Appendix D:

Crescent Computer System Components

Evaluation Report .

by

Booz-Allen & Hamilton Inc.

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The Crescent Evaluation

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Forward

The Crescent Project element of the HELP Program is a bi-national multi-jurisdictional cooperative research and demonstration initiative involving the public and private sectors in an application of advanced technologies for the creation of an integrated heavy vehicle management system. This initiative is a leading example of the commercial vehicle operations (CVO) aspect of the Intelligent Vehicle Highway Systems (IVHS) concept. Some of the advanced technologies demonstrated in this project include: (1) automatic vehicle identification (AVI); (2) weigh-in-motion (WIM); (3) automatic vehicle classification (AVC); and (4) data communications networks and systems integration.

The HELP program, initiated in the early 1980s, consisted of three phases which included assessing the feasibility of the concept, technical studies involving laboratory and field tests, and lastly, a demonstration phase. Perhaps the most significant activity of this project centered on the subject of institutional arrangements, associated with the integration of emerging technologies with current operational policies and practices, within both government and industry sectors.

The demonstration element of the program, referred to as the Crescent Demonstration Project, began in 1991 and involved six U.S. states and one Canadian province. This project was phased into full scale operation over a three year period.

This document is one of several cited below which comprise the evaluation of the Crescent Project The complete evaluation is reported in the following list of documents:

The Crescent Project: An Evaluation of an Element of the HEW, Program: Executive Summary

Appendices:

A. On-Site Analysis of HELP Technologies and Operations Evaluation Report

B. State Case Study Evaluation Report

c. Motor Carrier Case Study Evaluation Report

D. Crescent Computer System Components Evaluation Report

E. Crescent Demonstration Office Evaluation Report

F. State Line Beacon Project User Case Studies

The Evaluation team consisted of the following groups:

WHM Transportation Engineering Consultants, Inc. (lead group)
Castle Rock Consultants
Western Highway Institute, ATA Foundation

In addition, the evaluation team was supported in this effort by:

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The team members wish to acknowledge the participation and support of the many individuals and organizations who provided guidance, assistance and encouragement during the evaluation process. While the team members are solely responsible for the content accuracy of these evaluation documents, the process would have been greatly impaired without the recognition of the importance of this effort by all who contributed and their desire to promote efficiency and productivity in future freight systems. To all we are greatly appreciative and indebted.

C. Michael Walton

Chairman, Evaluation Team

CHAPTER 1. GENERAL BACKGROUND

INTRODUCTION

In 1990, Lockheed Integrated Systems Company (LISC) was awarded a contract under the Crescent Demonstration Project, to demonstrate the integration of Weigh-in-Motion (WIM), Automatic Vehicle Classification (AVC) and Automatic Vehicle Identification (AVI) technologies This award represented the beginning of the demonstration phase of the Heavy Vehicle Electronic License Plate (HELP) Program involving fifteen states, one port authority, and trucking industry representatives.

Starting as a research and demonstration project some four years earlier, the HELP Program sought to examine the future for improvements in heavy vehicle management technology and the cooperative efforts necessary among public and private sector stakeholders to make the application of the technology a reality. These first four years concentrated on research, development, and testing of the technologies then available for collecting truck data - primarily WIM and AVC equipment. After achieving some success in applying these technologies, especially in Oregon, a demonstration project was conceived among six states -- Washington, Oregon, California, New Mexico, Arizona and Texas -- to integrate these technologies, develop an AVI capability, and link them together by a computerized communications system and data base to be provided by a contractor. Thus began the Crescent Demonstration Project.

LISC developed a system architecture, based on the RFP requirements and implemented this system in 1992. This system continues in operation today, processing some 500,000 transactions per week, on average.

In September, 1992, at the request of the Federal Highway Administration (FHWA), the Crescent team prepared a plan to evaluate the Crescent Demonstration Project prior to September 30, 1993 – the end of the Federal project providing some funding to the effort The plan includes:

- the evaluation of the WIM, AVC and AVI equipment being used,
- an evaluation of the Crescent Demonstration Office (CDO) functions from the users (trucking company, states) perspective,
- an evaluation of state and motor carrier company usage of the system, and
- an evaluation of the Crescent computer system components.

The plan assumed that certain activities, including purchase and installation of equipment (involving highway construction activities by participating states) would be completed in accordance with a timetable agreed to by the stakeholders. This schedule would permit appropriate data collection and analysis to take place as part of the evaluation. In fact, the schedule proved to be very ambitious -- many of the schedules were not met. The result is a system which is only now beginning to take on shape as an "operational system". To become operational, several additional activities must be completed. Although the FHWA views the proposed evaluation to be that of an Operational Test of the Crescent System, in reality, it is more a review of the current status of the system, its components, and the lessons learned. From the Crescent Computerized System standpoint, the system as designed is nearly operational and many lessons learned can be derived from the experience. A few changes will likely be required in order to consider the system ready for a true "Operational Test", as envisioned by the FHWA.

The remainder of this section outlines the System Objectives as envisioned in the RFP and LISC's proposal. It will provide background and set the stage for the assessment of the six areas set out in the September Crescent Evaluation Plan:

- Systems Architecture
- Systems Communication
- Applications Software
- Crescent Database
- Site Availability
- Data Reconciliation

SYSTEM OBJECTIVES

There were four high level system objectives as outlined in the RFP and the LISC Proposal:

- Data collection for highway planning,
- Data to aid enforcement,
- Pre-clear and transparent border clearances of participating motor carriers, and
- One-stop credential and permit processing for participating states and motor carriers.

Data Collection for Highway Planning

Using WIM equipment, the system was to obtain vehicle weights from each site. AVC equipment was to provide classification data -- numbers and types of trucks. AVI equipment can provide information about origins and destinations, monitor hazardous materials movements and increase the efficiency of weigh station operations. The data from Crescent sites would provide data useful for transportation planning, traffic engineering, weight enforcement, pavement and bridge design and pavement management. The system was to collect this data from the appropriate equipment(s) and provide a means to store and retrieve it, as necessary, for use by states and motor carriers.

Data to Aid Enforcement.

The system was to provide a means to improve the efficiency of enforcement practices related to trucks. WIM provides a means to detect overloaded trucks (within tolerances). This information would be used at a weigh station to direct the truck to static scales where true weight and perhaps enforcement action could take place. WIM and AVC equipment can be used together to determine whether a truck is in compliance with axle weights and bridge formula laws designed to protect bridge infrastructure from potential unlawful damage. WIM, AVC and AVI can be used in combination to determine that a vehicles weight, dimensions, registration, safety inspection and permits are in order, or whether enforcement action is required.

Pre-clear and Transparent Border Clearances of Participating Motor Carriers

By using the above capabilities, participating vehicles can be "pre-cleared" or allowed to bypass weigh stations or to cross state lines without undue delay -- also known as "transparent borders". Weights, dimensions, registration, safety and permits can all be checked in real-time and time saved for the vehicle drivers and the enforcement personnel. The system was to assist in collecting and analyzing this information thus providing a means for implementing pre-clear and transparent border procedures for legal vehicles participating in the demonstration project

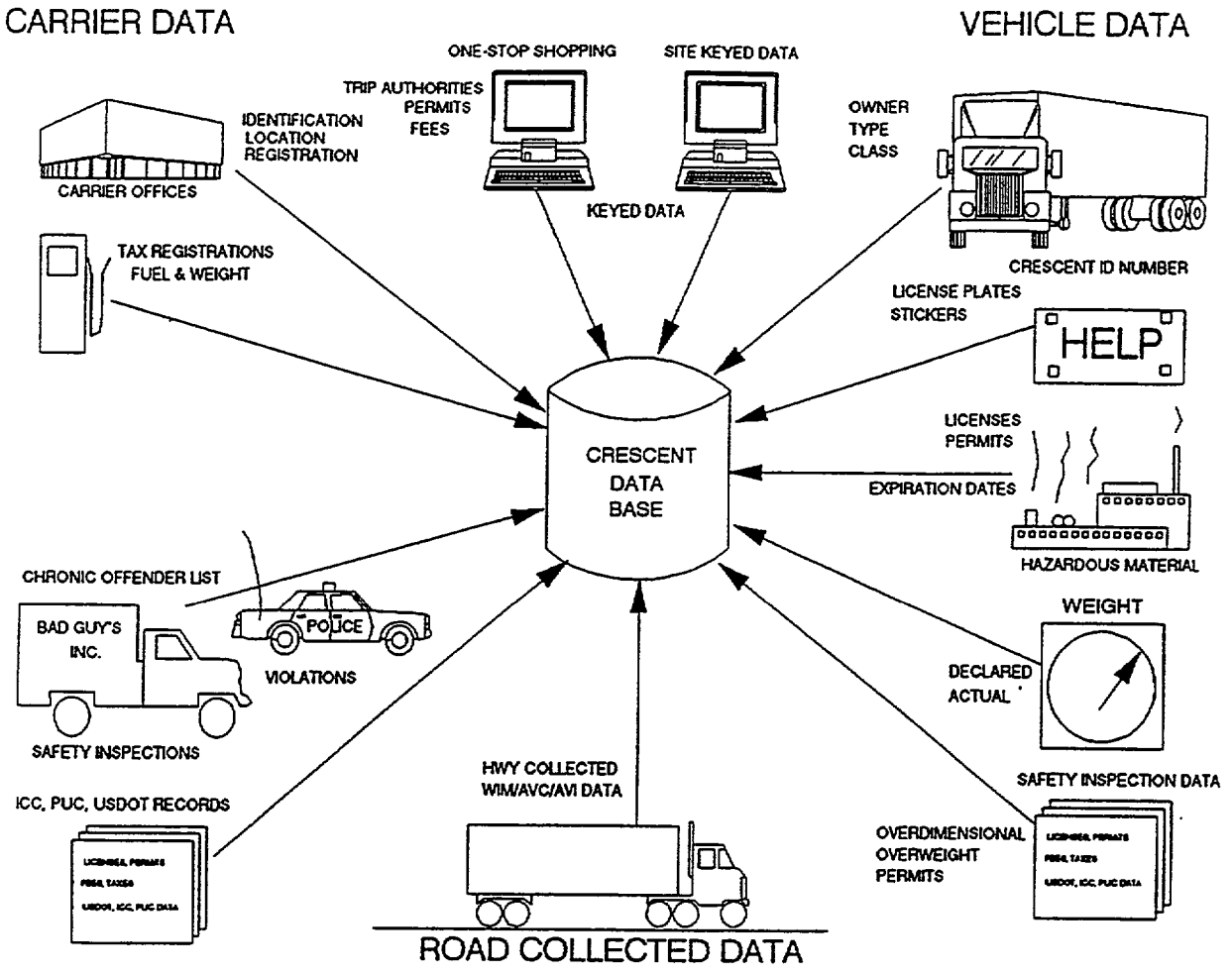
One-stop Credential and Permit Processing for Participating States and Motor Carriers

One-stop shopping is a logical extension of the automatic clearance concept. It allows a carrier to benefit from pre-clear and transparent border procedures through application to a regional authority for all necessary permits and clearances to travel through several participating states. The system was to provide the means necessary to support this concept.

SYSTEM COMPONENTS - OVERVIEW

The specific hardware and software components that comprise the System Architecture will be discussed in the next chapter. The data base at the heart of the system maintains information about three primary areas -- enrolled motor carriers, specific trucks owned or operated by the motor carriers, and the events occurring at individual WIM, AVC and/or AVI devices. Figure l-l (provided by LISC) depicts the types of information contained in the database.

Figure 1-1
Crescent System Components



CHAPTER 2. EVALUATION OF CRESCENT SYSTEM COMPONENTS

This chapter provides an evaluation of the Crescent system components as originally envisioned by HELP -- as defined in the HELP/Crescent RFP and LISC's proposal. ***This chapter is not an evaluation of Lockheed's contractual obligations. The*** objective of the evaluation is:

> ***To analyze the actual operating experience of the implemented system to determine if the HELP defined system architecture should be modified for continued system success, or adjusted for similar future implementations.***

Before beginning the "evaluation" the current status of the project as compared to the beginning objectives was reviewed. The following provides a summary level view.

Data Collection for Highway Planning -- The Crescent computer system has been designed to retain the appropriate data elements obtainable from WIM, AVC and AVI equipment. In addition, the database has been designed to retain carrier, vehicle and permit data necessary to carry out the functions envisioned in the RFP and proposed by LISC. The highway planning data is now being collected and stored at a central location (partitioned by State).

Data to Aid Enforcement -- The Crescent computer system now records WIM and AVC data containing gross weight, axle weight, and vehicle type. Using this data, it calculates various bridge formulas. Only two truck types are not being classified correctly on a consistent basis.-- car carriers with a low center section and nine axle combinations. The bridge formula has been implemented and is being calculated and displayed. It can screen most trucks. Some special configurations, such as car carriers, can not be physically recognized by the equipment. These special configurations can cause the system to incorrectly flag a legal truck as illegal (certainly better than vice-a-versa). Registration, safety inspection and permit data is generally not current and is being ignored by weigh station operators, at the present time. This problem is due mostly to motor carriers not providing the data to the CDO on a timely basis and ultimately, to not having a direct connection and access to state computers containing such data.

Pre-clear and Transnarent Border Clearances of Participating Motor Carriers -- The status of this objective, from a technical perspective, will be nearly the same as the previous objective. The system currently can pre-clear trucks, on or off of the mainline, based on weight, type and bridge formula. Further, the system could pre-clear based on registration, permits and safety inspections, if the information for these areas were up-to-date in the Crescent database.

One-stop Credential and Permit Processing for Participating States and Motor Carriers -- This objective has not been achieved. Information and data flows describing the process involved in each of the six participating states relative to permitting procedures is documented as a separate appendix to the overall Crescent Evaluation Report Regional permitting procedures do not exist, and will likely be addressed after some of the intra-state issues are resolved. This objective has been, and will be, affected by the status of the institutional barriers within and among the participating states. However, the Crescent computer system is able to support this functionality, when the institutional issues are resolved. For purposes of this evaluation, we believe that the system can provide the necessary support, even though it can not be "operationally" tested at this time.

The remainder of this chapter has been subdivided into the six categories as set forth in the Crescent Evaluation Plan:

- Systems Architecture
- Systems Communication
- Applications Software
- Crescent Database
- Site Availability
- Data Reconciliation

Each category is described and evaluated in terms of its current status, relative to the original plan as set forth in the RFP and the LISC Proposal. In addition, we have provided observations, where appropriate. Because our recommendations often involve more than one category, they are included as Chapter 3 -- Summary and Recommendations

SYSTEMS ARCHITECTURE

The Crescent System Architecture is hierarchical in nature. Information is collected at the site level, passed to the state level and finally recorded at the regional level (except for Oregon data which is first uploaded to a non-Crescent state computer and then later to the regional Crescent data base). Figure 2-l illustrates the data flow as proposed and implemented by LISC. As of July 23, 1993, there were 35 sites included in the project. Approximately 81% were considered functional (taken from the Site Status Report of July 23). These sites account for approximately 500,000 events per week -- WIM, AVC and AVI records.

The basic hardware architecture is depicted in Figure 2-2. It features Motorola Delta Series 3000 computers at the state and regional level and Everex 386120 computers at weigh stations and port-of-entry sites. The systems operate under the UNIX Operating System -- selected to satisfy the portability requirements of the HELP/Crescent RFP There are four (4) Motorola computers in the architecture -- one for the regional system and three for the state systems. Each state system is partitioned to process two states. The state computers are connected to mainline (unattended) sites via 9600 baud modem and to weigh stations via 19.2 kilo baud leased lines.

The Crescent System was developed under the lNFORMIX data base management system. The software was developed using INFORMIX's 4GL language and the C Programming Language. C Programming was used primarily for data conversion and input/output processing.

All four systems are collocated at the LISC CDO facility in Santa Clara, California, Motor carrier and vehicle data is entered from Crescent registration forms and updates, when provided by motor carriers. Permit and inspection data is not currently entered. WIM, AVC and AVI data is collected from mainline and weigh station sites by the Crescent state computers every two hours. The state computers poll each site and upload the necessary data. As indicated earlier, data from Oregon sites is processed differently. The sites are polled by the State's own non-Crescent computer and sometime later, the information is transferred to the regional computer located at the CDO. This unique procedure has caused some apparent discrepancies in reports to motor carriers and others, on occasion. It also emphasizes the most likely barrier to attempting to standardize a system such as the Crescent System – institutional barriers.

Figure 2-1
Crescent System Data Flow

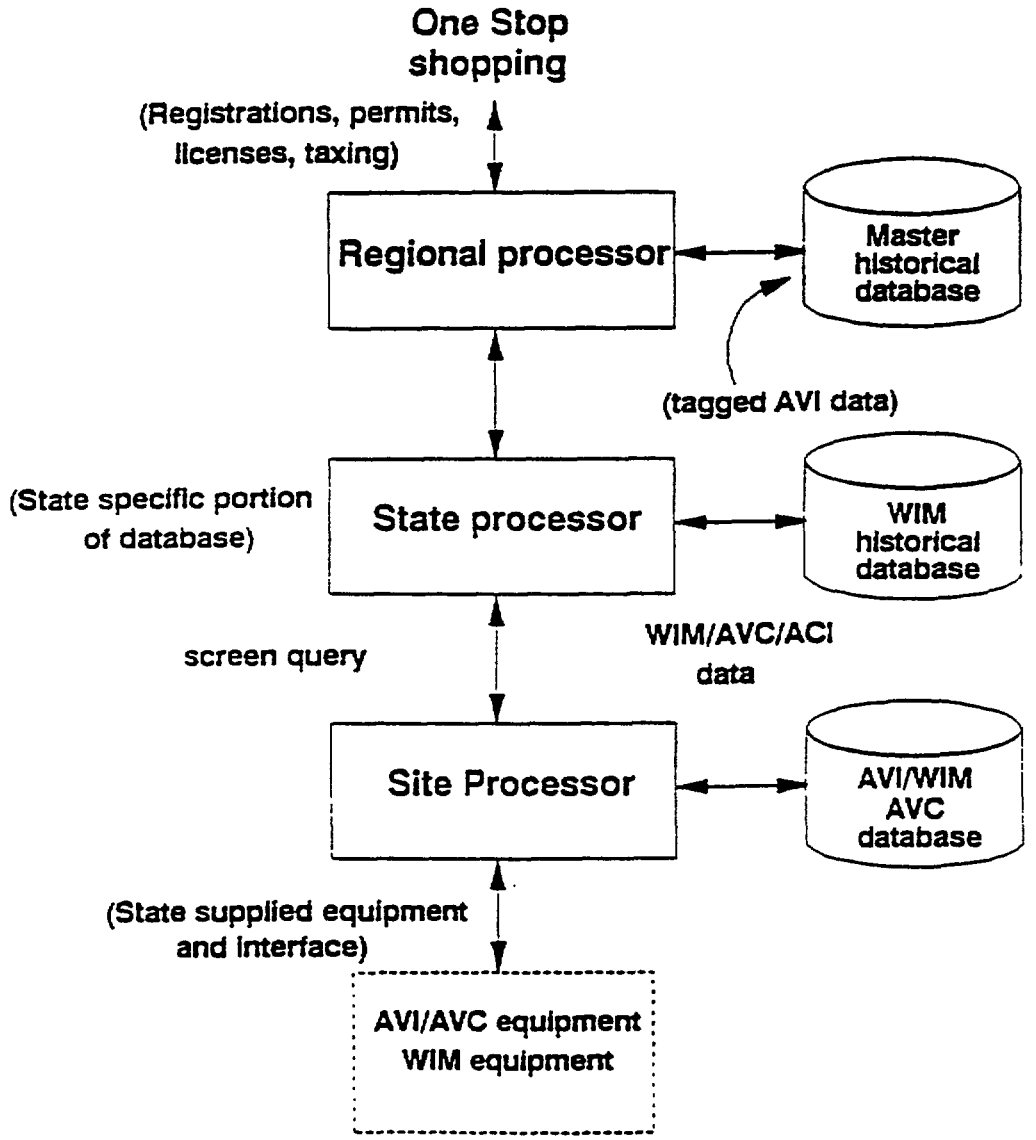
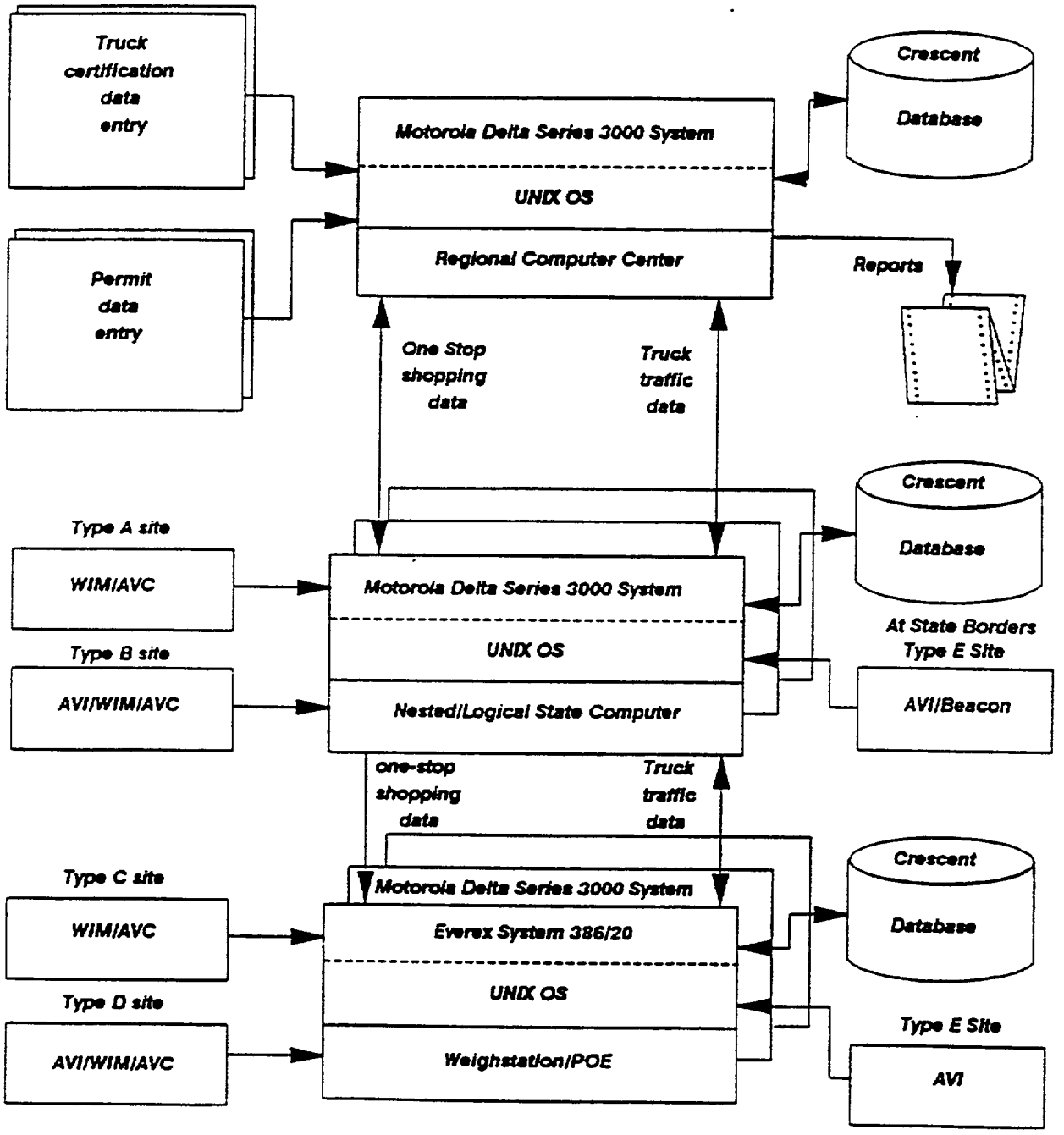


Figure 2-2
Crescent System Hardware Architecture



The system, as developed, supports the HELP/Crescent functions that have been implemented during the demonstration. WIM, AVC and AVI equipment have been successfully interfaced and the data is being correctly processed (by the Crescent computer systems) by weigh station computers, and by the state and regional computers. Data from mainline sites is being uploaded and processed routinely with some communications problems being encountered. The communications problems that have been encountered have primarily been with thoselinking some rural sites. Response times related to reporting features occasionally are unacceptable. This generally occurs when multiple users are accessing the same data files. These problems are discussed below under Systems Communications and Application Software.

Overall, the current system is, or could be, performing the processing functions that were required by the RFP and proposed by LISC. Clearly, the Crescent computer system can collect and store information from the installed WIM, AVC and AVI equipment in five of the states and can accept downloaded data from Oregon's computer -- although some scheduling improvements could be made. With enough vehicles and sites in the program, truck weights, truck classifications and origin/destination data could be collected and analyzed as part of the highway planning process. Because permit and inspection data has not been loaded into the Crescent database, and because registration data is not being provided to the CDO on a timely basis, weigh station sites often receive messages from the system indicating various violations. The weigh station operators understand the problem is often a lack of data, not a real violation. The processing and messaging provided by the system clearly demonstrates that pre-clear and transparent border processing could be effectively accomplished at sites configured like Santa Nella, California. If the data were correctly loaded into the Crescent database and updated on a timely basis, the system would aid truck violation enforcement at weigh stations and provide a means for follow-up when violations are recorded at mainline sites.

Based on these comments, we assess that the system is clearly able to support three of the four Crescent System objectives -- data collection for highway planning; pre-clear and transparent border processing; and providing data to aid enforcement. The last objective -- one-stop shopping for credentials and permits – could not be demonstrated well enough to provide a clear assessment of the system's ability to support it. The system appears to be able to support the output side of the function, as indicated by the comments above. The input functions could be so significantly complicated that some redesign would be necessary to ensure that Crescent database updates reached the regional, state and site computer systems in and efficient and timely manner and that the data was accurate enough to support appropriate clearance and enforcement goals.

SYSTEMS COMMUNICATIONS

The current communications architecture is telephone line based. Communications between weigh stations and the CDO are 19.2 kilo baud leased lines (except in Oregon). Dial-up modems are used by the CDO to access and upload information from mainline sites (except in Oregon). These modems operate at 9600 baud. Dial-in access to the Crescent database is provided to states and motor carriers through similar 9600 baud modems. Communications between the three state computers and the regional system is provided by the CDO local area network (LAN). Communications between the Oregon DOT (ODOT) and the CDO is via an SNA/RJE link using phone lines. The ODOT - CDO link is needed in order to provide the CDO with ODOT's site (weight station and mainline) data. This data is collected by ODOT and then uploaded to the Crescent system. Communications between mainline sensors and collocated weigh stations, as well as those between the weigh stations and appropriately configured vehicles, is accomplished using low power radio frequency (RF) communications. These units, designed and built by LISC, have only recently been deployed at a few sites.

Communications between several sites has been problematic. The problems have generally been due to poor phone lines, primarily in rural areas. Compounding the line problem is the apparent delays encountered in finding and correcting the problem -- often taking months to completely correct the problem These problems have resulted in significant "down time" of some sites and therefore loss (non-reporting) of site data.

When the communications are operating properly, the transmission speeds, protocols and polling schedules have been acceptable for the current level of testing. As new sites are added and more timely data is required for enforcement activities, communications resource demands will also increase. Further, in a truly operational environment, current line failure rates will not be acceptable. The elapsed time between failure and repair will also become unacceptable.

Although not implemented, "one-stop shopping", if incorporated into the system effectively, could place new, and different, demands on communications. The ultimate system would feature real-time query capabilities of various state or regional databases with expected response time of 5 - 10 seconds, or less. Since the benefits of "one-stop shopping" could be significant to both states and motor carriers (the true users of the system), its development should be carefully considered. In fact, we would speculate that failure of this function to provide advertised benefits could adversely impact the overall Commercial Vehicle Operations (CVO) program envisioned under the national Intelligent Vehicle-Highway Systems (IVHS) program. As

the "one-stop shopping" scenario develops, consideration of additional, and likely different, communications strategies will be required.

APPLICATIONS SOFTWARE

The following comments are intended to encompass the software components used to acquire vehicle data from sensors and the Oregon mainframe, to store the data in the Crescent database, and to provide users (state, motor carriers, weigh station sites and the CDO) with retrieval access and report production capabilities.

The underlying software architecture of the Crescent System includes the INFORMIX Data Base Management System (DBMS) operating under the UNIX Operating System environment and the C Programming Language. INFORMIX features a powerful Fourth Generation Language (4GL) capability. This shortens development time as well as normal enhancement and system maintenance time. The release version of INFORMIX currently being used is two releases behind the current release and yet another release is imminent. At the time of this report, LISC was investigating the effort and processing necessary to effect an upgrade to the new release. The UNIX Operating System was selected in response to the requirement for portability of the software as expressed in the RFP. At the time of development of the system, as today, UNIX applications can be "ported" to many hardware architectures. Present technology offers other comparable architectures. The C Programming Language was used to supplement the 4GL when special processing was required; specifically, for data conversion (site data format to host data base format) and for input/output process handling (again, primarily site related processing). The application system is considered to be modular -- more than 60 modules comprise the system

From a user perspective, the system is menu driven and generally user friendly within the menu structure. Some inconsistencies in the user interface do exist, but are considered minor as little effort would be required modify the interfaces. All parameters used by the system are contained in user-modifiable tables thus easing updates to the system as well as overall system maintainability. Reports are provided through query screens. Some queries take up to several minutes to process, especially if more than one user is accessing the same data tables within the system. Response time and access collision problems are expected to be eliminated after the INFORMIX DBMS upgrade.

Several reports were specifically called out in the Crescent System RFP. All of these reports have been implemented. Additional reports requested by various users were also developed by LISC -- often at their own expense. The project did not include tasks to design and develop reports beyond those specified in the RFP. Because there have been few actual "users" of the system (approximately 10 motor carriers and only a couple of the states), a review of the usefulness of the current reports would not be complete. As the Crescent System continues to evolve, it would be very beneficial to involve state, motor carrier and weigh station site personnel in a report design and development effort

Software design documentation was judged to be very basic. Future efforts on this project, or similar projects, should adopt a more structured systems development methodology -- a methodology focused on not only documenting the design, but also facilitating the enhancement and maintenance activities that are inherent in every computer system. This is critical as 60%70% of all system life cycle costs are incurred subsequent to system implementation.

CRESCENT DATABASE

The Crescent database contains more than 500 data elements. It was designed to record data about motor carriers, vehicles, permits, and inspections, as well as data captured by WIM, AVC and AVI sensors. The data base was implemented under the INFORMIX DBMS as was described above.

Data elements related to various permits, inspections and "good guy/bad guy" flags are empty as the data has not been available during the demonstration period. At the time of the review, only a few users were accessing the data base via modem dial-up. Approximately ten (10) motor carriers of 89 are considered "regulars". Only a few state representatives are accessing the data on an infrequent basis. This lack of user activity does not indicate that the data base architecture is at fault. Rather, based on comments obtained from various motor carrier users by WHI, there is major concern about the accuracy and consistency of the data. These problems can generally be attributed to the degree of calibration done (or not done) on the WIM, AVC and AVI sensor equipment. Specific comments regarding use of the data base may be found in the WHI material provided in Appendix E to the Crescent Final Report

The data base system includes SQL and query-by-example technologies. Both are appropriate for the target user base and should be retained in future enhancements and

implementations. Query-by-example is generally more successful for the average user. SQL is more appropriate for the more sophisticated user or the local "guru" tasked to develop special reports or answer specific, complex and non-recurring questions using the data base. Current response time problems encountered periodically by users was discussed earlier.

SITE AVAILABILITY

In general, sites not experiencing communications problems appear to have good availability profiles from a computer processing perspective. Where data is not reaching the Crescent data base, it is due mostly to hardware failure related to the WlM, AVC or AVI equipment or to physical problems related to the installation of the WIM, AVC and/or AVI components. Although much progress has been made in resolving some of these problems, many instances of partial or non- functional sites still exist. Any assessment of site availability made at this time would be premature. The sites need to reach a full operational status and be "accepted" as operational before such an evaluation can begin.

DATA RECONCILIATION

Reconciliation between the central system and the sites is accomplished through total file replacement, as necessary. Detection of problems is done manually. File replenishment is a manual process and is generally performed every 3 to 6 months depending on the site and the problems encountered. As would be expected, the frequency is related primarily to communications reliability, so sites in rural areas experiencing communications problems are generally replenished most often. Because the state computers were collocated with the regional computer, reconciliation was not an issue. Local file transfers could be done and monitored for success, real-time. The issues or problems likely to be encountered when entering permit and safety data, as well as updating registration data, were not really tested during the demonstration. Detection of data synchronization problems must be enhanced and its correction automated, where possible. Centralization of some of the Crescent database would significantly ease and simplify this problem area,

CHAPTER 3. SUMMARY AND RECOMMENDATIONS

In summary, we believe that from a technical perspective the Crescent System, as implemented has successfully demonstrated its ability to support three of the four major objectives of the project -- data collection for highway planning; pre-clear and transparent border processing; and providing data to aid enforcement. Further, portions of the "one-stop shopping" objective have been successfully demonstrated, from a computer processing perspective. True "one-stop shopping" must be better defined and the system tested against that definition before a real assessment can be made.

From an overall perspective, the system has been developed with input from a very limited group of stakeholders. Clear benefits to all stakeholders would be difficult to demonstrate given the current status of the system. Some problem areas, both technical and institutional, must be addressed and resolved. In fact, we believe that a complete and valid assessment, from an Operational Test perspective, can not be performed at this time. The "system" needs some additional shake-out period (perhaps 6- 12 months) before being ready for a true Operational Test. None the less, a significant number of lessons have been learned during the research and demonstration period. Based on these lessons, we provide the following list of recommendations for consideration. Each recommendation is further described below.

- Upgrade the System Hardware Architecture
- Centralize the Crescent Database and Provide States with Appropriate Access
- Evaluate Re-engineering of the Crescent System rather than Continued Enhancement
- Conduct User Reporting Requirements Analysis
- Document Optimal Weigh Station Site Design based on Crescent Experience
- Evaluate the use of Emerging Technologies, such as SMART Cards
- Conduct a Communications Strategy Assessment
- Update System Documentation to an "As-built" Specification
- Address the Institutional Barriers that may Hinder Technological Solutions

Upgrade the System Hardware Architecture -- The advancements in hardware architecture over the last several years have been astounding. In fact, significant advancements have also occurred in communications and data base management system products. It is time to review the overall architecture of the Crescent System. LISC has already conducted some preliminary assessments, internally. We would encourage a more comprehensive analysis be conducted based on currently available architectures and the future requirements and objectives of the Crescent program.

Centralize the Crescent Database and Provide States with Appropriate Access -- The concept of Regional versus State computer systems warrants discussion in several areas. Although the computer hardware resides in one physical location today, it could have been dispersed to the six states and all would have operated in nearly the same fashion -- the only exception would have been data transfers between the individual state computers and the regional computer. Since the state and regional computers were collocated, this transfer caused very few problems. Had communications lines been involved, perhaps some communications problems would have been encountered as they were between some sites and the state computers.

The collocation has provided the opportunity to more carefully assess the need for separate state level computers, from a technical perspective. We believe that LISC's view that state level computers are probably not needed, but rather that their functionality could be absorbed by the regional computer is well founded. Registration, safety and some permit data is of interest and is needed by more than one stakeholder. WIM, AVC and AVI data also has regional use, from the motor carriers perspective. Database reconciliation would be somewhat less complex -- one level of reconciliation would have been eliminated. Concerns about data privacy are routinely addressed under today's data base management systems, including the latest version of INFORMIX. Appropriate protections and accesses can be achieved with confidence. We would recommend that individual state computer systems be eliminated and that the regional system absorb its functionality.

The need for timely and accurate data at weigh station sites presents a classic distributed data base problem. Response times must be very fast (no more than 2-3 seconds) and the system must be "up" nearly 100% of the time. The most effective way to achieve these characteristics is to have the necessary data available on a "local" data base -- on site. The source of the carrier and vehicle data necessary to provide pre-clear and transparent border functionality and to aid enforcement at weigh stations will be through non-Crescent state computers or, at best, through the regional Crescent system computer. Real-time access (2-3 second response time) to the regional system or the various state systems will be difficult to achieve even with the best communications strategy. Distributed data base processing is the most likely solution. Future development should include a thorough analysis of the data requirements necessary to achieve system objectives within the context of a distributed data base architecture.

Evaluate Re-engineering of the Crescent System rather than Continued Enhancement – Much has been learned since the Crescent System was specified in the RFP and subsequently developed by LISC. The system has undergone the normal development, enhancement and maintenance cycles associated with research and development efforts. Some functions have been changed, others retrofitted to achieve successful implementation. New functions are envisioned and technology has undergone a revolutionary growth during the past few years. Continued enhancement and maintenance activities may overly complicate future maintenance and enhancement activities. Retrofitting some of the recent technological developments may represent compromise, at best.

We suggest that it may be time to review the system in light of lessons learned and current technology. A conscious decision should be reached as to whether to continue to enhance and maintain the existing software, or whether to consider the system a "prototype" and stepping stone to the ultimate Crescent System. At the very least, some re-engineering of portions of the system will likely be necessary to take advantage of new features provided by the current release of the INFORMIX DBMS; the implementation of different communications strategies; the centralization of the state and regional data bases; and the implementation of more sophisticated distributed data base features to address data reconciliation problems and timeliness requirements imposed by "one-stop shopping" requirements.

Conduct User Reporting Requirements Analysis – The output features of the system – user reports and screens -- were developed with little input from the user community at large. This approach was necessary in order to begin the research and demonstration efforts. However, it is time to step back and conduct a formal design and development effort focused on defining and implementing user reporting requirements. Because computer systems are usually best measured by the usefulness of the outputs, the importance of this effort can not be overemphasized. This may be the only way to expand the current user base and achieve acceptance of the Crescent concept by all stakeholders.

Document Optimal Weigh Station Site Design based on Crescent Experience -- The project has included implementations under various site designs. Some designs pre-date the project, some evolved in parallel and a few were directly affected by the project (Santa Nella, for example). The nature of the system demands that the "man-machine" interface points be optimized in order to achieve overall success. This includes the physical layout of data collection sites in order to take

advantage of the Crescent processing capabilities. Therefore, we believe that the lessons learned about site configurations during the project should be documented. Further, we believe that optimal designs can be specified for various types of sites. Early documentation and review of these designs by engineers and systems professionals can provide valuable guidance for future site construction, re-construction or modification. Significant reinstallation costs experienced in the past, as well as installation of unusable configurations, can be eliminated in the future. Future sites should be designed with Crescent technology in mind.

Related to the installation of the optimal site configuration is the issue of how often and where to place these installations. Many of the installations were introduced at existing weigh stations or at convenient locations along the Crescent routes. We believe that the stakeholders should take a system-wide approach to defining the locations and types of Crescent facilities to be installed and operated. Considering the technology available and the needs of the various stakeholders, the optimal configuration can balance installation, operations and maintenance costs with the expected benefits to be achieved, system-wide. Such a strategy provides a blueprint for the program.

Evaluate the use of Emerging Technologies, such as SMART Cards -- New technologies, such as read-write SMART Cards have evolved since the Crescent project began. These technologies can provide new features for the testing and implementation under the Crescent program. Carrier, vehicle, driver, load, permit, and inspection data can be contained on such cards for access by the appropriate sensors. Trip data, including driver logs can be automated. Under certain design scenarios, these technologies may provide alternative means for implementing distributed data base architectures -- the vehicles themselves may carry a portion of the data necessary for aiding enforcement, implementing pre-clear and transparent borders applications, and providing highway planning information.

Conduct a Communications Strategy Assessment -- Based on the experiences of the Crescent program and the availability and affordability of differing communications options, the Crescent team should evaluate alternative communications strategies in light of current goals of the program. LISC has already conducted a preliminary assessment of the benefits and costs of using satellite communications in lieu of telephone lines. Perhaps the solution lies in a combination of technologies. In any event, successful communication among the various components of the

system is imperative for system success in the long term. Naturally, this assessment should be performed as part of an overall design of the future Crescent System.

Update System Documentation to an "As-built" Specification -- The system design developed by LISC should be updated to reflect the current "as-built" condition. The design will facilitate enhancements and maintenance activities associated with the current system and will form a basis for system re-engineering, if assessed to be appropriate.

Address the Institutional Barriers that may Hinder Technological Solutions -- One of the early objectives was to use the HELP/Crescent research and demonstration project to evaluate the extent and complexities associated with overcoming institutional barriers. The involvement of six states, British Columbia, private industry and the federal government has demonstrated that certain barriers can be overcome, over time. Not to minimize the importance of the progress to-date, significant barriers still remain. Agreements to conduct research and limited demonstration efforts are more easily reached than the agreements necessary to implement systems or procedures that require long term commitments of resources and cooperation. Permanent agreements often require resolution of significant or sensitive "turf" issues. As an example, consider the complexities of achieving "one-stop shopping" at the state level, much less at the regional or national levels. Many organizations are involved, each with its own agenda, priorities and supporting organizational structure. Appendix B of the Crescent Final Report provides a detailed insight into the complex structures within the six states. "One-stop shopping" will only become a reality through a dedicated, and earnest, effort by all parties -- an effort that is justified by the significant benefits that can be achieved by all stakeholders, successful.