business Area Architecture Revision 3, December 2009, WO001-RS-001R3
CHART R4 Updated Software Requirements Revision 1, March 2010, WO17-RS-001R1
CHART Business Area Architecture Revision 4, April 2010, WO001-RS-001R4
CHART R5 Updated Software Requirements Revision 1, March 2010, WO18-RS-001R1
CHART Business Area Architecture Revision 5, September 2010, WO001-RS-001R5
CHART R6 Updated Software Requirements, August 2010, WO19-RS-001
CHART R7 Updated Software Requirements, February 8 2011, WO21-RS-001
CHART R8 Updated Software Requirements Revision 4, August 1 2011, WO23-RS-001R4
CHART R9 Updated Software Requirements, July 25 2011, WO24-RS-001
CHART Business Area Architecture Revision 10, April 2, 2012, WO1-BA-001R10
CHART R10 Updated Software Requirements, August 14, 2012, W028-RS-001
CHART Release 11/Mapping R10 Software Requirements, October 24, 2012, WO31-RS-001
CHART Business Area Architecture Revision 11, November 30, 2012, W01-BA-001R11
CHART R12 Software Requirements Revision 1, October 8, 2013, WO35-RS-001R1
CHART Business Area Architecture Revision 12, July 10, 2013, W01-BA-001R12
Design
CHART II R1B1 High Level Design, July 16, 1999, M361-DS-001R0
CHART II R1B1 Detailed Design, January 21, 2000, M361-DS-002R0
CHART II R1B1 Graphical User Interface (GUI) High Level Design, January 21, 2000, M361-DS-003R0
CHART II R1B1 GUI Detailed Design, January 21, 2000, M361-DS-004R0
CHART II R1B2 High Level Design, May 17, 2000, M361-DS-005R0
CHART II R1B2 Servers Detailed Design, May 2000, M361-DS-006R0
CHART II R1B2 GUI Detailed Design, May 2000, M361-DS-007R0
CHART II R1B3 High Level Design, January 2001, M362-DS-009R0
CHART II R1B3 Servers Detailed Design, March 2001, M362-DS-011R0

CHART II R1B3 GUI Detailed Design, March 2001, M362-DS-010
CHART II R1B4 National Transportation Communication for Intelligent Transportation Society (ITS) Protocol (NTCIP) Driver High Level Design, December 2001
CHART II R1B4 NTCIP Driver Detailed Design, May 2002
CHART Lite 2.0 System Design Document, April 2005
CHART II R2B1 Design, February 2006, M362-DS-019
CHART R2B2 Design, March 2006, M362-DS-020
CHART R2B3 Design, November 2006
CHART R3B1 Detailed Design, July 2007, W009-DS-001
CHART R3B2 Detailed Design, July 2008, W011-DS-001R2
CHART R3B3 Detailed Design, December 2008, W015-DS-001
CHART R4 Detailed Design Revision 1, March 2010, WO17-DS-001R1
CHART R5 Detailed Design Revision 1, March 2010, WO18-DS-001R1
CHART R6 Detailed Design, September 2010, WO19-DS-001
CHART R7 Detailed Design, March 2 2011, WO21-DS-001
CHART R8 Detailed Design, May 23 2011, WO23-DS-001
CHART R9 Detailed Design, August 26 2011, WO24-DS-001
CHART R10 Detailed Design Revision 3, August 14, 2012, WO28-DS-001
CHART R11 Detailed Design, November 26, 2012, WO31-DS-001
CHART R12 Detailed Design, September 20, 2013, WO25-DS-001
Studies
Java Benefits and Risk Analysis, M361-AR-001R0, July 7, 1999
C++/Java Performance Comparison for Distributed ITS Control Systems, M361-AR-002R0, March 30, 1999
CHART II Java Feasibility Investigation, M361-AR-003R0, July 1, 1999
Common Object Request Broker Architecture (CORBA) Object Request Broker (ORB) Evaluation for CHART II, M361-AR-004R0, March 19, 1999
Maryland Department of Transportation (MDOT) Intelligent Transportation System Transformation Report, M361-AR-005R0, Draft
An Assessment of Architecture Approaches for Data Integration and Archiving, M361-AR-006R0, December 3, 1999
Addendum to the Technical Memorandum for An Assessment of Architecture Approaches for Data Integration and Archiving, M361-AR-007R0, December 3, 1999

Summary of the Interviews for CHART II Data Needs and Requirements of Potential Users of an Archived Data User Service, M361-AR-007R0, December 3, 1999
Field Management Station (FMS) Simple Network Management Protocol (SNMP) Interface Tool Selection, M303-AR-001R0, March 21, 2000
CHART II High Availability Study, M361-AR-009R0, July 14, 2000
CHART System Database Strategic Plan, April 21 2011
CHART Middleware Assessment (slides), June 24 2011
Management and Schedule
CHART II System Development Schedule, September 15, 2000, M361-MP-004

2 FEATURE LIST VIEW

2.1 View Description and Typical Stakeholders

This view provides a brief high-level overview of the CHART ATMS and describes the features available in the system. This section is suitable for those who would like to have an easy-to-digest list of features CHART ATMS provides, such as representatives from other agencies interested in CHART ATMS's capabilities, as well as operators, support personnel, developers, and managers just coming in who are new to CHART, or who would like a quick refresher.

2.2 CHART ATMS Overview

The CHART ATMS is a set of software programs running on a combination of Windows 2008 Servers, connected to a statewide network of Closed Circuit Television (CCTV) cameras, overhead and portable Dynamic Message Signs (DMSs), Highway Advisory Radios (HARs), Traffic Sensor Systems (TSSs) (microwave traffic flow detectors), and remote weather stations. It is used identify and track traffic flow disruptions, send responders to correct the disruption and notify the public using the DMS and HAR devices, as well as sending notifications to the media and feeding data to a live traffic web site (http://www.traffic.maryland.gov) and Maryland 511. The software is built using Java and C++ and connects to a Microsoft SQL Server database. Interprocess communications is achieved using an industry standard CORBA (Common Object Request Broker Architecture) package and web services (typically Extensible Markup Language (XML) over Hyper Text Transfer Protocol (HTTP). A web-based Graphical User Interface is connected to the CHART ATMS services using CORBA listeners and provides full CHART ATMS functionality to authorized users over a browser. The system provides data to interested parties via multiple systems both inside and outside the CHART Program umbrella, including CHART's own CHARTWeb public web site and the CHART Mapping Intranet Map (both part of CHART), Maryland 511 (MD511) (not part of CHART but falls under the purview of the State Highway Administration (SHA)), and the Regional Integrated Transportation information System (RITIS) at the University of Maryland (largely independent of SHA). This data is provided by means of two data exporter services (one internal, one external). The CHART Program provides data which is originally created via the CHART ATMS through a secure connection to the MDOT network, by providing a secure Geographic Information System export and by providing Really Simple Syndication (RSS) XML feeds on the internet. CHART ATMS and the CHART Program as a whole provide video by transcoding the statewide video and feeding it in multiple video formats through the MDOT internal network, the Statewide Government Intranet (SwGI) and the internet.

2.3 Feature List

The complete list of all features supported by the CHART ATMS is shown below:

- Operations Center
  - Select Operations Center at Login
  - Add an Operations Center
  - Remove an Operations Center

    - Modify an Operations Center
- User management
    - Add and modify user accounts, assign user roles to them, reset passwords
    - Delete user accounts
    - Define user roles by assigning granular functional rights to them
    - Define external client roles by assigning (usually very few) functional rights to them
    - Log in, authenticate, grant rights to logged in users
    - Authenticate, grant rights to web service clients
    - Administratively force logout
    - Alert for unhandled resources controlled by operations center with no one logged in
- Areas of Responsibility (AOR) management
    - Create/modify/delete AORs
    - View AORs on map
    - Filter device lists based on AOR (and folder)
    - Filter location aliases based on AOR
    - Run traffic event based auto mode tours on monitors based on AOR
- Device management and control
    - Add or delete devices
    - Import and manage import of external DMSs and TSSs
    - View and modify device configuration information
    - Protect sensitive configuration data per organization
    - Set DMS online, offline, maintenance mode, reset DMS
    - Upload font to DMS, copy font from one DMS to another
    - Set TSS online, offline, maintenance mode
    - View TSS volume, speed, occupancy data (summary / per lane)
    - Protect volume, speed, occupancy data per organization
    - Set HAR online, offline, maintenance mode
    - Blank, monitor, reset HAR
    - View HAR Status
    - Set SHAZAM online, offline, maintenance mode
    - Reset SHAZAM to last known state
    - Associate DMS or SHAZAM to HAR as HAR Notifier
    - Associate HAR to Synchronized HAR as constituent HAR
    - Copy DMS/HAR/SHAZAM/TSS
    - Add, delete, modify port configuration information
    - View or modify device location
    - Sort/filter device lists by location, model, message, status, connectivity, etc.
    - Specify/retain columns to display in device lists

- Manage 8 models of DMS devices including NTCIP
- Manage 2 models of HAR devices
- Manage 2 types of SHAZAM devices
- Manage 2 varieties of Remote Traffic Microwave Sensor (RTMS) TSS devices
- Specify default font, line spacing character spacing on NTCIP DMSs
- Run pixel test on supported DMSs
- Get/view extended device status on supported DMSs
- Configure alerts/notification for device communications or hardware failures

- DMS Message Libraries
  - Create/delete message libraries
  - Create/delete library messages
- HAR Message Libraries
  - Create/delete message libraries
  - Create/delete library messages
    - Manage audio or text HAR messages
- DMS/HAR Messages
  - Put message on DMS, blank DMS
  - Play message on HAR, remove message from HAR
  - Manage audio HAR messages
  - Provide text-to-speech conversion of textual HAR messages
  - Automatic HAR word substitution for pronouncing word phonetically
  - Arbitrate between multiple desired messages on DMS/HAR
  - Combine up to two pages of suitably combinable DMS messages
  - Combine up to two minutes of HAR messages
  - Automatic/manual DMS Message Formatting
- Arbitration Queue
  - Add message to Device Queue
  - Evaluate Device Queue
  - Adjust priority of message in Device Queue
  - Remove message from Device Queue
  - Revoke item in response tabs
- Travel Routes
  - Create/modify/delete travel routes
  - Associate INRIX roadway links to travel routes for travel time calculation/display
  - Configure alerts/notifications for high travel times
  - Associate Vector toll routes to travel routes for toll rate display
  - Configure alerts/notifications for missing toll rates
  - Configure messages templates for standardized display of travel route data on DMSs

- Configure traveler information messages with template/routes for display on DMSs
- Enable/disable travel route information messages for display on DMSs
- Set default priority of travel time and toll rate messages relative to event messages
- Restrict travel time message display by time-of-day, globally or per-DMS

- Manage video distribution
  - View Camera, Monitor configuration information
  - Specify a current Monitor Group
  - Set Camera, Monitor online, offline
  - View Camera, Monitor Status
  - Display a camera on a CHART monitor
  - Display cameras on the desktop
  - Request Pan, Tilt, Zoom (PTZ) control of a CHART camera
  - Override PTZ control of a CHART camera
  - Command a COHU 3955 or 3960 camera
    - Pan/Tilt/Zoom/Focus
    - Iris control
    - Red/Blue color balance
    - Lens speed
    - Set camera title (first line)
    - Set camera title (second line)
    - Reset
    - Power on/off
  - Command a Vicon Surveyor 2000 camera
    - Pan/Tilt/Zoom/Focus
    - Iris control
    - Red/Blue color balance
    - Lens speed
    - Set camera title (first line)
    - Reset
    - Power on/off
  - Command an NTCIP camera
    - Pan/Tilt/Zoom/Focus
    - Iris control
    - Set camera title (first line)
    - Power on/off
  - Configure tour list
  - Start a tour list on a specified monitor or user’s own desktop

    - Stop a tour list running on a specified monitor or user's own desktop
    - View / Administratively stop desktop video to free resources
    - Block/unblock display of video to public/media
    - Block/unblock display of video to selected organizations
    - Revoke/Allow control of video camera to selected organizations
    - Manage monitor groups
    - Manage video distribution network: fabrics, switches, bridge circuits, video routes
    - Manage Streaming Flash Server (SFS) configurations of cameras
- DMS Plan Libraries
    - View/Filter plan libraries
    - Create/delete plan libraries
    - Create/delete plan items
- HAR Plan Libraries
    - View/Filter plan libraries
    - Create/delete plan libraries
    - Create/delete plan items
- Operations Log
    - Log user activity
    - Log system and device status information
- System Management/Monitoring
    - Provide FMS communications and port status
    - Support device communications failover between FMS servers
    - View CORBA trader offers (with delete if truly necessary)
    - Force discovery of CORBA objects
- Monitor services
    - Monitor/view service availability, up time, memory usage
    - Automatic restart of failed services
    - Manual stop/start of services via GUI
    - Provide Alerts, Notifications for failed or restarted services
    - View GUI heap usage, and object and request counts
- Configure System
    - Manage DMS/HAR decision support templates, substitutions
    - Manage which devices to import from RITIS
    - Manage criteria for importing events from RITIS
    - Manage many System Profile settings not otherwise mentioned herein
- Communications Log
    - Create/manage communications log entries
    - Search communication log entries

- Traffic Events
  - Create/manage events
  - Import external traffic events based on configurable selection criteria
  - Create/manage/utilize/schedule pending events
  - Create/manage/search event history log entries
  - View lists of devices near event
  - View map of devices near event
  - Suggest cameras for auto-mode (temporary tour) on AOR auto-mode monitors
  - Suggest DMSs/HARs for use in a response plan
  - Recommend removal of DMSs/HARs rules indicate are no longer needed
  - Suggest DMS/HAR messages
  - Put message on DMS, blank DMS, turn DMS beacons on/off
  - Put message on HAR/blank HAR
  - Activate/deactivate SHAZAMs and DMSs used as SHAZAMs
  - Manage web alert text displayed on public web site for high priority events
  - Alert users if event open past reminder time
  - Warn users of potential duplicate events during event creation
  - Alert users to duplicate events after event creation
  - Merge traffic events
  - Manage priority event list of highest priority statewide events
    - Support automatic or manual manipulation of priority event list
- Participant management
  - Select participants for traffic event
  - Select participant type for traffic event
  - Substitute specific participant when participant of desired type arrives on scene
  - Detect/mark participant as arrived on scene, with timestamp
  - Detect/mark participant as departed scene, with timestamp
  - Manage in-service/out-of-service status of participants
  - Track location of Automatic Vehicle Location (AVL) enabled participants
  - View AVL-enabled participants on map
- Traffic Signal management
  - Associate traffic signal(s) with action event
  - View traffic signals associated with action event on map
  - View traffic signals not associated with action event on map (only zoomed-in)
- Notification
  - Manage notification contacts and contact groups
  - Send/manage notifications
  - Search notification history

    - Manage notifications for DMS, travel routes, external events and connections
- Alerts
    - Create/display/manage alerts
    - Help users respond to alerts
    - Escalate alerts
- Schedules
    - Create/manage schedules
    - Execute schedules, when activated or immediately on demand
- Dictionaries
    - Banned words dictionary
    - Spell-check dictionary
    - Text To Speech Pronunciation dictionary
- External System Interfaces
    - Import selected DMSs/TSSs from RITIS, maintain/view their status
    - Import events from RITIS matching selected criteria
    - Mark matching imported RITIS event as “interesting”
    - Provide Alert/Notification for matching imported RITIS event
    - Export traffic events and related traffic signal data to CHART Map/Web and RITIS
    - Export DMS, HAR, SHAZAM, TSS, CCTV data to CHART Map/Web and RITIS
    - Import Travel Time data from INRIX
    - Accept Toll Rate data from Vector
    - Provide Alert/Notification for external connection in failed or warning state
    - Send Notifications via SMTP mail
- Operations support
    - CHART ATMS installer packages
    - Separate FMS installer, with simultaneous multiple CommService installation option
    - Support for multiple Server Sites (if desired)
    - Support for multiple Web Server Sites

3 FUNCTIONAL VIEW

3.1 View Description and Typical Stakeholders

This view into the CHART ATMS describes basic CHART ATMS functionality and some key operational concepts that drove how the system was constructed. This is not a User's Guide or tutorial. Although there are some design concepts presented, it does not get to the level of a formal design document. See the CHART ATMS User's Guide for additional information. This view is useful for anyone interested in how the CHART ATMS works at a high level, including developers, SHA management, MDOT management, and officials from other organizations, looking to interface with or build a system like the CHART ATMS.

3.2 CHART ATMS Web-based Graphical User Interface

The CHART ATMS GUI is web-based application. Users connect to the CHART ATMS GUI via any web browser (currently Microsoft Internet Explorer 9 is the officially supported browser, although other browsers generally work as well). Anyone connecting to a CHART ATMS web page is required to log in. User accounts can be created by a CHART ATMS administrator (who is simply a CHART ATMS user who has been granted many or all user rights). A CHART ATMS administrator can also grant rights to other users (thereby creating other CHART ATMS administrators as desired). User rights are grouped by CHART ATMS administrators into "roles" for ease in assigning rights to users. (To be more precise, all users are actually granted "roles", which are collections of rights, rather than being granted rights directly.)

The CHART ATMS GUI is designed as a two-window web-based application. It is intended for use with a dual-monitor workstation, with one window on each monitor, although it is generally equally functional on a single-monitor workstation. The two windows consist of a "home page" window and a "working" window. The "home page" is what the user sees immediately after logging into the CHART ATMS. The "home page" is the "home base" for CHART ATMS operations, providing access to traffic events, alerts, resources, and the primary ("home page") CHART ATMS map. It also provides the form for creating a new traffic event, and it provides a "navigation bar" (collapsible menu) down the left side for accessing all CHART ATMS functionality. Upon selecting a menu item from the home page, the appropriate page is opened in the user's "working" window, thus keeping the home page always accessible. The working window also provides a limited menu of popular functions as well, including access to recently viewed traffic events and an option to redisplay the home window in case it has gotten lost. Upon logging in, the user's working window is initially populated with an Operations Center Report, which provides an overview of activity occurring in the users own operations center. This report can be recalled and refreshed at any time. The CHART ATMS "working" window is used to perform tasks like editing traffic events, video display, camera control, working directly with signs, etc.

Users have an ability to select their own personal (or shared) "Home Monitor" when they log in. An icon representing this monitor is always visible on the home page, which provides direct access to managing video on that monitor. The home monitor is tracked as a user cookie and is not known to the server.

3.3 CHART ATMS Map

The CHART ATMS map, which is the map used in the CHART ATMS GUI, has sometimes been referred to as the "Integrated Map," to distinguish it from the "Intranet Map" and "Internet Map" provided by CHART Mapping (a completely separate system from the CHART ATMS, but part of CHART, the overall CHART Program). The CHART ATMS map uses an open source JavaScript mapping Applications Programming Interface (API) called Open Layers to render CHART traffic events and devices geographically within the CHART ATMS GUI process. There are multiple maps which can be seen within the CHART ATMS. The primary map is the Home Page Map, which provides users with a map view that is always available to them. A second type of map is the Nearby Devices Map which is available within to the details page of each traffic event. The Nearby Devices Map focuses on the display of devices near the traffic event, which could be used for verification or response. A third type of map is the Object Location Map. This map allows users to see a geographic view of where they are locating a traffic event or device. From here users can set or change the precise point location for the event or device as well. Another map is the Response Preview Map, which shows what devices near a traffic event would display/broadcast if the current response plan were to be executed.

For each type of map the GUI starts with a base map that is exported from the existing Environmental Systems Research Institute (ESRI) map server. This design leverages the work that has already been done by CHART Mapping and provides a consistent user experience. The map also provides exits and mileposts layers that are also each exported from the ESRI map server as a Web Map Service (WMS). The exits and milepost layers are displayed only when zoomed in to a high level of detail and can be independently toggled on or off in that case. Above these the map adds dynamic marker layers. Dynamic marker layers are layers that are populated using the JavaScript API. A marker icon is added to the map for each device or traffic event on the layer. The user can then click on these markers in order to obtain information about the object it represents via a callout graphic. The dynamic marker layers are ordered such that devices are below traffic events and traffic events are displayed on separate layers based on type. Incident type events are on the top layer. The data used to populate the dynamic markers is retrieved from the CHART ATMS GUI Servlet via Representational State Transfer (REST) Web Service requests. The CHART ATMS GUI responds with data in JavaScript Object Notation (JSON) format (a lightweight alternative to XML that is easier to parse using JavaScript) that describes each marker. The map JavaScript code parses this JSON data and passes it to the OpenLayers JavaScript API in order to add or update the marker and its associated callout.

The Home Page Map allows users to navigate their map to view any devices and traffic events that have been populated with a point location geographically. The Nearby Devices Map, on the other hand, allows users only to see devices within a specified distance from a target traffic event. This map is always centered on the reference traffic event, and cannot be panned. It can be zoomed in and out, however. This map is designed in the same way as the Home Page Map with the exception that it does not display any traffic events except for the target traffic event. Additionally the nearby devices map allows users to efficiently select nearby devices directly from the map that should be added to the response plan of the target traffic event. The map changes the display of the selected devices to indicate that they are the candidates for addition or removal.

The Object Location Map works in conjunction with a pulldown-based object location form that is currently used to set the location for traffic events and devices. When users make selections on the form they see visual feedback on the Object Location Map. For instance, if a user selects

Maryland from the list of states on the form, the associated map pans and zooms to the extents of the state of Maryland. When the user selects a county within Maryland the map further zooms to show only the county of interest. If the user clicks on a point on the Object Location Map, the object location form updates the selected state and county to show the state and county containing the point that was clicked. The GIS data required for this operation is queried from a REST web service provided by CHART Mapping. This service can return geographic extents for a state, the geographic extents and boundary polygons for a county within a state, as well as the state and county that a point resides in. Additionally this service can provide data about the mileposts and exits along a particular roadway within a particular county and state. This GIS knowledge was kept outside of the CHART ATMS map process in order to make it accessible to other CHART systems that might benefit from it.

In addition to the aforementioned map types, the CHART ATMS map also employs a REST web service that provides the non-spatial data that is consumed by the object location form such as the list of states, list of counties within a state, list of road types in a specified county and state, and list of roads of a particular type that exist within a specified county and state. Additionally this service provides a REST web service API that allows for the management and querying of location aliases. Location aliases are used by the Object Location Map and form to allow the user to quickly locate an object at a known landmark (example: "Bay Bridge") rather than having to select a number of drop downs or pan/zoom the map to get to this location. The addition, modification, or removal of a location alias via the web services API requires the calling client to digitally sign their request using a key issued by a CHART ATMS administrator. The API that returns the list of known location aliases is publicly available and may be used by any CHART system that needs this functionality.

3.4 Configurability – System Profile and Properties

One of the key aspects of the CHART ATMS is its configurability. Hundreds and hundreds of settings are configurable. Many are configurable via the "System Profile", a facility accessible within the CHART ATMS GUI by CHART ATMS administrators. Many more are configurable in various properties files. Every conventional service, every web service, and the GUI have a properties file ("*.props") with scores of well documented settings. Changes to a properties file requires a restart of the application which reads that properties file. Most System Profile settings take place immediately, or on the next cycle of whatever is being configured.

3.5 CHART ATMS Traffic Event Management

The CHART ATMS is a traffic event centric system. Messages are normally put on DMSs and HARs within the context of an open traffic event. Most traffic events include a "response plan" into which DMSs and HARs are inserted. Messages to go on these devices can be selected from a preconfigured "Plan", selected from a list of messages the "Decision Support" subsystem generates (based on traffic event parameters, the locations of the event and device(s), and pre-defined "message templates"), or can be input manually, singly or en masse. Once devices and messages are configured into the response plan, the response plan (or individual items within it) can be "executed" which puts the messages into an "arbitration queue" managed by the software object representing each physical device. The arbitration queue arbitrates between various messages being requested for its device, and puts the highest priority message (or messages) on the device. Users can change or "revoke" messages on devices at any time. Also, as lane closure status is changed within the traffic event, the Decision Support subsystem recommends

changes to the list of devices being used, and to the messages on those devices. When the traffic event is closed, any messages still on these devices are automatically removed from the queue and from the device. This was a major advantage over the predecessor system, which was a collection of manufacturer software to control the devices independently. With no overarching management system, there was potential for messages to be left on devices after they were no longer relevant.

CCTV Cameras can also be inserted into the response plan of a traffic event. When this response plan item is executed, the cameras are added to the "auto mode" tour list of any monitor configured for auto mode within the centers responsible for handling the event.

Decision support is discussed in more detail later in this section.

There are several types of traffic events supported by the system. In order of highest to lowest priority (with regard to arbitration of messages queued for DMSs and HARs), the traffic event types are:

- Incident (for accidents)
- Planned Roadway Closure
- Congestion (recurring or not)
- Weather
- Special Event (e.g., ballgames, Baltimore Grand Prix, Bay Bridge Walk, etc.)
- Action Event (utility problems, debris, signal problems, animal carcass, etc.)
- Safety (frequently used for public service announcements, Amber Alerts, etc.)

There is one other type of event, a Disabled Vehicle Event, but this type of event does not allow a response plan. (Note: if a disabled vehicle is blocking a travel lane, that is an Incident.)

In addition to the priority "buckets" for those event types, there are four others:

- Urgent (the highest priority – no messages are initially put here, but can be moved here)
- Toll Rate Message (used for Traveler Information Messages containing a toll rate)
- Travel Time Message (for Traveler Information Messages with a travel time, no toll rate)
- SHAZAM (Notification of a significant HAR message being broadcast in the vicinity)

Users with sufficient rights can reorder the queued messages on arbitration queue of any device, including moving queued messages a different bucket (such as the Urgent bucket).

CHART ATMS users can select a lane closure permit from the Lane Closure Permits (LCP) System to associate with a Planned Roadway Closure. This displays all the lane closure permit information with the Planned Roadway Closure event within the CHART ATMS.

For weather events and incidents, the CHART ATMS interfaces with SCAN and Lufft to help indicate weather conditions and specify pavement condition at the location of the event.

3.6 LCP Lane Closure Permit Integration

The CHART ATMS interfaces with the LCP system to facilitate the sharing of lane closure permit information. LCP is the currently the system used to enter and approve permits for contractors to close lanes in Maryland for roadwork or utility work requiring lane closures. This interface allows CHART ATMS users to associate a CHART Planned Roadway Closure Event with a lane closure permit. The user is presented with a text entry field where search criteria can be entered. If the user types part of a lane closure permit tracking number, the system suggests

permits from which the user can select. If the user does not see the permit sought, a search button can be clicked, which searches all active and queued permits from the permit tracking system. The searching feature is not limited to tracking numbers. It searches all the following fields of each permit: permit tracking number, start county name, end county name, permit type, route location, route type, route number, work order description, permittee name, contract number and days of week. Thus a user may search for permits using search text such as "Bridge Montgomery Monday". Returned permits are ranked according to their relevance to the search text specified.

This interface includes a synchronization feature that keeps the list of lane closure permits available in the GUI current without requiring all data for all permits to be passed across the LAN on every refresh. This is accomplished by determining when each permit was last modified in the permitting system and making this data available to the CHART ATMS via the SQL Server view.

3.7 Weather Integration

A CHART Web Service called the CHART Weather Service provides internal CHART systems with weather related data. This web service retrieves Weather Station data from external systems (currently SCAN and Lufft) and provides it to the CHART systems in a generic XML form that is not tied to any specific system.

The CHART ATMS GUI and Traffic Event Service use this Web Service to allow pre-population of Traffic Event Road Conditions where applicable and provide display of other weather details for a Traffic Event. This integration is primarily for operator convenience; however, the design anticipates a future expanded role by defining an extensible message set and isolating all weather system-specific fields and parameters into one area of the Weather web service.

- The design includes a modular approach to weather data sources. The addition of a new data source requires only the addition of an interface to the new source in the web service. This could be a new database (DB) connection, a flat file, access to another web service or similar format. The rest of the architecture remains unchanged.
- The design includes a modular approach to weather data clients. If the new client requires access to summary weather information (air temperature, wind speed and direction, surface temperature, surface conditions, or precipitation) then no changes to the weather web service is required. More detailed weather information such as relative humidity, dew point, trends, and historical reports would require changes to the messaging, though no changes to the architecture.

3.8 Participant Management and AVL

The CHART ATMS allows administrators to define event resource types and event resources that can be added as participants in events. These event resources and types can be added to operations centers to make them available as participants for traffic events controlled by the center and traffic events managed by the center's users. Event resources can be associated with Automatic Vehicle Location (AVL) devices and the location information is used by the system (optionally) to automatically detect when an event resource has arrived on the scene (or has departed the scene) of a traffic event. The system can also automatically detect when a specific resource arrives on the scene when a generic resource of that type was requested (for example if

the user requested a generic non-specific dump truck and then a specific dump truck arrives on the scene). The system optionally replaces the generic resource type with the specific resource when this occurs. The location information for an event resource is also used to help the user select participants to add to a traffic event by allowing the user to sort by distance from the event. Users can make annotations to each participant assigned to a traffic event. This allows the user to identify the participant's radio call sign, driver name, and add miscellaneous notes about the participant. The CHART ATMS also allows users to track the in-service and out-of-service status of field units and facilities, and allows AVL equipped event resources to be viewed on the Home Page Map. Other usability enhancements exist as part of this feature:

- An event resource can be associated with a camera, and links exist to allow the user to view the associated camera on the desktop (if supported) or to launch the form used to display the camera on a monitor.
- Event lists show the number of participants assigned to events and allow the user to set a participant as notified, arrived/responded, and departed directly from the event list. The user can also launch the form used to add participants to the event directly from the event list. These enhancements save time for the user as the user is no longer required to view the event details page for these tasks.
- When creating a traffic event, the user can select a specific field unit and that unit will be automatically be added as a notified participant in the newly created event.

The Participants / AVL feature exists directly in the TrafficEventModule. A CORBA-accessible object that provides for the management of event resources and types and an object that interfaces with the AVL system are in the module. By including these objects in the same module, processing efficiency is gained, by allowing them to share data via "in process" objects, rather than requiring CORBA or Web Service calls. This processing efficiency is required due to the large number of AVL vehicles and event resources that may exist in the system.

When AVL data is retrieved from the AVL service, the AVLDataManager object updates location data in memory and then calls the EventResourceManager object to associate the AVL data with event resources based on the AVL vehicle ID. The EventResourceManager then calls the TrafficEventFactory to notify it that event resource locations have changed and allow it to do its automatic AVL detection processing. All of this location-based processing accesses the same exact Java objects in memory, eliminating the need to pass large volumes of location data among various modules in the server.

When the TrafficEventFactory is notified that event resource locations have been updated, it performs its automatic AVL detection processing. There are three distinct types of detection that are attempted for each applicable traffic event participant, provided automatic AVL detection is enabled for the traffic event:

- Generic resource type on scene detection. This automated detection applies to participants that are an event resource type that has auto-configuration enabled. The system keeps track of all event resources of that type that fall within a configured arrival radius from the traffic event location and automatically changes the participant from a resource type to the closest specific resource of that type that has been on the scene for the required amount of time. The time requirement is configurable and is meant to keep the system from performing this action if a vehicle is merely driving by the scene. Once a participant that was a resource type is changed to be a specific resource, the remaining two detections apply.

- Arrival detection. This automated detection applies only to participants that are event resources with AVL support, and does not apply if the user has manually set the arrived/responded or departed flags for the participant. The system detects when the location of the event resource is within a configurable radius of the traffic event, and when this occurs, the system automatically marks the participant's arrived flag to true and sets the associated timestamp.
- Departure detection. This automated detection applies only to participants that are event resources with AVL support, and does not apply if the user has manually set the arrived/responded or departed flags for the participant. Additionally, this detection only applies if the participant's arrived/responded flag is set to true. The system detects when the location of the event resource falls outside a configurable radius of the traffic event, and when this occurs, the system automatically marks the participant's departed flag to true and sets the associated timestamp.

Note that with the arrival and departure detection, there is no requirement that the event resource be on the scene for a specific amount of time, or away from the scene a specific amount of time. It is assumed that since the resource is specifically assigned to the traffic event, if it is detected to be on the scene of the event it is not just passing by the incident, and once it is detected to have left the scene it is not coming back. In case these assumptions are ever wrong, the user always has the ability to override the Arrived and Departed flags.

In addition to obtaining location data from the AVL Service, the AVLDataManager also periodically polls the AVL service for inventory data. The AVLDataManager keeps track of a list of known vehicles in the AVL system so that it may detect additions, deletions, and changes to AVL vehicles and notify the EventResourceManager of these changes. The EventResourceManager uses these notifications to support the auto-configure feature that can automatically add event resources to the CHART ATMS based on the AVL vehicle type and configuration information in event resource types. Additionally, when an automatically configured event resource is found to no longer exist as part of the AVL inventory, CHART ATMS can automatically remove the event resource. The automatic removal of event resources can encounter the case where an event resource is in use in a traffic event at the time its removal from the AVL system is detected. CHART ATMS handles this by allowing event resources (and types) to be marked for deletion without actually deleting them. A periodic timer later detects when event resources and types are no longer in use and take them offline at that time. When taken offline, event resources and types are removed from memory and marked as offline in the database. An archival process removes any event resources that are marked offline after it has removed all traffic events that have been marked as offline.

3.9 Traffic Signals in Action Events

Users can associate Traffic Signal devices from the Signal Book database with an Action Event and describe one or more failures common to all signals in the event. Any number of signals can be associated with a traffic event but typically there is only one. The term 'Traffic Signal' is a bit misleading as the Signal Book contains traffic signals, cameras, beacons (school, bridge, warning), pre-emption signals (fire, bus, rail), reversible lane signals, and weigh station devices. Currently there are over 5000 objects in the Signal Book

The following key design decisions relate to the traffic signal integration feature in CHART ATMS:

- Traffic Signals devices that are currently associated with an Action Event are displayed on a separate map layer. This layer is visible on any zoom level of the home page and event creation maps.
- For performance reasons, Traffic Signals NOT currently associated with an Action Event are displayed on a separate map layer visible only on the two most zoomed-in zoom levels of the home page and event creation maps. Currently there are over 5000 Traffic Signals in the Signal Book.
- Traffic signals displayed on the event creation map can be used to populate the location fields on the event creation page.
- A user can associate a User Defined Signal to an Action Event. This feature is used when the traffic signal data available to CHART ATMS does not include a signal that a user wants to add to an Action Event. The user specifies a description for the signal when associating. User Defined Signals are only listed for the Action Event they were specified for. They are not displayed on the CHART ATMS map nor the Intranet Map and are not available to be associated with any other event.
- Traffic Signals associated with active traffic events are exported – primarily so the Intranet Map can display them.
- The CHART ATMS GUI periodically discovers updates to the traffic signals through a Traffic Signals web service (similar to the CHART Weather web service).
- Because of the large number of traffic signals, only enough information to support map requirements are cached in the GUI. Detailed location information for a traffic signal is requested from the web service only when needed.
- Also because of the number of traffic signals, objects representing signals are cached by the GUI in a separate traffic signal manager object instead of the generic data model. This is similar to how caching is managed for roadway links, another high-volume type of object (approximately 12,000).

3.10 MD511 Integration

CHART ATMS operators have a way to configure "floodgate" messages for use by Maryland 511 directly within the ATMS. A floodgate message plays for all callers who reach a given level in the MD511 call tree. Within a traffic event, an ATMS operator can define two strings (or paragraphs) of text: one intended to display in textual form to users of the MD511 web site, and one intended for text-to-speech conversion and playback to MD511 telephone callers. The text-to-speech text has a button for previewing the speech – as converted by CHART ATMS text to speech engine, which may not provide exactly the same output as the Maryland 511 text-to-speech engine, but may nonetheless be helpful. ATMS operators are also able to provide a public alert category (such as commercial vehicles, or amber or silver alerts), to aid MD511 in determining which MD511 users should be informed of a certain event. It should be noted that all these MD511 fields should be considered to be "hints" to Maryland 511 – MD511 is free to make whatever decisions are deemed appropriate from a MD511 perspective.

3.11 Object Location Using Known Roads

CHART ATMS provides the capability to populate event locations and device locations using the CHART ATMS map, pull down menus for known roads, or a combination of both. The

location choices are populated by calling the CHART GIS service, which serves up location data. The user first selects a county (the state of Maryland is always pre-populated by default). The user can also select a "region" (such as "Eastern Shore", "Western Maryland") if the county is not known. The user then specifies the primary route, by first selecting a roadway type from pick list. Route types include Interstate (I), United States (US), Maryland (MD), etc. The user then selects a route number. The user can also select a primary route by road name. The "intersecting feature" is specified next. First the "proximity" is selected. Choices include "at", "prior to", "past", and also directional proximities, such as "north of", "east of", etc. The feature type is then selected. Choices are exit, road, or mile marker. (Exit is preferred). Finally the intersecting feature of the appropriate type is selected. As for the primary route, an intersecting road can be specified by route type and route number, or by road name. If an exit is selected, the intersecting route or road is included as part of the exit description. Once a Maryland county is selected, the map zooms in to the extents of that county. Once an intersecting feature is selected, the map zooms in to that precise location. The user can then double-click the map to more precisely specify the location, if desired. The choices for each step in the process would be filtered based on the information already entered. For example, if the user had already chosen Howard County, I-95, only roads intersecting I-95 in Howard County would be available.

Data entry rules are enforced to produce more consistent location data in the database. If the user selects Maryland as the state, the user cannot use free-form text for county or region, or the route type and route number (or road name). Instead, if the user wishes to specify one of these fields, they must make a choice from the values presented in the pick list. If the state is not specified or is other than Maryland, free-form text is allowed in these fields. Choices are not provided and freeform text is required for primary road and intersecting feature if the state is not Maryland or if a region is selected rather than a county. Freeform text is always allowed when specifying an intersecting roadway, although this is highly discouraged unless absolutely necessary. Even if location information is free-formed, a point location should still be specified by double-clicking the map.

Other choices for "proximity," specifically for traffic events, are "between" and "from-to." A user can specify that the location of the event is between two features (meaning at an unknown point location somewhere between the two features), or from an intersecting feature and to a second intersecting feature (meaning the event is known to stretch between the two features, as a planned roadway closure). When the user selects either of these proximity values, they are provided with additional input fields that allow them to specify the second intersecting feature for the location. If a location can be determined for the two intersecting features the system displays markers at each of the locations to visually indicate to the user where the first and second intersecting feature being used in the event location are located. The system generally sets the location of the event initially to the location of the first intersecting feature (provided it has a defined latitude and longitude coordinate). If no coordinates can be determined for the first intersecting feature, the system attempts to use the latitude/longitude coordinates of the second intersecting feature as the initial event location. If the second intersecting feature has no defined coordinates either, the system cannot set an initial location for the event. Regardless of the initial location set, the user may double click any location on the map to specify that actual desired coordinate that should be used as the point location of the event. (Although the system does not prohibit using "between" or "from-to" for locating a device, in practice these are not used for devices, as a device location is always at a single point and the precise location of each device is always known. Furthermore it is important that the precise location of devices are input into the

system to allow selection (by users directly and by the Decision Support system) of appropriate devices to use in traffic event response plans.)

CHART ATMS also supports location aliases. The alias list contains "short cuts" for filling in the other location data. For example, selecting an alias of "Bay Bridge" would automatically fill in county of Anne Arundel, Route Type of "US" (United States), and Route Number of 50. The user could then fill in the remaining fields. An alias has an internal name and a public name. For instance, for the Francis Scott Key (FSK) Bridge, the public name may be "Key Bridge" and the internal name may be "FSK". The list of aliases and the alias details are configurable for a suitably privileged user.

Traffic event location descriptions and traffic event names are closely controlled. The GUI generates a traffic event location description using the values in the location fields. The traffic event name consists of the type of traffic event, an "at" sign ("@"), and the location description. Occasionally, depending on the traffic event type and specific information included in the event, related information is included in brackets at the end of the traffic event name. Users can override the GUI generated location description, although this is discouraged through the use of multiple warning messages. If the user overrides the location description, the traffic event name is updated to include the overridden description. The traffic event location and name are not fixed; these are regenerated throughout the life of the event as (and if) the underlying data changes.

3.12 Event Duplication Prevention and Merging

CHART ATMS helps prevent duplicate events and merge existing duplicate events. Duplicate events are identified based on the location data associated with each traffic event.

3.12.1 Event Duplication Prevention

The specific individually populated location fields (route type, route number, intersection) make it possible to help prevent duplicate traffic events from being entered. While the user selects these location fields, the system finds events with similar locations and displays them to the user in a list of potential duplicates. Initially, there are many potential duplicates, but as more and more location fields are specified, the list should shrink, ideally (typically) to zero. If any potential duplicates remain after all location information is specified, the user should review the list of possible duplicate events and may opt to abandon the creation of an additional event. Note that the type of traffic event is not considered in the list of potential duplicates, as the event type of the event being created has not been input by the user into the system at this time.

3.12.2 Event Duplication Identification

In the background, CHART ATMS detects existing open duplicate events based on their location and type. When a duplicate event is identified an alert is issued (if the system is configured to do so), upon which the operator can take action. That action may include deleting one of the events or merging the two events.

3.12.3 Event Merging

The process of merging events can be initiated from an alert of a duplicate event that is detected by the system, or can be initiated by the user directly. This feature can be used when different events exist in the system that may be using different resources. For example, Traffic Operations

Center (TOC) 4, Authority Operations Center (AOC) South, and the Statewide Operations Center (SOC) may all open events using different devices related to the Bay Bridge walk.

During a merge, the system shows the user data from each of the events involved in the merge, and allows the user make some high level choices about the data that is to be merged, based on the groups of data such as basic event data, roadway configuration, lane status, event history, participants (resources), response plan (devices), etc. The system then merges the events, combining the devices/messages, communications log entries, and other basic information based on the user input collected during the merge process. The target event is kept, with fields from the source event merged in as requested, and the other ("source") event is automatically closed as a false alarm.

3.13 Lane Configuration

3.13.1 Background

Lane configuration is an important aspect of most traffic events. (Some traffic events, namely Congestion, Special, Action, and Safety events, do not represent a physical roadway location and do not have lane configuration data.) A lane configuration is selected by the system if the event is geo-located and occurs on a significant enough highway to have lane configurations defined. Users can also build their own lane configuration, starting from either the lane configuration preselected by the system, or from a one of a set of "standard" lane configurations, or from an empty slate. The following types of lanes are configurable within CHART ATMS: "traffic" lanes (normal everyday lanes upon which traffic normally flows), shoulders, Collector-Distributor (CD) lanes, tunnel lanes, toll plaza lanes, medians, double yellow lines, center turn lanes, plus all the following which can be designated as "left" or "right": on ramps, off ramps, merge lanes, turn lanes, acceleration lanes, and deceleration lanes./separators, left exits, and multi-lane exits. Once a lane configuration is specified within the traffic event, lane closures of individual lanes can be specified. In addition, the current traffic flow direction of the lane can be specified (regardless of the side of the median where a lane exists). This accommodates situations such as when there is two- way traffic for example due to an accident or roadwork, in a single tunnel bore, bridge, or other roadway. In addition to setting a lane to a single direction, a lane can also be set to be bi-directional (alternating traffic) for use when a single lane of roadway is being controlled by a flagging or signaling operation.

3.13.2 CHART ATMS

The lane configuration features of the CHART ATMS GUI are provided by a standalone Lane Configuration Editor web service, which makes these features reusable in other systems. (It has always been expected that the lane closure permitting system would use this feature.) The CHART ATMS GUI accesses the lane configuration features via the web service's http / XML interface. In addition to providing an http / XML interface, the web service also serves the lane editor web page (HTML) and supports requests used by the web page as the user interacts with the form. The requests performed during user interaction with the form use AJAX techniques to perform these requests asynchronously to prevent form refreshes and provide a better user experience. All AJAX requests elicit a response that uses JSON (JavaScript Object Notation) to allow the responses to be more easily handled via JavaScript on the lane editor web page.

The general processing flow for editing the lane configuration and status for a traffic event in CHART ATMS is as follows:

The CHART ATMS GUI calls the Lane Configuration Editor web service via http / XML to initialize an editing session. The initialization provides information to the service to allow it to call the Mapping Lane Configuration web service to find lane configurations nearby the traffic event location. The initialization process also allows an existing lane configuration and status to be passed in to initialize the editor when the user is editing an existing lane configuration. The web service returns a unique identifier for the lane editing session.

The CHART ATMS GUI creates a popup window and sets its URL to the address of the Lane Configuration Editor web service's request to view a lane editor, passing the lane editing session ID as a parameter. The response is HTML for the lane editor web page.

The user interacts with the lane editor web page. The lane editor allows the user to choose a configuration from a list of configurations that includes lane configurations for the roadway that are near the traffic event location, as well as a list of standard lane configurations. The user can set the state (open, closed, unknown) for each lane and can also set the travel direction for each lane. Lanes of any type can be added to any selected lane configuration, and lanes of any type can be removed. As the user interacts with the form, the web page sends requests to the Lane Configuration Editor web service which keeps track of the lane configuration and status and generates the corresponding lane image. The Lane Configuration Editor web service responds with JSON that allows the web page to update its image as well as the image map that is used to allow the user to select lanes and perform actions on them.

The user submits the lane editor form. When the user clicks the submit button, a standard HTTP submit is not used, and instead a request is sent to the Lane Configuration Editor web service via AJAX. The Lane Configuration Editor web service calls back to the CHART ATMS GUI using http / XML to indicate the lane editing session has been submitted, and the CHART ATMS GUI updates the lane configuration and status for the traffic event. The CHART ATMS GUI responds back to the Lane Configuration Editor web service to indicate if its processing was successful, and in turn, the Lane Configuration Editor web service returns a JSON response to the lane editor web page to indicate success or failure. Additionally, if the lane editing session was initialized with a location that includes latitude/longitude coordinates and a primary route, the Lane Configuration Editor web service sends the lane configuration to the Mapping Lane Configuration web service via http / XML to allow the user specified lane configuration to be stored at the specified location so it is available for use the next time a traffic event occurs near that location. In this way, the system "learns" of lane configurations at various points along Maryland's highways, which is uses to supplement the initial set of configurations populated into the system.

The lane editor web page processes the response from the submit request. If an error is indicated, it is displayed to the user and the lane editing form remains open. If the submittal was successful, the lane editing form calls a JavaScript function in its parent window (if present) to let the parent window know the lane editing session has ended. The parent window can then update if needed to show the current lane configuration and status as specified by the user. Finally, the popup window containing the lane editor is closed.

In addition to lane editor related functionality, the Lane Configuration Editor web service also supports a request to allow a lane configuration to be rendered into a GIF image. This feature allows the client application to retrieve an image for a specified lane configuration and status for use within the client application. The returned data includes metadata for the image such as lane boundaries to allow clients to create an image map for the image, making features such as lane selection possible to implement.

3.13.3 Intranet Mapping

The Mapping Lane Configuration web service is part of CHART Mapping. The purpose of this web service is to provide access to lane configuration data available from the State's mapping database, and to allow this data to be augmented by lane configurations specified by users. The lane configuration data in the mapping database is stored per road segment, and the user specified lane configurations utilize this same scheme.

The Mapping Lane Configuration web service supports two requests, a query and a post. The query is used by client applications (e.g., the CHART Lane Configuration Editor web service) to locate lane configurations nearby a given point (latitude/longitude). A radius is provided, and a route can be provided to further narrow the results. The request is processed by finding all roadway segments that fall within the given search circle, narrowing it to include only those on the specified route (if one is provided), and returning lane configurations for those roadway segments (both those defined in the mapping database and those that are user specified).

The post request provides the ability for user specified lane configurations to augment the data that exists in the mapping database. The client application (e.g., the CHART Lane Configuration Editor web service) can post the lane configuration specified by the user for a specific latitude and longitude and route, and the Mapping Lane Configuration web service locates the roadway segment on the specified route that is closest to the specified latitude and longitude, and stores the specified lane configuration as the user specified configuration for that roadway segment. The next time a query is done that includes that same roadway segment, even by a different user, and/or different operations center, this configuration as specified by this user is returned as part of the query results. In this way, the system "learns" the appropriate configurations to use at all places on the highways. Each user specified lane configuration includes a timestamp indicating the time it was stored or last used, allowing for cleanup of the user specified lane configuration data in the future if needed (by a DBA).

Because the post request alters data in the database, the Mapping Lane Configuration web service allows this request to be performed by only authorized clients. The post request requires two parameters, a clientID and signature, which are used by the web service to determine if the request is from an authorized client. The web service keeps a list of all the authorized clients and the associated public key for each. When a post request is received, it uses the specified clientID to look up the public key and use the public key to verify the signature that was generated by the client using its private key. Only requests with a verified signature are processed – others result in an error being returned to the client.

3.14 Communications Log/Event Log

CHART ATMS provides a Communications Log, which is generally managed as a manually created log of communications CHART ATMS operators have with other entities, such as Safety Service Patrol (SSP) CHART Units or police. The Communications Log is also used to track the in-service and out-of-service status of CHART units. The communications log also contains system-generated entries in the Communications log, such as when traffic events are opened, closed, or renamed (relocated).

Each CHART traffic event includes a history of all activity regarding that traffic event, including device messages (system generated messages pertaining specifically to messages going on (or queued for) devices), other system generated messages, and user generated messages. CHART

ATMS provides views into event history logs that filter in or filter out device messages, (other) system messages, and user generated messages.

The log viewing capabilities include:

- Searching/Filtering: Users can search based on text in the log entries, operations center, and/or author fields, can specify start and/or end date and hour of day, limit to a specific source type (e.g., CHART Unit, State or Local Police, Citizen, etc.), as well as the message filter attributes.
- Filtering attributes: operator generated messages, user generated messages, and device generated messages can be filtered separately, or in combination. These attributes are automatically applied by the system when the messages are generated in the CHART ATMS. The messages are stored with their attributes in the CHART ATMS database.
- Paging: Users can control the number of entries per page and jump to a specific page of the log.

All the same searching, filtering, and paging capabilities apply to the Communications Log as well as the event history logs. Communications Log entries are removed from of the system after 12 hours. Event history log entries are removed from the system the traffic event they pertain to is taken offline, 12 hours after the event is closed. All Communications Log and Event Log entries are archived indefinitely.

3.15 Message Libraries

The CHART ATMS allows administrators to create libraries of DMS and HAR messages which can be used for event frequently used (or occasionally used) events over the life of the CHART ATMS. These include Amber Alerts; special events such as sporting events, Grand Prix, Bay Bridge walk, etc.; weather conditions (ice, fog, heavy winds, etc.); recurring congestion, bridge and tunnel closures and delays, BWI parking messages, safety messages (regarding drunk driving, use of safety belts, reporting suspicious activity, watching for motorcycles, deer, school buses, trick-or-treaters, etc.) and others. Messages are grouped into “libraries” for ease in managing the many messages. Library messages are not used directly by users, but instead used as source data for creating “Plans”, which tie generic library messages to specific DMSs and HARs. These plans are then used by users when managing the specific traffic events which are occurring at any given time. CHART ATMS currently has thousands of library messages stored in dozens of libraries.

3.16 Device Plans, Advanced Sort and Searching

CHART ATMS provides a concept of device plans (commonly referred to simply as “plans”), to support expedient handling of frequently occurring traffic events. A plan is a combination of devices and messages to go on those devices in response to an event which is suspected to occur from time to time (on a periodic or a periodic basis). CHART ATMS currently has hundreds of plans.

To help users manage and select from plans, CHART ATMS provides "filter attributes," by which plans can be classified. These filter attributes include: event type, operating center, county or region, location aliases, plus any other user-defined keywords.

Any or all of these attributes can be used to help classify a plan. The event type attribute means if the user is selecting a plan for, say, a congestion event, only plans tagged as congestion event plans appear by default in the resultant selection list. Users can always choose to ignore any or

all filter attributes, to widen the list of plans they have to select from, but this is what happens by default.

Multiple values of a given filter attribute may be specified. If multiple operating centers may occasionally use a plan, all those operating centers can be specified as filter attributes for that plan, so that users at any of those operating centers see those plans in their selection lists (provided all other relevant filter attributes also match). By the same token, users at all the other operating centers do NOT see those plans (unless they choose to ignore the operating center filter attribute).

The keyword attribute allows for specification of user-defined attributes, for instance, the keyword "summer" could be attached to special event plans which take place in the summer, or "winter" could be attached to weather events specifically relating to winter weather, even though the words "summer" or "winter" might not appear elsewhere in the plan name or message text. Textual searches beyond keywords are also supported. Users can search for text in the plan name, in the message text going to the devices, or in the device names themselves.

Filter attributes can be left unspecified. For instance, if a particular plan, such as a weather related plan, may be used for traffic events for any county or region in the state, no county/region filter needs to be specified for that plan (specifying no county/region attributes means the same as specifying ALL counties and regions).

3.17 Pending Traffic Events

CHART ATMS includes a concept of “pending” traffic events, which can be created in advance, before opening them (before it is time to open them). This is one step beyond device plans – as not only the response plan is created in advance, but the entire traffic event (which can include a response plan, which could be populated from a device plan) can be created in advance. These pending events can be scheduled and can be opened directly, without being scheduled. Pending Traffic Events are not “real” in the sense that they are not “open” or “closed”, they are never flagged as duplicates of “real” open events, they are never archived, and they never show up on either of the CHART Mapping maps nor on the public web site. Pending Traffic Events can be opened, in which case they become “real”, or they can be copied and opened, thus allowing the pending event to be retained in the system as a template for future instantiations of the same sort of event. Pending events can have any attributes that a “real” traffic event can have, including a location, specified in the same way as a regular traffic event, response plans, lane configuration and even lane closure information, lane closure permit information, etc. – although some attributes make more sense to leave till an event is actually created from the pending event before populating. The CHART ATMS currently contains scores of pending traffic events.

3.18 Event Scheduler

The CHART ATMS provides administrators with the capability to create and manage schedules. A schedule is a group of zero or more “actions” which can be scheduled to be activated at some time(s) in the future. The following are key terms which describe the concept.

Action – A schedulable task which can be put on a schedule. Currently the only type of action which can be scheduled is an “Open Event” action.

Activation – A schedule is activated when its next scheduled activation time arrives. Activation of a schedule causes an Execute Scheduled Actions Alert to be sent to the operations center

configured in the schedule. See Execute Schedule Alerts Alert just below to see resolution details for that alert.

Activation time – A time that a schedule will activate. A schedule can be configured with multiple activation times. Activation times can be specified by listing specific dates and times (such as for an Orioles schedule) or by recurring days of the week at a specific time period (such as for planned roadwork), possibly of undefined length (such as for recurring congestion).

Execution (of scheduled actions) – This refers to execution of actions defined in a schedule. Users can perform execution of schedule actions via two paths: 1) by responding to an alert (or alerts) generated by a schedule as the schedule activates (i.e., when the scheduled time for the schedule arrives); or 2) by selecting a schedule and choosing to manually run it immediately (instead of or in addition to its next scheduled activation time). In this latter case, the schedule actions can be executed without the schedule activating. See Execute Scheduled Actions Alert just below. At the time of a manual execution (path 2 above) the user has the option of suppressing the next scheduled activation of the schedule – if an activation is scheduled to occur within a few minutes of the current manual execution.

Execute Scheduled Actions Alert – An alert which contains all actions associated with a particular schedule. This may be zero, one, or more scheduled actions. If the schedule contains more than one action, the Resolve function for this type of alert takes the user to an Execute Schedule Actions page where the user can select/deselect actions to be performed and then execute them en masse. If the schedule contains one action, the Resolve function takes the user directly to a page more closely associated with the action. (Currently, since the only scheduled action is an open pending event action, this is always a pending event details page.) If the schedule contains zero actions, the Resolve function takes the user to the alert details page, from which the explanatory schedule description text can be read and the alert can be closed. This could be a reminder (such as from a supervisor, or from one's own self) to do something unrelated to opening a pending event.

At startup the Scheduler takes into account scheduled activations that were missed while the system was down. A configurable system wide parameter controls how far back the system looks for missed activations. Any missed activations for a schedule within this window cause the schedule(s) to be activated at startup.

The system automatically removes schedules that have not been used for a configurable period of time (some number of days). In this context, the term "used" means that the schedule has been activated, executed or modified.

3.19 Decision Support

The CHART ATMS includes a complex Decision Support system which helps the operator manage traffic event response plans. This includes determining the best DMS, HAR and CCTV camera devices to use in response to a traffic event and suggesting messages that the operator should consider putting on the selected DMS and HAR devices. The ATMS uses network routing ("driving directions") from each device to a particular traffic event to determine which devices may be useful for the event. All devices that are "upstream" from the event are considered, even those not on the same primary route as the event. If the driving directions from the device to the event are within a certain configurable (small) number of turns and within a certain configurable (very small) number of U-turns (such as zero U-turns), the device will be considered. The driving directions from each device to the event can also be displayed on a map,

aiding the operator in making the final determination as to whether the device is appropriate to use within that event.

3.19.1 Decision Support for DMS and HAR

Decision support with respect to DMSs and HARs are discussed in this section. First of all, the system can be pre-configured by administrators with message templates that pertain to one or more traffic event types, devices within certain proximities, and signs with specified geometries. Upon request, the system finds the devices near a traffic event (using devices further away as more lanes are closed) and then searches through the pre-configured templates looking for those that pertain to each device identified as being recommended for use in that traffic event's response plan. The variables in the template are then replaced with current data from the traffic event to create the suggested message. Each device can have multiple suggested messages, so the system presents the suggestions to the user with the highest scoring suggestion at the top. The system scores each message it creates from a template based on how specific the message content is. This is measured by counting the number of parameters in the template which could be populated from the available data relating to the traffic event. Templates which have parameters which cannot be filled are not suggested. In this way, the most detailed and complete message for each device is presented most visibly. Additional suggestions can be viewed by opening up a list of other suggestions for any device.

In addition to active message suggestions, CHART ATMS also indicates to the user when the current response plan does not contain a device that decision support rules indicate should be used, or when the response plan is using a DMS that the rules indicate should not be used. The response plan section of the page also allows the operator to request a Response Preview Map that shows all suggested response devices and what messages they would have on them if the response plan was executed.

3.19.2 Decision Support for CCTV

Within the Traffic Event Service, each traffic event allows a single video tour response plan item. The Traffic Event Service maintains a local cache of areas of responsibility that is updated periodically (at a configurable rate) by pulling from the server. The Traffic Event service makes use of the AORManager utility classes for this. The Traffic Event Service also maintains a cache of monitors and the areas of responsibility that are associated with each monitor.

The Traffic Event Factory has a periodic task that does the following for each traffic event: a) find the areas of responsibility that contain the traffic event, b) find the Monitors configured for those areas of responsibility, and c) update the response plan video tour to target those monitors. The Traffic Event Factory also has a periodic task that renews the set of tour entries for each monitor. The last executed set of cameras is sent to each of the last executed monitors. If a monitor does not get a renewal for a configured number of hours, it removes the tour entry that is outdated.

When a video tour response plan item is executed, the cameras in the response plan are added to the auto mode tour list of each monitor associated with an area of responsibility within which the traffic event is located. Any of these monitors which are in auto mode run a tour that contains these cameras, cycled through along with any other cameras that any other traffic event response plan executions have added to the auto mode tour list. A monitor running an auto mode tour list can be used as a normal monitor while it has no cameras on its auto mode tour list.

Each camera within a video tour response plan item can be associated with a preset. When an auto mode tour is running, when that camera is displayed within the tour, the camera is requested to move to that preset. All cameras have a throttle, though, which prevent them from changing presets too often (to reduce wear on camera PTZ units), so whether it moves or not is dependent on how long it has been since it last moved to a preset. (This is PTZ-saving feature is actually always in force (outside the realm of decision support, too).) The move to preset request is not "saved for later" – either it moves right away or the request is discarded. Therefore, the more places the camera tour is displayed the less likely it is that a given move to preset request will be honored.

Any tour, whether a response plan item auto mode tour or a standalone persistent tour, can have the same camera in it multiple times. This is useful without presets, to give more "air time" to a camera more significant within the tour, or with presets, to view a different camera angle from the same camera at different points in the tour. Note that having multiple presets within a tour exacerbates the limitation that a camera cannot move to preset too often, if the tour is displayed in more than one location. If the same tour runs in more than one place, the tours are not "coordinated" – each monitor or desktop video session runs its own tour independently, so each tour may be at different points in the tour, and the tours may actually drift with respect to each other.

3.19.3 Key Design Decisions

The following are key design decisions with respect to decision support:

- All Decision Support work is Traffic Event specific and relies heavily on the availability of current Traffic Event data in order to work. To optimize performance and reduce complexity, the Decision Support algorithms are implemented in the CHART ATMS Traffic Event Service.
- Although the Decision Support suggestions revolve around traffic events, it is not difficult to imagine the use of decision support type suggestions for other portions of the CHART ATMS. To ensure this type of flexibility, the DecisionSupportEnabled interface has been defined outside of the traffic event domain. This CORBA interface can be implemented by any component that needs to be able to make suggestions.
- The types of data suggested have also been designed for easy extensibility so that the system can suggest actions other than "put this message on this DMS" or "use this plan".
- The DecisionSupportUtility package contains decision support algorithms and utilities that are not traffic event specific. This allows for the potential re-use of code for other decision support related activities in the future.
- Assembling a list of suggested actions for an operator based on current system conditions can be a relatively long-running operation. The design takes advantage of the existing CommandStatus interface used for device communications and camera control requests to allow the UI to continue on without waiting for the suggestions. The server then updates the status text to inform the user of the progress on their request. The interface is designed to allow the server to stream back suggestions as they are found if desired.
- The CHART Mapping GIS Web Service allows the CHART ATMS to request information about the nearest exit to the traffic event, and also to determine if each device that is located on the same route as the traffic event is upstream or downstream from the traffic event.

- Each Traffic Event caches the list of devices that are nearby and whether that device is on the same route as the traffic event. If the device is on the same route the event also caches flags that indicate if the device is in the same direction as the traffic event and if the device is upstream or downstream from the traffic event. This cache is updated periodically on a configurable basis to account for the rare occasions when devices are added, deleted or moved. The cache is also be updated any time the traffic event location is changed. This cached information allows the system to quickly provide a list of devices that are recommended for use in the response plan for the traffic event (upstream devices in same direction) and a list of devices that are specifically NOT recommended for use (downstream devices in same direction).
- The Decision Support message templates are designed as an extension of the DMS message template framework that was created for travel time and toll rate messages.
- Monitor Auto Mode Tour Entries and Camera Temporary Presets can be created only within the context of Traffic Event Response plan. However, they are designed as generic features so that they could be expanded for other uses in the future.
- Auto Mode Tour display processing is done in a similar manner to standard video tour display processing.
- Clean up of Auto Mode Tour Entries and Temporary Presets
  - Done by owning Traffic event when needed.
  - System periodically removes un-needed Auto Mode Tour Entries and Temporary Presets that were not successfully removed by owner.
  - User with Configure Monitor or Configure Camera functional right can remove them if needed using the GUI.

3.20 DMSs

3.20.1 Models

CHART ATMS provides control of DMS devices via proprietary custom manufacturer protocols and via industry-standard NTCIP. There are relatively few proprietary DMSs left in the CHART ATMS. Once there are no more DMSs that use a specific protocol left, it is doubtful that any new ones would be added. (For instance, there are no more FP2001 DMSs. There are only about a handful at most of most of the others.) However, support for the proprietary protocols is still built into the CHART ATMS. The protocols supported, in addition to NTCIP, are:

- Addco
- FP1001
- FP2001
- FP9500
- PCMS
- Silvia
- Telespot TS3001

The various protocols vary somewhat in their facilities. For instance, some support a pixel test (all pixels on), and some support, and “extended status” query, which gathers additional information beyond that which can be acquired via a standard DMS poll. The standard DMS

poll operates at a minimal level to provide basic health and message querying capability, but does not collect any additional data.

CHART ATMS currently supports NTCIP DMSs, version 1 and version 2. It turns out that all basic features needed by CHART ATMS are supported identically in NTCIP version 1 and NTCIP version 2. This means that there is no flag or indicator to specify whether a particular NTCIP DMS is NTCIP version 1 or NTCIP version 2. NTCIP supports a pixel test and an extended status query. An NTCIP Compliance Tester for DMSs is kept up to date with CHART ATMS changes to the NTCIP protocol, so that the compliance tester always uses the latest CHART ATMS software.

3.20.2 Protocol Handlers

DMS communications are provided at the lowest level by DMS Protocol Handlers. The Protocol Handler encapsulates the specific manufacturer protocol (or industry-standard NTCIP protocol), translating the generic commands from the DMS objects, such as set message or blank sign, to protocol-specific commands. Historically, these were transmitted to the device via a communications port acquired from a Port Manager on an FMS by the DMS object and passed into the Protocol Handler, but now all DMS communications are accomplished via Transmission Control Protocol (TCP) over Internet Protocol (IP), so communications are conducted directly between the Protocol Handler and the device controller. The Protocol Handler also processes responses and pass responses success or failure indications back to the DMS objects.

3.20.3 Communications

All DMSs are communicated to via TCP/IP communications. Within the MDOT network, Raven-X wireless modems provide the TCP/IP communications paths, but as far as the CHART ATMS software knows, they are always-on, directly-connected TCP/IP devices. (In the past CHART ATMS supported communications to DMSs via Field Management Stations (FMSs) – standalone servers deployed throughout the state providing Plain Old Telephone System (POTS) and Integrated Services Digital Network (ISDN) modem communications (within one Local Access Transport Area (LATA) where possible). Initially this was the only method of communication with DMSs (and TSSs). Direct-wired RS232 communication was added as well. However, after a period of transition lasting several years, this usage of FMSs has by now been phased out entirely. Technically this could still be supported by CHART ATMS; however, recent releases of CHART ATMS have neither tested nor deployed POTS or ISDN based FMSs, so this facility is now of uncertain reliability.)

3.20.4 DMS Fonts

CHART ATMS supports character matrix, line matrix, and full matrix DMSs, and supports the designation of one font to be used for all messages on the DMS. CHART ATMS accurately models the properties of DMSs, including the sign type, actual size relevant to the sign type, and the actual font being used, which allow DMS message images that appear throughout the system to accurately depict how the message appears on the actual DMS inWYSIWYG ("What You See Is What You Get) format. Using this information, CHART ATMS can precisely determine if a message will fit on a DMS, even if a variable width font is employed.

To support this functionality, display-related data including the sign type, sign size, font, and other display related data is stored in a structure referred to as a DMS Display Configuration. One DMS Display Configuration can be shared by multiple DMSs. Therefore, when adding

DMSs of a standard type and size from a single manufacturer, an administrator can define the size, font, and other settings one time in CHART ATMS, and then reference that collection of settings, by name, for each DMS rather than having to define them separately for each DMS. DMSs that share a display configuration, they utilize the same font. This makes it easy to standardize fonts, which helps to provide consistency for the traveling public.

In CHART ATMS DMS message editors that allow editing messages for multiple DMSs at once, such as for a message library or to set the message on multiple DMSs used in a traffic event response plan, there are many variables that affect the DMS message image and the fit checking algorithm. A message that fits on one 3x20 sign may not necessarily fit on a different 3x20 full matrix sign that uses a larger font. These message editors show the user how the message will appear for each display configuration, rather than showing how it will look on every single DMS.

CHART ATMS actively manages the fonts stored within NTCIP DMSs. CHART ATMS uploads the font specified in the display configuration used by a DMS into the controller of NTCIP DMSs to ensure that the font definition used by CHART ATMS in its message images and its fit checking algorithm exactly matches the font used by the actual DMS. Whenever a DMS is put into maintenance mode or online, CHART ATMS checks that the font CHART ATMS expects is loaded in the DMS is in fact actually loaded, and if it is not, CHART ATMS reloads the font into the DMS automatically. With this active font management CHART ATMS can maintain accuracy with regard to message images and message fit on NTCIP DMSs.

CHART ATMS does not provide active font management for non-NTCIP DMSs. For non-NTCIP signs, CHART ATMS can be only as accurate as the font specified in the display configuration used by those DMSs. This means if the actual font used by a non-NTCIP sign is available and specified in the display configuration used by the non-NTCIP DMS, CHART ATMS can be very accurate with regard to its message images and fit check algorithm. Otherwise, the accuracy for the non-NTCIP signs may suffer.

The design for this aspect of CHART ATMS assumes that at some point in the future the system will be required to support the use of more than one font for a single DMS. This design supports this future expansion through the use of a font table in the display configuration and by defining "logical fonts". Currently there is only one font in the font table, and it is logically known as the default font. A specific slot (e.g., slot 1) is assigned for the default font, and that slot number is used on all NTCIP DMSs to store the one font that the display configuration allows in CHART ATMS. In a future release, more fonts could be stored in the DMS display configuration, with logical meanings such as "fixed width template font", "small font", "large font", etc.. Likewise specific slot numbers would be assigned to these logical fonts. By using logical fonts and standardized font slots for those logical fonts, DMS messages that target multiple DMSs (such as library messages) can utilize the logical fonts and the system can more easily ensure the proper font is used. For example, if the CHART ATMS IDL someday specifies that slot 5 is always used for a font known as the "large font", the MULTI that defines a message can include a tag such as <fn5> and the proper font would be used for message as defined in each DMS display configuration. If desired, certain DMS display configurations could use the same font for all defined logical fonts, in which case a single actual font would be used for all messages (the "large font" would not look different from the "default font"), even though some messages might include multiple "logical" fonts.

3.20.5 Alerts and Notifications

CHART ATMS allows alert and notification settings to be set for each DMS, regardless of its model. Separate values are supported to specify the op center to receive communication failure alerts, the op center to receive hardware failure alerts, the notification group to receive notifications of communication failures, and the notification group to receive notifications of hardware failures. Any or all of these values can be set to "None" to disable that particular alert or notification. When enabled, if CHART ATMS detects a status change related to the given type of failure (hardware or communication), CHART ATMS creates an alert and assigns it to the specified operations center and/or sends a notification to the specified notification group.

3.21 HARs

3.21.1 Background

A HAR is Highway Advisory Radio. These are also referred to in the industry as a "TAR" (Traffic Advisory Radio), but within the Maryland domain, they are referred to exclusively as HARs. A HAR is a limited power radio used to communicate traffic information to the travelling public. The range is typically in the neighborhood of two miles. (For this reason, the length of a HAR message is typically limited to 2 minutes (about 2 miles at 60 mph, assuming travel through the diameter of the HAR broadcast range). When a significant message is playing, "HAR Notifiers" (highway signs) inform the public that they should tune their radio to the specific frequency to hear the message. A HAR Notifier is typically a "SHAZAM" (see separate section within this Functional View), a painted highway sign with beacons that flash when a message is active. A HAR Notifier can also be a DMS which happens to be near the HAR. Within CHART ATMS, a HAR Notifier (SHAZAM or DMS) can be associated with exactly one HAR (or no HAR at all). When a DMS is used as a HAR Notifier, part of the DMS configuration indicates the message to display when the DMS is being used as a notifier.

3.21.2 Models

CHART ATMS supports two models of HARs. These are the model AP55 from Information Station Specialists (ISS) and the model DR1500 by Highway Information Systems (HIS). The AP55 was included very early in CHART ATMS; the DR1500 was included somewhat more recently.

Communications to the both models of HARs support Dual Tone Multi-Frequency (DTMF) telephony (telephone) communications. FMS servers provide the telephony communications. Additionally, the DR1500 supports digital TCP/IP communications, direct from the server without an FMS. The CHART ATMS FMS Comm Service utilizes a Dialogic telephony board to communicate with the HARs. CHART ATMS employs the Dialogic API for DTMF telephony communications.

3.21.3 Protocols

The HIS DR1500 protocol is essentially a superset of the AP55 protocol, therefore much of the ISS AP55 code was reused for the DR1500. Both the HIS DR1500 and the ISS AP55 support:

- Store message
- Play message
- Blank HAR

- Turn HAR transmitter On/Off
- Monitor broadcast
- Set up HAR
- Reset HAR (automatically followed by a Set up HAR command)

Because the HIS DR1500 has the additional capability to play messages in a synchronized manner across multiple HARs, the HIS DR1500 also supports:

- Play synchronized message
- Clear HAR memory (defragments and reclaims memory)

The HIS DR1500 also has the capability to respond to commands. Although the HIS DR1500 has more extended status/response capabilities, CHART ATMS processes only DR1500 responses to the commands that CHART ATMS sends to the HIS DR1500 in order to assess whether the commands succeeded or failed. This allows users to get feedback from the HAR. CHART ATMS also needs to get the HAR memory usage in order to defragment and reclaim HAR memory.

- Receive response to command
- Get HAR memory usage

3.21.4 Protocol Handlers

HAR communications are provided at the lowest level by HAR Protocol Handlers. The Protocol Handler encapsulates the specific manufacturer protocols, translating the generic commands from the HAR objects, such as download audio or set play list, to protocol-specific commands (play DTMF tone requests, or TCP messages in the case of IP-connected DR1500 HARs), and, in the case of the DR1500, can also process responses (DTMF or TCP/IP) and pass success or failure indications back to the HAR objects. In the case of DTMF, the Protocol Handler communicates via a VoicePort acquired from a Port Manager on an FMS by the HAR object and passed into the Protocol Handler.

3.21.5 Synchronized HAR

The HIS DR1500 provides the capability for multiple DR1500 HARs in close physical proximity to play messages in a synchronized manner. This is intended primarily for HARs so close along a highway that their broadcast ranges overlap. All broadcast on the same frequency, providing a continuous broadcast stream along the length of highway. (Of course synchronized mode can also be used for HAR which are not that close in proximity.)

Within CHART, a “Synchronized HAR” is a HAR-like entity that is comprised of one or more individual constituent HARs that play messages in a synchronized manner. The Synchronized HAR itself does not exist in the real world – it represents the collection of individual constituent HARs (although within CHART a Synchronized HAR is given a real location in the world that represents, for instance, the rough center of the collection of individual HARs being represented). The Synchronized HAR provides a single interface to command and control such a group of HARs. Currently a Synchronized HAR may be comprised of only HIS DR1500 HARs, since this is the only HAR model within CHART that supports synchronization. However, the converse is not true. A DR1500 does not have to be configured as a constituent HAR within a Synchronized HAR; it can alternatively be configured as an individual independent HAR not

associated with any Synchronized HAR. In fact, a DR1500 must be added to the system as an individual HAR first, and then added to a Synchronized HAR if desired.

In general, a Synchronized HAR appears to be a single HAR to the user and can be added to a traffic event's response plan and executed just like any other HAR within CHART ATMS. By default, online and maintenance mode messages put on a Synchronized HAR go out to all its constituent HARs. However, the user has additional options when putting a message on a Synchronized HAR. The user has the option to individually select which constituents on which to broadcast, and which notifiers those constituents should use.

A Synchronized HAR always ensures that every one of its constituent HARs either play the same message as all the others, or be completely silent (not transmitting). If the user chooses to broadcast on a subset of the available constituent HARs within a Synchronized HAR, the constituent HAR(s) not selected simply become silent. Had the typical default message be broadcast, it would interfere with the message being broadcast on the actively selected constituent HARs. This "silent" status is depicted in the GUI with the text "silent" and a slight graying of the background. This logic applies to playing a message in maintenance mode or as part of a traffic event.

The following administrative functions work with Synchronized HARs just like any other HAR within CHART ATMS:

- Put Synchronized HAR online
- Take Synchronized HAR offline
- Put Synchronized HAR in maintenance mode
- Perform synchronized HAR maintenance mode commands:
  - Store message
  - Play message
  - Blank HAR
  - Turn HAR Transmitter On/Off
  - Monitor broadcast
  - Set up HAR
  - Reset HAR
- Add Synchronized HAR to system (includes adding default header, message, trailer)
- Delete Synchronized HAR from system
- Edit Synchronized HAR (includes adding and deleting constituent HARs)

These administrative commands for a Synchronized HAR trickle down to its individual constituents. This means that if a user chooses to put a Synchronized HAR online, the individual synchronized HARs go online as well. This same logic applies for the other administrative functions listed above.

While the Synchronized HAR functions very much like any other HAR in the CHART ATMS, including having a description/location, message, device status, etc., users can drill down to the individual constituent HARs to see their status, etc. Users can see a table of constituent HARs on a Synchronized HAR details page, can see the status of those constituent HARs, and can turn individual constituents off when broadcasting a message. Users also can view the constituent HAR details. Also, suitably privileged administrators can perform administrative functions on individual constituent HARs. This means that an individual constituent may be placed offline,

online, or in maintenance mode. When in maintenance mode, a user can command the individual constituent HAR without generally affecting the other constituents or the Synchronized HAR itself. There are some cases where there are some restrictions on individual constituents. For instance, a constituent HAR in maintenance mode may not have its transmitter turned on if any of the other constituent HARs comprising the Synchronized HAR are online. This is to prevent conflicting messages from playing when the Synchronized HAR is online.

3.21.6 Multiple HAR Operations

CHART ATMS allows a user to command multiple HARs of any type using the Multiple HAR Response Plan Item (RPI) Editor. This means that a user can configure a broadcast of the same message on multiple HARs, including Synchronized HARs, including indicating which notifiers to activate based on direction. However, a user may not select individual constituent HARs of a synchronized HAR using the Multiple HAR RPI Editor.

3.21.7 Communications

In addition to providing telephony communications to AP55 HARs and DR1500 HARs, CHART ATMS also supports communications to DR1500 HARs via TCP/IP. An optional module known as the Digital Communications Controller (DCC) must be added to a DR1500 HAR to enable TCP/IP communications. Several existing DR1500 HARs are outfitted with this module. There are other DR1500 HARs that are currently fielded that do not have a DCC. CHART ATMS communicates with those DR1500 HARs using the traditional telephony FMSs and DTMF communications.

When adding a DR1500 HAR to the system, an administrator can specify TCP/IP communication. When TCP/IP is selected for a DR1500 HAR, the user may also enable polling of the device to have the system periodically check the status of the HAR. The communications type can be edited after a HAR is initially added to the system using the Control Line Communications Settings form.

3.21.8 Polling

When a DR1500 HAR is set to use TCP/IP communications and polling is enabled, the system queries its status on the interval as specified in the configuration. During each status poll, the system checks the HAR state as reported by the device against the HAR state as specified in CHART ATMS to determine if the HAR indicates it is doing what CHART ATMS last commanded it to do. CHART ATMS checks the play list, the transmitter on/off status, and the HAR Timestamp to determine if there is a status match. If the status does not match, CHART ATMS automatically queues a Setup command for the HAR to restore the appropriate clips, playlist, and transmitter status to the HAR

Another function performed during a poll of a DR1500 is to check status values against configured thresholds for those values. Configuration values are included to allow thresholds for various status values to be specified, and these values are used by the system during polling to determine if a hardware failure condition exists. If during a status poll CHART ATMS determines a status value lies outside the configured threshold it sets the HAR status to hardware failed. The values CHART ATMS checks against thresholds are the DC Voltage, Broadcast Monitor Percent, Modulation Percent, and Voltage Standing Wave Ratio (VSWR).

The status values obtained from the most recent poll of the HAR are displayed on the HAR's details page within the GUI and indicates which values (if any) are found to be outside the configured thresholds and therefore cause a hardware failure condition.

3.21.9 Monitoring HAR Audio

When a DR1500 HAR is operated using TCP/IP communications, monitoring the HAR's audio is not possible.

3.21.10 Alerts and Notifications

CHART ATMS allows alert and notification settings to be set for each HAR, regardless of its model and the type of communications used to control it. Separate values are supported to specify the op center to receive communication failure alerts, the op center to receive hardware failure alerts, the notification group to receive notifications of communication failures, and the notification group to receive notifications of hardware failures. Any or all of these values can be set to "None" to disable that particular alert or notification. When enabled, if CHART ATMS detects a status change related to the given type of failure (hardware or communication), CHART ATMS creates an alert and assign it to the specified operations center and/or sends a notification to the specified notification group.

Some HAR models (such as the AP55 and DR1500 configured to use a Telephony port) do not support polling or retrieving status, so these HARs cannot ever raise a hardware failed condition. Therefore, setting an op center and/or notification group for such HARs serves no purpose (nor does no harm). However, for simplicity, the feature exists for all HARs. The alert and notification feature is being developed generically to apply to all HARs to avoid rework in the future if support for other HAR models is added to the system.

3.22 HAR Audio Management

3.22.1 HAR Messages and Audio Clips

CHART ATMS allows operators to enter text or record voice at their workstation for broadcast on a HAR device. Each message consists of one or more "clips". A message can specify its own header clip or it can use the default header for the HAR(s) it is destined for. A message can also specify its own trailer clip, or can use the default trailer, or it can use no trailer. Typically (or virtually always), the default header and default trailer are specified for all messages. A user must specify exactly one "body" clip for a HAR message. This is where the actual unique part of the HAR message goes. (A message created within the HAR service can consist of multiple body clips when HAR messages are combined. The header plays once, all the body clips play, then the trailer plays once, and this cycle is repeated.) Each clip specified by a user can be recorded voice or text.

Because voice data can be very large, the passing of voice data with HAR messages is minimized through the use of wrapper objects and streamers.

Recorded voice is supported in the CHART ATMS for:

- immediate broadcast on a HAR
- storage in a slot on a HAR for future broadcast, and
- storage in a message library.

When voice is recorded the voice data is packaged in a HARMessageAudioDataClip object, which in turn is included in a HARMessage object. Upon receiving a HARMessageAudioDataClip, the object receiving it (a HAR, a TrafficEvent's ResponsePlanItem, or MessageLibraryDB) uses a utility class called an AudioClipManager to persist the "heavyweight" HARMessageAudioDataClip audio data and obtain a HARMessageAudioClip in its place. The HARMessageAudioClip contains a unique ID and a reference to an object known as a streamer that can provide access to the actual voice data given the ID. The AudioClipManager is a streamer and places a reference to itself in every HARMessageAudioClip it creates.

Because HARMessageAudioClip objects are small, they can be passed throughout the system as the part of the device status for a HAR without having a significant impact on network bandwidth usage. The only times the recorded voice data be passed across the network after its initial storage are when the user wishes to listen to the voice data from the HAR or the voice data needs to be recorded onto the HAR device. When this occurs, the HARMessageAudioClip is told to stream the data and the HARMessageAudioClip delegates the request to the streamer reference it contains, which is always the AudioClipManager where the data was originally stored.

As various software objects within CHART ATMS gain access to a HARAudioClip and find a need to have the data persisted, they register their interest in the clip with the AudioClipManager stored within the clip. The AudioClipManager never deletes the voice data associated with a clip as long as at least one clip "owner" is registered for it. A clip stored in a message library, specified in a ResponsePlanItem, and being broadcast on a HAR would have those three separate entities maintaining interest in the clip with the AudioClipManager.

3.22.2 Audio Clip Manager

Recorded voice data is cleaned up within the AudioClipManager as owners deregister interest in clips when they are no longer needed. As HARs, ResponsePlanItems, and MessageLibraryDB objects lose interest in a clip, they deregister interest in the clip, which passes the request on to the AudioClipManager. The AudioClipManager removes the association between the clip owners and the clip as deregister requests come in, and it deletes the voice data itself when there are no registered owners left for a clip. Because this system is not foolproof, and because audio data is large and expensive to store, the AudioClipManager periodically requests services to revalidate their interest in the clips they are registered for. This is a low-bandwidth operation during a period of low bandwidth usage (in the middle of the night), and is more efficient than coding the software entities to be fail-safe in deregistering interest. In other words, if the AudioClipManager happens to be down or unreachable, an audio clip owner need not take extraordinary effort to retain information about the failed deregistration attempt and undertake a complicated retry scheme.

3.22.3 Text-To-Speech Capabilities

CHART ATMS also provides the capability for Text To Speech. This is the preferred method for broadcasting HAR messages, as the text is easy to read and easy to type, provides a consistent sound for the traveling public, and can be maintained in the CHART ATMS archive database indefinitely, at low cost. Audio messages are not maintained once the need for the voice clip has passed. Some operators also are uncomfortable with having their voice broadcast publicly, and may find it difficult to record a voice message that they are satisfied with.

To facilitate the use of Text To Speech, CHART ATMS includes a pronunciation glossary. This enables operators to type text without having to alter spelling in order to improve the pronunciation in the text-to-speech engine. Any suitably privileged operator can maintain the pronunciation entries in the dictionary.

Operators should type all HAR messages using the correct spelling of all words. Any words not in the pronunciation dictionary should be added during the preview process, or as soon as possible. Any a word that requires substitution is substituted before the text-to-speech conversion is done. The operator need not be aware of this process. Some operators seem to prefer the way of typing HAR messages learned long ago, making extensive use of phonetic spellings, such as EYE for "I," "EGGS IT" for "EXIT", etc. This is not necessary, but works fine.

3.23 Arbitration Queues

A key feature of CHART ATMS DMSs and HARs is the "arbitration queue". An arbitration queue arbitrates the usage of a device by maintaining a prioritized message queue for the associated device. As messages are requested to be displayed or broadcast on a specific device, they are assigned priorities based on a predefined message priority scheme (discussed later) and are added to the queue. The Arbitration Queue has the responsibility of determining which message should be shown/broadcast by a messaging device. It allows any number of traffic events to add entries to a device's arbitration queue. The queue can hold multiple entries and decides which entry is to be placed on the device based on priority.

Each message in the queue is queued by a traffic event (or a DMS itself, in the case of a Traveler Information Message such as a travel time or toll rate message, or a HAR being used by a traffic event, in the case of a SHAZAM message being placed on a DMS). Likewise, a traffic event (or DMS or HAR) can have only one message at a time in a device's queue. A message is removed from the queue when the related traffic event is closed (or when the response plan item deactivates them), when the DMS Traveler Information Message is deactivated (either by a user or due to inadequate data), or when a HAR message using a DMS as a SHAZAM is no longer broadcasting the relevant message. Messages can be added to and removed from a device's arbitration queue regardless of the current communication mode of the device. In this way, a device that has been offline is automatically brought immediately up to date with the latest highest priority messages requested for it as soon as the device is brought online again. The queue is automatically be evaluated whenever a device is placed online, in order to ensure that the correct message is sent to the device.

Whenever a message is added to or removed from the arbitration queue, the queue evaluates all entries and decides which message (or messages) should be shown/broadcast by the queue's associated device as follows:

- If a message is added to the queue and the queue is empty, the message is put on the device.
- If a message is added to the queue and the queue is not empty, the queue evaluates the messages on the queue (including the new message), determines which message(s) has or have the highest priority, and places the highest priority message(s) on the device.
- If a message is removed from the queue and this leaves the queue empty, the device is blanked or a default message is broadcast depending upon the type of the device.
- If a message is removed from the queue and other messages remain on the queue, the queue evaluates the messages on the queue (excluding the removed message), determines

which message(s) has or have the highest priority, and places the highest priority message(s) on the device.

As alluded to in the processing described above, Arbitration Queues can allow multiple messages to share a device. In the case of a DMS two single page messages can be concatenated into a single two-page message. In the case of a HAR, multiple messages can be concatenated if the total amount of playtime of the messages is less than the configurable limit set by the administrator. The matrix in Table 3-1 provides a recent example of the pairings used to combine messages on DMSs. (Note that the shaded lower left part of the diagram is a mirror image of the upper right part of the diagram. This part of the diagram does not actually appear in the GUI, as it is redundant. In addition to the shaded cells in the last (SHAZAM) line, the SHAZAM-to-SHAZAM combinability cell is also meaningless, as it is not possible to have two SHAZAM messages on a DMS at the same time. There the entire last (SHAZAM) line does not appear in the GUI at all.)

Table 3-1. CHART ATMS DMS Message Combinability

Arbitration Queue Bucket	U	I	P	R	T	C	S
Urgent (U)	X	X					X
Incident (I)	X	X					X
Planned Roadway Closure (P)			X			X	X
Toll Rate (R)							
Travel Time (T)							
Congestion (C)			X			X	X
SHAZAM (S)	X	X	X			X	

A maximum of two messages are allowed for combining for a DMS. Only the top seven buckets (Urgent, Incident, Planned Roadway Closure, Toll Rate, Travel Time, Congestion, and SHAZAM) are allowed to be considered for combining, and only in the pairs indicated by Xs in the above matrix. For instance, an “Urgent” message can be combined only with another “Urgent” message, an “Incident” message, or a “SHAZAM” message. For HARs, messages can be combined up to a 2-minute limit (system-wide configurable parameter). All types of messages are eligible for combining on a HAR (the above matrix for DMS message combining does not apply for HARs). HAR Messages are searched in priority order until the 2-minute limit is hit. The search is terminated once a message is found which does not fit – rather than continuing the search to see if any lower priority messages that happen to be shorter would fit instead.

3.23.1 Priority Scheme

Each entry in the queue is assigned a priority. A number is used to indicate the priority of each message on the queue, with a higher number indicating a higher priority (and thus more likely to be placed on the device). When a message is added to a queue, it is given a default priority number that is based on the type of event from which the message originated and the number of

messages already in that arbitration queue category (often referred to as a “bucket”). The agreed-upon priority order of message types are, from highest to lowest,

- Urgent (nothing is enqueued here directly, but certain users can move messages here)
- Incident Event (enqueued by a Traffic Event on a DMS or HAR)
- Planned Roadway Closure Event (enqueued by a Traffic Event on a DMS or HAR)
- Toll Rate Message (enqueued by a DMS on itself (using Travel Route data))
- Travel Time Message (enqueued by a DMS on itself (using Travel Route data))
- Congestion Event (enqueued by a Traffic Event on a DMS or HAR)
- SHAZAM Message (enqueued by a HAR on a DMS configured as a notifier for it)
- Weather Event (enqueued by a Traffic Event on a DMS or HAR)
- Special Event (enqueued by a Traffic Event on a DMS or HAR)
- Action Event (enqueued by a Traffic Event on a DMS or HAR)
- Safety Event (enqueued by a Traffic Event on a DMS or HAR)

The concept of the "Urgent" category is to place messages in this category that should surpass all events added in the system. Sufficiently privileged users are able to move a message to (and out of) this level. Within a level, the FIFO (first in – first out) queue concept is used. Messages can be moved into other arbitration queue buckets or can be rearranged within a single arbitration queue bucket. Repositioning a message into a new bucket changes the priority of the message on the queue, but does not change the type of the event. For example, a congestion response plan moved to the incident level will not change the type of the event to incident. It just changes the priority of the activation of the plan on the device.

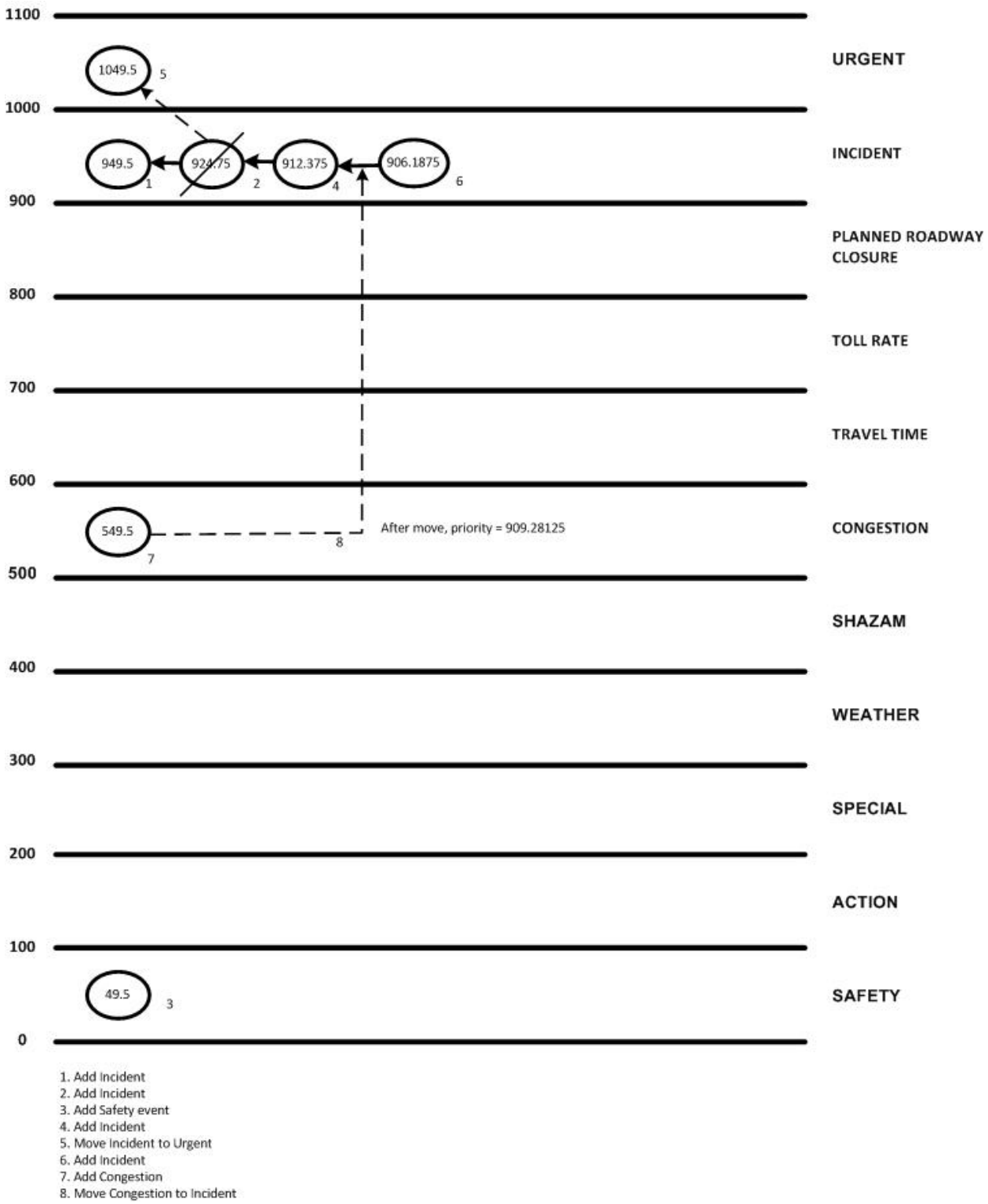

Figure 3-1. CHART ATMS Arbitration Queue Priorities

Figure 3-1 shows an example of a sequence of system actions that occur when response plans are added, removed or placed on different priority levels on a device's arbitration queue. Initially, the queue for a device is empty. When an incident response $plan_1$ is activated the message gets

placed on the device's queue. The priority number assigned is based on the pre-defined range level for the event type. In this example, the range level for incidents is between 900 and 999 (as the number 1000 is actually part of the Urgent bucket's range). The priority assigned to the event is the mean of the two limits, e.g., 949.5. An automatic evaluation of the queue places the message on the device, since it is the only message on the Arbitration queue. When another incident $message_2$ gets added to the queue, the system automatically assigns it a lower priority than the previous one. This is computed as the mean of the lowest priority message in the queue (949.5) and the bottom end of the bucket's numerical range (900), resulting in a value of 924.75. Assuming DMS message concatenation does not come into play, automatic evaluation of the queue at this time does not place the newly added message on the device. The message currently on the device has a higher priority and the associated response plan is still active in the system. A Safety $message_3$ and an $Incident_4$ response plan added are placed in their levels, each with an assigned priority. If at this point, the user gives the $incident_5$ the highest priority (a new priority is assigned), the currently active incident response $plan_1$ is suspended and the higher priority $message_2$ is activated. Moving a congestion response $plan_7$ between the two incident $messages_{4, 6}$ reassigns the congestion event a new $priority_8$ but does not change its event type.

The Chart2DMSImpl and HARImpl and implement the ArbitrationQueue interface defined for the Arbitration Queue. The responsibility to manage entries, i.e. add, remove, change priority, is delegated to the MessageQueue, a utility class. The entries in the list are ordered according to their assigned priority. The Chart2DMSImpl and HARImpl are responsible for evaluating the queue, concatenating messages, determining the message that should be sent to the device and sending queue updates to the CHART ATMS GUI.

3.23.2 Detailed Device Status and Arbitration Queue Manipulation

The CHART ATMS GUI allows users to view the entries in a device's arbitration queue. A user with the proper functional rights can manually change the priority of items on a device's queue to override the queue's automated prioritization scheme. When the priorities of messages on an arbitration queue are manually changed, the arbitration queue evaluates the priorities of the messages on the queue to determine if the message on the queue's associated device should be changed. New messages added after a reordering are placed in the proper relative position. When a user re-orders the queue, they do so by manually moving one message at a time to a new position in the queue. When a message is moved, the priority number of the message that was moved is changed to be slightly higher than the priority of the message immediately following it. In the case where a message is moved to be the last in the queue, it is given a priority number slightly less than the message above it. This is accomplished by using floating point numbers to indicate priority. If a user moves an incident message behind a roadwork message, new roadwork messages are placed behind this message while new incident messages are placed in the incident level below the lowest incident on that level. Each manual message repositioning is accomplished by issuing one request to the queue, to avoid the delays that locking the entire arbitration queue would entail.

The GUI also allows the user to view the queue and device status, i.e., current message prioritization, active message(s), and recent communication actions with the device. The CORBA event service is used to notify GUIs regarding any changes to the device's queue.

Figure 3-2 shows a representation of how the view is organized. The top section shows all the messages on the Arbitration Queue. A suitably privileged user is able to change priorities of the

messages. The middle section shows the Queue status regarding changes to the queue as they are being executed. The bottom section shows the device status while sending the message to it.

Message	Op Center	Type	State
Accident Ahead on I-495 near Exit 22	TOC3	Incident	Active
Drive Safely	SOC	Safety	Queued
Accident on 1-270 near Exit 3 (Montrose Road)	TOC3	Incident	Queued

Queue Status

Message " Congestion Ahead" removed from the Queue

Device Status

Dialing Device

Figure 3-2. CHART ATMS Arbitration Queue Status

3.24 SHAZAMs

3.24.1 Background

A "SHAZAM" is a sign on a roadway near a HAR which provides an indication that a message of some significance is being broadcast by the HAR nearby. The sign is mostly painted, like a standard highway sign, and also includes beacons (lights), typically two, which light up or, typically, flash on and off, generally in alternating fashion, to indicate a message is on the HAR. The painted part of the sign informs the traveling public of the radio frequency to tune to. The "SHAZAM" is a term which appears to be unique within the State of Maryland. Most of the ITS industry refers to these simply as "beacons". A SHAZAM is a standalone device operated independently of the HAR it is associated with (although the CHART ATMS helps to tie these devices more closely together). Even if there is a message on a HAR, operators can choose whether to activate any SHAZAMs or not. (Note: DMSs can also be used to inform the public of a message on a HAR. When a DMS is used in this fashion, the message is referred to (within Maryland) as a "SHAZAM message".)

3.24.2 Models

There are two models of SHAZAM supported by the system. The first one supported, the Viking RC2A, was designed to be operated via touchtone telephone. Basically, a person would dial the SHAZAM's telephone number and press one number to activate the beacons and a different number to disable the beacons. This model has long been supported within CHART ATMS using telephony based FMSs. The other SHAZAM model more recently introduced into the system is known as the HWG ER02a. The ER02a by itself is not a SHAZAM at all; it is a simple device that provides network access to two electronic relays. One of the two relays is connected to the beacon circuitry of the SHAZAM being controlled. The beacons themselves are configured within the SHAZAM to be always on, but they need the relay to be closed in order to complete the circuit and cause the beacons to flash. In all respects, the ER02a is the on-

off switch. The other relay is unused. When the SHAZAM is activated in CHART ATMS, CHART ATMS closes the relay that is used to turn the beacons on. Likewise, when the SHAZAM is deactivated in CHART ATMS, CHART ATMS opens the relay which causes the beacons to turn off.

3.24.3 Protocol Handlers

SHAZAM communications are provided at the lowest level by SHAZAM Protocol Handlers. The Protocol Handler encapsulates the specific manufacturer protocols, translating the generic commands from the SHAZAM objects, such as enable beacons or disable beacons, to protocol-specific commands (play DTMF tone requests for Viking SHAZAMs, or TCP messages for HWG-relay-based SHAZAMs), and, in the case of the HWG devices, can also process responses (TCP/IP) and pass success or failure indications back to the HAR objects. In the case of DTMF, the Protocol Handler communicates via a VoicePort acquired from a Port Manager on an FMS by the HAR object and passed into the Protocol Handler.

3.24.4 Communications

As for all other types of devices, when adding a SHAZAM to the system, an administrator can select the model of the SHAZAM being added. Either model, the Viking RC2A or HWG ER02a can be selected. When the Viking RC2A model is selected, Telephony port communications is automatically be selected as the only choice for this model, and the administrators enters the related fields such as the default phone number, access code, port manager connection timeout, and the port manager configuration. When the ER02a model is selected, TCP/IP communications is automatically selected as the only choice for this model, and the administrator enters the IP address and port.

3.24.5 Refresh / Polling

The CHART ATMS provides a refresh feature for SHAZAM devices. This feature allows refresh to be enabled for any SHAZAM and for a refresh interval to be specified. When refresh is enabled, CHART ATMS periodically connects to the SHAZAM and issues commands to set the SHAZAM's beacons to the state currently specified in CHART ATMS (beacons on or off). For the HWG ER02a, CHART ATMS can query the device for the status of its relay (and thus the status of the beacons) to be queried. When doing a refresh for a HWG ER02a SHAZAM, CHART ATMS checks the status of the relay after the refresh command to determine if the relay is set as CHART ATMS commanded it. If not, CHART ATMS sets the SHAZAM's status to indicate a hardware failure. This capability to query is not available for the Viking RC2A, so a Viking RC2A never detects such a problem, and the device is never reported as being in a hardware failure condition.

3.24.6 Alerts and Notifications

CHART ATMS allows alert and notification settings to be set for each SHAZAM, regardless of its model and the type of communications used to control it. Separate values are supported to specify the op center to receive communication failure alerts, the op center to receive hardware failure alerts, the notification group to receive notifications of communication failures, and the notification group to receive notifications of hardware failures. Any or all of these values can be set to "None" to disable that particular alert or notification. When enabled, if CHART ATMS detects a status change related to the given type of failure (hardware or communication),

CHART ATMS creates an alert and assigns it to the specified operations center and/or sends a notification to the specified notification group.

As noted above, only the HWG ER02a SHAZAM model supports detecting a hardware failure. The Viking RC2A never raises a hardware failed condition and therefore setting an op center and/or notification group for those SHAZAMs serves no purpose (although it causes no harm). The alert and notification feature is implemented generically to apply to all SHAZAMs to avoid rework in the future in case support for new SHAZAM models is added to the system in the future.

3.25 TSSs

3.25.1 Background

A TSS is "Traffic Sensor System". This is generally a radar based device when monitors the speed of vehicular traffic passing by. Within the CHART ATMS domain, TSSs are also known as RTMSs (after the model of TSS supported) or more simply as "detectors", or, less frequently, simply as "sensors".

In addition to measuring speed, detectors typically count the vehicles passing by; perform some level of classification (by length) of the various vehicles passing by; and compute a measure of "occupancy" of the highway (percent of time some part of a vehicle is being detected vs. the time no vehicle is being detected). A TSS can perform all these measurements and report results for multiple lanes, on a per-lane basis. In this context, the term "zone" comes into play. Typically (if not universally) each zone represents a single lane of traffic. Zones can be grouped into "zone groups", for instance, local lanes vs. express lanes, or northbound vs. southbound lanes. As this implies, a TSS can be positioned and configured to monitor both directions of traffic simultaneously, or just one direction. In the latter case, typically within Maryland two detectors are positioned at virtually the same point on the map, just across the median from each other and monitoring opposite direction of travel, to provide a complete picture and minimize necessary communications infrastructure (at least historically from the days of wired communications). Each time a TSS is polled, its counts are reset and it starts counting from zero again for the next poll cycle. A TSS is typically polled every five minutes within CHART ATMS.

Note that CHART ATMS can be configured to display a different granularity of data for different users, depending on the user's role and the rules established for the detector by the detector's owner. Some detectors require that only "summary" data be displayed for certain users. Speeds are grouped into "buckets', such as 0-30 mph, 30-50 mph, and 50+ mph. Some users can be granted privilege to see exact speed, and the capability exists to prohibit some users from seeing any data at all (only the existence and operational status of the detector). These rights can be set on a per-detector basis, based on the owning organization of the detectors. Such limitations currently apply only to "external" detectors (not polled directly by CHART ATMS at all, but imported from RITIS).

3.25.2 Models

CHART ATMS supports two models of TSS, both variants of RTMS (Remote Traffic Microwave System) developed by Electronic Integrated Systems (EIS), now owned by Image Sensing Systems (ISS). The two models are the older X3 and the newer G4. The G4 provides information for 12 detection zones; the X3 provides information for 8 zones. The G4 protocol is substantially different than the X3; it is built to support additional traffic parameters (such as gap

(a.k.a. headway)), up to 6 vehicle classes, additional zones, and future expansion. The X3 protocol provides 2 vehicle classes. However, classification data is not collected by CHART ATMS. The only vehicle counts saved and displayed by CHART ATMS are total vehicle counts. The CHART ATMS software allows an administrator to specify whether a TSS is a X3 RTMS or a G4 RTMS. When a detector is polled, volume, speed, and occupancy data is retrieved for each of the zones in use. The CHART ATMS GUI displays 12 zones for G4 RTMS sensors in each place where 8 zones can currently be displayed. All existing rules regarding display of summary data vs. actual data apply to the new additional zones, naturally.

The G4 protocol provides information for 12 detection zones instead of 8 zones like the X3. The G4 protocol is substantially different than the X3; it is built to support additional traffic parameters (such as gap (a.k.a. headway)), up to 6 vehicle classes, additional zones, and future expansion. The CHART ATMS allows the administrator to specify whether a TSS is a X3 RTMS (the "original" RTMS model) or a new G4 RTMS model. When a G4 model is indicated, zone groups defined for the TSS can use zones 1 through 12. When a G4 model is polled, volume, speed, and occupancy data is retrieved for each of the zones in use. The CHART ATMS GUI allows display of whatever zones are collected (12 or 8). All rules regarding display of summary data vs. actual data apply to the full complement of zones.

The data exporter support detectors with up to 12 zones as well. TSS simulation software built into the TSS service also supports simulating data with up to 12 zones from a G4 RTMS.

Raw traffic data is logged directly to the live CHART ATMS database. This is done for both the X3 and G4 models and for up to 8 or 12 zones of data as appropriate. Archive jobs move the TSS raw data from the live CHART ATMS database to the archive database.

3.25.3 Protocol Handlers

TSS communications are provided at the lowest level by TSS Protocol Handlers. The Protocol Handler encapsulates the specific manufacturer protocol, translating the generic commands from the TSS objects, such as polling for latest traffic statistics, to protocol-specific commands. Historically, these were transmitted to the device via a communications port acquired from a Port Manager on an FMS by the TSS object and passed into the Protocol Handler, but now all TSS communications are accomplished via TCP/IP, so communications are conducted directly between the Protocol Handler and the device controller. The Protocol Handler also processes responses and pass responses success or failure indications back to the TSS objects.

3.25.4 Communications

All CHART ATMS detectors use TCP/IP communications. This is accomplished via RavenX wireless modems that make all detectors appear to be hardwired TCP/IP nodes. Communication via POTS or ISDN modems or via direct RS-232 connection is technically supported by the system, but is no longer tested, and FMSs which would be necessary to employ such communication are no longer deployed.

3.25.5 Polling

The TSS Service used to run a Built-in Test (BIT) based on the receipt of a bad health bit during data polling. However, the G4 RTMS does not populate this health bit, and the manufacturer has recommended against this practice even for the X3 RTMS. For one thing, for both models, running BIT halts data collection for about 20 seconds (vehicles are not detected). As a compromise, the system can be configured to poll TSSs automatically once a night. A system-

wide TSS BIT execution time (expected to be during early morning hours, e.g., 3:00 in the morning) can be configured into the System Profile. Each TSS can be individually configured to run or not run BIT at the scheduled time. This facility is rarely used. Typically only flaky detectors are configured to run BIT, and most normally operating detectors are not.

To support multi-drop capability, the CHART ATMS software groups the polling of TSSs that use TCP/IP communications and have the same IP address and TCP port, or the same phone number. During the polling cycle, each detector that shares the same connection or phone number is polled sequentially to avoid having these detectors polled simultaneously, which is known to cause contention issues. During this polling process, detectors are checked to see if they are configured to run scheduled BIT, and if the test has not been run since the BIT time arrived. Any detectors needing to run BIT execute their BIT following data collection.

3.25.6 Configuration

An administrator can configure the map display options for a TSS. These changes can be made regardless of the TSS mode (online, offline, maintenance mode) and can be made to external detectors that have been imported into CHART ATMS as well as native CHART ATMS detectors. The map display options pages allow a user to specify the direction that the arrows for a TSS should be oriented when displaying on the map. The administrator can also indicate if each zone group should be displayed using an arrow that points toward the TSS bearing, using an arrow that points 180 degrees opposite the TSS bearing, or should not be displayed at all. If a TSS has multiple zone groups that are configured to display in the same direction the CHART ATMS administrator may configure their relative display order so that zone groups that represent outer lanes can be displayed further away from the root TSS latitude/longitude position and zone groups that represent inner lanes can be displayed closer to the center.

3.25.7 Map Display

When displaying a TSS on any of the CHART ATMS maps, the system always displays an icon on the map for any TSS that has a defined location. If a bearing has been defined and at least one zone group is configured for map display and the TSS is online the system renders the TSS on the map using an arrow for each configured zone group. The color of each arrow represents current speed for the zone group it represents. If any of those conditions are not met, the TSS is displayed using the same icon that is used in the GUI list pages for the TSS. When a TSS is added to the system, either via import from an external system or via an administrator action, it is added with no defined bearing. This implies that the system displays the TSS on maps using the list icon until an administrator manually sets the bearing. The system inspects the TSS route direction from its location settings and also inspects the direction of each configured zone group, and sets the display type to primary if the direction matches, to opposite if the direction is opposite, or sets the “do not display on maps” if the direction of the zone group is neither the same nor opposite the direction of the TSS route. The system does not attempt to default the display order if there are multiple zone groups in a single direction. Using this algorithm an administrator normally should need only set the TSS location, zone group directions, and then bearing in order to get the TSS to properly display on the map.

If external systems do not provide the route direction location information for an external TSS that has been imported from RITIS, in order for the external TSS to display properly on the map with traffic flow arrows, the CHART ATMS administrator must set the TSS bearing, then set the display type (primary, opposite, none) for each zone group in order to get the TSS to display

properly using arrows. This needs to be done only once per imported TSS. Once the TSS has been imported, it is stored permanently in the CHART ATMS database, and the CHART-specific TSS display settings are also stored there in the CHART ATMS database.

3.25.8 Key Design Decisions

Because there are many TSS objects that need to be rendered on maps, performance related decisions were key in the design of this feature.

- In order to avoid overloading the mapping server, the TSS objects are rendered client side.
- Because there would be over 400 TSS objects to render when viewing the entire state and surrounding areas, and because browser recommendations are that no more than 50-100 markers should be rendered client side (both to avoid clutter and to avoid CPU overload on the browser machine), the system allows the TSS layers to be visible only at configured map scales (zoom levels).
- Because the client browser has to request the data used to render the TSS objects using AJAX requests that return data in JSON format (ASCII Text), which the browser must parse into JavaScript objects, it is important to limit the size of the JSON documents being returned to the browser each time the user needs their map display updated. To that end, the system request JSON only for objects within the visible display area of the user's current map. This means that when a user pans the map to include a previously unviewed area, or zooms the map out (so that more area becomes visible around the previously viewed area) there is a delay of the appearance of the newly exposed TSS objects while the JSON data for the objects in the newly visible area are retrieved from the web server, parsed, and rendered.

3.26 Field Communications

3.26.1 FMSs

CHART ATMS was initially designed, going back to R1B2, to support communications via separate field servers known as FMSs (Field Management Stations, or, sometimes, Field Management Servers). FMSs were used for all communications to all DMSs and TSSs, via either POTS or ISDN modems, or direct RS-232 connections. In R1B3, support was added for HARs and SHAZAMs using a new port type, known as a Voice Port, provides access to a port on a Dialogic telephony board installed in an FMS server. The software which runs on an FMS is known as a Communications Service (Comm Service or CommService for short). A Comm Service hosts a Port Manager which manages the allocation of ports to device services that need them.

At this point no ISDN or POTS modem-based or RS-232-based FMS Comm Services still exist. All DMS and TSS communications are accomplished via TCP/IP. The device is configured within CHART ATMS to use TCP/IP communications, and the CHART ATMS backend service communicates directly with the device over the network and does not utilize a port manager at all, as used to be done for POTS, ISDN, and direct connect RS232 communications. TCP/IP device communications bypass the FMS servers and the CHART ATMS Communications Services entirely. SHAZAMs likewise have been entirely converted over to HWG ER02a devices that are also communicated to directly via TCP/IP. A few DR1500 HARs employ direct TCP/IP communications; however, many HARs still employ FMS telephony communications.

Communications servers are used in CHART ATMS to connect to HAR devices deployed throughout the state of Maryland. A communication server is outfitted with one or more pieces of communications hardware, such as Dialogic telephony cards, or (formerly) Integrated Services Digital Network (ISDN) and Plain Old Telephone System (POTS) modems. Each communications server in the system contains a PortManager software object through which access to the communications resources is granted.

3.26.2 FMS Description

In order to provide for reduced recurring telecommunications costs, the FMS servers were located in environmentally-controlled facilities (e.g., Closed Circuit Television [CCTV] vaults) within the same or an adjoining Verizon Central Office (CO) service region as the devices with which they normally communicated. In addition, communications between the FMS server and the field devices was provided via Integrated Services Digital Network (ISDN) Centrex service or local POTS. In this manner, any number of calls could be placed between the FMS server and the field devices at a fixed monthly recurring cost.

FMS server component communications were aggregated within a given Local Access Transport Area (LATA) via Verizon Frame Relay services to the local MDOT node. This data was then transported using the MDOT backbone to a CHART ATMS server site. This use of the MDOT backbone greatly minimized recurring telecommunications costs for the CHART Program.

3.26.3 Port Manager

A Port Manager is a software object that manages access to the communications hardware on a Communications Server. The HAR or SHAZAM software object acquires a voice port from one or more Port Manager objects. HAR and SHAZAM objects use voice port objects to command HAR and SHAZAM devices via DTMF. HAR software objects use voice port objects to play recorded voice or voice converted from text to a telephony-based HAR device so that it may be used by the HAR device for broadcast over the HAR's radio frequency. The HAR software object also uses voice port objects to connect to a HAR device's monitor telephone line and record a portion of the message that is playing to allow a CHART ATMS operator to verify that the correct message is playing.

3.26.4 Voice Port

A voice port provides access to a port on a telephony board. The voice port is capable of providing software access to analog telephone lines for the following purposes:

- Playing a voice file over a telephone to a device
- Recording voice received from the device over a telephone
- Sending DTMF signals
- Receiving DTMF signals

VoicePortImpl class implements the VoicePort class, which extends the Port interface. It implements the VoicePort connect method to open a port on a telephony board and make a telephone call. It also implements the VoicePort play and record methods to play and record 8 bit sound files on the connected call. Additionally, it also provides the capability of generating DTMF tones to command devices.

3.26.5 Voice Port Locator

Voice Port Locator is a utility class that extends the implementation of a PortLocator class to retrieve a VoicePort from a PortManager. The PortLocator class implements failover for clients of PortManagers.

3.26.6 Port Status

CHART also provides the capability to view the status of communication ports. Events are pushed using the CORBA event service to inform the interested parties of any changes to the port status.

3.27 CCTV Camera Display

3.27.1 Background

CHART provides management and control of video. CHART cameras can be displayed on CHART monitors, and also directly on users' desktops. Cameras which are controllable are controllable directly within CHART ATMS, rather than having to use this manufacturer's software for some cameras, other manufacturer's software for other cameras, etc. CHART ATMS provides a common look at feel for all camera control, regardless of the specific model of camera being controlled. Features that are not available for a specific camera due to camera limitations are grayed out or not displayed at all.

SHA CHART cameras are attached to the CHART network using IP based video encoders. Likewise, the SHA monitors are attached to the CHART network using IP-based MPEG-4 video decoders. Maryland Transportation Authority (MDTA) cameras and monitors are attached to one of two Vicon V1500 Video Switches (one at the Fort McHenry Tunnel (FMT) and one at the Baltimore Harbor Tunnel (BHT). MDTA cameras and monitors as also attached via MPEG-2 video codecs. CHART incorporates the MDTA Vicon V1500 video network into CHART ATMS by controlling the switches directly. CHART ATMS also manages the limited number of video connections between the CHART IP network and the MDTA V1500 network. Also, CHART ATMS manages the limited number of connections between the two MDTA video switches. By combining these technologies, CHART ATMS allows operators to display MDTA and CHART cameras on MDTA and CHART monitors. Each of these technologies, MPEG-4, MPEG-2, and the two Vicon V1500 switches, provide separate video "networks" referred to within CHART ATMS as video "fabrics".

This functionality was originally included in Release 3.0 of the Asynchronous Transfer Mode (ATM) Video Control Manager (AVCM), the predecessor system to CHART ATMS's video system. In fact, the C++-based AVCM V1500 Manager Service, originally developed and deployed with AVCM, is still being used by CHART ATMS to communicate with the V1500 switch. This module has been reused completely, wrapped in Java, and incorporated into CHART ATMS. CHART ATMS also provides a "video router" to manage the limited number of video connections amongst the disparate video fabrics. Note that the need for the video router has been greatly reduced by the use of "transcoding" video signals into multiple formats at (near) the source (camera).

3.27.2 Codec Video Display

CHART ATMS provides the capability to command CoreTec MPEG-4 decoders, Impath MPEG-2 decoders, or Impath H.264 decoders for the purpose of displaying video. The CoreTec decoders are controlled directly via Distributed Component Object Model (DCOM). The Impath MPEG-2 decoders are controlled using an SNMP based interface over TCP/IP. The Impath H.264 decoders are controlled using HTTP over TCP/IP. CHART ATMS switches the multicast address and port on the decoders to point to the multicast address and port of the corresponding encoder of the same variety.

3.27.3 Video Router

The CHART ATMS video router is utilized whenever an operator makes a request to display a video source (camera) that is part of a video fabric on a video sink (monitor) which is a part of a different video fabric. The purpose of the router is to manage display requests across the limited number of "bridge circuits" between video fabrics in order to minimize the number of required bridge circuits. The router makes unused bridge circuits available for display requests, guarantees a certain number of cross-bridge circuit images be available to high priority Monitor Groups, and minimizes the effects of overriding an existing bridge-circuit image in favor of a higher priority display request that must use a bridge circuit.

A "bridge circuit" is a mechanism by which video can be translated from one video fabric to another. For instance, an MPEG-4 encoder connected to an output port of a Vicon V1500 video switch can be used to route video from a V1500 fabric to the MPEG-4 fabric. Likewise, an MPEG-4 decoder connected to an input port of a Vicon V1500 video switch can be used to route video from the MPEG-4 fabric to the V1500 fabric.

The video router determines the best route to fulfill the display request and fulfill that request if possible. The C++-based video router has been re-used from AVCM and wrapped within Java. The computation of routes remains largely unchanged from AVCM. This design assumes there is only one video router in the CHART ATMS. If the video router is unavailable the images may not be displayed across bridge circuits.

The router design uses graph theory and set theory to build the set of routes that are available in the system. The video router maintains a set of all possible video routes. The video routes are the set of all paths through a directed graph consisting of a set V that contains all video fabrics defined in the system, a set E that contains all bridge circuits defined in the system (G(E,V)). The algorithm computes all paths from each video fabric that is an element of V to all other video fabrics that are an element of V using the bridge circuits that are elements in E, ensuring there are no cycles in the routes.

Through the use of transcoding of video camera images into multiple formats at (or near) the source (camera), the need for the video router has been greatly reduced. The most obvious use of the router now is for displaying SHA cameras at AOC Central. The video router is also necessary for moving MDTA camera images from the BHT video fabric to FMT monitors and vice versa.

3.27.4 Image Display Override

Due to the limited number of connections (bridge circuits) that exist between video fabrics, it may not be possible to complete all image display requests as the required bridge circuits may already be in use. CHART ATMS manages this by enforcing the business rules described below

and either override an existing image display or reject the image display request. These business rules are based on the business rules employed by AVCM.

AVCM made use of a site concept to articulate these business rules. In this context, a site is defined as a collection of equipment including monitors and workstations at a location. Because multiple operations centers can be based at the same physical location, an operations center is not exactly the same thing. Because there is no exact equivalent of a site in CHART ATMS, the CHART ATMS monitor group concept is utilized instead. An operator logs into an operating center, which has a default monitor group which normally represents the monitors that the operator can actually see. This means that monitor groups have an associated priority as well as an associated number of guaranteed inter-video fabric images.

Certain monitor groups are configured to have a guaranteed number of slots (cross-bridge-circuit image displays). An operator whose chosen monitor group is allocated a guaranteed number of slots and is not already using all of those slots will always be granted an image display request. If there are no freely available bridge circuits to accommodate this request, a bridge circuit will (with the requesting user's approval) be made available by overriding (removing) an existing image display in order to provide the guaranteed number of slots.

The following rules apply when CHART ATMS is selecting an image display to override. In the context of these rules, 'image' is an image being displayed over a bridge circuit when that image is being considered for override:

1. Guaranteed number of slots for certain monitor groups. Select an image in a monitor group displaying more than their guaranteed number of images over monitor groups that are not displaying their guaranteed number of images and over monitor groups that have no guaranteed number of images.
2. Monitor group hierarchy. Select an image being displayed at the lowest priority monitor group.
3. Total number of images displayed. Select an image that is only displayed on one monitor over an image that is displayed on multiple monitors.
4. Override an image from a camera that is not controlled.
5. Override the oldest connection.

These rules allow the following:

- A few high priority monitor groups can be configured to have guaranteed access to a configurable number of images from another video fabric.
- If any bridge circuits are not in use, they are made available for any image display, regardless of the priority of the requesting operator's monitor group.
- A high priority monitor group cannot accidentally use up all bridge circuits making them unavailable to other monitor groups. Images above and beyond the guaranteed amount are available for other lower priority monitor groups to override (oldest first).

When the system determines that an image override is required in order to fulfill an image display request, CHART ATMS employs logic similar to camera control override. A notification is sent to the operator requesting a cross-switch-fabric display providing information that a currently active image display will need to be overridden to fulfill the request. The notification provides the potential impacts of doing the override (e.g., which image displays are expected to be overridden if the operator chooses to override). The operator can then decide if the override should proceed. The actual impact is determined at the time the override is completed and the results are provided to the operator in the completion response. The actual

impact may be different from the original list of potential impacts due to the dynamic nature of the system. The override process attempts to display a "No Video Available" image on each monitor that is overridden. This requires a "No Video Available" source to be present on each video fabric.

3.27.5 Video Display Enhancements

Later updates have enhanced CHART ATMS video services. Administrators can now configure multiple video sending devices for each camera. This ability allows correct, clean use of transcoding video signals to avoid use of the video router. Use of multiple sending devices eliminates the old practice of creating multiple camera devices to display images from a single camera in different formats. This practice led to confusion and conflicts over video control. At the same time the ability to enable and disable public flash video streams came into existence. Disabling public flash video streams was colloquially known within CHART as using "the kill switch" or "the red button". Further enhancements have allowed any video stream to be disabled (or re-enabled), not just public video streams.

When a camera is added or edited, CHART ATMS provides links to add, configure, or remove encoders, switches and flash streams. As a link is clicked a table appears for the item being added. There is a separate table for each item type encoder, switch and flash video stream. As additional items are added they are added to an existing table. Each item has boxes that allow an administrator to modify attributes of the encoder, switch or flash video stream. Each item has a remove link that allows the administrator to remove the item from the table. Once the edited video source page is submitted, the video sending devices and flash video steams will appear on the video source page under the configuration section.

To display an image on a monitor, the system makes connections between video sources and video sinks by selecting receiving devices and sending devices on the same fabric if possible. If the monitor is not on the same fabric any of the camera's sending devices, the system uses the video router to look for a bridge circuit that will attempt to provide the needed route.

Flash video streams designated as "public" that are associated with a camera are automatically disabled as Block to Public is executed. The user simply clicks the Block to Public Monitors link and all public flash video stream configured are blocked along with the public monitors. Public flash video streams are automatically enabled as Unblock to Public Monitors is executed. The public flash stream, as well as others, can also be enabled and disabled directly.

3.27.6 Desktop Video

To display desktop video, the CHART ATMS GUI makes use of a camera's Flash video stream that has already been configured in one of the several Streaming Flash Servers (SFSs) used in the CHART ATMS using the SFS software. (Also note that a camera stream must be configured in the Transcoding Server to encode the image for use by a Streaming Flash Server). Examples of SFSs include: Internal, Public, SwGI, and Mobile. A given camera may have streams set up in some or all of the SFSs. A camera must be configured in CHART ATMS to specify which of the SFSs have streams representing it in order for CHART ATMS to support desktop video for that camera. At present time, each instance of the GUI uses only one specific SFS, so a camera is viewable only if it is configured for that SFS.

CHART also supports "Flash Only" cameras – cameras which are not transcoded at all within CHART, and may not even be CHART entities. For instance, cameras from Maryland counties could be added to CHART, with video streaming servers owned and maintained by the counties

in place of CHART SFSs. The CHART ATMS supports any number of video streaming servers per camera.

3.27.7 Video Sessions: Limiting and Tracking Desktop Video Usage

The concept of a "video session" is used to track and limit usage of desktop video. A video session represents the potential use of the network resources to stream a single live camera image, and can be thought of as a single video window that is open on a user's desktop. In an attempt to limit the network bandwidth usage by desktop video, the number of video sessions is limited per operations center. Each operations center can support only up to that maximum total number of video sessions, counting all sessions that all users logged into that center can have open. Before opening each video window, the system checks to make sure that the resource limit has not been exceeded. Once the initial resource limit check is made, the user can stream video without checking the resource limit again as long as that video window is open (regardless of whether video is actually streaming or not). An administrator can end a user's video session to free up system resources, which causes the video to stop streaming. Video sessions also provide status tracking information, and users are able to see who is viewing which cameras and tours via desktop video. In case for some reason a user's browser or the GUI servlet should fail to release the video session when a video window is closed, there is resource cleanup logic at both the GUI servlet level and at the CHART ATMS service level to make sure resources are released after a configurable timeout. If operations center's desktop video limit is reduced during operations to a point below the current usage, all current sessions are allowed to continue; however, no new sessions can be opened until the total for that operations center is below the new limit.

Video sessions are managed by the Resources Module (User Management Service) rather than by the Video Service, to simplify logic and reduce potential failure conditions that could occur. It might seem that video sessions should be managed by the Video Service, but what they really represent is network usage and they are completely independent of all of the types of objects hosted by the Video Service. Video sessions are really a negotiation between the GUI and Resource Management, as it is the GUI that is using the network resources and the Video Service does not need to be involved.

3.27.8 Camera Image Revocation

A suitably privileged operator shall have the ability to revoke a camera image from any monitors owned by a particular organization. Furthermore the camera image may be revoked from any number of owning organizations.

When a camera image is revoked from an organization, any monitors owned by that organization that are currently displaying the camera image will have a "No Video Available" image placed on the monitor. A camera that is revoked will not be available for display on monitors owned by revoked organizations until such time that they are un-revoked by a suitably privileged operator. Multiple organizations may be revoked for camera image display at one time.

Monitors in CHART ATMS can be designated as "public" monitors. These are typically monitors associated with media outlets, such as television stations and traffic reporting services. A camera image may be blocked from the public at any time. Any monitors designated as public monitors may have their camera image revoked by a suitable privileged operator who chooses to block the camera image from the public. The image on the monitor is replaced with a "No Video Available" image if possible (otherwise the screen goes black). A camera that is blocked from

the public will not be available for display on public monitors until such time that it is unblocked by a suitably privileged operator.

3.27.9 Blocking / Unblocking and Video Stream Status

Likewise the flash video associated with cameras can be blocked, either by blocking to public, or by blocking to specific organizations.

The Block / Unblock Camera To Public functionality affects only video streams designated as "public". Non-public SFSs are not affected by these "public" commands, although any flash stream associated with a camera can be blocked or unblocked via a separate command on an individual SFS basis (regardless of whether the SFS is public or not).

Currently the SFS software API does not support querying the existence or the blocking status of the camera streams within the SFS. As a result, CHART ATMS maintains its own status information for each camera stream within an SFS. To maintain the accuracy of this status, it is has to be assumed that blocking of a camera's stream is done only via CHART ATMS. The SFS software provides this capability as well, but it should never be used for this purpose. Should the status get out of synch, the workaround (using CHART ATMS) would involve issuing a block (or unblock) command to the individual SFS to get it back to a known state.

Blocking a camera to a given organization affects desktop video usage for the organization associated to the operations center at which the user logged in. If the matching organization is blocked, the users logged into that operations center are not able to view desktop video.

3.27.10 Video Tours

A video tour is a list of cameras (optionally with presets specified), which can be run on a physical monitor or via Flash. Note that cameras are prevented from moving to presets too rapidly while running a tour, in order to reduce wear on the camera's Pan/Tilt/Zoom PTZ motors. If a tour is running only on one monitor (or desktop), this generally does not come into play, but if a tour is running in multiple locations, each tour runs on its own clock, and the tours may be entirely out of phase with each other. This could have the effect of limiting or even preventing cameras from moving to presets within the tour, for any cameras which appear in the tour with more than one preset.

A user can view preconfigured (persistent) video tours via desktop video, with a couple of limitations. First, only cameras that have video streams configured for the GUI's assigned SFS are included in the tour. Second, any camera presets configured for the tour are ignored. (The use of presets would require camera communications, and multiple users viewing tours with presets would have the potential to cause serious communication problems with the cameras. Also, using presets with desktop video would have required precise timing between the application of the preset and the desktop video buffering in the GUI, which may not even be feasible.)

The video from multiple cameras in the tour is buffered one at a time, so that there is a slight delay when switching between camera streams. Because buffering is done one camera at a time, viewing a tour counts as a single video session with respect to the operations center resource limit. (More sophisticated buffering that could eliminate the delay, but would require use of two video sessions: one being actively viewed, and one buffering up the next video stream in the background.)

Normally only one instance of a camera is allowed on a desktop; however, desktop tours are permitted to contain the same camera as an existing desktop session – even if it is the only camera displaying in the desktop tour.

3.28 CCTV Camera Control

3.28.1 Models

CHART ATMS provides PTZ control of three types of cameras: Cohu 3955 (and other compatible models, such as the Cohu 3960 and Cohu 3965), the Vicon SurveyorVFT (also known as the SurveyorVFT, S2000, or S2K), and any suitably compliant NTCIP camera. The term "PTZ" in this context refers to not just panning, tilting, and zoom, but also other similar functionality.

As for other devices, a "protocol handler" has been written to support each camera model. A protocol handler handles the translation from application level actions such as Pan and Zoom to camera commands that the camera understands, to be delivered to the camera controller. Re-use has been incorporated where possible. For instance, the NTCIP camera protocol handler re-uses utility code that shared by protocol handler code that manages NTCIP communications to DMS devices.

3.28.2 Encoder Camera Control

CHART ATMS provides the capability to use CoreTec MPEG-4 encoders or iMPath MPEG-2 encoders to route the communications necessary to control the cameras from the CHART ATMS to the camera, and route responses back to CHART ATMS. A TCP/IP connection is established between the CHART ATMS server and the encoder and all camera commands and responses are exchanged over that socket.

3.28.3 Command Processor Camera Control

When the Vicon SurveyorVFT was added to the system, it was anticipated that the SurveyorVFT cameras would be commanded directly over an RS-232 port, and that multiple SurveyorVFT cameras may be attached to a single RS-232 port. Although this is no longer the case, the "Command Processor" developed for this purpose still exists within CHART ATMS, and could potentially be resurrected (although it is no longer tested)

The "Command Processor" was developed to provide CHART ATMS an ability to maintain a connection to an RS-232 port that can communicate with all Vicon SurveyorVFT cameras. It managed the commands sent to the cameras as transactions in a queue and each transaction would be serviced on a first in/first out (FIFO) basis. All Vicon SurveyorVFT cameras were be homed to a single server for this purpose (although the design could have been easily adapted to allow for multiple servers). The design also allowed for SurveyorVFT cameras to be controlled from multiple RS-232 ports on a server. At this point, CHART ATMS is a single server system, so all Vicon SurveyorVFT cameras are naturally on the same CHART ATMS server (although they no longer need to be for control purposes).

3.28.4 COM Port Camera Control

CHART ATMS also includes an ability to control a camera directly connected via a COM Port. This is used only for internal testing (and also for the NTCIP Camera Compliance Tester).

3.28.5 Viewing a Controlled Camera Image

For many years within CHART, prior to the introduction of desktop video, the CHART ATMS required a camera to be displayed on a local monitor (a monitor in the operator's monitor group, generally based on the operator's operations center) before the operator was allowed to gain PTZ control of the camera. Now with desktop video, if the camera is not already displayed on a local monitor when the user requests control and provided the camera is eligible for streaming, a desktop video session is automatically opened for the user so that they can see the effects of the control operations on the camera. Note that flash video lags on the order of three seconds behind live, so controlling a camera while monitoring it via flash is challenging, especially for the uninitiated.

Similarly, if a camera control session contains the camera's video and that same camera is later put on a local monitor, the user is then allowed to remove the desktop video session from the camera control session.

As it is with local monitors, for the purposes of camera control, a camera in a desktop tour does not satisfy the requirement that a user be able to view a camera before obtaining control. This is true even if the camera is the only one displaying in the desktop tour.

3.28.6 Pan, Tilt, Zoom, Focus

All models support these basic functions. However, for the SurveyorVFT there is no capability to programmatically toggle between auto and manual focus. The SurveyorVFT goes to manual focus mode if it receives a Focus Far or Focus Near command. It goes to auto focus mode if it receives a Zoom command

One area where control of NTCIP cameras differs from the Cohu and Vicon camera models is that the NTCIP protocol requires a speed parameter on every movement command. Rather than supporting variable speed movement via GUI controls, the approach is to allow default speed values to be set for each camera for each of 4 movements: pan, tilt, zoom, and focus. Each camera has one speed setting for Zoom and one speed setting for Focus. A single speed value for Pan and Tilt is not sufficient; however, because when zoomed in one needs the camera to move much slower than when zoomed out. A pan or tilt speed which is slow enough to be usable while zoomed all the way in is agonizingly slow when zoomed all the way out. To address this, there are two speed settings for each camera for Pan (minimum and maximum), and two settings for Tilt (minimum and maximum). When a pan or tilt operation is performed, CHART ATMS determines the speed to use on a percent-zoomed basis, based on the minimum and maximum speed settings and the current zoom level of the camera. Two additional settings, minimum zoom value and maximum zoom value also need to be configured for each camera to allow for this zoom based variable speed behavior.

3.28.7 Message Setup

The SurveyorVFT does not provide a software interface for setting camera and preset titles. This is done through the programming menus as described in the SurveyorVFT Camera Dome Programming Manual. CHART ATMS is programmed to execute pre-compiled macro commands that navigate through the menu, picking letters one at a time, in order to provide titling capabilities. This was very tedious, and it could take up to two minutes for a titling operation to complete. As noted earlier, execution of those macros use code that is reused from AVCM and called from CHART ATMS. In practice, this capability has been proven unreliable, so has been disabled. The SurveyorVFT does not provide a software interface for setting the

titles to either the top or the bottom of the display or for enabling or disabling the titles. These capabilities are provided through the programming menus of the SurveyorVFT as described in the SurveyorVFT Camera Dome Programming Manual. CHART ATMS provides a capability to access the SurveyorVFT programming menu.

3.28.8 Saving and Moving to Presets

The CHART ATMS provides the capability to store and move to preset positions (i.e., pan, tilt, zoom, and focus) for all camera types. This includes not only the preset but an associated title to be displayed on line 2 of the camera display. Also, when a camera is no longer displayed on any monitor, the camera is moved to a default preset, if a default preset is programmed.

CHART ATMS gathers the raw pan, tilt and zoom values when saving and setting preset positions for all camera types (Cohu 3955, Vicon SurveyorVFT and NTCIP cameras. CHART ATMS saves the values in the database when a preset is saved. However, this raw values are not used to command the camera to move. For all camera types, the preset location (PTZ) is stored on the camera itself, and the camera is commanded to move to a specific preset number. The camera then looks up the PTZ values within the camera controller, and moves to the indicated position.

For the Cohu and NTCIP cameras, the CHART ATMS then commands the camera to set the appropriate preset title on line 2 of the camera. The SurveyorVFT stores this title text with the preset, and displays the title directly. Although the SurveyorVFT may be commanded to move to a raw preset, there is no way to access line 2 of the camera title directly. The only way to access line 2 of the title is by associating it with a preset through the camera menu system. The SurveyorVFT menu system can be used for storing presets and titles. The method by which SurveyorVFT titles are stored on the camera, however, is not computer-friendly. Although it works reasonably well in a lab environment, in the field environment it has proven to be unreliable, so has been disabled. Titles can be stored manually using the SurveyorVFT menu system directly, if desired.

3.28.9 Color Gain

The SurveyorVFT does not provide a software interface to adjust the color gain of a camera. The color gain is accessed through the programming menus of the SurveyorVFT as described in the SurveyorVFT Camera Dome Programming Manual. A suitably privileged operator can activate a programming menu for color gain and then back out. The SurveyorVFT programming menu is accessed by executing pre-compiled macros re-used directly from AVCM. Execution of those macros uses code that is re-used from AVCM and called from CHART ATMS.

Note that the macros are used to set the proper camera color gain mode (automatic or manual) and to adjust the color balance itself.

3.28.10 Camera Power

The SurveyorVFT does not provide a software interface to power the camera on and off. For the SurveyorVFT, the power indicator indicates if the receiver is online or offline. The camera is considered to be online when it responds to a status query. Otherwise, it is offline.

3.28.11 Lens Speed

The SurveyorVFT does not provide a software interface to retrieve the current lens speed of the camera. The SurveyorVFT has 3 lens speeds – slow, medium, and fast. CHART ATMS

provides an interface to toggle the lens speed but does not provide feedback as to the current setting of the lens. The SurveyorVFT camera can be programmed to enable the lens title with fade control enabled for the lens title. If enabled, this provides feedback to the operator on a monitor where the image is displayed when the lens speed is toggled; then that indication fades from the image. See the SurveyorVFT Camera Dome Programming Manual for details on how to enable the lens title and how to enable fade control for the lens title. The lens title may also be positioned anywhere on the display.

3.28.12 Reset Camera

This issues a factory reset command to the camera. The camera does not respond to control commands while it is resetting itself. Depending on the camera, this can take up to 2 minutes.

3.28.13 SurveyorVFT Programming Menu

Many configuration capabilities of the SurveyorVFT camera are provided through the programming menus of the SurveyorVFT as described in the SurveyorVFT Camera Dome Programming Manual. CHART ATMS provides an interface that a suitably privileged operator can use to activate the programming menu. The operator navigates through the SurveyorVFT programming menus by looking at the monitor(s) displaying the camera image. Although automatic titling using pre-compiled macros has been disabled, a suitably privileged operator can use the programming menu manually to accomplish this.

3.28.14 Camera Control Revocation

A suitably privileged operator shall have the ability to revoke a camera control from any operators whose chosen (or default) monitor group is owned by a particular organization. Camera control may be revoked from any number of owning organizations.

When camera control is revoked from an organization, any active camera control sessions initiated by operators whose monitor group is owned by the revoked organization are terminated. A camera that is revoked is not available for control by operators with monitor groups that are owned by revoked organizations until such time that they are un-revoked by a suitably privileged operator. Multiple organizations may be revoked for camera control at one time. If an operator is controlling a camera by virtue of desktop video display, control is revoked based on the operator's operations center's owning organization.

3.29 Notification Services

The CHART ATMS notification service provides three major functions: the ability to send notifications (manually via operator request, or automatically when certain conditions occur), to view notification history, and to manage contact groups and individuals.

3.29.1 Send Notification

The CHART ATMS provides users with the capability to issue (send) notifications. A notification is important information sent to an individual person or a group of people. Users with the appropriate rights can send notifications using the GUI. These notifications can be created in standalone mode or as part of a traffic event. When creating the notification, the user selects recipients and provides a text message, possibly using provided available shortcuts. If the notification is being created from within the context of a traffic event, many shortcuts are available to help create the text of the message. For instance, the user can ask the system to

suggest a message, or the user can, with one click, add text to describe specific characteristics of the event, such as its location, or lane closure information, or the user can select a and paste in a facility name (such as BHT or FMT). The sender's initials are automatically appended to the message. The user must input the appropriate initials once per login-session, and the initials are remembered from that point forward. The recipients consist of individuals and/or groups that are configured within the CHART ATMS System Profile.

The CHART ATMS also provides the ability for subsystems of the CHART ATMS itself to send notifications, automatically, when trouble or other noteworthy information is acquired. For instance, notifications can be sent when device failures are detected, when external connections problems are detected, when toll rates expire or are not received on the expected schedule, when CHART ATMS services are failed or are automatically restarted by the CHART ATMS watchdog, when travel times exceed expected levels. All of these are configurable. For some notifications, such as external connection failures and device hardware failures, the CHART ATMS can also be configured so that notifications are also sent when the condition that caused the notification to be sent clears up. One other type of automatic notification that can be sent is administrators can specify that a notification should be sent if an incoming external event comes in that meets certain criteria (such as on I-95 or I-495 above a certain latitude and all lanes closed). (Although such can be a sign of traffic trouble as in this case, this is not a trouble condition within the system, in the same sense as induces other automatic notifications.)

The CHART ATMS notification service sends the notifications via an SMTP mail server. All notifications are sent from CHART ATMS via email. Some users may have the ability to receive a text via a specially configured email address from the cell phone provider, but CHART ATMS sends them out via email. Pages could be sent out the same way.

The notification service uses the JavaMail API for sending e-mail via SMTP. The notification service supports primary and backup email server configurations. The server configurations consist of an IP address, port, name, password, and SMTP_AUTH configuration.

3.29.2 View Notification History:

CHART ATMS users have the ability to view notification histories for all online notifications. The users are able to browse notification statuses either page by page or with direct page access.

Notifications that have existed in the system longer than a system-prescribed time are taken offline. Those notifications that are too old are marked as offline and are no longer be visible in the CHART ATMS. Notifications associated with traffic events are not taken offline until their corresponding traffic event is taken offline.

3.29.3 Manage Contact Groups and Individuals

A notification contact is either an individual or an agency. Notification contacts are composed of a name, email address, and timestamp which indicates when the contact was added or updated. The key design difference between an agency and individual is that an individual has a first and last name, while an agency has a single name. Notification contacts can be a member of 0 or more contact groups.

Notification groups provide a means for grouping notification contacts. Groups can contain 0 or more notification contacts. Notification contacts and contact groups are stored directly in the CHART ATMS database. Minor IDL changes are required to allow the display of a contact's e-mail address within CHART ATMS to allow contacts to be agencies rather than individuals, and support CRUD functionality of notification objects.

The email notifications sent out can include an informative subject in the notification, based on the notification type, as provided by the calling services. In addition, the subject line contains a configurable prefix. Currently subject lines for notifications are administratively disabled within the CHART ATMS, because different text services count email subjects differently in measuring a text against the service-specific text size limitation (e.g., 140 characters). However, the CHART ATMS is able to configure these subject prefixes as follows:

- Device notifications include the device type, name, and device status in the subject line
  - <Device Type> <DeviceName> <Status Type>
- External event import notifications include "External Event Imported" in the subject line.
- External connection notifications include the connection name and the status type
  - <External System> - <Status Type>
- Watchdog notifications include the service name and an indicator the service was restarted.
  - <Service Name> @ <Site> <Info>

A separate log file is written by the notification service regarding the sending of notifications. This log file contains communications information between the mail server and the notification service and the text of all messages sent. Additionally, the traffic event history log includes the contents of the notification and the configured recipients.

3.30 Alerts

CHART ATMS also provides the capability to create and manage alerts. The following alerts can be generated:

- Unhandled controlled resources
- Device in hardware failure or communication failure
- Duplicate traffic events
- Traffic event not closed by a specified time
- Time to execute actions specified in a schedule
- External connection failure (or warning, if configured)
- Incoming external event detected to meet alert criteria (roadway, % lanes closed, etc.)
- Service detected failed or restarted by watchdog
- Toll rates expired or missing
- Travel time exceeds alert threshold
- Manual, operator-initiated alerts

Each alert has a state, and alerts can transition from state to state during their lifetime. The alert states are: new, accepted, closed, and delayed. The accepted and delayed states are time-limited. Accepted and delayed alerts which have been in that state too long (beyond a certain "reminder time") are returned to the new state automatically. Alerts in the new, accepted, or delayed state will not be duplicated. That is, if condition which caused the alert clears, then occurs again, another alert with the exact same details is suppressed as long as there is already an alert in the new, accepted, or delayed state. If conditions are oscillating, causing alerts to occur repeatedly, an alert can be delayed, to suppress the duplicate alerts until the underlying problem is resolved.

The possible actions which an operator can take on an alert are:

- Accept the alert, with an optional reminder time. This moves it from 'new' or 'delayed' to 'accepted' and indicates the accepting operator intends to soon take some action necessary before the alert can be closed. The system moves the alert back to 'new' at the reminder time. If a reminder time is not specified, a default reminder time is used.
- Unaccept the alert. This moves it from 'accepted' to 'new' and indicates the operator has changed his mind and will not soon be working on the alert.
- Close the alert. This moves it from 'new', 'accepted', or 'delayed' to 'closed', and requests if the same thing happens again, issue a new alert for it.
- Delay the alert, with an optional reminder time. This moves it from 'new' or 'accepted' to 'delayed'. This indicates the alert is bogus, not of interest, repetitive, or already handled. The system moves the alert back to 'new' at the reminder time. If a reminder time is not specified, a default reminder time is used.
- Undelay the alert. This moves it from 'delayed' to 'new'.
- Escalate the alert. This requests the alert immediately be escalated rather than waiting until the escalation timeout occurs.
- Provide a comment on the alert. The comment entered by the user appears in the timestamped history log of the alert. All other operator-initiated alert state changes can also be accompanied by an optional user-provided comment (presumably about why the alert is being transitioned to the new state).

Alerts are filtered by alert state. By default, the new alerts are shown; however, the user can easily view alerts in other states (accepted, delayed, or closed). The CHART ATMS home page shows a summary of alerts by state (new, accepted, delayed, or closed). The user can also filter alerts to show those for which they are personally responsible (those which they individually have accepted or delayed), those for which their center is responsible, or all alerts (if they have a special functional right).

Each alert has a history, which can be viewed on the alert's details page. The history shows the state transitions of each alert, indicating who modified the alert and when. A record of all operations centers with visibility to the alert is shown, indicating when each operations center was added to the alert's visibility.

Each operations center is configured to have one or more backup operations centers, to be used for alert escalation. Every alert is initially issued to one or more operations centers (in a future release this may be changed to be one or more AORs). If an alert remains in the new state for more than a configurable escalation time period, the alert is automatically escalated to the backup operations center(s) configured for each of the operations centers the alert is currently issued to. Escalation is forced immediately by the system if no users are logged in with the functional right to manage the alert's type at the currently specified operations centers. Escalation is additive: When an alert is escalated, the list of backup operations centers is ADDED to the list, rather than replacing the current list. In this way the universe of operators available to handle the alert never shrinks because the alert was escalated.

Functional rights include:

- View user's own operations center's alerts (by alert type)
- View all alerts

- Manage user's own operations center's alerts (by alert type)
- Manage all alerts
- Create Manual Alerts

Closed alerts have an expiration time. Closed alerts automatically expire and are removed from the system (like traffic events are) after a configurable period of time, such as 8 hours, for example. Closed alerts do not influence system behavior – i.e., their existence in the system does not suppress generation of new alerts for the same item. If suppression is desired, the delay feature can be used.

The subsystems which use alerts are designed, to reasonable extent, to avoid creation of duplicate alerts. (For instance, for a duplicate traffic event, the newer event is flagged as a duplicate of the older, not vice versa.) Furthermore, the alert manager also automatically detects and deletes duplicate alerts. For instance, a device hardware failure triggers an alert only when the device first transitions into hardware failure, but the alert manager de-duplication process prevents duplicate alerts for a device which is oscillating between OK and hardware failure, or between comm failure and hardware failure (as long as the first alert is not closed). The delay feature can further be used to explicitly suppress certain bothersome repetitive alerts.

All alert data is persisted and depersisted such that restarting an alert manager has no visible effect on the system, once the alert manager returns to full operational status. All alert data, including all history, is archived.

3.31 Travel Routes

A "travel route," as defined in CHART, represents a segment of roadway, usually starting at a DMS and ending at some well known point (an exit number, route number, etc.). CHART ATMS travel routes are used to supply travel time and/or toll rate data to a DMS for inclusion in a traveler information message. Each travel route may have one or more roadway links included. Each roadway link is identified by an ID, which corresponds to a link that exists in the INRIX system, which provides travel time data to CHART. (The system is designed with potential support for multiple travel time providers in mind, however.) A travel route with no roadway links included cannot be used for travel times. Travel routes may also have a toll rate source assigned. Toll rate sources are identified by a beginning and ending ID, which correspond to a toll route in the Vector system, which provides toll rate data to CHART. (The system is designed with potential support for multiple toll rate providers in mind, however.) Travel routes without a toll rate source assigned cannot be used for toll rates.

Travel Routes are the building blocks for "Traveler Information Messages", which are defined within CHART ATMS as messages which provide travel time and toll rate data to the public. In addition to being building blocks for traveler information messages; however, Travel Routes are also useful in their own right, in that they allow CHART ATMS users to view current travel times and toll rates. For display on DMSs, travel times can be constrained to a minimum value (e.g., conforming to the minimum travel time for the distance if the speed limit is obeyed). Internally for CHART ATMS users; however, actual travel times are displayed. Alerts and/or notifications can be configured if travel times exceed a certain value. These alerts are not intended for incident detection, but can provide hints as to where to look. Sorting and filtering capabilities as well as recent data trends providing users with another means to assess current roadway conditions.

3.31.1 Traveler Information Messages

Traveler information messages combine a pre-defined message template with data from one or more travel routes to show motorists current travel times and/or toll rates on DMSs. Traveler information messages are automatically updated as data from their associated travel routes changes. Traveler information messages are created for any DMS where travel times or toll rates are to be displayed. These messages can be created in advance, and activated by users when desired. Traveler information messages can be designated as being applicable to only certain days of the week, and/or only on holidays or non-holidays. Multiple traveler information messages for a DMS can be created in advance and multiple traveler information messages can be enabled; however only one may be active on a DMS at any given time. The system determines based on day-of-week, holiday/non-holiday settings and message priority to select the highest priority message applicable for a given day.

Traveler information messages, when activated, utilize the DMS arbitration queue. Two arbitration queue "buckets" are used to set the initial queue priority for toll rate and travel time messages. Any traveler information message that contains toll rate data is considered a toll rate message (even if it also contains travel time data) and is initially be placed in the "toll rate" queue bucket. Any traveler information message that contains travel time data (but not toll rate data) is considered a travel time message and is initially placed in the "travel time" queue bucket. The system allows the administrator to override this behavior per DMS and specify different buckets to be used for toll rate and travel time messages. Once a traveler information message is on a DMS arbitration queue, all existing arbitration queue features apply, including the ability to reprioritize the message within the queue, and the ability to combine the message with other messages on the queue (if so configured).

CHART ATMS includes a travel time display schedule which specifies the periods during the day when travel time messages may be displayed. Travel time messages may be enabled or remain enabled during times when travel times are not scheduled to be displayed; however the message is displayed on the DMS only during times when travel time display is scheduled. The system-wide travel time display schedule can be overridden per DMS. Typically within CHART ATMS travel time messages are displayed between 5:00 a.m. and 9:00 p.m. The schedule allows messages to remain enabled overnight without being displayed. Display automatically resumes at the designated time the next morning. A travel time summary page helps users determine which messages are active or inactive for all DMSs with at least one travel time message configured.

3.31.2 Traveler Information Message Templates

Traveler Information Message Templates are another building block for traveler information messages. An administrator creates templates that specify the layout and content of traveler information messages. These templates are for a specific DMS display configuration, and at least one template must exist for each display configuration used by all the DMSs where a traveler information message is displayed. In addition to static text (such as "TRAVEL TIME TO", or "TOLLS"), the content may include data fields, which are place holders within the message where data from travel routes is to be inserted. The following data fields are available:

- Destination
- Travel Time (actual)
- Travel Time (range)

- Toll Rate
- Distance
- Toll Rate Effective Time (the "as of" time)

Templates allow the administrator to specify which fields are supplied by the same travel route. This allows templates to contain data from one or more travel routes, with the data from each route correlated properly. Templates also allow the administrator to specify the format to be used for each type of data field included in the template. All fields of the same type share a common format, eliminating the possibility for a mismatch within the same messages. Because it's possible that data fields specified in a template may become unavailable during its actual use, the administrator also specifies a missing data rule for each template. Using the missing data rule, the administrator can specify that the entire message should be considered invalid (and therefore not posted) if any data is missing; or that the page containing the missing data is to be considered invalid, or that just the row containing the missing data is invalid. The appropriate rule to choose depends on the content and layout of the template.

3.32 External Travel Time Interfaces from INRIX and MDTA

External interfaces to the INRIX and MDTA travel time systems are used to obtain travel times for travel routes. INRIX is a web service available to paying customers on the Internet, and CHART ATMS connects to it periodically (currently every 2 minutes) via HTTP to obtain travel time data for roadway links within Maryland. The MDTA travel time system conforms to the INRIX interface, and was developed for providing travel times on MDTA managed roads where INRIX cannot distinguish between managed and unmanaged roadways, such as along the HOT lanes north of Baltimore. Once travel time data is obtained from the provider, CHART ATMS updates the travel time data for roadway links used by CHART ATMS travel routes, and the travel routes update their overall travel time by adding together the travel times of each link contained in the travel route. Changes to travel time data for a travel route propagate within CHART ATMS to any active traveler information message using data from that travel route, and travel times for all travel routes are updated in the GUI.

Settings in CHART ATMS allow a percentage of a link to be used when computing the overall travel route travel time to accommodate situations such as when locations of DMSs intended to display travel times do not match cleanly to pre-defined link starting points. Other settings in CHART ATMS specify a minimum data quality (as supplied by travel time provider) for each roadway link, and CHART ATMS travel routes consider the travel time unavailable if too many links fall below their configured minimum quality level.

3.33 External Toll Rate Interface from Vector

An external interface to the MDTA Vector system is used by CHART ATMS to obtain current toll rates for CHART ATMS travel routes. Toll rate data is pushed to the CHART ATMS by the Vector system via a web service interface which runs within CHART ATMS. The CHART ATMS interface supports either HTTP or Hyper Text Markup Language Secure (HTTPS) connections and expects data in an XML packet conforming to an Interface Control Document (ICD) written by the CHART ATMS developers. The Vector system connects to this service via HTTP. When the CHART web service receives data from the Vector system, it updates the current toll rate data for any CHART ATMS travel route that has a Vector specified as the toll rate source (currently Vector is the only toll rate source transmitting data to CHART). Changes

to the toll rate for a CHART travel route are propagated to any traveler information message that includes toll rate data from that travel route.

3.34 External Interface from RITIS

CHART collects data from RITIS (Regional Integrated Traffic Information System), a regional clearinghouse for traffic information within and well beyond the state of Maryland. RITIS is run by the Center for Advanced Transportation Technology (CATT) Lab at the University of Maryland (UMD). The transport layer is RITIS-specific using Apache's ActiveMQ implementation of the Java Messaging Service (JMS). The traffic event data layer implements the J2354 standard with a few RITIS extensions to the standard. The DMS and TSS data layers implement the Transportation Management Data Dictionary (TMDD) standard for each of these devices. The sections below describe further concepts related to RITIS data importing.

CHART collects information on traffic events, DMSs, and TSSs from around the region from RITIS. Filtering mechanisms are provided to manage the data and gain access to a desired subset of the larger set of information available.

3.34.1 Connection Status

The status of the RITIS connection is displayed on the View External Events Page. By default, the status is shown only when the connection is known to be failed, and the list of external events is cleared if the connection is failed for a specified period of time. An administrator can control this behavior, and has the option of making the status display at all times (instead of just when failed) and can control when the event list is cleared (if at all) in the case of a failed connection.

The connection status is also shown on the event details page for an external event if the connection which supplied the event is failed. This display can also be made to display at all times, even when a failure does not exist.

3.34.2 Operation Centers

A special "RITIS" operations center is defined be the default controlling operations center for all external events. External events never generate Unhandled Resource Alerts so there is no problem if no one is logged into this new operations center. Future releases could provide for operations centers to automatically be created as new agencies are found in the external data stream; however, so far this has not been a coveted feature.

3.34.3 Owning Organizations

When importing traffic events, DMS devices, and TSS devices, CHART ATMS utilizes a mapping from external system / agency to a CHART organization. If a mapping is not found for a traffic event or device that is imported, the system uses a default organization.

3.34.4 External Event Views

Users have three views of external events:

1. View External Events Page: All open external events are displayed on a page similar to the page for viewing internal open events, except it also has an "interesting" column displaying the flag that indicates whether it should appear in the External Event tab on the Home Page. It also has a column that shows the originating agency for the event.

Users have the option of setting or clearing the 'interesting' marker, and choosing to view closed external events.

2. Home Page: A tab is available on the Home Page to hold external events identified as "interesting." The fields for this tab are event type, name, location, county/state, and a lane closure graphic (if applicable).
3. External Event Details: From either of the previous views, a user can bring up an external event details page which is similar to that of a normal CHART ATMS event. The primary differences are an indication that the event is external and therefore cannot be modified, and the indication as to whether the event has been marked as "interesting." Sections that do not apply to an external event, such as the response plan and participants, are not shown.

Any external event within the users operations center's AOR that is not currently associated with a linked event, but has been marked as interesting appears highlighted in the following summary reports:

- Operations Center Report
- Open & Open/Closed Event List
- Home Page Event List
- Open Events and Devices with Messages List

3.34.5 Linked Events

Users cannot modify external events or devices imported from RITIS. For events that are relevant enough, CHART ATMS users can "link" a CHART event to an external event. When this is done, the user can select which of four sections (basic event data, location data, lane configuration data, and incident info) should be loaded and continually updated from the external event, and which of these sections should be merely monitored. In the latter case, if the monitored information changes, the data is flagged as changed until a CHART operator acknowledges the change. CHART operators can change at any time which of the four sections are automatically updated or merely monitored, for each linked traffic event. In a linked event, CHART-specific sections which cannot be linked to the external event (as well as sections not being automatically updated) can be freely updated by CHART operators. The CHART-specific sections are the response plan, participants, notifications, roadway conditions, and associated events.

The only control CHART ATMS administrators have over an actual external event is the ability to close it (for example if it is stale because the RITIS connection was lost). See External Event Closure below.

3.34.6 Persistence

To ensure continuity between CHART ATMS restarts, the lists of external events and devices are persisted in the CHART ATMS database. After restart, the external events list is refreshed once the RITIS connection is regained, possibly closing some of the persisted external events.

3.34.7 External Event Filtering

Because there are many events available in RITIS that are not relevant within Maryland, several filtering options are available with regard to external events. For starters, filtering of external events always includes rejecting badly formed external traffic events, rejecting external traffic

events that have no meaning in CHART ATMS (e.g., parking events), and ensuring CHART ATMS does not receive its own events back. Beyond this, CHART ATMS includes the ability to define traffic event import rules that are applied automatically by the RITIS traffic event importer. Each rule can contain one or more filter criteria, including geographical areas, route types, etc., as defined below. A RITIS event must match all criteria specified in a rule to match the rule.

Administrator-settable filtering includes:

- Filtering by geographic area. Administrators can set up geographic areas within which events must be located in order to be selected. A geographic area can be a wide area, such as following county boundaries, or can be small polygons which follow the contours of a road. Although users can see and draw Areas of Responsibility directly in CHART, this ability has not been retrofitted into geographic areas. Users cannot see or draw these polygons on a map to view or define these areas. An administrator can define a geographical area as a polygon containing 3 or more points specified by latitude/longitude, or, more likely, can draw polygons in a third party system (such as Google Maps / Google Earth), export them to KML, and import the resulting KML data into the CHART ATMS.
- Filtering by route type. Interstate Route, US Route, State Route, etc.
- Filtering by "Regional" flag. External Events can contain a "Regional" flag by which the external agencies can mark the event as possibly of interest to other agencies. (Other filtering criteria such as geographic filtering can be used in concert to determine if it is regional near the Maryland border or regional near another of the border states.)
- Filtering by number of lanes closed.
- Filtering by Event/Incident type. Incident, Planned Closure, Congestion, Weather, etc. These are CHART event types (into which the external event would be categorized), not all the external agencies' event types.
- Filtering by included text. External fields searched are the Name, Description, Route Number, and County. For instance, "I-95" could be a search string (matching name or description) or "95" could be a search string (matching route number).

If a potential (candidate) incoming external traffic event matches a rule, it is imported into the CHART ATMS. In addition, each import rule can also contain rule actions. These actions are performed when a RITIS event matches the rule (and is therefore being imported into the CHART ATMS). The available actions are Issue Alert, Send Notification, and Mark as Interesting. The Issue Alert action, when enabled, causes the CHART ATMS to send an alert to a specified operations center when an event is imported that matches the rule. The Send Notification action, when enabled, causes the CHART ATMS to send a notification to a specified notification group when an event is imported that matches the rule. The Mark as Interesting action, when enabled, causes the CHART ATMS to set the "interesting" flag for the event when an event is imported that matches the rule. The "interesting" flag causes the event to appear on the home page of the CHART ATMS GUI in the external events tab.

3.34.8 External Event Closure

There are two ways external events are closed in the CHART ATMS. The normal way is for the external owning agency to close the event; however this assumes the external event listener,

RITIS, and the external agency are all functioning normally. When this is not the case and an external event is orphaned, CHART ATMS administrators are able to close them manually.

CHART ATMS does not have control over how external agencies manage their traffic events so, unlike a CHART event; it is possible for a closed external event to be re-opened. In this case, if the closed external event has not yet been archived, it is re-opened within CHART ATMS. If the closed external event has already been archived out of CHART ATMS, a new external event is created with no relationship to the previous external event.

Closed external events are aged out of the system and archived just like normal internal events. In this context, 'closed' refers only to the CHART perspective – the external event may or may not still be existing and open from the perspective of other agencies.

3.34.9 Archiving of External Events

External events are archived for offline analysis along with internal CHART events, and are permanently flagged as external events in the archive.

3.34.10 DMS and TSS Import

Whereas events are transient objects, being opened and closed continuously and constantly changing, "rules" determine which events are imports. Devices, on the other hand, are relatively static, rarely created and remaining in service for years. Therefore, devices can be carefully hand-selected and included with deliberation. This is referred to as a "candidate review" process.

The CHART ATMS allows the administrator to specify which devices from RITIS are to be included in CHART ATMS, as well as those the administrator explicitly wants excluded from CHART ATMS. A query capability that includes several search criteria allows the administrator to search the potentially large list of DMS and TSS devices that may exist in RITIS so that they may choose devices to include in CHART ATMS or mark as excluded. The search feature also allows the administrator to view and evaluated the devices they have already marked as included, already marked as excluded, and/or not yet marked as either included or excluded. The advantage of explicitly excluding devices from CHART ATMS, is that the next time the candidate review process is undertaken, perhaps months later, the explicitly excluded devices do not have be considered for import again. By marking devices (e.g., very distant devices) as excluded, they do not have to be considered and re-evaluated for inclusion again. As noted, however, the list of explicitly excluded devices can be requested for candidate review and consideration again if desired, but this should not normally be necessary.

The CHART ATMS DMS and TSS lists allow users with rights to view external DMS or TSS to show or hide these external devices within the lists. When external devices are shown, the system allows the user to filter the list to hide CHART ATMS devices and to filter the list to show only external devices from specific agencies. CHART ATMS uses a different background color to differentiate external devices from CHART devices within device lists. The device details pages for external devices are read-only for all users, except that privileged users are permitted to mark the external device as "excluded", removing it from the CHART ATMS. (This is a shortcut to going back through the candidate review process again, if, for instance, a device has been marked as "included" by accident.)

Once added to the CHART ATMS, the CHART RITIS import service keeps the status of these devices updated within the CHART ATMS.

3.34.11 Archiving of External DMS and TSS Data

External DMSs and TSSs that have been imported into the CHART ATMS are archived for offline analysis along with internal CHART DMSs and TSSs, and are permanently flagged as external devices in the archive.

3.35 CHART Data Exporter

3.35.1 Background

CHART includes a web service that allows pre-approved external systems to obtain data from the CHART ATMS. External systems can issue data requests (via HTTPS) and receive the requested data in the form of an XML document. CHART allows traffic events, DMS, TSS, HAR, SHAZAM, and CCTV data to be retrieved in this manner. Authentication and data protection schemes ensure that only authorized clients can retrieve data, and that clients can only retrieve data for which they are permitted to receive.

The CHART ATMS Data Exporter replaced the former CORBA-based export in order to protect CHART ATMS operational system from direct calls by external systems. It prevents access to CHART ATMS data by not providing IDL level access. External systems retrieve data using defined requests (via HTTPS). Data exported is guarded by the access rights granted to the client by the administrator. An administrator in CHART ATMS grants rights to an external client – like a CHART ATMS user, most data may be viewed by virtue of being an authenticated user. Also like a CHART ATMS user, additional rights are needed before being able to view sensitive data such as fatalities. The Data Exporter can be considered a second user interface or presentation layer. In this light, it is natural that user rights and roles are applied just as they are applied to the GUI and its users.

The Data Exporter service allows the consumer to request inventory and status in its entirety or based on a lookback time period. The full inventory and status contains data for all requested data type entities in the CHART ATMS. The lookback inventory and status restricts the data exported based on how far back to look in time for changes to the requested data type entities in the CHART ATMS.

In addition to this pull-based mechanism, a more responsive push-based option is available, whereby client provides a URL where the Data Exporter can post real-time updates. Updates are pushed to this URL as they happen. Updates are queued during times when the consumer is unavailable, unreachable, or temporarily unable to keep up with the throughput. Once the queue is full, the queue is flushed and a flag is set in the next message informing the client that they have missed data and should pull a fresh inventory.

There are four systems which receive CHART data via the Data Exporter. Two are internal to the overall CHART Program: CHART Mapping (which serves the Intranet Map) and the public web site (a.k.a. CHARTWeb, a.k.a. CHART on the Web), which also services the CHARTWeb Map. Two are external to CHART: RITIS and MD511. However, there are only three clients of the Data Exporter, as explained below. There are also two Data Exporter Services – one internal, serving the internal CHART systems, and one external, serving external systems. Each Data Exporter is capable of serving any number of clients. The external Data Exporter resides in the SOC demilitarized zone (generally referred to exclusively by its acronym, DMZ), with a firewall to provide protection to internal systems such as the CHART ATMS. The internal Data Exporter that serves CHART Mapping and CHARTWeb runs entirely inside the firewalls.

3.35.2 Data Exporter Clients

The Intranet Map and CHARTWeb (including the CHARTWeb map) are special clients of the Exporter in that they do not communicate directly with the Data Exporter. Instead a separate Export Client application acts as an intermediary. There is just one Export Client for both these two applications. The Export Client's prime responsibility is to gather data from the Data Exporter and update the database shared by the Internet/Intranet Map and the public web site. When configuration changes are detected by this application, it notifies CHART Mapping via a HTTP message. This triggers the maps to re-cache their data. The CHART Exporter Client does this by sending an HTTP GET request to the CHART Mapping Synchronization Application, a standalone application which then notifies the map software via .NET interfaces.

The RITIS system and MD511 are the clients of the external Data Exporter. Because RITIS and MD511 are an external systems, they connect to a separate Data Exporter than the Export Client used by the CHART Mapping and CHARTWeb. RITIS and MD511 use two different models for receiving data from the CHART ATMS. RITIS "subscribes" to updates from the CHART ATMS, and receives unsolicited data from the Data Exporter in near real-time. RITIS also periodically polls the Data Exporter for current state, to make sure it's view of the CHART ATMS data is fresh. MD511 does not subscribe to updates. It gets its data exclusively through polling the Data Exporter.

The Data Exporter was designed with the idea that and number of clients could obtain CHART data by connecting to the Data Exporter. The emergence of RITIS has made this less likely, but nonetheless MD511 does connect directly to the Data Exporter to get its data. All that would be required is for a CHART ATMS administrator to set up a another external client account with appropriate rights and pass the resultant generated private key to the client organization. (That and firewalls would need to be opened to allow the necessary connection/data to flow.) Additional clients from the inside could also connect to the Internal Data Exporter, but that is even less likely (but equally easy to set up).

3.35.3 Export Client Data Management

The Data Exporter does not guarantee delivery; therefore it is possible for event and device data to be lost or dropped (although in practice, this is rare). To account for this possibility, the CHART Data Export Client is configured to retrieve a full inventory and status update of devices and traffic events from the CHART Data Exporter at a configurable interval. Also, each time the CHART Data Exporter Client is started, it also retrieves a full inventory and status update. Thus, the update model becomes a push model with an occasional pull for failsafe. In addition, a special administration page in the CHART Mapping Intranet Map allows the administrator to manually request for full inventory update for events and devices.

This process is used to recover from the following situations:

1. The CHART Data Exporter Client receives no data because the CHART Data Exporter is down or other network related issues.
2. The CHART Data Exporter Client is up but did not receive new data from the CHART Data Exporter.
3. The CHART Data Exporter Client is up but is failing to send requests to the synchronization application to update the spatial information.

Another likely scenario is that the CHART ATMS server or service(s) restart. As the CHART ATMS services would not be processing events during this time, no events are likely to be

missed. Therefore, the CHART Data Exporter Client does not need to do anything special to handle a CHART ATMS server or service(s) restart.

(Note that management of these considerations within the RITIS application is strictly within the domain of RITIS, and beyond the scope of this document.)

3.35.4 Traffic Event Data Export

Figure 3-3 shows the common ground between the CHART traffic event data in the left circle, and Advance Traveler Information System (ATIS) standards in the right circle, along with the exported data available to the external entities shown in the lower circle. Often CHART data could not be fully expressed by the ATIS standard message set so additional elements were added as necessary (listed on the left of the figure).

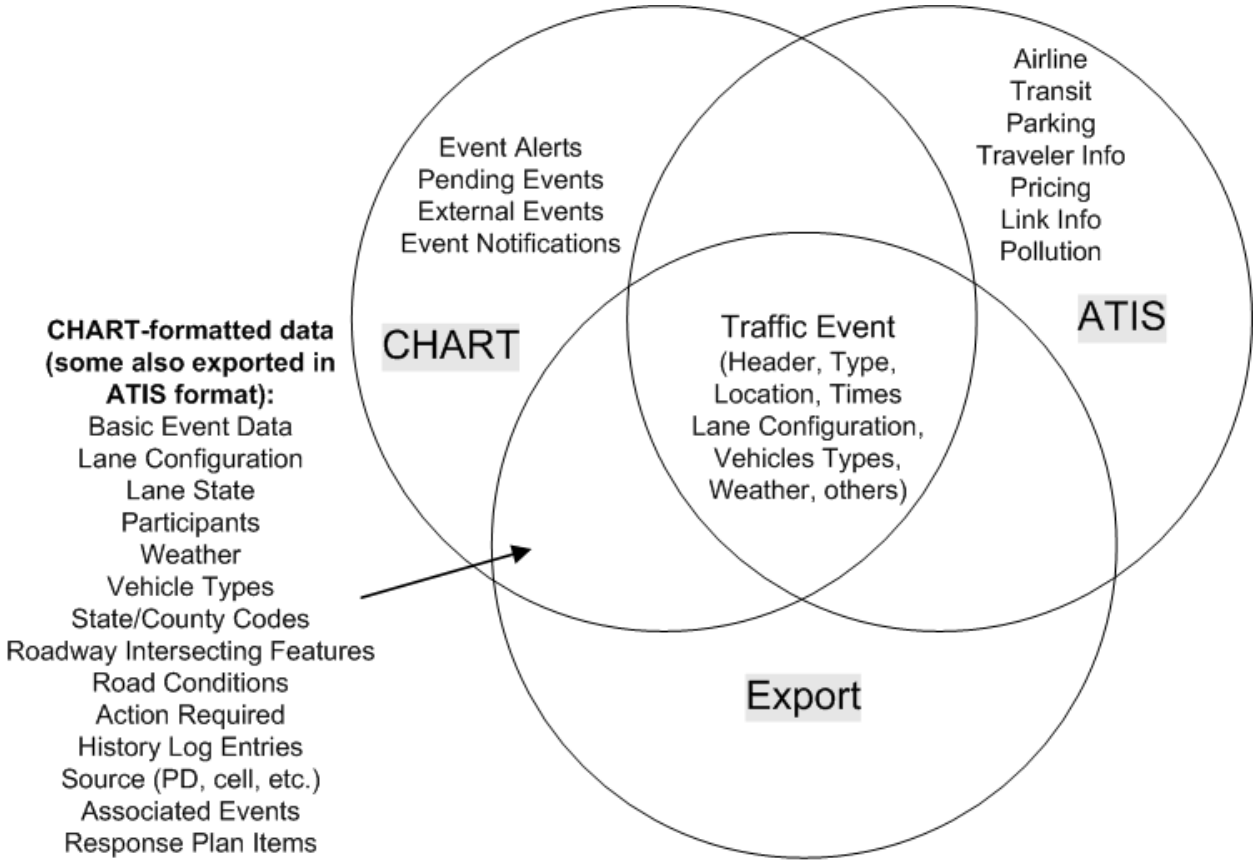

Figure 3-3 Export ATIS Events

The following extensions were added to the ATIS standards to support CHART specific data:

- <statusBlock> contains elements that indicate whether the response is a full inventory. If this message is sent in response to a subscription request, the missedData flag indicates to the client that there was a problem with the previous publication back to the client's URL so the client may wish to request a full inventory to ensure they are up-to-date.
- <AdminAreaGroup> to include information for region name, state code and county code.
- routeLocation was extended to include CHART specific route information, location alias public, location alias intersection, intersecting feature and direction.

- IncidentInformation was extended to include CHART basic event data, incident data, lane configuration, weather conditions data, action data, lane closure permit tracking number, participant, response plan information, event history log and related events.

The Traffic Event Export ICD contains additional details on how each field is exported.

3.35.5 Device Data Export

Figure 3-5 shows the common ground between the CHART device data in the left circle and TMDD standards in the right circle, along with the exported data that is available to the external entities in the lower circle.

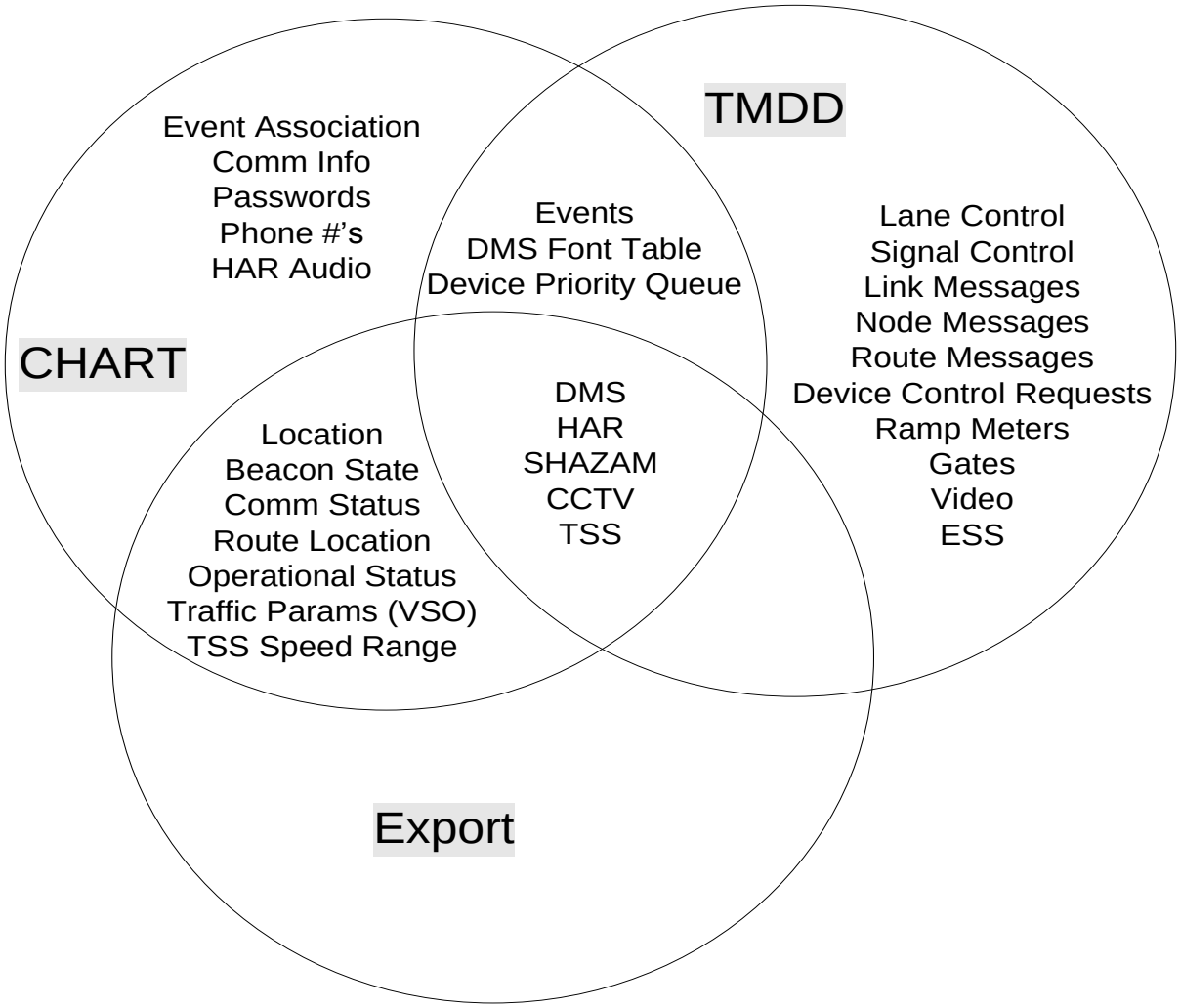

Figure 3-5 Export TMDD Devices

The Device specific export ICDs provide additional details on how each field is exported.

3.36 User Management Web Service Interface

3.36.1 Background

The User Management Web Service interface provides clients external to the CHART ATMS with the ability to query the CHART ATMS for their access rights. CHART Mapping uses this mechanism to control what data users logged into the Intranet Map may see, as there is some data (speed data from certain TSSs) which is restricted and must be controlled by user rights, as explained below.

There are three mapping components within the overall CHART Program:

- CHART ATMS Map – the map within the CHART ATMS, provides tactical maps to aid CHART ATMS operators in geo-locating events and devices.
- Intranet Map – internal map within CHART Mapping, for CHART operators and other agencies connected to the CHART network.
- Internet Map – external (public) map within CHART Mapping and displayed by CHARTWeb (CHART on the Web) for external users.

The CHART ATMS Map is the only map that this document is generally concerned with; however, there is a point of contact between the CHART ATMS and the CHART Mapping, in that CHART ATMS provides data to CHART Mapping (and CHART on the Web) – and provides a user authentication and authorization process for the CHART Mapping.

Generally only internal objects are displayed on the Intranet and Internet Maps; however, external detectors cam be displayed on the Intranet Map as well. This need arose specifically for NAVTEQ detectors, which are "external" to CHART even though they physically exist within the State of Maryland. The point to be made here is that an external detector is defined as one that is not controlled by the CHART ATMS, regardless of whether it is located within the State of Maryland or not.

The display of external detector data comes with complexity. Due to contract restrictions, only actual Maryland State Highway Administration (MDSHA) employees are permitted to view detailed speeds from some of the external detectors; specifically NAVTEQ detectors. Other users may view which range the speed falls in (e.g., under 30 mph, 30-50 mph, 50+ mph); however, they must be prevented from seeing precise speeds from these detectors.

Since the CHART ATMS has already for many years supported the granting of detailed rights to manage the display of detector data to its users, the same ability to manage user rights has been made available to the Intranet Map so that it may apply those same rights to its users. This was accomplished by creating a User Management Web Service that the Intranet Map can use to access back-end User Management functions. Only a little of the back-end service's features are exposed at this time, namely the validation of a username and password and the retrieval of an authorized user's rights. The design supports the easy addition of the remaining features to the User Management Web Service as they are needed in future releases. This design also makes it easier for other systems (e.g., LCP) to use the same User Management rights in the future possibly leading to a single sign-on for all CHART systems.

3.36.2 Impact on Intranet Mapping

When users first open the Intranet Map they are given rights associated with a default user. This default user is defined by the CHART ATMS administrator and is expected to always be

configured to allow viewing all the CHART events and all CHART devices and their corresponding data, but no external detector data (or at least no external detector data that is subject to limited distribution). Some external detectors available on the Intranet Map require special rights in order to view their data (e.g., NAVTEQ detectors). For these, the default user sees either no speed or only a speed range, depending on how the CHART ATMS administrator configures the default user's rights. To view more information for these detectors, the user is required to log in to the Intranet Map using their normal CHART ATMS username and password. Then, based on any rights they gain by logging in, they might be able to view more or better information for these detectors. Because all detectors (internal as well as external) use the existing CHART ATMS rights mechanism, the CHART ATMS administrator can even control how users may view internal detectors on the Intranet Map. This feature could be expanded in future releases to provide additional restricted features on the Intranet Map.

It is conceivable that the act of logging in could actually remove rights if it happens that the user's CHART ATMS login provides fewer rights than the default user. This unlikely scenario would be in error in setting up the user's rights, and could be quickly remedied by the CHART ATMS administrator.

3.37 External System Connection Status

CHART ATMS includes the ability to view the status of all external connections, including those connections from the CHART ATMS to RITIS and to INRIX, and connections to the CHART ATMS from Vector and from clients using the CHART Data Exporter web service. For clients using the Data Exporter, each external client's connection for each data type they subscribe to is monitored and reported separately. Likewise, for the CHART ATMS's connection to RITIS for incoming data, the connections for each data type is monitored and reported separately.

The CHART ATMS also allows the administrator to configure alerts and notifications for each external connection. The administrator can configure the system to alert a specified operations center when a connection failure is detected. Notification groups can also be specified to receive a notification when a connection failure is detected. Optionally, the administrator can also configure the system to send alerts or notifications when warning conditions are detected, on a per-connection basis. Finally the administrator can specify that notifications also be sent when any connection transitions back to OK status. This setting is global: it affects all external connections at once. The system employs an administrator-specified threshold time to prevent a flood of alerts and/or notifications from being sent if a connection is in a state where it is frequently transitioning between OK and Failed.

3.38 Intranet Map Interfaces

This document is not about CHART Mapping, but since there are interface points between CHART ATMS and CHART Mapping, a few words are in order. Some interfaces have already been discussed. Other interfaces are discussed below.

The CHART Mapping system design utilizes a web-based multi-tier system architecture. The application is partitioned into the data tier, the business tier and the user (presentation) tier. The data storage is managed at the data tier by the databases using Microsoft SQL Server and ESRI ArcSDE platforms. The main business logic is hosted in the two applications (Internet and Intranet Maps) in the web server. They are implemented using the ASP.Net platform. The final user interface is implemented with the ASP.Net with client side JavaScript. Because mapping is an area in which there are many requirements related to client side interactions with the graphic

content of the application, application logic is partitioned based on the most appropriate location to execute them. The client side JavaScript on the web browsers help provide instantaneous feedback to the user.

The CHART Exporter, the CHART Data Export Client, and the CHART Mapping Synchronization Application have already been covered in Data Exporter discussions above. Other applications include the CHART Spatial Web Service and the Satellite Imagery WMS. The Spatial Web Service hosts an HTTP/XML interface for the CHART ATMS GUI. The Intranet Map connects to the Satellite Imagery Web Map Service (WMS) on an HTTP/JSON interface.

CHART Mapping provides a number of interfaces for use by other CHART applications (e.g., CHART ATMS). The CHART Mapping GIS Web Service provides the ability to serve and update roadway lane configuration data for other CHART applications. Currently, the CHART ATMS is the only user of this data. The CHART Mapping GIS Service provides proximity information (including exits and milepost proximity data) to the CHART ATMS for the purpose of locating events or supporting decision support capabilities within the CHART ATMS. The CHART Mapping GIS REST Services provide cached map tiles for map background data and exits and mileposts to the CHART ATMS. The CHART Mapping Map GIS Service provides the capability to serve and write Area of Responsibility related polygon data for use in other applications, but currently is used by only the CHART ATMS.

3.39 Watchdog

CHART ATMS includes "watchdog" services that monitor other services for availability. A watchdog service is installed on each CHART ATMS server and is configured to periodically query each of the other CHART ATMS services on that server to determine if the service is available and to collect runtime statistics from the service. A second watchdog service is installed on each server to allow the primary watchdog service to also be monitored. Likewise, the first watchdog is configured to monitor the second watchdog among all the other services it monitors, so all services, including both watchdogs, are monitored by one watchdog. The watchdog service can be configured to automatically restart a service that has failed, and can also be configured to send alerts and/or notifications. The watchdog can also restart a service which provides a warning indication. Currently the only warning indication provided is one of low heap memory available. The GUI allows the status of each service, as determined by the watchdog monitoring the service, to be viewed in detail. Details about watchdog services themselves can also be viewed in the GUI, such as the list of services they are monitoring and the monitoring configuration for each. The GUI also allows commands to be issued to a watchdog to have it stop, start, or restart any service which it monitors, or to ping (query on demand) any service it monitors, or all those services at once.

3.40 CHART NTCIP Compliance Testers

CHART has developed NTCIP Compliance Testers to test NTCIP-compliance and compatibility with CHART ATMS for NTCIP DMSs and NTCIP Cameras. These compliance testers can be used in-house by SHA or support personnel, or they can easily be delivered to the device vendors for them to use themselves. These testers have been used in both these ways.

The NTCIP DMS Compliance Tester is a standalone application that allows sign vendors to test if their sign they believe is NTCIP-compliant sign is compatible with the CHART ATMS. This tester application makes use of actual CHART ATMS application code to ensure that all low

level interactions between the tester application and an NTCIP compliant DMS are identical to the interactions made between the CHART ATMS and an NTCIP compliant DMS. The NTCIP DMS Compliance Tester utilizes a graphical user interface to allow the user to configure the tester for communications with the sign being tested, and to allow the user to execute tests, see the test results, and optionally save the test results. Note that this tester is not in any way connected to the live CHART ATMS – it is completely standalone, and it interacts directly with the DMS being tested.

The NTCIP Camera Compliance Tester is a separate standalone application that allows camera vendors to verify that their camera they believe is NTCIP-compliant will work with the CHART ATMS. The design of this tester is based on the design of the NTCIP DMS Compliance tester. It differs in the user commands it supports and the protocol handler it uses, however, the design of the basic framework of the tester, such as the base application and communications features are similar. Like the DMS Compliance Tester, the Camera Tester uses actual CHART ATMS code wherever possible, so that all interactions with the tester are guaranteed to be the same way the interactions will occur within the live CHART ATMS system later. These Compliance Testers are rebuilt and redelivered with each CHART ATMS release, to ensure the latest operational CHART ATMS code is included within the Compliance Testers.

3.41 Maintenance GUI

The Maintenance GUI is a portal into the existing CHART ATMS GUI that provides a view of the system tailored to device maintenance personnel. Upon login, the user can choose to view the maintenance portal instead of the normal CHART ATMS GUI pages. Users use their normal CHART ATMS username and password to log into the maintenance portal, and the user rights assigned within the normal CHART ATMS GUI apply to use of the maintenance portal. In fact, the code used to log into the maintenance portal is the same as that used to log into the standard GUI.

Upon login, if the user has selected to view the maintenance portal, the GUI sets a flag that causes all pages displayed to the user in the main browser window to utilize a custom framing template which is used to display all pages shown while logged into the portal. This framing template contains only information useful to maintenance personnel and does not contain features such as the communications log, site search, or links to various areas of the system or external systems.

After the user is logged into the maintenance portal, the system directs the user to a custom home page. The maintenance portal does not make use of a separate home page window and working window like the standard GUI. Instead, when the user logs into the maintenance portal, the same window they used to log into the system is used to display content.

The content of pages shown in the maintenance portal, other than the home page, is mostly the same as when the user logs into the standard GUI. The device lists, device details pages, and search results (for the search from the maintenance portal home page), however, are customized. The content of other pages is unchanged (other than the different framing template). Most pages that are normally displayed in pop-up windows in the standard GUI are not pop-ups in the maintenance GUI; most pages appear within the main browser window. (Certain pages such as those used to listen to HAR audio must remain as pop-up windows due to technical issues).

To support customized pages for the maintenance portal (and other portals that may be required in the future), the CHART ATMS GUI Servlet was changed to include generic processing that can customize pages just prior to rendering the page for display to the user. This processing

allows a customized outer (framing) template and request-specific page content templates to be defined for each portal (the maintenance GUI being the one and only portal at this time). The generic processing also allows the portal type to specify whether or not pop-up windows are preferred when the user is logged into the portal.

3.42 Access Control

Users gain access to the system through a login process. As a result of this process each user is provided an access token which contains a description of the functional rights that the user has previously been granted by a system administrator. The token also contains information describing the operations center that they are acting on behalf of. Each restricted system operation requires this token to be passed for functional right verification purposes. If the token contains the appropriate functional right to perform the operation the system then verifies that the user is logged in to the operations center that is currently responsible for any targeted shared resources.

The system provides for the concept of a shared resource. A shared resource is any resource that can be "controlled" ("owned" in a sense) by a particular organization. Each shared resource is allowed to be controlled by only one operations center at a time. Access to a shared resource is controlled through the functional rights of the user attempting to gain control of the resource and through an arbitration scheme that prioritizes requests to the resource.

3.42.1 Security Management

Administrator privileges are required in order to modify user login information. A record of all changes that are made to user login information is logged in the operations log. Also user login/logout actions and failed login attempts are logged in the operations log.

All CHART systems are located behind firewalls to protect them from unauthorized access through the network. The presentation of data from CHART to the outside world is through a push of the data from the CHART ATMS to external systems responsible for handling public access.

Because CHART ATMS is a system that resides on the MDOT Enterprise Network, all remote access is governed by the policies and procedures approved at the MDOT Security Working Group.

Access to CHART ATMS objects is controlled at the application level. The implementation of additional levels of access control for objects will be evaluated as necessary.

Physical security of installation sites is the responsibility of the site owners and is not within the scope of this document.

3.43 Shift Handoff Report

The Shift Handoff Report is a means of sharing important operations information with operators. Each operations center has control over its own Shift Handoff Report. The report is provided using a third part product, WordPress, and as such does not contain any custom design elements. WordPress provides the ability to include dynamic information to operators in the form of blog posts and static reference information in the form of web pages. A built-in menu system allows operators to navigate through the site to view both types of information. A link is provided within the CHART ATMS to point to the Shift Handoff Report.

3.44 Areas of Responsibility

Areas of Responsibility is a fairly new and still developing feature for CHART. An Area of Responsibility represents a geographic area on a map that defines an area for which a certain CHART entity is responsible (e.g., an operations center or a monitor). Currently the CHART ATMS is the only CHART system employing Areas of Responsibility, although the facility is available for incorporation into other CHART systems.

Server-side rendering. Areas of responsibility are displayed on the map using server-side rendering. Server-side rendering was chosen due to the potential size of the data required to display an area of responsibility and the expected number of areas of responsibility. Area of responsibility data is expected to seldom change, but it can become very large if boundaries are drawn with many data points.

Web Service. Areas of responsibility are managed by a web service. The data is stored directly in the Mapping GIS database. This would allow other systems (outside of CHART ATMS) to define and use areas of responsibility if the need were to arise.

AOR Manager. An AORManager class exists in the CHART2.webservices.util package to manage AORs. This class is a Singleton and can be used by any CHART ATMS application code (GUI and/or server). The class maintains an updated cache of areas of responsibility. The class uses a synch API to keep the cache up to date. The AOR Manager can be configured with or without a cache. In non-caching mode, the AOR Manager can be used to determine if an area of responsibility still exists in the system.

Generic AOR Associations. The association of areas of responsibility with other CHART ATMS objects is generic. Currently, Areas of Responsibility can be associated only with Monitors and Operations Centers. A generic form is used to associate areas of responsibility with CHART ATMS objects, and a generic CHART ATMS database table stores the associations of areas of responsibility to CHART ATMS objects.

Filtering. Location aliases and device lists are filtered for users based on areas of responsibility. The list of location aliases available to the operator when setting an object location is initially filtered by the areas of responsibility associated with the user's operations center. The filter can be removed to view all location aliases in the system. If no areas of responsibility are associated with a user's operations center, the location aliases will not be filtered. Device lists are initially filtered using both the system folders and the areas of responsibility associated with the user's operations center. The initial set of devices presented is the union of all devices associated with the user's center's AOR plus the devices in the system folder associated with the user's center. This filtering can be removed to view all devices in the system. If no areas of responsibility are associated with a user's operations center, the device lists will be filtered based on the system folders only (unless no system folders are associated to the operations center either in which case all devices will be displayed.

3.45 Exception Processing

Since CHART ATMS is a distributed object system, it is expected that any call to a remote object could cause an exception to be thrown. The system provides two levels of exception handling. The first is aimed at providing the user with immediate feedback on the failure status of the requested operation. The second is aimed at maintaining a log of system errors to enable system administrators to trace and correct problems. Each application maintains a running log

file of software system status. Exceptions thrown by the applications contain a user displayable text status and a more detailed debug text status that is recorded in the application log file.

3.46 Long Running Operations

Many device control operations cannot be executed in a user responsive manner. Therefore the software has been designed to perform these operations in an asynchronous fashion. The initiator of a long running operation is provided the opportunity to supply a callback status object. This allows the application to supply progress information back to the initiating client as the operation proceeds. Each operation provides a final status that indicates overall success or failure. This is indicated in the Command Status window by final success or failure indication and bright green (success) or red (failure) bars across the top and bottom of the Command Status page. All operators are intimately familiar with the "green bars" and (less frequently) the "red bars".

A typical example is putting a message on a device such as a telephony connected HAR. The system must dial up the device, wait for the HAR to answer, send the message to the device (which takes a long to send as the length of the message itself, as it is played in real time), and finally disconnect the communications path. At each point in this process status information is available to the initiator via the callback status object. This allows, for example, the display of a progress window to inform an operator of the status of their request to put a message on a HAR.

Another example of a long running operation is changing the color balance on a SurveyorVFT camera. The camera interface requires a long running macro be used to navigate through a menu system as though an operator were manually stepping through the camera menu. Queuing a request to control a camera is a long running operation. (Once a camera control session is established, routine camera control operations such as panning and tilting are instantaneous operations, not subject to queuing, and therefore not classified as long running operations.) There are countless other examples of long running operations.

3.47 Replication

SQL Server Replication is used to provide the University of Maryland with current versions of the CHART ATMS operational and archive databases. SQL Server Replication is a form of data replication from a principal site to one or more secondary sites. The principal database publishes its data and multiple receivers can subscribe to this publication.

CHART ATMS publishes both the CHART ATMS operational and archive databases and two subscribers have been set up at the University of Maryland. These two subscribers act as a backup for each other. A distributor database has also been set up as part of the SQL Server Replication. This distributor database acts as a reliable store-and-forward mechanism to transfer all the database transactions from the publisher to the subscriber. To facilitate replication over the Internet, the distributor database is set up in the DMZ part of the CHART network.

There are multiple versions of SQL Server Replication available. CHART ATMS has implemented the transaction replication version. This choice is dictated by the requirement to constantly copy all database changes to the subscribers, with all data moving in one direction from CHART ATMS to the University of Maryland. At a high level, as each database transaction in committed at the CHART ATMS database it is also written to the database logs. The logs are subsequently read, on a near realtime basis, and the data is copied to the store-and-forward distributor database. The subscribers, on a separate polling pattern, then pull the data from distributor database and apply it to their local databases.

Replication enables the reporting system developed by the University of Maryland to be accomplished near real time using the databases instances local to the University of Maryland CATT Lab. This is accomplished with standard database features with no custom coding. The reporting system uses a combination of data acquired via replication and data acquired via the data exporter to generate its reports. Aside from CHART ATMS providing the data, this reporting system is beyond the scope of the CHART ATMS. Early within the design of each release, discussions are held to determine what new reports might be necessary and what new data may need to be created and provided by CHART in order to support those new reports. Then CHART ensures that the data is created and provided as necessary, and University of Maryland develops the reports. The CHART and RITIS development and operations teams meet monthly to ensure these and other activities are coordinated properly.

4 SYSTEM VIEW

4.1 View Description and Typical Stakeholders

The System View describes what the CHART ATMS hardware components are, how they are configured, what they support, and how they connect to each other. This view focuses on the internal structure of the system and its components (the view from within), whereas the Interface View focuses on external interfaces (the view from outside). This view will be of primary use to system administrators, software developers and architects and others interested in the system-level architecture.

4.2 System Overview

4.2.1 CHART Description

Figure 4-1 presents an overview of the CHART Program Architecture organized according to the Enterprise Architecture Framework as defined by the National Institute of Standards and Technology and how the CHART ATMS fits within it. This approach gives a holistic view of the enterprise and is organized into 5 layers:

- Enterprise Business Architecture Layer
- Enterprise Information Architecture Layer
- Enterprise Application Architecture Layer
- Enterprise Application Integration Architecture Layer
- Enterprise Infrastructure Architecture Layer

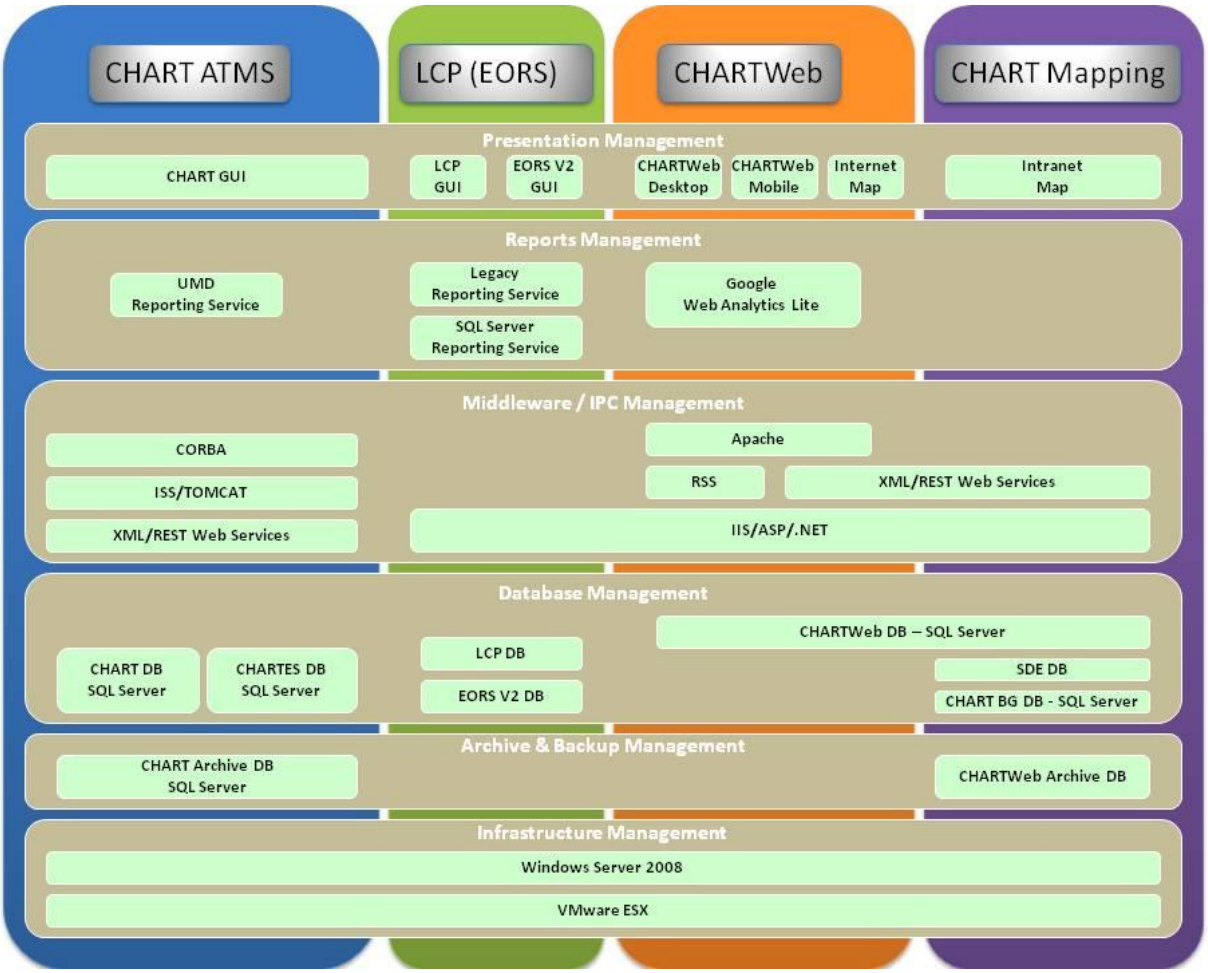

Figure 4-1. CHART ATMS Architectural Overview

Figure 4-2 shows a high level view of the CHART systems.

The CHART ATMS consists of four major software systems.

- **Core Services –** The heart and brain of the CHART ATMS. It provides the interface for the CHART ATMS GUI, traffic management functions, and CCTV distribution and control. This includes web services written by the CHART ATMS development team, which run on the CHART ATMS server and on a CHART Mapping server.
- **Field Management System (FMS) Services –** This system provides device communications and device data distribution functions for CHART field devices.
- **GUI Services –** This server provides access to CHART ATMS functionality to users via a web interface.
- **Database Instance and Database Archive –** This system stores CHART ATMS event data and all other operations data, both immediate operational and log-term archive, and provides query and maintenance functionality. This system also provides data to the CHART Reporting function done at University of Maryland.

These software systems are supported by the MDOT Enterprise network infrastructure. The network infrastructure is a key supporting ingredient of the CHART systems (of which the CHART ATMS is one), but is not itself part of the CHART Program.

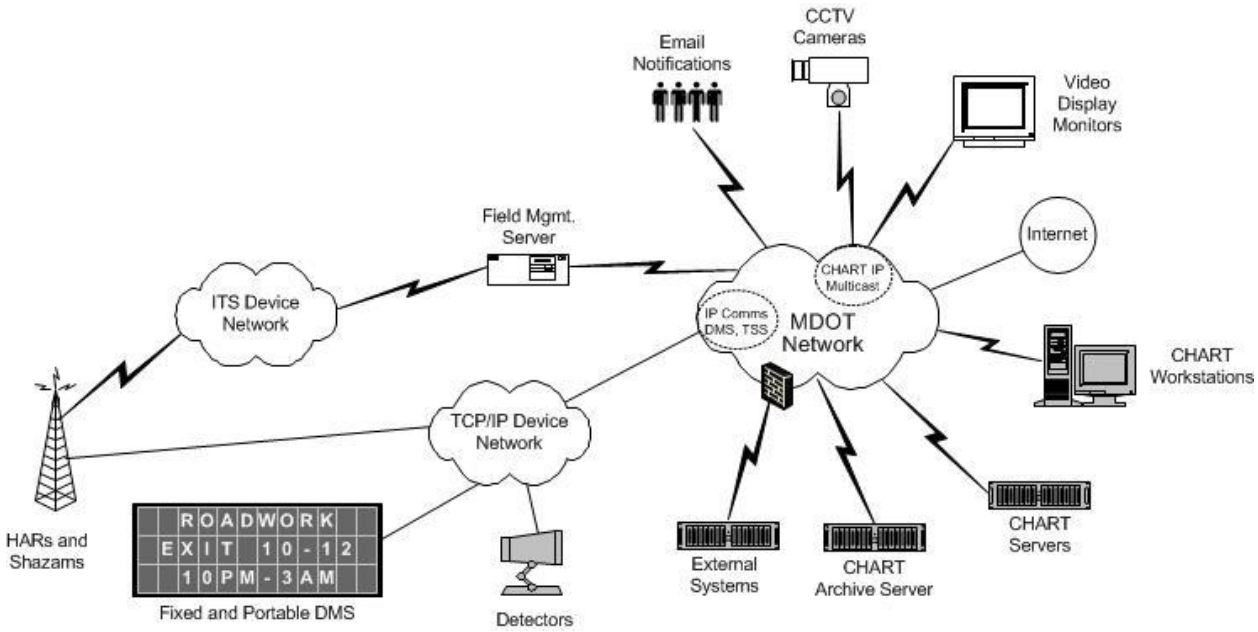

Figure 4-2. CHART ATMS

The next two diagrams show various views of the CHART system architecture and how the CHART ATMS fits within it. Figure 4-3 presents a high-level connection oriented architecture diagram showing how all of the internal and external systems connect to each other. Figure 4-4 presents a more detailed view of the components specific to the CHART system.

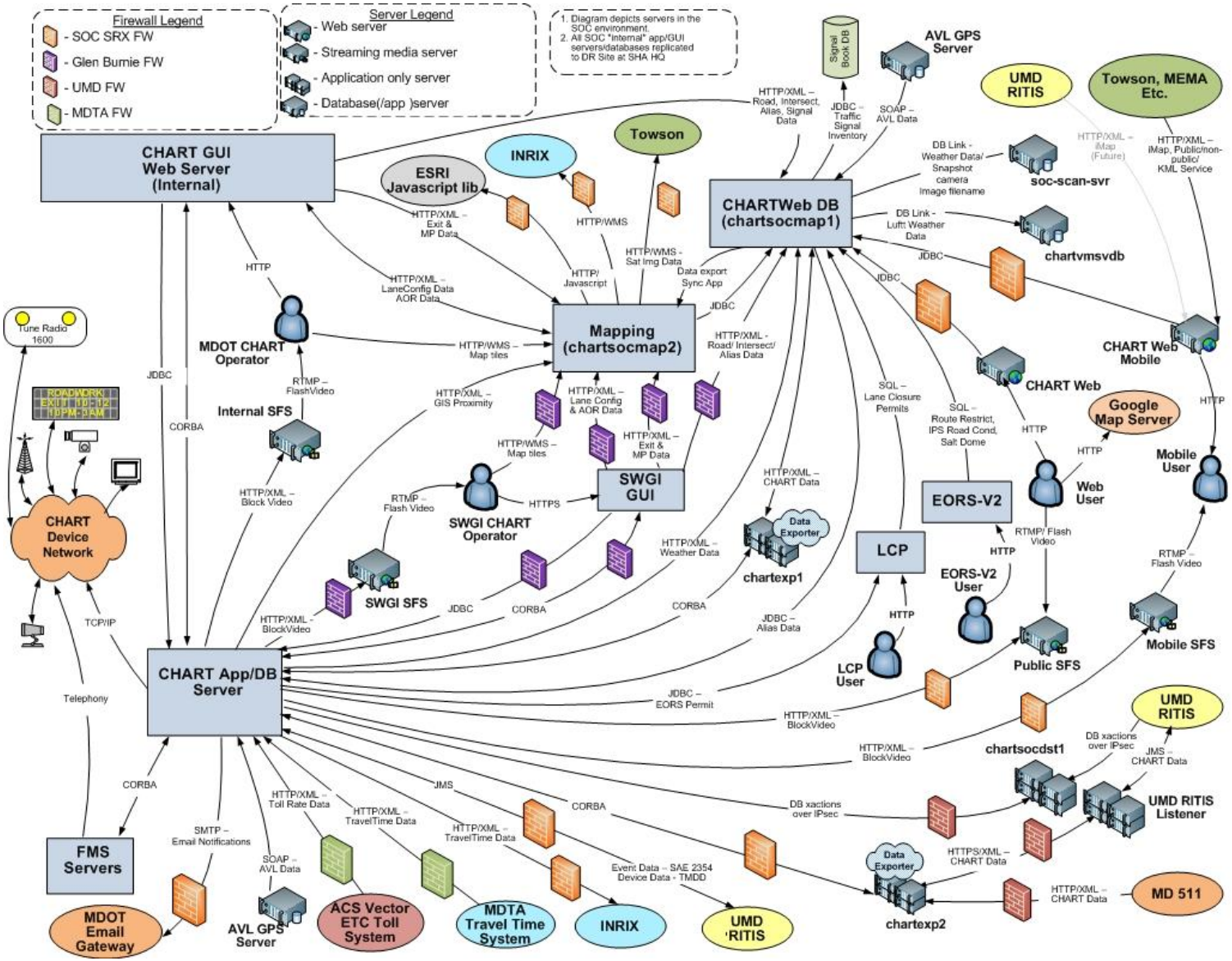

Figure 4-3. High Level CHART Systems Architecture

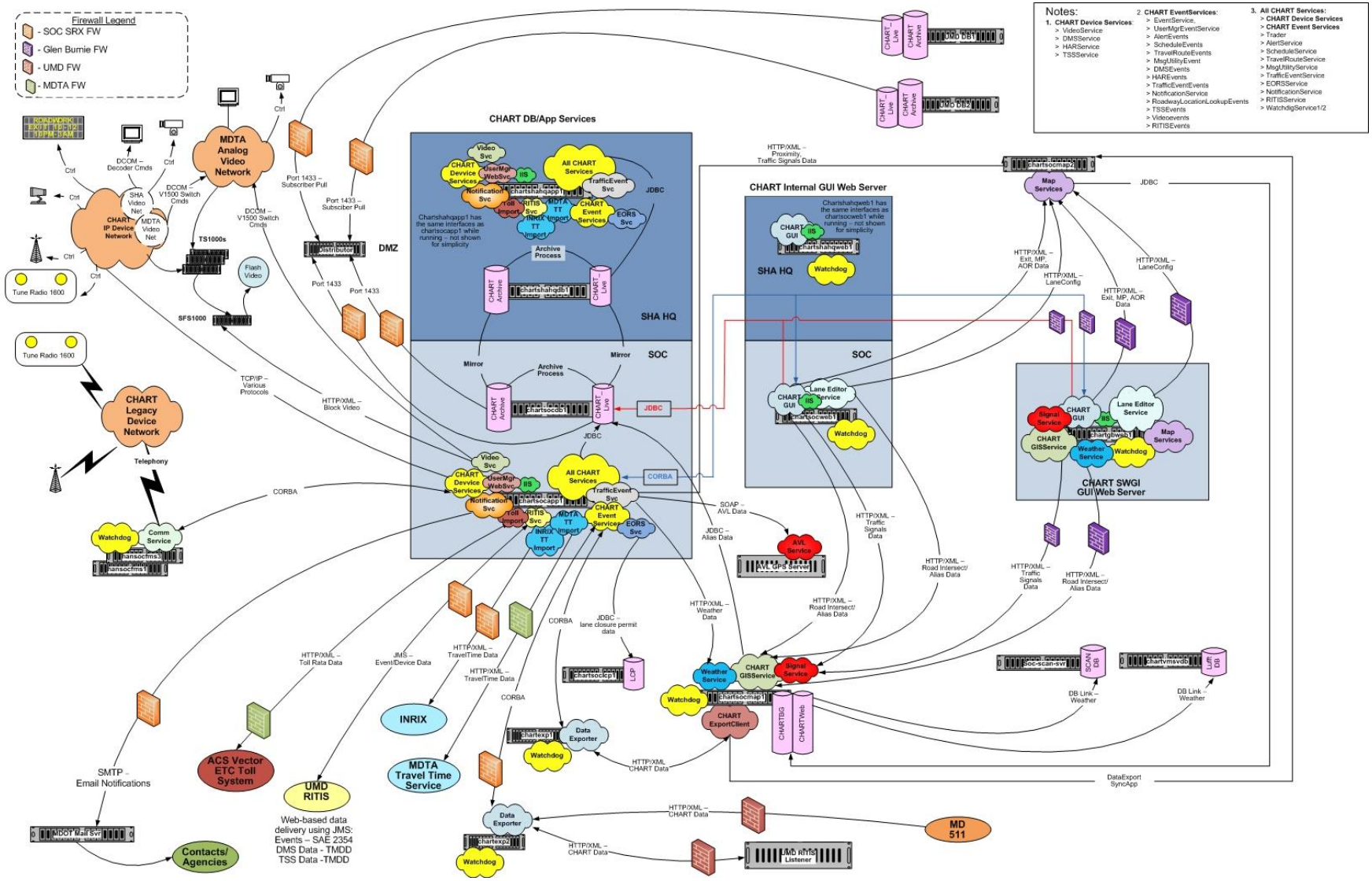

Figure 4-4. CHART ATMS Detailed System Architecture

4.3 Software components

4.3.1 Software CIs

There are five software CIs comprising the CHART ATMS.

- **CHART –** This CI consists of those subsystems providing direct support to the CHART operations staff. This includes the backend applications and the GUI.
- **FMS –** This CI consists of those subsystems providing low speed communications support functions for traveler information devices, traffic detection devices, and other telecommunications support required by the CHART ATMS.
- **COTS –** This CI is a collection of all the COTS packages used by the CHART ATMS. These are collected into a CI for configuration control purposes.
- **CHART ATMS Archive –** This CI consists of the archive database itself, plus subsystems supporting the duplication and archiving of CHART ATMS data.
- **Database Instance –** This CI consists of only the database for the live CHART ATMS database.

4.3.2 Communications

4.3.2.1 Interprocess Communications

The CHART ATMS GUI and application services are able to locate needed software objects through the use of the CORBA Trading Service. Each CHART ATMS service that publishes CORBA objects offers the objects through the CORBA Trading Service. The general approach is that a service publishes one manager type object that then provides access to objects under its purview. The GUI collects knowledge of virtually all objects in the system, and provides a unified view of the system.

In addition to showing the software objects throughout the system on a single interface, it is also necessary to reflect the current state of the software objects as they are changed during real time operations. The CORBA Event Service is used to allow objects to push changes in their state to the GUI, other backend CHART ATMS services, the CHART Data Exporter, or any other interested CORBA clients. The CORBA Event Channel Factory is an extension of the CORBA Event Service that allows multiple event channels. Each CHART ATMS service whose objects are subject to real time changes creates one or more Event Channels in its local Event Channel Factory. Each event channel is earmarked for a specific class of events (such as DMS events). Each service that creates channels in the CORBA Event Channel Factory publishes the event channel in the CORBA Trading Service and then uses the channel to push events relating to object state, configuration updates, etc.

An interface that wishes to listen for events at a system wide level discovers all of the event channels via the CORBA Trading Service and registers itself as a consumer on each of the event channels. Using this scheme, an interface uses the Trading Service to discover all software objects and Event Channels. The interface may then provide the user with a unified view of the system, both in the objects presented and the ability to show near real time updates of these objects. Since the nature of the system is dynamic, processes periodically rediscover new objects and event channels via the Trading Service. The GUI can also be commanded to discover new objects on demand. This is generally not necessary, as changes are pushed dynamically. Figure 4-5 illustrates the relationship between the CORBA and Trading Event Services.

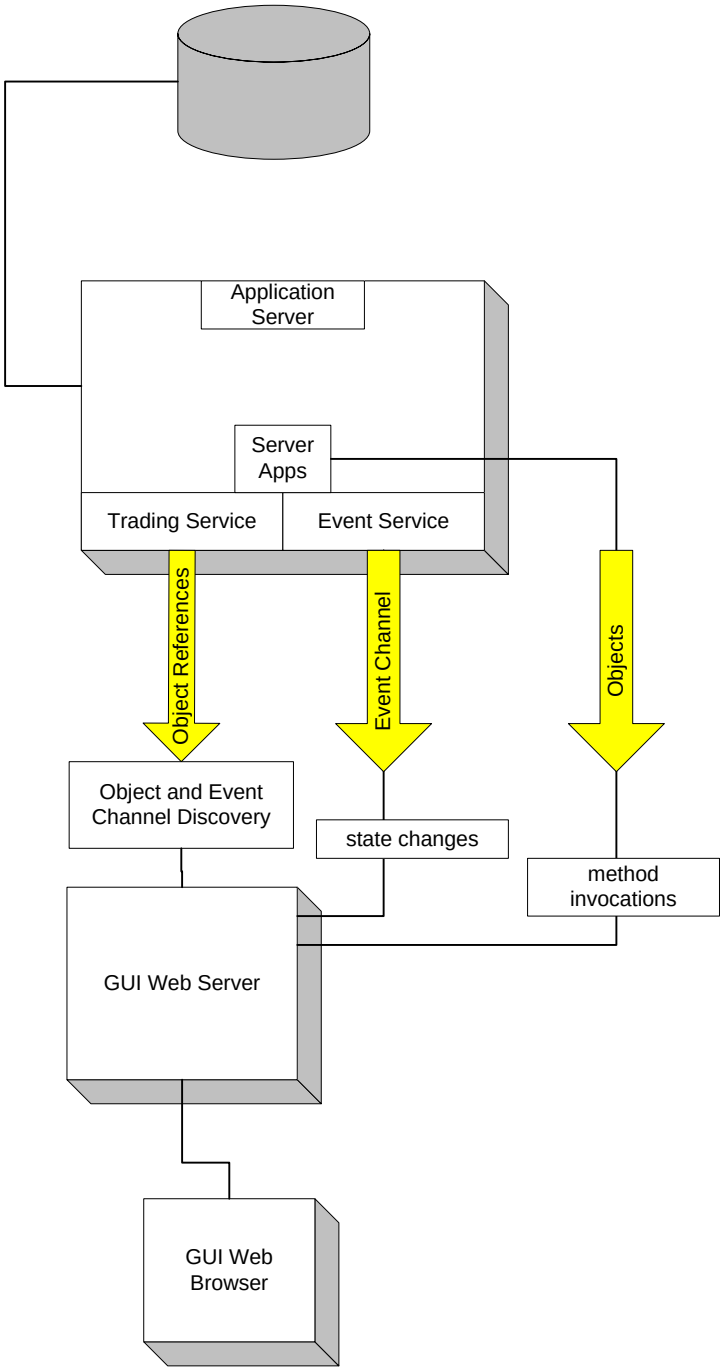

Figure 4-5. CORBA Trading and Event Services

Most CHART ATMS software objects used in this system are typical distributed software objects. The data inside an object pertains only to the instance of the object and operations pertain only to the instance of the object on which they are performed. Other parts of the system must go to the instance of an object to view the object's data or perform operations (via method invocations) on the object. For example, there is one and only one software object in the system that represents a specific DMS in the field. If an operation such as setting the message needs to

be done to the field DMS, the user interface must perform the operations on the one and only software object that represents the DMS.

4.3.2.2 Device Communications

CHART ATMS background services which communicate with physical devices deployed along Maryland highways do so via TCP/IP for DMSs, TSSs, and SHAZAMs. Some HAR device communications are also done via TCP/IP. For the remaining HAR devices, communications are done via FMS server. One CHART ATMS Communications Service runs on each FMS in the system (formerly multiple Communication Services supporting different types of communication would run concurrently on one FMS server, but now there is only one type of communications supported (telephony). The only remaining CHART ATMS background service requiring FMS services for this purpose is the HAR Service. Currently all CHART DMSs and TSSs utilize TCP/IP communications. The communications between the HAR Service and the Communications Services are IIOP, over TCP/IP. Communications from the Communications Services out to the physical devices are accomplished via telephone, via Telephony DTMF communications. Formerly communications to field devices could also be provided by FMS over ISDN or POTS modem, or via direct serial connection. Telephone service from FMS servers to devices is usually provided via landline, although cellular service occasionally needs to be utilized.

The remaining CHART ATMS background service controlling physical field devices is the Video Service. Video communication is accomplished via TCP/IP. Communication to CoreTec decoders is accomplished via proprietary CoreTec protocol via DCOM. Communication to iMPath decoders is accomplished via SNMP over TCP/IP, with published Management Information Bases (MIBs). The CHART ATMS does not directly command either the iMPath or the CoreTec encoders; they are used only as a pass-through to pass camera control commands and responses to/from the attached cameras. CHART ATMS's communication with the encoders, then, is via TCP/IP with no proprietary protocol involved. Communications to the Vicon V1500 NTSC video switch is accomplished via a proprietary Vicon protocol via DCOM. Once a video connection is established, the video stream is directed from encoder to decoder via MPEG2 or MPEG4 over TCP/IP, and/or through a V1500 analog video switch. The CHART ATMS software also has support for multiple transmission devices for cameras. This was done to support the ongoing effort to transcode video into multiple formats in order to more effectively share video with various CHART partner organizations and the public. This infrastructure allows an MPEG2 encoded video source to be viewed on a monitor attached to an MPEG2 decoder, a monitor attached to an MPEG4 compatible SHA decoder, and as a Flash video stream on the CHART ATMS GUI desktop, Intranet map, Public web site, and video web page on the SwGI.

4.3.2.3 Web Services Description and Diagrams

External entities receive CHART data via an HTTPS/XML interface rather than by the CORBA interface. The HTTPS/XML interface provides security features and data filtering capabilities not possible via the CORBA interface.

4.4 Database

The overall CHART ATMS database architecture is shown in Figure 4-6.

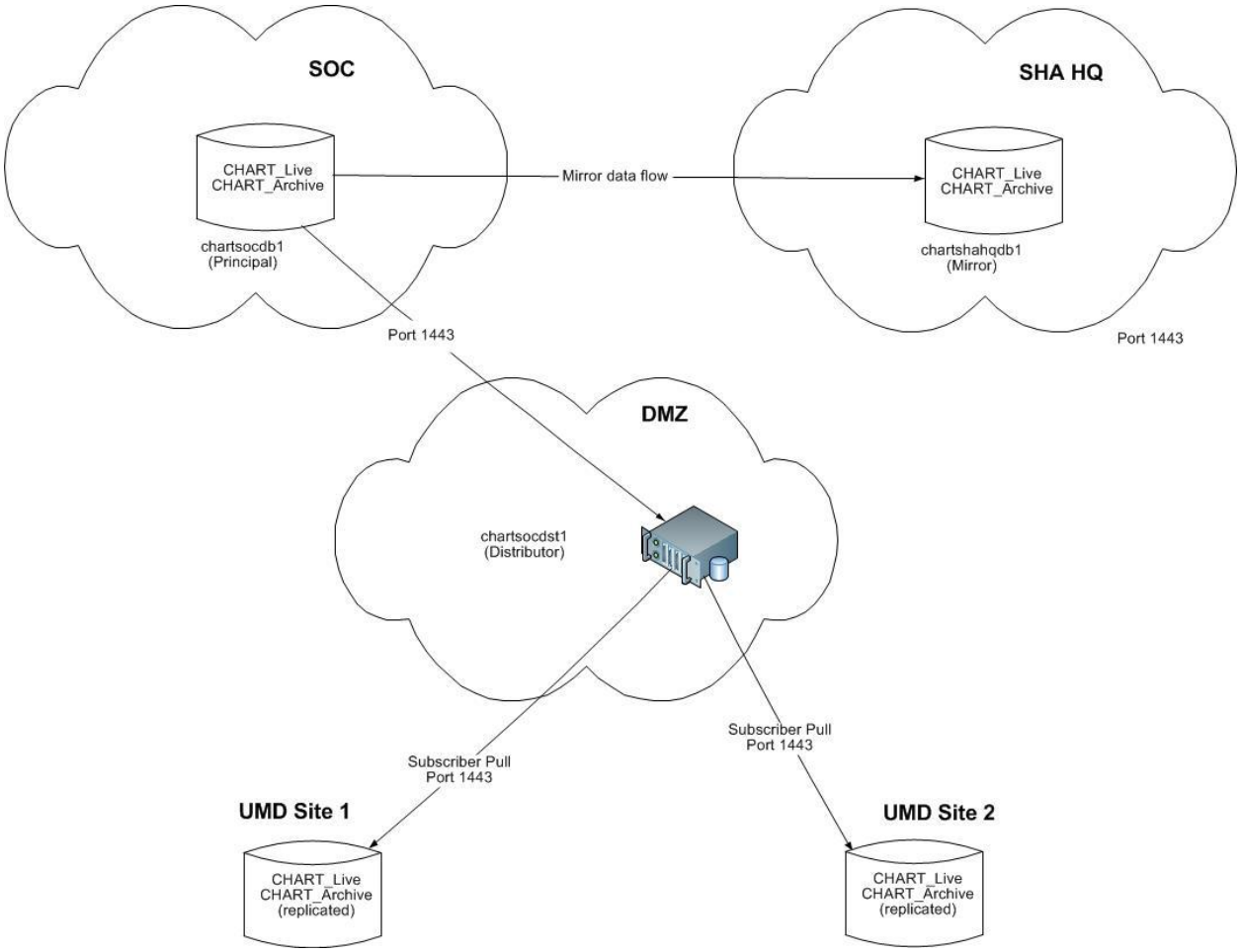

Figure 4-6. Database Architecture

Both databases are mirrored to SHA Headquarters. The mirror databases are used for disaster recovery scenarios. Database replication is used to provide query and reporting capabilities to the University of Maryland reporting system and is described in Section 4.4.3. Archiving is discussed in the following section.

4.4.1 Archiving

The Data Management subsystem handles the archiving of CHART ATMS data into the CHART ATMS Archive database. The CHART ATMS Archive database stores data from the CHART ATMS operational system as part of a permanent archive. Periodic database jobs are run to move data from the CHART ATMS operational system to the CHART ATMS Archive database. Most of the data which is archived is archived once a day, in the early hours of the morning after midnight when the system is otherwise least busy.

The CHART ATMS Archive database design bears some semblance to the CHART ATMS operational system, but is structured differently and contains only that information necessary to run the various required reports. For instance, very little device configuration data is included in the archive database: information about how to communicate to the devices, display configurations of signs, etc., is not needed for the various device reports, which are generally limited to what messages were posted when, what speed/volume/occupancy data came from

detectors, etc. The information required to be stored for devices is generally limited to mapping internal CHART ATMS IDs of devices to device names, so that reports can identify devices by name rather than by unfriendly CHART ATMS ID. Therefore, all devices are stored in a single lookup table in the archive database, whereas they are stored in type-specific tables in the live database (DMSs in a DMS table, HARs in a HAR table, etc.) Status information is not stored for devices, as these statuses are constantly fluctuating anyway (the status of a device at the time it was last archived is meaningless).

One set of device status data from devices which is stored in its entirety is speed, volume, and occupancy data reported by detectors (TSSs). Detectors are polled every five minutes, and data is generally collected per lane. The major output of the CHART ATMS is accumulated information about all the traffic events which transpire across the state on a continual basis. Virtually every piece of information about all the CHART traffic events is archived nightly. Traffic events are archived no sooner than twelve hours after they are closed, so that CHART ATMS operators can review and update traffic events within the CHART ATMS even after they are closed. All this data is accumulated and archived from the live system into the archive database as part of the nightly archive jobs. Closed alerts are also

Most data archived into the archive database is stored indefinitely, including all traffic event related data and detector data. The CHART ATMS archive database holds data going back to the year 2001. However, information pertaining to travel times, as reported by INRIX and as displayed on DMSs, is archived for only three months. INRIX provides a long term archive of all collected data. CHART's use of archived travel time data is primarily concerned with what travel time was posted on a DMS at a particular time in the recent past, or, if no travel time was posted, why not? Beyond a certain point, such questions are unlikely to be asked. Including all travel times for individual roadway links and accumulated travel routes, and status data that can explain the myriad reasons why a travel time was not posted are quite voluminous.

Data required to run and manage the CHART ATMS is generally not archived. This includes data pertaining to user management, system profile, libraries, and plans

4.4.2 Mirroring

The two CHART databases, CHART_Live and CHART_Archive, are mirrored from the Principal location at the SOC to the Mirror location at SHA Headquarters (HQ). This provides a duplicate copy of each database at SHA Headquarters, to be used by CHART services running at the SHA Headquarters failover site. These services are not running routinely. Before they can run, the mirrored databases at SHA Headquarters must be set to be Principal.

4.4.3 Replication

CHART publishes both the CHART ATMS operational and archive databases and two subscribers are set up at the University of Maryland. These two subscribers act as a backup for each other. A distributor server is set up as part of the SQL Server Replication. This distributor acts as a reliable store-and-forward mechanism to transfer all the database transactions from the publishers to the subscribers. To facilitate replication over the Internet the distributor database runs in the DMZ part of the CHART network.

4.5 Hardware components

This section presents the hardware CIs that make up the CHART ATMS. Each hardware CI is described and a list of major components is provided.

4.5.1 Hardware CIs

There are seven hardware CIs.

- **CHART ATMS Application Server –** Supports CHART ATMS applications.
- **CHART ATMS Database Server –** Supports the CHART ATMS Database Instance and CHART ATMS Archive software CI subsystems
- **CHART ATMS GUI Web Server –** Provides the conduit between the CHART ATMS services and the browser based interface GUI.
- **FMS Server –** Support the FMS software CI subsystems.
- **CHART ATMS Data Exporter Server –** Supports export of CHART ATMS data – both internally and externally.
- **CHART ATMS Emergency Server –** Provides a degraded CHART ATMS when the primary system is not available, and the backup system is not available or is not being used electively. Elements of the CHART ATMS Application Server, CHART ATMS GUI Web Server, and CHART ATMS Database Server all run on this one server.
- **CHART ATMS Workstation –** Supports CHART ATMS client-side functions for operations users. The need for maintaining this item as a CI has been reduced by the adoption of the browser-based CHART ATMS GUI as the one and only supported CHART ATMS GUI. However, this CI is still maintained for historical purposes, if nothing else.

4.5.2 CHART ATMS Application Server Description

The CHART ATMS application server system supports the CHART ATMS software CIs. This system consists of a server along with associated storage array and network connection devices. These systems are currently deployed in a virtual environment at the SOC in Hanover, and on an identical backup at SHA Headquarters in Baltimore.

The CHART ATMS Application Server system configuration is:

- Intel XEON X5650 2 processor 8 Virtual CPU (vCPU) 2.67 GHz
- 16 GB Total SDRAM
- 50 GB D: drive, 200 GB E: drive, 1.2 TB F: drive
- DVD Drive
- Gigabit NIC card

4.5.3 CHART ATMS Database Server Description

The CHART ATMS Database Server supports the CHART_Live database used to store all data relating to the CHART ATMS, and also the CHART_Archive database used to archive all CHART ATMS data deemed to be historically significant. It also hosts the other CHART ATMS Archive subsystems. The system accepts queries related to operations of the CHART ATMS and support operations performed by maintenance personnel. There are two CHART ATMS Database Servers: a primary one at the SOC in Hanover and an identical backup at SHA Headquarters in Baltimore.

The CHART ATMS Database Server system configuration is:

- Intel XEON X5650 2 processor 8 vCPU 2.67 GHz

- 32 GB Total SDRAM
- 50 GB C: drive, 400 GB E: drive, 1.2 TB F: drive
- DVD Drive
- Gigabit NIC card

4.5.4 CHART ATMS GUI Web Server Description

The CHART ATMS GUI Web servers are currently deployed in a virtual environment at the SOC with a backup capability at SHA headquarters. There are two CHART ATMS GUI systems in normal use: the standard GUI system at the SOC and the SwGI GUI located at Glen Burnie. There is also a backup standard GUI system at SHA Headquarters in Baltimore.

The standard CHART ATMS GUI Web Server system configuration is:

- Intel XEON X5650 4 processor 4 vCPU 2.67 GHz
- 8 GB SDRAM
- 40 GB C: drive, 50 GB D: drive
- Gigabit NIC card

The SwGI CHART ATMS GUI Web Server system configuration is:

- Intel XEON X5680 2 vCPUs 2.67 GHz
- 6 GB SDRAM
- 20 GB C: drive, 50 GB D: drive, 200 GB E: drive
- DVD Drive
- Gigabit NIC card

The SwGI CHART ATMS GUI Web Server also runs CHART Mapping services that serve map tiles to the CHART ATMS GUI, since regular CHART Mapping services cannot be easily accessed from this SwGI GUI network.

4.5.5 FMS Server Description

The two FMS Servers are both are located at the SOC. (Therefore, FMS services may not be available in certain failover scenarios.) The existing FMS server components were developed for, and tested and fielded on, the following hardware platforms:

The FMS Server system configuration is:

- Intel XEON ES-2403 4 CPU 1.8 GHz
- 8 GB SDRAM memory
- 3 PCI, and one PCI/ISA
- 50 GB C: drive, 500 GB D: drive
- Gigabit NIC card
- Hot Plug Redundant Power Supply

Network communications are provided via the embedded Compaq 10/100 TX PCI UTP Controller on the CPU motherboard. ISDN communications were supported through the use of Dialogic Diva Server ISDN boards but are no longer needed. Communications over POTS were

supported by Digi International RAS-8 boards, but these are no longer needed, either. Dialogic Springware D4PCI-U boards are used to provide the existing telephony functionality.

Modem-based communications have been completely phased out in favor of wireless Ethernet services. This has resulted in the decommissioning of most of the FMS servers. The only two FMS servers which remain support telephony services for legacy AP-55 HARs. These FMSs do not contain the Diva boards or RAS-8 boards which would be needed to support ISDN or POTS communications. The FMS software still contains the modules which still support these cards if they were installed.

4.5.6 CHART ATMS Data Exporter Server Description

The CHART ATMS Data Exporter Server supports the export of all CHART ATMS traffic event management, detector, DMS, HAR, SHAZAM, and CCTV operational data. There are two CHART ATMS Data Exporter Servers, both located at the SOC, and both of which run together at the same time. There is no backup capability for these servers, so Data Exporter services may not be available in certain failover scenarios. One CHART ATMS Data Exporter Server supports export of data within the SOC to the CHARTWeb database (where it is used by CHARTWeb and the CHART Mapping (Intranet Map and Internet Map). This is known as the "Internal" exporter. The other CHART ATMS Data Exporter Server supports export of data to "external" entities. There are two external consumers of exported CHART ATMS data: one is the RITIS system, located at the University of Maryland, and the other is Maryland 511. The external CHART Data Exporter Server resides on the DMZ in the SOC.

The CHART Data Exporter Server system configuration is:

- Intel® XEON X5650 2 processor 4 CPU 2.67 GHz
- 6 GB SDRAM
- 40 GB C: drive, 40 GB D: drive
- Gigabit NIC card

4.5.7 CHART ATMS Emergency Server Description

The CHART ATMS emergency server system supports software CIs for the CHART ATMS Emergency System. This system consists of a single server located at the Authority Operations Center (AOC). Because only selected elements of the full CHART ATMS services run on this server there are resources available to also run CHART ATMS database services and a specially configured GUI web service which makes it clear that it is the CHART Emergency System (often abbreviated as CHART-ES). The database has identical structure to the operational CHART ATMS database, but only selected portions of it are populated, as necessary. The database content is kept current while CHART-ES is not running by database scripts which run on this server. Despite the name, CHART-ES is not used exclusively during emergencies; it has also been used during scheduled system upgrades.

The CHART ATMS Emergency Server system configuration is:

- Intel XEON E5640 4 CPU 2.67 GHz
- 6 GB Total SDRAM
- 50 GB D: drive, 300 GB D: drive
- DVD Drive

- Gigabit NIC card

4.5.8 CHART ATMS Workstation Description

Since CHART ATMS became a web-based application which can run on any workstation with a browser, the CHART ATMS Workstation is no longer maintained as a Hardware CI under the purview of CHART ATMS. Many CHART ATMS Workstations located at numerous locations across the state may come in a large variety of configurations. Their numbers and configurations not actively tracked.

5 INTERFACE VIEW

5.1 View Description and Typical Stakeholders

The Interface view describes connections to systems and users outside of the CHART ATMS. Most of CHART's external connections are to systems that then re-package the information for presentation to their end-users. In some cases the consumers are actually other CHART systems such as users of the Intranet Map and LCP who need CHART ATMS information on a read-only basis and do not actually manage incidents.

CHART ATMS imports information from agencies and systems within Maryland and from systems outside of Maryland to gain a regional perspective.

Typical stakeholders of this section are representatives from other agencies interested in CHART ATMS's capabilities, specifically software and system architects who may be looking to interface with CHART ATMS.

5.2 External Interfaces

Figure 5-1 shows the external interfaces to the CHART ATMS. The inner cloud is the CHART ATMS proper whose mission is the active management of traffic on Maryland roadways. The larger CHART cloud includes other systems that CHART ATMS communications with to complete its mission. These other systems often interface with each other as well however as the focus of this diagram is CHART ATMS those interfaces are not included here.

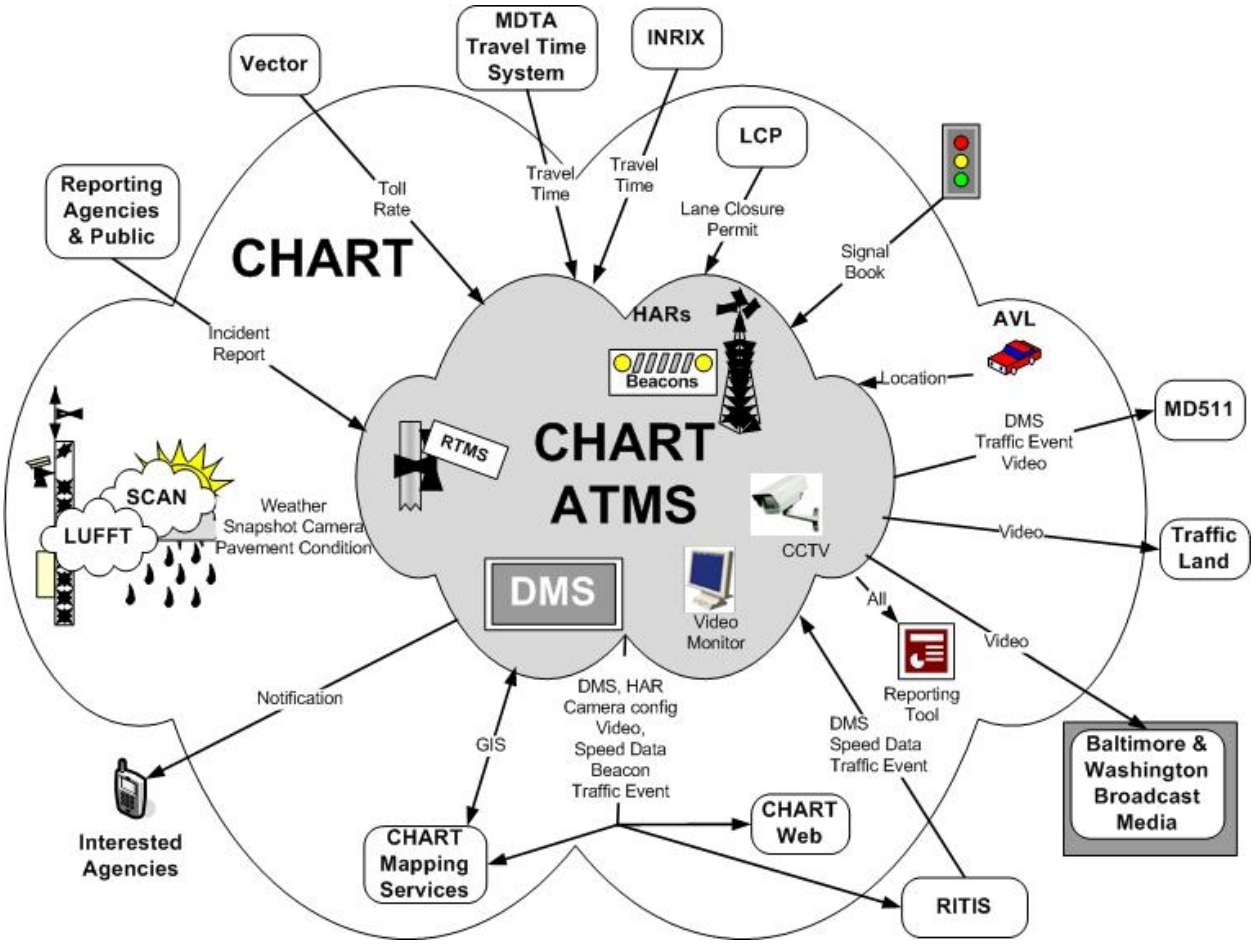

Figure 5-1. CHART ATMS External Interfaces

CHART ATMS's external interfaces consist of:

- **CHARTWeb** – This public-facing site displays incident reports, lane closures, speed data, DMS messages, and camera configurations obtained from the CHART ATMS via an HTTPS/XML interface. CHARTWeb also displays map and video data from other CHART sources.
- **CHART Mapping Services** – These services provide GIS support for CHART ATMS and other CHART systems. Included in these services is support for location aliases, roadway intersection/exit/milepost lookup, roadway lane configurations, object proximity, AOR configurations, and map background tile overlays. The Intranet Map is included in this suite which provides a geographical view of CHART ATMS objects including incident reports, lane closures, speed sensors, DMS data and camera configurations.
- **Lane Closure Permits (LCP)** – System providing permit information on planned and active road closures and road status.
- **TrafficLand, Baltimore Media, and Washington Media** –These external media organizations receive video from CHART. CHART ATMS users control where the cameras are pointed and are able to selectively block these video feeds on demand.

- **SCAN** – SHA legacy system supplying weather sensor data including pavement conditions. SCAN is in the process of being phased out.
- **Lufft** – System to supply weather sensor data including pavement conditions to CHART applications. The transition to this system from the SCAN system is still in progress as of CHART ATMS Release 11.
- **CHART Reporting tool** – Developed and maintained by the UMD CATT Lab, this web site generates reports from replicated copies of the archive CHART ATMS database.
- **Regional Integrated Transportation Information System (RITIS) –**

  This system was developed by the University of Maryland Center for Advanced Transportation Technology (CATT) Lab. It both imports and exports CHART ATMS information:

  - **Export** – RITIS receives Society of Automotive Engineers (SAE) ATIS standard incident and TMDD standard device configuration and status updates from CHART ATMS via an HTTPS/XML interface. RITIS also receives video feeds from CHART which can be dynamically blocked/unblocked from within CHART ATMS.
  - **Import** – RITIS provides CHART ATMS with SAE ATIS standard regional traffic events and TMDD standard DMS and TSS data via Java messaging service connections. These data are collected from Northern Virginia, Washington Metropolitan Area Transit Authority (WMATA), District of Columbia Department of Transportation (DCDOT), Navteq, SpeedInfo and even MDOT.
- **Interested Agencies** – Requesting agencies receive notifications from CHART ATMS about occurrences of interest via e-mail or text messages. Text messages are sent out as SMTP messages and converted to text by the email provider.
- **INRIX** –Provides roadway travel times to CHART ATMS for display on selected DMSs. CHART ATMS connects to INRIX via an HTTP/XML interface.
- **Vector** – MdTA system provides dynamic toll rates to the CHART ATMS. The Vector system connects to CHART ATMS via an HTTP/XML interface.
- **MD511** – Receives incident reports, DMS messages, and video feeds from CHART. Incident descriptions and travel times are converted to audio and played for callers. All collected information is available on its public website. CHART ATMS can dynamically block these video feeds as necessary.
- **Signal Book** – CHART ATMS accesses the SHA Signal Book database containing locations of non-CHART, state-owned arterial devices including traffic signals, cameras, beacons (school, bridge, and warning), pre-emption signals (fire, bus, and rail), reversible lane signals, and weigh station devices.
- **AVL** – Automatic Vehicle Location system provides real-time vehicle locations over a SOAP interface which CHART ATMS uses to identify the closest incident responders. CHART ATMS also uses it to track when responders actually arrive and depart an incident.
- **Reporting Agencies and Public** – In addition to incident reports coming from the general public, CHART ATMS also receives incident reports from many agencies including SHA and MDTA personnel, local and state police, and CHART's own Safety Service Patrol (also called CHART Units).

6 DATA VIEW

6.1 View Description and Typical Stakeholders

This view into the CHART ATMS shows how data move into, out of, and around the CHART ATMS and describes at a high level how CHART ATMS data is stored in the operational and archive databases associated with the CHART ATMS. This view is useful for CHART ATMS DBAs, management, developers, and stakeholders affiliated with the various systems with which the CHART ATMS interfaces.

6.2 Data Flow

Data flows for the CHART ATMS are illustrated in Figures 6-1, 6-2, and 6-3.

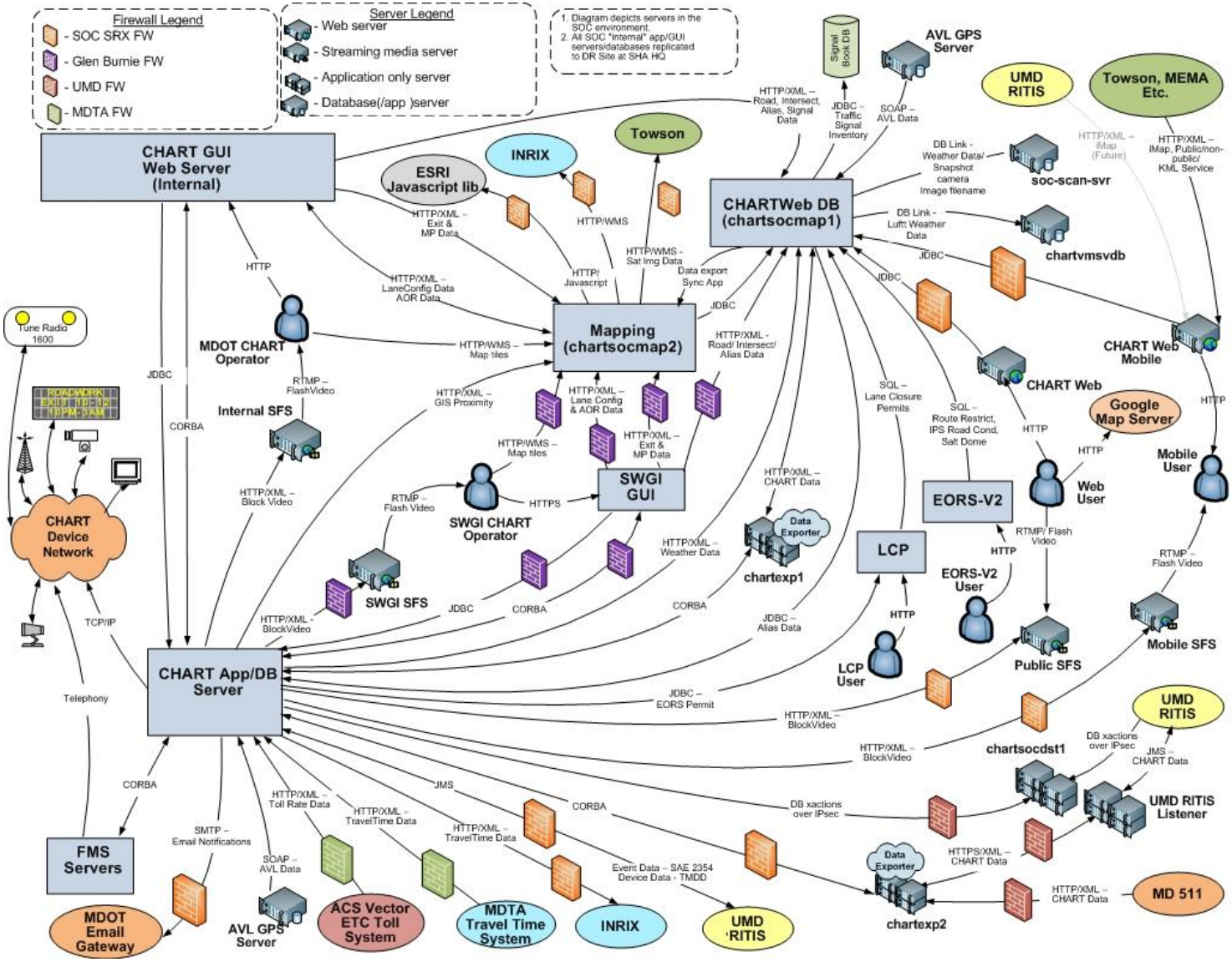

Figure 6-1. CHART High Level Data Flow

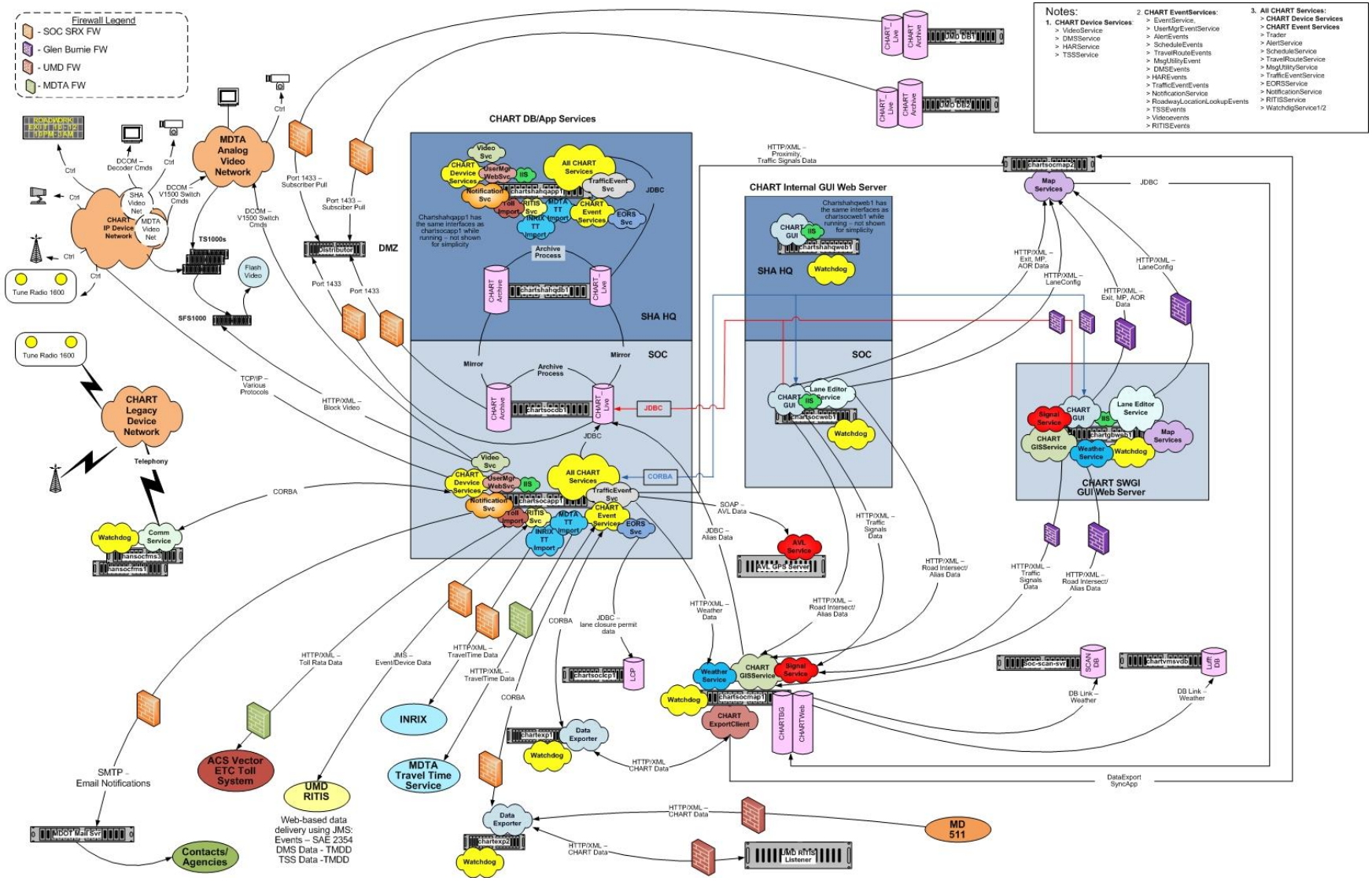

Figure 6-2. CHART ATMS Detailed Data Flow

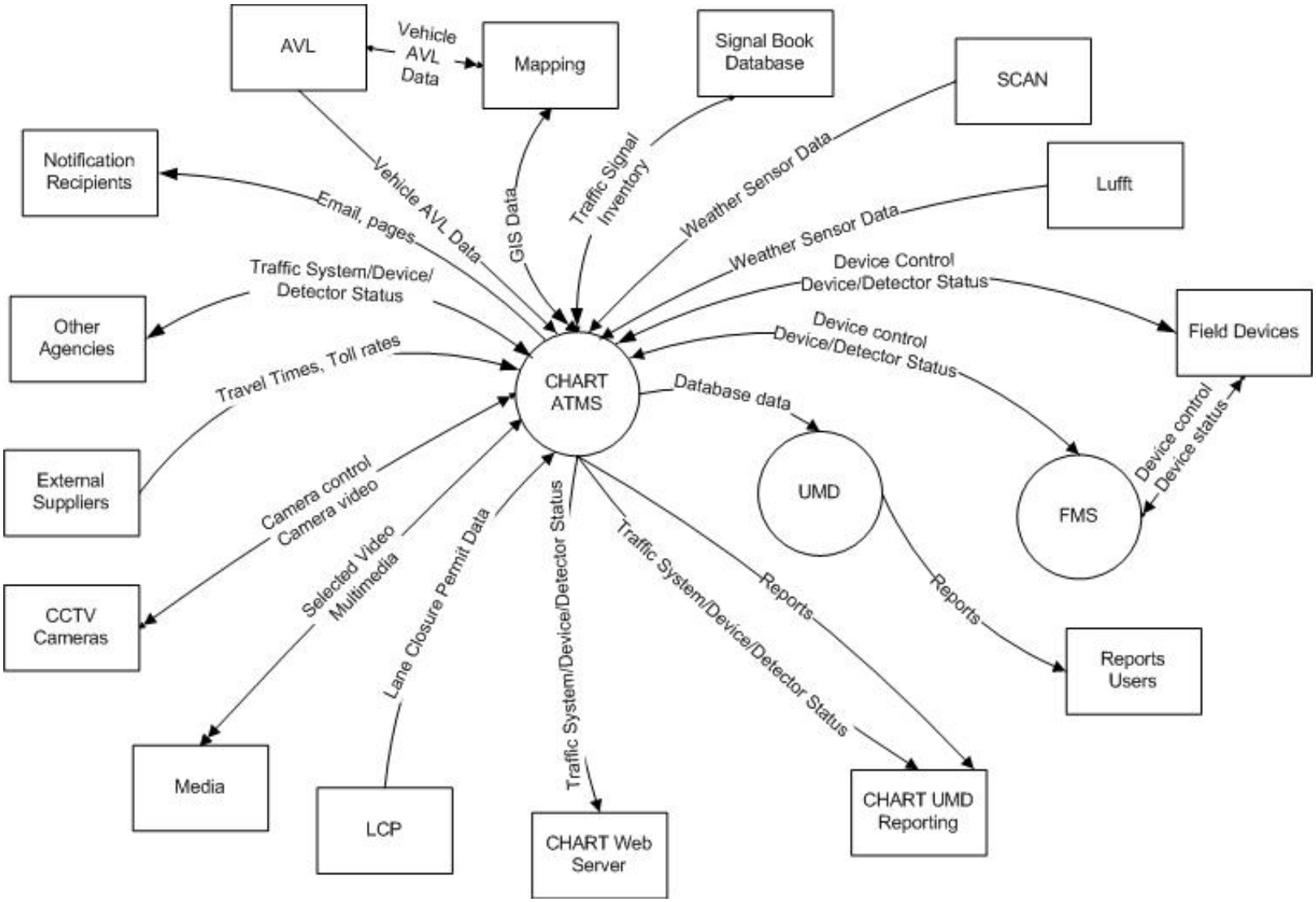

Figure 6-3. CHART ATMS System High Level Data Flow

6.3 Database

This section describes the CHART ATMS operational database design, at a high level. The design is based on the CHART Business Area Architecture and the CHART System requirements. The database design consists of these major areas:

- System/Configuration Management
- User Management
- Device Configuration
- Device Status
- Audio Data
- Device Support
- Traffic Event Management
- Traffic Event Response Planning
- Decision Support
- Data Import
- Log Data
- Alert Management
- Notification Management
- Schedule Management
- Travel Route Management

6.3.1 System/Configuration Management

The System/Configuration Management area encompasses system level data, including system profile settings, user profile settings, operations centers, geographical area definitions, location aliases, organizations, camera regions, and standard lane configurations. This data is generally static, in the sense that it is updated by users, on a fairly infrequent basis (as opposed to dynamic data which is updated directly by system software on a steady recurring basis). Most of this data is not archived. Operations centers are archived nightly, and a history of changes to operations centers is maintained in the archive.

6.3.2 User Management

The user/system management area consists of the complete suite of information to tie together the users and external applications approved to log into and use the system, roles, and functional rights. This also included folder information, which aids operators by showing (by default) only devices and objects associated to their operations center. All this data is generally static. While users may be added or removed on a weekly basis, this data is input via CHART administrators, and is relatively infrequent. Roles and external applications change very rarely (generally only after a new release of the CHART ATMS is deployed). The data in this area is not archived.

6.3.3 Device Configuration

The DMS, HAR, SHAZAM, TSS, Camera, Monitor, and other CCTV video entities include data that define the configuration of the devices themselves. This includes device names, locations,

organization, communications configuration data, etc. This area also includes the configuration of static video tours, which can be displayed on monitors in place of a solitary camera. Device configuration data is generally static. While this data is changeable to reflect configuration changes in the fielded equipment and the addition of new devices, these changes occur infrequently.

For the most part, the data in this area is not archived. Device names and IDs are archived (in one conglomerated device table), but the numerous configuration items for each device are not archived. The only exception is anything to do with displaying travel routes on DMSs, for the purposes of reviewing why a travel route message was not displayed on a particular DMS at a particular time, is archived for 90 days (then discarded from the archive).

6.3.4 Device Status

The DMS, HAR, SHAZAM, TSS, Camera, and Monitor entities include data that define the status or state of the devices. This data is fairly dynamic. Some status information (e.g. last poll time, last polled detector speed data) changes very frequently, on a regular, time-driven basis. Other status information (e.g., the message on a DMS) changes less frequently (although even travel time data is updated on a machine-driven, regular cycle).

The data in this area is not archived. The only exception is any status information which could help review why a travel route message was not displayed (or what travel route message was displayed) on a particular DMS at a particular time is archived for 90 days (then discarded from the archive). Note that the operations log, from which some status information can be gleaned (what messages were displayed on DMSs, device communications mode changes) is archived, however.

6.3.5 Audio Data

There are several tables within the system responsible for maintaining recorded audio data. This data is used by HARs, traffic events, and message libraries. This data is relatively static. Most HAR messages created on the fly are created as text messages rather than recorded audio, and, in any case, this data can be generated only as fast as an operator can talk, and only as traffic conditions warrant HAR message changes. This data is not archived.

6.3.6 Device Support

This area consists of “Arbitration Queues” which are maintained by devices (and generally written by traffic event and travel route entities) to store messages, potentially multiple prioritized messages which must undergo an arbitration process which determines which message(s) go on a field device at a given time. This area also includes dictionaries, which prevent banned words from going to devices, helping operators to use standard, and correct, words on devices, and to help the CHART Text to Speech entities pronounce words and numbers correctly. Dictionary and pronunciation data is quite static. Arbitration queue data update frequency varies – messages generated by operators occur only as fast as events occur and operators queue up messages for DMSs and HARs, but messages generated by travel times can change up to every two minutes, for several dozen signs. The data in this area is not archived.

6.3.7 Traffic Event Management

Traffic Event Management data is the primary data which CHART is designed to produce. This area includes all data associated with traffic events, including basic event details, location,

response plan data, participation, etc. This area also includes the traffic event history, a record of all system, device, and user generated log entries pertaining to the creation, management, and cleanup of the event, and the Communications Log, a record of telephone/radio voice communications between CHART operators and other people, such as participants at or potentially targeted to travel to specific roadside events, police, CHART units, etc.

The Event History Log and Communications Log are the two types of log data that do not fall under the Log Data area discussed further on in this section, as the Event History Log and Communications Log hold the primary mission data (or data directly ancillary to the primary mission data) which the CHART ATMS is designed to manage and produce. All other logs are concerned more with the operation and maintenance of the system rather than being a part of the primary data output of the system.

This area also includes weather data, gathered from weather devices near a newly created traffic event; participant/AVL data, from managed locations of participants and the associations of participants with locations; and signal data, which can be associated with action events pertaining to traffic signal problems. All this data (and the event history as much as any of it) is moderately dynamic. Weather data, participant/location data, and signal data does not add much to the dynamic nature of this data, as weather data is collected only when a new traffic event is created, participant/location data is not stored unless a participant is associated with a specific CHART event, and signal data is generally associated to an event only as an event is created. Traffic signal data is also stored at its source in a database which is outside of the CHART ATMS. The CHART ATMS team wrote a Signals Web Service which reads the source database and provides the data to the CHART ATMS (Traffic Event Service).

This area also includes Pending Traffic Events, which are used infrequently within the system. (Although Pending Events might more logically be thought of as "Traffic Event Response Planning", the tables used to store Pending Events are in fact the same tables used within this area to store live traffic events.) The tables in this area generally grow continuously. Records in these tables are generally inserted, occasionally updated, and infrequently deleted.

Traffic Event data is archived indefinitely, as one of the primary historical outputs of the CHART ATMS. Archive jobs periodically remove older records, and move them to the archive database. This includes external events imported from RITIS. Although external events share the same tables as CHART events within the operational database, within the archive database external events are stored in a separate set of tables from CHART events. Traffic Event data is not archived and removed from the operational database until some number of hours after the events have been closed, to allow operators to review and update traffic events in the system after they have been closed.

6.3.8 Traffic Event Response Planning

The CHART ATMS includes libraries and plans to use in support of traffic event management. Libraries are pre-canned DMS and HAR messages which are created in advance to aid operators in managing the response plans of traffic events when the planned-for situations actually occur. Operators do not use library messages directly, but use "plans" which pre-associate the generic library messages with specific local DMSs and HARs in the vicinity where the preconceived situations are expected to occur. This data is considered to be fairly static, although libraries and plans are easily updated. Plans and libraries are generally created and updated only by administrators and senior operators. The data in this area is not archived.

6.3.9 Decision Support

The CHART ATMS includes Decision Support components which help operators by proposing DMSs, HARs, and Cameras recommended to be used for a given traffic event, and by proposing messages to be put on the DMSs and HARs, all based on the type, details, and location of the traffic event, and the locations of the proposed devices. This area includes the data which provides the table-driven "intelligence" for the decision support function. This data is fairly static. When new decision support functionality is released, some activity is required to update the decision support tables, but these updates occur only as fast as the CHART ATMS administrators create them. The data in this area is not archived.

6.3.10 Data Import

This area includes some of the data the CHART ATMS collects from various external entities, including RITIS, INRIX, and Vector. The data imported from RITIS is stored in the Traffic Event Management area or the Device Configuration and Device Status areas, but the data used to manage the import process is stored within this area. This includes support data used to determine which data is to be imported and what to do with it when it is imported. (Travel time data collected from INRIX and toll rate data collected from Vector is stored within the Travel Routes area, and data collected from AVL and Weather services are stored within the Traffic Event Management area.) Data used to manage the RITIS interface and what is imported is quite static – it is rarely changed. The data in this area is not archived.

6.3.11 Log Data

The events entity includes all ongoing log data not related to traffic events. None of the logs within this area are accessible within the CHART ATMS. These records are written for only offline analysis. This includes, most significantly, the Operations Log, the historical log of everything significant that happens within the CHART ATMS. It can be used for troubleshooting purposes or for reporting purposes. This also includes the Communications Failure Log, a record of failed communications to field devices, logs regarding the management of temporary video tours on auto-mode monitors in the context of traffic events, logs related to the display of travel times and toll rates on DMSs (or why they were not displayed). This data is fairly dynamic, and is continuously growing. Records in these tables are inserted only, never updated or deleted.

The data in this area is archived. Nightly archive jobs remove older records, and move them to the archive database as necessary. Since these logs are not needed by the system, these logs are completely cleared out every night when the archive jobs run.

6.3.12 Alert Management

The alerts entity includes all informational data related to alerts. Alerts are dynamic data. Most alerts are created by the system automatically, although manually generated generic alerts are also supported. Alerts within the system are generally well controlled and efficiently managed, so there is generally not a large volume of alert data created. Alert data is generally continuously growing. The data in this area is archived nightly.

6.3.13 Notification Management

The Notification Management area includes all data related to notifications. Notifications are texts or emails that are sent out via an SHA SMTP server. There are two primary types of

notifications: those sent by operators (generally, though not exclusively within the context of a specific traffic event), and those sent by the system to alert personnel who may not be logged into or monitoring the system of a problem within the system that the system has detected. Notifications are dynamic data, although notifications are not sent out extremely frequently. Data concerning notifications is generally continuously growing.

The data in this area is archived. Nightly archive jobs archive off notifications which are sufficiently old, and whose associated traffic event (if any) is also closed and sufficiently old enough to be archived.

6.3.14 Schedule Management

The Schedule Management area includes all data related to schedules. Schedules can be used within the system to remind or notify operators of actions which may need to be taken within the system. Currently, such actions consist of only one type of action: opening a pending traffic event as a live traffic event. (The pending events themselves are stored within the Traffic Event Management area.) Schedules are dynamic data, but of very low volume due to their limited use within the system. Users add schedules to the system and delete them when they are done. Schedules have minimal dynamic associated status or history data. The data in this area is not archived.

6.3.15 Travel Route Management

The travel routes area includes all data related to travel routes, used to provide travel time and/or toll rate data for use in traveler information messages. Administrators add travel routes to the system in preparation for displaying travel times or toll rates on DMSs. Travel time data collected from INRIX and toll rate data collected from Vector is also stored within this area. Although the configurations of the travel routes themselves are fairly static, in general this area is very dynamic. Some of the tables in this area are continuously growing. Records in such tables are inserted only, never updated or deleted. Toll rate data and especially travel time data is quite voluminous. Toll rate data is updated for approximately 25 toll routes every 10 minutes, and travel time data is updated for approximately 800 roadway links currently used in CHART travel routes every 2 minutes.

The data in this area is archived multiple times per day. Archive jobs periodically remove older records, and move them to the archive database as necessary. Although all other archive jobs run nightly, archive jobs for this area run every 4 hours, due to the volume of data. This data is archived for 90 days, and then discarded, due to its volume.

6.3.16 TSS Detector Data Management

The CHART ATMS polls its detectors (approximated 200 of them) every five minutes. This data is stored in the CHART ATMS database and archived off nightly. Most detectors collect data on a per-lane basis, so speed, volume, and occupancy are collected for every lane for 200 detectors every five minutes. This data is archived indefinitely.

7 DEPLOYMENT VIEW

7.1 View Description and Typical Stakeholders

The deployment view describes the physical locations of servers and services. This view is useful for Operations and Maintenance personnel to identify relationships within and between servers. Network engineers may be particularly interested when identifying which protocols are expected between any pair of servers in the system.

7.2 Deployment Configurations

The nominal CHART ATMS software service configuration is shown in the table below. Under normal conditions the primary server executes all CHART ATMS software subsystems. In a fail-over situation the failover virtual environment supports all CHART ATMS software subsystems. The required COTS packages to support CHART ATMS are also installed on each server per the CHART R11 Operations and Maintenance Guide.

Table 7-1. CHART ATMS Deployed Services and Modules Per Site

Site	Server	Purpose	Service Name (Modules)
Hanover - SOC	chartsocapp1	Alert Management	AlertService (AlertModule)
		DMS Control	DMSService (DMSControlModule)
		LCP (formerly EORS) Interface	EORSService (EORSModule)
		Geographical Information Service	RoadwayLocationLookupService (GeoAreaModule)
		HAR Control, HAR Notification	HARService (HARControlModule, SHAZAMControlModule)
		INRIX Import Management	INRIXImportService (INRIXDataImportModule)
		Notification Management	NotificationService (NotificationModule)
		RITIS Import Management	RITISService (EventImportModule, DMSImportModule, TSSImportModule)
		Schedule Management	ScheduleService (ScheduleModule)
		System Monitor	(2) WatchdogService (WatchdogModule)
		Toll Rate Import Management	Toll Rate Import Service under Apache Tomcat
		Traffic Event Management	TrafficEventService (TrafficEventModule, CommLogModule)
		Traffic Sensor System Management	TSSService (TSSManagementModule)
		Traveler Information Management	TravelRouteService (TravelRouteModule)
		User Management	UserManagerService (UserManagementModule, ResourcesModule)

Site	Server	Purpose	Service Name (Modules)
		User Management Web Service	UserManagerWebService (WSUserManagerModule)
		Utilities	MsgUtilityService (DictionaryModule, AudioClipModule, TTSControlModule, MessageLibraryModule, PlanModule, MessageTemplateModule)
		Video Management	VideoService (CommandProcessorModule, CameraControlModule, MonitorControlModule, VideoSwitchControlModule, RouterControlModule)
		CORBA Object Request Broker	TradingService, EventService, AlertEventService, DMSEventService, HAREventService, MsgUtilityEventService, NotificationEventService, RITISEventService, RoadwayLocationLookupEventService, ScheduleEventService, TravelRouteEventService, TrafficEventEventService, TSSEventService, UserManagerEventService, VideoEventService
	chartsocweb1	CHART User Interface	chartlite under Apache Tomcat
		Lane Configuration	LaneEditorService under Apache Tomcat
		System Monitor	(2) WatchdogService (WatchdogModule)
	chartsocmap1	Weather Import Management	WeatherService under Apache Tomcat
		Intranet Map and CHARTWeb Data Collection	CHARTExportClientService under Apache Tomcat
		CHART ATMS GUI Alias and Roadway Location/Intersection Lookup	GISService under Apache Tomcat
		Signal Service	SignalService under Apache Tomcat
		System Monitor	(2) WatchdogService (WatchdogModule)
		<failover only> CHART Mapping GIS Service (lane config, milepost & exit lookup, AOR support)*	IIS(MapGISService/MapGISService.aspx) *

Site	Server	Purpose	Service Name (Modules)
		<failover only> CHART ATMS Map Tiles Service (background tiles and map layers for exit and milepost tiles) *	ArcGIS(CHARTBG_Cache, CHART_Exits_Mileposts_Cache) *
	chartsocmap2	CHART Mapping GIS Service (lane config, milepost & exit lookup, AOR support)	IIS(MapGISService/MapGISService.aspx)
		CHART ATMS Map Tile Service (background tiles and map layers for exit and milepost tiles)	ArcGIS(CHARTBG_Cache, CHART_Exits_Mileposts_Cache)
		<failover only> Weather Import Management *	WeatherService under Apache Tomcat *
		<failover only> Intranet Map and CHARTWeb Data Collection *	CHARTExportClientService under Apache Tomcat *
		<failover only> CHART ATMS GUI Alias and Roadway Location/Intersection Lookup *	GISService under Apache Tomcat *
		<failover only> System Monitor *	(2) WatchdogService (WatchdogModule) *
	chartexp1	Internal Export (within MDOT)	DataExportService
		System Monitor	(2) WatchdogService (WatchdogModule)
	chartexp2	External Export (out of MDOT)	DataExportService
		System Monitor	(2) WatchdogService (WatchdogModule)
	hansocfms1	Field Device Comm Service	CommunicationsService (FieldCommunicationsModule)
		System Monitor	(2) WatchdogService (WatchdogModule)
	hansocfms3	Field Device Comm Service	CommunicationsService (FieldCommunicationsModule)
		System Monitor	(2) WatchdogService (WatchdogModule)
Glen Burnie - TSO	chartgbweb1	CHART User Interface	chartlite under Apache Tomcat
		Lane Configuration	LaneEditorService under Apache Tomcat
		System Monitor	(2) WatchdogService (WatchdogModule)
		CHART ATMS Map Tile Service (background tiles and map layers for exit and milepost tiles)	ArcGIS(CHARTBG_Cache, CHART_Exits_Mileposts_Cache)
		CHART Mapping GIS Service (lane config, milepost & exit lookup, AOR support)	IIS(MapGISService/MapGISService.aspx)
		Signal Service	SignalService under Apache Tomcat

Site	Server	Purpose	Service Name (Modules)
		Weather Import Management	WeatherService under Apache Tomcat
		CHART ATMS GUI Alias and Roadway Location/Intersection Lookup	GISService under Apache Tomcat
AOC	chartes-aoc	CHART-ES User Interface	CHART GUI
		Alert Management *	AlertService (AlertModule) *
		DMS Control	DMSService(DMSControlModule)
		Geographical Information Service *	RoadwayLocationLookupService (GeoAreaModule) *
		HAR Control *, HAR Notification *	HARService(HARControlModule, SHAZAMControlModule) *
		INRIX Import *	INRIXImportService (INRIXDataImportModule) *
		Notification Management	NotificationService (NotificationModule)
		Toll Rate Interface	Toll Rate Import Service
		Traffic Event Management *	TrafficEventService (TrafficEventModule, CommLogModule) *
		Traffic Sensor System Management *	TSSService (TSSManagementModule)
		Traveler Information Management	TravelRouteService (TravelRouteModule)
		User Manager	UserMgrService (UserManagementModule, ResourcesModule)
		Utilities	MsgUtilityService (DictionaryModule, AudioClipModule *, TTSControlModule *, MessageLibraryModule *, PlanModule *, MessageTemplateModule)
		Video Management	VideoService (CommandProcessorModule, CameraControlModule, MonitorControlModule, VideoSwitchControlModule, RouterControlModule)
		CORBA Object Request Broker Services	TradingService, DMSEventService, HAREventService, * TrafficEventEventService *, TSSEventService *, ScheduleEventService *, TravelRouteEventService, RITISEventService *, NotificationEventService, MsgUtilityEventService, AlertEventService *, RoadwayLocationLookupEventService, * EventService
Baltimore SHA HQ	chartshahqapp1	<failover only> * (See Hanover - SOC chartsocapp1 for details.)	* (See Hanover - SOC chartsocapp1 for details.)
	chartshahqweb1	<failover only> *(See Hanover - SOC chartsocweb1 for details.)	* (See Hanover - SOC chartsocweb1 for details.)

Site	Server	Purpose	Service Name (Modules)
* Note: Items marked with a * are not normally executed (only during failover/emergency situations).			

7.3 Deployment Diagram

Figure 7-1 depicts the physical allocation of services to servers. The arrows are annotated with the network transport used to communicate between services pointing from the initiator of the connection to the target of the connection – not necessarily the direction of data flow. The focus here is on the CHART ATMS Application Server however external servers and services are included for clarity. Generally any server that communicates through a firewall is external to the CHART network.

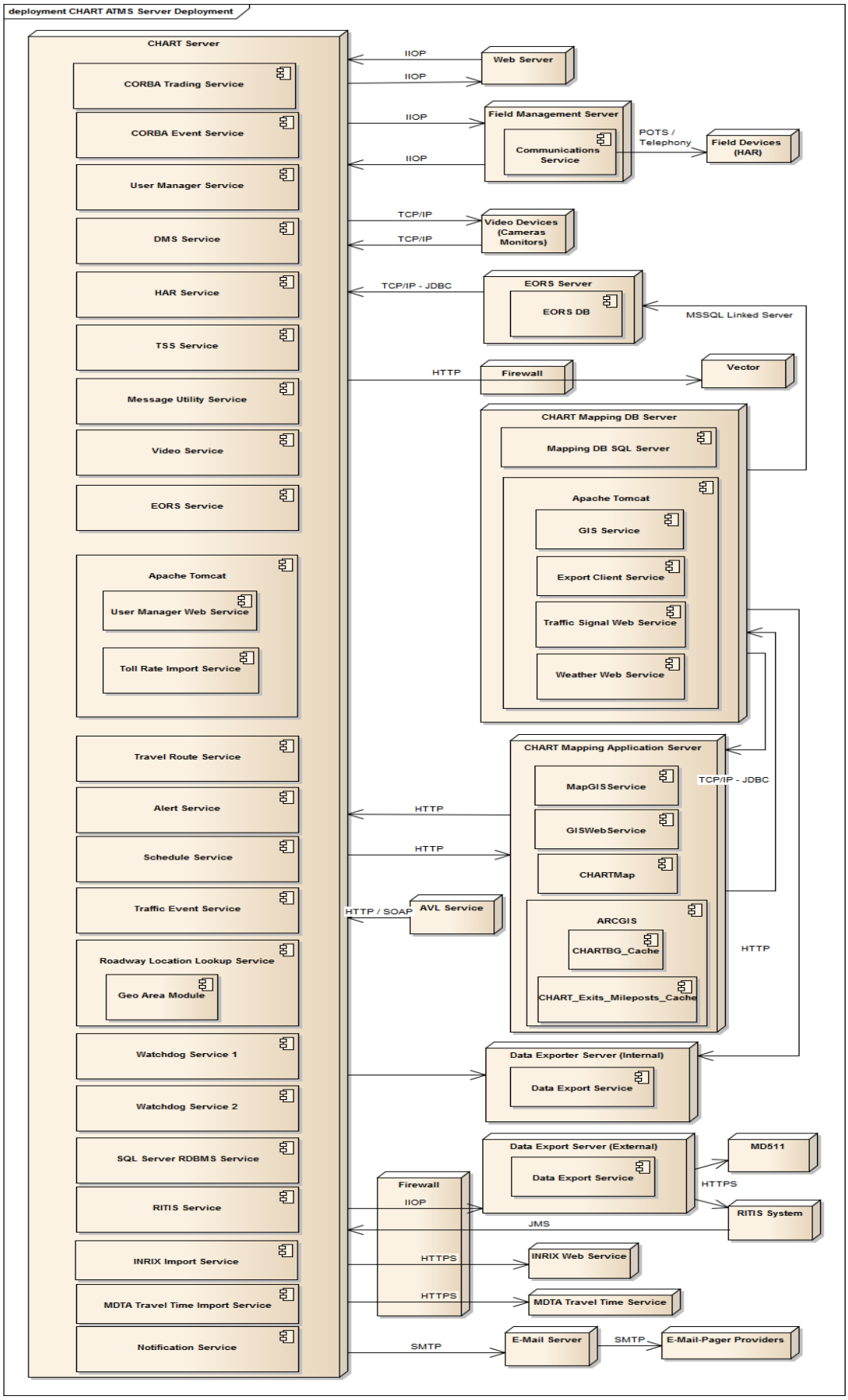

Figure 7-1. CHART ATMS Deployment

7.4 Network Diagram

Figure 7-2 shows the network diagram for the CHART ATMS.

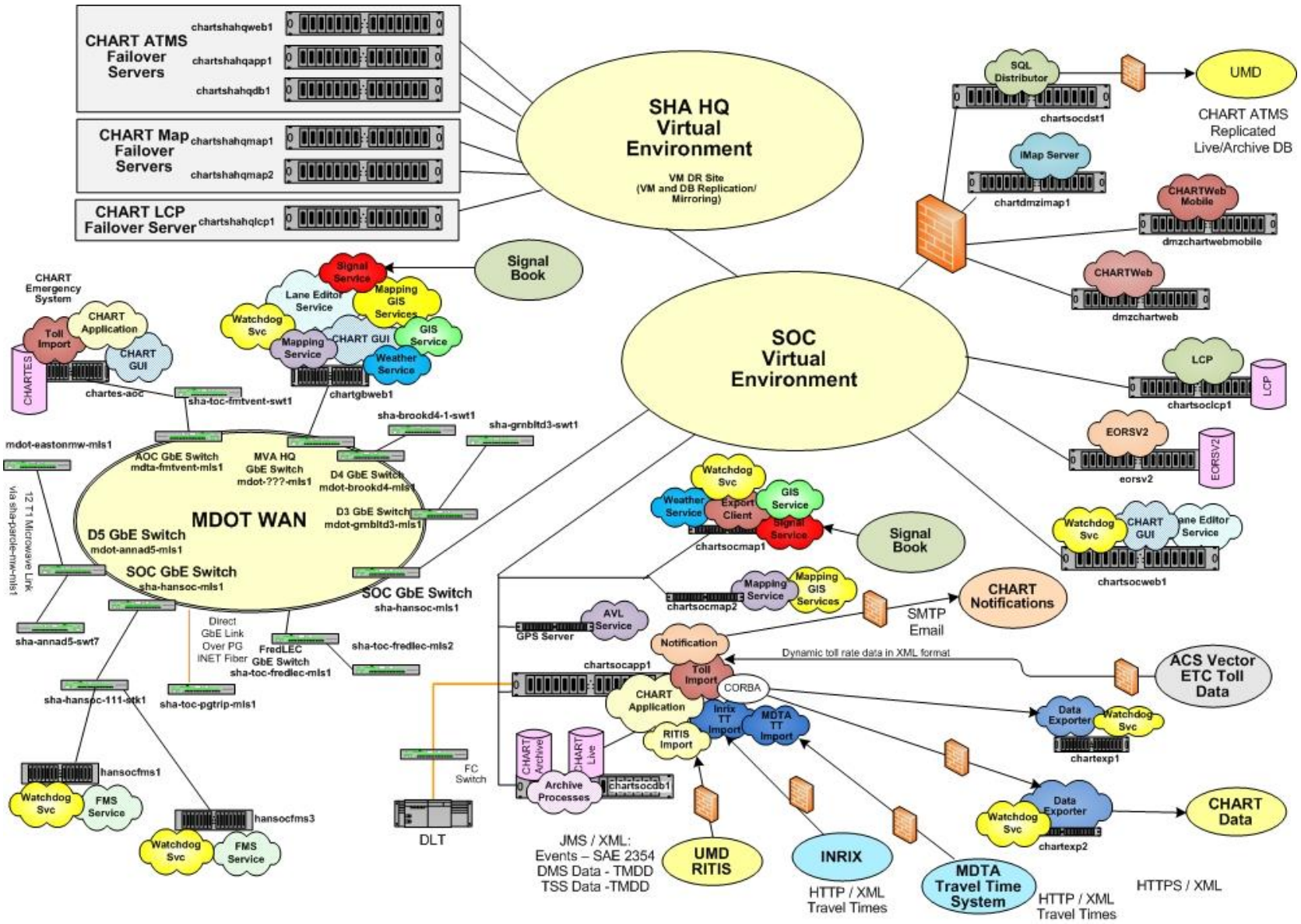

Figure 7-2. CHART ATMS Server/Switch Deployment

7.5 Facilities

This section presents the recommended deployment of hardware at each facility.

7.5.1 Node Sites

CHART ATMS application and GUI web servers are primarily located at the SOC. The SOC houses the CHART ATMS virtual environment and is the central site for the coordination of CHART ATMS activities. The list below describes the equipment to be deployed at each site.

1. Hanover Statewide Operations Center (SOC) –
    - Virtualized CHART ATMS application system
    - Field Management Servers (FMS) servers (2)
    - Virtualized CHART ATMS GUI Web Server
    - Virtualized SQL Server Database Servers (2)
        2. SQL Server Engine
        3. SQL Server Distributor
    - Virtualized CHART ATMS Mapping Server
    - Virtualized CHART ATMS Mapping Database Server
    - Data Exporter Servers (one internal to MDOT, one external)
4. Authority Operations Center (AOC)
    - CHART ATMS Emergency System (CHART ES)
5. Glen Burnie
    - One CHART ATMS GUI / Mapping Web Server
6. SHA Headquarters
    - Virtualized CHART ATMS application system
    - Virtualized CHART ATMS GUI Web Server
    - Virtualized SQL Server Engine Database Server

7.5.2 Traffic Operations Centers

Each TOC has the capability to run the CHART ATMS GUI on its workstations. The number and configuration of the workstations is determined on a case by case basis depending upon the activity level at the TOC and the available space.

7.5.3 Other CHART ATMS Client sites

The implementation of the SwGI has allowed CHART ATMS Applications to run on agency owned computers on networks that are connected together and protected by firewalls. Previously CHART ATMS would have to extend the MDOT Network to agencies that wanted to use CHART applications and provide workstations. Gradually CHART partners have been converting to SwGI and CHART has been removing workstations. The level of access to CHART ATMS applications and functionality are determined on a case by case basis depending upon the user's needs at the site.

7.5.4 Equipment and Vehicle AVL Installation

In addition to CHART interest in AVL, other SHA offices have deployed AVL equipped vehicles (e.g. dump trucks, state and contractor operated snowplows). The actual number of AVL installations has reached several hundred.

7.5.5 Field Management Server (FMS) Sites

Most of the CHART devices have been converted from serial and dial-up to use TCP/IP communications. As a result some 28 of the original 30 FMS servers have been decommissioned. The remaining 2 FMS servers are fielded in controlled, indoor environments at the SOC.

7.6 System Management and Support

This section discusses CHART system management activities and support provided for system monitoring and problem tracking.

7.6.1 Data Backup and Recovery

vRanger is used to create snapshots of the virtual machines then copies them to the failover site (Baltimore SHA HQ). The procedures responsible for performing the backups run automatically and require only periodic checks from CHART personnel to verify correct operation.

The system architecture and design minimizes the likelihood of having to recover an entire disk volume. The use of RAID 1 and RAID 5 arrays means that the system can perform self recovery in most instances. A more likely scenario would be the recovery of data due to corruption of some type. By taking periodic snapshots of the mission critical data and maintaining the Virtual Machine (VM) snapshots for a reasonable period of time a corrupted file could be restored to its last uncorrupted state.

7.6.2 System Monitoring

There are several levels of monitoring routinely performed on the CHART ATMS. The CHART ATMS Monitor (Watchdog) subsystem monitors CHART ATMS services for availability and performs automatic restart attempts for non-responsive services. The System Monitor (as configured) generates Alerts and Notifications when an automatic restart has been completed or when an automatic restart fails to correct a non-responsive service. Transportation Business Unit (TBU) personnel monitor CHART ATMS server performance using vFoglight.

7.6.3 Performance Monitoring

Device failure status information is logged and can be reported on to provide device communications performance measures. Additional system level and network performance data are gathered by the Network Operations Center (NOC). CHART ATMS operational performance measures such as traffic event response time, incident cleared, etc are reported from the CHART ATMS Reporting Tool maintained by the UMD CATT Lab.

7.6.4 Problem Identification and Tracking

The CHART project uses the problem tracking tool Mantis to support CHART ATMS system problem reporting and tracking. Problems discovered prior to delivery of a release to operations are recorded as Level B Problem Reports (PRs) and problems discovered in an operational

release are recorded as Level A PRs. PRs are handled as described in earlier documents "Level B System Problem Reporting in ClearQuest, CHART-CM-TE-006, June 2009" and "Level A System Problem Reporting in ClearQuest, CHART-CM-TE-004, June 2009". Although the CHART Program has recently switched issue tracking systems, from IBM/Rational ClearQuest to MantisBT, the essence of the workflow described in these documents is generally unchanged.

Problems discovered by the NOC are logged in the NOC's Maximo system. Problems determined to be CHART ATMS software problems are used to create problem reports in the CHART ATMS Mantis system for tracking and resolution.

8 SUBSYSTEM VIEW

8.1 View Description and Typical Stakeholders

The Subsystem View describes the subsystems of the CHART ATMS, their purpose, and how they are used. It describes all the COTS used in the system, and the source, version, usage, and redistributability of all the COTS. This view will be of primary use to developers, configuration managers, and management of CHART.

8.2 Software Subsystems

Table 8-1 lists each software and hardware Configuration Item (CI) and the subsystems comprising the CI. The sections that follow provide functional descriptions for each CI.

The CHART ATMS is dependent upon network services provided through the MDOT backbone network. The management and control of the network is outside the scope of this document.

Table 8-1. CHART ATMS Configuration Items and Subsystems

CI Name	Subsystems
Core Services	Alert Management Audio Management AVL Management Communications Log Management Data Export Management Data Import Management Decision Support Device Management Dictionary Management DMS Control HAR Control HAR Notification Message Library Management Message Template Management Notification Management Plan Management Resource Management Schedule Management Signals Management Simulation (future) System Monitor (Watchdog) Traffic Event Management Traffic Sensor System Management Traveler Information Management User Management Utility Video Management Weather Station Management
GUI Services	GUI Management Map Management
FMS Services	Port Manager Port Configuration Utility
Database Instance	Operational DB
Database Archive	Archive DB Mirroring Query Report Generation (UMD) Replication

CI Name	Subsystems
COTS	Adobe Flex SDK Apache ActiveMQ Apache Ant Apache Tomcat Apache XML-RPC ArcServeIT CoreTec Decoder Control Dialogic API Eclipse GIF89 Encoder GNU Bison GNU Flex IBM Rational ClearQuest IBM Rational RequisitePro Installer2Go 4.1.3 JacORB Event Service JacORB ORB JacORB Trader Java SDK Java Runtime Environment (JRE) JavaHelp JavaService JAXB Jaxen JDOM joeSNMP JSON-simple Java Topology Suite (JTS) Krakatau PM Microsoft Visual C++ (legacy C++ compiler) Microsoft Visual Studio 2010 Ultimate (current C++ compiler) Microsoft SQL Server Microsoft SQL Server JDBC Driver Microsoft Windows NeoSpeech Text To Speech Engine 3.11.5 NullSoft Scriptable Install System (NSIS) 2.45 OpenLayers O”Reilly Servlet Prototype JavaScript Library RedGate DBA Bundle

CI Name	Subsystems
	SAXPath Subversion Subversion browser TortoiseSVN 1.6.15 Velocity Template Engine Vicon V1500 API WordPress

8.2.1 Core Services Subsystems

The software subsystems comprising the Core Services CI are briefly described below. The detailed descriptions of the business processes that are to be implemented in each subsystem are presented in Table 10-1 of this document. (See Section 4.3 of the BAA for descriptions of all the business processes and sub-processes.)

8.2.1.1 Alert Management

This subsystem provides alert management and processing functions. It provides the methods to support the creation and delivery of alerts and maintains the status of alerts in the system. Alerts may be automatically created by applications or manually created by users. Alerts, if enabled, are directed to an operations center where acknowledgement by a user is required.

Some example CHART ATMS alerts are listed below.

- Device Failure – used to alert centers of device failures (hardware or comms failures)
- Event Still Open – used to alert centers of events that have been left open past a reminder time
- Duplicate Event – used to alert centers that there are multiple open events at the same location
- Travel Time – used to alert centers that a travel time has exceeded a configurable threshold
- Toll Rate – used to alert centers that there is a problem with the Toll Rate interface
- External Interface – used to alert centers that there is a problem with one of the CHART ATMS external interfaces
- External Event – used to alert the centers that there is an external event of particular interest
- Execute Scheduled Actions – alerts operators that it is time to open a scheduled event
- Unhandled Resource – used to alert centers that there are unhandled resources such as open traffic events or devices in maintenance mode that are controlled by center that has no logged in users
- Service – alerts operators that the watchdog has detected a service non-responsive, or restarted a service
- Manual Alert – operators can send alerts manually by typing a message and providing a list of centers to which to deliver the alert

- Transfer of Responsibility (future) – provides an alert to the receiving center of a transfer of responsibility to that center (e.g. transfer of responsibility for an open event)
- Incident from Detector (future)– alerts a center that detector data indicates a possible incident
- Mayday from AVL (future)– generated when an AVL equipped vehicle sends a Mayday message
- Weather Sensor (future) – generated when a weather sensor reports data outside of a set range (e.g. temperature below freezing)

Alerts that require a response within a specified time period can be configured to escalate up a configurable operations center hierarchy if not acknowledged within a configurable time period.

The client side of alert management provides the user with the capability to manually generate an alert and to respond to alerts they receive.

8.2.1.2 Audio Management

This subsystem provides distributed access to a text-to-speech engine that is utilized by the HAR subsystem for the conversion of text format messages into audible data that can be downloaded to the HAR device for broadcast. It also provides the ability to store and stream recorded audio data. Audio can be sent to users for listening purposes or to HARs to load messages onto the HARs.

8.2.1.3 AVL Management

AVL data from CHART and District vehicles is read by the CHART ATMS to support managing participation of AVL vehicles in traffic events. (AVL vehicle position and status data is also fed directly into the CHART Mapping Intranet map application for display.)

8.2.1.4 Communications Log Management

This subsystem provides a general logging mechanism for operators to record communications and activities in a central repository. All recorded communications are made available to all other operators in near real time through the user interface. The communications log also provides a filtered searching capability that allows an operator to select entries for viewing. Users may select entries to convert to a traffic event. These entries will become the base entries in the traffic event's history log.

8.2.1.5 Data Export Management

The Data Export Management subsystem provides a mechanism to make CHART ATMS data available to external entities. This subsystem generates standards-based, XML-formatted data streams with pre-defined content. This data is provided via a secure HTTP interface using both an on-demand (pull) and subscription (push) model. CHART ATMS exports ATIS J2354-based Traffic Event data, and TMDD-based status and configuration data for TSS and DMS. CHART ATMS also exports CCTV, HAR, and SHAZAM configuration data.

8.2.1.6 Data Import Management

The Data Import Management subsystem provides a mechanism for CHART ATMS to ingest data from external entities. This data is currently made available by RITIS and includes Traffic event, DMS, and TSS data.

8.2.1.7 Decision Support

The Decision Support subsystem helps users manage traffic events by suggesting DMSs, HARs, and cameras which should be used by traffic events, and it also suggests messages which should go onto the DMSs and HARs. This subsystem also suggests which DMSs and HARs currently in use by the traffic event might no longer be needed – for instance, as lanes reopen.

8.2.1.8 Device Management

This subsystem handles the control of device state change functions (to online, offline, or maintenance mode) and the management of device arbitration queue entries.

8.2.1.9 Dictionary Management

This subsystem provides administrator managed collections of banned and known words. Banned words are those words that are not allowed to be displayed or broadcast on traveler information devices. Known words are used to provide spell checking and rudimentary substitution suggestions when unknown words are detected.

8.2.1.10 DMS Control

This subsystem provides DMS control capabilities. It supplies support for multiple device manufacturer protocols. In addition, this subsystem provides the business logic required for arbitration of a particular DMS between competing traffic events.

The following types of Dynamic Message Sign are supported:

- NTCIP (subset of version 2, specifically version 2.35)
- FP9500
- FP1001
- FP2001
- TS3001
- Sylvia
- Display Solutions (PCMS)
- Addco

8.2.1.11 HAR Control

This subsystem provides HAR control capabilities. It supplies support for manufacturer protocols used by SHA HAR devices. In addition, this subsystem provides the business logic required for arbitration of a particular HAR between competing traffic events.

The following types of Highway Advisory Radio are supported:

- Information Station Specialists (ISS) AP55
- Highway Information Systems (HIS) DR1500
  - Includes Highway Information Systems (HIS) DR1500 telephony protocol and DCC IP protocol

8.2.1.12 HAR Notification

This subsystem provides management functions for the control of HAR notification devices such as SHAZAMs and DMS devices used as SHAZAMs.

The following types of SHAZAM are supported

- Viking RC2A remote on/off controller based SHAZAM
- HWG ER02a IP Relay controlled SHAZAM

8.2.1.13 Message Library Management

This subsystem provides message library management capabilities. It supports the creation of multiple message libraries for user-defined stored messages for use on DMS and HAR messages. (Unlike message templates, stored messages are pure text – there is no replaceable meta-data in library messages.) Each message in a library can be assigned a category for user classification purposes.

8.2.1.14 Message Template Management

The Message Template Management subsystem manages storage, editing, and use of templatized messages for DMSs and HARs, including for DMS toll rate messages, DMS travel time messages, and Decision Support templates for DMS and HAR usage with traffic events. Message templates include "placeholder" parameters to be replaced with actual data during execution of the template, for instance, for toll rate data, travel time data, and traffic event data (including location, and which lanes are closed, etc.).

8.2.1.15 Notification Management

This subsystem provides capabilities for managing the notification of personnel via text, page or email. (All messages go out via an SMTP email service, but most texting and paging services provide an email address which translates to a text or paging recipient.)

8.2.1.16 Plan Management

This subsystem provides the ability to associate library messages with devices (DMSs and HARs). Each item in a plan associates a stored message with one or more devices. These plans can be used to quickly construct traffic event response plans for traffic events that are recurring in nature or can be planned for ahead of time.

8.2.1.17 Resource Management

This subsystem provides for management of user login sessions and the control of shared resources. This subsystem also monitors the system for resources which should have a responsible owning center but do not.

8.2.1.18 Schedule Management

This subsystem supports the creation, management, and execution of lists of actions to be performed at predetermined times. Currently the only action which can be scheduled is the creation of a pending traffic event.

8.2.1.19 Signals Management

This subsystem provides an interface to the signals database in order to obtain traffic signal inventory and location information from the Signal Book for use by the CHART ATMS. This includes a web service which runs on one of the CHART Mapping servers. The extent of the use of this data now is to associate one or more (malfunctioning) traffic signals with an action event, and to use a traffic signal location to assign the location of an action event. (The CHART ATMS

operator has to know the signal is malfunctioning – the signals database does not provide this information.)

8.2.1.20 Simulation (future)

The Simulation subsystem is to be provided by the University of Maryland and integrates with the CHART ATMS.

8.2.1.21 System Monitor (Watchdog)

This subsystem provides system health monitoring processes that run on each CHART ATMS application server and FMS server. Each service application is monitored to determine if it is currently available. Alerts and/or Notifications can be generated when services are found to be unavailable and self-recovery is attempted.

8.2.1.22 Traffic Event Management

This subsystem provides for the management and recording of information pertaining to traffic events that are currently being worked on by system operators. It also provides for the control of traveler information devices via a traffic event's response plan. The response plan is composed of system actions, including device control commands. When the plan is executed the system actions are performed and any device control actions result in an entry being placed on the arbitration queue for the target device. Traffic Event Management also includes decision support capabilities for selecting appropriate traveler information devices and the messages that will be utilized by those devices. The decision support capabilities also include facilities for selecting CCTV cameras for display.

Each traffic event maintains a running history log of actions performed and user comments. Additionally, each traffic event maintains records of devices controlled, resources notified and utilized, when resources arrived and departed the scene, and related events, among other historical data. This data can be used (outside of the CHART ATMS) for offline reporting and statistical analysis purposes through tools maintained externally by the University of Maryland.

8.2.1.23 Traffic Sensor System Management

This subsystem provides control and data handling functions for traffic detector and speed measurement devices. Historical data summaries are compiled and archived. In the future, current traffic detector information may be compared with historical traffic detector information and alerts may be generated for conditions exceeding specified tolerances.

8.2.1.24 Traveler Information Management

This subsystem ingests traveler information, including travel time data and toll rate data, from external sources, assimilates it, and makes it available to the CHART ATMS for display in the CHART ATMS GUI and on DMS signs. Alerts can be configured for travel times above a certain threshold, toll rates missing, and loss of data feeds.

8.2.1.25 User Management

This subsystem provides the capability to create and manage user profiles and access rights.

8.2.1.26 Utility

The Utility subsystem provides various utility functions for the CHART ATMS and collects processes that do not have a home elsewhere. These include, for instance, the chat function.

8.2.1.27 Video Management

This subsystem manages cameras and their configurations and status, and coordinates access to camera control functions. This subsystem also provides the ability for managing monitors, monitor configurations, and display of camera video on monitors and desktops. This subsystem also provides control access to video the public, including Internet users and media outlets.

8.2.1.28 Weather Station Management

This subsystem collects weather data from weather sensors along the roadways and provides the data to traffic events.

8.2.2 GUI Services Subsystems

The GUI Services CI provides the user interface for the CHART ATMS. The GUI Services CI, like the Core Services CI, communicates via CORBA to provide a highly available system. There are two GUIs which run within the CHART ATMS normally: one is used to provide access to the CHART ATMS to SwGI users; the other supports all other users. GUI Services communicate to Core Services via CORBA, and also connects to Web Services over HTTP/XML.

The software subsystems comprising the GUI Services CI are described below.

8.2.2.1 GUI Management

This subsystem provides the user interface for the CHART ATMS. It runs as an Apache Tomcat service.

8.2.2.2 Map Management

This subsystem retrieves and displays the CHART ATMS map and provides management of the map, its layers and icons, and associated callouts and callout actions. This subsystem runs as part of the overall CHART ATMS GUI. It provides the home page map, object location maps, and the nearby devices map and response preview map that appear in Traffic Event Details Pages.

8.2.3 FMS Subsystems

The FMS provides communications services to CHART field devices. The FMS software, like the Core Services CI, uses a set of distributed applications communicating via CORBA to provide a highly available system. Each FMS server is a standalone system capable of communicating with any field device for which it has a matching communications port type. All user interaction with the FMS is handled through the CHART ATMS user interface. The FMS infrastructure is being phased out in favor of direct TCP/IP communications with CHART field devices. TCP/IP communications are supported for at least one model of every type of CHART field device. For R11 only ISS AP55 HARs are communicated to via FMS. Other HARs and all DMSs, TSSs, and SHAZAMs are communicated to via direct TCP/IP.

The software subsystems comprising the FMS CI are described below. All user interaction with the Port Manager, the only user-facing FMS subsystem, is handled through the CHART ATMS GUI.

8.2.3.1 Port Manager

The FMS software that manages access to communications resources is a Port Manager. A Port Manager is configured specifically for the hardware that it will manage. The communications resources are modeled in software as Port objects. Specific types of port objects exist for each type of communications resource that is supported. Currently the only types of ports configured in the system are telephony ports. Formerly the system supported ISDN modem ports, POTS modem ports, and direct serial ports. (Although these types of ports are no longer tested or deployed, they are still part of the code base and could be resurrected if necessary, although that seems unlikely.)

Upon startup of the FMS software, a Port Manager object is created and published to the CORBA trading service, making it available for discovery and use by other applications. The Port Manager creates port objects to represent each of the physical communications resources which it is configured to manage. The actual type of object created depends on the type of port, for each type of port object contains functionality specific to the resource it represents. After the port manager is started, it accepts requests for ports by other application software that has communications requirements.

Applications request Port objects by type and priority. When a request for a port is received, the Port Manager finds a port of the specified type that is not currently in use and returns a reference to the port object to the requester. If all instances of a requested type of port are in use, a timeout value supplied by the requester is used to determine how long the requester is willing to wait for a port to become available. In the event there are two or more requesters waiting for a port to become available, the priority is used to determine which requester gets the next available port. This happens behind the scenes and is not visible to the user.

Once a port is acquired, it is accessed directly by its user to perform functionality specific to the type of port, such as connecting to a remote modem and/or sending and receiving bytes.

After a requester has finished using a port, it releases the port back to the Port Manager. The port manager has a background process that reclaims ports as may be necessary if the application object using the port is not well behaved.

8.2.3.2 Port Configuration Utility

The Port Configuration Utility is a standalone utility which can be used to configure the ports to be made available to, and by, a specific Port Manager. Since FMSs are rarely introduced, this utility is rarely used, although it is still deployed.

8.2.4 Database Instance Subsystems

There is only one software subsystem comprising the Database Instance CI. This subsystem is briefly described below.

8.2.4.1 Operational DB

This subsystem comprises the live Microsoft SQL Server database used by the CHART ATMS, which is named “CHART_Live”. The live database stores and manages access to all data used by the live Core Services and GUI Services CIs, including configuration data, status data,

collected statistical data, log data, traffic event data, etc. The CHART_Live database is mirrored to SHA Headquarters backup site for redundancy purposes, and is replicated to University of Maryland for reporting and statistical analysis purposes.

8.2.5 Database Archive Subsystems

The software subsystems comprising the Database Archive CI are briefly described below.

8.2.5.1 Archive DB

This subsystem comprises the archive SQL Server database used to archive selected data from the CHART_Live database, and the scripts which actually perform the archiving. The archive database is named "CHART_Archive". The CHART_Archive database includes all data which has been deemed to be of historical significance. The CHART_Archive database is mirrored to the SHA Headquarters backup site for redundancy purposes by the Mirroring subsystem, and is replicated to University of Maryland for reporting and statistical analysis purposes by the Replication subsystem.

8.2.5.2 Mirroring

This subsystem comprises the Microsoft SQL Server functionality that mirrors the CHART ATMS databases between the primary CHART ATMS site located at the Statewide Operations Center (SOC) in Hanover and the backup CHART ATMS site located at State Highway Administration (SHA) Headquarters in Baltimore. Although this subsystem is listed within the Database Archive CI, both the CHART_Live and CHART_Archive databases are mirrored. Mirroring is configured, monitored, and managed by the CHART ATMS DBAs.

8.2.5.3 Query

This subsystem provides the ability to query the database, for purposes of examining the database and manipulating data in the database, from a program perspective and via the SQL Management Studio, and also, not formally part of the CHART ATMS, by the Report Generation subsystem for the purpose of generating reports on the system. Report Generation is under the purview of the University of Maryland.

8.2.5.4 Replication

This subsystem comprises the Microsoft SQL Server functionality that replicates the CHART ATMS databases to the University of Maryland for reporting purposes. Although listed in the Archive DB CI, both the CHART_Live and CHART_Archive databases are mirrored. Replication is configured, monitored, and managed jointly by the CHART ATMS DBAs and University DBAs.

8.2.5.5 Report Generation

This subsystem, not part of the CHART ATMS per se, is employed by the University of Maryland to perform reporting and statistical analysis functions.

8.2.6 COTS

The COTS CI collects all COTS packages into a single CI for configuration control purposes. This CI will be used to track the COTS packages and versions used. Rather than list each subsystem in paragraphs, the COTS packages used throughout the system are described in Table

8-2 below. Package redistributability is designated as Open source, Free (freely available, but without source), or Proprietary (purchased or otherwise restricted). Usage is listed as Development, Runtime, both Development and Runtime, or Administrative. For COTS that is both Development and Runtime, the predominant usage, if that makes sense, is listed first. Administrative usage is listed when the product is not required to build the system, even if the product is a key part of the development effort, such as Sparx Enterprise Architect, which developers use extensively.

Table 8-2. COTS Packages

Product Name	Version	Description/Purpose	Redistributability	Usage
Adobe Flex SDK	3.3	The CHART ATMS GUI uses the Flex 3 SDK to provide the Flex compiler, the standard Flex libraries, and examples for building Flex applications.	Open source	Development
Apache ActiveMQ	5.5 & 4.1.1	CHART ATMS uses ActiveMQ 4.1.1 to connect to RITIS JMS queues for import from RITIS and ActiveMQ 5.5 to export to CHARTWeb for CHART Mapping / CHARTWeb and to RITIS and MD511.	Open source	Runtime
Apache Ant	1.8.4	CHART ATMS uses Apache Jakarta Ant to build CHART applications and deployment jars.	Open source	Development
Apache Tomcat	6.0.24 x64	CHART ATMS uses Apache Tomcat as its web server container. This is used to host the CHART ATMS GUI and all the various CHART ATMS Web Services.	Open source	Runtime
Apache XML-RPC	3.1.2	CHART ATMS uses the apache xmlrpc java library that uses XML over HTTP to implement remote procedure calls. The video Flash streaming “red button” (“kill switch”) API uses XML over HTTP remote procedure calls.	Open source	Runtime
CoreTec Decoder Control	1.0	CHART ATMS uses a CoreTec supplied decoder control API for commanding CoreTec decoders.	Proprietary	Runtime Development
Dialogic API	6.0	CHART ATMS uses the Dialogic API for sending and receiving Dual Tone Multi Frequency (DTMF) tones for HAR communications.	Proprietary	Runtime Development
Eclipse	3.6 and higher	The standard Java development environment. CHART ATMS developers collectively use a variety of versions and are free to update at their discretion. However, 3.6 is the minimum required to support Java 7.	Open source	Development
GIF89 Encoder	0.90 beta	Utility classes that can create .gif files with optional animation. This utility is used for the creation of DMS True Display windows.	Open source	Development

Product Name	Version	Description/Purpose	Redistributability	Usage
GNU Bison	2.1	CHART ATMS uses Bison and Flex as part of the process of compiling binary macro files used for performing camera menu operations on Vicon Surveyor VFT cameras.	Open source	Development
GNU Flex	2.5.4a-1	CHART ATMS uses Bison and Flex as part of the process of compiling binary macro files used for performing camera menu operations on Vicon Surveyor VFT cameras.	Open source	Development
IBM Rational RequisitePro	7.0.0.2	The CHART Program uses IBM Rational RequisitePro for managing CHART software requirements.	Proprietary	Administrative
JacORB Event Service	2.3.1 (as patched for CHART ATMS)	CHART ATMS uses a compiled, patched version of JacORB 2.3.1. The JacORB source code, including the custom patched code updated by the CHART ATMS software development team, is kept in the CHART ATMS source repository.	Open source (enhanced with custom CHART ATMS patches)	Runtime Development
JacORB ORB				
JacORB Trader				
Java SDK	1.7.0_07	The Oracle Java Software Development Kit (SDK) is the Java compiler for the CHART ATMS.	Open source	Runtime Installation
Java Runtime Environment (JRE)	1.7.0_07	The Java Runtime Environment (JRE) is the runtime environment for the CHART ATMS.	Open source	Runtime Installation
JavaHelp	1.1	The JavaHelp system is used to develop the online help system for the CHART ATMS. The text thus developed for the online help is also ported verbatim into the CHART ATMS User's Guide.	Open source	Development Runtime
JavaMail	1.4.4	The CHART ATMS Notification Service uses this API to deliver SMTP mail (notifications).	Open source	Development Runtime
JavaService	2.0.10.0	CHART ATMS uses JavaService to install the server side Java software components as Windows services.	Open source	Runtime
JAXB	hudson-jaxb-ri-2.1-833	CHART ATMS uses the jaxb java library to automate the tedious task of hand-coding field-by-field XML translation and validation for exported data.	Open source	Runtime Development
Jaxen	1.0-beta-8 dated 2002-01-09	The Jaxen project is a Java XPath Engine. Jaxen is a universal object model walker, capable of evaluating XPath expressions across multiple models.	Open source	Runtime Development

Product Name	Version	Description/Purpose	Redistributability	Usage
JDOM	b7 (beta-7) dated 2001-07-07	CHART ATMS uses JDOM as a way to represent an XML document for easy and efficient reading, manipulation, and writing.	Open source	Development
joeSNMP	0.2.6 dated 2001-11-11	The joeSNMP project is a Java-based implementation of the SNMP protocol. CHART ATMS uses for commanding iMPath MPEG-2 decoders and for communications with NTCIP DMSs.	Open source	Runtime Development
JSON-simple	1.1	CHART ATMS uses the JSON-simple java library to encode/decode strings that use JSON (JavaScript Object Notation).	Open source	Runtime Development
Java Topology Suite (JTS)	1.8.0	CHART ATMS uses the Java Topology Suite (JTS) for geographical utility classes.	Open source	Runtime Development
Krakatau PM	2.11	CHART ATMS uses Krakatau PM by Power Software for source code metrics.	Proprietary	Administrative
MantisBT	1.2.10	The CHART Program uses MantisBT (Mantis Bug Tracker) for tracking problem reports (PRs)	Open source	Administrative
Microsoft SQL Server	2008 R2 and 2005	CHART ATMS uses Microsoft SQL Server 2008 to host its databases. It uses the same version for retrieving roadway location, weather, and traffic signal data from CHART Mapping and lane closure permits from LCP. The reporting component EORS v2 uses SQL Server 2005.	Proprietary	Runtime
Microsoft SQL Server JDBC Driver	4.0	CHART ATMS Java software accesses the Microsoft SQL Server database using the JDBC Driver 4.0 produced by Microsoft for this purpose.	Proprietary	Development Runtime
Microsoft Visual C++	6, Service Pack (SP) 6	Although for the most part CHART ATMS has migrated to Visual Studio 2010 Ultimate for C++, CHART ATMS still uses Visual C++ Version 6, Service Pack 6 C++ library files for the previously compiled legacy V1500 Manager. Necessary library files are used in the runtime environment.	Proprietary	Runtime

Product Name	Version	Description/Purpose	Redistributability	Usage
Microsoft Visual Studio 2010 Ultimate	2010 Ultimate	CHART ATMS uses Microsoft Visual Studio 2010 Ultimate for C++ source code development. Necessary library files are used in the runtime environment.	Proprietary	Development Runtime
Microsoft Windows	2008 Server	CHART ATMS uses Microsoft Windows 2008 Server as its standard runtime platform for the CHART ATMS application servers, database servers, FMS servers, and GUI servers.	Proprietary	Runtime
Nuance Vocalizer	4.0	For text-to-speech (TTS) conversion CHART ATMS uses a TTS engine that integrates with Microsoft Speech Application Programming Interface (MSSAPI), version 5.1. CHART ATMS uses Nuance Vocalizer 4.0 with Nuance SAPI 5.1 Integration for Nuance Vocalizer 4.0.	Proprietary	Runtime
Nullsoft Scriptable Install System	2.20	CHART ATMS uses the Nullsoft Scriptable Install System (NSIS) as the installation package for CHART NTCIP Conformance Test components, for NTCIP DMS and NTCIP cameras.	Open source	Development Installation
OpenLayers	2.8	The CHART ATMS Map feature uses the Open Layers JavaScript API 2.8 (http://openlayers.org/) in order to render interactive maps within a web application without relying on vendor specific software. Open Layers is an open source product released under a BSD style license which can be found at (http://svn.openlayers.org/trunk/openlayers/license.txt).	Open source	Development Runtime
O'Reilly Servlet	1.11	Provides classes that allow the CHART ATMS GUI to handle file uploads via multi-part form submission.	Open source	Development Runtime
Prototype JavaScript Library	1.6.1	The CHART ATMS GUI uses the Prototype JavaScript Library, a cross-browser compatible JavaScript library, which provides many features, including easy Ajax support.	Open source	Development Runtime
RedGate SQL Backup Pro	6	CHART ATMS uses these parts of the RedGate DBA Bundle monitoring tools to support the backup and restore processes and to monitor database performance	Proprietary	Runtime
RedGate SQL Monitor	2.3.0			

Product Name	Version	Description/Purpose	Redistributability	Usage
SAXPath	1.0-beta-6 dated 2001-09-27	CHART ATMS uses SAXPath, an event-based API for XPath parsers, that is, for parsers which parse XPath expressions.	Open source	Runtime Development
Sparx Enterprise Architect	9.3.934	CHART ATMS developers use Enterprise Architect by Sparx for UML modeling and design tool.	Proprietary	Administrative
Subversion	1.6	CHART ATMS uses Apache Subversion for source code control.	Open source	Development
Subversion browser TortoiseSVN	1.6.15	Official CHART ATMS builds use TortoiseSVN subversion browser. Some developers may use TortoiseSVN as well.	Open source	Development
Tritonus	0.3.6	The CHART ATMS uses the Tritonus implementation of the Java Sound API for manipulating audio files.	Open source	Development Runtime
Velocity Template Engine	1.6.1	Provides classes that CHART ATMS GUI uses in order to create dynamic web pages using velocity templates.	Open source	Runtime Development
Vicon V1500 API		CHART ATMS uses a Vicon-supplied API for commanding the ViconV1500 CPU to switch video on the Vicon V1500 switch	Proprietary	Runtime Development
vRanger Backup & Replication	5.3.1	The CHART Program uses vRanger Backup & Replication by Quest Software to maintain system backups. This subsystem is not part of the CHART ATMS per se, but serves in a support role. Therefore it is listed as having Administrative usage, rather than Runtime usage.	Proprietary	Administrative
WordPress	3.04 3.02	WordPress is a blogging tool. The production CHART ATMS employs WordPress 3.0.4 for maintaining, editing, and viewing Shift Handoff Reports. The CHART development team uses WordPress 3.0.2 for maintaining, editing, and viewing a "Developer's Blog" for timely distribution of information relevant to developers, as well as maintaining a historical archive of that information.	Open Source	Runtime Administrative

Product Name	Version	Description/Purpose	Redistributability	Usage
XML Spy	2009 Pro SP 1	CHART ATMS developers use XMLSpy to visualize, edit, and generate XML and XSLT used by the CHART ATMS and by some of the external systems which interface with the CHART ATMS.	Proprietary	Development

9 STANDARDS VIEW

9.1 View Description and Typical Stakeholders

This view into the CHART ATMS describes how the CHART ATMS conforms to various national standards, in multiple contexts. This view is useful for MDSHA management, CHART ATMS developers, and those looking to interface with the CHART ATMS, from either a Center to Center or device level perspective.

9.2 Standards Overview

The CHART ATMS has been and is being designed to be as compliant with ITS national standards where possible and practical. The system design utilizes existing standards, within four contexts of the system: data storage, external communications, internal communications, and field communications.

9.2.1 Data Storage

In the early years of the project, the CHART ATMS development team made an effort to utilize the TMDD to define attributes stored in the CHART ATMS database. The TMDD contains the national ITS standard data definitions for data elements. Wherever practical, data elements existing in the TMDD and needed by the application were created with TMDD definitions. Additional attributes needed to implement the CHART ATMS system requirements were added to these standard table definitions. These elements, of course, do not interfere with the ability to access the TMDD-standard elements. This effort reached its height during the incorporation of video processing into the CHART ATMS. During this phase several extra CCTV-related TMDD attributes which had no purpose in the planned CHART ATMS processing were nevertheless added to the CHART ATMS graphical user interface and the CHART ATMS database for the sole purpose of achieving the goal of fully conforming to the TMDD: among them, horizontal and vertical datum type, latitude and longitude (back before the CHART ATMS populated these otherwise), height, vertical level, control type, and supported command set. However, in practice, these extra attributes generally have never been populated, and today they are generally ignored, so hence this objective was no longer emphasized and the focus on the TMDD has fallen out of favor.

9.2.2 External Communications

This section describes interfaces CHART ATMS has with other system outside of the CHART ATMS Program.

9.2.2.1 Center-to-Center Communications

Export

The CHART ATMS Data Exporter provides a broad selection of ITS data in XML format using both an on-demand and a subscription based HTTP transport.

Traffic event messages are compliant with the SAE ATIS J2354 STANDARD (ATIS-Draft-03-00-79.xsd) and include extensive customizations. The customizations are implemented per the standard's localization feature so the resulting messages remain compliant with the standard.

Device messages are compliant with the TMDD standard (TMDD v3.0 Design v2.0) and also include extensive customizations. Like the Traffic Event messages, the device messages also include extensive customizations but again these were accomplished using TMDDs localization feature so the resulting messages remain compliant with the standard. Device information available over this interface included DMS, HAR, TSS, Beacons, and CCTV configuration; video is not available.

Both traffic event and device messages are currently consumed by the University of Maryland's RITIS system and by MDSHA's MD511 traveler advisory system.

Import

CHART ATMS imports traffic and device data from the University of Maryland's RITIS system using messages similar to the export messages.

Like CHART ATMS's export messages, the RITIS traffic event messages follow the SAE ATIS J2354 STANDARD (ATIS-Draft-03-00-79.xsd) however their customizations are more modest than CHART's.

Also like CHART ATMS's export messages, the RITIS device messages follow the TMDD standard (TMDD v3.0 Design v2.0) with modest customizations. Currently CHART ATMS imports DMS and TSS data from RITIS using this mechanism.

9.2.2.2 Data-Specific Communications

CHART ATMS collects roadway travel times from INRIX for displaying travel times on DMSs. Although INRIX messages do not follow a standard themselves, they do include TMC codes in their messages which is an international standard (ISO-14819).

The remaining external interfaces simply follow an HTTP / XML interface standard however the content of the messages themselves do not follow any specific standard.

9.2.2.3 Inter-CHART Communications

CHART ATMS shares messages with other CHART systems such as weather systems, AVL, LCP, and CHARTWeb. With the exception of CHARTWeb, these interfaces are not compliant with any recognized standard primarily because no standard exists for these interfaces. The exception, CHARTWeb, uses the same export messages and standards as described in Section 9.2.2.1 to retrieve CHART ATMS data.

9.2.3 Internal Communications

This section describes interfaces within the CHART ATMS itself. There are two major varieties of interfaces: interfaces between the many processes which make up the CHART ATMS, and communications to CHART field devices.

9.2.3.1 Interprocess Communications

In general, the older CHART ATMS design components use CORBA for transactions between internal software components. When the CHART ATMS (then known as CHART2) was just getting underway, CORBA had been chosen as one of two approved methods of communication between ITS software components by the NTCIP Center to Center committee. So when the CHART ATMS was originally developed, the design team referenced the burgeoning object model being developed by the Center to Center committee. At that time, however, it had not yet

defined the system interfaces. Thus, the CHART ATMS was developed to isolate standard interfaces from those that are clearly CHART ATMS specific. (For instance, CHART ATMS includes a class called a "CHART2DMS," which contains data and interfaces thought to be specific to Maryland's implementation of an ATMS, and "CHART2DMS" extends a base class called a "DMS," which contains data and methods considered more universal). CORBA has been dismissed within the IT industry since the original center to center communications standards were defined. As a result, the CHART ATMS has moved towards an HTTPS/XML interface for receiving and sending data from/to entities outside of the CHART ATMS. These interfaces are described in later sections.

9.2.4 Field Communications

In the area of field communications, the CHART ATMS design has been and continues to move towards conformance with NTCIP, which defines the current national standards for communications with field devices in the ITS industry. NTCIP is the National Transportation Communications for ITS Protocol (ITS itself of course being an acronym for Intelligent Transportation Systems). The CHART ATMS currently supports NTCIP communications for DMSs and CCTV cameras. Currently within the CHART ATMS some 90% of the 300+ DMSs communicate via NTCIP. DMS manufacturers were the first to embrace the NTCIP standard. Only about 1% of the approximately 800 CCTV cameras managed by CHART ATMS support the NTCIP standard. The CHART ATMS is designed to add support for NTCIP (and other) protocols with minimal effort. Separate protocol handlers are designed and coded separately from the base code which manages the devices themselves, thus, adding support for a new protocol does not require significant amounts of code to be written to manage devices that communicate via a new protocol. Prior to development and widespread support of NTCIP, this design was used initially to add support for non-NTCIP devices. Lately this approach has been used to add support for NTCIP communications, by adding an NTCIP protocol handler for DMSs and an NTCIP protocol handler for cameras.

10 BUSINESS ARCHITECTURE VIEW

10.1 View Description and Typical Stakeholders

This section provides a view into how the CHART Program aligns with the CHART Business Area Architecture, which lays out the business case and business objectives for CHART, and attempts to align those with current and desired future capabilities. This section lays out a business strategy for achieving those goals, in line with available and long-term resources. Interested stakeholders would include MDSHA management and CHART Program Management, especially those who participated in the BAA process, or those would like to learn more about CHART's business plan and its mapping to CHART capabilities.

10.2 Business Area Architecture

The CHART System concept of operations encompasses of four major categories of business objectives:

- CHART is intended to be a statewide traffic management system, not limited to one or two specific corridors of high traffic volumes, but expandable to cover the entire state as funds, resources, and roadside equipment become available to support traffic management.
- CHART is intended to be a coordination focal point, able to identify incidents, congestion, construction, road closures and other emergency conditions; and then able to direct the resources from various agencies, as necessary, to respond to recurring and nonrecurring congestion and emergencies. It should also manage traffic flow with traveler advisories and signal controls, and coordinate or aid in the cleanup and clearance of obstructions.
- CHART is intended to be an information provider, providing real-time traffic flow and road condition information to travelers and the media broadcasters, as well as providing real-time and archived data to other state agencies and local, regional, inter-state, and private sector partners.
- CHART is intended to be a 7 day per week, 24 hours per day operation with the system performing internal processing and status checks to detect failed system components and resetting or reconfiguring itself where appropriate, or notifying operators and/or maintenance staff where necessary for service.

Figure 10-1, from the BAA, summarizes the Business Process Model. For more detail, see the full breakdown in Appendix B of the CHART Business Area Architecture Revision 10, April 2, 2012, WO1-BA-001R10.

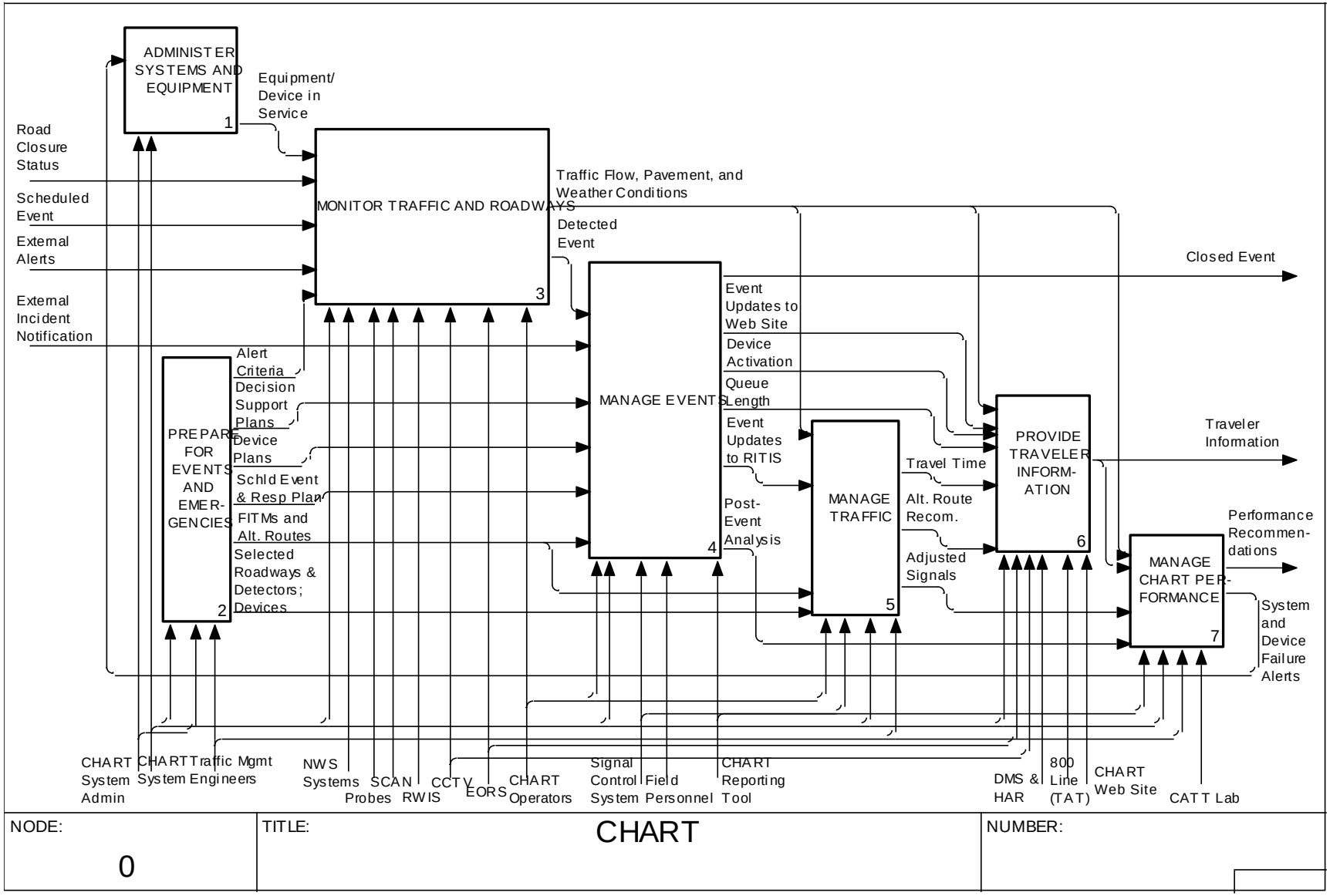

Figure 10-1. CHART High Level Business Process Model

10.3 BAA Process to Subsystem Matrix

A mapping between the business processes identified in the BAA and the CHART system CIs and subsystems appears in Table 10-1. This table presents the Business Process to Configuration Item matrix as aligned with the most recent BAA revision (October 2006). Note that GUI Management is involved in virtually every process, and is not listed. Note that the true intent of the items listed cannot always be ascertained by merely reading the name of the process. (For instance, "Measure CHART operations performance" might appear to involve the CHART System Monitor (Watchdog), but it has nothing to do with monitoring the performance of the various CHART executables; it has to do with analyzing the archive of traffic events generated within CHART to determine CHART's effectiveness and efficiency. The last group of processes is especially prone to misinterpretation.) **It is recommended that the mappings below should not be reviewed or re-evaluated in a vacuum, without consulting the process descriptions from the BAA.**

Table 10-1. Business Process to Configuration Item Matrix

BAA Process				CI	Subsystem(s)
Administer systems and equipment				various; see below	various; see below
	Administer CHART organizations, locations, and users			Core Services	User Management
		Maintain CHART organizations and geographic areas of responsibility		Core Services	User Management
			Maintain organization types	(Not implemented)	(Not yet implemented)
		Maintain geographic Areas of Responsibility		Core Services	User Management
		Maintain organization		Database Instance	MS SQL Server
		Maintain CHART functional rights		Database Instance	MS SQL Server
		Maintain CHART roles		Core Services	User Management
		Maintain users		Core Services	User Management
Maintain message libraries				various; see below	various; see below
	Maintain dictionaries			Core Services	Dictionary Management
	Create message library entry			Core Services	Message Library Management
	Create DMS/HAR message template			Core Services	Message Template Management
	Maintain map			GUI Services	Map Management
	Manage CHART control			various; see below	various; see below
		Control login		Core Services	Resource Management
		Perform shift hand-off (incoming)		Core Services	Resource Management
		Maintain shift hand off report		COTS (Runtime)	Wordpress
		Use CHART chat		Core Services	Utility
		Control logout and transfer control		Core Services	Resource Management
	Install and maintain devices			Core Services	Device Management

BAA Process			CI	Subsystem(s)
		Install equipment/ devices	Core Services	Device Management
		Put equipment/ devices on-line	Core Services	Device Management
		Perform routine maintenance	Core Services	Device Management
		Respond to equipment/ device outage	Core Services	Device Management
Prepare for events and emergencies			various; see below	various; see below
	Maintain decision support plan		various; see below	various; see below
		Name decision support (DS) plan	Core Services	Decision Support
		Select DS plan conditions	Core Services	Decision Support
		Associate devices to DS plan	Core Services	Decision Support, Traffic Event Management
		Associate notifications and resources to DS plan	Core Services	Traffic Event Management, Decision Support, AVL Management
		Associate FITM or alternate route	(Not implemented)	(Not yet implemented)
		Set DS plan status	(Not implemented)	(Not yet implemented)
	Simulate emergencies and other scenarios		(Not implemented)	(Not yet implemented)
	Maintain traffic plans		various; see below	various; see below
		Maintain roadway plans - FITMs and alternate routes	(Not implemented)	(Not yet implemented)
		Identify roadways for signal control and travel time	Partially implemented in Core Services	Partially implemented in Plan Management, Traveler Information Management, DMS Control
		Maintain device plans	Core Services	Plan Management, Audio Management
	Define alert criteria		Core Services	Alert Management

BAA Process				CI	Subsystem(s)
	Schedule events			Core Services	Schedule Management
Monitor traffic and roadways				various; see below	various; see below
	Detect conditions			Core Services	Video Monitor Management, Traveler Information Management, Traffic Sensor System Management
	Record conditions			Core Services	Traffic Event Management
	Issue alert or post information			Core Services	Alert Management, Notification Management, Resource Management, DMS Control, HAR Control, Traveler Information Management, Traffic Event Management, Data Import Management, Data Export Management, System Monitor (Watchdog), Schedule Management
	Receive and respond to alert			Core Services	Alert Management
Manage events				various; see below	various; see below
	Open event			various; see below	various; see below
		Record event details		various; see below	various; see below
			Specify location and impact	Core Services, GUI Services	Traffic Event Management, Map Management
			Capture day/date/time	Core Services	Traffic Event Management
			Capture weather conditions	Core Services	Traffic Event Management, Weather Station Management

BAA Process					CI	Subsystem(s)
			Identify event source		Core Services	Traffic Event Management
			Capture related events		Core Services	Traffic Event Management
			Specify nature of problem		Core Services	Traffic Event Management
			Determine event type		Core Services	Traffic Event Management
		Deploy resources			various; see below	various; see below
			Verify event location and specifics		Core Services	Traffic Event Management
			Evaluate event response recommendations		Core Services	Traffic Event Management
			Select/ modify course of action		Core Services	Traffic Event Management
				Select/ deselect resource or device	Core Services	Traffic Event Management, AVL Management
				Enter reference/ charge numbers	(Not implemented)	(Not yet implemented)
				Select or enter appropriate message	Core Services	Traffic Event Management, Decision Support, Plan Management, Audio Management
				Adjust camera parameters and monitor assignment	Core Services	Decision Support, Traffic Event Management, Camera Control, Video Monitor Management
			Execute course of action		Core Services	Traffic Event Management, DMS Control, HAR Control, Video Monitor Management, Camera Control
	Respond to and monitor event				various; see below	various; see below

BAA Process				CI	Subsystem(s)
		Monitor event		various; see below	various; see below
			Monitor resource status	Core Services	Traffic Event Management, AVL Management
			Monitor activities	Core Services	Traffic Event Management, Decision Support, AVL Management, Video Monitor Management, Camera Control,
			Monitor device status	Core Services	DMS Control, HAR Control, Traffic Event Management
		Control on-scene traffic		Not a CHART ATMS function	Not a CHART ATMS function
		Manage affected area traffic		(Not implemented)	(Not yet implemented)
		Perform scene activities		Not a CHART ATMS function	Not a CHART ATMS function
	Close event			various; see below	various; see below
		Verify scene clear		Partially implemented in Core Services	Partially implemented in Video Monitor Management, Camera Control
		Determine event closure or transfer		Core Services	Traffic Event Management, Resource Management, Decision Support
		Change event type		Core Services	Traffic Event Management
		Record event closure		Core Services	Traffic Event Management
		Conduct post-event analysis		Database Archive	Replication, Query, Report Generation

BAA Process		CI	Subsystem(s)
Manage traffic		various; see below	various; see below
	Control signals and roadway access	(Not implemented)	(Not yet implemented)
	Recommend alternate routes	(Not implemented)	(Not yet implemented)
	Calculate travel times	Core Services	Traveler Information Management, DMS Control, Message Template Management
Provide traveler information		various; see below	various; see below
	Broadcast information	Core Services	Traveler Information Management, DMS Control, Message Template Management
	Maintain [external] web site information	Supported by Core Services	Supported by Traffic Event Management, DMS Control, HAR Control, Traveler Information Management, Data Export Management
	Provide recorded information	Supported by Core Services	Supported by Traffic Event Management, DMS Control, HAR Control, Traveler Information Management, Data Export Management
	Provide CHART info to third parties for public dissemination	Core Services	Video Monitor Management, Traffic Event Management, Data Export Management

BAA Process			CI	Subsystem(s)
	Provide camera video feeds		Core Services	Video Monitor Management, Camera Control
Manage CHART performance			various; see below	various; see below
	Measure CHART operations performance		Database Archive	Replication, Query, Report Generation
	Measure traffic management		Database Archive	Replication, Query, Report Generation
	Manage and measure device performance		various; see below	various; see below
		Check and validate system and status	Partially implemented in Core Services	Partially implemented in DMS Control, HAR Control, Traffic Sensor System Management, Camera Control
		Update device/ system status	Core Services	DMS Control, HAR Control, Traffic Sensor System Management, Camera Control, Video Monitor Management
		System/device attempt corrective action	Partially implemented in Core Services	Partially implemented in System Monitor (Watchdog)
		Notify NOC of device/ system status	Partially implemented in Core Services	Partially implemented in DMS Control, HAR Control
		Initiate corrective action and follow to closure	(Not implemented)	(Not yet implemented)

BAA Process			CI	Subsystem(s)
		Generate device reports	Database Archive	Replication, Query, Report Generation
	Simulate CHART operations and traffic management performance		(Not implemented)	(Not yet implemented)
	Analyze performance and develop CHART recommendations for improvement		Not a Core Services function	Not a CHART ATMS function

10.4 Future CHART Releases

Future releases include a wide variety of features as specified in the BAA. Table 10-2 below shows some of the major functionality planned for upcoming releases and the subsystems affected.

Table 10-2 CHART Future Release Functions

CI	Subsystem	Function
Core Services	Traveler Information Management	Blend CHART TSS data with INRIX data for improved travel times
	Traffic Event Management	Use INRIX and/or TSS data to compute queues associated with traffic events
	Device (DMS)	Further support for full matrix NTCIP DMS

10.5 Near Term Goals

10.5.1 NTCIP Device Control

CHART would like to enhance its support for NTCIP DMS and NTCIP Cameras, such as needs for additional DMS and camera control protocols are identified.

A long term goal is that CHART would move away from proprietary protocols for all field devices: elimination of non-NTCIP DMSs and non-NTCIP cameras, development of NTCIP protocols for HARs, SHAZAMs, and TSSs such as those protocols are refined and widely adopted by the industry.

10.5.2 Moving away from slow speed communications

Together with the movement towards NTCIP for the communications protocol, movement towards higher speed (and fully digital) mechanisms for the communications medium is a desired goal. This goal has been largely, but not entirely achieved, as there are no DMSs or detectors using dial-up FMS-based communications anymore.

10.5.3 Further Automation Improvements for Operators

A general objective is to reduce the burden on CHART ATMS operators to make and implement decisions, so Decision Support functionality is expected to be enhanced in coming releases. Improvements which can reduce the amount of operator typing and can streamline navigation of the system and execution of desired actions is also a target. Operators are very cognizant of every mouse click and keystroke they have to make. Reducing clicks and keystrokes is a desired objective for the system.

10.5.4 Consolidation of Operator Functions

“Single Sign-On” has long been a stated goal of the CHART Program. This would consolidate users, passwords, and privileges to the program level. One sign-on would control access and privileges to the CHART ATMS, the CHART Mapping Intranet Map, LCP, etc. Tighter integration of the various projects is also a goal. For instance, work is underway at time of this writing to more tightly integrate CHART and LCP.

11 SYSTEM MAINTENANCE VIEW

11.1 View Description and Typical Stakeholders

This section provides a view into the high level CHART ATMS maintenance tasks. This includes system maintenance (including backup and recovery), database maintenance, and routine software maintenance. The CHART ATMS Operations and Maintenance Guide contains much more detailed information on these routine maintenance tasks. Roadside device and other hardware and network maintenance tasks are outside of the scope of both this document and the CHART ATMS Operations and Maintenance Guide. Interested stakeholders would be system administrators, software and system architects, and any other parties interested in a high level view of maintenance tasks for the CHART ATMS.

11.2 Data Backup and Recovery

Data backup and recovery are implemented at both the system level and the database level. Database level backups are needed in order to guarantee transactional integrity and to prevent database backup corruption.

11.2.1 Data Backup

11.2.1.1 Virtual Environment

Procedures for backing up the virtual environment are not covered in the CHART Operations and Maintenance Guide. These tasks are performed by Transportation Business Unit (TBU) personnel following procedures maintained by TBU staff. Most of these procedures can be found in the CHART Virtualization Operations and Maintenance Guide.

- The ability to "snapshot" a virtual server provides the ability to roll back a server to a previous state should an issue occur with that server, and simplifies maintenance and administration by allowing patches and upgrades to be easily and quickly backed out if necessary.
- Full image snapshots are taken nightly and copied to an offsite location at SHA Headquarters (HQ) in Baltimore. Included in these snapshots are local snapshots with file and image-level restore functionality.

11.2.1.2 Database

Database backup tasks and the procedures for executing those tasks are detailed in Section 3.9 of the CHART Operations and Maintenance Guide. There are procedures for both the active (CHART_Live) database and the archive (CHART_Archive) database. Backup jobs are run using the SQL Backup tool by Redgate. Those tasks include:

- Full database backup
- Transactional database backup
- Differential backup

In addition, the CHART ATMS databases are mirrored from the SOC to the backup site at SHA HQ. The database mirroring procedures are described in Section 3.9 of the CHART Operations

and Maintenance Guide. The mirrored databases can be recovered to the prime site at the SOC or utilized at SHA HQ in a failover scenario.

11.2.2 Data Recovery

11.2.2.1 Virtual environment

The site at SHA HQ exists as a redundant and disaster recovery capable location where individual pieces or the entire suite of CHART applications (CHART ATMS, CHART Mapping, LCP, etc.) can exist if necessary. All CHART servers may be instantiated at SHA HQ, including both the CHART ATMS servers and other servers within the CHART enterprise, including a number of applications that the CHART ATMS interfaces with. Should a full site recovery at SHA HQ be necessary, all non-database data would be recovered within a datastore replication window. For the CHART ATMS itself, all relevant data is stored in the database and the database recovery process is executed as an additional step after servers have been instantiated at SHA HQ.

11.2.2.2 Database

Database recovery can be accomplished through these mechanisms as detailed in Section 3.9 of the CHART Operations and Maintenance Guide:

- Recovering database backup
- Recovering mirrored database from SHA HQ
- Utilizing mirrored database at SHA HQ

11.3 System Monitoring

Cern Virtual Infrastructure (CVI) administrators will access the environment through a variety of tools, depending upon the task and required method of access.

11.3.1 Virtual environment

- The vSphere Client provides the most comprehensive access to the VMware environment, allowing administrators to add, delete, modify, move, and monitor the physical and virtual machines. “Console” access is granted through this tool, as well as providing basic monitoring and environmental health visible through the client. The client may be downloaded via web browser using the address of the vCenter server, one of the individual hosts, or from www.vmware.com.
- An Secure Shell (SSH) client, such as Putty, may be used for access into the root console of the VMware hosts for administration or maintenance that is not available within the vSphere Client. This typically is used for application of hotfixes and upgrades to the physical hosts, detailed log viewing, or high-level administrator activities.
- vFoglight provides monitoring capabilities with limited access to virtual machines and physical hosts. vFoglight is accessed via web browser through a specific port for both monitoring and configuration. vFoglight is used to monitor CPU usage, memory usage, disk usage, and I/O statistics, etc. vFoglight can generate alarms and notifications based on defined thresholds.

- Hewlett-Packard (HP) 4000 Centralized Management Console (CMC) provides access to the storage backend. This is where new volumes are created and deleted and assigned or unassigned from servers.
- Integrated Lights-Out (iLO) provides access to the HP hardware, which can be managed from the Blade Enclosure management connection, or from a web browser pointed to the correct IP address. In addition, hardware can be managed from a Liquid Crystal Display (LCD) screen on the front of the blade enclosure, directly connecting into the blade via a dongle connection, or through keyboard-video-mouse (KVM) switch connection to the Storage Area Network (SAN) or Blade hardware.

11.3.2 Database

Database backup jobs are monitored using Red Gate SQL Backup tools. These tasks are detailed in Section 3.9 of the CHART Operations and Maintenance Guide. Specific tasks include:

- Observing last backup run time and status
- Check of physical file backup on the appropriate server

The database mirroring process is also monitored using Red Gate tools. These procedures also are described in detail in Section 3.9 of the CHART Operations and Maintenance Guide.

11.3.3 CHART ATMS

The CHART ATMS itself provides some system related monitoring, alerting, and notification capabilities. CHART ATMS Alerts are indications of various conditions displayed to operators directly within the CHART ATMS GUI. Notifications are emails which are received by email or text messages. These include:

- Ability to send alerts and/or notifications when various conditions occur including roadside device hardware and communications failure, external interface failure (e.g., RITIS connection failure or Toll rate failure), and CHART ATMS service failures and automatic restarts.
- A Monitor Services capability which reports on CHART ATMS application service status through a Watchdog service. The Watchdog communicates via CORBA with CHART ATMS services. This provides an additional layer of service health monitoring. Types of monitoring include up time, number of service failures, service restarts, heap usage, and number of service failure and restart notifications and alerts.

11.4 High Availability

The CHART system design provides high availability through these methods.

- Redundancy within virtual environment
- Redundancy of communications paths
- Database mirroring
- Offsite backup capabilities for the CHART ATMS and the entire virtual environment
- CHART Emergency System (CHART-ES), a limited functionality off-site CHART ATMS installation
- Automatic recovery within the CHART ATMS application

Each of these methods will be discussed in more detail below.

11.4.1 Redundancy within the Virtual Environment

The CHART Virtual Infrastructure provides redundancy through the implementation of a cluster of hardware and software packages.

- Storage is provided by a multi-node Internet Small Computer System Interface (iSCSI) SAN cluster with redundant network connections accessible by all devices. This storage is replicated nightly to the SHA HQ site. The current configuration allows several individual component failures within the SAN without loss of data or the need to fail over.
- Hardware hosting the virtual servers provides protection against data and service loss with several components having 100% redundancy. For instance, the "Flex 10 networking modules" are completely redundant. The physical hosts themselves can tolerate the loss of 1/3 of the available physical hosts and still maintain full capabilities when the impacted virtual hosts are moved to the remaining physical hosts(s).
- Network and power redundancy are also at 100% with the ability to lose a full network or power feed without adversely affecting the environment.
- Local backups provide an additional layer of security, allowing the retrieval of full VMs instantly, and file-level recovery without resorting to SAN backups.
- VM Application and hardware configuration provides automatic failover of many components, including the ability to distribute resources, re-locate virtual servers on demand, take snapshots of servers prior to updates/upgrades, etc.

11.4.2 Redundancy of Communications Paths

There are redundant or backup communications paths for communicating with field devices, supporting video and CHART Backbone network traffic.

The FMS servers provide communications services to the CHART ATMS for the purpose of controlling and receiving data from traveler advisory devices and traffic monitoring devices. In the event of an FMS server failure one or more other FMS servers can provide backup for the failed server. This occurs transparently to the users of the system.

11.4.3 Database Mirroring

SQL Server mirroring has been established between the databases at the principal node at the CHART SOC data center and mirror node at the SHA HQ data center. Both the CHART operational and CHART Archive databases are mirrored. Two identically configured servers reside at each of the nodes from both a hardware (virtual) and software perspective.

As database transactions are committed in the principal node these transactions are copied over to the mirror node. The copying happens in real time and the data is in a synchronized state between the nodes. The level of synchronization can be set to be either dual commit or single commit mode. In a dual commit mode the database transaction is written to both nodes and only then will the relevant locks be released. In a single commit synchronization mode, transactions are committed at the principal node and locks are released. As a follow-on action these transactions are forwarded to the mirror node.

The CHART ATMS database is configured in a single commit synchronization mode. In a future release, the CHART ATMS application could be modified to take advantage of automatic

failover, in which case the dual commit synchronization mode with automatic failover could be used.

In case of a database failure at the principal node, the CHART ATMS database will be manually failed over to the mirrored node. A pre-configured CHART ATMS application installation exists at the mirrored node to point to the mirrored database. This allows failover to a secondary site in minimal time as the data will be copied in real time to the secondary site.

Additionally, in case of a database failure at both the primary and secondary SHA sites, the replicated database instances at the University of Maryland can be backed up and restored at a CHART site.

11.4.4 Offsite Backup Capabilities for the Virtual Environment

Full image snapshots are taken nightly and copied to the SHA HQ location in Baltimore. Included in these snapshots are local snapshots with file and image-level restore functionality.

The site at SHA HQ exists as a redundant and disaster recovery capable location where individual pieces or the entire CHART system can exist if necessary. Currently, the entire CHART network at the SOC can be failed over to SHA HQ. Details are provided in the CHART Virtualization Operations and Maintenance Guide. It is also possible for just the CHART ATMS core processes to be run at SHA HQ. The CHART ATMS core processes include all CHART ATMS application services and the CHART ATMS GUI. At a minimum, this allows operators to work with Traffic Events and perfrom administrative functions. Operators may also send Notifications and control, and receive status from roadside devices when network access to those assets has not been compromised due the conditions that caused the need to fail over in the first place. Other CHART ATMS functionality and interfaces may or may not be available depending on the conditions that led to the manual failover.

Details of the CHART ATMS manual failover procedure can be found in Section 3 of the CHART Operations and Maintenance Guide.

Additional details on CHART ATMS failover to SHA HQ can also be found in the CHART Application Recovery Plan.

11.4.5 CHART-ES

CHART-ES is a standalone single-node system which runs at the Authority Operations Center (AOC). This can be used during maintenance periods or unscheduled downtime in the standard CHART ATMS system when it is not desired or possible to use the backup CHART system at SHA Headquarters. CHART-ES consists of a database, a complete set of CHART back-end services (only some of which will be configured to run, and a slightly modified CHART ATMS GUI installation. The CHART-ES system is designed to allow operators to control DMSs, receive Toll Rate data to post on DMSs, to switch video, and to control cameras.

11.4.6 Automatic Recovery within the CHART ATMS Application

The CHART ATMS itself provides some recovery capabilities through its Watchdog functionality. The Watchdog services can be configured to poll CHART ATMS application services via CORBA, receive status, and automatically restart those services if the services are non-responsive. Currently, most CHART ATMS application services are configured to be automatically restarted if they are non-responsive. The Watchdog also provides some alerting and notification capabilities described in section 11.3.

11.5 CHART ATMS Administrator Maintenance Tasks

There are a number of routine maintenance type tasks that can be performed through the CHART GUI, generally by those users that are granted the Adminstrator role. Those tasks include:

- User management. This includes adding, editing and deleting users, resetting passwords, creating roles, and assigning users to roles.
- Notification management. This includes adding, editing, and deleting contacts, creating groups, and assigning contacts to groups.
- External Client management. This includes providing security credentials for clients wishing to consume CHART data feeds (e.g., RITIS).
- System profile. The system profile includes a large number of user configurable CHART ATMS system parameters. Most change very infrequently.

11.6 Software Distribution

This section presents the procedures and processes used to control and manage the development and distribution of the CHART ATMS software.

11.6.1 Configuration Management and Version Control

The overall Configuration Management (CM) plan for CHART is presented in the document "CHART Configuration Management Plan, PM-PL-004, August 2008." The specific objectives of the CHART CM program are to ensure that:

- CHART hardware, software, and data configuration items (CIs) are appropriately selected and identified
- CHART project baselines are established at the correct time
- Changes to the CHART baselines are authorized, evaluated, implemented as approved, verified, and tracked in accordance with established procedures
- Commercial off-the-shelf (COTS) tool upgrades are fully assessed and their impact evaluated
- The status of CHART baselines and proposed and approved changes is accounted for and reported
- Baseline and other required CM audits are carried out and the results reported
- The integrity of the system design is maintained
- The delivered system and all accompanying deliverables are accurately defined and described

The CHART ATMS development team is using Subversion as the configuration management tool to support CHART ATMS software development. The configuration management policies and procedures for the CHART ATMS software are defined in a set of standards and procedures documents. These standards and procedures documents are listed below.

- Review and Approval of COTS Upgrades, CHART-CM-PR-001, 2/2009

11.6.2 Software Installation

The installation of new versions of CHART ATMS software components is controlled through a Software Control Notice (SCN) as described in the document "Software Control Notice

Procedure, June 2009". The detailed plan for executing the installation is contained in the CHART ATMS Implementation Plan that is customized for each CHART ATMS software release. For new site installations the software components are installed and configured prior to integration of the system into the operational environment. Appendix A of the CHART Operations and Maintenance Guide presents instructions for performing software installations on operational system components. This includes installation of both COTS and of the CHART ATMS software proper.

11.7 Training

Training of CHART operations staff in the use of the CHART ATMS is provided via several means.

The CHART ATMS can be installed in a training environment where users can operate the system without interfering with production. The system supports an online training capability in the form of field device simulators. Field device simulators or actual field devices set up for test purposes (e.g. a portable DMS) may be connected to the system and controlled by operations personnel in a training exercise.

A training plan is developed for each CHART ATMS software release. Training sessions are conducted by MDSHA at their discretion.

LIST OF ACRONYMS

The following table lists the acronyms used in the document.

Acronym	Description
AOC	Authority Operations Center
AOR	Area of Responsibility
API	Applications Programming Interface
ATIS	Advanced Traveler Information System
ATM	Asynchronous Transfer Mode
ATMS	Advanced Traffic Management System
AVCM	ATM Video Control Manager
AVL	Automatic Vehicle Location
BAA	Business Area Architecture
BHT	Baltimore Harbor Tunnel
CATT	Center for Advanced Transportation Technology
CCTV	Closed Circuit Television
CHART	Coordinated Highways Action Response Team
CM	Configuration Management
CMC	Centralized Management Console
CORBA	Common Object Request Broker Architecture
COTS	Commercial Off-The-Shelf
CVI	Cern Virtual Infrastructure
DB	Database
DBA	Database Administrator
DCDOT	District of Columbia Department of Transportation
DCOM	Distributed Component Object Model
DMS	Dynamic Message Sign
EIS	Electronic Integrated Systems
EORS	Emergency Operations Reporting System (the former name of LCP)
ER	Entity Relationship
ERD	Entity Relationship Diagram
ESRI	Environmental Systems Research Institute
FC	Fibre Channel

Acronym	Description
FMS	Field Management Station
FMT	Fort McHenry Tunnel
FSK	Francis Scott Key [Bridge]
GUI	Graphical User Interface
HA	High Availability
HAR	Highway Advisory Radio
HIS	Highway Information Systems
HP	Hewlett-Packard
HQ	Headquarters
HTTP	Hyper Text Transfer Protocol
HTTPS	Hyper Text Transfer Protocol Secure
I	Interstate
ICD	Interface Control Document
iLO	Integrated Lights-Out
IP	Internet Protocol
iSCSI	Internet Small Computer System Interface
ISDN	Integrated Services Digital Network
ITS	Intelligent Transportation Society
JSON	JavaScript Object Notation
KVM	Keyboard-Video-Mouse [Switch]
LATA	Local Access Transport Area
LCD	Liquid Crystal Display
LCP	Lane Closure Permits
MD	Maryland
MD511	Maryland 511 (Maryland's 511 Traffic information System)
MDOT	Maryland Department of Transportation
MDSHA	Maryland State Highway Administration
MDTA	Maryland Transportation Authority
MIB	Management Information Base
NOC	Network Operations Center
NTCIP	National Transportation Communication for ITS Protocol
ORB	Object Request Broker
POTS	Plain Old Telephone System

Acronym	Description
PR	Problem Report
PTZ	Pan, Tilt, Zoom
REST	Representational State Transfer
RITIS	Regional Integrated Transportation Information System
RSS	Really Simple Syndication
RTMS	Remote Traffic Microwave Sensor
SAE	Society of Automotive Engineers
SAN	Storage Area Network
SCSI	Small Computer System Interface
SFS	Streaming Flash Server
SHA	State Highway Administration
SHAZAM	Sign with controllable beacons to indicate a message of significance is playing on a nearby HAR. (SHAZAM is not an acronym.)
SNMP	Simple Network Management Protocol
SOC	Statewide Operations Center
SP	Service Pack
SSH	Secure Shell
SSP	Safety Service Patrol
SwGI	Statewide Government Intranet
TCP	Transmission Control Protocol
TMDD	Transportation Management Data Dictionary
TOC	Traffic Operations Center
TSS	Transportation Sensor System
TTS	Text-to-Speech
UMD	University of Maryland
US	United States
vCPU	Virtual CPU
VM	Virtual Machine
WAN	Wide Area Network
WMATA	Washington Metropolitan Area Transit Authority
WMS	Web Map Service
WYSIWYG	What You See Is What You Get
XML	Extensible Markup Language

A DESIGN STUDIES

This section provides information on analysis, prototyping, and trade studies dating from the initial system design effort to the current time.

A.1 C++/Java Performance Comparison

The purpose of this study was to compare the performance of the Java and C++ languages as they pertain to the development of an ITS control system. The tests included in this comparison were developed to investigate the performance characteristics of those language features that are most frequently utilized in the creation of an ITS control system. The study demonstrated that either language was a suitable candidate for the development of an ITS control system. The details of the study are found in the document, "C++/Java Performance Comparison for Distributed ITS Control Systems", M361-AR-002R0, March 30, 1999.

A.2 Java Feasibility

This study was originally conducted to investigate the feasibility of using the Java programming environment to develop the CHART ATMS. The investigation was targeted at resolving what were identified as high-risk tasks for Java programming, specifically some areas related to the GUI. The details of the study are found in the document, "CHART II Java Feasibility Investigation", M361-AR-003R0, July 1, 1999. (Note: the CHART ATMS was once known as "CHART II".)

A.3 CORBA ORB

This study was conducted to evaluate vendors of Common Object Request Broker Architecture (CORBA) Object Request Broker (ORB) products for use in the implementation of the CHART ATMS. An initial field of twenty potential vendors was reduced to three candidates for evaluation. Based on how well each vendor scored on a set of ten criteria it was determined that the ORBacus product from Object Oriented Concepts best served the needs of the CHART ATMS. This product is now owned by IONA Corporation. The details of the study are found in the document, "CORBA ORB Evaluation for CHART II", M361-AR-004R0, March 19, 1999.

A decision was made to replace ORBacus as part of CHART R2B3. The CHART ATMS now uses a customized version of JacORB, a freely available ORB. CHART ATMS developers have made numerous patches to JacORB, both to correct and enhance it.

A.4 Text-to-Speech Conversion

The generation of audio for download to Highway Advisory Radios (HARs) was identified as an area of improvement in the CHART ATMS. It was desirable to have the capability in the CHART ATMS to generate speech from text files in order to free CHART ATMS operations personnel from having to manually record the audio for HARs. An evaluation of available text-to-speech (TTS) conversion applications was conducted to determine if the generation of speech from text files could be performed at a high enough quality for use in the CHART ATMS.

There are two methods in general use in the industry for the conversion of text to speech. Rule-based systems use a set of rules for creating computer-generated speech from input text. Applications based on the concatenation algorithm method use a library of pre-recorded phonemes (speech fragments) to build audio from input text.

The quality of audio output was the main criteria for the evaluation of TTS applications. A number of rule-based applications and two concatenation-based applications were surveyed as potential candidates. A text file with a sample HAR message was created and a wav file generated from the text using each of the potential TTS applications. Based on a review of the output wav files by development and SHA personnel it was determined that none of the rule-based applications generated audio of sufficient quality for consideration. The product currently in use for the CHART ATMS is the NeoSpeech text to speech engine.

A.5 Storage Area Network

A Storage Area Network (SAN) is an approach to data storage that moves storage systems from captive devices connected to dedicated servers to network devices in a peer-to-peer topology. The main purpose behind the installation of a SAN is to facilitate the growth of storage and servers independently of each other. A SAN uses Fibre Channel (FC) connections to provide higher transfer rates between devices than Small Computer System Interface (SCSI), and all SAN traffic runs independently of Local Area Network (LAN) traffic. In addition to the higher transfer rates, a SAN FC can operate over distances of 10km. A SAN can also serve as a key element in High Availability (HA) systems. By implementing a Tape Library as a SAN device, backups and restores can be done at any time of the day without affecting LAN performance. For these reasons a SAN was implemented to support the CHART ATMS and other elements of the CHART Program.

A.6 High Availability Architectures

A High Availability study was conducted to evaluate the options for providing increased availability in the CHART ATMS. The details of the study are found in the document, "CHART II High Availability Study", M361-AR-009R0. Three options were evaluated and compared with a CHART ATMS baseline system. The three options were:

- Use Oracle Advanced Replication services to replicate the CHART ATMS database at CHART ATMS server sites.
- Use a Storage Area Network to maintain mirror copies of CHART ATMS server disks at the SOC.
- Use the Microsoft Cluster Server based solution to cluster two servers together for load-sharing and redundancy.

Each of the three options has its advantages and disadvantages. As a result of the High Availability study, an interim configuration of Legato Co-Standby Advanced Availability Manager was implemented at the SOC. In December 2007, a Microsoft Cluster Services solution was implemented in conjunction with a SAN. Subsequently, however, a decision was made to not continue with any HA architecture at the SOC. This decision was primarily made because the CHART ATMS had become more fully realized as a truly distributed system across multiple nodes, thereby de-emphasizing the importance of the SOC in terms of the CHART ATMS system architecture.

A.7 Node Consolidation

In the spring of 2010, an effort to consolidate some of the CHART ATMS application server nodes was initiated. There were multiple reasons for that effort including system stability, licensing costs, and a de-emphasis on the need for a distributed architecture to protect against

network failure on the MDOT Wide Area Network (WAN). With that in mind, the initial node consolidation began in the summer of 2010. The number of CHART ATMS application nodes was reduced from eight to five. Further efforts to reduce the number of nodes from five to one were initiated in 2012. This required a robust backup solution for the application and the database, and encompassed a transition from an Oracle database solution to a Microsoft SQL Server database solution. This solution was deployed as R9S in September of 2012.

The CHART ATMS application is designed to be fully distributed and scalable and can theoretically be expanded by adding additional nodes to the system. However, an increased communications overhead comes with that expansion. The CHART ATMS services must all communicate amongst each other via CORBA and adding additional nodes causes an exponential growth in the number of CORBA connections in the overall system. Each such connection introduces possible communications failure into the system which in turn creates potential stability problems.

At the time of the study, each application server node hosted an Oracle database instance and each Oracle instance carried a substantial licensing cost. After delivery of R9S, there is one SQL Server installation at the SOC, and a complete, mirrored backup installation at SHA Headquarters in downtown Baltimore.

Part of the reason for the distributable architecture had been to allow nodes to function autonomously in the event that they were cut off from the rest of the nodes. Operators homed to an isolated node would still be able to operate their roadside devices and perform their traffic management tasks. However, over time, the WAN has proved to be very stable. The isolated node scenario has not occurred.

A.8 CHART Systems Database Strategic Plan

The purpose of this study, completed in April 2011, was to identify database options for the full CHART Program that would maximize technical and financial benefit to SHA's business goals. The subsequent CHART Work Order Scope and Estimate Request Form requested the production of a white paper document to recommend a 5 year strategic plan for the CHART systems databases and also, after a checkpoint with SHA, to create a plan including a schedule, assumptions and risks to implement the approved recommendations.

The assessment was approached using the Enterprise Architecture Framework as defined by the National Institute of Standards and Technology. This approach gives a holistic view of the enterprise. The Enterprise Architecture has 5 layers. The five layers are:

- Enterprise Business Architecture Layer
- Enterprise Information Architecture Layer
- Enterprise Application Architecture Layer
- Enterprise Application Integration Architecture Layer
- Enterprise Infrastructure Architecture Layer

The Enterprise Business Architecture Layer review for SHA was carried out previously by CSC and is reflected in the Business Area Architecture document: BAA Report Revision 6, January 2011. The recommendation for this layer was to continue on those specified in BAA.

The Enterprise Information Architecture Layer is comprised of the Presentation Management and Reports Management layers. In the Presentation Management layer of SHA, there are several Graphical User Interfaces identified. These are CHART GUI, EORS V2 GUI, LCP (known as EORS Legacy at the time) GUI, CHARTWeb Desktop, CHARTWeb Mobile and the

Intranet Map. The recommendation for this layer was to establish a single EORS (LCP) GUI, establish CHART Analytics GUI, establish an Attention Admin GUI and continue to use the following GUIs; CHARTWeb Mobile, CHARTWeb Desktop, CHART GUI, Intranet Map (ArcGIS) and implement a portal tool that will unify and enable a role-based Single-sign on.

In the Reports Management portion of the Enterprise Information Architecture, several report conduits were identified: SREE, SQL Server Reporting Service, Legacy Reporting Service, and Google Web Analytics Lite. The recommendation for this layer was to retire SREE, consolidate all SQL Server Reporting services, establish CHART dashboards, CHART Analytics (Business Intelligence tool) and use Google Urchin.

The Enterprise Application Architecture Layer is comprised of four core applications, which are the CHART ATMS, LCP (EORS at that time), CHARTWeb and CHART Mapping. The recommendation at this layer was to continue to have the applications remain independent of each other and integrate in the middleware layer.

The Enterprise Application Integration Architecture Layer is comprised of the middleware/IPC management layer. The CHART middleware management is using CORBA, Apache Tomcat, IIS, ASP, .NET, RSS, XML Web Services, and REST Web Services. The recommendation for this layer was that CHART is already on a good path and should continue to use TOMCAT, IIS, ASP, .NET, RSS, and Apache. It was recommended that CHART implement an Enterprise Service Bus (ESB), establish web orchestration using BPEL, establish a form of Workflow mechanism using BPM, and establish a Web Services Manager and Service Registry. These middleware upgrades could possibly lead to the replacement of CORBA as an IPC solution for the CHART ATMS at some point in the future.

The Enterprise Infrastructure Architecture Layer is comprised of Database Management; Archive and Backup Management; and the physical Infrastructure Management. The recommendation for the Database Management portion was for SHA to use web services for communication and take the "Federated Option" which consists of the following components:

- Attention Database (paging system)
- A consolidated CHART Database
- CHART BG Database (SDE & Mapping)
- A consolidated database for LCP (EORS at that time)
- CHART Web Cache Database
- CHART Analytics Database (CHART-A)

This recommended approach would give SHA flexibility for growth, while systems and development cycles remain independent. It also provides a quicker patching cycle and keeps all application communication at the middleware layer. At the database layer, the recommendation is to consolidate databases where possible and implement an enterprise data governance strategy. The recommendation for the physical Infrastructure Management portion is for SHA to continue on the path of establishing VMware ESXi and upgrading to a more recent version of the Windows Server operating system. The ArcServe Backup product recommended by CHART's infrastructure team will be implemented

B MAJOR PROTOTYPES

One of the key elements in our approach to designing the CHART ATMS is prototyping. Prototyping is a valuable tool to establish proof of concept before implementation, it provides an opportunity for SHA to experience the look and feel of parts of the system in order to validate the design, and reduces risk by verifying technological solutions before committing funds for full deployment. Several prototypes have already been developed as part of the design process and several more prototype efforts are planned for the future. These are described below.

B.1 Event Logs

An Event Log prototype was developed to verify the user interface for event log management. This prototype consisted of a portion of the GUI for event management along with logic for performing some of the event management functions such as event creation, adding event entries, and closing out events. This work was performed as part of the high level design for CHART Release 1 Build 2 (R1B2). User feedback from the prototype was used to further refine the design.

B.2 HAR

A HAR prototype was developed to test the quality of broadcast for the latest generation of text to speech engines. Actual generated audio files and to verify the interface to the HAR. An actual HAR device was used in the prototype. Audio files were downloaded to the HAR and the quality of output monitored using the dial-up monitor port on the HAR (actual broadcast was not allowed with this device). Some of this work was later repeated when testing the quality of the Nuance and NeoSpeech text to speech products.

B.3 CCTV Distribution

A CCTV distribution prototype was developed to test the feasibility of a statewide system for the distribution of video. This prototype was also used to validate the architectural principal of CHART video being viewed by many different centers simultaneously. The prototype was also used to validate the ability to simultaneously control multiple camera types from a single user interface. The feasibility of this prototype was so successful that it was operational for 7 years. Release 2 of the CHART ATMS included the distribution of video into the CHART ATMS, along with the decommissioning of the prototype system.

B.4 Automatic Vehicle Location

An Automatic Vehicle Location (AVL) capability for the CHART Program was studied in calendar year 2000. A pilot program sponsored by the Department of Budget and Management (DBM) [now known as DoIT] evaluated two AVL products paired with two wireless communications providers.

B.5 Oracle to SQL Server

In 2011, some prototyping work was done to convert the CHART ATMS database from Oracle to SQL Server. The prototype converted DMS related tables and data from Oracle to SQL Server and then the CHART ATMS DMS service database driver was switched to work with

SQL server. This work was done to help estimate the entire effort of using SQL Server for the entire CHART ATMS.

B.6 Future Prototypes

A key element of the CHART ATMS design approach is prototyping. Prototyping has been a key part of the development process for every CHART ATMS release, and prototyping will be used throughout the implementation of the CHART ATMS whenever technology evaluation is needed or when early customer experience and feedback with a portion of the system is desired.

C ENTITY RELATIONSHIP DIAGRAMS

This appendix provides Entity Relationship Diagrams (ERDs) for the database used in current release of the CHART ATMS, in Figures C-1 through C-20. The ER diagrams are laid out such that as few lines as possible connect from one page to another, but some interpage connections (relationships) are unavoidable. The diagrams are numbered by row and column – so that, if they were placed in a grid, with ERD 1-1 in the upper left corner, ERD 1-2 to its right, likewise with ERDs 1-3, 1-4, and 1-5 in the upper right corner, followed by the next five diagrams in row 2, the last 5 in row 3, with ERD 3-5 in the lower right corner, they would form one large picture with lines connected across the individual pages where necessary. Note that many tables are not interconnected due to the CHART ATMS's history as a multi-server, multi-database distributed system where entities which might otherwise be related are not related because they could be (could have been) stored in separate databases.

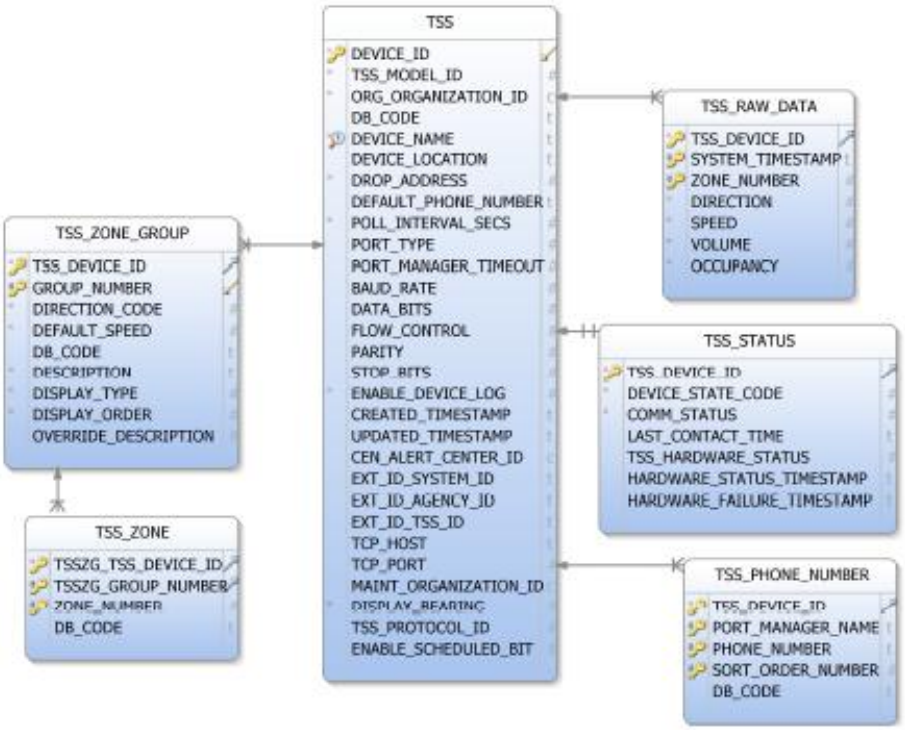

Figure C-1. Entity Relationship Diagram 1-1

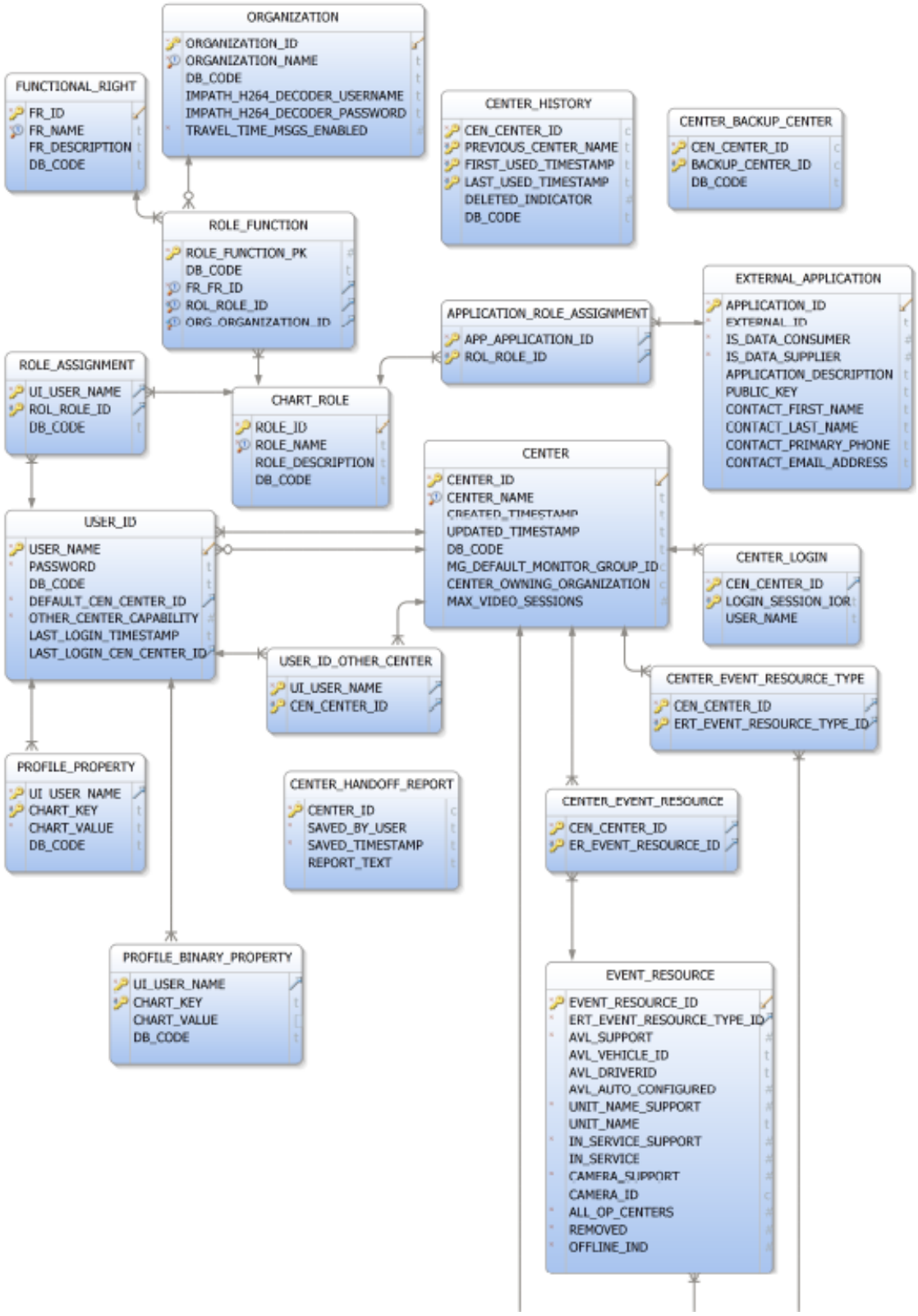

Figure C-2. Entity Relationship Diagram 1-2

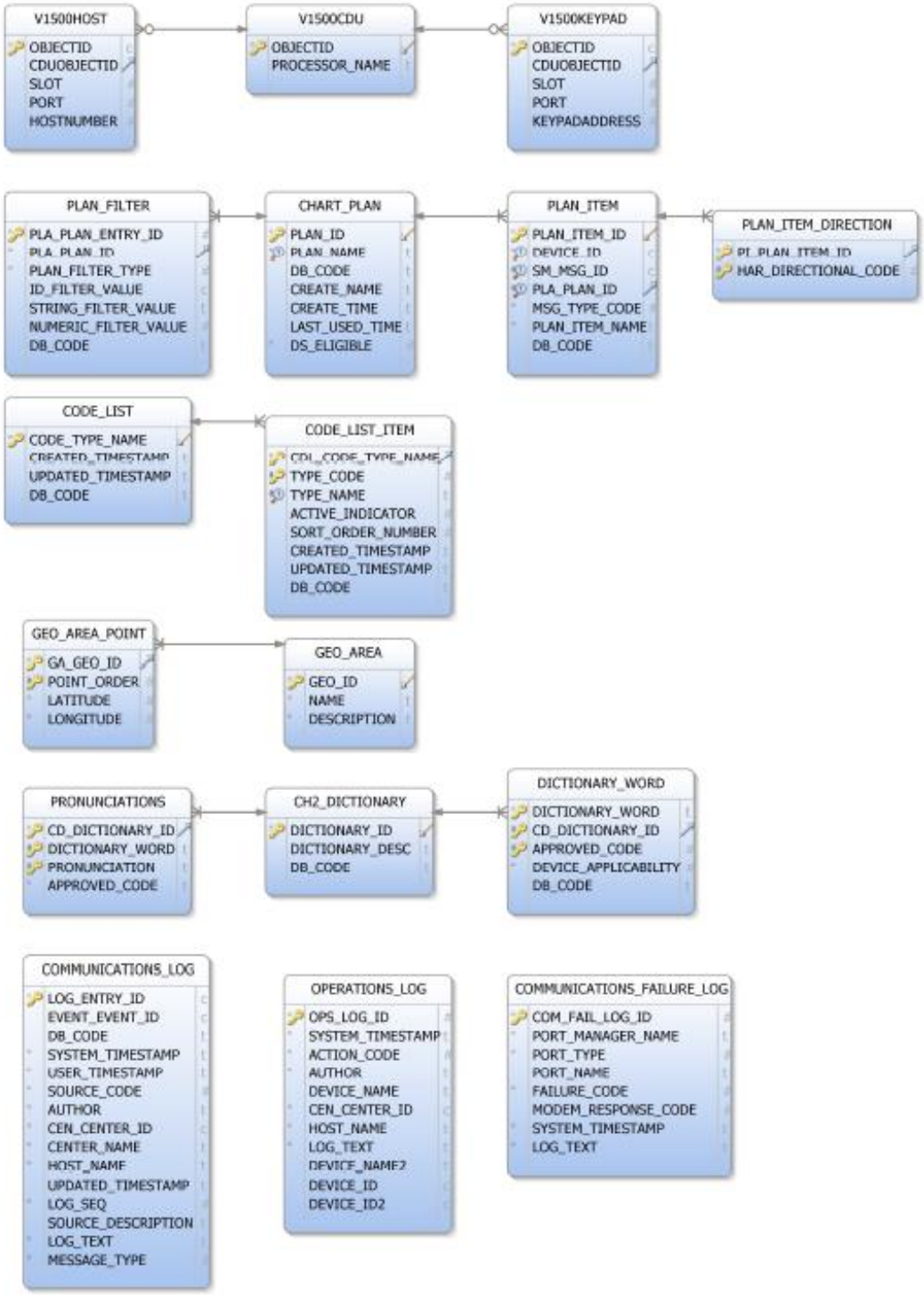

Figure C-3. Entity Relationship Diagram 1-3

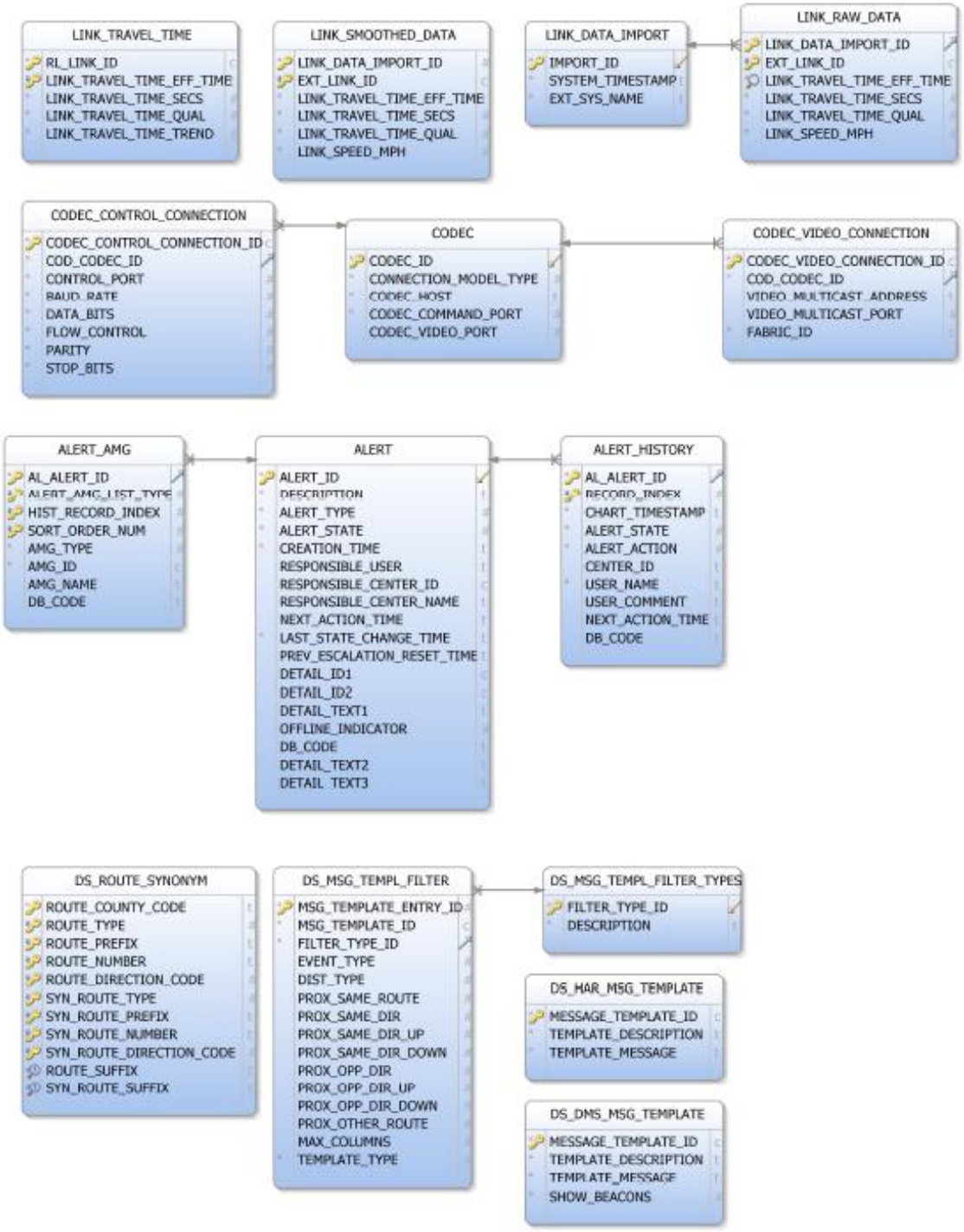

Figure C-4. Entity Relationship Diagram 1-4

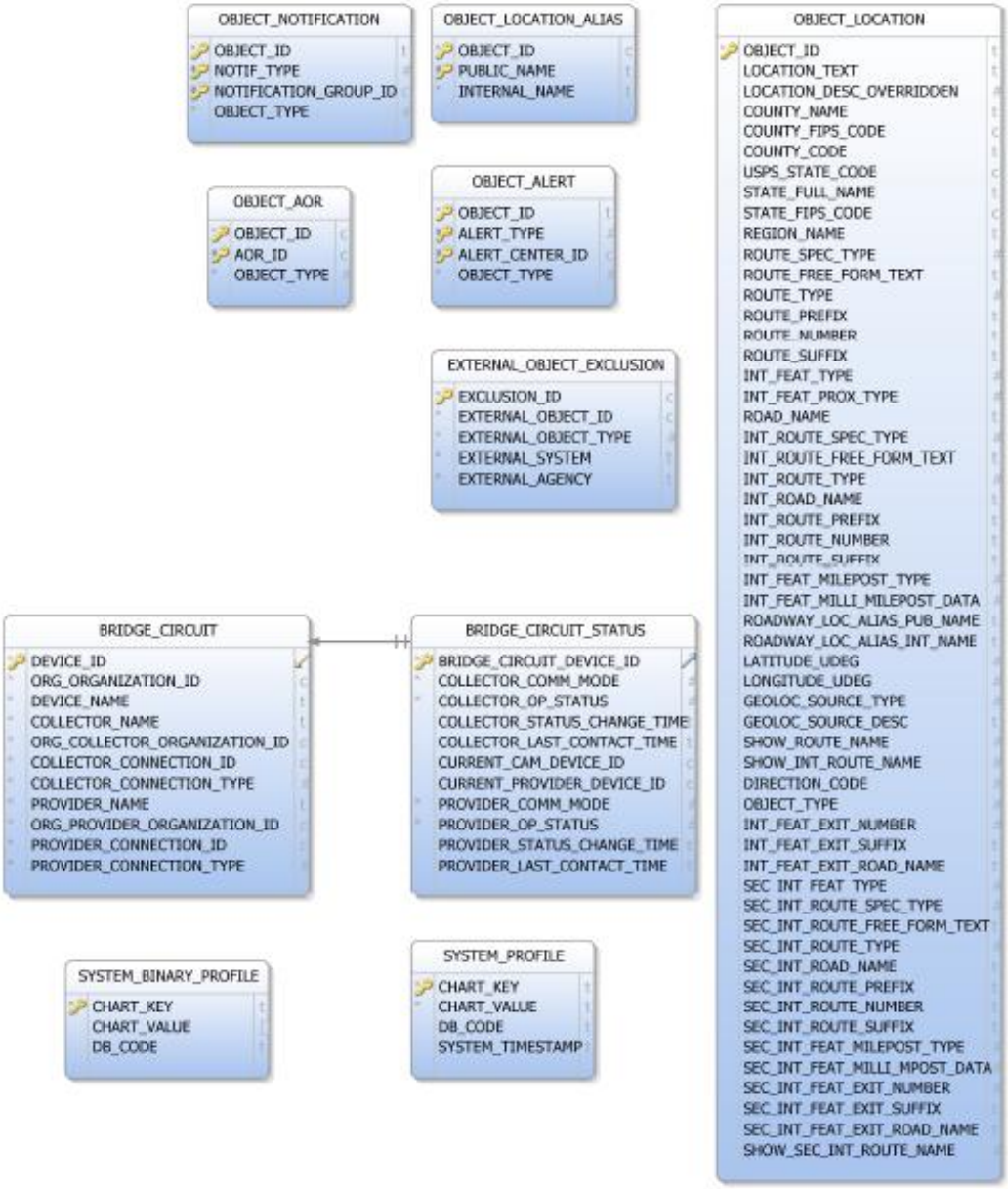

Figure C-5. Entity Relationship Diagram 1-5

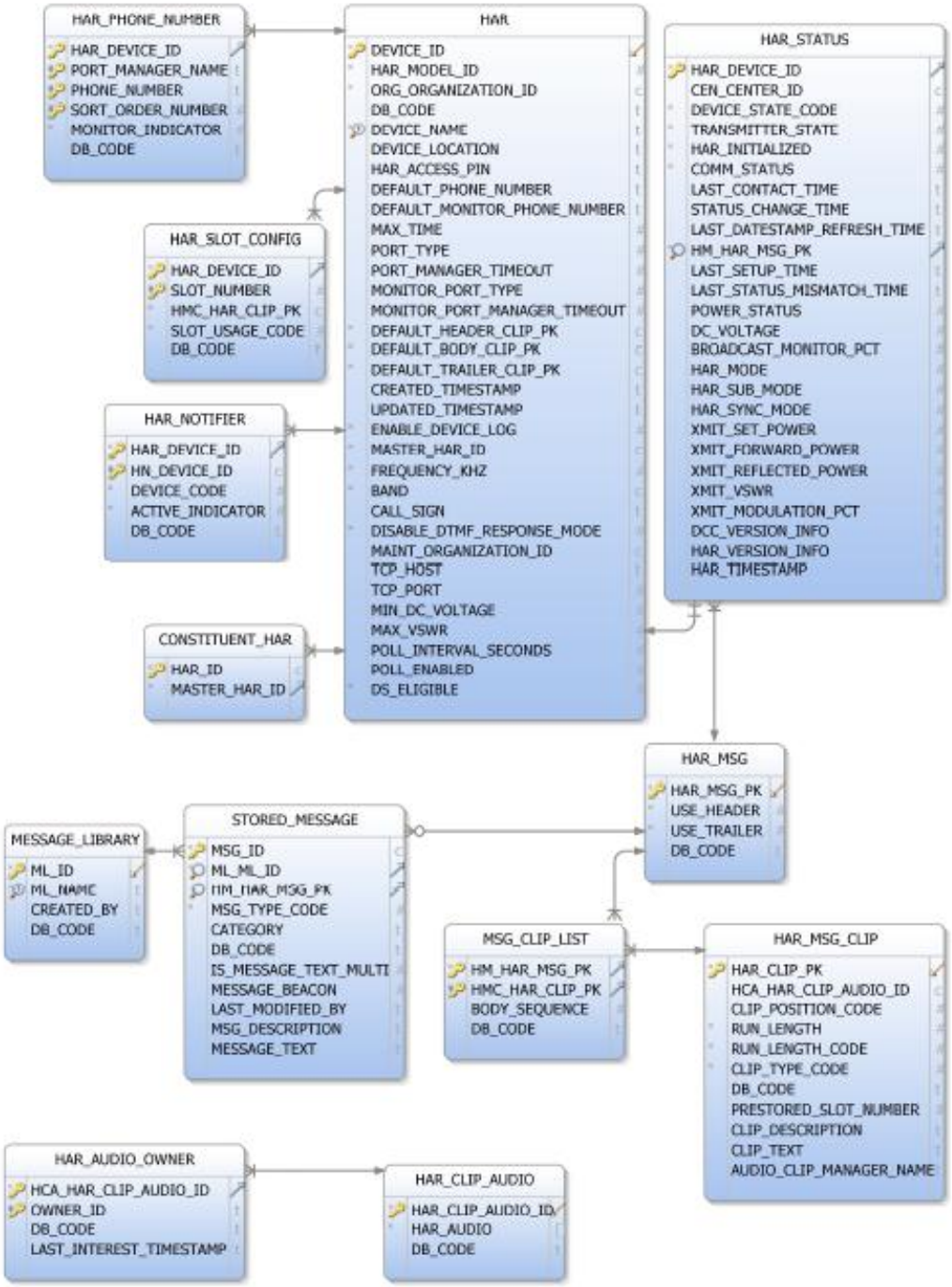

Figure C-6. Entity Relationship Diagram 2-1

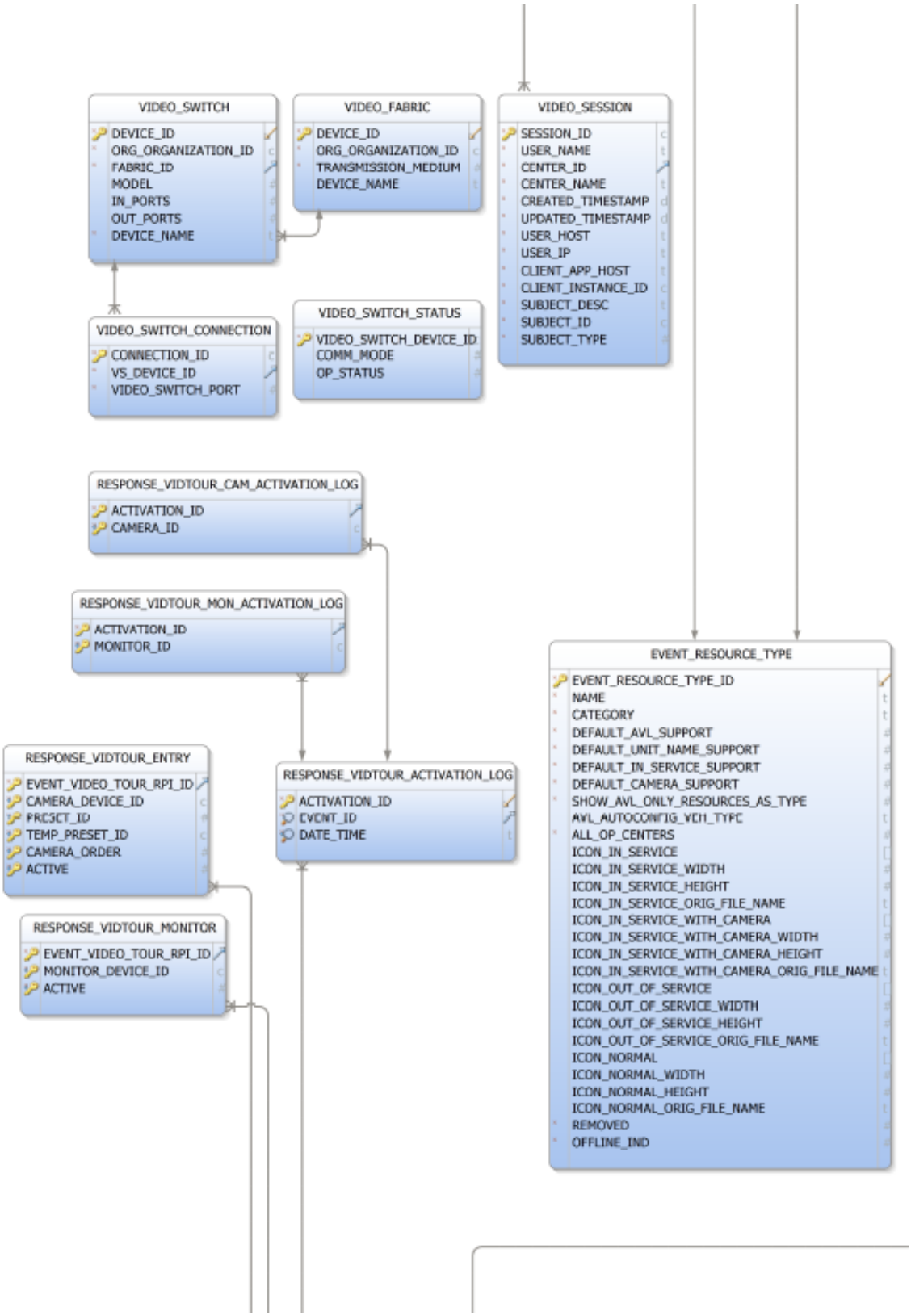

Figure C-7. Entity Relationship Diagram 2-2

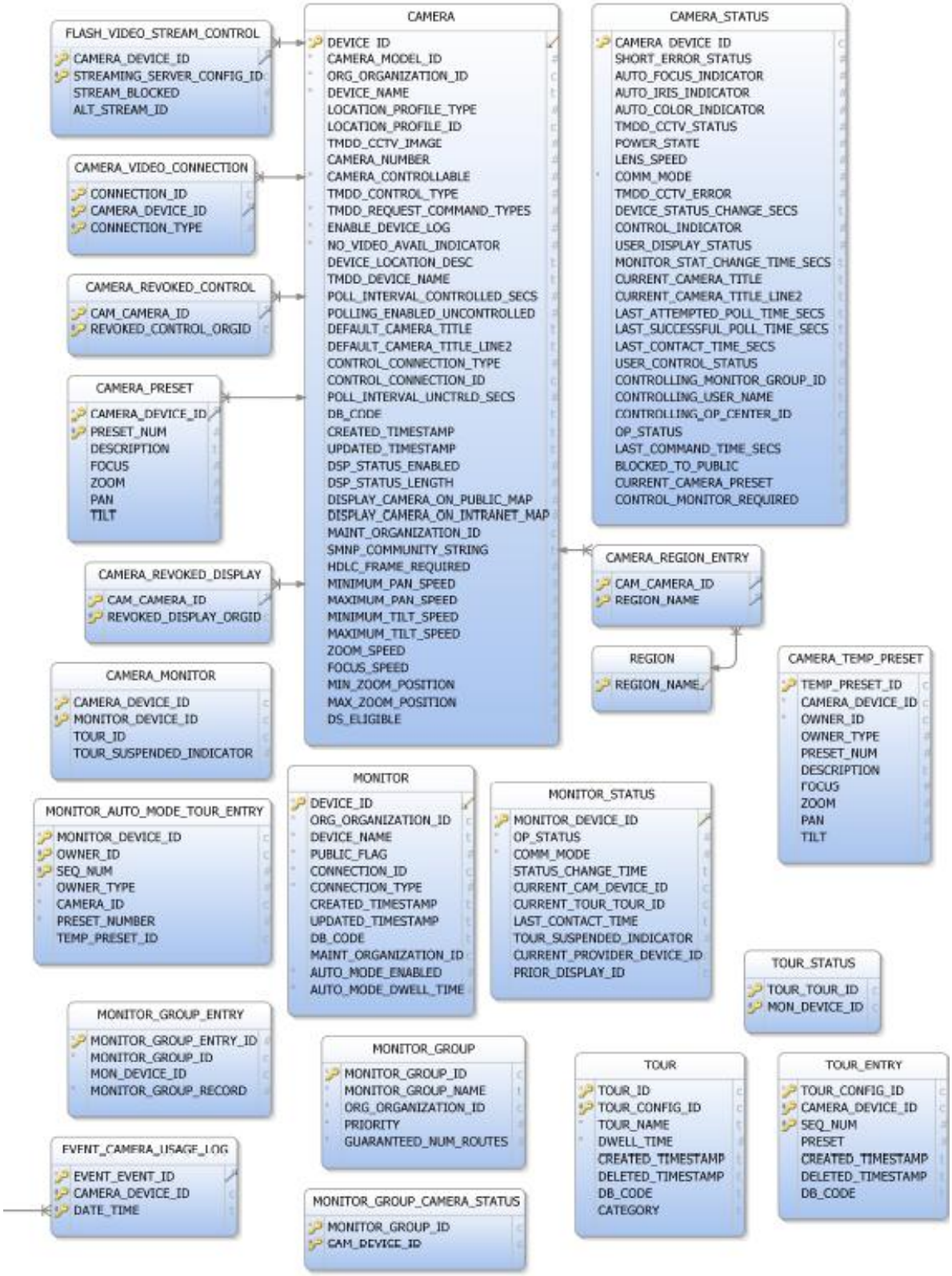

Figure C-8. Entity Relationship Diagram 2-3

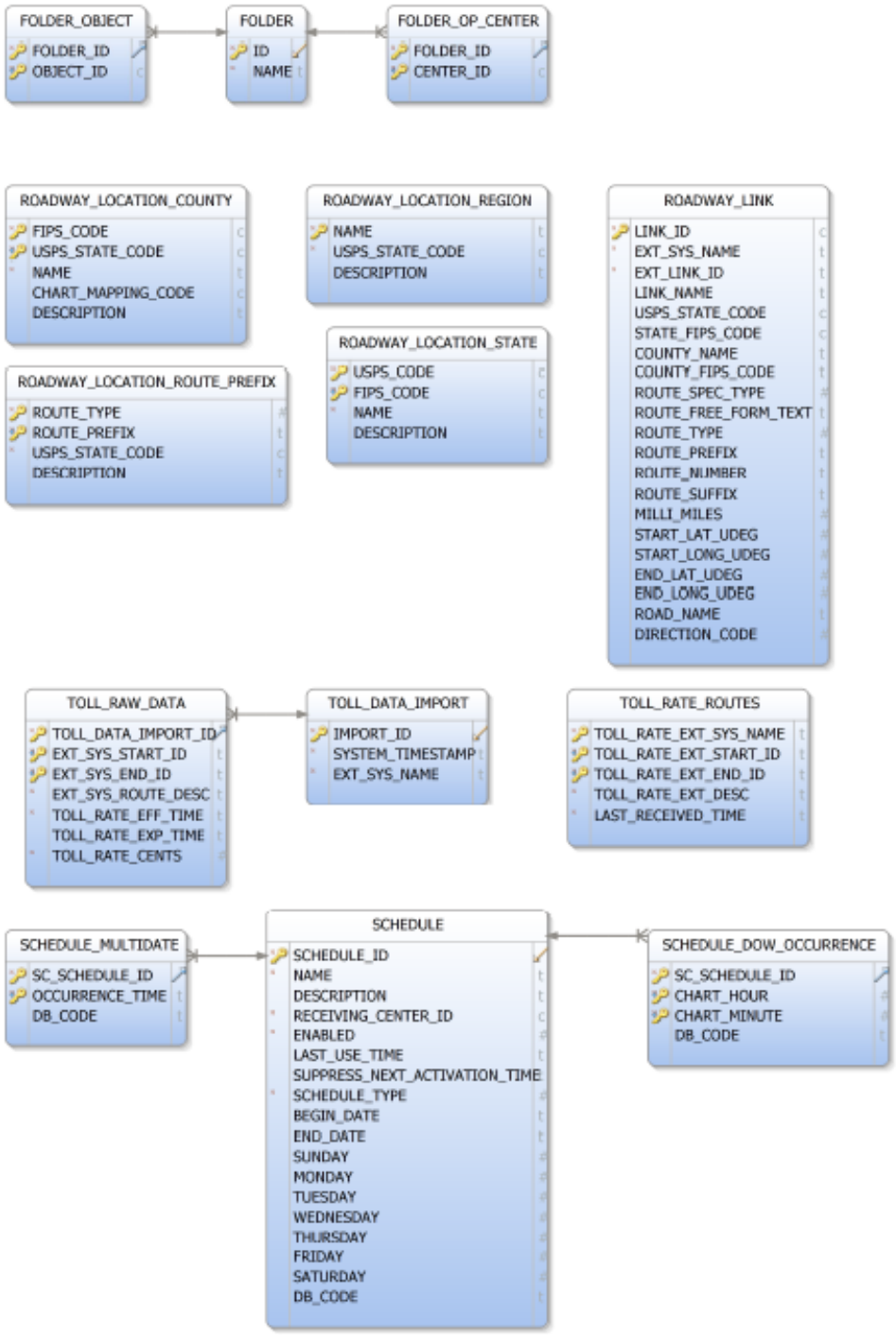

Figure C-9. Entity Relationship Diagram 2-4

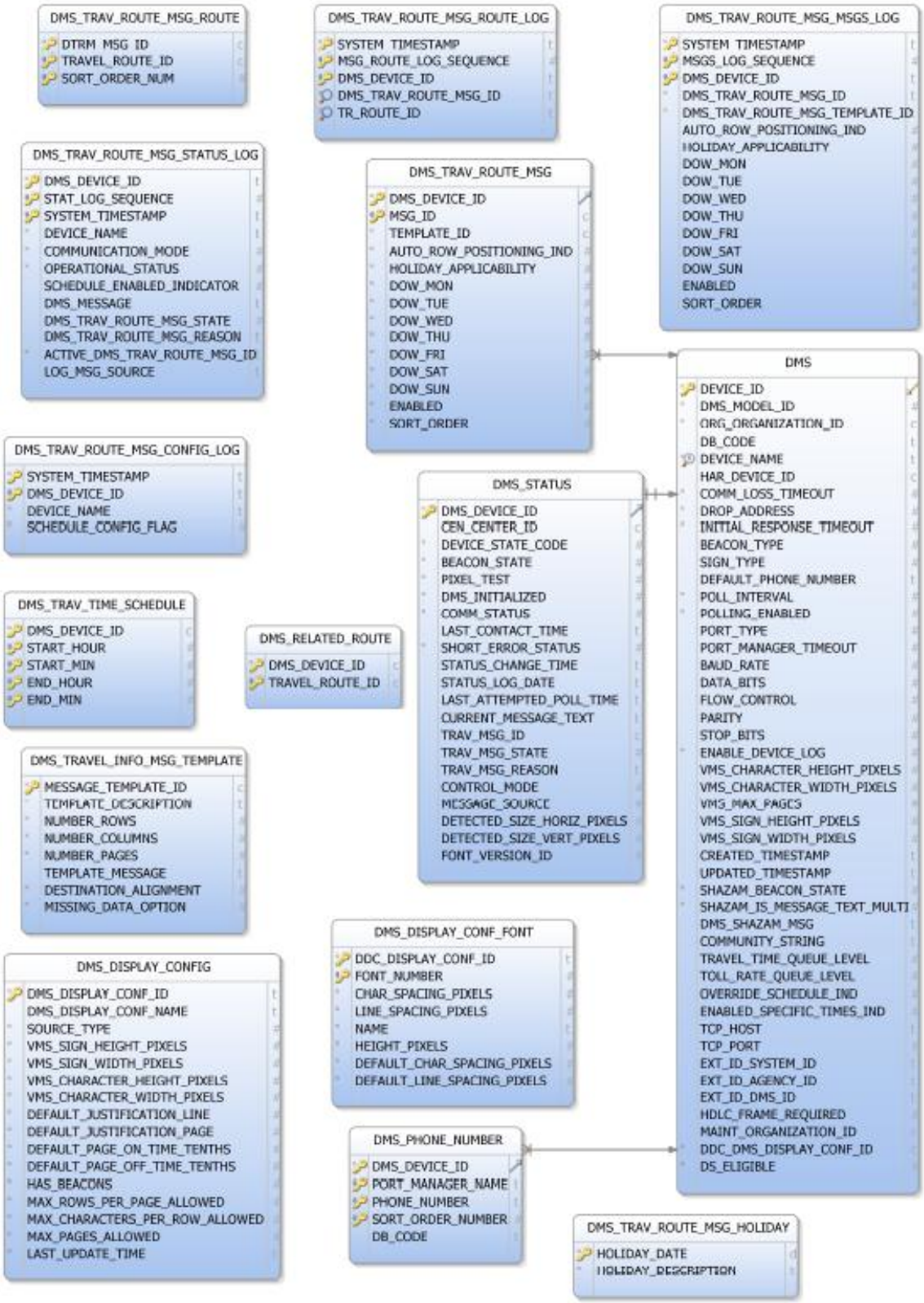

Figure C-10. Entity Relationship Diagram 2-5

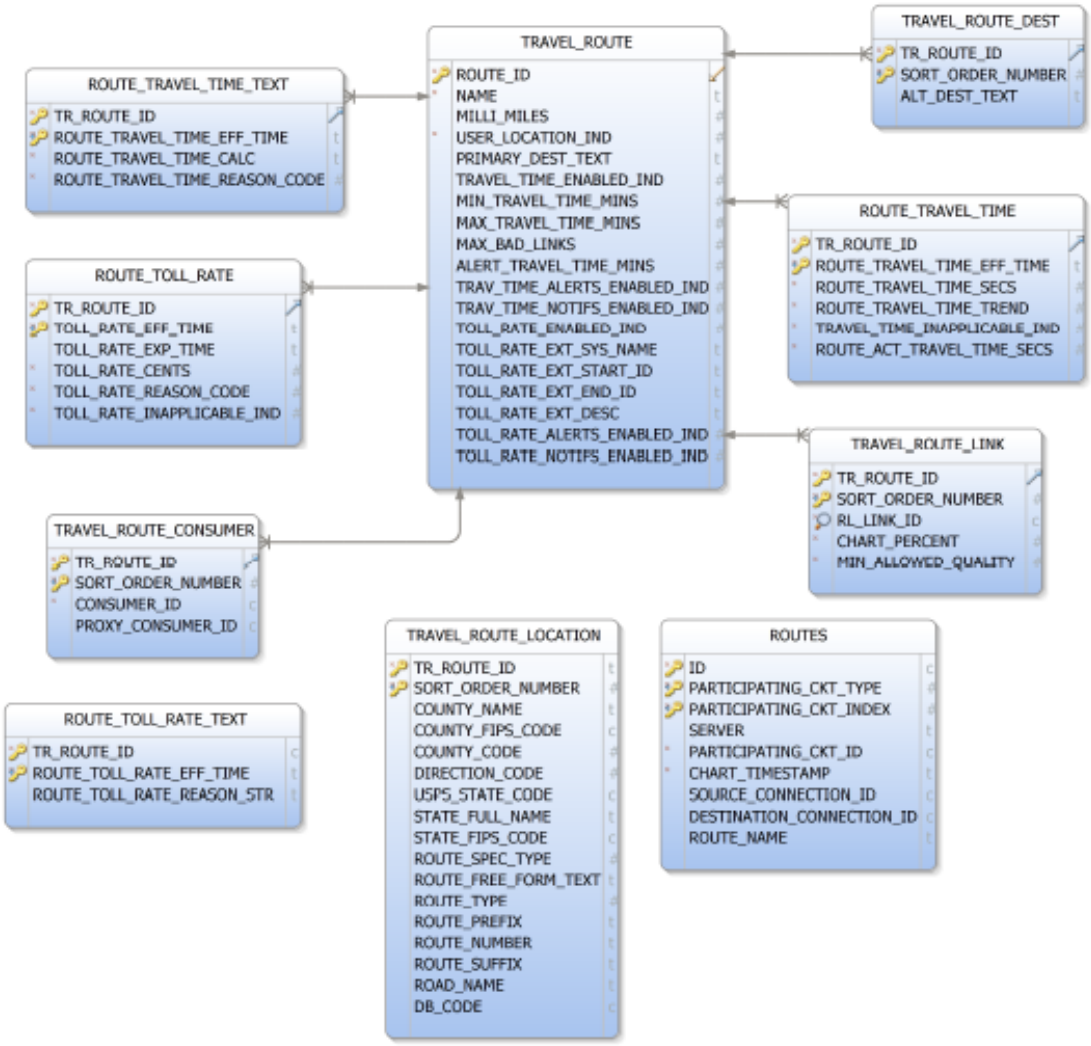

Figure C-11. Entity Relationship Diagram 3-1

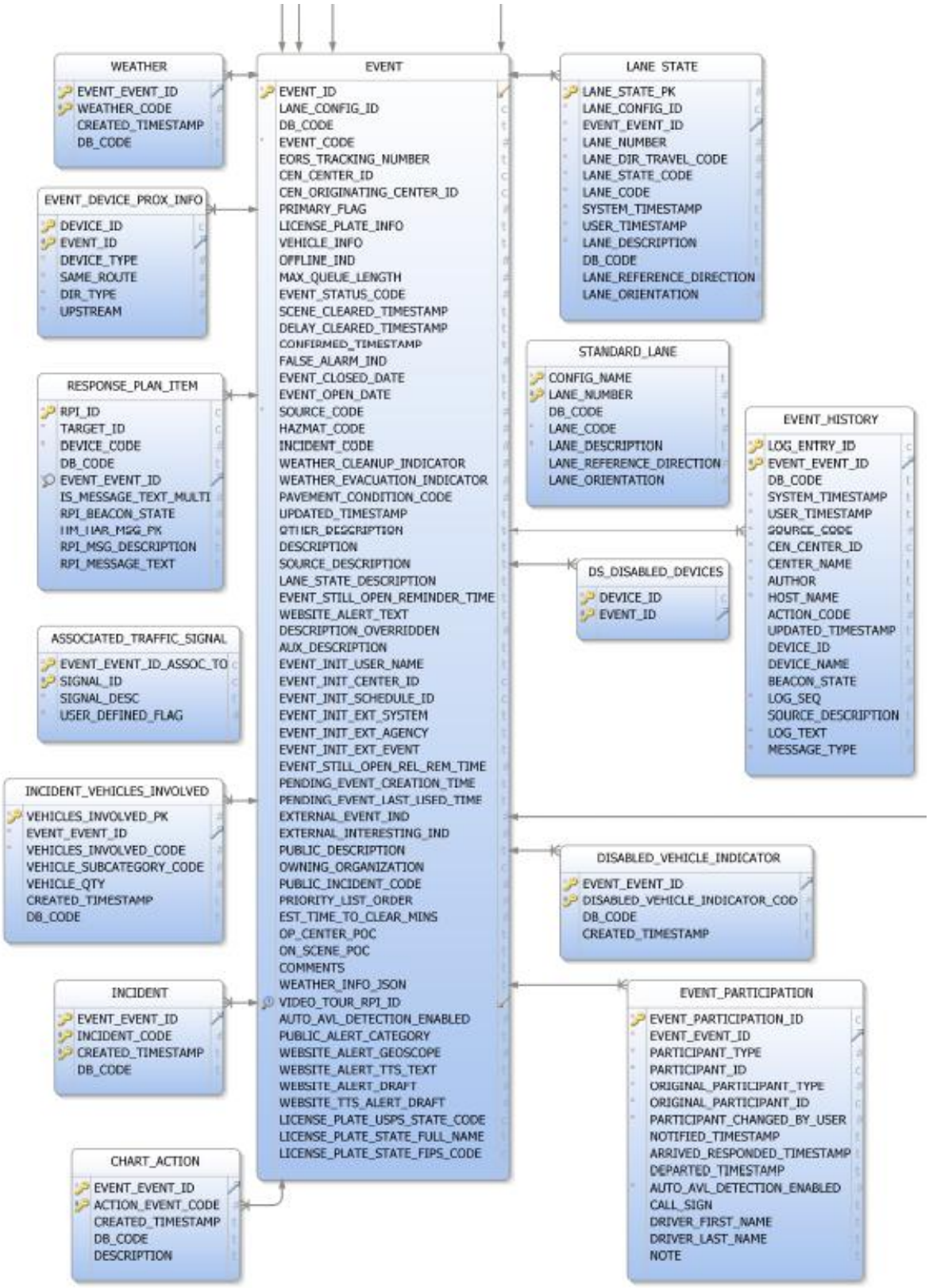

Figure C-12. Entity Relationship Diagram 3-2

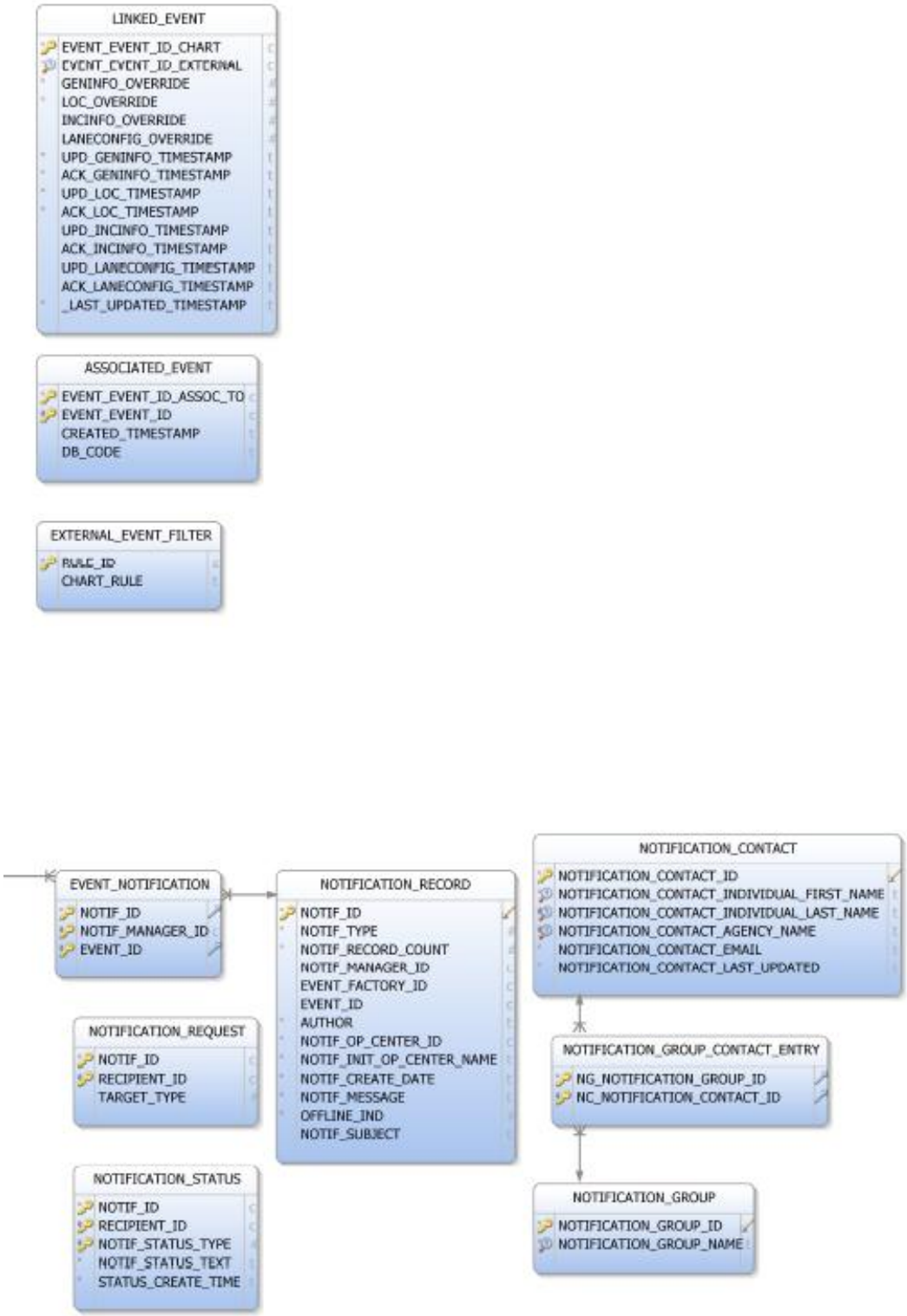

Figure C-13. Entity Relationship Diagram 3-3

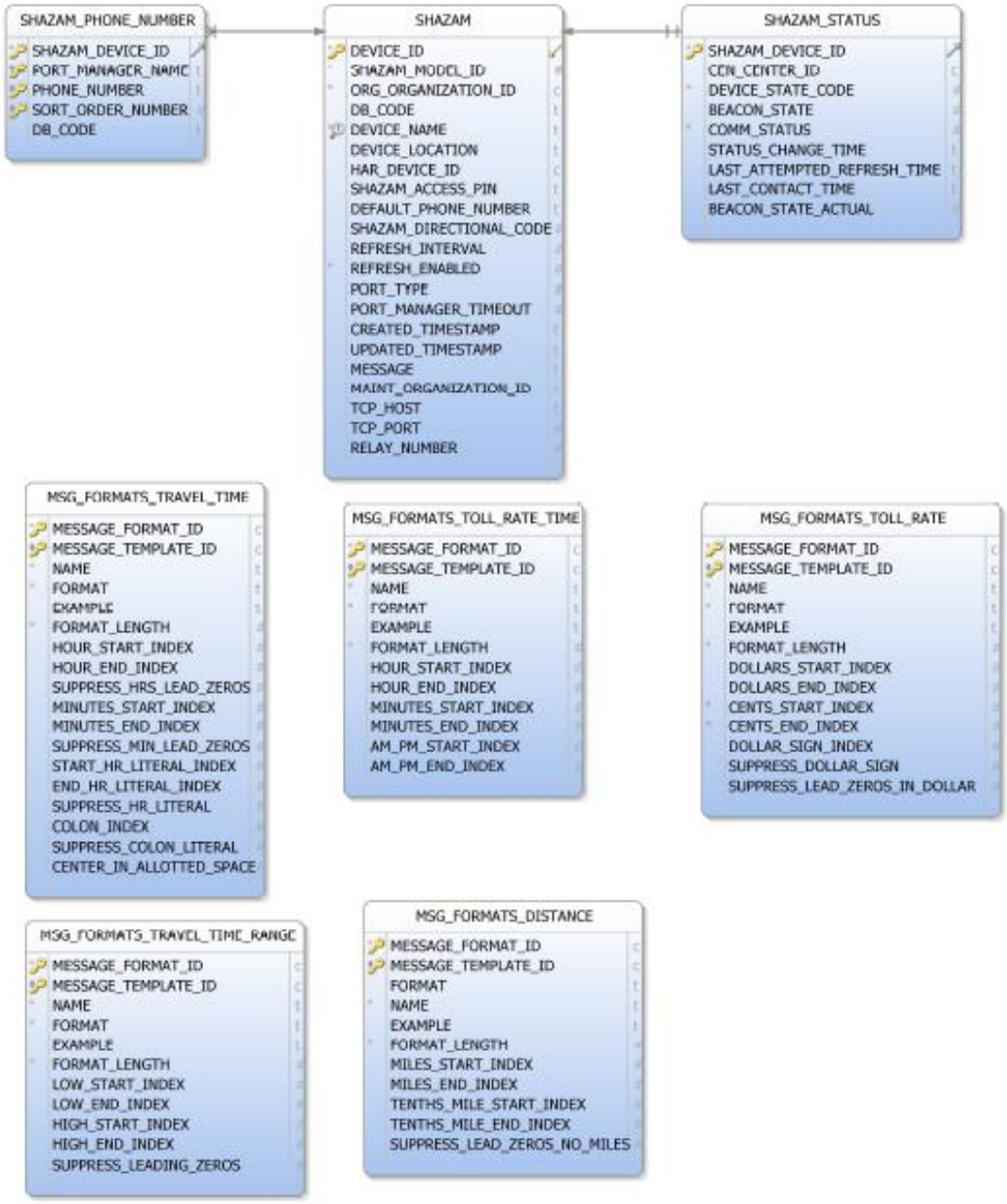

Figure C-14. Entity Relationship Diagram 3-4

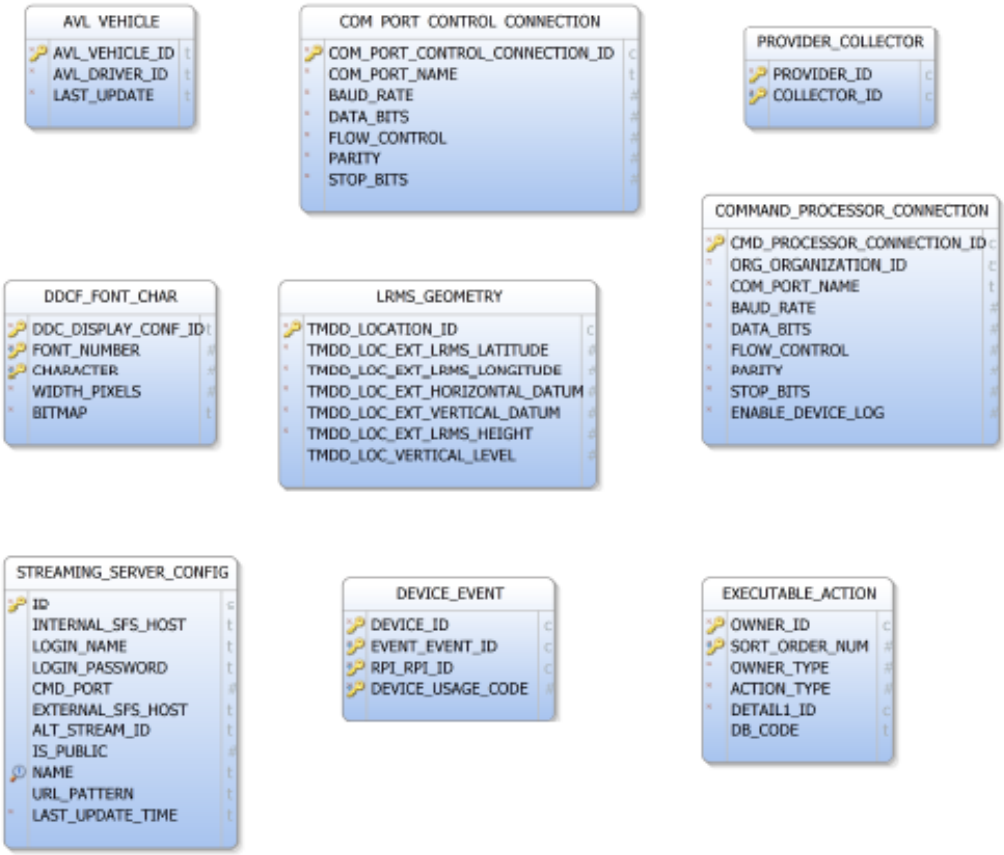

Figure C-15. Entity Relationship Diagram 3-5

D RELEASE HISTORY

The CHART system has been evolving over a long period of time. Release 1 provided the foundation on which future releases are based and was the first operational release. Subsequent releases have added additional functions prioritized by CHART operations needs. Hardware resources have been deployed in a phased manner to support each system release. A detailed schedule for each release broken down by release and build was provided in the original CHART System Development Schedule. A summary description of the system capabilities for each of the CHART releases is presented in the following sections.

D.1 CHART Release 1

Release 1 of the CHART ATMS consisted of four separate "builds" (R1B1, R1B2, R1B3, and R1B4). The final build, R1B4, was deployed June 13, 2003. Release 1 provided system administration, DMS, HAR, and basic traffic management support. The Release 1 software capabilities as they existed after the final build of Release 1 are listed in Table D-1. Release 1 was deployed with a dual server system in a local SAN located at the SOC. The text-to-speech conversion software was hosted on the backup server at the SOC and on an interim system located at the Greenbelt site. Multiple remote client systems (the "fat" Java GUI) were deployed as needed. Release 1 also included the deployment of a redesigned FMS server system. Figure D-1 shows the server configuration as it existed at the Hanover, Greenbelt, and Brooklandville sites at the end of Release 1. Since CCTV video distribution had not yet been integrated with the CHART system, the existing video distribution system (AVCM) servers remained as separate components. This diagram is a high level view of the system and is meant to impart the architecture concepts. In the interest of keeping the diagram readable, not every system component is shown.

Table D-1. CHART ATMS Release 1 Functions

CI	Subsystem	Function
Core Services	Audio Management	TTS conversion, audio management
	Communications Log Management	Communication Log
	Device Management	Device online/offline/maintenance mode, maintenance commands
	Dictionary Management	Approved words and banned words for DMS and HAR
	DMS Control	8 models of DMS including NTCIP
	HAR Control	ISS AP55 HAR
	HAR Notification	EIS RTMS SHAZAM
	Message Library Management	Libraries
	Plan Management	Plans
	Resource Management	User login, resource tracking
	System Monitor	Logging system actions

CI	Subsystem	Function
	Traffic Event Management	Manual incident data entry Operator selection of incident response actions EORS (initial interface) (EORS is now LCP)
	Traffic Sensor System Management	RTMS Support
	User Management	Roles and functional rights
	Utility	CHART Chat
GUI Services	GUI Management	Navigator GUI
FMS Services	Port Manager	ISDN, POTS, Telephony
	Protocol Handlers	DMS, HAR, SHAZAM, TSS
Database Instance	Operational DB	
Database Archive	Archive DB	Interim storage for archive data
	Query	Querying capability
	Report Generation	Reporting

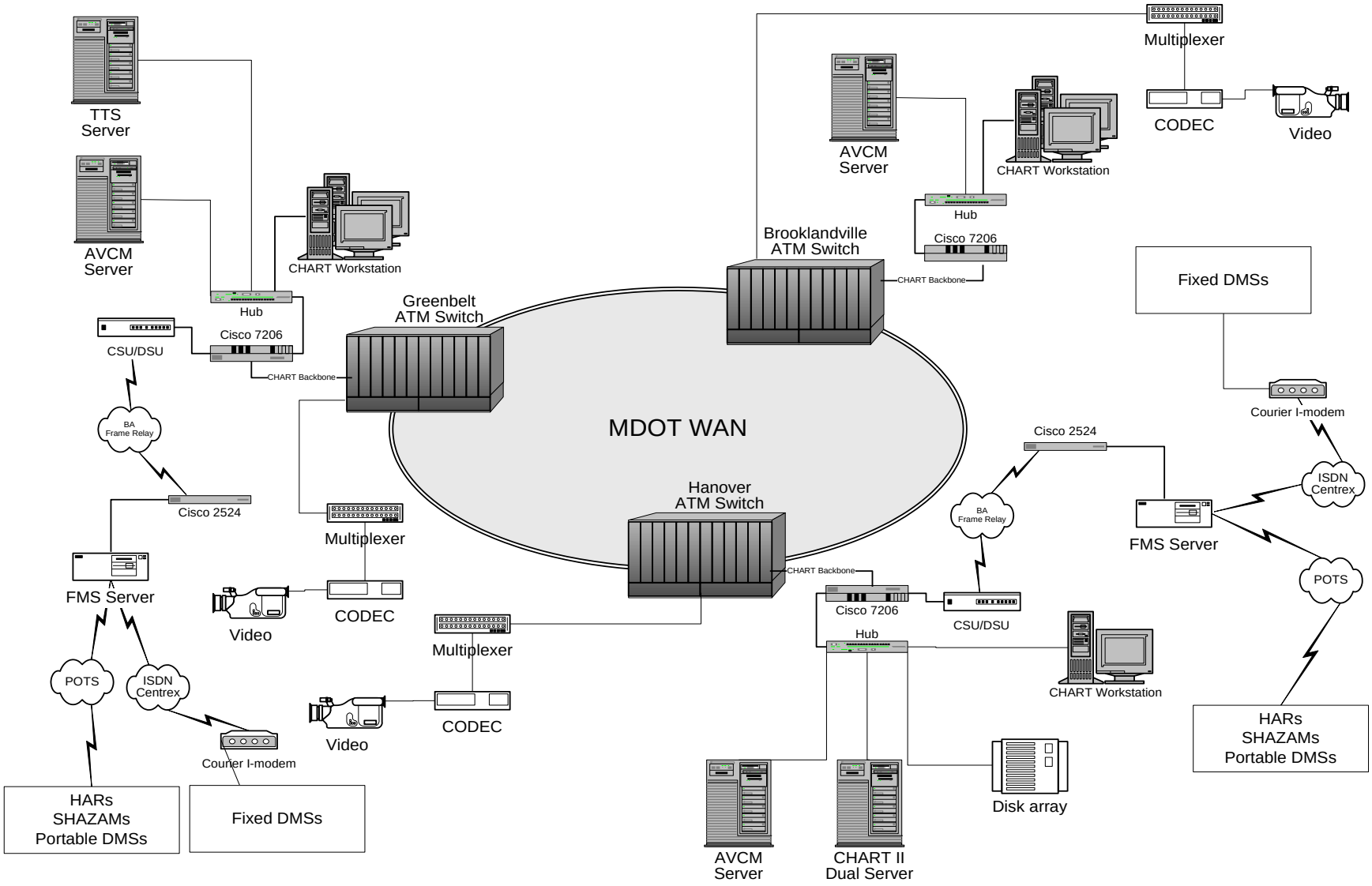

Figure D-1. CHART ATMS Release 1 Server Installations

D.2 CHART ATMS Release 2

Release 2 release consisted of three builds (R2B1, R2B2, and R2B3). The final build, R2B3, was deployed April 27, 2007. Release 2 provided video integration into CHART, un-federation of the CHART servers, disabling the "fat" Java-based CHART GUI, the addition of direct connect communications ports for low speed data communications, and support for a new CORBA ORB (JacORB). These changes are summarized in Table D-2. This release worked exclusively with the CHARTLite browser-based GUI. This release provided upgraded MDTA integration capabilities. Additionally, this release provided support for additional models of HARs for the CHART HAR subsystem. An updated CHART Reporting capability was released during this time period, however it was considered independent of CHART ATMS Release 2. Figure D-2 is a high level view of the system and is meant to impart the architecture concepts of this release. In the interest of keeping the diagram readable, every system component is not shown.

Table D-2. CHART ATMS Release 2 Functions

CI	Subsystem	Function
Core Services	Video Management	New Video Management subsystem added to support Camera Control; Camera Display on Monitors, including V1500 control and Video Router
	HAR Control	HIS DR 1500 HAR, synchronized HARs
GUI Services	GUI Management	Web based GUI replaces fat Java based "Navigator" GUI
FMS Services	Port Manager	Direct Port Communications
	Port Configuration Utility	
Database Instance	Operational DB	CHART operational data Detector data
Database Archive	Archive DB	
	Report Generation	Operational reports

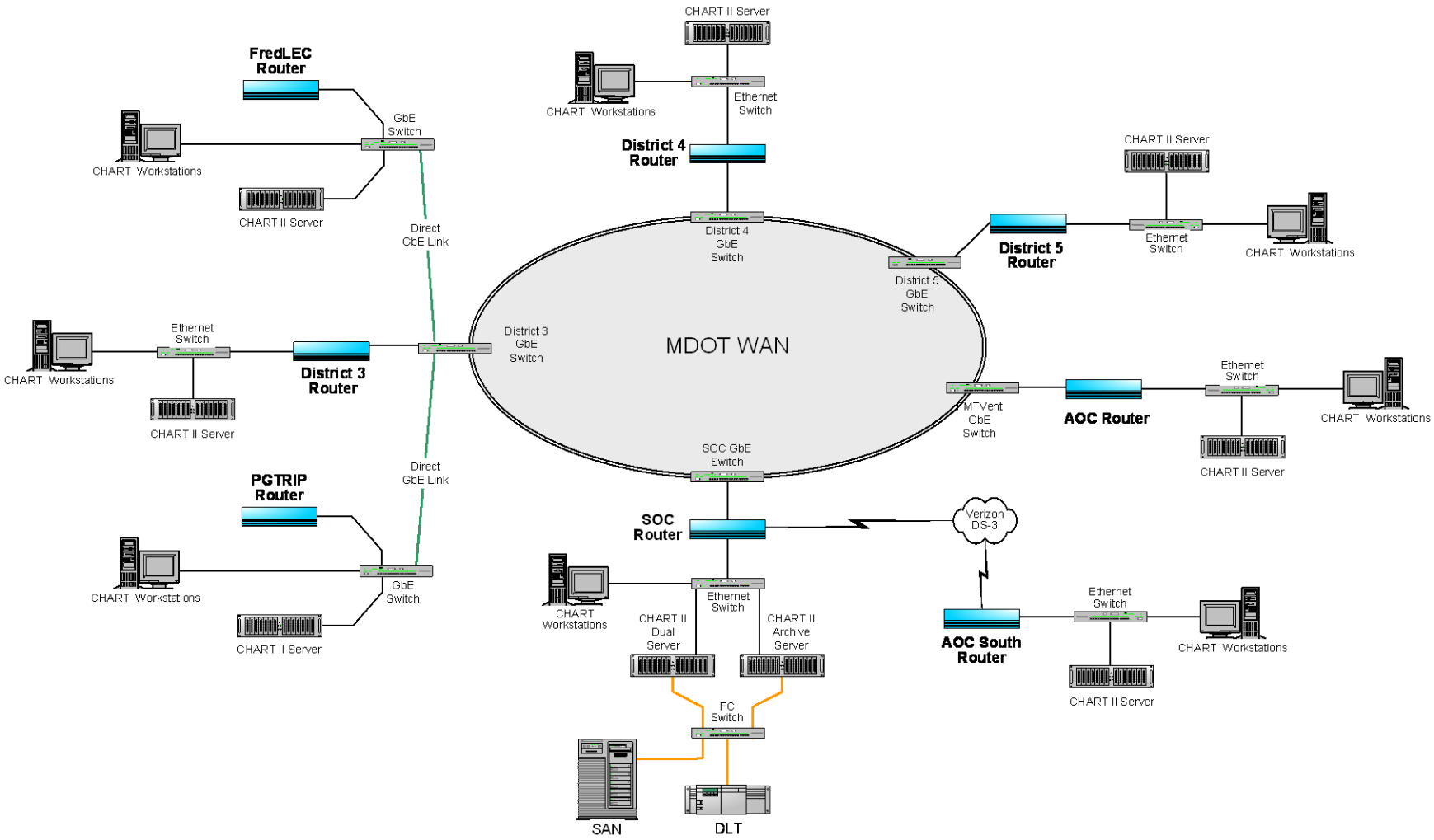

Figure D-2. CHART ATMS Release 2 Server Installations

D.3 CHART ATMS Release 3

Release 3 consisted of three builds (R3B1, R3B2, and R3B3) and was the last CHART ATMS release to be released in multiple builds. The final build, R3B3, was deployed December 8, 2009. Release 3 added a newly designed CHART GUI, alert support, schedule support, notification support, additional incident management capabilities, operational reports, data import capabilities from external systems, and support for automated Travel Times and Toll Rates on DMSs. It also provided support for a new type of HAR, the synchronized DR1500 HAR, and geo-location capabilities for all types of devices and for traffic events. It also continued to enhance the traffic management capabilities. This release updated the CHART Archive interface with general reporting and predefined query capabilities. These changes are summarized in Table D-3. Server installations are illustrated in Figure D-3.

Table D-3. CHART ATMS Release 3 Functions

CI	Subsystem	Function
Core Services	Alert Management	New Alert Management subsystem to create and process alerts, manage escalation rules
	Data Import Management	New Data Import Management subsystem to import data from RITIS, INRIX, Vector
	DMS Control	TCP/IP communications, automated Travel Times and Toll Rates
	HAR Control	HIS DR 1500 HAR
	Message Template Management	New Message Template Management subsystem to manage templates for travel time and toll rate messages
	Notification Management	New Notification Management subsystem to support email, texting via email, and paging via email
	Traffic Event Management	Advanced management Improved Lane graphic control Geo-location
	Traveler Information Management	Travel times and toll rates for display in GUI and on DMSs
	Traffic Sensor System Management	TCP/IP communications support
	User Management	Operations
	Utility	CHART Chat Map import Equipment inventory

CI	Subsystem	Function
	DMS Control, HAR Control, HAR Notification, Traffic Sensor System Management, Video Management	Geo-location of CHART devices

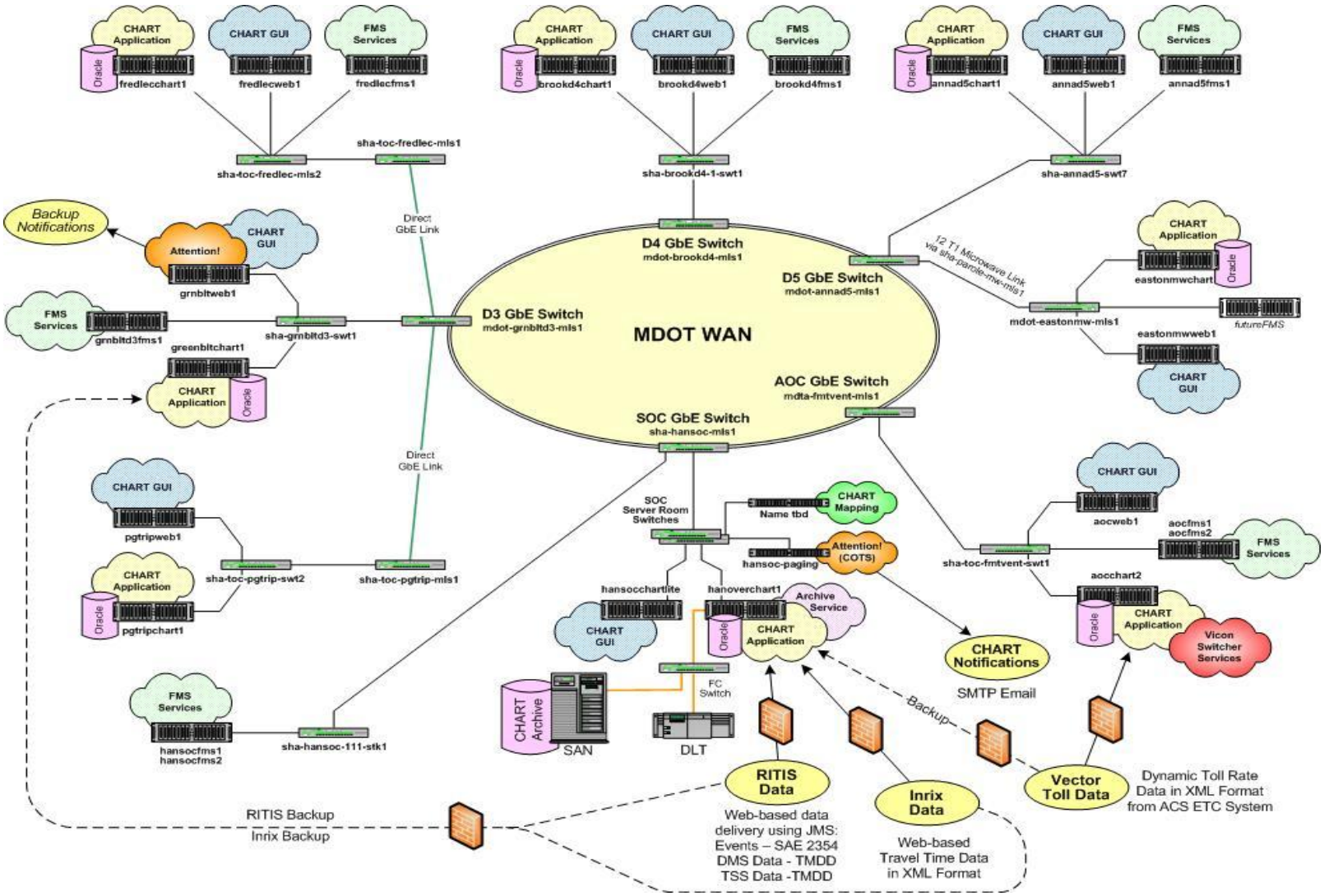

Figure D-3. CHART ATMS Release 3 Server Installations

D.4 CHART ATMS Release 4

Release 4, deployed April 12, 2010, added the System Monitor subsystem, via a new service known as the Watchdog. This new service was (and still is) installed on every CHART ATMS server and FMS server and monitors the availability of each CHART ATMS service on the server where it is installed. A second Watchdog service on each server allows monitoring of the Watchdog services. The Watchdog provides the ability for alerts and notifications to be sent automatically when a service is detected to be failed, and provides for the ability to auto-restart services when failures are detected. Release 4 also added a new GUI portal known as the maintenance GUI, which provides a simplified view of the system tailored to device maintenance personnel for use via laptops, tablets, and smartphones in the field. Release 4 included updates to the NTCIP DMS model to support version 2 of the protocol and to add several status fields and features. Lastly, Release 4 added an updated version of the middleware used by all CHART ATMS services to address stability issues. These changes are summarized in Table D-4. There were no changes to the Server Installations for Release 4, so no illustration is provided. See CHART ATMS Release 3 Server Installations above.

Table D-4. CHART ATMS Release 4 Functions

CI	Subsystem	Function
Core Services	Alert Management	System Alert added.
	DMS Control	Updates to NTCIP DMS model to support version 2 and add functionality.
	System Monitor	Watchdog services added.
GUI Services	GUI Management	Device Maintenance Portal added.

D.5 CHART ATMS Release 5

Release 5, deployed October 19, 2010, added an integrated map, through which users are able to set and view the locations of CHART devices and traffic events on a map. Release 5 also added a Data Exporter feature – an interface into the CHART ATMS to allow external systems to receive DMS, TSS, Traffic Event, HAR, and SHAZAM configuration and status information from the CHART ATMS. Finally, CHART ATMS Release 5 provided some enhancements to video so that a camera can be configured with multiple video sending devices. These changes are summarized in Table D-5. Server installations are illustrated in Figure D-4.

Table D-5. CHART ATMS Release 5 Functions

CI	Subsystem	Function
Core Services	Data Export Management	New Data Export Management subsystem to export CHART data
	Video Management	Enhancements to Camera Display

CI	Subsystem	Function
	DMS Control, HAR Control, HAR Notification, Traffic Sensor System Management, Traffic Event Management	New Map Management subsystem and Core Services updates to support map integrated into the CHART ATMS
GUI Services	Map Management	

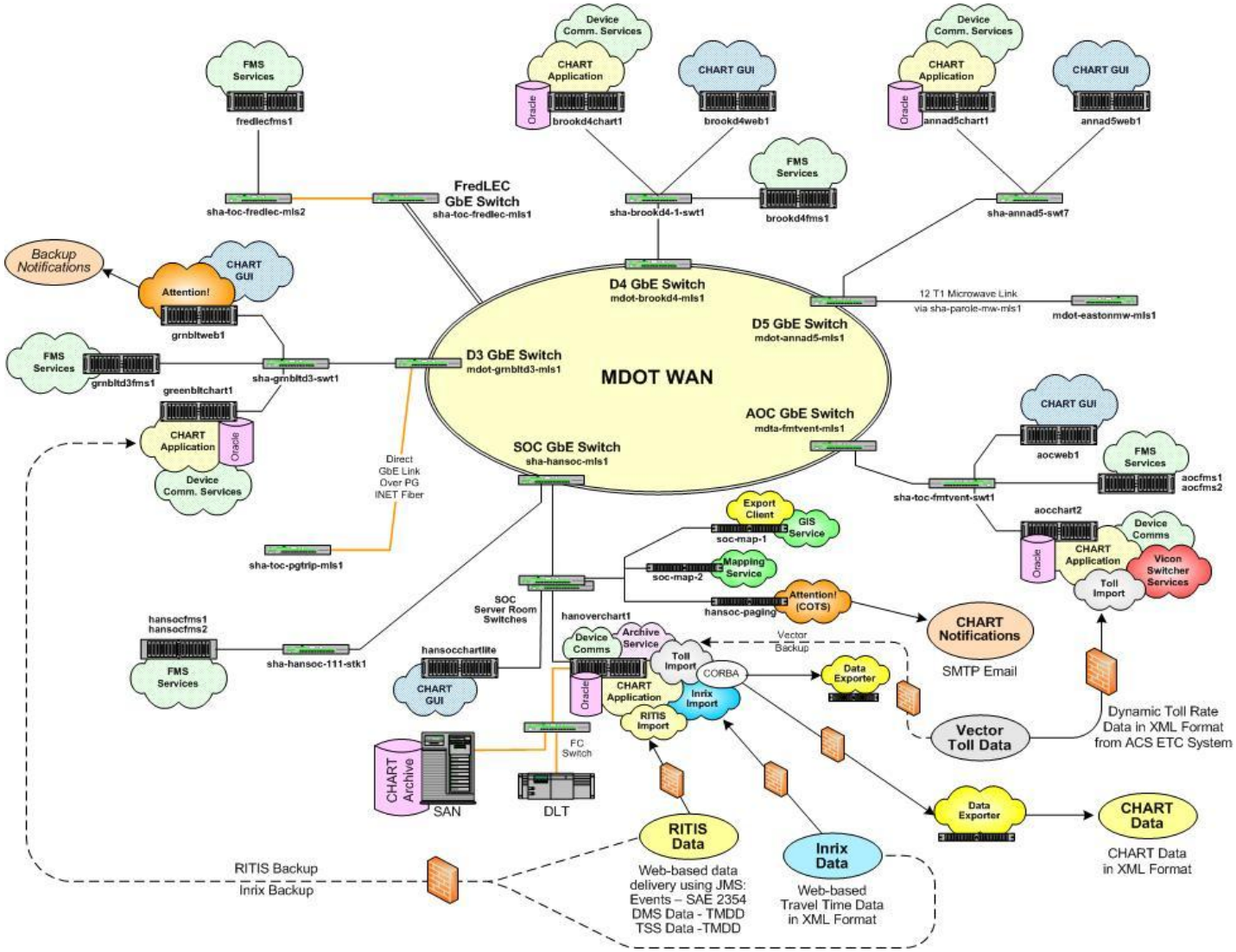

Figure D-4. CHART ATMS Release 5 Server Installations

D.6 CHART ATMS Release 6

Release 6, deployed February 24, 2011, added enhanced lane configuration capability, including suggested lane configurations based on the location of a traffic event and the ability for the user to edit and create lane configurations. Release 6 also added the ability to specify event locations as being between two features or spanning a length of roadway from one location to another location. Another enhancement made it easier for users to associate CHART planned closure events with a lane closure permit. External detectors (received via RITIS rather than native to the CHART ATMS) are exported from the CHART ATMS and can be displayed on the CHART Mapping maps. As of Release 6, camera configuration data is now centralized in the CHART ATMS (rather than requiring additional configuration within CHART Mapping). These changes are summarized in Table D-6. Server installations are illustrated in Figure D-5.

Table D-6. CHART ATMS Release 6 Functions

CI	Subsystem	Function
Core Services	Data Export Management	Updated to export event "between" and "from/to" locations, CCTV configuration information, and "external" TSS status and configuration information..
	Data Import Management	Import of NavTeq detectors
	Device Management	Import of NavTeq detectors, centralized camera configuration data.
	Traffic Event Management	Enhanced lane configuration
	User Management	New user manager web service to allow CHART Map to authenticate CHART users for access to NavTeq data.
GUI Services	GUI Management	Enhanced lane configuration, event "between" and "from/to" locations, enhanced planned closure event to EORS (now LCP) permit association, centralized camera configuration data.

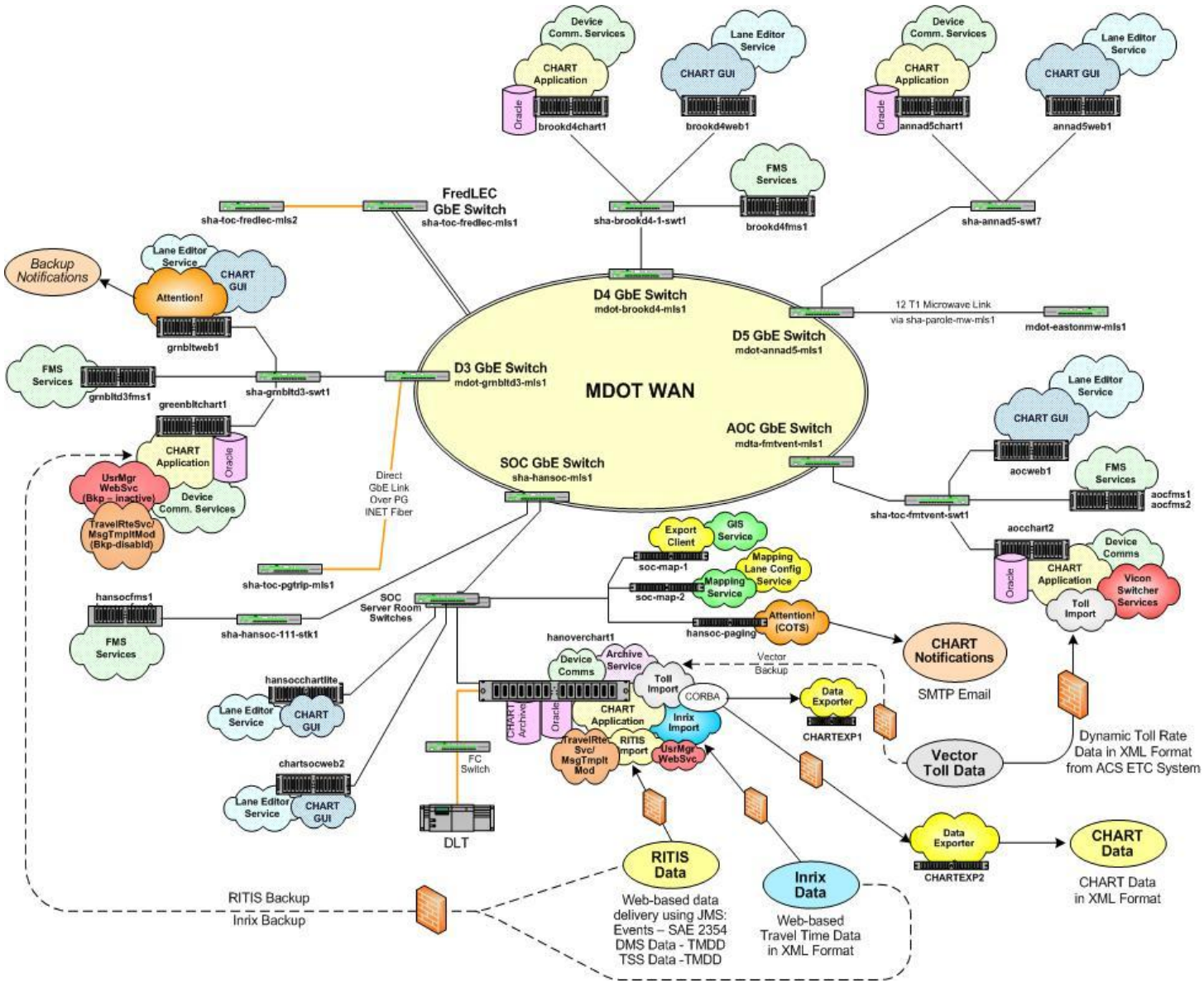

Figure D-5. CHART ATMS Release 6 Server Installations

D.7 CHART ATMS Release 7

Release 7, deployed August 17, 2011, added camera control based on the National Transportation Communications for ITS Protocol (NTCIP) for CCTV cameras, importation of SCAN weather data into CHART, an enhancement to CHART Mapping to display TSS icons showing the directional orientation of the detectors, and a redesigned method for generating the Shift Hand-Off Reports utilizing WordPress. These changes are summarized in Table D-7. Server installations are illustrated in Figure D-6.

Table D-7. CHART ATMS Release 7 Functions

CI	Subsystem	Function
Core Services	Device Management	Added NTCIP-compliant CCTV camera control
	Traffic Event Management	Import of SCAN weather data into Traffic Events
	Utility	Shift Hand-Off Report generation re-hosted to WordPress
	Data Export Management	Added directionally-orientated TSS icons on the CHART Map and exports the orientation data
GUI Services	Map Management	

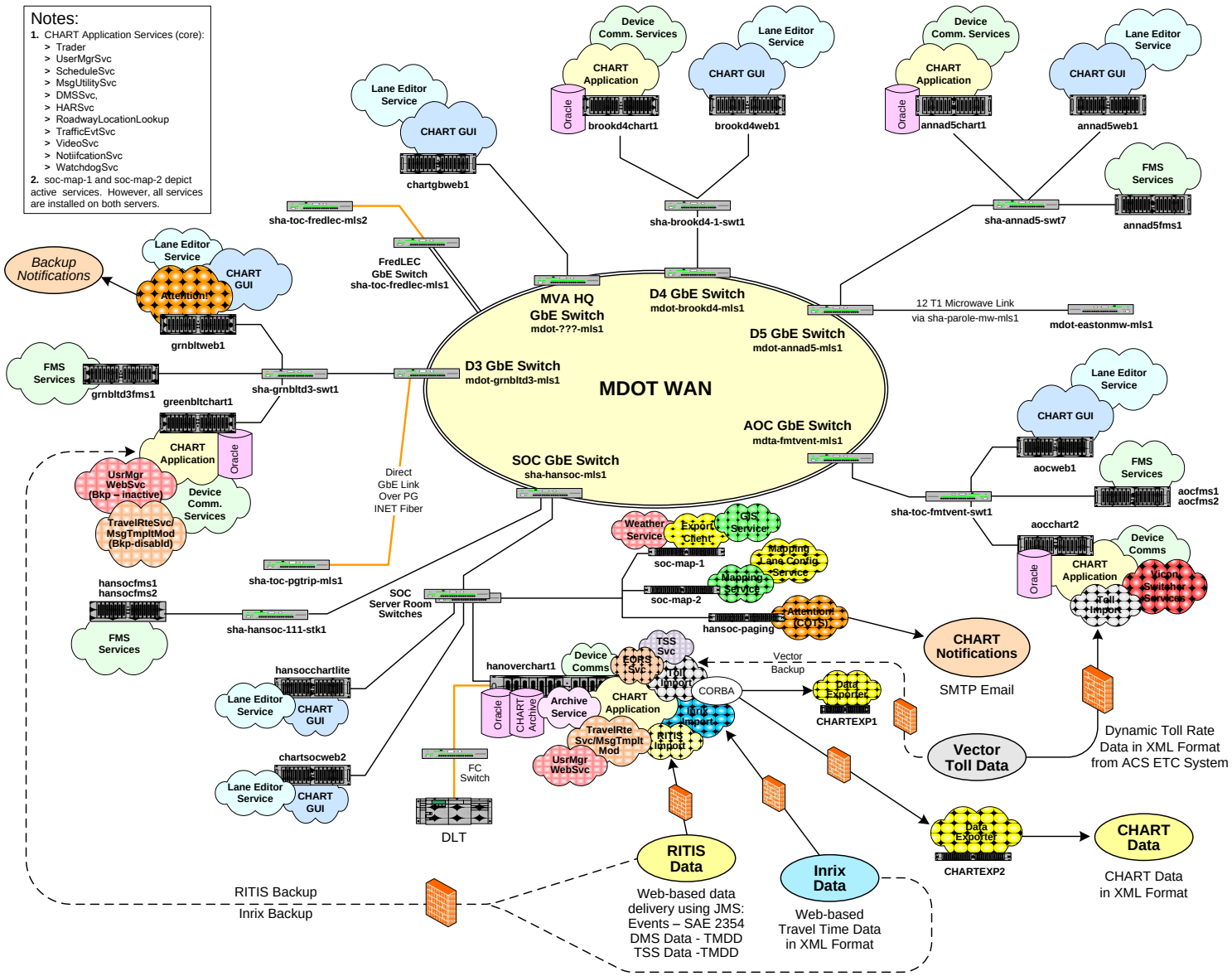

Figure D-6. CHART ATMS Release 7 Server Installations

D.8 CHART ATMS Release 8

Release 8, deployed November 1, 2011, and added TCP/IP-based control for the HIS DR1500 HAR and TCP/IP-based control for SHAZAM signs using HWG-ER02a IP relay switches. Additionally, while originally planned for incorporation in Release 9, Release 8 also included the protocol handler for the new EIS G4 speed sensors. These changes are summarized in Table D-8. CHART's server environment had been recently virtualized, and Release 8 was deployed into this new virtualized server environment (summer of 2011) as illustrated in Figure D-7.

Table D-8. CHART ATMS Release 8 Functions

CI	Subsystem	Function
Core Services	HARControl	Support for TCP/IP HAR
	HAR Notification	Support for TCP/IP relay switch to control SHAZAMs
	TSS Control	Support for EIS G4 RTMS, multi-drop communications

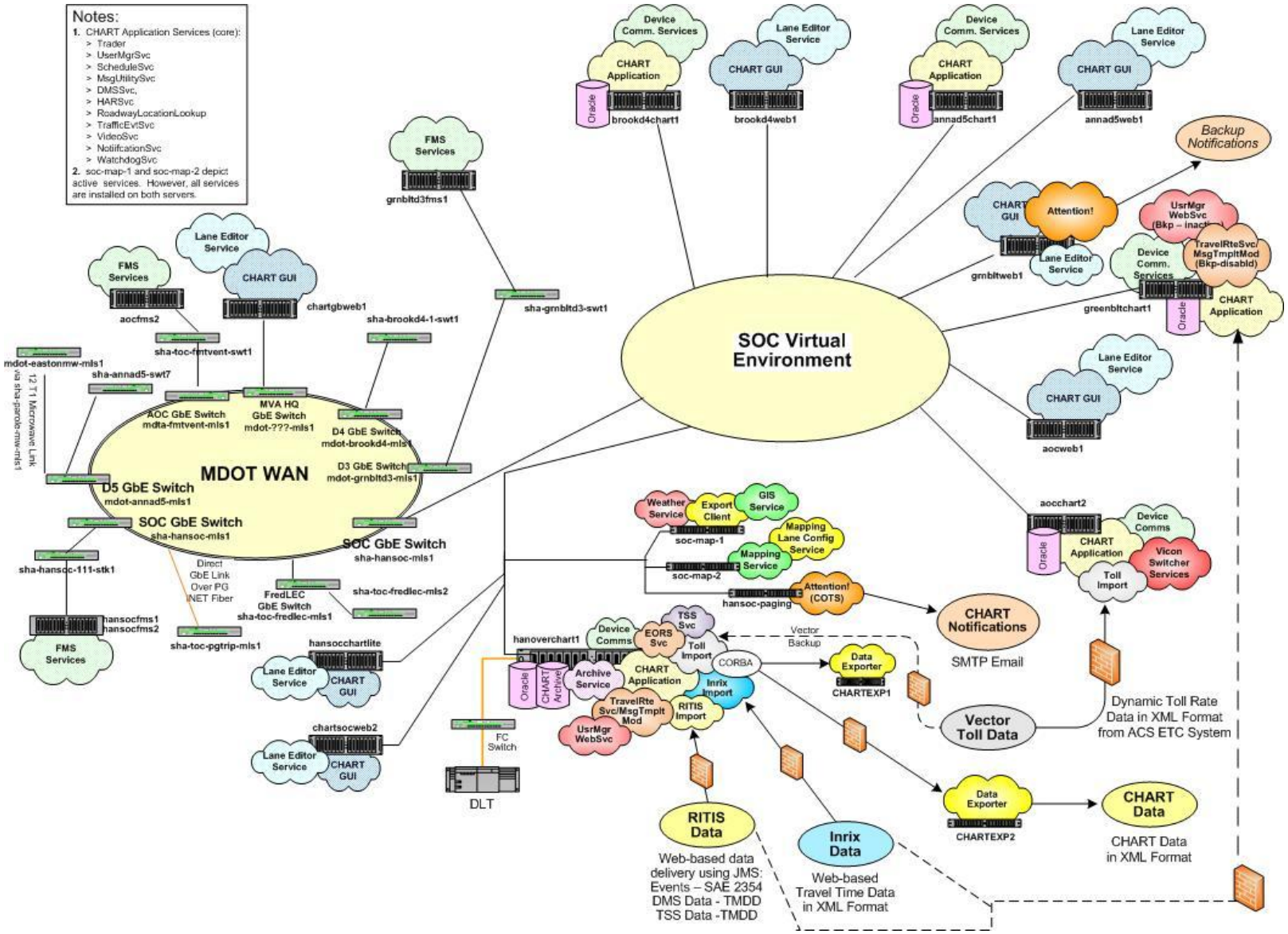

Figure D-7. CHART ATMS Release 8 Server Installations

D.9 CHART ATMS Release 9

Release 9, deployed March 13, 2012, and added decision support capabilities to suggest device messages and appropriate DMS based on conditions in a traffic event. Additional decision support capabilities include suggesting appropriate cameras for display within the context of a traffic event. Release 9 also added the capability to display video within the CHART GUI. Release 9 also extended the capability to block flash video at the source (the Streaming Flash Server (SFS)), to block video at any SFS rather than at just the public SFS. These enhancements are summarized in Table D-9. There were no significant hardware/interface changes for Release 9. The Release 9 CHART virtualized server environment is illustrated in Figure D-8.

Table D-9. CHART ATMS Release 9 Functions

CI	Subsystem	Function
Core Services	DMS Control, Traffic Event Management	Decision support: suggest DMS usage and messages for traffic event
	Video Management, Traffic Event Management	Decision support: suggest cameras in the context of a traffic event
	Video Management	Flash video on desktop

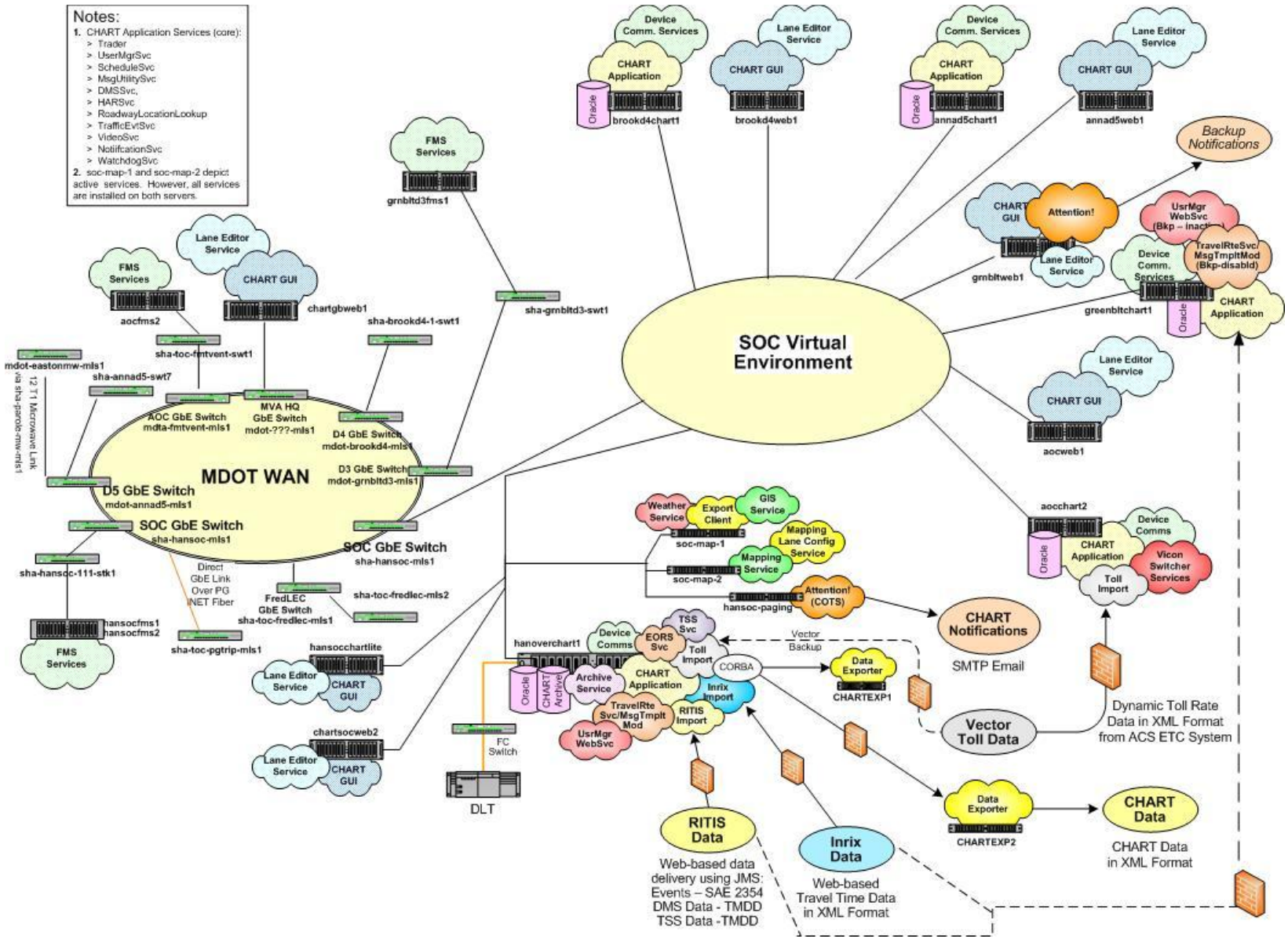

Figure D-8. CHART ATMS Release 9 Server Installations

D.10 CHART ATMS Release 9S

Release 9S, deployed September 19, 2012, consolidated CHART to a single node and included a database conversion. The node consolidation element reduced the amount of CHART server nodes from five to one, which will facilitate lower hardware, software, and network costs. The database element converted Oracle databases to Microsoft SQL Server in accordance with the strategic plan for CHART databases to realize reduced software licensing costs and to ensure vendor support for the database software. The databases were moved off of the application server and onto a separate database server. These changes are summarized in Table D-10. The corresponding application changes required for the database conversion were included in the conversion work. The Release 9S server environment is illustrated in Figure D-9.

Table D-10. CHART ATMS Release 9S Functions

CI	Subsystem	Function
Core Services	Device Management	Moved arbitration queue to database
CHART Database	Operational DB	Live database converted to MS SQL Server
CHART Archive	Archive DB Query, (Support for) Report Generation, Replication	Archive database converted to MS SQL Server Live and archive databases replicated to UMD for query and report generation

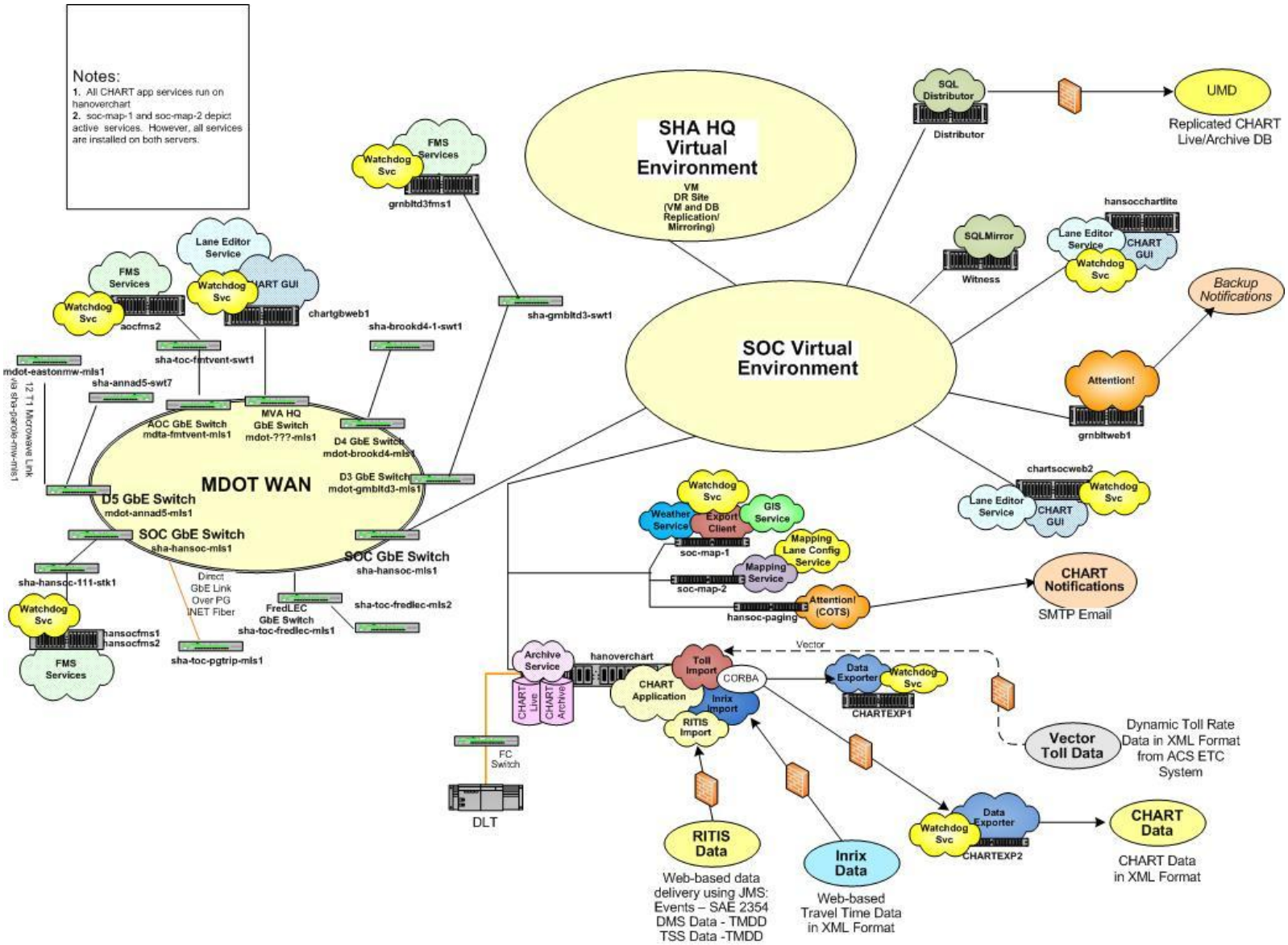

Figure D-9. CHART ATMS Release 9S Server Installations

D.11 CHART ATMS Release 10

Release 10 added additional decision support capabilities, to include adding cameras to a response plan item, which, when executed, cycle in a tour on monitors associated with the location of the traffic event. Release 10 provided control of NTCIP DMS fonts, including the ability to upload and download (but not design) custom fonts, and display DMS messages in the DMS's font in true WYSIWYG style. Release 10 also reprogrammed the notification system to manage notification recipients (individuals/agencies and groups) internally within CHART itself, and to send emails directly from CHART (eliminating the Attention!NS COTS notification management system). Also, cameras were modified to reject tour-directed moves to preset faster than a minimum dwell time, in order to conserve PTZ motors. These enhancements are summarized in Table D-11. The only hardware/interface change for Release 10 is the elimination of the paging servers hansoc-paging and grnbltweb1. The Release 10 CHART virtualized server environment is illustrated in Figure D-10.

Table D-11. CHART ATMS Release 10 Functions

CI	Subsystem	Function
Core Services	Traffic Event Management, Camera Control, Video Monitor Management	Decision support: include suggested cameras in traffic event response plan; Cameras form temporary tour for traffic event, auto-mode monitors in area of responsibility show temporary traffic event video tour
	DMS Control	Upload/Download fonts in DMSs; Display true WYSIWYG DMS Messages
	Notification Management	Manage contacts and groups directly within CHART

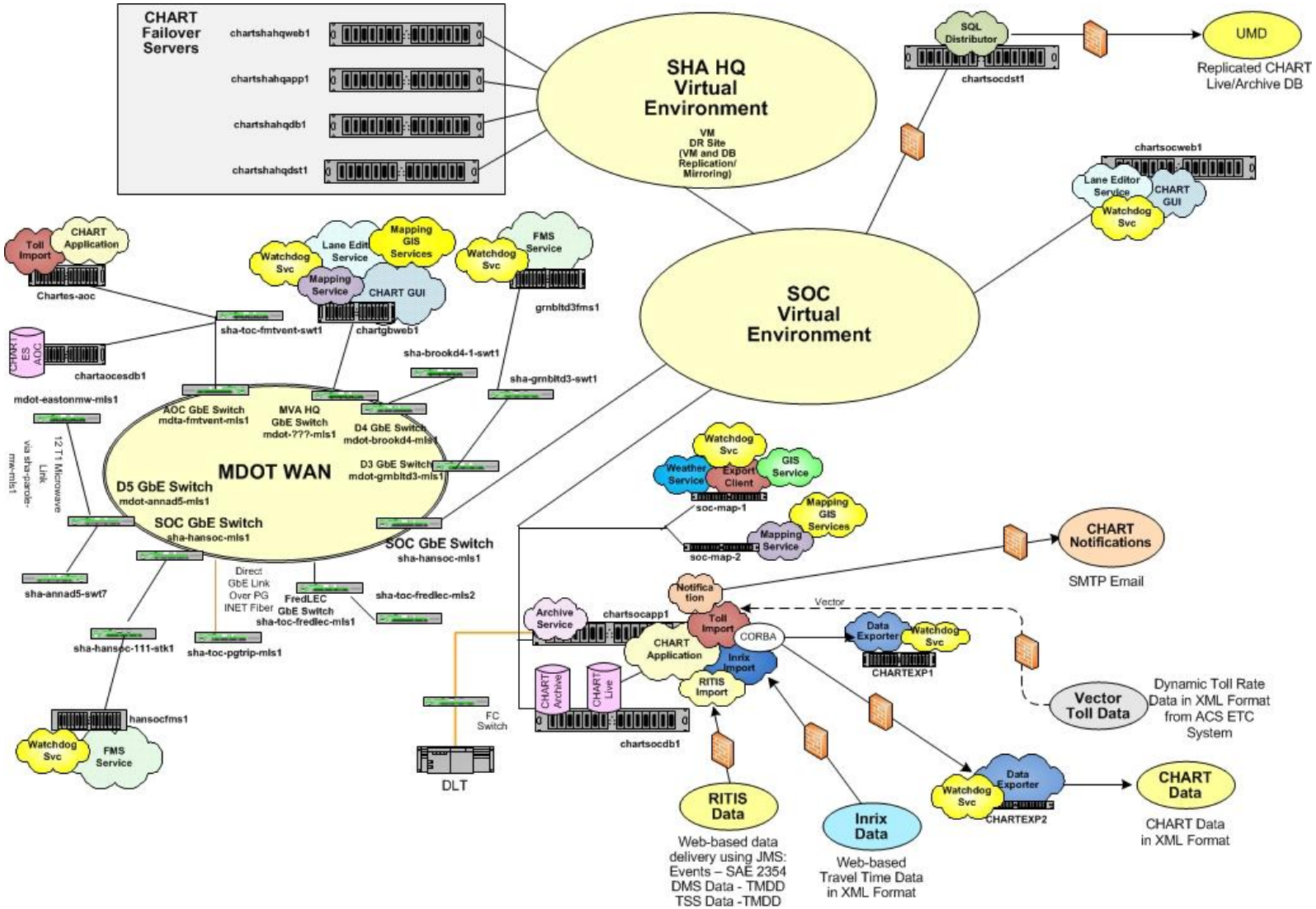

Figure D-10. CHART ATMS Release 10 Server Installations

D.12 CHART ATMS Release 10C

Release 10C upgraded some of the COTS used by the CHART ATMS. There was no new functionality provided with CHART R10C, it was strictly an architecture refresh. The COTS upgrade included an upgrade from Windows 2003 Server to the Windows 2008 Server operating system and compiler upgrades. The Release 10C server environment is illustrated in Figure D-11.

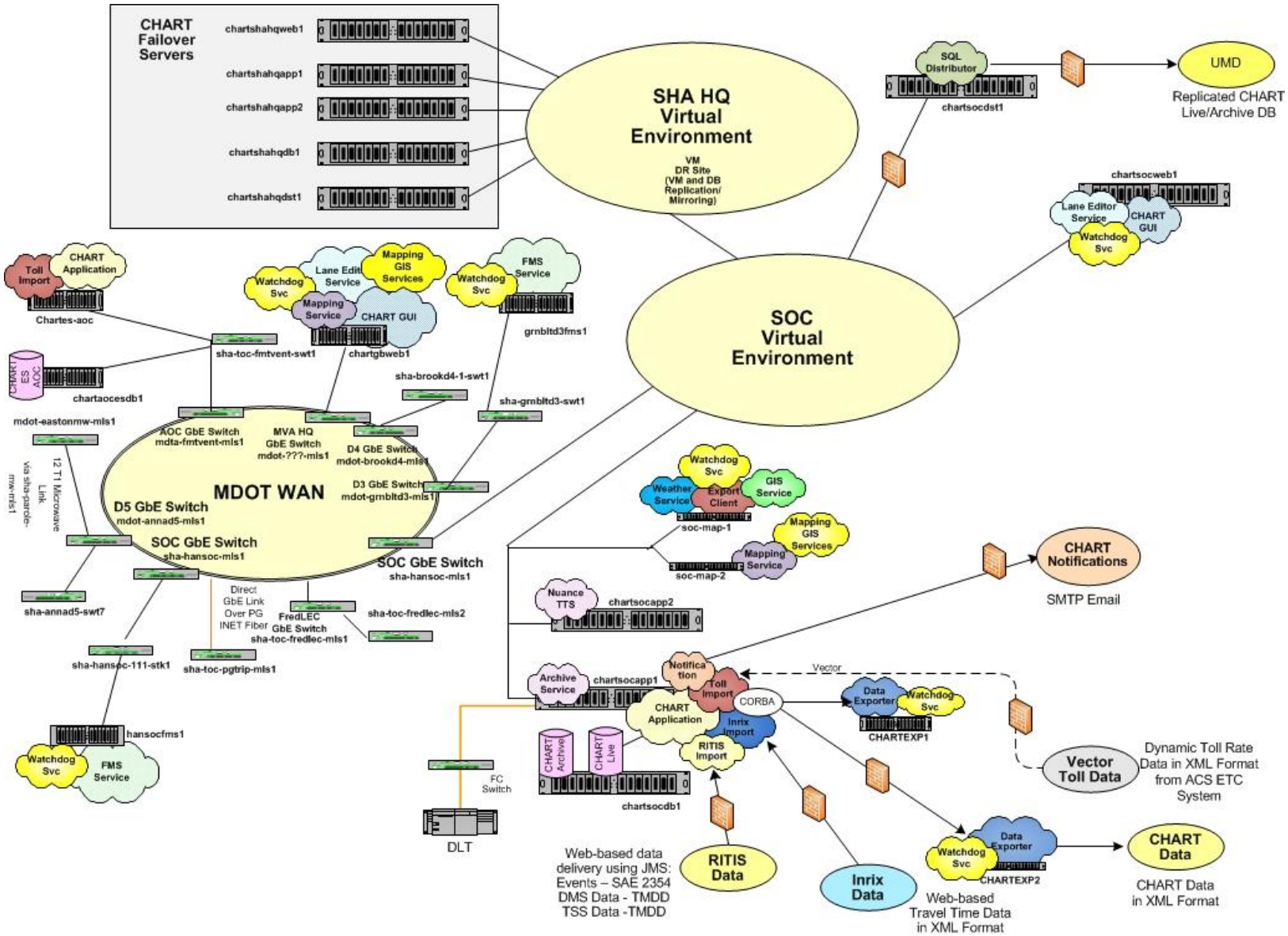

Figure D-11. CHART ATMS Release 10C Server Installations

D.12 CHART ATMS Release 11

Release 11 added several improvements related to traffic event processing in the CHART ATMS. Release 11 brought decision support capabilities to HARs, so the CHART ATMS now suggests HARs and messages for HARs in response to traffic events. Release 11 also added AVL processing to the CHART ATMS directly, which aids in marking participant involvement in traffic events, including automatic marking of arrival times and departure times. With Release 11 the CHART ATMS now has direct access to the "Signal Book" database of traffic signals in the state, allowing users to select and associate traffic signals to action events. Finally, Release 11 also brought improvements in notification text automatically generated from traffic events. These enhancements are summarized in Table D-12. The Release 11 CHART virtualized server environment is illustrated in Figure D-12.

Table D-12. CHART ATMS Release 11 Functions

CI	Subsystem	Function
Core Services	Decision Support, Traffic Event Management	Decision support: suggest HARs and HAR messages for use in traffic events
	AVL Management, Traffic Event Management	New AVL Management subsystem added to facilitate use of participants in traffic events
	Signals Management, Traffic Event Management	New Signals Management subsystem added to allow association of traffic signals to action events
	Notification Management	Enhancements to notification text generated from traffic event details

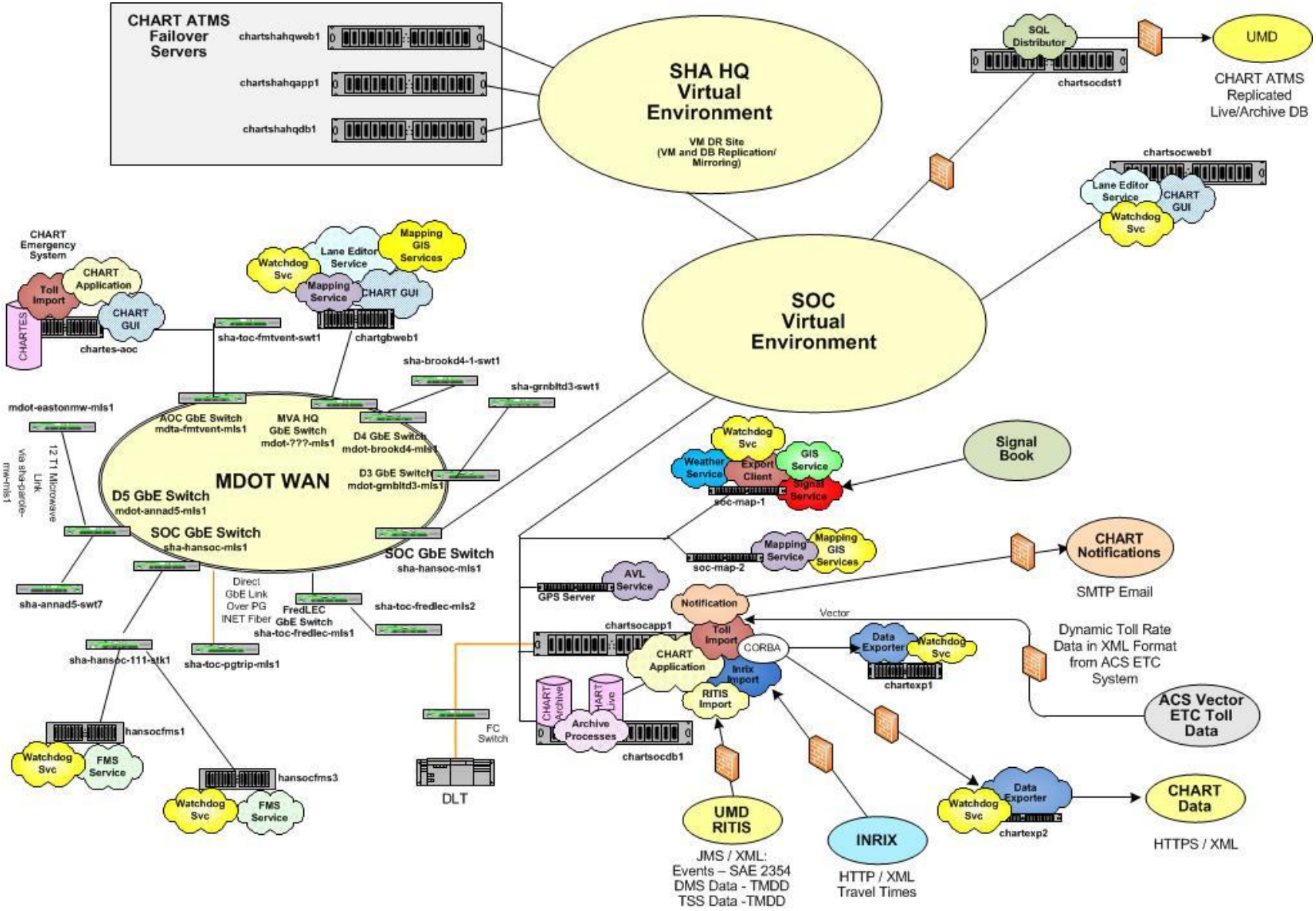

Figure D-12. CHART ATMS Release 11 Server Installations

D.13 CHART ATMS Release 12

Release 12 added several travel time improvements, including the ability to designate travel time specific traveler information messages as pertaining to certain days of the week,and/or holidays or non-holidays and the ability to enable multiple travel time messages simultaneously (the system selecting the most appropriate message to enable based on day of week, holiday/non-holiday status, and priority). Release 12 also brought the ability to enable or disable travel time messages system-wide, on a per-organization basis, and added support for collecting travel time data from a second provider, specifically an MDTA-sponsored provider (conforming to the INRIX interface) for soon-to-be opened HOT lanes north of Baltimore. One more travel time improvement was a travel time summary page providing details on all DMSs with at least one travel time message configured. CHART ATMS R12 also provides better RITIS integration to make better use of traffic events from CAD / 911 call centers, allowing ATMS operators to "link" a CHART event to an external event, with the linked CHART event selectively updating automatically based on changes to the external event. CHART ATMS R12 integrated better with MD511, allowing CHART operators to define event public alert categories and to configure "floodgate" messages for MD511, with separate texts for textual display and for text-to-speech audio for telephone callers. Decision Support was enhanced to use network routing ("driving directions") to help locate roadside devices (DMSs, HARs, cameras) upstream from a traffic event but not necessarily on the same primary route as the event. Finally R12 provided support for new H.264-capable video CODECs developed by Impath, allowing for a new H.264 video fabric. These enhancements are summarized in Table D-13. The Release 11 CHART virtualized server environment is illustrated in Figure D-13.

Table D-13. CHART ATMS Release 12 Functions

CI	Subsystem	Function
Core Services	Traveler Information Management	Multiple enabled travel time messages per DMS; system-wide control of travel time messages; travel times from MDTA
	Data Import Management, Traffic Event Management	Support for "linked" CHART events that can selectively update automatically based on chances to their linked external event
	Decision Support, Traffic Event Management	Decision support: suggest upstream DMSs, HARs, and cameras not on a traffic event's primary route, based on network routing (driving directions)
	Data Export Management, Traffic Event Management	Support for MD511 "floodgate" messages and event public alert categories
	Camera Control, Video Monitor Management	Support for Impath H.264-capable encoders and decoders

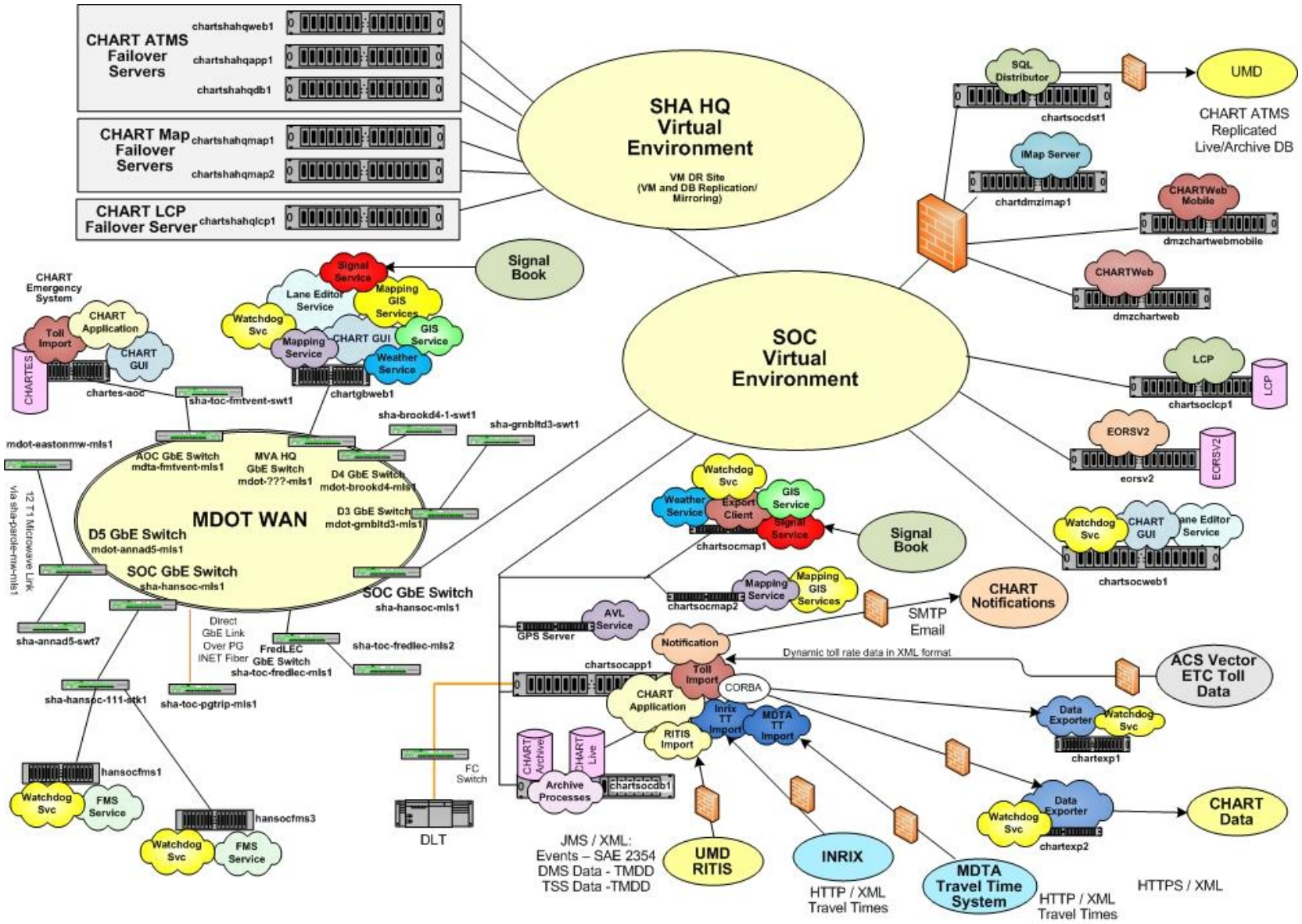

Figure D-13. CHART ATMS Release 12 Server Installations