Paper Title:

A Demonstration Adaptive Signal System:
The San Francisco Bay Area Experience

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Paper Summary

This paper will present the main challenges associated with the implementation of a fully adaptive signal system in one of the largest counties in the San Francisco Bay Area. Some of the main challenges have included the procurement of an adaptive system that that is not fully developed, vehicle detection and equipment modifications to meet the adaptive system's requirements and the lack of available funding for the project. The project is a shared endeavor between two adjacent jurisdictions, the County of Santa Clara and the City of Sunnyvale to install an adaptive system along some of the heaviest traveled streets in the area. The adaptive system is a non-cycle based, i.e., without a background signal cycle, which will enable the County to retain all of the existing NEMA controllers and cabinets and their central control system. The City will utilize a remote workstation to establish and revise system parameters accordingly. Adaptive control of the system will be enabled and disabled using either time-of-day commands or traffic volume thresholds.

INTRODUCTION

The County of Santa Clara and the City of Sunnyvale embarked on a shared project to reduce congestion and harmful air emissions in the Silicon Valley region through the use of advanced technologies for traffic management. By utilizing an adaptive traffic signal system, it was anticipated that traffic congestion during both the peak and non-peak periods could be reduced substantially along one of the County's heaviest traveled expressways, Lawrence Expressway. This particular segment of Lawrence Expressway experiences heavy travel throughout the day, with a combination of office and commercial land uses in the area.

The project area consists of nine intersections in a crossing arterials pattern. The main street is Lawrence Expressway with three major City streets crossing it. The Expressway carries between 50,000 and 80,000 vehicles per day, and the City arterials carry between 30,000 and 40,000 vehicles per day.

A particular challenge is providing traffic signal coordination between the expressway and the City's arterials. A particular concern is achieving coordination during the non-peaks and on weekends. This is because the expressways demand a significantly higher signal cycle length than the City's adjacent intersections. Thus, it was determined that using a common background signal cycle would not be applicable for this demonstration project.

However, the more established adaptive systems depend primarily on a background signal cycle length. Thus, these systems were not considered, leaving the Technical Advisory Committee to look further into much less mature adaptive systems that did not utilize the concept of background cycles.

EXISTING CONDITIONS

The following summarizes the existing conditions of the project site. Figure 1 shows the entire study area, including the locations of existing system detection loops and closed-circuit television (CCTV) camera installations.

Field Equipment Configurations

Currently, all of the City of Sunnyvale's signals are controlled by old Type 90 controllers housed in NEMA cabinets. Most of the intersections have advance loops and no stopline loops on the main street. All intersections have stopline loops on the minor street. Currently, none of the City's signals are interconnected.

The County of Santa Clara has a standardized configuration in each cabinet, i.e., controller, number and type of detectors, conflict monitor, EVP, etc,. The signals are controlled by NEMA TS-2 controllers all housed in Type P cabinets. The local and master controllers are monitored and controlled by a central system located at the County's new Traffic Operations Center. All of the County's signals are interconnected via 4800 baud modems to a field masters which in turn communicates with the central master at the Traffic Operations Center via a 9600 baud modem. In addition, the County has a fiber link to each of their project intersections for video monitoring.

All three intersections have advance loops on the through lanes and stopline loops on the left-turn lanes of the Expressway, and stopline loops only on the side streets. There are no loops on right-turn lanes. The advance loops are located between 210 feet and 250 feet from the stopline. Sampler loops have been installed on all departures where they are mainly located 500 feet from the stopline. Closed circuit television (CCTV) cameras (fixed) have been installed at all three intersections for video monitoring.

Signal Coordination Challenges

The current fixed time of day plans along Lawrence Expressway work well during the peak periods of the day. However, during the off-peak periods when traffic volumes on Lawrence Expressway are low and the traffic patterns relatively unpredictable, the fixed time of day plans tend to be ineffective in reducing stops and delays. While signal coordination can be provided on Lawrence with a certain level of effectiveness, crossing arterial coordination is very difficult to achieve.

SELECTION OF THE ADAPTIVE SYSTEM

For the selection of the adaptive, a formal Request for Proposals (RFP) and oral interviews/system demonstration was conducted. Using a Technical Advisory Committee, the detailed evaluations and selection of the preferred adaptive system was carried out. The selection process included written submittals and a half-day long presentation and system hardware and software demonstration.

While many adaptive systems are commercially available, it was determined that only two systems satisfied the “non-background cycle” requirement. Thus, only the SPOT system from PEEK and the RHODES system from Siemens-Gardner Transportation Systems were selected for final consideration (written and oral).

Both systems had limited to no installations within the United States. In fact, the RHODES system was not yet fully developed. While the SPOT system was more mature with one deployment in the US at the time, it had substantially fewer features compared with RHODES. Thus, the technical advisory committee selected RHODES as the preferred adaptive system for deployment.

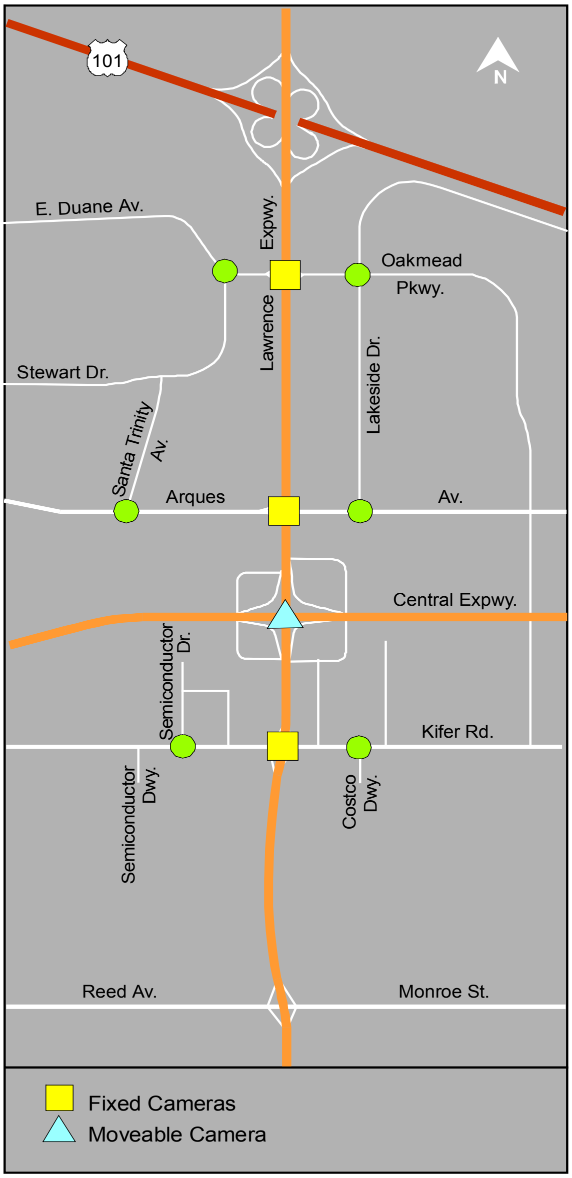

Figure 1 - Project Area

SYSTEM DESIGN

Once the decision was made to move forward with the deployment of the RHODES system, a series of negotiations sessions were conducted between DKS Associates, the overall System Manager, the County of Santa Clara, the City of Sunnyvale and Siemens-Gardner Transportation Systems.

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Due to very limited funding, the first order of work was to obtain a feasible system design within the funding constraints. Designing the system to fit within the available funds proved to be a very difficult process. The main areas of cost for the system were determined to be the following:

- Vehicle Detection
- Traffic Controller Cabinets
- Communications Network

Each of these issues is described separately below.

VEHICLE DETECTION

The RHODES system requires substantially more detection compared with traditional adaptive systems. In addition, the use of video detection was not an option as this would mean an additional level of complexity the project partners were not willing to include. With the elimination of certain in-pavement loops, a feasible system was achieved. However, this would come at the price of the adaptive system's effectiveness for vehicle arrival, departure and queuing predictions. By eliminating the advance loops on external links to the system, this reduced the detection to about 70% of the preferred detection requirements for the system. Also, by shortening up the advance loop distances to the stoplines, substantial costs were saved. Figure 2 illustrates the final detection scheme for the system.

Some of the functionalities that would be compromised included the ability of the system to properly account for the random arrivals of the vehicles entering the system including their location and speed. This would have some effect on how the Expressway signals timings and phase sequences would be modified to service City traffic entering the Expressway system.

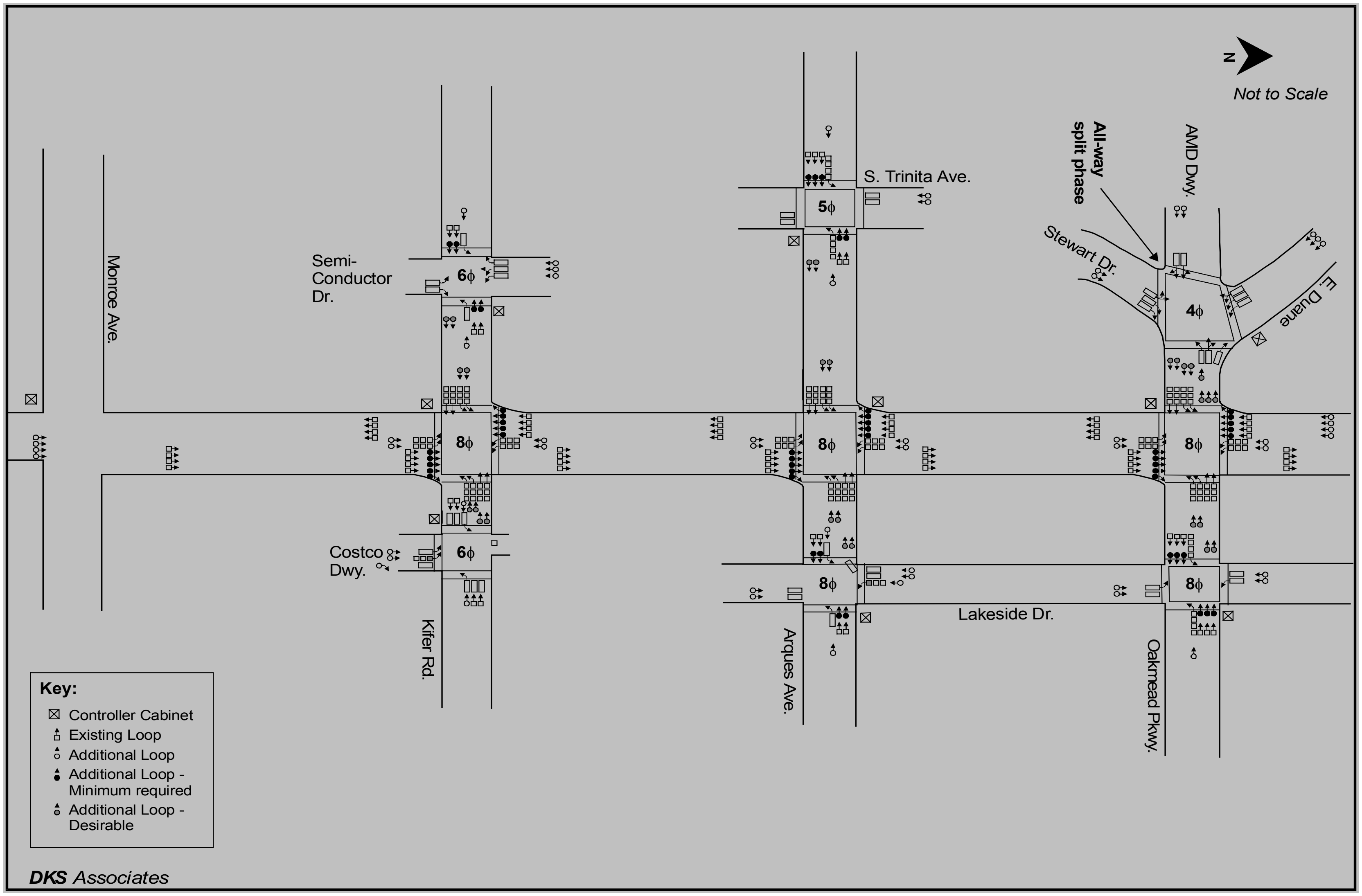
N
Not to Scale
All-way split phase
AMD Dwy.
Stewart Dr.
E. Duane
4ϕ
S. Trinita Ave.
5ϕ
Semi-Conductor Dr.
6ϕ
Monroe Ave.
8ϕ
8ϕ
8ϕ
Costco Dwy.
6ϕ
8ϕ
8ϕ
Lakeside Dr.
Kifer Rd.
Arques Ave.
Oakmead Pkwy.
Key:
Controller Cabinet
Existing Loop
Additional Loop
Additional Loop - Minimum required
Additional Loop - Desirable
DKS Associates

Figure 2 - Vehicle Detection Strategy

TRAFFIC CONTROLLER CABINETS

The City's older traffic controllers and controller cabinets needed to be either replaced or re-wired to accommodate the new and additional equipment. Moreover, the County wanted to retain their existing cabinets and controllers operating the traffic signals. In either case, some additional cabinet re-wiring was required to accommodate the additional set of loops. In some cases on the Expressway, up to 62 discrete loop inputs would need to be accommodated.

It was determined that half of the City's cabinets would be re-wired and the other half would be replaced. In one case, the City wanted a Type 333 (dual rack cabinet) to be installed which necessitated the installation of an additional detection panel to accommodate the additional loops. Figure 3 shows this cabinet with the additional detector panel.

Figure 3 - Type 333 (dual rack) Cabinet with Additional Detector Panel

It was proposed by Siemens, and accepted by the TAC to use Model 2070 controllers for the City signals, with a VME card running the RHODES software. At the County's signals where they have NEMA TS-2 controllers and cabinets, a Remote Adaptive Control Unit (RACU) would sit external to the traffic controller running the RHODES software and triggering inputs and outputs with the cabinet. Given that the RHODES system was still under development, there did not exist an off the shelf RACU. When a prototype was finally produced, it turned out to be a slimmed down Model 2070 controller with a VME card housed within a carrier card to fit into a standard Model 2070 chassis (see Figures 4 and 5).

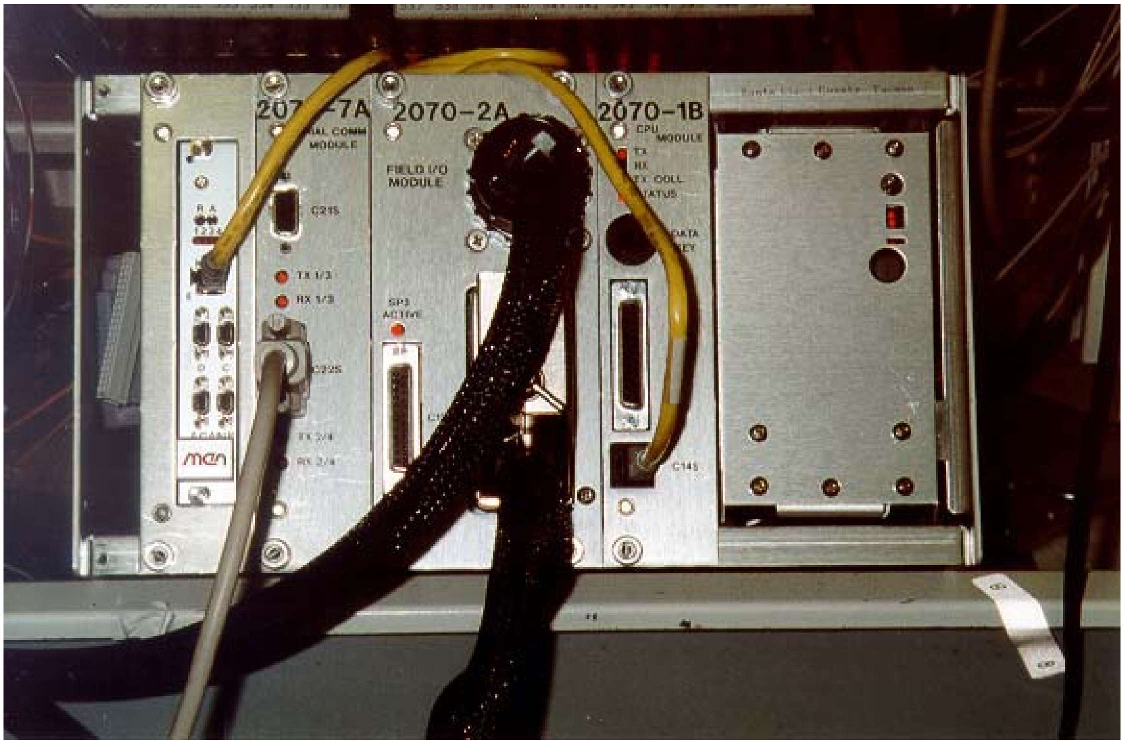

Figure 4 - Remote Adaptive Control Unit (RACU)

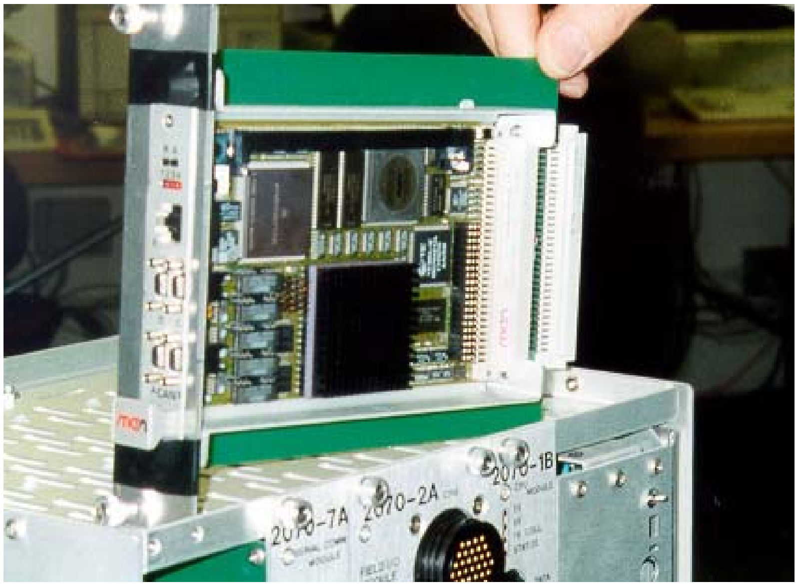

Figure 5 - VME Board for the RACU

COMMUNICATIONS NETWORK

Since none of the City signals were interconnected, the single largest cost factor was the communications network. An initial assessment was performed to determine the cost to install a hardwired communications network. The estimate proved to be much higher than the entire project's available funding. Thus, alternative solutions were investigated.

One solution proposed by Siemens-Gardner Transportation Systems was the use of a leased packet radio system. Their proposal involved leasing services from Metricom's Ricochet network. This solution was accepted by the TAC, with Siemens agreeing to cover the service costs up to the end of the demonstration period. With the system design nearly complete, including several field tests of the wireless transmission system, Metricom filed for bankruptcy halting all service. This prompted the TAC to consider other wireless alternatives. After several months of testing, it was determined that the use of Cellular Digital Packet Data (CDPD) technology would work replacing the packet radio solution. Figure 6 below illustrates the high level communications network for the system.

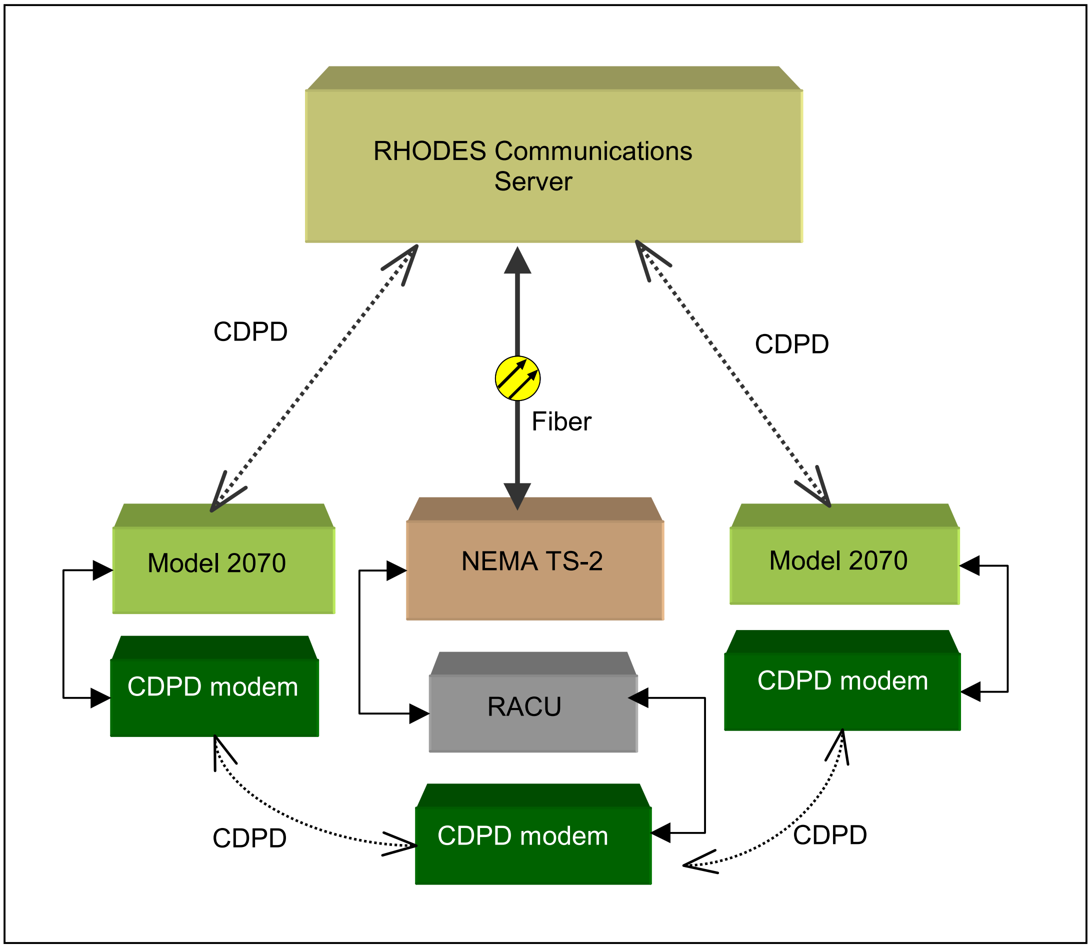

Figure 6 - Systems Communications Configuration

The County has a fiber optic link to their traffic controller cabinets which is used for the video images from these intersections. The City of Sunnyvale has a workstation at their facilities with a standard dial-up link to the RHODES communications server.

SYSTEM IMPLEMENTATION

Since the project was primarily funded using federal funds, a large portion of the field elements had to be procured using the standard competitive low-bid process. The first set or construction documents that were bid on by electrical contractors had to be rejected due to all of the bids being higher than the available funds. The second set of construction documents had the County and City supplying some of the field equipment such as controller cabinets, and County forces performing some of the specialized in-cabinet work including wiring terminations. This “re-bidding” caused some delays to the overall implementation schedule.

The RHODES adaptive system software is still undergoing development with a few promising field deployments in the US. The first field operational test in the US occurred in the Seattle, Washington with another field test in Tucson, Arizona. These tests have resulted in identifying the software and configuration issues with RHODES, but has not resulted in the system being expedited for implementation in the County of Santa Clara. In fact, the software development process alone has resulted in implementation delays of over a year from the original anticipated completion date.

The system is currently in the last stages of implementation with the final field testing slated to occur in the Spring of 2003. Once the system is fully configured, rigorous field testing will commence and once all of the “bugs” are worked out, a comprehensive before and after evaluation will occur.

CONCLUSIONS

While the San Francisco Bay Area has not deployed a fully adaptive traffic signal system, there are several projects underway that will change this. In the County of Santa Clara and the City of Sunnyvale in the San Francisco Bay Area, the first fully adaptive signal system is currently in its final stages of deployment.

Based on the experiences gathered through the process of designing and implementing an adaptive system, one major consideration in the selection process should always be the maturity of the software. Those systems that have few actual deployments should be scrutinized closely for how “off-the-shelf” the software is. If the system software is not as mature as other under developed systems, ample time must be allocated for the inherent delays that will be experienced. In addition, clear and concise functional requirements must be developed in order to avoid overlooking significant details of the system.

ENABLING TECHNOLOGIES AND INNOVATIONS

Once completed, the system will enable the County and the City to coordinate their traffic signals without the use of a common background cycle. This operation will be very critical particularly during the non-peak, or lunchtime hours when signal coordination in nearly impossible to achieve between adjacent intersections. This will mark the first use of non-cycle based, adaptive coordination across adjacent jurisdictions in the San Francisco Bay Area.

The Remote Adaptive Control Unit (RACU) design is the first of its kind using the standard chassis of a Model 2070 controller and VME cards. The RACU is basically a Model 2070 controller complete with the standard software operating system (OS/9), the CPU card (1B), the Field I/O card (2A) and the communications card (7A). The VME card is charged with running the adaptive algorithms and is linked with the CPU card via an Ethernet link. The use of an RACU enables the County to maintain full control of their NEMA-based system while enjoying the full benefits of the RHODES adaptive system. Figure 7 shows an RACU and a Model 2070 controller and Figure 8 shows the RACU undergoing bench testing in a NEMA cabinet.

Figure 7 - RACU with a Model 2070 Traffic Controller

Figure 8 - Bench Testing the RACU with a NEMA Controller and Cabinet

Since this project is a demonstration project, it is anticipated that if other adaptive systems need a field deployment site for testing, this project would be set up for it. As much as is possible, the equipment has been standardized with additional detector inputs and field outputs along with the capability for other detection technologies including video detection.