Final Feasibility Report
EXECUTIVE SUMMARY

On August 7, 2006, Southern California Edison Company (SCE) published an Advanced Metering Infrastructure (AMI) Conceptual Feasibility Report (CFR).\(^1\) The CFR documented the results of SCE’s efforts during the first eight months of AMI Phase I effort, and concluded that SCE’s AMI solution was conceptually feasible.\(^2\) This Final Feasibility Report (FFR) builds upon the CFR by summarizing information gathered during the final five months of AMI Phase I, which followed the publishing of the CFR.

Approved on December 1, 2005, AMI Phase I was initially scheduled to take 18 months to complete, including the development of working prototypes and engagement of an Engineering Design Contractor. However, based on the significant progress made by meter and telecommunication providers in 2006 and verified by SCE’s design and testing results and market assessment activities, SCE successfully completed AMI Phase I in about 13 months. The results of Phase I were universally positive, and support the continuation of SCE’s three-phase AMI deployment strategy. Consequently, on December 21, 2006, SCE filed Application (A.)06-12-026, requesting authority to proceed with AMI Phase II, the pre-deployment phase.\(^3\)

The system architecture activities conducted during the latter part of Phase I were focused on furthering the information contained within the AMI Conceptual Architecture model into a Platform Independent Reference Architecture. The Platform Independent Reference Architecture will evolve into a Platform Specific Reference Architecture once SCE selects the meter and telecommunications technologies and suppliers in Phase II through competitive Request for Proposals (RFP) processes.

An RFP for an AMI system integrator was issued on June 21, 2006 to identify, qualify and secure the services of a system integrator in support of Phase II planning functions. Part of that process

\(^1\) The CFR is available in the regulatory filings section of SCE’s AMI web site: [http://www.sce.com/ami/](http://www.sce.com/ami/).
\(^2\) AMI Phase I was approved by the California Public Utilities Commission (CPUC) in Decision 05-12-001, issued December 1, 2005.
\(^3\) Copies of the Phase II application are available in the regulatory filings section of SCE’s AMI web site: [http://www.sce.com/ami/](http://www.sce.com/ami/).
was to establish pricing and terms that could, at SCE’s option, be used as a basis for continuing system integration work in support of AMI Phase II activities, including the development of the Meter Data Management System (MDMS) and back office information systems.

SCE issued the Meter and Telecommunications RFP on December 13, 2006 and a separate RFP for MDMS suppliers on December 15, 2006. The proposals will be received and are scheduled to be evaluated during AMI Phase II. The RFP results will provide the basis for contract negotiations and awards for the execution of the Phase II field test and implementation of the MDMS in an SCE test environment in Phase II and subsequent deployment of meters and MDMS in Phase III.

SCE’s testing activities in Phase I focused on verifying the functionality of currently available and emerging technology with the goal of determining whether technology will be able to meet SCE’s stated AMI functionality objectives. SCE refined test processes and developed several new tests in anticipation of receiving integrated products from potential suppliers in Phase II. SCE also tested a number of AMI components from several suppliers, including standalone and integrated service switches, radio frequency (RF) neighborhood-area-network (NAN) communications, and home-area network (HAN) communications.

As of December 2006, SCE received “next generation” AMI residential meter prototypes from three different suppliers. SCE also received limited quantities of a prototype AMI commercial meter from one supplier. These “next generation” residential meters contain many advanced features and capabilities. Two meters contained an integrated service switch that enables remote connect and disconnect and will be located under the cover of the meter itself. Of the three AMI residential meter prototypes received in Phase I, two contained integrated communications components and the third prototype has a developer’s kit available to allow development of compatible communications components.
## Table of Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EXECUTIVE SUMMARY</strong></td>
<td>1</td>
</tr>
<tr>
<td>I. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>II. FINANCIAL ASSESSMENT</td>
<td>1</td>
</tr>
<tr>
<td>III. CUSTOMER FOCUS</td>
<td>2</td>
</tr>
<tr>
<td>IV. MARKET ASSESSMENT</td>
<td>3</td>
</tr>
<tr>
<td>A. Status of Meter and Telecommunication Products</td>
<td>3</td>
</tr>
<tr>
<td>B. Meter and Telecommunication RFP Summary</td>
<td>4</td>
</tr>
<tr>
<td>V. METER DATA MANAGEMENT SYSTEM (MDMS) UPDATE</td>
<td>5</td>
</tr>
<tr>
<td>A. MDMS RFP Summary</td>
<td>7</td>
</tr>
<tr>
<td>VI. SYSTEM DESIGN</td>
<td>7</td>
</tr>
<tr>
<td>A. Introduction</td>
<td>7</td>
</tr>
<tr>
<td>B. EPRI Intelligrid Integration of SCE AMI Use Cases</td>
<td>7</td>
</tr>
<tr>
<td>C. SCE AMI Architecture</td>
<td>8</td>
</tr>
<tr>
<td>1. Overview</td>
<td>9</td>
</tr>
<tr>
<td>2. Message Architecture and Analysis Model</td>
<td>10</td>
</tr>
<tr>
<td>3. Network Analysis</td>
<td>10</td>
</tr>
<tr>
<td>4. Integration Analysis</td>
<td>11</td>
</tr>
<tr>
<td>5. Security Architecture</td>
<td>12</td>
</tr>
<tr>
<td>D. Updates to AMI Requirements</td>
<td>13</td>
</tr>
<tr>
<td>E. Potential Gas and Water Meter Interface</td>
<td>14</td>
</tr>
<tr>
<td>F. System Integrator</td>
<td>14</td>
</tr>
<tr>
<td>VII. DESIGN AND TESTING RESULTS</td>
<td>15</td>
</tr>
<tr>
<td>A. Summary</td>
<td>15</td>
</tr>
</tbody>
</table>
B. Telecommunications Testing Overview and Results ................................................................. 15
C. March AFB Testing Overview and Results ................................................................................. 17
D. Meter Testing Overview and Results .......................................................................................... 17
  1. Service Switches .................................................................................................................... 18
  2. Two New Tests Developed .................................................................................................... 18
     a) Accelerated Life Test (ALT): ............................................................................................ 18
     b) End-of-Life Test (EOLT): .................................................................................................. 19
  3. Testing Overview and Results ............................................................................................... 19
E. Home Area Network .................................................................................................................. 21
  1. Testing overview and results .................................................................................................. 21
  2. Home Area Network Interactive Demo .................................................................................. 22

VIII. CONCLUSION .......................................................................................................................... 23
APPENDICES ................................................................................................................................ 24
A. ARCHITECTURE DELIVERABLES ........................................................................................... 25
  1. Conceptual Architecture Deliverables ................................................................................. 25
  2. Reference Architecture Deliverables ..................................................................................... 28
B. AMI INFORMATION ASSURANCE (IA) SUMMARY .............................................................. 31
C. ACRONYM GLOSSARY ............................................................................................................. 34
<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Figure 1 Panoramic view of Alhambra Test Site</td>
<td>16</td>
</tr>
<tr>
<td>2</td>
<td>Figure 2 Aerial photo of March Air Force Base testing location.</td>
<td>17</td>
</tr>
<tr>
<td>3</td>
<td>Figure 3 Climate Chamber in Westminster</td>
<td>18</td>
</tr>
<tr>
<td>4</td>
<td>Figure 4 AMI Demonstration Display</td>
<td>22</td>
</tr>
</tbody>
</table>
I. INTRODUCTION

On August 7, 2006, SCE published an Advanced Metering Infrastructure (AMI) Conceptual Feasibility Report (CFR). The CFR documented the results of SCE’s efforts during the first eight months of AMI Phase I effort, and concluded that SCE’s AMI solution was conceptually feasible. This Final Feasibility Report (FFR) builds upon the CFR by summarizing information gathered during the final five months of AMI Phase I, which followed the publishing of the CFR.

This FFR includes updates to SCE’s AMI Market Assessment, development of a Platform Independent Reference Architecture and updates to the AMI system requirements. The “Design and Testing Results” identified as a deliverable of AMI Phase I is provided in Section VII of this report.

II. FINANCIAL ASSESSMENT

In the fall of 2006, SCE developed a preliminary estimate of its benefits and costs for AMI incorporating the added functionality of the new metering and telecommunication system capabilities. Building on the earlier Use Case work and conceptual cost-benefit analysis, SCE was able to add significant benefits while reducing the level of uncertainty accompanying its earlier cost estimates. Although the cost-benefit analysis process is comprehensive, the results are still considered “preliminary” primarily because of the pending Request for Proposals (RFP) for meter / telecommunications, Meter Data Management System (MDMS) and deployment contractor. Midway through Phase II, SCE expects to re-visit the cost-benefit analysis to incorporate the results of the RFPs in early 2007, and will continue the development of time-of-use and critical peak pricing tariffs. A final business case that incorporates SCE’s technology selections and supplier pricing will be developed for SCE’s AMI Phase III full deployment application that is expected to be filed with the CPUC in mid-2007.

---

4 The CFR is available in the regulatory filings section of SCE’s AMI web site: [www.sce.com/ami/](http://www.sce.com/ami/).
5 AMI Phase I was approved by the California Public Utilities Commission (CPUC) in Decision 05-12-001, issued December 1, 2005.
SCE’s preliminary cost benefit analysis for AMI is set forth in Exhibit SCE-3 of SCE’s Application for Approval of Advanced Metering Infrastructure Pre-Deployment Activities and Cost Recovery Mechanism (A.06-12-026), filed on December 21, 2006. All exhibits for A.06-12-026 are available in the Regulatory Filings section of SCE’s AMI web site: http://www.sce.com/ami/.

III. CUSTOMER FOCUS

In early October 2006, key resources from across SCE’s organization representing Transmission & Distribution, Customer Service, Regulatory Policy, Strategic Planning, Information Technology, and Power Procurement participated in a dynamic two-day workshop to better understand the trends and socioeconomic and technology drivers that will shape SCE’s customers' future experience. Key presenters at the workshop included noted futurist Peter Schwartz, DYG’s Charles Kennedy, Geoff Gougeon from Tribal DDB and John Jurewitz, SCE director, Regulatory Policy. The objective of the workshop was to initiate a common vision of SCE’s expected customer experience in 2012. The workshop was, in effect, a kick-off to a longer process that will shape new tariff and product development that will begin in earnest in AMI Phase II.

The group started to think differently about how the future would shape SCE’s business. Customers’ expectations are changing rapidly, and SCE’s thinking about how best to serve its diverse and dynamic customer population must change even faster in order to provide an exceptional customer experience in the years ahead. SCE is already beginning this transformation through AMI and other initiatives. The workshop participants considered how to leverage these efforts to better meet customers’ future needs and expectations.

At the conclusion of the workshop, Lynda Ziegler, Senior Vice President Customer Service, remarked that while clearly no one can predict the future with total accuracy, it's important to think ahead. She also noted that SCE must listen to its customers and think about how SCE’s actions will...
affect them. Finally, Ms. Ziegler indicated that SCE needs to focus on customizing programs, services and communications to fit customers' preferences.

The customer experience workshop was the beginning of a conversation that will continue to broaden in scope and participation in 2007 and for AMI will serve as a foundation for developing products and tariffs based on customer preferences, and will be followed by customer focus groups.

IV. MARKET ASSESSMENT

A. Status of Meter and Telecommunication Products

As described in the CFR, SCE had received encouraging feedback from its Market Survey solicitation initiated in December 2005. The Market Survey was conducted through a Request for Information (RFI) process, and was developed to acquire information surrounding the level and extent of product development activities among suppliers, and the possible alignment with SCE’s conceptual core requirements and desired product capabilities. As discussed in the CFR, SCE was encouraged by the suppliers’ stated development time-lines and the quoted target price ranges. The information obtained also revealed that significant technology development activities were underway with a large number of industry suppliers.

Based on SCE’s research and continued dialogue with product manufacturers and industry leaders, it has become evident that significant changes are coming to the meter marketplace. Within the next six months, most of the major North American meter manufacturers and some new market entrants are expected to offer a new generation of meters that will include many of the advanced features and capabilities that SCE has been advocating, including an integrated service switch that enables remote connect and disconnect and will be located under the cover of the meter itself. This feature is slated to be offered at a fraction of the price historically charged for these devices. Some of the additional features expected to be available in this new generation of meters include remote upgradeability, more memory and some limited power quality reporting capabilities. SCE has also seen evidence that the meter manufacturers have been working more openly with multiple industry partners to provide greater
choice in communications options and interoperability. Additionally, many of the Automated Meter Reading (AMR)/AMI communications suppliers have been developing enhanced network capabilities that include supporting two-way communications to premise devices using the meter as an information gateway. Several of the industry leaders have announced development and/or actual availability of Home Area Network communications using non-proprietary protocols, which include IEEE 802.15.4, also referred to as the ZigBee™ wireless standard.

Since the release of the CFR, through ongoing dialogue with the suppliers, SCE has been able to narrow the pool of candidate technologies being developed by leading manufacturers that appear to be aligned with SCE’s preliminary AMI system requirements. These suppliers, meter manufacturers and communications technology providers were notified of their respective standing and requested to work together in developing integrated AMI solutions. As of December 2006, SCE received “next generation” AMI residential meter prototypes from three different suppliers. SCE also received limited quantities of a prototype AMI commercial meter from one supplier. The manufacturers were also requested to deliver integrated product (AMI meter with integrated communications) to SCE for testing by February 2007, and SCE expects to receive at least four integrated products by that time.

B. **Meter and Telecommunication RFP Summary**

SCE issued the Meter and Telecommunications RFP on December 13, 2006 with proposals to be evaluated early in Phase II. The RFP results will provide the basis for contract negotiations and awards for the execution of the field test in Phase II.

The main objectives of SCE’s Meter and Telecommunications RFP are to:

1) meet AMI business and technical requirements by selecting up to two communications suppliers and two meter suppliers;

2) minimize total cost of ownership by considering, and balancing multiple cost drivers such as functionality, performance, future upgrades, etc.; and

3) shift performance risk to supplier by developing contract terms and conditions that support key business benefits and cost drivers.
The AMI Metering and Telecommunications System RFP includes electric meters with a communications card integrated under the meter cover; telecommunications network equipment; any required wide area network service; a data center aggregator (DCA) built upon a Commercial-Off-The-Shelf (COTS) software application that provides telecommunications network management and control and provides a “gateway” to and from the meters to upstream applications, such as MDMS. The component parts are expected to work together to provide the two-way transmission of data and information in accordance with SCE’s requirements.

SCE desires to select a single communications supplier as part of this RFP (the “majority” communications network) but may need a second communications supplier (the “minority” communications network) for remote or hard to reach parts of SCE’s service territory, or to supplement coverage deficiencies identified during field testing. The communications supplier(s) will need to clearly identify how it proposes to meet SCE’s Information Assurance security requirements for protecting the confidentiality and integrity of any data transmitted over the communications network. These robust security requirements are intended to ensure the integrity and confidentiality of the information that is exchanged between the Data Center Aggregator and the AMI Meters and are a response to inadvertent and malicious risks within the environment.

SCE plans to have at least two meter suppliers, at least one of which is able to provide commercial as well as residential meters. As part of the RFP, each meter supplier shall be required to demonstrate that it can provide a meter that includes a communications card procured from the communications supplier and a service switch, among other required components, integrated under the meter cover.

V. METER DATA MANAGEMENT SYSTEM (MDMS) UPDATE

The Meter Data Management System (MDMS) is a key component of the AMI Program and is central in capturing the key benefits to be delivered from AMI. The MDMS provides the core functionality of a Meter Data Repository (MDR), including loading meter data from the telecommunications network, processing the data through Validation, Editing and Estimating (VEE)
processes, and making data accessible to users and other systems. The MDMS facilitates value-added functionality to be enabled through use of data acquired via the AMI System and managed in the MDMS. The functions of the MDMS will provide a substantial expansion of the uses for meter data. Data processed and made available via MDMS to SCE systems will provide near-real-time intelligence to many areas of SCE’s operations. The MDMS will enable many other functions to access data and use it to improve SCE’s customer experience and business operations.

Based on the market survey and analysis conducted in early 2006, SCE proceeded with development of preliminary high level business requirements for an MDMS COTS application and issued a Request for Information in June of 2006 to seven MDMS suppliers. The RFI was structured to provide SCE with a comprehensive view of current MDMS COTS product capabilities and test the assumption that MDMS suppliers will provide enhancements to their COTS applications in terms of functionality and timeframes that are consistent with, and aligned with, SCE’s AMI program needs.

All the suppliers invited to participate in the MDMS RFI issued on June 23, 2006 responded in July 2006. SCE subsequently invited five MDMS suppliers to make presentations and provide detailed demonstration of their products. The results of the RFI and demonstrations were evaluated between July and October 2006 with the assistance of IBM (SCE’s System Integrator for Phase I). The evaluation process led to some key discoveries and direction for developing an MDMS and provided SCE with an analysis of how well each MDMS supplier’s product matched SCE’s expected business functions under the AMI program. The analysis looked at the functionality, costs, risks, implementation time, development time, and license fees.

Based on the market survey and RFI responses, SCE was able to confirm that one or more MDMS COTS applications were presently available in the market place that would, with reasonable enhancements, meet SCE’s initial functionality requirements to support initial AMI program deployment. Moreover, MDMS suppliers’ planned enhancements to their MDMS COTS applications were shown to be in alignment with SCE’s vision for AMI. SCE verified the earlier conclusion that the most effective approach to meet the AMI program MDMS requirements is to acquire an MDMS COTS software package.
A.  **MDMS RFP Summary**

   Building upon the information gathered from the MDMS market survey and RFI, SCE further refined detailed business and technical requirements and issued an RFP to MDMS suppliers on December 15, 2006.  The RFP was sent to the vendors that responded to the June 2006 RFI.

   Key components of the RFP include a detailed response describing how the supplier’s MDMS COTS application currently meets SCE’s detailed business and technical requirements.  If a requirement is not currently met, the supplier is asked to indicate if they plan to provide the feature/functionality/capability and if so, when it will be provided.

   In addition to the written responses, suppliers will be asked to participate in a “Conference Room User Test,” in which SCE will evaluate the user interface and usability of the application as well as application scalability testing in which SCE will evaluate how well the COTS application performs under various simulated operating conditions.

   SCE expects to make a selection of an MDMS supplier in the second quarter of 2007.

**VI. SYSTEM DESIGN**

A.  **Introduction**

   The following information on SCE’s AMI System Design summarizes the information SCE has gathered since releasing the CFR.  Please review sections IV-A "System Design - Overview" of the CFR to obtain additional information regarding SCE AMI System Design activities occurring between December 2005 and July 2006.

B.  **EPRI Intelligrid Integration of SCE AMI Use Cases**

   SCE leveraged the prior efforts of the Electric Power Research Institute’s (EPRI) IntelliGrid Architecture project to provide an initial guiding framework and scope for the requirements gathering process for the SCE AMI project.  The Intelligrid Project utilized “Use Cases” as a means of gathering system requirements, and provided the initial set of uses that SCE adopted for its AMI requirements
gathering process. Once the use cases were completed by the SCE teams, SCE contracted with EPRI to take SCE’s use case content and integrate it back into the Intelligrid model for widespread use by the electric energy industry. This modeling effort was the first attempt to integrate the work of many users and to convert it from an independent requirements gathering activity into a common industry model that can be used to document, specify and ultimately construct and manage AMI systems for electric energy companies. The model can also be used to assist with EPRI’s standards integration and harmonization work to bring the industry together on open systems development. EPRI’s Project Manager for the Intelligrid project has recognized SCE’s leadership and the structured systems engineering approach as a valuable contribution to the industry.

The SCE Use Cases did not precisely conform to the Domain Template format and requirements specification approach used by Intelligrid because SCE customized the template to suit its specific needs. Thus, the EPRI effort was undertaken to merge the SCE Use Cases with the Intelligrid Domain Template format and the associated Unified Modeling Language model thereof. In addition, EPRI was also able to extract requirements from other documentation developed by SCE through the course of the requirements elicitation and refinement process. The model provides a way to manage the complexity of these systems and also provides context for common terminology. This work was completed in October, 2006 and will be published on the EPRI Intelligrid Architecture website as well as the OpenAMI website in early 2007.

C. **SCE AMI Architecture**

SCE’s systems engineering process provides a disciplined approach to designing, deploying and operating an Advanced Metering Infrastructure that meets the needs of its users within a predictable budget and schedule. Engineering principals were covered in detail in the CFR. The following section describes the additional effort in evolving the AMI Conceptual Architecture described in the CFR into a Platform Independent Reference Architecture, which is required to evaluate the capabilities of the proposed supplier products and solutions.
1. **Overview**

The AMI system design work created during Phase I of the project included the development of 18 Use Cases for the AMI technology. These Use Cases are supported by a set of requirements necessary to enable each Use Case. The individual architecture elements and capabilities of each element needed to deliver the functionality to support the AMI Use Cases were developed as part of the Conceptual Architecture documentation completed in June 2006. The Conceptual Architecture provides a total AMI system view and provides the context necessary to understand how supplier solutions fit into SCE’s overall AMI solution.

As SCE’s system design team worked with the supplier community through our Technology Capability Maturity (TCM) framework to understand the capabilities of each offering, it was clear that the technology existed to satisfy SCE’s requirements. However, it was also apparent that some aspects of end-to-end system design and architecture needed more focus to ensure that SCE understood how each supplier’s solution would be integrated into SCE’s entire AMI system. Hence, the system design team used the Conceptual Architecture, completed in the first half of Phase I and described in the CFR, as input to the Platform Independent Reference Architecture with a focus on analyzing the following areas:

- Message Architecture and Analysis Model;
- Network Architecture;
- Integration Architecture;
- Security Architecture.

The goal of Reference Architecture is to develop a set of architecture models that describe how AMI will satisfy specific scenarios and requirements in each Use Case. The system engineering approach adopted by SCE is not only designed to yield a business-aligned architecture but also to ensure the performance requirements of the system are well understood and can be satisfied by the candidate solutions. The following is a summary of the analysis undertaken in each of the architecture areas of the Reference Architecture.
2. **Message Architecture and Analysis Model**

SCE’s AMI system design team developed a platform independent analysis model comprised of Unified Modeling Language (UML) based diagrams. UML is an industry-standard graphical language for specifying, visualizing, constructing, and documenting the artifacts of complex systems. The analysis model describes the system at a high level of abstraction that helps the AMI team comprehend the complexity of the solution and communicate how the system will work. Specifically, the diagrams that comprise the analysis model include the following:

- **Activity diagrams** – Shows the flow of activities involved to complete a process or scenario. Swim lanes representing the elements of the AMI system are represented on the activity diagram to show interfaces and system capabilities.
- **Sequence diagrams** – Sequence diagrams describe the messages that must be passed between objects and actors in a system to satisfy a process or scenario.
- **Class diagrams** – Describe message structure and system behavior necessary to support activities and messages.

The analysis model was used to develop a comprehensive message matrix which identified over 1,200 messages. Each message was analyzed to determine if it is unique or belong to a common set of messages that could be satisfied by a single class. Additionally, the message matrix and activity diagrams were used to identify interfaces as an input to the integration analysis. To the extent possible, unique messages were estimated in size to forecast the average and peak bandwidth required for AMI as part of the network analysis.

3. **Network Analysis**

The system design team developed a set of candidate AMI network design types (for example “full mesh” or “meter to tower”). Using various radio frequency (RF) modeling and simulation tools designed to simulate each network design in SCE’s control area, a network analysis was conducted for each unique network design type. This helped the team understand the operational characteristics of each network design type in SCE’s control area.
Based on the message matrix, a forecast was developed using a scenario that would exercise the AMI system to the fullest extent (for example, a “hot day” with supply constraints, frequent demand response events, remote firmware upgrades, small and distributed outages and regular meter reads.) Each network design type has points of throughput constraints that were calculated to understand if the network design type could perform in the scenario with acceptable capacity left.

The RF analysis and the forecast provided the system design team with an understanding of the AMI network performance requirements and the ability of each solution to satisfy the requirements. Several of the candidate network design types meet the estimated performance requirements while maintaining acceptable levels of network capacity.

Because the AMI network’s performance is a function of reliability, a recommended approach to Reliability, Availability, Maintainability and Safety (RAMS) analysis was developed. Specifically, the approach recommends the development of the following: a reliability block diagram (RBD); overall scenario reliability estimates; and a weakest-link analysis during Phase II of the AMI program.

4. **Integration Analysis**

Using the analysis model as an input, the system design team developed a catalog of interfaces that need to be developed over the AMI implementation period (2007 – 2012). Each interface identified is a high-level logical interface supporting many messages between systems enabling AMI. The interface catalog describes the source and destination of the information to be passed between systems as well as the process and performance requirements of each interface.

Many of the subscribing systems to the AMI information will be decommissioned and replaced over the four year implementation period. Hence, it is necessary to represent interface diagrams at different points in time to gain an understanding of the complex systems integration needed to enable AMI. Four different interface diagrams were developed to represent the integration required for completion of major AMI milestones. This provides the AMI program as well as other SCE enterprise programs with an understanding of when interfaces need to be developed, tested and in
production. The initial integration analysis performed is a framework for managing the complex system integration task over the next four years as well as an estimating basis for SCE’s AMI business case.

5. Security Architecture

SCE recognized the introduction of new capabilities, such as a home-area network coordinator and an integrated service switch under the cover of each AMI meter, introduced new security risks that have not been directly addressed on a total AMI System of Systems level by the utility industry. In order to better understand the scope of the risk, the system design team used SCE’s Unified Information Assurance framework as the foundation to formally analyze the threats and vulnerabilities to AMI. However, SCE also recognized AMI as a complex network-centric system with unique security risks that would not be addressed by the UIA framework. Thus, SCE extended the UIA with elements of the federal government’s Common Criteria method. This provided a structured approach to developing the robust set of security requirements necessary to provide an adequate level of information assurance and reliability for AMI, SCE and its customers. The analysis included the following activities:

- Identification of key AMI resources and assets;
- Identification of security domains;
- Performance of a high-level threat assessment and vulnerability analysis;
- Development of a conceptual security architecture for the AMI network.

As the system design team worked through the vulnerability analysis and understood the risks, SCE sought input from security industry experts, the AMI supplier community, the academic community and other industries to create a conceptual security architecture that mitigated the threats without compromising network performance or unreasonably increasing implementation costs. The resulting conceptual security architecture identified several new security requirements for AMI communications suppliers. Specifically, SCE identified the need to encrypt the network from the AMI meter to SCE’s data center by using encryption keys unique to every device in the network. This requires an electronic key management service to maintain encryption and secure the AMI network end-
to-end. A vulnerability that the conceptual architecture is designed to mitigate is the risk of unauthorized control of the AMI network from an end device.

Appendix B “AMI Information Assurance (IA) Summary” is an exhibit to SCE’s Meters and Telecommunications RFP and provides more detail about SCE’s security architecture and requirements.  

D. **Updates to AMI Requirements**

An on-going review of the AMI requirements was conducted since the CFR was made available in July. The review resulted in modifications to 166 of the previously existing 430 requirements, and the development of 71 additional requirements. The additional requirements focused on three primary areas: security, reporting and network management.

Security requirements included the following capabilities:

- Device Authentication – assurance in edge device (*i.e.*, meters) identification and validation;
- Confidentiality of data in transit – assurance that information while in transit is not disclosed to unauthorized persons, processes, or devices;
- Confidentiality of data at rest – assurance that AMI devices provide active tamper and compromise resistance and recovery;
- Data integrity – assurance that data is unchanged from its source and has not been accidentally or maliciously modified, altered, or destroyed;
- Security Auditing – assurance that malicious activity is detected and reported;
- Secure Update – assurance that AMI devices can be securely and remotely updated and patched.

Additional AMI reporting requirements were designed to address:

- Performance metrics;

---

• Management summaries;
• Automated report generation;
• Ad hoc queries.

Network management requirements were also added, which focused on:

• Real-time alarm notification;
• Fault management/isolation;
• Configuration management;
• Utilization tracking.

Release dates were also assigned to each requirement to provide a time-frame in which each of the AMI system capabilities will be available.

E. **Potential Gas and Water Meter Interface**

SCE met with gas and water company representatives to develop use case scenarios and technical requirements to support possible continuation of SCE’s contract meter reading services, as noted in the CFR filed in July.

On December 14, SCE met with Southern California Gas Company (SCGC) representatives to discuss the potential for joint feasibility testing of gas meter prototypes at SCE’s Telecommunications Test Site during Phase II. The meeting was positive and identified a number of areas for potential cooperation. SCE encouraged SCGC to begin talking with the meter/telecommunications manufacturers that received SCE’s RFP as well as with suppliers that may be able to develop a ZigBee™ gas module. SCE and SCGC agreed to continue communications on this topic and meet again in the first quarter of 2007. SCE remains available and open to discussion with gas and water companies in its territory that are interested in leveraging SCE’s AMI infrastructure.

F. **System Integrator**

A competitive system integrator RFP was issued on June 21, 2006 to identify, qualify and secure the services of a system integrator in support of Phase II planning functions. Part of that process was to
establish pricing and terms that could, at SCE’s option, be used as a basis for continuing system integration work in support of AMI Phase II activities, including the MDMS and back office information systems development.

VII. DESIGN AND TESTING RESULTS

A. Summary

SCE’s testing activities in Phase I focused on verifying the functionality of currently available and emerging technology with the goal of determining whether technology will be able to meet SCE’s stated AMI functionality goals. SCE refined current test processes and developed several new tests in anticipation of receiving integrated products from potential suppliers. SCE also tested a number of AMI components from several Original Equipment Manufacturer (OEM) suppliers, including stand alone and integrated service switches, RF neighborhood-area-network (NAN) communications, and home-area network (HAN) communications. The test procedures and results are described below.

SCE has seen significant progress in the development of next-generation AMI products that will meet SCE’s AMI requirements for functionality and project timing. Therefore, SCE will not have to engage an Engineering Design Contractor to develop design specifications. Instead, SCE will be able to take advantage of the developing market. SCE is confident that these next generation AMI products will provide the added functionality and capabilities SCE requires.

Looking ahead to Phase II, SCE will continue product testing activities, including component level testing and product qualification testing of the candidate AMI meters in advance of planned field tests. SCE will also utilize lab environment testing results to help shape the development of the Field Test plan that will be implemented in Phase II. This will include establishing criteria for testing the majority communication system’s performance in up to ten geographically diverse field test sites.

B. Telecommunications Testing Overview and Results

AMI Phase I included the development of a RF communications test environment and initial testing of some currently available meter communications. To assess AMI communication technology
performance and capabilities, SCE constructed a test facility in Alhambra, California in September 2006. The facility was designed to simulate an environment similar to what is found in a typical Southern California neighborhood. Forty 8’x8’ framed structures wrapped in “chicken wire” were constructed to approximate the typical stucco-wire exterior wall construction commonly found in SCE’s service territory. Meter panels were installed in various locations on each of these framed structures to simulate the wide variety of meter panel locations.

SCE’s RF testing gathers information about the radio network using special tools and software and also observes how the network functions under extreme conditions such as interference. The types of tests conducted include:

- Bandwidth saturation;
- Interference;
- Bit error rate;
- Throughput;
- Interoperability (if applicable);
- Signal Strength.

Since beginning testing in October 2006, SCE has evaluated communications technologies from three suppliers. Results to date have validated SCE’s test environment and processes for evaluating the communications solutions offered. SCE will continue to work with suppliers and test products in Phase II in support of the RFP assessment process.
C. March AFB Testing Overview and Results

To better understand the capabilities and limitations of 900MHz and 2400MHz communications technologies in a real world environment, SCE conducted tests in the abandoned housing units at March Air Force Base (AFB) in Riverside County, California.

To test potential 900MHz RF solutions, 21 low power radios were installed on houses spread over a neighborhood development of stucco homes with distances between devices ranging from 15 feet to 1000 yards. The ability of each radio to recognize the other 20 radios and metrics such as signal strength were recorded. The test also highlighted the effects even minor terrain and foliage obstructions present to radios spaced far apart, and points to the need to closely evaluate the number of repeaters or collectors needed during the deployment phase. To evaluate the 2400MHz band, SCE conducted feasibility tests using a commercially-available Wi-Fi access point and an 802.11g PCMCIA wireless laptop adapter. Signal strength measurements were recorded in varying circumstances and distances.

D. Meter Testing Overview and Results

SCE’s state-of-the-art Meter Test Lab in Westminster was actively involved with technology and product evaluation during Phase I. In addition to developing two new tests to support the AMI Program,
SCE’s Meter Test Lab evaluated of the leading service switches from three manufacturers, two current generation solid-state meters, and two AMI prototype meters.

1. **Service Switches**

The products evaluated included standalone service switches, switches integrated with a well-known meter manufacturer’s product, and switches attached to a meter collar. Limited operational testing was performed on the integrated switches to verify the service switch could open and close via an optical port on the meter or via an RF signal on the collar. Results were positive and confirmed the maturity and ability of the technology to satisfy SCE’s AMI functionality requirement.

2. **Two New Tests Developed**

For meters, two tests were developed as part of SCE’s goal of reducing future meter failure rates and ensure overall meter product longevity. The two tests are the Accelerated Life Test (ALT) and the End-of-Life Test (EOLT):

![Figure 3 Climate Chamber in Westminster](image)

a) **Accelerated Life Test (ALT):**

This test draws upon the U.S. Department of Defense MIL-STD-883E test method standards for microcircuits to predict the life expectancy of a product and identify which of the components within a meter are likely to fail. The test repeatedly subjects meters to extreme climate
cycling and checks whether the meters continue to function accurately. Extreme climate cycling means temperatures ranging from -50° C to +100° C and humidity conditions from zero percent to 100 percent. Observation of the meters and recording the time-of-failure allows SCE to extrapolate an expected useful life based on the Arrhenius equation correlating to an operating temperature of 60°C.

b) **End-of-Life Test (EOLT):**

These tests are structured to determine *how* a product will fail at the end of its expected life. It includes determining whether the meter will fail in a hazardous and/or dangerous way (*e.g.*, fire, non-passive failure, etc.). The EOLT employs similar condition cycling as the ALT and/or uses meters that have undergone ALT to simulate end-of-life conditions. The meters are then subjected to electrical stress conditions such as voltage and current transients, high voltage and high currents and observed for failure behavior. EOLT equipment is composed of a booth, ventilation system, and electric power supply. The ventilated booth provides containment of possible debris or fumes from a meter when it fails. The electric power supply provides source power to test equipment that will subject the unit under test (UUT) to electrical disturbances designed to cause the UUT to fail.

3. **Testing Overview and Results**

Three suppliers provided the Westminster Meter Test Lab with AMI prototype residential meters (one with communications and two without) in great enough quantity to conduct the standard SCE battery of product qualification tests. In addition, a prototype commercial AMI meter was provided for software evaluation only. The testing performed includes:

- **Functionality, Environmental, and Safety Testing**
  - As-found functionality
  - Accuracy
  - Effect of variation of line voltage
  - Temperature cycle
  - Effect of relative humidity
- Momentary power loss
- Power consumption
- Insulation breakdown
- Surge withstand capability (SWC)
- Power line surge
- Effect of RF interference
- RF conducted and radiated emission
- Electrical fast transient (EFT)
- External magnetic field
- Electrostatic discharge (ESD)
- Shipping and vibration
- Power on/off

- **Service Switch Testing** (on AMI integrated prototypes)
  - Switching conditions: voltage, frequency, and short circuit
  - Switching load: resistive and inductive
  - Power failure switching
  - Switching logic

- **Software/Firmware Testing** (when software documentation was made available)

- **Power Quality Testing** (which looks at meter behavior around six main parameters)
  - Voltage
  - Sag
  - Swells
  - Current
  - Total Harmonic Distortion (THD)
  - Individual harmonics

- **Accelerated Life Testing** (as described above)

Phase I testing has yielded the following two main conclusions:
1. Test results support SCE’s revised 20-year useful life. SCE performed accelerated life testing on two solid-state simple kWh meters and two electromechanical meters. The main purpose was to develop and validate the testing process for future AMI products. However, the testing resulted in a predicted life of greater than 20 years for the solid-state meters, exceeding SCE’s initial 15-year life expectation. Traditional electromechanical meters have a 30-year rated life; and

2. The market is quickly moving in the direction needed to support SCE’s stated AMI technical requirements and functionality, and SCE fully expects several integrated AMI products to be available for the February 2007 product qualification testing.

E. Home Area Network

As a central element of SCE’s customer experience and intelligent grid initiatives, the home area network component picture came into sharper focus during Phase I. SCE continued to monitor the technology landscape and confirmed the broader industry’s move to support the ZigBee™ wireless communications IEEE 802.15.4 standard for home automation and systems control. Discussions with major appliance and Programmable Communicating Thermostat (PCT) manufacturers inform SCE that commercially available products will be available in 2007. Due to this wide support from home appliance and control companies, SCE decided to join the ZigBee™ Alliance in October 2006 to actively participate in the dialogue shaping the direction of the standard and keep abreast of products in development.

1. Testing overview and results

As mentioned in the CFR, it appears that ZigBee™ is emerging as the industry’s leading choice for a HAN communications protocol for residential applications. SCE began to evaluate ZigBee™ in October 2006 on an informal basis. SCE set up a portable, 100mW Effective Isotropic Radiated Power (EIRP) - ZigBee™ radio and mounted another 100mW EIRP radio next to a meter at an employee’s home and conducted tests to look at:
- Packet loss;
- Received Signal Strength Indication (RSSI);
- Interference from construction features and other consumer electronics (like Wi-Fi routers and microwave ovens) that operate in the 2400MHz frequency.

The goal was to evaluate and become familiar with the ZigBee™ communication standard. The test results were very positive with the radios able to communicate in all 29 areas of the single family, 1,600 square foot, single story stucco house where measurements were taken. This includes areas where the radios were 10-15 meters apart and there were 5-6 intervening walls.

As SCE continues to evaluate ZigBee’s™ capabilities to meet SCE’s AMI requirements, testing will carry into Phase II as potential supplier products equipped with ZigBee™ communication become available. Testing will also be organized to evaluate ZigBee™ behavior in other types of dwellings, including multi-family, multi-story apartment complexes.

2. **Home Area Network Interactive Demo**

![AMI Demonstration Display](image)

Figure 4 AMI Demonstration Display

To better communicate SCE’s vision of empowering the customer to manage their lifestyle through its AMI system, SCE commissioned an interactive demonstration display through one of the suppliers receiving its RFP. The demonstration illustrates the HAN capabilities of SCE’s design by using a ZigBee™-type radio that communicates with customer devices around the home, including a PCT, a remote appliance control (RAC) device, and an in-home display. The demonstration shows how
customers potentially will be able to get their energy usage information in near-real time, use software tools to set and track a monthly budget, remotely control their thermostats, and receive messages and critical peak power alerts from SCE.

SCE showed the demonstration to a wide audience at its Quarterly Stakeholder Briefing on November 30, 2006 and at the Edison Electric Institute (EEI) Investors Conference in early-November. In Phase II, SCE will develop an updated demonstration once the final supplier selection has been made.

VIII. **CONCLUSION**

AMI Phase I was initially scheduled to take 18 months to complete, including the development of working prototypes and engagement of an Engineering Design Contractor. However, based on the significant progress made by meter and telecommunication providers in 2006 and verified by SCE’s design and testing results and market assessment activities, SCE’s AMI Phase I has been completed in about thirteen months. The results of Phase I were universally positive, and have demonstrated that SCE’s AMI solution is technically and financially feasible. Consequently, SCE is ready to proceed with AMI Phase II, the pre-deployment phase. On December 21, 2006, SCE filed Application (A.)06-12-026, requesting authority to implement AMI pre-deployment activities during 2007, which will lay the groundwork for full AMI deployment to begin in early 2008.8

8 SCE’s Phase II application (A.06-12-026) is available in the regulatory filings section of SCE’s AMI web site: [http://www.sce.com/ami/](http://www.sce.com/ami/).
APPENDICES
## 1. Conceptual Architecture Deliverables

<table>
<thead>
<tr>
<th>Architecture Deliverable</th>
<th>Definition</th>
<th>AMI Activity &amp; Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global Actors List</td>
<td>When an event occurs that causes interactions between a system and its environment, entities in the environment are involved in the interaction. Some of the entities initiate the event; others interact with the system as a result of the event. These entities are known as actors. An actor is a role, not a person; therefore, in order to understand how an actor interacts with the system across many use cases, it is necessary to have a Global Actors List.</td>
<td>The Global Actors list defines a coherent set of roles (actors) that users of the system may play when interacting with it. This list shall ensure that actors have consistent names across all use cases. To fully understand the system's purpose you must know who the system is for, that is, who will be using the system and how the system responds to a particular actor’s interaction with the Advanced Metering Infrastructure (AMI).</td>
</tr>
<tr>
<td>Use Cases</td>
<td>A use case describes the system’s behavior under various conditions as the system responds to a request from the primary actor. The use case describes a sequence of actions that provide a measurable value to an actor when the primary actor’s goal is accomplished.</td>
<td>The AMI System Design Team conducted use case workshop sessions to develop 18 use cases. Use cases are the vehicle to capture requirements for the AMI. The use cases also serve as the basis for allocating functionality to components and architecture elements within the AMI solution to help SCE communicate our vision of the AMI system implementation.</td>
</tr>
<tr>
<td>Requirements Report</td>
<td>A functional requirement specifies the capabilities which the system must be able to support. While a non-functional requirements specify “how quickly, how often and/or how much” as well as what range of conditions the system is required to perform under.</td>
<td>The purpose of the requirements report is to collect, detail and organize the set of functional requirements that completely describe capabilities desired by SCE from our AMI solution as well as detail the set of non-functional requirements that describe the performance boundaries and operational characteristics desired by SCE from our AMI solution.</td>
</tr>
<tr>
<td>Architecture Deliverable</td>
<td>Definition</td>
<td>AMI Activity &amp; Purpose</td>
</tr>
<tr>
<td>--------------------------</td>
<td>------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>Component Architecture</td>
<td>The term &quot;component&quot; is defined as an encapsulated part of a system, ideally a non-trivial, nearly independent, and replaceable part of a system that fulfills a clear function in the context of a well-defined architecture.</td>
<td>Component architectures help SCE manage the complexity of our AMI system design by providing the architecture team with logical segments of the AMI solution. The component architecture is used to facilitate communication of our requirements to suppliers and other stakeholders and describe SCE’s expectations on what capability each element within the AMI solution should have to meet our project goals.</td>
</tr>
<tr>
<td>Requirements to Component Matrix (a.k.a. Traceability Reports)</td>
<td>Requirements are analyzed and mapped to the components that will fulfill each requirement. Components and their capabilities are mapped to the AMI business case through the requirements and scenarios.</td>
<td>The requirements to components matrix allows the System Design team to understand the required behavior of each component necessary to realize the use cases. Additionally, the matrix allows the architecture and engineering teams to understand component interface boundaries and how components must function together within the AMI solution to fulfill a particular use case scenario. Requirements and scenarios are linked to architectural elements and SCE’s business case for AMI.</td>
</tr>
<tr>
<td>Candidate Standards catalog</td>
<td>A listing of candidate standards that may be applicable to AMI.</td>
<td>The engineering design team evaluated a number of candidate standards to determine fit with our AMI objectives and design principles.</td>
</tr>
<tr>
<td>Initial Security Analysis</td>
<td>The initial security analysis is an initial identification of the data requiring protection within the AMI system.</td>
<td>The result of this analysis is a spreadsheet identifying the data requiring protection within the AMI system, cross-referenced with a variety of technologies and methodologies that might be able to protect that data. This serves as the foundation for a more in depth AMI security analysis in the reference architecture document.</td>
</tr>
<tr>
<td>Architecture Deliverable</td>
<td>Definition</td>
<td>AMI Activity &amp; Purpose</td>
</tr>
<tr>
<td>--------------------------</td>
<td>------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>TCM Analysis</td>
<td>The Technology Capability Maturity frameworks are a series of scales consisting of numbers from 0 to 5 used to evaluate the capability of an AMI system in a number of different technology categories</td>
<td>The TCM scales represent a superset of the requirements identified in the Requirements Report and are used to understand the suppliers’ capabilities and the direction the industry is evolving AMI products and solutions.</td>
</tr>
<tr>
<td>Key Integration Points Diagram</td>
<td>A data flow diagram describing the data exchange between the AMI high level actors.</td>
<td>This diagram provides the basis for understanding the information flow across the SCE enterprise and to external entities necessary to support the business case. The diagram contains layers that may be turned on or off to isolate specific use cases and business domains.</td>
</tr>
<tr>
<td>Initial Message Matrix</td>
<td>A catalog of messages necessary to enable the scenarios and steps from the use cases.</td>
<td>Each of the over 1200 messages necessary to support the use case scenarios is listed in a spreadsheet identifying the source, destination, sequence, periodicity, and type of the message, as well as the Interface from the Interface Diagram that the message belongs to. Eventually this Message Matrix will be used to estimate the required performance of the AMI network during reference architecture.</td>
</tr>
<tr>
<td>Conceptual Architecture Report</td>
<td>A highly generic and generalized view of the system that is used to communicate the boundaries of the scope of the project and major architectural elements.</td>
<td>The purpose of the conceptual architecture is to convey an understanding of the high-level structure of the intended AMI system to the stakeholders and project team.</td>
</tr>
</tbody>
</table>
## 2. Reference Architecture Deliverables

<table>
<thead>
<tr>
<th>Architecture Deliverable</th>
<th>Definition</th>
<th>AMI Activity &amp; Purpose</th>
</tr>
</thead>
</table>
| AMI Platform Independent Models | A platform independent model (PIM) describes a system without any knowledge of the final implementation platform or technology. The model is described using the following UML diagram types. 
- Use Case Interaction Diagrams 
- Activity Diagrams (with swim lanes) 
- Sequence Diagrams 
- Class Diagrams | The engineering and architecture teams developed a set of UML models that describe component interactions within the system and characterize the features required for each component. The PIM serves as a means to evaluate supplier solutions and determine any gaps that might exist. |
| AMI Message Analysis & Network Sizing Estimates | A matrix that captures all the messages found in the AMI Message Sequence Diagrams. | The AMI Message Matrix includes over 1200 messages identified in the Sequence Diagrams needed to support the scenarios in the use cases. The purpose of the matrix is to:
  - Determine the minimum set of unique messages required to support all the AMI use cases.
  - To classify the messages in a logical manner so the behavior of the AMI can be analyzed.
  - To define each interface defined in the Interface Diagram as a set of messages. To forecast the average and peak bandwidth required for the AMI. |
<table>
<thead>
<tr>
<th>Architecture Deliverable</th>
<th>Definition</th>
<th>AMI Activity &amp; Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMI RF Analysis Reports</td>
<td>An analysis of selected RF-based candidate solution patterns (i.e. full mesh or meter to tower) probable performance in the SCE control area.</td>
<td>The purpose of the analysis was to provide SCE with an indication of the RF coverage that SCE can expect in our service territory, an estimate of orphaned meters, number of collectors/network equipment needed to cover the territory using the transmit power of the radio’s, frequencies used, available channels, channel spacing etc that SCE anticipates from the supplier products that will become available in the near future. The findings are used to refine AMI network requirements and serve as an estimating basis for the business case.</td>
</tr>
<tr>
<td>High-Level Security Architecture</td>
<td>The High-level security architecture includes a security framework, identification of security domains, threat and vulnerability analysis and a conceptual security architecture diagram.</td>
<td>The High-level security architecture is used to identify and mitigate new and ongoing security-related risk to the SCE business model incurred by the AMI in a systematic, verifiable, and documented fashion.</td>
</tr>
<tr>
<td>Integration Architecture Analysis</td>
<td>The AMI integration architecture analysis includes an interface catalog, a set of interface diagrams representing integration at various points over the next four years and an initial interface implementation plan.</td>
<td>Using the key integration points, message matrix and activity diagrams as inputs the integration architecture analysis is intended to describe high-level logical interfaces that will need to be implemented between systems in order to enable the AMI use cases.</td>
</tr>
<tr>
<td>Use Case Test Report</td>
<td>A report that documents gaps between the PIM and the requirements.</td>
<td>The purpose of the use case test report is to highlight gaps and challenges of the Advanced Metering Infrastructure (AMI) architecture as it relates to the requirements derived from SCE’s AMI use cases. The methodology used to perform the analysis was to review the use case documents, sequence diagrams, activity diagrams and system interface diagram and determine if the architecture meets the stated requirements. The report is used to identify areas of focus in the development of the Platform Specific model in Phase II.</td>
</tr>
<tr>
<td>Architecture Deliverable</td>
<td>Definition</td>
<td>AMI Activity &amp; Purpose</td>
</tr>
<tr>
<td>---------------------------</td>
<td>------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>RAMS Analysis Approach</td>
<td>A document recommending an approach to Reliability, Availability, Maintainability and Safety (RAMS) analysis for SCE’s AMI.</td>
<td>The RAMS analysis approach will be used to develop SCE’s approach to RAMS analysis for AMI in phase II. Specifically, the approach recommends the development of the following: a Reliability block diagram (RBD); overall scenario reliability estimates; and a weakest-link analysis.</td>
</tr>
</tbody>
</table>
| AMI Technology Roadmap    | The AMI Technology Roadmap identifies entities, organizations, standards and milestones that SCE should consider throughout the technological development of the SCE AMI. | The AMI Technology Roadmap contains:  
- A description of the goals of an ideal AMI system from an open systems perspective  
- A list of obstacles in the way of achieving those goals  
- A list of milestones toward achieving those goals and a diagram illustrating dependencies between the milestones.  
This document will be used to communicate our system design goals and principles to new AMI team members and suppliers and as a mechanism to maintain focus on our design goals. |
| Reference Architecture Report | The Reference Architecture Report is a summary of all of the reference architecture work completed during phase I of SCE’s AMI project. | The Reference Architecture consists of a Platform Independent set of architecture models, analyses and reports that describe the candidate technologies, standards and component boundaries in sufficient detail to use as a mechanism to understand how individual supplier solutions fit into the overall AMI and how closely each satisfies SCE’s AMI requirements. |
B. AMI INFORMATION ASSURANCE (IA) SUMMARY

The architectural considerations and functionality presented within this AMI Information Assurance (IA) architecture summary are for context and reference. The AMI IA conceptual architecture is based on the notion that security functionality is an engineered response to risks (i.e., threats) within the AMI environment. The mechanisms discussed within this summary, which are specified in the requirements, are focused on the system level risks. As with any system, product specific security deficiencies have the potential to compromise the greater system. For this reason, suppliers must design and implement an appropriate level of system and product level assurances.

The end-to-end cryptographic solution presented within this summary mitigates the largest and potentially most costly vulnerabilities associated with management and control of the AMI Meter and HAN devices. These vulnerabilities are related to the confidentiality of information in transit, access controls, accountability of various AMI components, and the integrity of the information and resources. Vulnerabilities related to availability and Denial of Service (DoS) are required, but not covered in this conceptual architecture.

Cryptographic functionality is critical to overall robustness of the AMI system. AMI Cryptographic Services encompass both the distribution and use of cryptographic material. Successful implementation of the Cryptographic Services requirements should provide both confidentiality and integrity of information in transit, as well as, strong device authentication. The conceptual architecture targets the minimum base functional requirements and any deviation from this conceptual architecture that enhances the overall security is welcome.

AMI Cryptographic Services requirements are based on the notion that information and resources should only be accessed by authorized entities. More specifically, access and control of meter data and meter configurations should only be accessed by the authorized field and back office systems and users. This access consideration suggests two end points of an authorized communication channel (i.e., DCA and meter). Critical information flowing between these two logical end points should be
cryptographically bound. Simply stated, encryption of critical meter data needs to be performed at the AMI Meter and decrypted at the back office Head-end System.

To facilitate such end-to-end confidential exchange, a certain amount of cryptographic functionality is envisioned within the DCA. DCA functionality should include management, accounting and distribution of cryptographic materials. Specifically, DCA should handle all functions related to generation, distribution, safeguarding, auditing, and replacement of cryptographic materials. In addition to confidentiality considerations, a correctly implemented cryptographic management service will enable secure meter authentication, registration and revocation. The Cryptographic Services associated with the DCA should be both modular and scalable. The interface should be designed and implemented in such a way as to allow the suite of DCA related cryptographic functions to be published and called.

Data generated at the AMI Meter should be encrypted before transmission. The actual encryption and decryption algorithms and handling requirements are called out in Federal Information Processing Standards Publications 140-2 and 197. Additional algorithms outside the scope of the symmetric cipher should be sufficiently strong and ultimately provide additional security robustness. Unique cryptographic material (e.g., key or certificate) should be used to authenticate edge devices (e.g., AMI Meter). This authentication material can be used in negotiation and secure session generation. Any key material used within AMI communication infrastructure should remain under the administrative control of SCE.

Ideally, devices within the HAN should also be authenticated. The Cryptographic Services can be used to authenticate the HAN edge devices. This technique extends the cryptographic enforcement and authentication techniques beyond the AMI Meter. This approach may require standards definition beyond the scope of this RFP.

The preferred AMI authentication method involves the use of cryptographic functionality. In certain instances, cryptographic methods may be cumbersome. Specifically, local AMI Meter authentication through the optical port and back office user access should at the very least use strong two and three factor authentication methods.
AMI devices should use both defense in depth and breadth techniques for assuring the integrity of the system. In addition to the AMI cryptographic functions, the communications infrastructure should be designed to include several logical filters within the system. Each one of the filters provides a means of segmenting more critical aspects of the network. Filtering functions should be implemented in all logical aggregation points. This includes HAN segmentation using AMI Meter based filtering and meter segmentation using aggregation point filtering. The robustness and sophistication of the filtering should increase as the information nears the AMI Meter data collection point in the back office. Filters within the edge device should validate the structure, destination and source of the message. Conversely, Head-end System filters should provide a full complement of firewall functionality, including deep packet inspection and intrusion prevention (i.e., IPS).

All elements within the AMI architecture will use preemptive and preventative measures to minimize damage and to enable a successful compromise recovery. Compromise and tamper requirements are intended to provide mechanisms that prevent compromise resulting from deliberate or inadvertent acts and as a consequence of naturally occurring events. Specifically, AMI devices should implement compromise resistance and tamper resistant mechanisms. AMI devices should prevent, detect, and resist electronic and physical tampering.

AMI requires all devices to provide an auditing function to ensure that all relevant security related events can be traced and analyzed. These audits should be accessible and/or stored in, a central repository. This repository will enable the active tracking, intrusion detection and pattern recognition associated with overt and subtle threats posed by both external and internal activities. The audit functions and data are often a target of malicious use. To this end, AMI audit services should provide access control mechanisms to protect and ensure the confidentiality and integrity of audit data.
<table>
<thead>
<tr>
<th>ACROnym</th>
<th>Glossary</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMI</td>
<td>Advanced Metering Infrastructure</td>
</tr>
<tr>
<td>AMR</td>
<td>Automated Meter Reading</td>
</tr>
<tr>
<td>CFR</td>
<td>Conceptual Feasibility Report</td>
</tr>
<tr>
<td>COTS</td>
<td>Commercial-Off-The-Shelf</td>
</tr>
<tr>
<td>CPUC</td>
<td>California Public Utilities Commission</td>
</tr>
<tr>
<td>CSBU</td>
<td>Customer Service Business Unit</td>
</tr>
<tr>
<td>DCA</td>
<td>Data Center Aggregator</td>
</tr>
<tr>
<td>EPRI</td>
<td>Electric Power Research Institute</td>
</tr>
<tr>
<td>ERP</td>
<td>Enterprise Resource Planning</td>
</tr>
<tr>
<td>FFR</td>
<td>Final Feasibility Report</td>
</tr>
<tr>
<td>HAN</td>
<td>Home-Area Network</td>
</tr>
<tr>
<td>IA</td>
<td>Information Assurance</td>
</tr>
<tr>
<td>IT</td>
<td>Information Technology</td>
</tr>
<tr>
<td>MDMS</td>
<td>Meter Data Management System</td>
</tr>
<tr>
<td>MDR</td>
<td>Meter Data Repository</td>
</tr>
<tr>
<td>NAN</td>
<td>Neighborhood-Area-Network</td>
</tr>
<tr>
<td>OEM</td>
<td>Original Equipment Manufacturer</td>
</tr>
<tr>
<td>RAMS</td>
<td>Reliability, Availability, Maintainability And Safety</td>
</tr>
<tr>
<td>RBD</td>
<td>Reliability Block Diagram</td>
</tr>
<tr>
<td>RF</td>
<td>Radio Frequency</td>
</tr>
<tr>
<td>RFI</td>
<td>Request For Information</td>
</tr>
<tr>
<td>RFP</td>
<td>Request For Proposals</td>
</tr>
<tr>
<td>SCE</td>
<td>Southern California Edison</td>
</tr>
<tr>
<td>TCM</td>
<td>Technology Capability Maturity</td>
</tr>
<tr>
<td>UML</td>
<td>Unified Modeling Language</td>
</tr>
<tr>
<td>VEE</td>
<td>Validation, Editing And Estimating</td>
</tr>
</tbody>
</table>