SYSTEMS ENGINEERING MANAGEMENT PLAN

for the

CITY OF ROSE GARDEN
Adaptive Traffic Control System

Version 2.0

Submitted to:

Prepared by:

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## Document History

<table>
<thead>
<tr>
<th>Document Name</th>
<th>Submittal Date</th>
<th>Version No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Draft System Engineering Management Plan</td>
<td>April 12, 2006</td>
<td>Version 1.0</td>
</tr>
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<td>Revised First Draft System Engineering Management Plan</td>
<td>May 22, 2006</td>
<td>Version 1.1</td>
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</tbody>
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1.0 PURPOSE OF DOCUMENT

As part of the first task of this project, this document, the Systems Engineering Management Plan (SEMP), is intended to serve as a guidebook for the City of Rose Garden, System Engineer, (The Consultant Team), and the System Vendor, throughout the course of the project. The SEMP will not only identify the tasks to be completed, but also detail out the schedule of the tasks, who is responsible for completing the tasks, and how the final products will be integrated, installed, verified, and supported. The SEMP will enable the Team to manage the project using systems engineering principles and methods to maximize the quality of the system being implemented, while minimizing the budget and schedule required for its completion.

The primary objectives of this document are:

- To provide modern, state-of-the-art, project management requirements for the design, procurement, construction, integration, testing, and maintenance of technical systems;
- To limit and reduce the proliferation of management documentation and to implement relevant aspects of applicable standards;
- Identify relevant directives and references;
- To provide evidence that control over the design, procurement, installation, integration, testing and support and that inspections which demonstrate acceptability of material and services will be performed;
- To provide emphasis on a disciplined integrated systems development approach;
- To inform the stakeholders with concepts of systems engineering management and techniques;

This SEMP is intended to be a living document, as information is gathered through the life of the project, some tables included in this document can be updated to reflect the most current data. The SEMP follows the systems engineering approach to project completion as illustrated above by the Vee Diagram.
2.0 SCOPE OF PROJECT

The City of Rose Garden, California is currently pursuing the selection and implementation of an off-the-shelf traffic adaptive system that will provide real-time coordination of signals along Magnolia Avenue, a major east-west corridor in the City. Due to the proximity of the corridor to major trip generators in the area and US 422, the corridor experiences both the expected (typical peak period surges) and unplanned variations (diverted traffic due to incidents), as well as unexpected fluctuations from major trip generators, in traffic flow. Traffic signal systems that respond in real-time to changes in traffic patterns are known as “adaptive.” Adaptive Traffic Control Systems (ATCS) belong to the latest generation of signalized intersection control. It is envisioned that the new adaptive traffic system will adjust to the daily fluctuations in traffic flow due to both the expected and unexpected events. Reacting to these volume variations is intended to result in reduced delays, shorter queues and decreased travel times.

A complete ATCS provides system software with algorithmic intelligence to overcome the limitations of pre-timed control and responds to changes in traffic flow by adjusting signal timings on a cycle-by-cycle basis in accordance with fluctuations in traffic demand. Such a system can be implemented through real-time detection and reliable communications between the system’s components (vehicle detection, traffic signal controller, and ATCS software). When implemented, the adaptive traffic control system will ideally work to provide decreased overall travel delays along Magnolia Avenue and serve as a test location for possible implementation to other applicable corridors in the City. Upon initial set-up and operation, the new system is expected to handle the variations in traffic flow with minimal user interference.

Below is a listing of the project stakeholders, their roles and responsibilities on this project, and key staff identified from each entity. It is recommended that this group meet regularly at critical points of the project. These critical decision points are further defined in the SEMP below.

<table>
<thead>
<tr>
<th>Stakeholder</th>
<th>Role</th>
<th>Interest in Project</th>
<th>Key Staff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public Works</td>
<td>Traffic management, operation of traffic signals, detectors, maintenance of signal hardware</td>
<td>Adaptive operation of signals to react to fluctuations in traffic. Better management of the traffic.</td>
<td></td>
</tr>
<tr>
<td>Fire Department</td>
<td>Public safety</td>
<td>Emergency signal pre-emption</td>
<td></td>
</tr>
<tr>
<td>Police Department</td>
<td>Public safety</td>
<td>Emergency signal pre-emption</td>
<td></td>
</tr>
<tr>
<td>Rose Garden CityBus</td>
<td>City wide bus service</td>
<td>Transit signal priority</td>
<td></td>
</tr>
<tr>
<td>Community Media</td>
<td>Information provider to City residents</td>
<td>Communication infrastructure (i.e. fiber optics)</td>
<td></td>
</tr>
<tr>
<td>IT</td>
<td>Manage computer technologies (i.e. hardware and software) throughout the City.</td>
<td>Hardware and software maintenance and compatibility with City LAN</td>
<td></td>
</tr>
<tr>
<td>Purchasing</td>
<td>Procurement</td>
<td>Contracting with the system engineer and system vendor</td>
<td></td>
</tr>
<tr>
<td>Caltrans</td>
<td>Traffic management, operation of traffic signals, detectors, maintenance of signal hardware</td>
<td>Adaptive operation of signals to react to fluctuations in traffic. Better management of the traffic.</td>
<td></td>
</tr>
<tr>
<td>System Engineer</td>
<td>System engineer</td>
<td>Identify and assist in the</td>
<td></td>
</tr>
</tbody>
</table>
To date, the following meetings have taken place:

- Kick-off meeting with City’s Public Works staff
- Project Stakeholders meeting with all of the stakeholders listed above (except the system vendor).

The System Engineer, The Consultant Team, role on the project will be to assist the City in the analysis and selection of a new adaptive traffic control system, development of detailed design plans (PS&E) of any field equipment that are deployed, oversight of the deployment process (deployment of the adaptive system to be done by the System Vendor and the deployment of the field equipment to be done by City staff), and completion of a before/after evaluation. The detailed design and oversight activities will be based on the traffic control system that is selected.

The System Vendor that is selected, will provide the necessary hardware (i.e. desktop, servers, etc), installation support, and training for the new traffic adaptive system. The details of this work effort (deployment plan, integration plan, etc) will be dependent on the system that is selected.
3.0 TECHNICAL PLANNING AND CONTROL

The following section lays out the plan for the systems engineering activities.

3.1 WORK BREAKDOWN

The major activities identified to select, deploy, and operate a pilot project that would provide a traffic adaptive system along one corridor, Magnolia Avenue, at nine intersections are listed below. It also includes inputs and deliverables required to complete the work.

It should be noted that what is identified here in the work breakdown and detailed later in the SEMP are intended to be guidelines. Many of the tasks and work plans are dependent on the adaptive system that will be selected and will have to be developed once a System Vendor has been selected. For example, the Implementation Plan identified in WBS 5 will need to be developed by the System Vendor. In that document, they will identify the approaches, methods, and techniques for implementing the new system based on the needs of their particular COTS adaptive module. This SEMP simply provides an outline for them.

Due to the nature of this project and the fact that an off-the-shelf software/hardware package is proposed for this project, with guidance from FHWA staff, the system engineering process was tailored to better fit the needs of this project. For example, the High Level Design component of the system engineering process, which describes the hardware/software architecture of the system, was not seen as necessary since an off-the-shelf system will be deployed in Rose Garden and no customization/software development will be needed.

WBS 1: Select and Contract with a System Engineer
The City of Rose Garden prepared a Request for Proposals, which included a description of the required scope of work, for the selection and deployment of a pilot traffic adaptive system at nine intersection along Magnolia Avenue. Consultant, Inc. (system engineer) was selected and a contract negotiated. Work by the system engineer commenced March 8, 2006.

WBS 2: Prepare Systems Engineering Management Plan
The system engineer will prepare and maintain the Systems Engineering Management Plan – this document. The SEMP will be a living document updated throughout this project. City and FHWA staff will provide review of this document.

WBS 3: Develop Concept of Operations
The concept of operations, to be developed by the system engineer, will document, from the City’s view of operations, the traffic adaptive module being deployed.

WBS 4: Identify System Requirements
The system engineer along with City of Rose Garden staff will identify and develop a list of essential and/or desirable requirements and functionalities that are preferred to be included in the new functionality of the traffic control system. These requirements and functionalities will be determined through discussions, workshops and meetings with City staff. These requirements and functionalities will not only include special features the system should have in operating the signals, but also the user interface components that allow a user to efficiently use the system.
WBS 5: Develop Technical Plans
Specific technical plans necessary for the successful deployment of this project will be developed by the systems engineer. Included with each are details about the procedures and tools, that will be used throughout the project. These plans include:

- Technical review plan
- System integration plan
- Verification / validation plan
- Deployment plan
- Operation & maintenance plan
- Training plan
- Configuration management plan
- Risk management plan

WBS 6: Select a System Vendor
The system evaluation and selection task will identify the most reliable (i.e. lowest O&M costs) and cost-effective traffic control system that will manage the nine intersections along Magnolia Avenue proposed as part of this project and be capable of handling potential future expansions to other corridors in the City.

WBS 6.1: Identify potential candidate systems
The system engineer will conduct research on available systems and develop a comprehensive list and available functionalities of applicable, off-the-shelf, adaptive systems

WBS 6.2: Develop request for proposals
The system engineer will prepare a Request for Proposals (RFP) for procurement of an off-the-shelf traffic adaptive system. The RFP will incorporate or reference the Concept of Operations, System Requirements, Verification Plan, and High Level Design. City staff will review and provide comments to the RFP.

WBS 6.3: Select system vendor
The system engineer will assist in responding to questions from proposers, review submitted proposals and provide comments, help address specific issues raised by a proposal, help prepare requests for clarification from proposers if appropriate, help prepare questions during interviews, participate in interviews if appropriate, and help evaluate further information provided during interviews. Based on the proposals and interviews, the City of Rose Garden will select a system vendor to implement the traffic adaptive system.

WBS 6.4: Negotiate a contract with the system vendor
Based on contract terms in the request for proposals, and the successful proposal, the City of Rose Garden will negotiate a contract with the selected system vendor.

WBS 6.5: Identify field element needs for the new adaptive system
Once the traffic control system has been selected, the system engineer will prepare a technical memorandum summarizing the field elements that will be required to allow for the proper operation of the traffic adaptive system.

WBS 7: Develop Plans, Specifications, and Estimate (PS&E) for field elements
The system engineer will develop a Project Design Report (PDR) that will detail the project elements, any new equipment or infrastructure that is required, the existing equipment and infrastructure to be utilized, and the preliminary cost estimate to procure and deploy the
equipment needed to provide full functionality of the new adaptive system. City staff to review and provide comments on the PDR.

The system engineer will develop plans and specifications for various components of the project. The final plans, specifications, and estimates (PS&E) to include all necessary improvements to be performed by City staff for a complete and operational system.

The PS&E packages will be submitted to the City of Rose Garden at 65 and 100 (Final) percent completion. The Final PS&E will be prepared based on final comments from City and Caltrans staff. Plans will be prepared on AutoCAD in English or metric units, as directed by the City.

**WBS 8: Deploy/Construct Field Elements**

The system vendor will be responsible for deploying the traffic adaptive module of to the traffic control system. In parallel, City maintenance staff will deploy the necessary field equipment (i.e. controllers, detection, etc) to allow for the proper operation of the traffic adaptive system. The system engineer will then verify that the adaptive system operates as per the user needs and requirements.

**WBS 9: System Deployment and Testing**

The system engineer will assist the City of Rose Garden in the procurement of the traffic control system and provide construction assistance. In addition, during this task, acceptance testing activities will also be performed by the system engineer and the City.

The acceptance testing will verify that each element of the ATCS and field elements deployed are performing as required, and that the intended adaptive control operation is performing as specified by the ATCS vendor. The testing will evaluate each functional and detailed specification criteria identified Test Plan and it will the responsibility of the system vendor to make sure all City requirements are met.

When a component or feature of the deployed ATCS fails to perform according to the specifications as illustrated by a “did not pass” designation, the system vendor will be notified of the issue and asked to correct the deficiency for a re-test of the feature/component. Should the system vendor be unable or unwilling to make modifications or corrections to the ATCS for the identified issue, system engineer will document the component failure, and the process to correct it (or attempt to correct it).

**WBS 10: System Evaluation**

This task will provide a quantitative measure of the improvements gained with the deployment of the new system. The system engineer will conduct field data measurements including travel times before and after the proposed system deployment.

### 3.1 Control Gates

Control gates represent critical activities that must be satisfactorily completed before a task is considered completed. Table 1 provides a list of those critical activities and which stakeholder can provide its approval.
<table>
<thead>
<tr>
<th>Critical Activity</th>
<th>Deliverable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Select and Contract with a System Engineer</td>
<td>Selection of System Engineer</td>
</tr>
<tr>
<td>Prepare Systems Engineering Management Plan</td>
<td>Draft &amp; Final SEMP</td>
</tr>
<tr>
<td>Develop Concept of Operations</td>
<td>Concept of Operations</td>
</tr>
<tr>
<td>Identify System Requirements</td>
<td>System Requirements</td>
</tr>
<tr>
<td></td>
<td>Signal System Evaluation and Recommendation Report</td>
</tr>
<tr>
<td></td>
<td>RFP for the Procurement of the System</td>
</tr>
<tr>
<td></td>
<td>Recommended System Hardware Requirements for Implementation</td>
</tr>
<tr>
<td>Develop Technical Plans</td>
<td>Technical Review Plan</td>
</tr>
<tr>
<td></td>
<td>Verification &amp; Validation Plan</td>
</tr>
<tr>
<td></td>
<td>System Integration Plan</td>
</tr>
<tr>
<td></td>
<td>Deployment Plan</td>
</tr>
<tr>
<td></td>
<td>O&amp;M Plan</td>
</tr>
<tr>
<td></td>
<td>Training Plan</td>
</tr>
<tr>
<td></td>
<td>Configuration Management Plan</td>
</tr>
<tr>
<td></td>
<td>Risk Management Plan</td>
</tr>
<tr>
<td>Select a System Vendor</td>
<td>Development of RFP</td>
</tr>
<tr>
<td></td>
<td>Selection of System Vendor</td>
</tr>
<tr>
<td>Develop PS&amp;E for field elements</td>
<td>65% and Final (100%) PS&amp;E package</td>
</tr>
<tr>
<td>Deploy/Construct Field Elements</td>
<td>Adaptive traffic control system</td>
</tr>
<tr>
<td></td>
<td>Field elements to support adaptive system</td>
</tr>
<tr>
<td>System Deployment and Testing</td>
<td>Deployment of traffic adaptive system</td>
</tr>
<tr>
<td>System Evaluation</td>
<td>Before and after study</td>
</tr>
</tbody>
</table>
3.2 Resources

The following is a summary of the resources needed for each task in the WBS including lead organization, level of effort and the technical expertise required to complete the task.

<table>
<thead>
<tr>
<th>Task</th>
<th>Organization</th>
<th>Level of Effort (hours)</th>
<th>Technical Expertise Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>WBS 1: Select and Contract with a System Engineer</td>
<td>City</td>
<td>100</td>
<td>City</td>
</tr>
<tr>
<td>WBS 2: Prepare Systems Engineering Management Work Plan</td>
<td>System Engineer</td>
<td>100</td>
<td>System engineering &amp; signal system expertise</td>
</tr>
<tr>
<td>WBS 3: Develop Concept of Operations</td>
<td>System Engineer</td>
<td>40</td>
<td>System engineering &amp; signal system expertise</td>
</tr>
<tr>
<td>WBS 4: Identify System Requirements</td>
<td>System Engineer</td>
<td>30</td>
<td>System engineering &amp; signal system expertise</td>
</tr>
<tr>
<td>WBS 5: Develop Technical Plans</td>
<td>System Engineer</td>
<td>50</td>
<td>System engineering &amp; signal system expertise</td>
</tr>
<tr>
<td>WBS 6: Select a System Vendor</td>
<td>System Engineer &amp; City</td>
<td>120</td>
<td>Available COTS adaptive traffic control system</td>
</tr>
<tr>
<td>WBS 7: Develop Plans, Specifications, and Estimate (FSBE) for field elements</td>
<td>System Engineer</td>
<td>100</td>
<td>ITS FSBE expertise</td>
</tr>
<tr>
<td>WBS 8: Deploy/Construct Field Elements</td>
<td>System Vendor &amp; City</td>
<td>160</td>
<td>Available COTS adaptive traffic control system &amp; ability to deploy hardware in the field</td>
</tr>
<tr>
<td>WBS 9: System Deployment and Testing</td>
<td>System Vendor</td>
<td>140</td>
<td>Available COTS adaptive traffic control system</td>
</tr>
<tr>
<td>WBS 10: System Evaluation</td>
<td>System Engineer</td>
<td>80</td>
<td>Ability to conduct before and after studies</td>
</tr>
</tbody>
</table>

In summary, The City of Rose Garden is responsible for selecting and hiring the system engineer (the Consultant Team was selected for this work) and the system vendor that will deploy the adaptive traffic control module. The Consultant Team is responsible for the technical oversight of contracted and in-house systems engineering activities identified in this plan during the design development, procurement, construction, installation, integration and testing, as well as maintenance phases. This activity in concert with the City's responsibilities form the Systems Engineering Management Team (SEMT). This element performs all the system engineering activities required to define and control the ITS requirements and system specifications as defined by the project stakeholders. Activities include:

- Establish, document and maintain documentation standards and provide advice and example model texts for any documentation required during the system life cycle phases;
- Prepare reports on the status of the project systems, subsystems, standards, plans, and procedures;
- Review and audit products and processes as and when necessary for conformance to SEMP and to project requirements;
- Agree with the user format, content, and standard of the documentation to be prepared for the project;
- Provide information on amendments and change proposals to contractual identified specifications and standards and their impact to the project if accepted or not accepted;
- Identify procedures for statistical methods and techniques required for establishing, controlling and verifying the process and products.
3.3 SCHEDULE

The project has been divided into ten tasks. To ensure that the project objectives and requirements are being met, each task requires one or more deliverable submittals. Figure 1 provides the project schedule.

The project schedule was derived based on the time required to complete the various tasks, the relationships between tasks, and the City’s funding requirements (funding must be obligated by August 2006). It is envisioned that the critical path will be driven by the funding requirements. The project schedule will be updated and maintained on a weekly basis. Inputs to the schedule will include person hours per task, person hours expended to date, budget per task, budget expended to date, long-lead items, and progress derived from the progress review meetings. MS Project will be used to develop and maintain the project schedule.

Figure 1. Project Schedule

3.4 PROJECT SPECIFIC TECHNICAL PLANS

The adaptive traffic control system deployed as part of this project will be comprised of existing COTS hardware and software. As part of the initial steps of this project, the System Engineer will develop a set of functional requirements and that will guide the City in selecting an adaptive traffic control system. Since the system that will be selected is intended to be COTS with no customization, the details of deployment have not been determined and will be based on the system itself. For example, some of the available adaptive systems require new field controllers, servers at the TMC, and workstations to operate the system. Other systems will only require an upgrade to the City’s existing traffic control system. As such, the System Vendor that is selected will provide the necessary hardware (i.e. desktop, servers, etc), installation support, and training for the new traffic adaptive system. The details of this work effort (deployment plan, integration plan, training plan, configuration management plan etc) will be developed by the System Vendor. The System Engineer will then develop the verification/validation plan based on the adaptive system that has been selected.

3.4.1 Technical Review Plan

The addition of an adaptive traffic control system module to the City’s existing system would require the review of a number of technical documents. Table 1 in Section 3.2, Control Gates, provides a summary of the deliverables and the entity responsible for conducting the review.
The System Engineer (Consultant) will develop, the City will provide comments, and the System Engineer will be responsible for responding to those comments on the following technical submittals:

- Draft & Final SEMP
- Concept of Operations
- System Functional Requirements
- RFP for the Procurement of the System
- Signal System Evaluation and Recommendation Report
- 65% and Final (100%) PS&E Package of the Recommended System Needs
- Verification & Validation Plan
- Deployment Oversight of Traffic Adaptive System
- Before and After Study

The City and System Engineer (Consultant) are required to provide comments and the selected System Vendor is responsible for developing and responding to comments on the following technical submittals:

- Adaptive System Hardware needs for implementation (i.e. field controllers, detection and location of detectors, etc)
- Deployment Plan
- Integration Plan
- O&M Plan
- Configuration Management Plan
- Deployment of traffic adaptive system, associated training, and documentation

3.4.2 Systems Integration Plan

As previously mentioned, the system will be an off the shelf system. The City’s existing signal system will continue to serve the remainder of the City’s signalized intersection. The adaptive traffic control system will, initially, only serve the study intersection along Magnolia Avenue.

Although the system will initially serve a small area of the City, it may eventually be used along other qualified corridors in the City. Regional connections to other agencies to enhance the regional flow of traffic is also a future consideration for the City. The System Vendor will develop an integration plan for this initial deployment and potential future expansion of the system.

3.4.3 Verification/Validation Plan

A key element of the systems engineering process is requirements traceability, ensuring that the functionality and operation of the adaptive traffic control system meets the City’s needs, objectives, requirements and project constraints. The requirements traceability matrix is the primary resource that will be used to map requirements to subsystems, configuration items, and functional areas. The requirements traceability matrix will at a minimum contain the user requirements, system components that fulfill the user requirements, budget status, system and requirements analysis, and a description of the resulting deliverables. Once the adaptive system has been selected, the System Engineer will develop a verification/validation plan to review and accept the deployment of the new system. This will include the
verification/validation of the new field equipment (if any is deployed), servers, workstation, and the new system.

**Requirements Baseline Validation**
Validating the requirements established from the requirements analysis will vary depending on the system. The systems being evaluated for this project are comprised of commercial off the shelf (COTS) hardware and software which shall comply with the standards identified in Section 3.5.1.

**Functional Verification**
The functional verification will be conducted in the same manner as the requirements baseline validation. Because the systems being selected are COTS hardware and software with accepted standards, the functional verification will be conducted prior to and validation following construction (field and acceptance testing).

After the user needs and requirements have been developed, the systems engineer will prepare the Verification/Validation Plan, which identifies acceptable procedures for verification (acceptance testing) of each system requirement, such as inspection, demonstration, analysis, or test. Test cases will be identified based on the concept of operations. The stakeholders will review the Verification Plan. Based on the Verification Plan, the system engineer will later develop a detailed acceptance test plan in which the system vendor will have to follow.

### 3.4.4 Deployment Plan
It is envisioned that the deployment of the adaptive module and field elements will occur simultaneously. As mentioned previously, the details of the deployment, including who will deploy, scheduling, training, etc, will be developed based on the specific needs of the COTS adaptive system selected. The deployment plan will then have to be developed by the System Vendor and approved by the City and the System Engineer. Below is a listing of the items that might be needed for deployment.

**Traffic Adaptive Module**
This will be a COTS deployment and will provide the City with adaptive traffic control capabilities to operate a pilot corridor.

**System Detection**
One of the most important components of the ATCS are the system detectors. These detectors provide the second-by-second vehicular demand to the ATCS which enable the system to make critical decisions concerning the traffic operation. Fluctuations in vehicular demand will then trigger different signal operations (i.e. cycle lengths, splits, offsets, etc). Depending on the adaptive system selected, the placement requirements of these detectors will be different.

**Communication Infrastructure**
Another important aspect of the ATCS is the communication network which enables the central system to process the second-by-second data collected by the system detectors. Depending on the type of communication media used, closing or replacing any communication gaps will be important.

**Controller Assemblies**
Assumptions were made early on in the project to use the existing controller assemblies (rack mount). If a system is selected that is not compatible with rack mounted controllers and Type 332 or 336 cabinets, additional time will be necessary to deploy this equipment.

3.4.5 Operations and Maintenance Plan

The City currently has a number of field devices deployed along the study intersections that could support the traffic adaptive system. It is envisioned that additional field equipment would be needed to supplement the existing elements. Ideally, the additional equipment will be compatible with the existing elements and City staff will be familiar with their operation and maintenance. The traffic adaptive module will be an off-the-shelf system and the operation of and maintenance of it will be well documented from other deployments.

3.4.6 Training Plan

During construction of the new adaptive module, the system vendor must understand the requirements that the system must have in order to satisfy the City’s needs. These requirements must be fully communicated to the vendor in order to ensure that the project continues to completion on-budget and on-time.

Although it is envisioned that eventually the system will successfully operate with minimal user inputs, when the acceptance testing of the new system is complete, the regular system users should still be trained to operate and troubleshoot the system. Training system users to operate and troubleshoot the system is necessary in order to successfully run the new ATCS at the desired levels. The users should be aware of the system capabilities, the necessary initial and regular inputs, as well as the “quick fixes” should minor issues occur during the life of the new system. It will be the responsibility of the System Vendor to develop the Training Plan and provide the appropriate training to City staff.

Potential additional field elements required to operate the ATCS will include controller upgrades, system detection, and communication linkage. These are all equipment that the City is currently familiar with in use/operation and maintenance. Additional training might be necessary on the new controllers.

3.4.7 Configuration Management Plan

Through the course of the project, the amount of information collected and analyzed will require an information repository to ensure no data is lost. This project will have both an electronic repository with scanned documents in PDF form, as well as hard copies of any information provided by the involved agencies. Any analysis conducted will also be filed in the repository for quick reference and back traceability.

For the deployment of the traffic adaptive system and the required field elements to support the system, no customization will be necessary as an off-the-shelf system will be required. As such, all equipment and software will be procured as-is and the configuration management will be straightforward and the responsibility of the System Vendor.

3.4.8 Risk Management Plan
There are no safety risks foreseen associated with the installation of the new system. The traffic adaptive module is meant to enhance the operation of an existing system with safeguards for failure currently in place. However, in order to minimize and risks with a new system deployment, warranties for the new system (including software and hardware) should be included. In addition, the existing time-of-day signal coordination patterns should still be available. This will allow for the operation of the signals in a coordinated fashion in case the adaptive module is not operational.

There are some inherent operational risks associated with any project. Specific to this project, these might include malfunctioning of the new controllers (if new controllers are deployed) and the use and operation of the new software (controller software and central system software). However, these can be mitigated by bench testing the controllers and obtaining proper training in the use of the new software.
4.0 SYSTEMS ENGINEERING PROCESS

The most significant objective of the system engineering process (SEP) is to ensure that the resulting design meets the technical performance requirements of the ITS system and field elements throughout the project lifecycle. To meet this objective the systems engineering process is utilized to minimize changes to the detailed design once it has been completed. This goal is accomplished by ensuring that all relevant concerns have been included in the overall design process and at the right time.

Consultant’ approach to the application of the SEP is to identify ITS deployment stakeholders, determine their needs, and follow a logical process in defining a system architecture and functional design that can be reviewed and verified to meet stakeholder needs. The key concept in this approach is to identify system requirements, track the requirements to ensure they link to the stakeholder needs, and then verify that the requirements have been satisfied by the installed system.

4.1 CONCEPT OF OPERATIONS

The City of Rose Garden, California is currently pursuing the selection and implementation of an off-the-shelf traffic adaptive system that will provide real-time coordination of signals along Magnolia Avenue, a major east-west corridor in the City. There are a total of nine signalized intersections along the project corridor; seven are owned and operated by the City of Rose Garden and two are owned and operated by Caltrans. The corridor currently operates under a centralized system. This project would only provide an additional capability, adaptive operation. Magnolia Avenue between North Sutter Avenue and Pioneer Avenue, will serve as the “test” corridor for the selection and implementation of a traffic signal system that will provide real-time coordination of signals. The intent is that this new traffic adaptive system will adjust to the dynamic daily variations in traffic flow, and will accommodate unanticipated fluctuations due to incidents, special events, transit vehicles and similar unplanned changes in traffic flow. In addition, the system will be able to adjust to other activities or influx of traffic due to the Rose Garden Junior Magnolia, High School, and Middle School.

Traffic signal systems that respond in real-time to changes in traffic patterns are known as “adaptive.” Adaptive Traffic Control Systems (ATCS) belong to the latest generation of signalized intersection control. ATCS continuously detect vehicular traffic volume, compute “optimal” signal timings based on this detected volume and simultaneously implement them. Reacting to these volume variations is intended to result in reduced delays, shorter queues and decreased travel times. It is the City of Rose Garden’s desire to select and implement an ATCS using the federally-recommended System Engineering process through the development of a SEMP.

A complete ATCS provides system software with algorithmic intelligence to overcome the limitations of pre-timed control and responds to changes in traffic flow by adjusting signal timings on a cycle-by-cycle basis in accordance with fluctuations in traffic demand. Such a system can be implemented through real-time detection and reliable communications between the system’s components (vehicle detection, traffic signal controller, and ATCS software). Figure 2 provides an example of variability that occurs in traffic demand, resulting in 40 to 50% increase or decrease in volumes from the mean. Time of day signal coordination is designed to provide the optimal operation for about 85 to 90 percent of the traffic flow. However, fluctuations in flow are never well captured by standard time of day plans. Figure 2 illustrates
how TOD coordination is not able to respond to such fluctuations in flow, thus the need for an adaptive type system.

Figure 2. Sample Traffic Demand Variability & Time of Day Operation

Traffic adaptive systems are able to better capture fluctuations in traffic flow. Based on traffic volume data obtained from field detectors, the cycle length, splits, and offsets are modified to meet the demand. Figure 3 illustrates how volume fluctuations are captured by a traffic adaptive system.
The initial deployment will serve as a starting point for implementation to other applicable corridors and possible regional connections for the adaptive traffic control system. With the development of the system’s functional requirements and the selection of a system (along with a System Vendor), the details of the Concept of Operation will be developed.

4.2 REQUIREMENTS AND FUNCTIONAL ANALYSIS

Requirements analysis will be used to develop the functional and performance requirements for the adaptive traffic control system; that is, customer (City staff, motoring public, etc.) requirements are translated into a set of requirements that define what the system must do and how well it must perform. Consultant’ systems engineers must ensure that the requirements are understandable, unambiguous, comprehensive, complete, and concise. The requirements analysis must clarify and define functional requirements and
design constraints. The functional requirements will define quantity (how many), quality (how good), coverage (how far), time lines (when and how long), and availability (how often). Design constraints define those factors that limit design flexibility; for the Rose Garden system, these include project schedule, maximum use of existing infrastructure, etc.

The requirements of the adaptive traffic control system to be deployed must relate directly to the performance characteristics required by the City for the operation of the project corridor, including the stated life-cycle customer needs and objectives for the adaptive traffic control system, and the relation of these needs and objectives to how well the system will work in its intended environment. Requirements are the primary focus in the systems engineering process because the primary purpose of the process will be to transform the requirements of the adaptive traffic control system into the design documents to procure and implement the system. The process develops these design documents within the constraints, such as minimizing the construction of new infrastructure. They eventually must be verified as meeting the system's needs, objectives, requirements and project constraints.

The system requirements analysis will be conducted in detail at a future date after detailed discussions with City staff.

4.3 **SYSTEM ANALYSIS**

4.3.1 **Trade-Off Analyses**

The trade-off analyses will be completed by the City and the System Engineer (Consultant) and will be determined by the responses to the RFP or RFI process. If the selected respondents cannot meet all the requirements desired by the City, the City will make the final decision concerning revisions to their user needs and subsequent system requirements. By outlining the future goals of the system, the City can make their decision concerning any trade-offs.

4.3.2 **System/Cost-Effectiveness Analyses**

A benefit-cost analysis will be conducted as part of WBS 10, System Evaluation. The system's performance measures will be measured and quantified.
5.0 TRANSITIONING CRITICAL TECHNOLOGIES

The systems being evaluated for selection will be COTS hardware and software that are compliant with industry accepted standards. The project will utilize existing infrastructure and hardware to the extent possible. The methods for installing the new system will be tried and true methods. No new or untested technologies for operation and maintenance (O&M) will be used for this system.

6.0 INTEGRATION OF THE SYSTEM

The new system will be comprised of COTS hardware and software, including the adaptive traffic control system fully compliant with Caltrans standards, NTCIP standards and protocols, and the Bay Area regional architecture. Although the new system will not initially connect to neighboring agency’s systems, it is intended that the system be evaluated for future integration with other agencies. The System Integration Plan will based on the system selected and will be developed by the System Vendor as described earlier in the SEMP.
7.0 INTEGRATION OF THE SYSTEMS ENGINEERING EFFORT

To ensure an efficient and coordinated project development process, and the delivery of a high quality product within budget and on schedule, Consultant has assembled a Systems Engineering Management Team (SEMT). The SEMT will mainly be comprised of Consultant staff, with support from select staff members of subconsultants.

The project will be headed by Consultant staff, with Luther Tarcod serving as Project Manager. Joe Footprint of Consultant and George Tallman of subconsultant will serve as a technical advisor on the project. Luther, Joe, and George will be supported by other experienced engineers from Consultant who will assist in the selection of the traffic signal system, SEP, and PS&E development. Subconsultant staff will provide their expertise in traffic adaptive systems and Subconsultant will provide a third party evaluation of the effectiveness of the deployed system. Table 5 provides an illustration of the proposed staffing chart the major tasks of the project.

<table>
<thead>
<tr>
<th>Task</th>
<th>Responsible Organization</th>
<th>Task Lead</th>
</tr>
</thead>
<tbody>
<tr>
<td>WBS 1: Select and Contract with a System Engineer</td>
<td>City</td>
<td>City</td>
</tr>
<tr>
<td>WBS 2: Prepare Systems Engineering Management Plan</td>
<td>System Engineer</td>
<td></td>
</tr>
<tr>
<td>WBS 3: Develop Concept of Operations</td>
<td>System Engineer</td>
<td></td>
</tr>
<tr>
<td>WBS 4: Identify System Requirements</td>
<td>System Engineer</td>
<td></td>
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<tr>
<td>WBS 5: Develop Technical Plans</td>
<td>System Engineer</td>
<td></td>
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<tr>
<td>WBS 6: Select a System Vendor</td>
<td>System Engineer &amp; City</td>
<td></td>
</tr>
<tr>
<td>WBS 7: Develop Plans, Specifications, and Estimate (PS&amp;E) for field elements</td>
<td>System Engineer</td>
<td></td>
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<tr>
<td>WBS 8: Deploy/Construct Field Elements</td>
<td>System Vendor &amp; City</td>
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<tr>
<td>WBS 9: System Deployment and Testing</td>
<td>System Vendor</td>
<td></td>
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<tr>
<td>WBS 10: System Evaluation</td>
<td>System Engineer</td>
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</tbody>
</table>
8.0 APPLICABLE DOCUMENTS AND REFERENCES

With any project, the success of the system is often dependant on following the correct standards and procedures (directive documents). A number of directive documents were used to create this document. The following documents and reference were utilized when creating the systems engineering management plan:

- **Systems Engineering Guidebook for ITS Presentation**
  Frank Cechini – Federal Highway Administration

- **Federal Highway Administration California Division**
  California Department of Transportation Division of Research & Innovation
  Systems Engineering Guidebook for ITS, Version 1.1
  *February 14, 2005*

- **IEEE Computer Society**
  IEEE Standard 1220-2005
  Standard for Application and Management of the Systems Engineering Process
  *Approved December 8, 1998; revised September 9, 2005*

- **NTCIP – National Transportation Communications for ITS Protocol**

- **Caltrans Transportation Electrical Equipment Specifications (TEES)**

- **Caltrans TMC Standards and Specifications**

- **Caltrans Information Technology (IT) Deployment Plans and Standards**

- **Fiber Optics Communication System Design Guidelines**

- **City of Rose Garden Signal Timing Standards and Existing Plans**

- **City of Rose Garden Design Standards**

- **City of Rose Garden IT/IS Standards**

- **Caltrans CADD Users Manual**

- **Work Area Traffic Control Handbook (WATCH manual) published by the American Public Works Association (updated 2006).**
### 9.0 ACRONYMS AND ABBREVIATION

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>ATCS</td>
<td>Adaptive Traffic Control System</td>
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<tr>
<td>CADD</td>
<td>Computer Aided Drafting Design</td>
</tr>
<tr>
<td>CALTRANS</td>
<td>California Department of Transportation</td>
</tr>
<tr>
<td>COTS</td>
<td>Commercial off-the-shelf</td>
</tr>
<tr>
<td>FHWA</td>
<td>Federal Highway Administration</td>
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<tr>
<td>IS</td>
<td>Information Services</td>
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<tr>
<td>IT</td>
<td>Information Technology</td>
</tr>
<tr>
<td>ITS</td>
<td>Intelligent Transportation System</td>
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<tr>
<td>MOE</td>
<td>Measures of Effectiveness</td>
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<tr>
<td>MOU</td>
<td>Memorandum of Understanding</td>
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<tr>
<td>NTCIP</td>
<td>National Transportation Communications for ITS Protocol</td>
</tr>
<tr>
<td>O&amp;M</td>
<td>Operations and Maintenance</td>
</tr>
<tr>
<td>PDR</td>
<td>Preliminary Design Review</td>
</tr>
<tr>
<td>PS&amp;E</td>
<td>Plans, Specifications, and Estimates</td>
</tr>
<tr>
<td>RFI</td>
<td>Request for Information</td>
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<tr>
<td>RFP</td>
<td>Request for Proposal</td>
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<tr>
<td>SBS</td>
<td>System Breakdown Structure</td>
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<td>SE</td>
<td>System Engineer</td>
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<td>SEMP</td>
<td>Systems Engineering Management Plan</td>
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<td>SEMS</td>
<td>Systems Engineering Master Schedule</td>
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<tr>
<td>SEMT</td>
<td>Systems Engineering Management Team</td>
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<tr>
<td>SEP</td>
<td>Systems Engineering Process</td>
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<tr>
<td>TEES</td>
<td>Transportation Electrical Equipment Specifications</td>
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<tr>
<td>TMC</td>
<td>Traffic Management Center</td>
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<tr>
<td>TOD</td>
<td>Time-of-Day</td>
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