

AMI Risk Assessment and Security Requirements

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Technical Update, November 2009

EPRI Project Manager

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PRODUCT DESCRIPTION

Advanced Metering Infrastructure (AMI) is a transforming technology that has broad impact on the energy market and its consumers. AMI allows utilities to balance supply, demand, and capacity making a smarter, more efficient, grid by pushing aspects of grid monitoring and control out to the endpoints of delivery. Stakeholders are implementing the systems and technologies required to deploy AMI today.

AMI systems promise to provide advanced energy monitoring and recording, sophisticated tariff/rate program data collection, and load management command and control capabilities. Additionally, these powerful mechanisms will enable consumers to better manage their energy usage, and allowing the grid to be run more efficiently from both a cost and energy delivery perspective. These advanced capabilities will also allow utilities to provision and configure the advanced meters in the field, offering new rate programs, and energy monitoring and control. With the advanced functionality, however, comes great responsibility. It is the purpose of this document to provide utilities with some guidance to build security into the basic fabric of this deployment.

In Chapter 1, a qualitative methodology for identifying key AMI assets, their threats, vulnerabilities, and risks to support security control development is presented. While many such methods exist for information technology and industrial control systems today, no method is adapted for the needs presented by the increased exposure of the AMI field systems. The method used proceeds by characterizing critical assets and their security concerns, system threats, critical asset vulnerability, and concludes with a method for analyzing risk. The method is then applied to a representative high level set of AMI assets.

This Security Risk Assessment (SRA) described in Chapter 1 is a tool to help stakeholders identify the risk values in each AMI security domain, and in turn make effective decisions about how to mitigate those risks.

The purpose AMI Security Specification in Chapter 2 is to provide the utility industry along with supporting vendor communities and other stakeholders a set of security requirements that should be applied to AMI implementations to ensure the high level of information assurance, availability and security necessary to maintain a reliable system and consumer confidence. While this specification focuses on AMI, the security requirements contained in the document may be extended to other network-centric, Smart Grid solutions.

Results and Findings

The reader of this document will obtain an initial set of risk values in each AMI security domain and the security requirements that need to be met to mitigate the risks that are posed by the known threats to the AMI System based on the use cases collected. Utility security experts can use this information to develop Request for Proposals (RFP) for AMI Vendors for procurement of AMI technology for their service territories.

Challenges and Objectives

This report is intended for utility AMI security experts and the AMI vendors that are developing products in this space. The liability associated with security breaches in Smart Grids would make this report very useful to utilities that are deploying or planning to deploy AMI systems. These utilities would be well advised to continue supporting this research work to analyze new AMI security related use cases to add to the list of risk values based on additional transactions and derive new security requirements to mitigate the risks identified. This is an ongoing research activity funded by the EPRI Intelligrid Program. The EPRI Intelligrid Program cyber security research team is collaborating with the NIST Cyber Security Coordinating Task Group (CSCTG) as well as the UCA Advanced Security Acceleration Project (ASAP-SG) initiative to develop AMI security requirements as part of the overall Smart Grid security architecture development.

Applications, Values, and Use

The AMI security requirements gathering process is ongoing in 2009 within the EPRI Intelligrid Program under Project Set 161 E (Cyber Security). A new AMI Security requirements document will be released by EPRI in December 2009 as a Technical Update to this document.

EPRI Perspective

EPRI is an unbiased research and development organization that strives to offer its members objective advice on science and technology issues. This report provides such objectivity in its analysis of the risks associated with AMI systems and the security requirements that need to be met to mitigate these risks to the utility infrastructure. The uniqueness of this document in the market is that it is based on a collaborative research model that has brought skilled cyber security professionals from academia, national labs, utilities, and the business world to work together to build an industry consensus on AMI system risk assessment and the security requirements. The diversity of opinion and the vast informational resources that were used to carry out the risk assessment and derive security requirements makes this document truly unique in the industry.

Approach

The goal of this document was to identify and assess the cyber security risks associated with AMI Systems and the security requirements that have to be met to mitigate the risks identified. A use case methodology was used to carry out the work. This information could be valuable for utilities that are evaluating AMI Systems for deployment in their service territories for supporting business critical applications such as automated meter reading, auto connect/disconnect and Demand Response.

Keywords

Advanced Metering Infrastructure (AMI)

Cyber security

Use Case

Risk assessment

Security Requirements

Security Architecture Description

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AMI SECURITY RISK ASSESSMENT

Introduction

Overview

Advanced Metering Infrastructure (AMI) is a transforming technology that has broad impact on the energy market and its consumers. AMI allows utilities to balance supply, demand, and capacity making a smarter, more efficient, grid by pushing aspects of grid monitoring and control out to the endpoints of delivery. Stakeholders are implementing the systems and technologies required to deploy AMI today.

Advanced metering infrastructure systems promise to provide advanced energy monitoring and recording, sophisticated tariff/rate program data collection, and load management command and control capabilities. Additionally, these powerful mechanisms will enable consumers to better manage their energy usage, and allowing the grid to be run more efficiently from both a cost and energy delivery perspective. These advanced capabilities will also allow utilities to provision and configure the advanced meters in the field, offering new rate programs, and energy monitoring and control. With the advanced functionality, however, comes great responsibility. It is the purpose of the EPRI Intelligrid Program to provide utilities with some guidance to build security into the basic fabric of this deployment.

In this chapter, a qualitative methodology for identifying key AMI assets, their threats, vulnerabilities, and risks to support security control development is presented. While many such methods exist for information technology and industrial control systems today, no method is adapted for the needs presented by the increased exposure of the AMI field systems. The method used proceeds by characterizing critical assets and their security concerns, system threats, critical asset vulnerability, and concludes with a method for analyzing risk. The method is then applied to a representative high level set of AMI assets.

The Security Risk Assessment (SRA) described in this chapter is a tool to help stakeholders identify the risk values in each AMI security domain, and in turn make effective decisions about how to mitigate those risks.

Scope

This chapter provides guidance for conducting the SRA in support of AMI architecture development. Organizations involved with AMI deployments will find the information contained in this chapter to be a valuable resource in understanding AMI system risk. This assessment is designed to address the specific security needs, organizational objectives, utility products and services, and processes and specific practices in regard to utility AMI deployment.

Security issues are elicited and aggregated for AMI critical assets from Premise Edge Services to Utility Operations. This assessment does not address non-AMI utility networks.

AMI-SEC has defined and tailored a risk assessment methodology specifically for AMI that includes:

- Identification of security domains,
- Identification of key AMI assets for each security domain,
- Description of security concerns for each asset,
- Identification of threats and threat agents,
- Evaluation of vulnerabilities associated with assets and security domains,
- Consideration of attack likelihood, and
- Evaluation of successful attack consequences

The valuation of asset security concerns is considered input to the risk assessment methodology utilities may use to determine asset exposure and ultimately, control selection. This document does not advise mitigating measures or prescribe controls against risk determination. Control recommendations are conducted in a separate document.

Assumptions about AMI Security

The following assumptions are listed to better clarify the scope of the risk assessment problem within the advanced metering infrastructure system [SPP05].

- AMI is a new application domain for system stakeholders, requiring new application of risk assessment, and subsequent security controls prescription.
- Consumers of this document have the ability to identify inputs to the risk assessment process.
- Consumers of this document are responsible for mapping and adapting its tenets to the protection of the value of their individual business values.
- An AMI system security design should incorporate principles of system survivability.
- Stakeholders for this document give preference to openness in security standards, guidelines, methodologies, and ultimately technology.

Methodology

Risk Assessment Steps

There are many definitions of risk, but each has different implications for the nature of the AMI security problem. We leverage two definitions of risk that match the AMI community concerns

- A systems definition of Risk: The level of impact on organizational operations (including mission, functions, image, or reputation, organizational assets, or individuals resulting from the operation of an information system given the potential impact of a threat and the likelihood of that threat occurring. [NIST800-53 Rev2]
- How to compute Qualitative Risk: a function of the likelihood of a given threat-source's exercising a particular potential vulnerability, and the resulting impact of that adverse event on the organization. [NIST800-30]

We adapt a methodology of understanding AMI critical system asset risk. The risk assessment is presented in terms of a static assessment in this document, but must become part of a recurring

risk management process for utilities implementing AMI-SEC recommendations to make it compliant with a goal of system survivability.

The following steps are taken directly from NIST 800-30 as a reasonable process for determining and documenting qualitative asset risk:

Step 1 – System Characterization (Asset Identification for the purposes of AMI)

Step 2 – Threat Identification

Step 3 – Vulnerability Identification

Step 4 – Control Analysis [not considered by this document]

Step 5 – Likelihood Determination

Step 6 – Impact Analysis

Step 7 – Risk Determination

Step 8 – Control Recommendations [not considered by this document]

Step 9 – Results Documentation

For the purposes of the initial assessment, Steps 4 and 8 of the NIST SP 800-30 process are not addressed, but rather deferred to a future design document as this document presumes no specific system architecture. As an organization matures and systems are deployed, the utility can easily incorporate existing mitigations into their process. Note steps 2, 3, 4 and 6 may be done in parallel after step 1 is completed. AMI specific policies for assessing risk are described in each of these steps below.

Mapping Risk through Security Domains

In the interest of approaching risk assessment in a way that is manageable, scalable and traceable, this document utilizes the IntelliGrid concept of Security Domains to aggregate logically cohesive system security requirements. A Security Domain (SD) represents a set of resources (e.g. network, computational, and physical) that is governed/secured and managed through a consistent set of security policies and processes. Thus each Security Domain that might be considered for AMI-SEC is responsible for its own general security process (e.g. Assessment, Policy, Deployment, Monitoring, and Training).

A Security Domain provides a well-known set of security functions that are used to secure transactions and information within that domain. We scale our risk assessment process by grouping AMI assets into Security Service Domains and subsequently treating risk by domain. This approach manages the explosion of relationships possible across the number of assets, threats, and vulnerabilities, and allows the mapping of Security Objectives (sometimes called Security Functional Requirements) to Security Service Domains. The rationale and design of the AMI security domains is given in a separate document.

Figure 1-1 illustrates relationships considered for mapping approach.

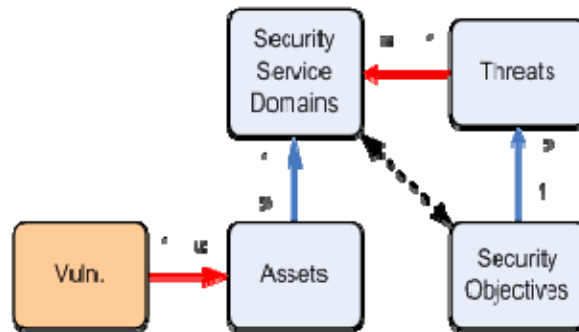


Figure 1-1
Risk Assessment Element Mapping

AMI-SEC utilizes the following definitions from NIST IR 7298 for purposes of the mapping process:

Asset: A major application, general support system, high impact program, physical plant, mission critical system, or a logically related group of systems. (Note: this is a systems definition of the term “asset,” which is appropriate for this level of analysis. Other uses of the term in this document are accompanied by explanation or definition.)

Threat: Any circumstance or event with the potential to adversely impact organizational operations (including mission, functions, image, or reputation), organizational assets, or individuals through an information system via unauthorized access, destruction, disclosure, modification of information, and/or denial of service.

Vulnerability: Weakness in an information system, system security procedures, internal controls, or implementation that could be exploited or triggered by a threat source.

Security Objective: Requirements levied on an information system that are derived from laws, executive orders, directives, policies, instructions, regulations, or organizational (mission) needs to ensure the confidentiality, integrity, and availability of the information being processed, stored, or transmitted.

Additionally, AMI-SEC utilizes the following definition in the mapping process

Security Service Domain: A set of assets with common security concerns and requirements.

This model captures the fact that threat agents (especially when malicious) do not always directly attack the end-target asset. The threat agent is not limited to the particular set of vulnerabilities associated with the end-target asset, but can instead exploit any vulnerability belonging to any asset within the same security service domain. The threat agent may subsequently leverage any existing and legitimate trust relationship within the domain to compromise the end-target asset. Thus, evaluation of the legitimacy or probability of a threat exploiting a specific vulnerability becomes moot.

The mapping process most importantly results in the ability to link security objectives (requirements) with security service domains. This link may subsequently be traced back through

individual assets to determine appropriate mitigating controls for vulnerabilities within a specific domain.

Asset Identification Methodology

Assets are things of business value to the stakeholder that it desires to protect and sustain. The asset identification phase within the SRA is the first step in the assessment of critical infrastructure. Each asset identified will have a degree of due diligence applied to its risk assessment output. It is important to limit assets considered by risk management efforts to those with true value to the AMI system. Any culling of assets should occur at this early stage. To help determine asset risk, we attempt to identify its context of use, its value, its impact, and specific security concerns it may have for its use context.

Asset Identification Inputs

Inputs into the Asset Identification process can include just about anything contributing value or considered for protection. However, we are most concerned with assets having high likelihood of being compromised, high consequences resulting from compromise, or sufficient combination thereof. The list will cover assets such as:

- Business Values
- Hardware
- Software
- System Interfaces
- Data and Information
- People
- System Mission

Asset Identification Outputs

Outputs of the Asset Identification process will include:

- Description
 - Name
 - Security requirements domain
 - Asset type
 - Contexts of use
- Security Profile
 - Security concerns
 - Value
 - Impact & consequence

Description

Each asset will be described by name, the security service domain in which it resides, asset type (e.g.: information, equipment, etc...), and any contextual use information that helps situate it in the AMI architecture.

Security Concerns

Protection concerns are varied as they are derived from the security attributes required by a particular system. Depending on role, location, and context an asset will have different sensitivities for each of the security attributes. These security attributes include confidentiality, integrity, availability, authentication, access control, and accounting.

Value Concerns

At the highest, most abstract level, assets are traced through business functions to organizational mission and values. The value of an individual system-level asset is ultimately derived from its role and criticality in an organization achieving said mission by the enablement of associated business functions.

Impact & Consequence Concerns

Consequence is the result of an unwanted incident, caused either deliberately or accidentally, which affects the assets. The consequences could be the destruction of certain assets, damage to the IT system, and loss of confidentiality, integrity, availability, accountability, authenticity or reliability. Possible indirect consequences include financial losses, and the loss of market share or company image.

Impact is a measurement of the magnitude of influence associated with results of an unwanted incident. The measurement of impacts permits a balance to be found between the results of an unwanted incident and the cost of the safeguards to protect against the unwanted incident. [SSE-CMM v.3]

The following table highlights a suggested classification of consequence severity due to expected asset impact based on an ANZ 4360:2004 example:

Table 1-1
Example policy for consequence severity determination

		Consequence Types			
		Project Cost	Financial Impact	Customer Impact	Regulatory and Compliance Impact
Severity Level	High	\$3M or more	\$50M or more	10,000 or more	Substantial financial penalties
	Medium	\$1M - \$3M	\$1M-\$49M	1,000 to 9,999	Limited financial penalties
	Low	\$1M or less	\$1M or less	Less than 1,000	No regulatory or compliance issues

These consequences are provided as an example. Each utility will need to define its own thresholds for severity and impact.

Mission criticality is defined as the extent to which a system is an integral, functioning part of the business and mission of the organization. NIST has identified three categories of criticality that can be assigned to specific systems. Criticality can be interpreted as the impact on the system operation, on human lives, on operational cost and other critical factors, when a leveraged function is compromised, modified, or unavailable in the operational environment.

**Table 1-2
Criticality Categories**

Category	Definition	Criteria
Mission Critical	Systems that would preclude an organization from accomplishing its core business functions if they fail.	Supports a core business function. Single-source of mission-critical data. May cause immediate business failure upon system failure
Important	Systems that would preclude an organization in the short term from accomplishing its core business functions if they fail.	Backup source for critical data. Extended period of time.
Supportive	Effectiveness and efficiency issues. Failures affect day-to-day business operations.	Cause loss of business efficiency and effectiveness. Tracks/calculates data for convenience.

Threat Assessment

A threat can be defined as a potential violation of a security mechanism. It is possible to classify threats into four broad classes [SHIREY00]:

- **Disclosure** – Unauthorized access to information
- **Deception** – Acceptance of false data
- **Disruption** – Interruption or prevention of correct information
- **Usurpation** – Unauthorized control of some part of the system

The following security services counter these threats [BISHOP02]:

- **Authentication** – Ensures that device, system, or user access is strongly mutually authenticated.
- **Authorization** – Ensures that access levels are authorized based upon strong mutual authentication. (This function is addressed within the AMI-SEC security service of Access Control.)
- **Confidentiality** - Ensures that data is shared only with authorized individuals on a need-to-know basis, and that intentional or unintentional disclosure of the data does not occur.

- **Integrity** - Ensures that data is authentic, correct and complete, and provides assurance that the data can be trusted.
- **Availability** - Ensures that data, applications and systems are available to those who need them when they need them.

Sometimes, non-repudiation is also included as a component of information security [PARKER02]. Non-repudiation refers to the assurance that a person who claims or is claimed to have created, modified, or transmitted data is in fact that person, and is unable to deny that they are responsible for the data's content or transmission.

In essence, non-repudiation is about tying a specific actor to a specific action in an undeniable manner. This function is accommodated by the AMI-SEC security service of Accounting.

Threat Model Development

A threat model is a description of a set of possible attacks to consider when designing a system. Furthermore, the threat model can be used to assess the probability, severity, and reasoning of certain attacks and allow for designers to implement proper controls for mitigation purposes. The development of a threat model includes listing the security assumptions, threat agents, motivations, threats, vulnerabilities, controls, and assets in the system of interest. Figure 1-2 shows the interaction of some of these functions.

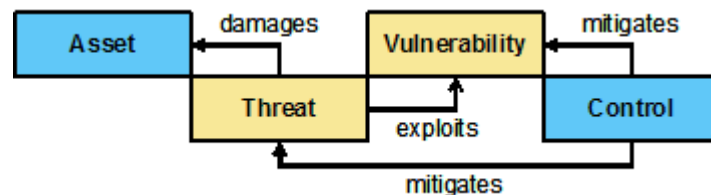


Figure 1-2
A Generic Threat Model

Threats and Threat Agents

Threat agents are characterizations of entities that may have the motivation, opportunities, or means for compromising an advanced metering system. Threat agents are used to represent individuals or groups that can manifest a threat [OWASP]. These agents may be classified using four criteria:

- Objectives – The end-goal(s) of the threat agent.
- Access – The ability of the attacker to gain physical or logical proximity to the system, as well as any inherent trust assumptions.
- Resources – The financial, temporal, or manpower assets available to the threat agent.
- Expertise – The threat agent's understanding or expertise in the advanced metering infrastructure system, the electric power system, and/or the network technologies deployed by such systems.

- Risk Aversion Profile – The threat agent’s tolerance for consequences that differ from the general population (e.g.: arrest, publicity, safety, etc...).

The following table gives examples of some possible threat agents [OWASP]:

**Table 1-3
Threat Agents**

Threat Agents	
Non-Target Specific	Non-Target specific Threat Agents are Computer Viruses, Worms, Trojan Horses and Logic Bombs.
Employees	Staff, Contractors, Operational and Maintenance Staff, Security Guard who are annoyed with the company.
Organized Crime and Criminals	Criminals target information that is of value to them, such as bank accounts, credit cards or intellectual property that can be converted into money. Criminals will often make use of insiders to help them.
Corporations	Companies engaged in offensive Information Warfare. Partners and Competitors come under this category.
Human Unintentional	Accidents, Carelessness
Human Intentional	Insider, Outsider
Natural	Flood, Fire, Lightning, Meteor, Earthquakes

Additionally, other non-deliberate threat agents are possible including natural disasters, environmental and mechanical failure, as well as inadvertent actions of an authorized user may be considered [NIST80082]. This study will not consider these from an information systems security viewpoint, but should be examined in the disaster recovery and business continuity planning.

Threats are the means through which the ability or intent of a threat agent to adversely affect the goals and objectives of the advanced metering infrastructure system can be carried out [SHIREY00]. Threats are different from threat agents in that they do not necessarily imply intent. Possible threats include:

- Brute Force - Performing an exhaustive search of all possible values for a security credential or attribute (e.g. key, password or passphrase)
- Bypass - Bypassing system security functions and mechanisms.
- Destruction - Causing the destruction of system data, business data or configuration information.
- Disclosure - Losing data confidentiality.
- Denial of Service - Overloading the network and/or system resources.
- Hijack - Commandeering one-side of an existing authenticated connection.
- Malware - Deploying malicious software developed for the purposes of doing harm to a computer system or network (e.g. viruses, Trojan horses, backdoors, etc).

- Man In the Middle - Inserting undetected between two connections, where the attacker can read, insert and modify messages at will.
- Physical - Causing physical damage to or destruction of an asset.
- Privilege Escalation - Causing an unauthorized elevation of privilege.
- Replay – Creating an unauthorized replay of captured traffic.
- Repudiate - Refuting an action or association with an action.
- Sniff - Performing unauthorized traffic analysis.
- Social Engineering - Manipulating knowledgeable entities to gain privileged information or access.
- Spoof - Impersonating an authorized user or asset.
- Tamper - Modifying, in an unauthorized manner, system data, business data or configuration information.

Three steps to analyzing threats are:

Step 1 - determine threat-sources.

Step 2 - determine if threat sources have motivation, resources, and capabilities to carry out a successful attack.

Step 3 - apply a qualitative value to a successful attack (results of Step 2) taking into account likelihood of occurrence and impact per occurrence.

Threat Agent: Motive

Motivation can be defined as an attacker's purpose or intent to cause a desired effect on the advanced metering system. There are a variety of attacker 'attitudes' that impact individual motives, and thus vary the risk to the advanced metering system. The lack of motive reduces the likelihood that an attack will be executed. Possible motivations include:

- Profit
 - Avoid Billing
 - Derive Revenue
 - Directly Profit
 - Resell AMI Hosted BotNet
 - Manipulate the Energy Market
 - Manipulate Unrelated Market
 - Manipulate the Economy
- Revenge
 - Defame Individual
 - Degrade Revenue
 - Degrade Corporate Image
 - Degrade Service Delivery

- Degrade Infrastructure
- Extortion
- Degrade Billing Integrity
- Privacy / Secrecy
 - Maintain Confidentiality
 - Become Anonymous
 - Mask Behavior
 - Spoof Behavior
 - Become Unobservable
 - Deter Meter Deploy
 - Delay Meter Deploy
- War
 - Degrade Infrastructure
 - Degrade Dependent Infrastructure
 - Degrade Service Delivery
 - Degrade Economy
- Ego
 - Achieve Bragging Rights
 - Prove Something
 - Publish
- Spying
 - Degrade Confidentiality
 - Reconnaissance
 - Capability Assessment
 - Economic
 - Technological
 - Determine Operational Advantage
 - Determine Market Advantage
- Curiosity
 - Explore
 - Understand
- Civil Disobedience
 - Degrade Infrastructure
 - Vandalism
- Activism
 - Exploit

- Manipulate Attention to Specific Issue
- Manipulate Attention to Broad Issue
- Manipulate Attention to Unrelated Issue
- Degrade Service Delivery
- Vandalism

Threat Agent: Means (Capability)

A threat agent must possess the means or capability in order to carry out a successful attack. Several factors should be considered in evaluating threat agent capabilities from attack cost to special skills required.

Attack cost – involves the resources necessary in order to perform a successful attack including money, time and people. A government or activist group would likely have more resources than an individual by comparison.

Complexity of attack – it is desirable to make complexity high in order for a threat agent to compromise a system. Complexity is gained through adding controls and performing defense in-depth practices. Complexity for an attacker means they will have to be knowledgeable in several areas of the system, possibly need more time to execute, and require more cost. On the other hand if a system is easy to attack, likelihood is that it will be attacked.

Exploit availability – availability of known exploits to platforms increases the likelihood that it will be used in order to degrade the system.

Time factors of attack – time plays a role in when a system may be vulnerable to attack. For example, banks usually get robbed during the day when they are open for business, but not after hours when the vaults are sealed and no one is around to open them.

Special skills required to carry out the attack – involve special knowledge and ability in order to compromise a system. An example may be that the attacker would have to understand how to use special equipment to intercept signals and then write special programming in order to infiltrate the system.

Threat Agent: Opportunity

AMI security should be configured and implemented in such a way as to diminish opportunity for threat agents to conduct an attack.

Access requirements:

Physical proximity requirements – the likelihood of an attack increases considerably the closer a threat agent is to an asset; conversely, the further a threat agent is from an asset the less likely a compromise in security will occur. An example of proximity

Trust requirements – a threat agent (human or another system) may require some level of trust to be granted in order for the opportunity to exploit a vulnerability.

Circumstantial requirements – Some vulnerabilities may be exploited only if the proper conditions exist.

Current treatment of vulnerability – the current treatment of a vulnerability can expose an opportunity of attack.

Vulnerability

Vulnerabilities are weaknesses in the AMI system assets which increase asset exposure to attacks. Vulnerabilities stem from requirements, design, or implementation defects in the AMI system. Many general application vulnerabilities are available at the [OWASP] site.

3rd Party Network - Unauthorized access to the advanced metering system via a 3rd party network.

- Abuse – misuse by a valid user
- API Abuse - The most common forms of API abuse are caused by the returner failing to honor its end of this contract, returning erroneous data.
- Authentication - Weakness in the authentication mechanisms.
- Coarse Access Control - Access controls that do not allow for proper separation of duties or desired granularity.
- Code Permission - Software that requires unnecessarily elevated privileges for normal operation.
- Code Quality - Poor code quality that leads to unpredictable behavior, poor usability, and low assurance.
- Cryptographic Vulnerability – insecure, incorrect, or improperly implemented algorithms
- Dangerous API - Use of an Application Programming Interface that has known vulnerabilities, is no longer supported, or does not meet system requirements.
- Enforcement – lack of policy enforcement / assurance
- Error Handling - Improper error handling that can or does cause unintended or unpredictable behavior.
- Fail-Open: Systems should fail only into secured states (fail-secure), and never fail-open.
- Input Validation - Input that is not validated for proper formatting and content.
- Logging and Auditing - Poor or inadequate recording, retention, and handling of events of interest.
- Misconfiguration – gap between having security features and using them properly / effectively
- Protocol - Use of unknown/unproven protocols or protocols with known weaknesses inappropriate for system design.
- Sensitive - Inadequate protection of data value in transit, storage, and processing.
- Separation of Privileges – Failure to use privilege separation
- Services - Unnecessary services enabled on system components.
- Synchronization and Timing – improper design leads to weakness in synchronization and timing subsystems. E.g. clock manipulation
- Session Management - Inadequate session identifiers, often leading to replay attacks.

Risk Determination

System stakeholders are highly concerned with denying or handling consequence of specific attacks on system assets. To understand the risk associated with a given concern, various factors may be taken into consideration including monetary value. The likelihood and consequence of attack to the asset stakeholder should be the primary concerns to the system builder. At high levels, these factors are easily and effectively described through subjective ranking factors and are easily derived from asset protection and classification requirements.

A preliminary rough qualitative assessment of risk due to attack or perceived vulnerability is provided by assessing summary attack likelihood and attack consequences. Additional considerations or tables may be made to derive summary likelihood or consequence; however, in the risk assessment, the summary rating of a threat event against a specific asset is used.

Likelihood is summarized on a subjective scale from A to E with A being the most certain and E being rare. Consequence is summarized on a subjective scale from 1 to 5 with 1 being negligible consequence and 5 being severe consequence. Certain combinations of likelihood and consequence result in a subjective risk rating selected from low (L), medium (M), High (H), and extreme (E). A policy is first deployed for interpreting the component subjective values and subsequent assignment of risk ratings to various likelihood/consequence combinations. See Table 1 for an example subjective rating interpretation policy. See Table 2 for an example risk assignment policy. It is expected that specific risk ratings generate minimal due-diligence requirements for management of controls against the threat and threat sources.

AMI-SEC Likelihood Interpretation Policy

Likelihood is determined qualitatively by determining the threat agent's means, motive, and opportunism. The table below shows an example of a possible means for determining a likelihood interpretation policy. Note that if any one component of motive, means or opportunity does not exist then likelihood is negligible. Controls are the mechanisms developed to mitigate risks. Removing motive, means or opportunity from a threat agent during the control development process significantly reduces the likelihood of a successful attack occurring.

Table 1-4
Example: Motive, Means, Opportunity, & Likelihood Matrix

Motive	Means	Opportunity	Likelihood
Low	Low	Low	Rare
Low	Low	High	Possible
Low	High	Low	Possible
Low	High	High	Likely
High	Low	Low	Possible
High	Low	High	Likely
High	High	Low	Likely
High	High	High	Almost Certain

AMI-SEC Consequence Interpretation Policy

Consequences can also be interpreted qualitatively as a measure of impact that a successful attack would produce. We have given a rating example of 1 to 5 where (1) equals negligible impact on the low end to (5) severe consequence of impact on the high end. Refer to Table 1-5. The rating is based against impact to accomplishing organizational goals and objectives.

Table 1-5
Example: Qualitative Risk Assessment Interpretation

Consequence	
1	Negligible - no impact/consequence
2	Minor - would threaten an element of the function
3	Moderate - necessitating significant adjustment to overall function
4	Major - would threaten functional goals / objectives
5	Sever - would stop achievement of functional goals / objectives

Likelihood	
A	Almost Certain - expected in most circumstances
B	Likely - will probably occur in most circumstances
C	Possible - could occur at some time
D	Unlikely - not expected to occur
E	Rare - exceptional circumstances only

AMI-SEC Risk Interpretation Policy

In a qualitative analysis interpretation of risk for purposes of this document will be calculated by scoring consequence against likelihood. As shown in Table 1-6, Risk is scored from (L) Low Risk to (E) Extreme Risk. Risk levels are assigned to security assets within the AMI domain. The body of the matrix may be adjusted to an organizations' specific exposure to risk. In general low risk assets map to the lower left corner where likelihood is low and consequence to impact of an attack is negligible; and extreme risk assets map to the upper right of the matrix where likelihood of a successful attack is high and the resulting consequence is a severe impact on performing organizational functions to reach goals and objectives.

Table 1-6
Example Risk Rating Policy

		Consequences				
		Negligible 1	Minor 2	Moderate 3	Major 4	Severe 5
Likelihood	A (Almost certain)	M	H	H	E	E
	B (Likely)	M	M	H	H	E
	C (Possible)	L	M	M	H	E
	D (Unlikely)	L	M	M	M	H
	E (Rare)	L	L	M	M	H
E		Extreme Risk: Immediate action required to mitigate the risk or decide not to proceed				
H		High Risk: Action should be taken to compensate for the risk				
M		Moderate Risk: Action should be taken to monitor the risk				
L		Low Risk: Routine acceptance of the Risk				

Risk Assessment

Introduction

Neither the clients nor providers of AMI can afford to have it fail or become compromised. The concern of loss or degradation of AMI drives the need for the risk assessment process. Stakeholders in AMI do not want to become the authors of a Greek tragedy; to find that in their effort to provide better service gives an enemy a new platform to which they can wage attacks. As mentioned earlier, a risk assessment serves as a tool to help stakeholders identify the risk value in order to make effective decisions about how to mitigate risk concerns.

A risk assessment is the first step in the risk management process and should be an iterative process. The need to revisit the risk assessment process is made necessary by the emergence of new technologies, availability of new exploits, and new threats arise as time progresses.

Vulnerabilities

The initial phase of categorizing vulnerabilities for assets is generic. The goal is to relate vulnerabilities to AMI Security Domains through assets. The goal is to group threats by known categories and then apply them to assets during the asset definition phase. One or more vulnerabilities will map to a single asset (refer to Figure 1-1). Table 1-12 in Chapter 1, AMI-SEC RA: Appendix B – Threat Model Support catalogs threats by category and provides a detailed description of each.

Assets

Assets are the items of protection, the target of threats, the possessors of exposures, and the beneficiaries of controls [JAQUITH07]. System assets can be defined as any software, hardware, data, administrative, physical, communications, or personnel resource within an information system [CNSS4009]. Similarly, it is possible to define assets as information, resources, or services. For the purposes of AMI, assets are considered as business services that provide value streams for the organization. To accomplish this the components required to provide a service and arrive at an abstract value stream are aggregated. The value streams are what the organization wishes to protect at a context level risk assessment.

1. Information Assets
 - a. Audit Data
 - b. Information Object
 - c. Policy
 - d. Other Configuration Information
 - e. Locally Protected Information
 - f. Traffic Flow
2. Resource Assets
 - a. AMI Virtual Network
 - b. AMI components
 - i. Software

- ii. AMI applications
 - iii. Operating System
 - iv. Hardware
 - c. Tokens
- 3. Service Assets
 - a. Order Key Service
 - b. Deliver Key Service
 - c. Track and Control Keys Service
 - d. Membership Management Service
 - e. Initialization Service
 - f. Software Download Service
 - g. Configured Cryptographic Element Interface Service
 - h. Policy Imposition Service
 - i. Trust Anchor Service
 - j. Network Infrastructure Services
 - k. Primary Security Services
 - i. Access Control Services
 - ii. Integrity Services
 - iii. Confidentiality Services
 - iv. Accountability Services
 - v. Identification, Authentication, and Authorization Services
 - vi. Availability Services
 - vii. Audit Services
 - l. System Enrollment Services

It is important to note that each of the above assets include user data and the protection mechanisms.

Attacks

An attack is an attempt to gain unauthorized access to an information system's services, resources, or information, or the attempt to compromise an information system's integrity, availability or confidentiality. An attack implies intent due to the definition as an attempt. However, not all attempts are malicious.

Attacks upon the security functions themselves are called direct attacks. All assets are subject to this type of attack. Most malicious direct attacks (other than denial of service attacks) target authentication and access control mechanisms first, since defeating those mechanisms may yield additional system privileges and may provide a platform from which to launch additional attacks.

Attacks upon external entities that occur over advanced metering interfaces are called forwarded attacks. For example, an external entity floods the advanced metering network with more traffic

than was allocated to the particular component—this may result in a denial of service on the network.

A third type of attack is a system attack. This sort of attack happens when the system itself, without prompting from an external user, attacks internal or external assets. This would usually occur only in the case of a malicious developer or serious hardware/software failure.

Adding security controls to an advanced metering system does not mean that the system will not be attacked, nor does it mean that the system will be impossible to compromise. An adversary with the necessary time, funding, and expertise can often compromise the most secure system.

Scenarios and Prioritization

Developing a set of attack scenarios allows for efficient application of security controls to help mitigate the defined attack vectors. The sole purpose of these controls is to reduce both the likelihood, and the impact of a successful attack. The likelihood of an attack refers the probability that this attack vector would be used. The impact of an attack refers the financial, reputation, or other business impact a successful penetration would have.

It is often beneficial to qualitatively sort possible attacks in terms of risk using both the likelihood and severity of the attack.

Each threat is given a severity, which is one of the following: Low, Medium, or High. The severity indicates the level of harm to the system if this threat were to succeed. A Low severity should result in no disclosure of information but, for example, might create an improperly or inconveniently configured system. A potential disclosure of information is an example of a Medium threat to the system security. A potential continuing disclosure of information is an example of a High threat.

Each threat is also given a likelihood, which is one of the following: Unusual, Unlikely, or Likely. In the case of a non-malicious threat, the likelihood is purely a probability of the threat occurring. In the case of malicious threats, the likelihood includes motivation to attack this way, whether the attack is coming from a user that some trust is placed in, and the gain from a successful attack. For malicious attacks, likelihood is less related to probability directly, since an attacker will attack a system at its weak point. Note that the likelihood is assigned before any protections are put in place. So, a threat of enrolling a user through unauthorized mechanisms is a Likely threat, simply because an attacker would be highly motivated to do it. In neither case does the likelihood include any mitigation factors implemented by the system or the environment. An unusual likelihood has an extremely low probability of occurrence. Unlikely threats have a low probability of occurrence. Likely threats are expected to be encountered and therefore require the strongest mitigation based on severity.

Some threats have a narrower focus than other threats. These threats were made specific because they have important implications in the system. The top threats were realized by combining threat components with assets to create threat statements. The following list of threat statements should be considered most apropos:

The following attacks are considered HIGH risk with a HIGH severity if realized and a LIKELY degree of likelihood:

- A threat agent may attempt to shut off large population of meters.
- A threat agent may hijack or spoof one or more trusted systems.
- A threat agent may craft a denial of service attacks at the utility back-office.

The following attacks are considered MEDIUM risk with a HIGH severity if realized and an UNLIKELY degree of likelihood:

- A threat agent may try to obtain key material from the system.
- A threat agent may craft a denial of service attacks to a large population of meters.

The following attacks are considered MEDIUM risk with a MEDIUM severity if realized and a LIKELY degree of likelihood:

- A threat agent may try to obtain key material from a meter.
- A threat agent may attack the system using test development software or other field tools typically used by technicians or manufacturers.
- A threat agent may try to spoof the meter using stolen key material or as a man in the middle attack.

The following attacks are considered LOW risk:

- A threat agent may try to sniff messages in order to maliciously control or alter functionality.
- A threat agent may try to tamper with application protocols to maliciously control or alter functionality.
- A threat agent may try to physically modify a meter to steal power.

Conclusion

AMI systems offer a tremendous amount of potential, yet it introduces the requirements for industry proven, strong, robust, scalable, and open standards-based security. The goal in this chapter was to define an exhaustive list of the potential security threats to the systems, and to perform detailed analysis of each threat to determine the threat levels and risks that it presents. The goal through this discovery process is to deliver information necessary to implement proper controls that will mitigate the security concerns surrounding AMI.

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AMI-SEC RA: Appendix A – Asset Identification Support

Summary

The spreadsheet contains several tabs covering the following areas:

- System Asset Identification
- System Interfaces
- System Messages
- System Logical Architecture

**Table 1-7
Asset Identification Support**

Asset Name	AMI Security Services Domain	Asset Category	Sub-category	Asset Type	Security Level	Criticality Level	Classification	Asset System Descr.
Advanced Metrology	Edge Services - Utility			Logical/ Physical Components				
Aggregated Demand Response Dialogue	Utility Operations	Information	Sensitive	System Messages				
Aggregated Measurements	Utility Operations	Information	Sensitive	System Messages				
Aggregated Measurements (subset)	Network Operations	Information	Sensitive	System Messages				
Aggregation Transport	Communication Services			Logical/ Physical Components				
AMI Component Vendor	Edge Services - Utility			Actors				
AMI Data Collection	Edge Services - Utility			Logical/ Physical Components				
AMI Data Marts	Utility Operations			Logical/ Physical Components				
AMI Data Warehouse	Utility Operations			Logical/ Physical Components				
AMI Database Server	Utility Operations			Logical/ Physical Components				

Asset Name	AMI Security Services Domain	Asset Category	Sub-category	Asset Type	Security Level	Criticality Level	Classification	Asset System Descr.
AMI Headend	Communication Services			Logical/ Physical Components				
AMI Meter	Edge Services - Premise			System Component				
AMI Meter	Edge Services - Premise			Logical/ Physical Components				
AMI Real-time Customer Web Access	Utility Operations			Logical/ Physical Components				
Archival Storage	Utility Operations			Logical/ Physical Components				
Automated Distribution Regulators	Edge Services - Utility			Logical/ Physical Components				
Automated P/E	Edge Services - Utility			Logical/ Physical Components				
Bills	Utility Operations	Information	Sensitive	System Messages				
Building Management System	Edge Services - Premise			Logical/ Physical Components				
Capacitor Bank Control	Communication Services			Logical/ Physical Components				
Cellular	Communication Services			Logical/ Physical Components				
Central Capacitor Control System	Edge Services - Utility			Logical/ Physical Components				
Circuit & Automatic Recloser Lockout Alarms (CARLA)	Edge Services - Utility			Logical/ Physical Components				
CIS	Network Operations			Logical/ Physical Components				

Asset Name	AMI Security Services Domain	Asset Category	Sub-category	Asset Type	Security Level	Criticality Level	Classification	Asset System Descr.
Communications System Operator	Network Operations			Actors				
Concentrators	Communication Services			Logical/ Physical Components				
Cost Calculations	Utility Operations	Information	Sensitive	System Messages				
Customer	Edge Services - Premise			Actors				
Customer Contact	Utility Operations	Information	Sensitive	System Messages				
Customer Display Access	Edge Services - Premise	Information	Sensitive	System Messages				
Customer Messages	Edge Services - Premise	Information	Sensitive	System Messages				
Customer Representative	Utility Operations			Actors				
Customer Service Requests	Utility Operations	Information	Sensitive	System Messages				
Customer Service System	Utility Operations			System Component				
Data Center Aggregator	Network Operations			System Component				
Data Center Aggregator	Utility Operations			Logical/ Physical Components				
Data Center Network	Utility Operations			Logical/ Physical Components				
Data Collector Unit	Communication Services			Logical/ Physical Components				
Data Retrievers	Communication Services			System Component				

Asset Name	AMI Security Services Domain	Asset Category	Sub-category	Asset Type	Security Level	Criticality Level	Classification	Asset System Descr.
Demand Response Dialogue	Utility Operations	Information	Sensitive	System Messages				
Demand Response Services	Network Operations	Information	Sensitive	System Messages				
Dispatcher	Network Operations			Actors				
Display Device	Edge Services - Premise			System Component				
Distribution Automation Node	Network Operations			System Component				
Distribution Automation Nodes	Communication Services			Logical/ Physical Components				
Distribution Control & Monitoring System	Edge Services - Utility			Logical/ Physical Components				
Distribution Generation	Edge Services - Premise			Logical/ Physical Components				
Distribution Management System (DMS)	Network Operations			Logical/ Physical Components				
Distribution Resources Availability and Control System	Network Operations			System Component				
Distribution Status	Network Operations	Information	Sensitive	System Messages				
DR Enrollment and Status	Utility Operations	Information	Sensitive	System Messages				
Edge Servers	Utility Operations			Logical/ Physical Components				
Energy Market	Edge Services - Utility	Information	Sensitive	System Messages				

Asset Name	AMI Security Services Domain	Asset Category	Sub-category	Asset Type	Security Level	Criticality Level	Classification	Asset System Descr.
Energy Trader	Edge Services - Utility			Actors				
Equipment Control	Edge Services - Premise	Information	Sensitive	System Messages				
Equipment Orders	Utility Operations	Information	Sensitive	System Messages				
Equipment Procurement System	Utility Operations			System Component				
Event Notifications	Network Operations	Information	Sensitive	System Messages				
FFA	Network Operations			Logical/ Physical Components				
Field Elements	Edge Services - Utility			System Component				
Field Person	Edge Services - Utility			Actors				
Field Tool	Edge Services - Utility			System Component				
Firewalls	Network Operations			Logical/ Physical Components				
Fixed Wireless or PLC	Communication Services			Logical/ Physical Components				
Forecasting & Settlement	Network Operations			Logical/ Physical Components				
Gateway Management	Edge Services - Premise	Information	Sensitive	System Messages				
Grid Control Center	Network Operations			System Component				
HAN Telecom	Edge Services - Utility			Logical/ Physical Components				

Asset Name	AMI Security Services Domain	Asset Category	Sub-category	Asset Type	Security Level	Criticality Level	Classification	Asset System Descr.
Independent System Operator	Edge Services - Utility			Actors				
In-home Display	Edge Services - Premise			Logical/ Physical Components				
Initial Program	Edge Services - Premise	Information	Sensitive	System Messages				
Installation Data	Edge Services - Premise	Information	Sensitive	System Messages				
Intelligent Fault Indicators	Edge Services - Utility			Logical/ Physical Components				
Invoices	Utility Operations	Information	Sensitive	System Messages				
LAN/WAN Telecom	Communication Services			Logical/ Physical Components				
LCD Display	Edge Services - Premise			Logical/ Physical Components				
Load Control	Utility Operations			Logical/ Physical Components				
Load Control Device	Edge Services - Premise			System Component				
Load Control Devices	Edge Services - Premise			Logical/ Physical Components				
Local Measurements and Status	Edge Services - Utility	Information	Sensitive	System Messages				
Local Meter Maintenance	Edge Services - Utility	Information	Sensitive	System Messages				
Maintenance Planner	Utility Operations			Actors				
MCU & Flash Memory	Edge Services - Premise			Logical/ Physical Components				
Measurements and Status	Communication Services	Information	Sensitive	System Messages				

Asset Name	AMI Security Services Domain	Asset Category	Sub-category	Asset Type	Security Level	Criticality Level	Classification	Asset System Descr.
Meter and Distributed Generation Status	Network Operations	Information	Sensitive	System Messages				
Meter Communications	Communication Services			Logical/ Physical Components				
Meter Data Management System	Utility Operations			System Component				
Meter Data Management System	Utility Operations			Logical/ Physical Components				
Meter Display Access	Edge Services - Premise	Information	Sensitive	System Messages				
Meter Management	Utility Operations	Information	Sensitive	System Messages				
Meter Management System	Utility Operations			System Component				
Metering	Edge Services - Utility			Logical/ Physical Components				
Meters	Edge Services - Premise			Logical/ Physical Components				
Middleware	Utility Operations			Logical/ Physical Components				
Monitored Equipment	Edge Services - Premise			System Component				
Neighborhood Aggregators	Communication Services			Logical/ Physical Components				
Network Management	Network Operations	Information	Sensitive	System Messages				
Other Measurements	Utility Operations	Information	Sensitive	System Messages				

Asset Name	AMI Security Services Domain	Asset Category	Sub-category	Asset Type	Security Level	Criticality Level	Classification	Asset System Descr.
Other Meters	Edge Services - Premise			Logical/ Physical Components				
Outage Coordination	Network Operations	Information	Sensitive	System Messages				
Outage Management System	Utility Operations			System Component				
Outage Management System (OMS)	Network Operations			Logical/ Physical Components				
Planners, Forecasters, etc.	Utility Operations			Actors				
PLC	Communication Services			Logical/ Physical Components				
Pole Top Collectors	Communication Services			Logical/ Physical Components				
Power Procurement System	Utility Operations			System Component				
Premise Gateway	Edge Services - Premise			System Component				
Premise Gateway	Communication Services			Logical/ Physical Components				
Programmable Communicating Thermostat (PCT)	Edge Services - Premise			Logical/ Physical Components				
Programmable Disconnect Switch	Edge Services - Utility			Logical/ Physical Components				
Programmable Firmware	Edge Services - Premise			Logical/ Physical Components				
Public/Private Network	Network Operations			Logical/ Physical Components				

Asset Name	AMI Security Services Domain	Asset Category	Sub-category	Asset Type	Security Level	Criticality Level	Classification	Asset System Descr.
Publishers	Communication Services			Logical/ Physical Components				
Radio	Communication Services			Logical/ Physical Components				
Rate and Prepayment Info	Utility Operations	Information	Sensitive	System Messages				
Real-time Response Feedback	Network Operations	Information	Sensitive	System Messages				
Remote Automatic Reclosers	Edge Services - Utility			Logical/ Physical Components				
Remote Control Switches	Edge Services - Utility			Logical/ Physical Components				
Remote Fault Indicators	Edge Services - Utility			Logical/ Physical Components				
Remote Transmission Switches	Edge Services - Utility			Logical/ Physical Components				
Remote Vacuum Fault Interrupters	Edge Services - Utility			Logical/ Physical Components				
Repeater	Communication Services			Logical/ Physical Components				
Revenue Metrology	Edge Services - Utility			Logical/ Physical Components				
RF Network System Controller	Communication Services			Logical/ Physical Components				
RFID	Communication Services			Logical/ Physical Components				
Routers	Network Operations			Logical/ Physical Components				
SAP	Network Operations			Logical/ Physical Components				

Asset Name	AMI Security Services Domain	Asset Category	Sub-category	Asset Type	Security Level	Criticality Level	Classification	Asset System Descr.
SCADA	Network Operations	Information	Sensitive	System Messages				
SCADA	Network Operations			Logical/ Physical Components				
Settlement-Ready Usage Data	Utility Operations	Information	Sensitive	System Messages				
Small Power Transformer/Power Supply	Edge Services - Utility			Logical/ Physical Components				
Sub-metering	Edge Services - Premise			Logical/ Physical Components				
Switches	Network Operations			Logical/ Physical Components				
System Management Console	Network Operations			System Component				
System Management Console	Network Operations			Logical/ Physical Components				
System Operator	Network Operations			Actors				
Tape Backup	Utility Operations			Logical/ Physical Components				
Telecom Control Center	Network Operations			System Component				
Theft/Tamper Detection	Edge Services - Premise			Logical/ Physical Components				
Third Parties	Edge Services - Utility			System Component				
Third Party Meter Reader	Edge Services - Utility			System Component				

Asset Name	AMI Security Services Domain	Asset Category	Sub-category	Asset Type	Security Level	Criticality Level	Classification	Asset System Descr.
Troubleshooting and Provisioning Services	Network Operations	Information	Sensitive	System Messages				
Utility Web Site	Utility Operations			System Component				
Validated Measurements	Communication Services	Information	Sensitive	System Messages				
Validated Measurements (subset)	Communication Services	Information	Sensitive	System Messages				
Web Self Service	Utility Operations			Logical/ Physical Components				
Web Services Application Server	Utility Operations			Logical/ Physical Components				
Web Services Portal Server	Utility Operations			Logical/ Physical Components				
Website Customer Access	Utility Operations	Information	Sensitive	System Messages				
Website Customer Information	Utility Operations	Information	Sensitive	System Messages				
Wholesale Transaction Records	Utility Operations	Information	Sensitive	System Messages				

AMI-SEC RA: Appendix B – Threat Model Support

Summary

The Common Criteria considers both threats and the technical remedies needed to counter those threats doing so in a more formal language. The following is an extended set of common criteria threat material for inclusion into an AMI system level protection profile.

AMI is another name for an advanced metering system. It refers to any system that measures, collects, and/or analyzes resource consumption from advanced devices such as electricity meters, gas meters, and/or water meters.

An entity is defined as a device (e.g., meter, relay, switch, router, collector), system (e.g., metering system, load control system), person (e.g., utility employee, customer), or a self-contained piece of data that can be referenced as a unit within the Advanced Metering Infrastructure system.

Threats to the AMI system are listed below by category:

Table 1-8
Threat Model: Assumptions

ASSUMPTION NAME	DESCRIPTION
AN.ADMIN	The AMI system administrators are competent, adhere to the applicable guidance, and are not willfully negligent or malicious, but capable of error.
AN.CERTIFICATE_AUTHORITY	The CA used to validate AMI certificates is a trust anchor.
AN.COMMS_ACCESS	In accordance with organizational policy, physical access to communication media, and connections to the media, and services allowed to go over the communications media (e.g., internet access, e-mail) is controlled, as is access to devices that display or output system control information.
AN.COMMS_ACCESS	In accordance with organizational policy, physical access to communication media, and connections to the media, and services allowed to go over the communications media (e.g., internet access, e-mail) is controlled, as is access to devices that display or output system control information.
AN.CORPORATE	Security controls relevant to the protection of the AMI system may be provided by the corporate environment.
AN.CRYPTO	Cryptographic algorithms used in AMI are resistant to cryptanalytic attacks.
AN.CUSTOMER	The AMI system does not host private customer data.
AN.EXTERNAL	The ICS network may have connectivity with non-ICS system networks through which Internet connectivity is possible.
AN.OPS_CONNECT	Business and operational connections exist between the AMI system and other systems.
AN.PHYSICAL	Controls are in place to deter casual physical access to the facility.
AN.PHYSICAL_ACCESS	In accordance with organizational policy physical access controls are applied at designated physical access points throughout the system whose perimeters are defined by the organization, and personnel with authorized access is documented and maintained. Entry to secure areas is controlled and monitored on a periodic basis.
AN.PUBLIC	The AMI system does not host public data.

ASSUMPTION NAME	DESCRIPTION
AN.REMOTE	Authorized administrators may NOT access the AMI system remotely from external networks.
AN.REMOTE	Remote access to ICS components may be available to authorized individuals.
AN.TRUSTED_NET	Components in the AMI system may have connectivity with trusted networks.

**Table 1-9
Threat Model: Threat Agents (A)**

THREAT AGENT NAME	EXPERTISE	FUNDING	TIME	DESCRIPTION
TA.INSIDER	1-3	1	2	Authorized persons with employee relationship to the AMI system acting inappropriately.
TA.OUTSIDER	1-3	1-3	1-3	Unauthorized external party, including foreign governments, hacktivists, rival companies, and hobbyists.
TA.CUSTOMER	1	1	3	Authorized persons with customer relationship to the AMI system acting inappropriately.
TA.PRIOR_INSIDER	1-3	1	3	Former authorized persons to the AMI system (e.g. employee, contractor, vendor or customer) acting inappropriately.
TA.NATURAL_DISASTER	N/A	N/A	N/A	Fire, flood, tornados, extreme heat/cold, storms, and other various acts of God.

**Table 1-10
Threat Model: Threat Agents (B)**

THREAT AGENT NAME	THREAT AGENT	EXPERTISE	RESOURCES	MOTIVATION
TA.INSIDER	Trusted employee, contractor, vendor or customer	Low/High	Substantial	Non-malicious
TA.EVIL_INSIDER	Trusted employee, contractor, vendor or customer acting inappropriately	Low/High	Substantial	Malicious
TA.PRIOR_INSIDER	Former trusted employee, contractor, vendor or customer	Low/High	Moderate	Malicious
TA.OUTSIDER	Unauthorized external party	High	Minimal/Moderate	Malicious
TA.NATURE	Environmental sources of threats such as earthquakes, flood and fire	N/A	Substantial	N/A

Table 1-11
Threat Model: Threats (A)

THREAT NAME	DESCRIPTION
T.BRUTE	Exhaustive search of all possible values for a security credential or attribute (e.g. key, password or passphrase)
T.BYPASS	Bypass of system security functions and mechanisms.
T.DESTROY	Destruction of AMI system data, business data or configuration information.
T.DISCLOSURE	Loss of data confidentiality.
T.DOS	Overloading the network and/or system resources.
T.HIJACK	Commandeer one-side of an existing authenticated connection.
T.MALWARE	Malicious software developed for the purposes of doing harm to a computer system or network (e.g. viruses, Trojan horses, backdoors, etc).
T.MITM	Undetected insertion between two connections, where the attacker can read, insert and modify messages at will.
T.OUTAGE	Outage of main power supply.
T.PHYSICAL	Physical destruction of an asset.
T.PRIVILEGE	Elevation of Privilege.
T.REPLAY	Unauthorized replay of captured traffic.
T.REPUDIATE	Identity Repudiation.
T.SNIFF	Unauthorized traffic analysis.
T.SOCIAL	Social engineering of authorized users.
T.SPOOF	Impersonating an authorized user or asset.
T.TAMPER	Unauthorized modification of AMI system data, business data or configuration information.

Table 1-12
Threat Model: Threats (B)

THREAT NAME	THREAT	DESCRIPTION
T.DISCLOSURE	Unauthorized Information Disclosure	An unauthorized individual (AGENT.EVIL_INSIDER, AGENT.PRIOR_INSIDER, AGENT.OUTSIDER) directs an attack (ATTACK.SNIFF, ATTACK.SOCIAL) to acquire sensitive information (ASSET.COMMS, ASSET.CTRLINFO, ASSET.BUSINFO) stored on ICS components.
T.EVIL_ANALYSIS	Unauthorized Analysis	An unauthorized individual (AGENT.EVIL_INSIDER, AGENT.PRIOR_INSIDER, AGENT.OUTSIDER) directs an attack (ATTACK.SNIFF, ATTACK.SOCIAL) to analyze sensitive information flows (ASSET.COMMS, ASSET.CTRLPROCESS, ASSET.CTRLINFO, ASSET.BUSINFO) protected by the STOE.
T.EVIL_MODIFICATION	Unauthorized Modification	An unauthorized individual (AGENT.EVIL_INSIDER, AGENT.PRIOR_INSIDER, AGENT.OUTSIDER) directs an attack (ATTACK.MODIFY, ATTACK.BYPASS, ATTACK.SNIFF) to modify sensitive information (ASSET.CTRLPROCESS, ASSET.CTRLINFO, ASSET.BUSINFO) stored on ICS components.

THREAT NAME	THREAT	DESCRIPTION
T.EVIL_DESTRUCTION	Unauthorized Destruction	An unauthorized individual (AGENT.EVIL_INSIDER, AGENT.PRIOR_INSIDER, AGENT.OUTSIDER) directs an attack (ATTACK.DESTROY, ATTACK.BYPASS) to destroy sensitive information (ASSET.CTRLPROCESS, ASSET.CTRLINFO, ASSET.BUSINFO) stored on ICS components.
T.CTRL_TAMPER	Tampering with control components	The tampering of ICS components (ASSET.ACTUATOR, ASSET.SENSOR, ASSET.CONTROLLER, ASSET.HMI, ASSET.REMOTE, ASSET.COMMS) by malicious individuals (AGENT.EVIL_INSIDER, AGENT.PRIOR_INSIDER, AGENT.OUTSIDER) via the following attacks (ATTACK.MODIFY, ATTACK.BYPASS, ATTACK.PHYSICAL).
T.BAD_COMMAND	Integrity of Control Commands	An authorized operator (AGENT.INSIDER) accidentally issues bad commands (ATTACK.ERROR) resulting in the modification of controlled ICS processes and components (ASSET.CTRLPROCESS, ASSET.ACTUATOR, ASSET.SENSOR, ASSET.CONTROLLER, ASSET.HMI).
T.SPOOF	Spoofing legitimate users of the STOE	An unauthorized individual (AGENT.EVIL_INSIDER, AGENT.PRIOR_INSIDER, AGENT.OUTSIDER) directs an attack (ATTACK.SNIFF, ATTACK.SPOOF, ATTACK.SOCIAL) to obtain user credentials (ASSET.REMOTE, ASSET.COMMS) stored on ICS server components to impersonate authorized users.
T.REPUDIATE	Identity repudiation	An authorized user (AGENT.INSIDER) denies having performed an action (ATTACK.ERROR) on the ICS interactive systems (ASSET.REMOTE, ASSET.COMMS, ASSET.HMI).
T.DOS	Denial of Service	An unauthorized individual (AGENT.EVIL_INSIDER, AGENT.PRIOR_INSIDER, AGENT.OUTSIDER) directs an attack (ATTACK.DESTROY, ATTACK.DOS) that denies service to valid users by making ICS components (ASSET.ACTUATOR, ASSET.SENSOR, ASSET.CONTROLLER, ASSET.HMI, ASSET.REMOTE, ASSET.COMMS) temporarily unavailable or unusable.
T.PRIVILEGE	Elevation of privilege	An unprivileged individual (AGENT.EVIL_INSIDER, AGENT.PRIOR_INSIDER, AGENT.OUTSIDER) directs an attack (ATTACK.ERROR, ATTACK.SNIFF, ATTACK.SPOOF, ATTACK.SOCIAL) to obtain user credentials (ASSET.REMOTE, ASSET.COMMS) stored on ICS server components to elevate privileged access to ICS components for malicious purposes.

THREAT NAME	THREAT	DESCRIPTION
T.NO_FAULT_RECORD	Fault Detection	Faults generated by the system (AGENT.INSIDER) as a consequence of operator error and/or security breach (ATTACK.ERROR) while performing their routine tasks are not detected nor audited on ICS interactive systems (ASSET.REMOTE, ASSET.COMMS, ASSET.HMI) for further analysis and correction.
T.DISASTER	System Unavailability due to Natural Disaster	A natural disaster (AGENT.NATURE) ceases operation of one or more components of the ICS (ASSET.ACTUATOR, ASSET.SENSOR, ASSET.CONTROLLER, ASSET.HMI, ASSET.REMOTE, ASSET.COMMS) as a consequence of earthquake, fire, flood or other unpredictable event (ATTACK.NATURE).
T.OUTAGE	System Unavailability due to Power Outage	A natural disaster, malicious or non-malicious individual (AGENT.NATURE, AGENT.INSIDER, AGENT.EVIL_INSIDER, AGENT.PRIOR_INSIDER, AGENT.OUTSIDER) inadvertently (or otherwise) causes a power outage affecting the availability of one or more components of the ICS (ASSET.ACTUATOR, ASSET.SENSOR, ASSET.CONTROLLER, ASSET.HMI, ASSET.REMOTE, ASSET.COMMS).
T.INFECTION	Virus Infection	An individual (AGENT.INSIDER, AGENT.EVIL_INSIDER, AGENT.PRIOR_INSIDER, AGENT.OUTSIDER) maliciously or accidentally introduces a virus to the ICS network (ATTACK.VIRUS) causing unnecessary system downtime and corruption of data (ASSET.ACTUATOR, ASSET.SENSOR, ASSET.CONTROLLER, ASSET.HMI, ASSET.REMOTE, ASSET.COMMS, ASSET.CTRLPROCESS, ASSET.CTRLINFO, ASSET.BUSINFO).
T.PHYSICAL_ACCESS	Unauthorized physical access	An unauthorized individual (AGENT.PRIOR_INSIDER, AGENT.OUTSIDER) directs an attack (ATTACK.PHYSICAL) to gain physical access to protected ICS components (ASSET.ACTUATOR, ASSET.SENSOR, ASSET.CONTROLLER, ASSET.HMI, ASSET.REMOTE, ASSET.COMMS).

Table 1-13
Threat Model: Assets (A)

ASSET NAME	DESCRIPTION
AS.AUDIT_SERVICE	Secure logging and analysis for events of interest.
AS.BACKHAUL	The IP Backhaul is a WAN architecture that can be deployed over multiple physical substrates.
AS.C1219_MESSAGE	An ANSI C12.19 message in the AMI system.
AS.C1222_INTERFACE	The ANSI C12.22 protocol is used for communications between the AS.COLLECTION_ENGINE and AS.METER.
AS.CELL_RELAY	The AMI Cell Relay functions as an application level router with minimal access control protections.

ASSET NAME	DESCRIPTION
AS.COLLECTION_ENGINE	The AMI Collection Engine is a logical set of multiple commodity blade servers that are responsible for data aggregation from one or more AS.METER.
AS.CRYPTOGRAPHIC_ENFORCEMENT	A highly-trusted proxy that handles signing and decrypting of messages.
AS.DEPOT_CRYPTOGRAPHIC_SERVICE	Provides provisioning of the meter.
AS.KEY_MANAGEMENT_SERVICE	The AMI Key Management Service is responsible for generating and storing the keys for the system.
AS.KEY_MATERIAL	Private and symmetric keys used in the AMI system.
AS.METER	The AMI CENTRON meter records a variety of specialized events, such as time sets, reprograms, and logins to ensure that an audit log is maintained for key events in the life of the meter. The AMI CENTRON meter generates tamper flags in response to tamper-related events.
AS.RF_LAN	The AMI RF LAN is a proprietary frequency hopping RF network deployed in North America in the 900 Mhz ISM band.
AS.SECURITY_OPERATIONS_CONSOLE	The AMI security operations console provides a high-level reporting view of the system's security posture.
AS.WEB_SERVICES	Internally, the AMI AS.COLLECTION_ENGINE uses web services interfaces to coordinate between the individual processes that comprise it. All web service calls into the AMI AS.COLLECTION_ENGINE return a document that contains an overall invocation status of the call. That is, the AS.COLLECTION_ENGINE always returns a document that tells the calling system if the call was successful, and if not, why with an error token.
AS.ZIGBEE_RF	ZigBee provides low-cost, ultra-low power, long battery life wireless mesh networking based on the 802.15.4 IEEE standard, and is the interface AS.METER uses for interactions with the HAN.

Table 1-14
Threat Model: Assets (B)

ASSET NAME	ASSET	DESCRIPTION
AS.ACTUATOR	Actuator	One or more devices that receive the controlled variables from the controller and feeds them into the controlled process for action.
AS.SENSOR	Sensor	One or more devices that sense or detect the value of a process variable and generates a signal related to the value (includes the sensing and transmitting parts of the device).
AS.CONTROLLER	Controller	The computer system or components that processes sensor input, executes control algorithms and computes actuator outputs (e.g. Programmable Logic Controllers).
AS.HMI	HMI	The hardware or software through which an operator interacts with a controller, providing a user with a view into the manufacturing process for monitoring or controlling the process.

ASSET NAME	ASSET	DESCRIPTION
AS.REMOTE	Remote Diagnostics & Maintenance	The hardware and software devices responsible for diagnostic and maintenance activities performed on the ICS from remote locations (e.g. Remote Terminal Units, pcAnywhere). May also include the communications mechanism or protocol used to access to the ICS (e.g. VPN).
AS.COMMS	Communications Infrastructure	The communications infrastructure used to bridge the control loop within an ICS. Also includes the network protocols and control equipment used to integrate ICS components and subsystems (e.g. Ethernet, wireless, RS-232 etc).
AS.CTRLPROCESS	Controlled Process	The process subject to analysis and control by the ICS (including the inputs and outputs to the process).
AS.CTRLINFO	Process Control Information	The process control information being collected by, processed by, stored on and transmitted to or from the components that constitute the process control network
AS.BUSINFO	Process Control Business Information	The process control business or financial information being created by, processed by, stored on and transmitted to or from the components that constitute the process control network

**Table 1-15
Threat Model: Vulnerabilities (A)**

VULNERABILITY NAME	DESCRIPTION
V.3RD_PARTY	Unauthorized access to the AMI system via a 3rd party network.
V.API_ABUSE	The most common forms of API abuse are caused by the returner failing to honor its end of this contract, returning erroneous data.
V.AUTHENTICATION	Weaknesses exist in the authentication mechanisms, including poor passwords and single factor exclusiveness.
V.COARSE_ACCESS_CONTROL	Poor or weak access controls are used that do not allow for proper separation of duties or desired granularity.
V.CODE_PERMISSION	Software code that must run in elevated privilege mode.
V.CODE_QUALITY	Poor code quality that leads to unpredictable behavior, poor usability, and low assurance.
V.DANGEROUS_API	Using vulnerable, obsolete, or insecure APIs.
V.ERROR_HANDLING	Improper error handling that leaves the system in an insecure state.
V.INPUT_VALIDATION	Input that is not validated often leading to overflow, range, and type errors. Path traversal vulnerabilities are also included.
V.LOGGING_AUDITING	Poor or inadequate auditing and logging mechanisms.
V.PROTOCOL	Use of 'clear text', weak, or proprietary protocols.
V.REMOTE	There are remote access vulnerabilities.
V.SENSITIVE	Insecure protection of sensitive data in transit and storage.

VULNERABILITY NAME	DESCRIPTION
V.SERVICES	Unnecessary services are enabled on system components.
V.SESSION_MANAGEMENT	Poor session identifiers leading to replay attacks.

Table 1-16
Threat Model: Vulnerabilities (B)

VULNERABILITY NAME	VULNERABILITY	DESCRIPTION
V.PLAINTEXT	Use of clear text protocols	The use of clear text protocols and the transmission of business and control data unencrypted over insecure communication channels (e.g. FTP, TELNET).
V.SERVICES	Unnecessary services enabled on system components	The presence of unnecessary system services on key ICS components and subsystems that may be exploited to negatively impact on system security (e.g. Sendmail, Finger services).
V.REMOTE	Remote access vulnerabilities	Uncontrolled external access to the corporate network (e.g. through the Internet) allowing unauthorized entry to the interconnected ICS network. Also includes vulnerabilities introduced through poor VPN configuration, exposed wireless access points, uncontrolled modem access (e.g. through networked faxes) and weak remote user authentication techniques.
V.ARCHITECTURE	Poor system architecture design leading to weaknesses in system security posture	Business and operational requirements impacting on the effectiveness of deployed or planned security measures to protect the confidentiality, integrity and availability of the ICS and its components. Poor security architecture may also lead to the bypass and tamper of ICS security functions.
V.DEVELOPMENT	Poor system development practices leading to weakness in system implementation	Lack of quality processes (e.g. configuration management, quality testing) leading to errors in system implementation and third party products such as buffer overflows and errors in control algorithms.
V.NOPOLICIES	Inadequate system security policies, plans and procedures	Lack of formal system policies, plans and procedures (e.g. weak password policies, no incident response plans, irregular compliance audits, poor configuration management policies and procedures, poor system auditing practices, backup procedures etc).
V.SPOF	Single Points of Failure	Poor security architecture design leading to one or more single points of failure in the ICS and resulting in system unavailability.
V.NOTRAINING	Inadequate user training	Inadequate training on system security issues leading to poor user security awareness.

VULNERABILITY NAME	VULNERABILITY	DESCRIPTION
V.3RDPARTY	Unauthorized access to ICS via 3rd party network	Unauthorized user access to the ICS or its components via a 3rd party network connection.
V.NORISK	Lack of risk assessment	Inadequate risk assessment activities performed on critical assets leading to a poor understanding of the security posture of the ICS and the security controls needed to counter security risks to the organization.

**Table 1-17
Threat Model: Controls**

CONTROL NAME	DESCRIPTION
C.ANTI_REPLAY	Mechanisms (nonces, RNG, timestamps) are in place to ensure detection of replay attacks.
C.AUDIT	An historical record of transactions against assets is maintained and protected.
C.AUTHENTICATION	The means by which an asset asserts their identification.
C.AUTHENTICATION.BIOMETRICS	
C.AUTHENTICATION.GOOD_PASSWORD	PW Complexity / Expiration / Rotation
C.AUTHENTICATION.OTP	
C.AUTHENTICATION.SINGLE_SIGN_ON	
C.AUTHENTICATION.SMART_CARD	
C.AUTHENTICATION.TWO_FACTOR	
C.AUTHORIZATION	The rights that are assigned to an asset.
C.AUTHORIZATION.ACL	Access Control Lists
C.AUTHORIZATION.CONTENT_BASED	Flexible / Extensible Security Domain Definition
C.AUTHORIZATION.ROLE_BASED	Role Based Access Control
C.BACKUP.FULLY_AUTOMATED	
C.BACKUP.OFFSITE	
C.BACKUP.REDUNDANT_HARDWARE	
C.CONFIDENTIALITY	Assets and messages are kept secret.
C.CONFIDENTIALITY.ENCRYPTION	Open Standards Based Algorithms
C.CONFIDENTIALITY.STRONG_ENCRYPTION	High Key Strength, End-to-End, FIPS 140-2 Compliant
C.DOCUMENTATION	
C.FAULT_TOLERANCE.APPLICATION_CHECKPOINTING	

CONTROL NAME	DESCRIPTION
C.FAULT_TOLERANCE.DISK_MIRRORING	
C.FAULT_TOLERANCE.MULTIPLE_LOCATIONS	
C.FAULT_TOLERANCE.REDUNDANT_HARDWARE	
C.FILTER	Selective discarding of messages based on a set of rules.
C.IDENTIFICATION	The means by which an asset is distinguished from other assets.
C.INTEGRITY	An asset or message is tamper-evident.
C.KEY_MANAGEMENT	Dynamic Key Change and Management
C.NON_REPUDIATION	A transaction between two assets cannot be denied by either asset.
C.PHYSICAL	There are minimal physical barriers for access to assets.
C.PHYSICAL.24X7_GUARD	
C.PHYSICAL.24x7_MONITORED	
C.PHYSICAL.MAN_TRAP	
C.PRIVACY	The asset has control over data disclosure.
C.TAMPER_DETECTION.PHYSICAL_SEALS	
C.TAMPER_DETECTION.PHYSICAL_SENSORS	
C.TRAINING	

Table 1-18
Threat Model: Attacks (A)

ATTACK NAME	DESCRIPTION	IMPACT	LIKELIHOOD
AK.1	T.SPOOF of the AS.CRYPTOGRAPHIC_ENFORCEMENT	3	3
AK.2	T.HIJACK of the AS.CRYPTOGRAPHIC_ENFORCEMENT	3	3
AK.3	T.SPOOF of the AS.KEY_MANAGEMENT_SERVICE	3	3
AK.4	T.HIJACK of the AS.KEY_MANAGEMENT_SERVICE	3	3
AK.5	T.SPOOF of the AS.COLLECTION_ENGINE	3	3
AK.6	T.HIJACK of the AS.COLLECTION_ENGINE	3	2
AK.7	T.DOS of the AS.COLLECTION_ENGINE	3	2
AK.8	T.DISCLOSURE of AS.KEY_MATERIAL stored on AS.COLLECTION_ENGINE	3	2
AK.9	T.TAMPER of AS.C1219_MESSAGE at AS.COLLECTION_ENGINE	3	2
AK.10	T.DOS of a large population of AS.METERs through the AS.COLLECTION_ENGINE's AS.WEB_SERVICES	3	1
AK.11	T.DISCLOSURE of AS.KEY_MATERIAL stored on AS.METER	3	1
AK.12	T.DISCLOSURE of AS.KEY_MATERIAL stored on AS.CELL_RELAY	3	1
AK.13	T.DOS via a T.PHYSICAL to AS.CELL_RELAY	2	2

ATTACK NAME	DESCRIPTION	IMPACT	LIKELIHOOD
AK.14	T.DOS to AS.BACKHAUL	2	2
AK.15	T.TAMPER of AS.C1219_MESSAGE at AS.CELL_RELAY	2	1
AK.16	T.TAMPER of AS.C1219_MESSAGE at AS.IP_BACKHAUL	2	1
AK.17	T.TAMPER of AS.C1219_MESSAGE at AS.RF_LAN	2	1
AK.18	T.TAMPER by TA.CUSTOMER	1	3
AK.19	T.DISCLOSURE of AS.CELL_RELAY using V.REMOTE	1	3
AK.20	T.DISCLOSURE of AS.METER using V.REMOTE	1	2
AK.21	T.TAMPER of AS.C1219_MESSAGE at AS.AS.METER	1	2
AK.22	T.TAMPER of AS.C1219_MESSAGE at AS.ZIGBEE_RF	1	2
AK.23	T.DOS via a T.PHYSICAL to AS.RF_LAN	1	1
AK.24	T.SPOOF of the AS.METER	1	1
AK.25	T.SPOOF of the AS.ZIGBEE_RF	1	1

Table 1-19
Threat Model: Attacks (B)

ATTACK NAME	Description			
	Attack	Method	Vulnerabilities	Opportunity
AK.SNIFF	Unauthorized traffic analysis	Packet capture tool, keystroke logger etc	V.PLAINTEXT, V.ARCHITECTURE, V.REMOTE, V.3RDPARTY, V.NORISK	Locally & Remotely
AK.REPLAY	Unauthorized replay of captured traffic	Packet capture tool, keystroke logger etc	V.PLAINTEXT, V.ARCHITECTURE, V.REMOTE, V.3RDPARTY, V.NORISK	Locally & Remotely
AK.SPOOF	Impersonating an authorized user	Exploitation of weak user authentication mechanism	V.PLAINTEXT, V.REMOTE, V.ARCHITECTURE, V.NOPOLICIES, V.3RDPARTY, V.NORISK	Locally & Remotely
AK.DOS	Overloading the network	Denial of service attack from the Internet causing system downtime	V.SERVICES, V.REMOTE, V.ARCHITECTURE, V.SPOF, V.3RDPARTY, V.NORISK	Remotely
AK.ERROR	Operator error	ICS system operator error causing security breach	V.SERVICES, V.NOPOLICIES, V.NOTRAINING, V.NORISK	Locally
AK.SOCIAL	Social engineering of authorized users	Unsolicited contact with employee with the intent of discovering user credentials or acquiring sensitive information	V.NOPOLICIES, V.NOTRAINING, V.NORISK	Locally & Remotely

ATTACK NAME	Description			
	Attack	Method	Vulnerabilities	Opportunity
AK.VIRUS	Virus infection of ICS system components	Virus propagation via email system or Internet downloaded content (e.g. Trojan)	V.SERVICES, V.REMOTE, V.ARCHITECTURE, V.NOPOLICIES, V.NOTRAINING, V.3RDPARTY, V.NORISK	Locally
AK.DESTROY	Destruction of ICS control data, business data or configuration information	File deletion on compromised ICS file servers	V.SERVICES, V.REMOTE, V.ARCHITECTURE, V.NOPOLICIES, V.NOTRAINING, V.NORISK	Locally & Remotely
AK.MODIFY	Modification of ICS control data, business data or configuration information	File modification on compromised ICS file servers	V.SERVICES, V.REMOTE, V.ARCHITECTURE, V.NOPOLICIES, V.NOTRAINING, V.NORISK	Locally & Remotely
AK.BYPASS	Bypass of system security functions and mechanisms	Modification of ICS configurations of components	V.SERVICES, V.REMOTE, V.ARCHITECTURE, V.NORISK	Locally & Remotely
AK.PHYSICAL	Compromise of poorly implemented and/or controlled physical security mechanisms	Unauthorized access to physically secured areas housing system assets (e.g. perimeter security breach)	V.ARCHITECTURE, V.NOPOLICIES, V.NOTRAINING, V.NORISK	Locally
AK.NATURE	Acts of nature causing system unavailability	Environmental occurrences such as earthquake, flood and fire	V.ARCHITECTURE, V.NOPOLICIES, V.NOTRAINING V.SPOF, V.NORISK	Locally

**Table 1-20
Threat Model: Security Policies**

POLICY NAME	DESCRIPTION
P.EVENT	The organization shall monitor security events to ensure compliance with security policies (e.g. security incident response plan).
P.PERSONNEL	The organization shall have in place policies, training programs, and reporting and enforcement mechanisms such that personnel know their security role in the organization
P.INFRASTRUCTURE	The organization shall provide an organizational structure to establish the implementation of the security program, in which the policies can be established, maintained and enforced throughout the organization.
P.CONFIGURATION	The organization shall provide management and operational security controls necessary to manage the system's configuration during operations and evaluate and control changes to ensure that the system remains secure.

POLICY NAME	DESCRIPTION
P.PHYSICAL	Adequate physical security shall be provided to detect or prevent unauthorized access or connection to the system and its components.
P.POLICY	The organization and system shall comply with organizational and regulatory policies and controls governing the use of, and implemented by the system to ensure secure operations.
P.ASSETS	The organization shall provide documentation of the system and its components, to understand the overall security posture.
P.SAFETY	The organization shall comply with relevant standards to ensure the safety of the system and its operators.
P.NO_INTERFERE	ICS security controls shall be implemented so as not to impede the minimum required operational capabilities of the ICS, and so as to not impede the safety systems that protect the ICS.
P.BUSINESS	The ICS shall be operated in accordance with a business continuity policy that addresses the identification of and response to events that adversely affect the ability of the ICS to operate in fulfilling its design goals (e.g. power outages, acts of nature etc).
P.RISK	The ICS shall be designed, implemented, and operated to meet the risk objectives resulting from a system life-cycle risk management program. The risk management program shall establish a comprehensive and integrated set of risk management goals for issues affecting ICS operation, safety and security.
P.ENVIRONMENT	The STOE operating environment shall have adequate security controls to counter those threats originating from outside of the defined STOE. The implementation and maintenance of these security controls should be in accordance with organizational security policies similar to those listed in this table and be selected based on the outcomes of a risk assessment.

**Table 1-21
Threat Model: Risk Categories**

RISK CATEG'Y NAME	RISK CAT. DESCR.	THREATS	VULNERABILITIES	ASSETS
R.MANAGE	Risks associated with the security roles and responsibilities applicable to all ICS users, as well as risks associated with the successful implementation of the organizational security policies.	T.BAD_COMMAND, T.REPUDIATE, T.PRIVILEGE, T.NO_FAULT_RECORD,	V.PLAINTEXT, V.SERVICES, V.REMOTE, V.ARCHITECTUREV.NOPOLICIES, V.NOTRAINING, V.3RDPARTY V.NORISK	AS.ACTUATOR, AS.SENSOR, AS.CONTROLLER, AS.HMI, AS.REMOTE, AS.COMMS, AS.CTRLPROCESS
R.SECPOLICY	Risks associated with the development, endorsement and maintenance of the instruction stipulated by the corporate security policies.	T.BAD_COMMAND, T.REPUDIATE, T.PRIVILEGE, T.NO_FAULT_RECORD, T.INFECTION	V.PLAINTEXT, V.SERVICES, V.REMOTE, V.ARCHITECTUREV.NOPOLICIES, V.NOTRAINING, V.3RDPARTY V.NORISK	AS.ACTUATOR, AS.SENSOR, AS.CONTROLLER, AS.HMI, AS.REMOTE, AS.COMMS, AS.CTRLPROCESS, AS.CTRLINFO, AS.BUSINFO

RISK CATEG'Y NAME	RISK CAT. DESCR.	THREATS	VULNERABILITIES	ASSETS
R.RISKMAN	Risks associated with the management of the risk assessment processes for the ICS.	T.DISCLOSURE, T.EVIL_ANALYSIS, T.EVIL_MODIFICATION, T.EVIL_DESTRUCTION, T.CTRL_TAMPER, T.BAD_COMMAND, T.SPOOF, T.REPUDIATE, T.DOS, T.PRIVILEGE, T.NO_FAULT_RECORD, T.DISASTER, T.INFECTION, T.PHYSICAL_ACCESS	V.PLAINTEXT, V.SERVICES, V.REMOTE, V.ARCHITECTURE, V.SPOF, V.NOPOLICIES, V.NOTRAINING, V.3RDPARTY V.NORISK	AS.ACTUATOR, AS.SENSOR, AS.CONTROLLER, AS.HMI, AS.REMOTE, AS.COMMS, AS.CTRLPROCESS, AS.CTRLINFO, AS.BUSINFO
R.COMPLY	Risks associated with not meeting internal and statutory requirements.	TBD	V.ARCHITECTUREV.NOPOLICIES, V.NOTRAINING, V.3RDPARTY V.NORISK	AS.ACTUATOR, AS.SENSOR, AS.CONTROLLER, AS.HMI, AS.REMOTE, AS.COMMS, AS.CTRLPROCESS, AS.CTRLINFO, AS.BUSINFO
R.ASSETCTRL	Risks associated with asset classification, labelling, media management and accountability.	T.REPUDIATE, T.PRIVILEGE, T.INFECTION, T.PHYSICAL_ACCESS	V.PLAINTEXT, V.SERVICES, V.REMOTE, V.ARCHITECTURE V.NOPOLICIES, V.NOTRAINING, V.3RDPARTY V.NORISK	AS.ACTUATOR, AS.SENSOR, AS.CONTROLLER, AS.HMI, AS.REMOTE, AS.COMMS, AS.CTRLPROCESS, AS.CTRLINFO, AS.BUSINFO
R.PERSONNEL	Risks associated with personnel vetting, security awareness, training, separation of duties and system usage agreements.	T.BAD_COMMAND, T.SPOOF, T.REPUDIATE, T.PRIVILEGE, T.NO_FAULT_RECORD, T.DISASTER, T.INFECTION, T.PHYSICAL_ACCESS	V.PLAINTEXT, V.SERVICES, V.REMOTE, V.ARCHITECTURE, V.SPOF, V.NOPOLICIES, V.NOTRAINING, V.3RDPARTY V.NORISK	AS.ACTUATOR, AS.SENSOR, AS.CONTROLLER, AS.HMI, AS.REMOTE, AS.COMMS, AS.CTRLPROCESS, AS.CTRLINFO, AS.BUSINFO
R.PHYSICAL	Risks associated with unauthorized physical access and/or damage to system components.	T.PHYSICAL_ACCESS	V.ARCHITECTUREV.NOPOLICIES, V.NOTRAINING, V.NORISK	AS.ACTUATOR, AS.SENSOR, AS.CONTROLLER, AS.HMI, AS.REMOTE, AS.COMMS
R.ENVIRON	Risks associated with the effects of natural disasters, such as fire, flood and earthquake.	T.DISASTER	V.ARCHITECTUREV.SPOF, V.NOPOLICIES, V.NOTRAINING, V.NORISK	AS.ACTUATOR, AS.SENSOR, AS.CONTROLLER, AS.HMI, AS.REMOTE, AS.COMMS, AS.CTRLPROCESS, AS.CTRLINFO, AS.BUSINFO
R.EVIL_ACCESS	Risks associated with the illicit use, modification and destruction of company data or inappropriate access to information.	T.DISCLOSURE, T.EVIL_ANALYSIS, T.EVIL_MODIFICATION, T.EVIL_DESTRUCTION, T.CTRL_TAMPER, T.BAD_COMMAND, T.SPOOF, T.REPUDIATE, T.DOS, T.PRIVILEGE, T.NO_FAULT_RECORD	V.PLAINTEXT, V.SERVICES, V.REMOTE, V.ARCHITECTURE, V.SPOF, V.NOPOLICIES, V.NOTRAINING, V.3RDPARTY V.NORISK	AS.ACTUATOR, AS.SENSOR, AS.CONTROLLER, AS.HMI, AS.REMOTE, AS.COMMS, AS.CTRLPROCESS, AS.CTRLINFO, AS.BUSINFO

RISK CATEG'Y NAME	RISK CAT. DESCR.	THREATS	VULNERABILITIES	ASSETS
R.NEED2KNOW	Risks associated with the threat to information confidentiality and privacy, unauthorised disclosure and clear desk practices.	T.DISCLOSURE, T.EVIL_ANALYSIS, T.SPOOF, T.PRIVILEGE	V.PLAINTEXT, V.SERVICES, V.REMOTE, V.ARCHITECTURE, V.NOPOLICIES, V.NOTRAINING, V.3RDPARTY V.NORISK	AS.REMOTE, AS.COMMS, AS.CTRLPROCESS, AS.CTRLINFO, AS.BUSINFO
R.INTEGRATE	Risks associated with the integration of security requirements into the systems development cycle and the selection of third party products.	TBD	V.SERVICES, V.REMOTE, V.ARCHITECTURE, V.SPOF, V.NOPOLICIES, V.NOTRAINING, V.3RDPARTY V.NORISK	AS.ACTUATOR, AS.SENSOR, AS.CONTROLLER, AS.HMI, AS.REMOTE, AS.COMMS, AS.CTRLPROCESS, AS.CTRLINFO, AS.BUSINFO
R.NETCOMMS	Risks associated with the protection of network communications at the logical and physical layers.	T.DISCLOSURE, T.EVIL_ANALYSIS, T.CTRL_TAMPER, T.SPOOF, T.DOS, T.NO_FAULT_RECORD, T.INFECTION, T.PHYSICAL_ACCESS	V.PLAINTEXT, V.SERVICES, V.REMOTE, V.ARCHITECTURE, V.SPOF, V.NOPOLICIES, V.NOTRAINING, V.3RDPARTY V.NORISK	AS.ACTUATOR, AS.SENSOR, AS.CONTROLLER, AS.HMI, AS.REMOTE, AS.COMMS, AS.CTRLPROCESS, AS.CTRLINFO, AS.BUSINFO
R.CONNECT	Risks associated with connections to other IT systems.	T.DISCLOSURE, T.EVIL_ANALYSIS, T.EVIL_MODIFICATION, T.EVIL_DESTRUCTION, T.CTRL_TAMPER, T.SPOOF, T.DOS, T.PRIVILEGE, T.NO_FAULT_RECORD, T.INFECTION	V.PLAINTEXT, V.SERVICES, V.REMOTE, V.ARCHITECTURE, V.SPOF, V.NOPOLICIES, V.NOTRAINING, V.3RDPARTY V.NORISK	AS.ACTUATOR, AS.SENSOR, AS.CONTROLLER, AS.HMI, AS.REMOTE, AS.COMMS, AS.CTRLPROCESS, AS.CTRLINFO, AS.BUSINFO
R.INTERNET	Risks associated with the use of the Internet and email services both internal and external to the ICS.	T.DISCLOSURE, T.EVIL_ANALYSIS, T.EVIL_MODIFICATION, T.EVIL_DESTRUCTION, T.CTRL_TAMPER, T.SPOOF, T.DOS, T.PRIVILEGE, T.INFECTION	V.PLAINTEXT, V.SERVICES, V.REMOTE, V.ARCHITECTURE, V.SPOF, V.NOPOLICIES, V.NOTRAINING, V.3RDPARTY V.NORISK	AS.ACTUATOR, AS.SENSOR, AS.CONTROLLER, AS.HMI, AS.REMOTE, AS.COMMS, AS.CTRLPROCESS, AS.CTRLINFO, AS.BUSINFO
R.REMOTE	Risks associated with the connection of remote users to the ICS network.	T.DISCLOSURE, T.EVIL_ANALYSIS, T.EVIL_MODIFICATION, T.EVIL_DESTRUCTION, T.CTRL_TAMPER, T.SPOOF, T.DOS, T.PRIVILEGE, T.INFECTION	V.PLAINTEXT, V.SERVICES, V.REMOTE, V.ARCHITECTURE, V.SPOF, V.NOPOLICIES, V.NOTRAINING, V.3RDPARTY V.NORISK	AS.ACTUATOR, AS.SENSOR, AS.CONTROLLER, AS.HMI, AS.REMOTE, AS.COMMS, AS.CTRLPROCESS, AS.CTRLINFO, AS.BUSINFO

RISK CATEG'Y NAME	RISK CAT. DESCR.	THREATS	VULNERABILITIES	ASSETS
R.ONLINE	Risks associated with the delivery of online services, including statutory requirements, security issues and controls, publishing and third-party security.	T.DISCLOSURE, T.DOS, T.NO_FAULT_RECORD, T.INFECTION	V.PLAINTTEXT, V.SERVICES, V.REMOTE, V.ARCHITECTURE, V.SPOF, V.NOPOLICIES, V.NOTRAINING, V.3RDPARTY V.NORISK	AS.ACTUATOR, AS.SENSOR, AS.CONTROLLER, AS.HMI, AS.REMOTE, AS.COMMS, AS.CTRLPROCESS, AS.CTRLINFO, AS.BUSINFO
R.OPSMANAGE	Risks associated with managing system changes, such as changes not approved or audited correctly, lack of consultation with relevant parties, loss of skilled people, and lack of correct documentation. Risks associated with the use of technology for data and system control, including data protection, backup, disaster recovery, inadequate security, and insufficient capacity, etc.	T.DISCLOSURE, T.EVIL_ANALYSIS, T.EVIL_MODIFICATION, T.EVIL_DESTRUCTION, T.CTRL_TAMPER, T.BAD_COMMAND, T.SPOOF, T.REPUDIATE, T.DOS, T.PRIVILEGE, T.NO_FAULT_RECORD, T.DISASTER, T.INFECTION, T.PHYSICAL_ACCESS	V.PLAINTTEXT, V.SERVICES, V.REMOTE, V.ARCHITECTURE, V.SPOF, V.NOPOLICIES, V.NOTRAINING, V.3RDPARTY V.NORISK	AS.ACTUATOR, AS.SENSOR, AS.CONTROLLER, AS.HMI, AS.REMOTE, AS.COMMS, AS.CTRLPROCESS, AS.CTRLINFO, AS.BUSINFO
R.IDS	Risks associated with security auditing, security breach detection and response, incident reporting and forensic evidence requirements.	T.BAD_COMMAND, T.REPUDIATE, T.NO_FAULT_RECORD,	V.SERVICES, V.NOPOLICIES, V.NOTRAINING, V.NORISK	AS.ACTUATOR, AS.SENSOR, AS.CONTROLLER, AS.HMI, AS.REMOTE, AS.COMMS, AS.CTRLPROCESS
R.CONTINUITY	Risks associated with ensuring the uninterrupted availability of all key business resources required to support essential (or critical) business activities.	T.EVIL_DESTRUCTION, T.CTRL_TAMPER, T.BAD_COMMAND, T.DOS, T.DISASTER, T.INFECTION, T.PHYSICAL_ACCESS	V.PLAINTTEXT, V.SERVICES, V.REMOTE, V.ARCHITECTURE, V.SPOF, V.NOPOLICIES, V.NOTRAINING, V.3RDPARTY V.NORISK	AS.ACTUATOR, AS.SENSOR, AS.CONTROLLER, AS.HMI, AS.REMOTE, AS.COMMS, AS.CTRLPROCESS, AS.CTRLINFO, AS.BUSINFO

**Table 1-22
Threat Model: Security Objectives**

OBJECTIVE NAME	DESCR.				
O.PHYSICAL	The STOIE must provide protection at the physical boundaries of the ICS to prevent access to the protected assets by unauthorized users.				
O.RISK	ICS risk assessment shall be conducted throughout the life-cycle of an ICS, such that a documented and approved risk assessment process is conducted initially, and reviewed with each change to the manufacturing process or change to the ICS; and to ensure that changing vulnerabilities do not degrade the security of the ICS.				
O.NON_INTERFERENCE	The ICS security functions shall be implemented in a non-interfering manner such behavior of the ICS functions and safety functions are able to meet their performance constraints.				
O.INTERCONNECTIVITY	ICS security functions shall include the capability to secure interfaces and interconnectivity of ICS related safety systems, as required.				

OBJECTIVE NAME	DESCR.				
O.DATA_BACKUP	<p>The STOЕ must include provisions for ICS data and control information (including executable software and control data) to assure the ability for timely recovery to an operating state if the ICS is compromised or damaged. The data backup procedures should follow industry best practices including (but not limited to) secondary storage locations, testing of recovery procedures, and a back up interval either driven by configuration changes or a specified time interval or a combination of both.</p>				
O.DATA_AUTHENTICATION	<p>The STOЕ shall authenticate configuration change commands such that configuration (control algorithms, set points, limit points, etc.) cannot be changed unless the origin of the command can be positively established.</p>	<p>The STOЕ shall authenticate financial or other business critical information sent from the STOЕ to external systems.</p>			
O.CONTINUITY	<p>The ICS shall ensure continuity of operations in accordance with a business continuity policy that addresses a known set of anticipated events that might adversely affect the operational capability of the ICS.</p>				

OBJECTIVE NAME	DESCR.				
O.MANAGEMENT	<p>A policy for governing security shall be defined to establish the following:</p> <ul style="list-style-type: none"> - An organization-wide, security management infrastructure - Identified roles and responsibilities, together with explicit authority to ensure operational security within the management infrastructure 				
O.MIGRATION	<p>The ICS shall have a migration strategy providing the capability to govern the evolution of the control system throughout its security operational life cycle. The migration strategy shall address at a minimum:</p>	<p>Assessment of new vulnerabilities and appropriate/necessary mitigating actions to control/reduce new vulnerabilities. This may include maintenance of the current system state (components, configuration, patches, etc).</p>	<p>The integration between computer implemented and personnel implemented procedures.</p>		
O.COMPLIANCE	<p>The ICS shall be operated in compliance with relevant governing mandates.</p>				
O.3RDPARTY	<p>Policies governing the roles, responsibilities and activities authorized for individuals not employed by the control system operating organization shall be developed.</p>				
O.REMOTE	<p>The policies shall establish methods for on-site internal, on-site remote, and off-site remote access to control system resources.</p>				

OBJECTIVE NAME	DESCR.				
O.ACCESS_CONTROL	The ICS shall provide the capability to grant or deny access to control system resources based upon the action being performed, and the authorizations associated with authorized subjects.	The ICS shall deny unauthorized agents access to every control system resource.	The ICS shall require that each agent authorized to use the control system is identified and is provided with credentials to authenticate their identity.	The ICS must be able to include knowledge of the control system state and/or the controlled process state when making an access control decision.	The ICS shall include knowledge of time and location in the rules for making an access control decision.
O.SECURE_COMMS	The ICS shall provide the capability to prevent or detect, as required, the loss of integrity of the ICS operational communications capability.	The ICS shall provide the capability to allow information flows only between those endpoints authorized by the system.			
O.DATA_INTEGRITY	The ICS shall provide the capability to protect information flows from replay, substitution or modification.	The ICS shall provide the capability to allow the recipient of an authorized information flow to verify the correctness of the received information.			
O.CONFIDENTIALITY	The ICS shall protect the confidentiality of information determined by the respective owners as requiring protection, including, but not limited to, information related to business, financial and control data.				
O.AVAILABILITY	The ICS shall have continuity of availability for operational capability.	The ICS shall be capable of continuing operation if a control server is unavailable for any reason.	The ICS shall be capable of continuing operation if the primary communications channel is unavailable for any reason.		
O.SYSTEM_INTEGRITY	The ICS shall provide the capability to prevent or detect, as required, the loss of integrity of the ICS operational system configuration and capability.	The ICS shall provide the capability to restrict access to the functions used to establish and maintain the secure operational configuration of the ICS.			

OBJECTIVE NAME	DESCR.				
O.SYSTEM_DIAGNOSTICS	The ICS shall be capable of performing self-tests to verify the configuration and integrity of the security functions of the ICS.	The ICS shall provide the capability for self-test to be executed on start-up, at periodic intervals, and on demand.			
O.MONITORING	The ICS shall be capable of detecting unauthorized activity, unusual activity and attempts to defeat the security capabilities of the ICS.				
O.AUDIT	The ICS shall provide the capability to record and maintain event traces that reflect the successful and unsuccessful security relevant activities involving ICS resources.				
O.IDS	The ICS shall be capable of detecting unauthorized activity, unusual activity and attempts to defeat the security capabilities of the ICS.	The control system shall be capable of initiating action in response to the detection of a potential violation of the ICS security policy.			

AMI-SEC RA: Appendix C – Assumptions

Assumptions are items that the security functions of the AMI system itself cannot implement or enforce. Assumptions do not specify functional requirements on the environment; that is done with a threat or policy statement.

Table 1-23 describes relevant assumptions, which may contribute to satisfying portions of the identified policies and will modify the impact of these policies on identified security objectives.

Table 1-23
AMI-SEC RA: AMI Assumptions

ASSUMPTION NAME	DESCRIPTION
AA.Admin_Available	At least one Security Administrator is available at all times to respond to TOE security incidents, alerts, and alarms.
AA.Audit_Analysis	Mechanisms exist outside the TOE but within the TSE to perform sophisticated audit analysis (e.g., audit reduction and trend analysis) to augment TOE capability.
AA.Back_Up	Backups of TOE files and configuration parameters are performed as required in accordance with site security policy. They are sufficient to restore TOE operation in the event of a failure or security compromise.
AA.Clearance	All authorized users and administrators with access to the TOE will be authorized by their government to have access to, and the need-to-know, specified categories of TOE information.
AA.Comms_Available	Communication capability with adequate service levels exists between TOE physical environments and is not part of the TOE.
AA.Environment	This Problem Profile addresses the security environment of the TOE but specifically excludes the definition of the physical environmental tolerances (temperature, shock, vibration, etc.)
AA.External_Networks	External networks that interface with the TOE are single-level attributed networks.
AA.KeyMat_Source	Key material for the TOE will be supplied from external sources.
AA.KeyMat_Source_Trust	The source of key material, after authentication, will be trusted.
AA.Backhaul_Network_Errors	The Backhaul Network will report error indications to the TOE.
AA.Personnel_Untrusted	Users (operational and management, local and remote) are not trusted to operate within their allocated authority.
AA.Physical_Protection	The environment is capable of physically protecting the TOE by signaling the occurrence of fire, flood, power loss, and environmental control failures that might adversely affect TOE operations.
AA.Partial_Physical_Security	Some TOE components are located within controlled access areas that provide protection against unauthorized physical access and tampering by unauthorized agents.
AA.Policy_MoA	The U.S. negotiates multinational information sharing policy with the partner nations and all member nations enforce it.
AA.Printer_Security	The printer outputs of TOE components are protected from observation by unauthorized personnel.
AA.TOE_Design	The TOE is designed, manufactured, installed, and configured in accordance with its evaluated configuration and conforms to applicable security policies.
AA.TOE_Maintenance	The TOE will be maintained by the System Administrator or by designated maintenance personnel who have been properly cleared and trained, and who perform under the supervision of the System Administrator.
AA.TOE_Operation	The TOE is operated, maintained, and managed in accordance with its accredited configuration and conforms to applicable security policies.
AA.TOE_User	TOE users will be either U.S. or coalition nation personnel who have been specifically authorized to participate in the operation or mission.

ASSUMPTION NAME	DESCRIPTION
AA.Trained	All users, administrators, and maintainers are appropriately trained.
AA.Trusted_Source	A trusted source for key material, policy and software exists external to the TOE.
AA.Visual_Security	The visible outputs of TOE components are protected from observation by unauthorized persons.

AMI-SEC RA: Appendix D – Threat Descriptions

Administrative Threats

Administrative threats are those threats that are caused by malicious or negligent administrators. These threats are listed below in Table 1-24.

Table 1-24
Threat Descriptions - Administrative

THREAT NAME	SEVERITY	LIKELI-HOOD	DESCRIPTION
T.Admin.Cred.1			An entity gives access to information assets to inappropriate users
T.Admin.Cred.2			An AMI entity with proper access gives access to resource assets to inappropriate users
T.Admin.Cred.3			An AMI entity with proper access gives access to service assets to inappropriate users
T.Admin.Enroll.1			An AMI entity with proper access enrolls a user with inappropriate levels of access control. .
T.Admin.Lockout.1			An entity uses the Lockout service asset in an unauthorized manner to lock out a user.
T.Admin.Lockout.2			An entity uses the Lockout service asset in an unauthorized manner to unlock a locked out a user.
T.Admin.Policy.4			An entity gains unintentional access to objects in another system due to information sharing between the two information systems.
T.Admin.Policy.5			An AMI entity with access creates a large policy causing an exhaustion of storage space.
T.Admin.Policy.7			An AMI entity without proper access exploits policy flaws to gain improper (unintended) access to assets.
T.Admin.Policy.9			An AMI entity with access enters/modifies AMI policy incorrectly, due to a lack of understanding of the policy system.
T.Admin.Policy.10			An AMI entity with access enters/modifies AMI policy incorrectly, due to a lack of understanding of the current policy.
T.Admin.Policy.11			An AMI entity with access enters/modifies AMI policy maliciously to cause information disclosure or loss.
T.Admin.Policy.12			An AMI entity with access enters inconsistent AMI policy.
T.Admin.Policy.13			An AMI entity with access imports a malicious AMI organizational policy.
T.Admin.Policy.14			A policy authority provides a malicious AMI organizational policy.
T.Admin.Policy.17			Required organizational policies are inconsistent resulting in denial of service.

Audit Threats

Audit threats are those threats that involve the AMI audit logs. The specific threats are listed below in Table 1-25.

**Table 1-25
Threat Descriptions - Audit**

THREAT NAME	SEVERITY	LIKELI-HOOD	DESCRIPTION
T.Audit.1	<i>Medium</i>	Likely	An entity creates a large number of auditable events in order to cause the AMI audit logs to run out of resource space.
T.Audit.2	Medium	<i>Likely</i>	An AMI entity with proper access to the audit logs fails to clear enough space for the logs, causing the AMI audit logs to run out of resource space.
T.Audit.3	Medium	Likely	An entity causes the AMI auditing function to fail, allowing an entity to perform non-recorded auditable actions.
T.Audit.4	High	Likely	An entity reads AMI audit logs when it does not have authorization to read any audit logs.
T.Audit.5	Medium	Likely	An entity reads AMI audit logs with a security attribute it does not possess.
T.Audit.6	High	Likely	An entity modifies AMI audit logs to hide other actions.
T.Audit.7	High	Likely	An entity deletes AMI audit logs it does not have authorization to delete.
T.Audit.8	Low	Likely	An AMI entity with proper access misinterprets audit data, and thus cannot detect inappropriate actions of other principals.
T.Audit.9	Low	Likely	An AMI entity with proper access cannot find the desired audit data within the AMI audit logs, and thus cannot detect inappropriate actions of other principals.
T.Audit.10	Medium	Unlikely	An AMI entity with proper access is not provided enough information by the AMI audit logs to detect inappropriate actions of other principals.
T.Audit.11	Medium	Unlikely	An AMI entity with proper access is not provided enough information by the AMI audit logs to identify principals who take inappropriate actions.

Crypto Threats

Crypto threats are those threats that directly involve the cryptography of the system. These threats include brute force attacks, mathematical attacks, etc. The specific threats are listed below in Table 1-26.

**Table 1-26
Threat Descriptions - Crypto**

THREAT NAME	THREAT	LIKELI-HOOD	DESCRIPTION
T.Crypto.Break.1	<i>High</i>	Unusual	An entity breaks the cryptographic mechanisms that protect assets through mathematical means.
T.Crypto.Break.2	<i>High</i>	Unusual	An entity breaks the cryptographic mechanisms that protect assets through brute force computational means.

THREAT NAME	THREAT	LIKELI-HOOD	DESCRIPTION
T.Crypto.Invalid_Keys.1	<i>Medium</i>	Unusual	An AMI entity with access uses invalid cryptographic keys causing the system to enter a non-operational state.
T.Crypto.Invalid_Keys.2	<i>High</i>	Unusual	An AMI entity with access uses invalid cryptographic keys causing the system to enter an insecure state.
T.Crypto.Weak_Keys.1	<i>High</i>	Unlikely	An entity breaks the cryptographic mechanisms that protect assets because of the use of weak keys.

Download Threats

Download threats are those threats that directly involve the download source interface. The specific threats are listed below in Table 1-27.

**Table 1-27
Threat Descriptions - Download**

THREAT NAME	SEVERITY	LIKELI-HOOD	DESCRIPTION
T.Download.1	<i>Medium</i>	Unusual	An entity performs a denial of service attack that prevents the Download service asset from being able to download. This may lead to failure of a critical upgrade and continued exploitation of a weakness.
T.Download.2	<i>High</i>	Unusual	An AMI entity with access to the Software Download service asset provides faulty software/configuration information to the AMI component resource asset.
T.Download.3	<i>Low</i>	Likely	An AMI entity with proper access to the Download service asset loads software/configuration into an AMI component resource asset out of sequence.
T.Download.4	<i>Low</i>	Likely	An AMI entity with access to the Download Software service asset loads software/configuration into the wrong AMI component resource asset.
T.Download.5	<i>Medium</i>	Unusual	A non-AMI entity without access to the Download Software service asset replays download messages to cause a denial of service.

Eavesdropping Threats

Eavesdropping threats are those threats that involve network or communication eavesdropping. The specific threats are listed below in Table 1-28.

**Table 1-28
Threat Descriptions - Eavesdropping**

THREAT NAME	SEVERITY	LIKELI-HOOD	DESCRIPTION
T.Eavesdrop.Apps.1	<i>Medium</i>	Unlikely	An entity eavesdrops on the Applications Interface (e.g. via logger process) in an attempt to read policy, information content, or information attributes information assets.

THREAT NAME	SEVERITY	LIKELIHOOD	DESCRIPTION
T.Eavesdrop.Comm.1	<i>Medium</i>	Likely	An entity eavesdrops on the Backhaul network in an attempt to read an information asset (e.g., in order to receive covert channel communications or perform traffic analysis).
T.Eavesdrop.Comm.2	<i>Medium</i>	Likely	An AMI entity eavesdrops on the AMI Virtual Network in an attempt to read an information asset (e.g., in order to receive covert channel communications or perform traffic analysis).
T.Eavesdrop.Comm.3	<i>Low</i>	Likely	An entity eavesdrops on the Policy Authority Interface in an attempt to read a policy, policy mechanism, or traffic flow information asset.
T.Eavesdrop.Comm.4	<i>Medium</i>	Likely	An entity eavesdrops on the AMI Systems Interface in an attempt to read information content, information attributes, policy, policy mechanism, or traffic flow information assets.
T.Eavesdrop.Comm.5	<i>Medium</i>	Likely	An entity eavesdrops on the non-AMI Systems Interface in an attempt to read information content, information attributes, or traffic flow information assets.
T.Eavesdrop.Comm.6	<i>Low</i>	Unlikely	An entity eavesdrops on the Download Source Interface in an attempt to diagnose AMI configuration and derive attacks on other AMI systems that weren't upgraded yet.
T.Eavesdrop.Comm.7	<i>High</i>	Likely	An entity eavesdrops on the Key Management Systems Interface in an attempt to read policy, policy mechanisms, or traffic flow information assets.
T.Eavesdrop.HMI.1	<i>Medium</i>	Likely	An entity eavesdrops on the Users Interface (e.g. via a camera or a tap in the monitor cable) in an attempt to read policy, information content, or information attributes information assets.
T.Eavesdrop.HMI.2	<i>Medium</i>	Likely	A valid AMI user leaves the workstation unattended, does not logout, and leaves the AMI Token in the workstation. An entity sits at the unattended workstation and improperly accesses information assets.
T.Eavesdrop.HMI.3	<i>Low</i>	Unlikely	An entity sits at the unattended, inactive workstation, and attempts to access information assets.
T.Eavesdrop.HMI.4	<i>Medium</i>	Likely	An entity eavesdrops on the Users Interface because an authorized user viewed information assets in an unauthorized area.

Flawed Implementation Threats

Flawed implementation threats are those threats that arise due to an incorrect or insecure implementation of AMI. Specific threats are listed below in Table 1-29.

Table 1-29
Threat Descriptions - Flawed Implementation

THREAT NAME	SEVERITY	LIKELI-HOOD	DESCRIPTION
T.Flawed_Imp.Backdoor.1	<i>High</i>	<i>Unusual</i>	An entity gains improper access to assets via a backdoor mechanism.
T.Flawed_Imp.Developer.1	Medium	Likely	An entity exploits flaws in the AMI component [software, hardware] resource assets to gain improper access to assets.
T.Flawed_Imp.Developer.2	Medium	Likely	An entity exploits flaws in the AMI component [software, hardware] resource assets to perform a denial of service attack.
T.Flawed_Imp.Developer.3	Medium	<i>Likely</i>	An entity exploits flaws in the AMI component [software, hardware] resource assets to exfiltrate an information asset.

Identification & Authentication Threats

Identification and authentication (I&A) threats are those threats that involve the user identification and authentication process. The specific threats are listed below in Table 1-30.

Table 1-30
Threat Descriptions - Identification & Authentication

THREAT NAME	SEVERITY	LIKELI-HOOD	DESCRIPTION
T.Ident_Auth.1	<i>High</i>	<i>Likely</i>	An entity discovers user authentication information from a AMI component resource asset.
T.Ident_Auth.2	<i>High</i>	<i>Likely</i>	An entity discovers user authentication information by external methods (i.e. human intelligence).
T.Ident_Auth.3	<i>Low</i>	<i>Likely</i>	An AMI entity forgets its passphrase.
T.Ident_Auth.4	<i>High</i>	<i>Likely</i>	An AMI entity attempts to crack I&A mechanisms through brute force methods (e.g., a password cracker).
T.Ident_Auth.5	<i>High</i>	<i>Likely</i>	An entity is able to guess a passphrase because the passphrase was too simple (e.g., too short, it is "password", etc.)
T.Ident_Auth.6	<i>High</i>	<i>Unlikely</i>	An entity spoofs the I&A process to gain access to the user authentication information assets.
T.Ident_Auth.7	<i>High</i>	<i>Unlikely</i>	An entity has access to a user's AMI Token, and attempts to login to a AMI Workstation.
T.Ident_Auth.8	<i>High</i>	<i>Unlikely</i>	An entity steals or borrows a valid user's AMI Token, and duplicates it with the intent of using it for access by a different individual, or returning it modified to the original user.

Information System Threats

Information system threats are those threats that involve other information systems, whether those systems are other AMI System security domains or non-AMI systems. The specific threats are listed below in Table 1-31.

Table 1-31
Threat Descriptions - Information System

THREAT NAME	SEVERITY	LIKELI-HOOD	DESCRIPTION
T.InfoSys.1	<i>High</i>	<i>Likely</i>	An entity installs a secret trapdoor into another information system so as to gain access to AMI.
T.InfoSys.2	Medium	Likely	An entity changes the dissemination of an object to which he had access after it has been moved to another information system.
T.InfoSys.Filter.1	<i>Medium</i>	Likely	An AMI entity with access makes use of an ineffective filter (e.g., dirty word filter) at the information system interface.
T.InfoSys.Printer.1	Medium	Likely	An entity waits for a AMI entity with access to an information asset to print that information asset to a printer the entity has access to, and gains access to the information asset via the printout.

Initialization Threats

Initialization threats are those threats that occur during initialization of AMI components and during distribution of AMI components. The specific threats are listed below in Table 1-32.

Table 1-32
Threat Descriptions - Initialization

THREAT NAME	SEVERITY	LIKELI-HOOD	DESCRIPTION
T.Initialize.Configuration.1	<i>High</i>	<i>Unusual</i>	An AMI entity with access to the Initialization service asset provides faulty configuration information to the AMI component resource asset.
T.Initialize.Configuration.2	<i>High</i>	<i>Unusual</i>	An AMI entity with access to the Initialization service asset provides faulty trust anchors to the AMI component resource asset.
T.Initialize.Configuration.3	<i>High</i>	<i>Unusual</i>	An AMI entity with access to the Initialization service asset provides faulty hardware as a AMI component resource asset.
T.Initialize.Distribution.1	<i>High</i>	<i>Likely</i>	An entity intercepts distribution of AMI components, and replaces AMI hardware with malicious hardware.
T.Initialize.Distribution.2	<i>High</i>	<i>Likely</i>	An entity intercepts distribution of AMI components, and replaces AMI software with malicious software.

Insider Threats

Insider threats are those threats that directly involve authorized users of the system operating maliciously or negligently. The specific threats are listed below in Table 1-33.

**Table 1-33
Threat Descriptions - Insider**

THREAT NAME	SEVERITY	LIKELIHOOD	DESCRIPTION
T.Insider.Aggregation.1	<i>Low</i>	<i>Unusual</i>	An AMI entity with access browses files to collect information (aggregation attack).
T.Insider.Confusion.1	<i>Medium</i>	<i>Likely</i>	An AMI entity with access configures the system incorrectly because the system is too complex.
T.Insider.Confusion.2	<i>Medium</i>	<i>Likely</i>	An AMI entity with access performs some insecure actions because the system is too complex.
T.Insider.Confusion.3	<i>Medium</i>	<i>Likely</i>	A non-English speaking AMI entity performs insecure actions due to confusion about how to use the system securely.
T.Insider.Misinfo.1	<i>High</i>	<i>Unusual</i>	An AMI entity with access improperly enters, edits, or imports content resulting in misinformation.
T.Insider.Mislabel.1	<i>Medium</i>	<i>Likely</i>	An AMI entity with access creates, enters, edits, or imports content and labels it with incorrect security attributes resulting in unauthorized disclosure.
T.Insider.Mislabel.2	<i>Medium</i>	<i>Likely</i>	An entity enters, edits unauthorized values in the information attributes resulting in exfiltration of information assets.
T.Insider.Misuse.Info.1	<i>Medium</i>	<i>Likely</i>	An AMI entity with access to an information asset attempts to exfiltrate that information asset to a potential covert channel.
T.Insider.Misuse.Info.2	<i>Medium</i>	<i>Likely</i>	An AMI entity with access to an information asset prints that asset and discloses it to an inappropriate individual.
T.Insider.Misuse.Res.1	<i>Low</i>	<i>Unlikely</i>	An AMI entity with access to a resource asset attempts to access greater than its quota of that resource asset (e.g., bandwidth quota or data repository quota).

Key Management Threats

Key Management threats are those threats that involve the Key Management Systems with which AMI is interfacing. The specific threats are listed below in Table 1-34.

**Table 1-34
Threat Descriptions - Key Management**

THREAT NAME	SEVERITY	LIKELIHOOD	DESCRIPTION
T.KeyMan.Deliver.1	High	<i>Likely</i>	An AMI entity with proper access to the Deliver Keys service asset downloads duplicate keys with different attributes. This can lead to unauthorized access to assets.
T.KeyMan.Deliver.2	High	Likely	An AMI entity with proper access to the Deliver Keys service asset downloads weak keys that can be broken. This can lead to unauthorized access to assets.

THREAT NAME	SEVERITY	LIKELIHOOD	DESCRIPTION
T.KeyMan.Deliver.3	High	Likely	An AMI entity with proper access to the Deliver Keys service asset downloads keys with inappropriate attributes. This can lead to unauthorized access to assets.
T.KeyMan.Deliver.4	Medium	Unlikely	An entity performs a denial of service attack that prevents the Deliver Keys service asset from being able to deliver keys.
T.KeyMan.Membership.1	Medium	Likely	An AMI entity with access to the Membership Management service asset fails to report an individual whose keys should be revoked.
T.KeyMan.Membership.2	Low	Unusual	An AMI entity with access to the Membership Management service asset reports revocation of individual whose keys should not have been revoked.
T.KeyMan.Membership.3	Low	Unusual	An AMI entity with access to the Membership Management service asset delivers Membership Management information with inappropriate attributes for users.
T.KeyMan.Obsolescence.1	Medium	Likely	Key Management services evolve in ways that are not backwardly compatible with AMI (may be included in KMS).
T.KeyMan.Order.1	Medium	Unusual	An AMI entity with proper access to the Order Keys service asset annoys the Key Management Systems with nuisance orders causing the Key Management Systems to stop services to that AMI System security domain.
T.KeyMan.Order.2	Medium	Unlikely	An AMI entity with proper access to the Order Keys service asset orders the wrong keys from the Key Management System and causes a failure to share information.
T.KeyMan.Order.3	Medium	Unlikely	An entity performs a denial of service attack that prevents the Order Keys service asset from being able to order keys, creating an inability to access or verify information assets.
T.KeyMan.TrackControl.1	Low	Unlikely	An entity performs a denial of service attack that prevents the Tracking and Control service asset from being able to report the correct information. This may lead to incomplete analysis and may cause: <ul style="list-style-type: none"> • Inappropriate compromise recovery actions • Damage assessment errors

Malicious Code Threats

Malicious code threats are those threats that involve malicious code execution or implantation. The specific threats are listed below in Table 1-35.

Table 1-35
Threat Descriptions - Malicious Code

THREAT NAME	SEVERITY	LIKELIHOOD	DESCRIPTION
T.Malicious_Code.App.1	High	<i>Likely</i>	An entity implants malicious code in an application in order to modify the operating system, other applications, or data leading to disclosure of information assets, modification of information assets, denial of service, repudiation.
T.Malicious_Code.App.2	High	<i>Likely</i>	An entity implants malicious code in an application in order to modify the operating system, other applications, or data leading to exfiltration of information assets to potential covert channels.
T.Malicious_Code.App.3	High	<i>Unlikely</i>	An entity implants malicious code in an application in order to receive covert channel communication to direct the application to modify the operating system, other applications, or data. (See T.Malicious_Code.App.1 and T.Malicious_Code.App.2)
T.Malicious_Code.App.4	High	<i>Likely</i>	An entity implants malicious code in an application in order to attack external entities through a AMI interface.
T.Malicious_Code.Info.1	Medium	<i>Likely</i>	An entity implants malicious code in an information asset in order to gain access to an asset it is not authorized to access.
T.Malicious_Code.Info.2	Medium	<i>Likely</i>	An entity implants malicious code in an information asset in order to exfiltrate information assets to a potential covert channel.
T.Malicious_Code.Info.3	Medium	<i>Likely</i>	An entity implants malicious code in a AMI component information asset in order to modify information assets.
T.Malicious_Code.Info.4	Low	<i>Unlikely</i>	An entity implants malicious code in a information asset in order to launch a denial of service attack.
T.Malicious_Code.Info.5	Medium	<i>Likely</i>	An entity causes a user to execute malicious code in a AMI component information asset in order to modify information assets.
T.Malicious_Code.Info.6	Medium	<i>Likely</i>	An entity causes a user to execute malicious code in an information asset in order to gain access to an asset.
T.Malicious_Code.Info.7	Medium	<i>Likely</i>	An entity causes a user to execute malicious code in an information asset in order to exfiltrate information assets to a potential covert channel.
T.Malicious_Code.Info.8	Low	<i>Unlikely</i>	An entity causes a user to execute malicious code in an information asset in order to launch a denial of service attack.
T.Malicious_Code.Proxy.1	Medium	<i>Unlikely</i>	An entity implants malicious code in an AMI system security domain component to enable an authorized entity to act as a proxy for him.
T.Malicious_Code.Res.1	Medium	<i>Likely</i>	An entity implants malicious code in an AMI component resource asset in order to gain access to an asset.

THREAT NAME	SEVERITY	LIKELIHOOD	DESCRIPTION
T.Malicious_Code.Res.2	High	<i>Likely</i>	An entity implants malicious code in an AMI component resource asset in order to exfiltrate information assets to a potential covert channel.
T.Malicious_Code.Res.3	High	<i>Likely</i>	An entity implants malicious code in an AMI component resource asset in order to modify information assets.
T.Malicious_Code.Res.4	Medium	<i>Unlikely</i>	An entity implants malicious code in an AMI component resource asset in order to launch a denial of service attack.
T.Malicious_Code.Res.5	Medium	<i>Likely</i>	An entity causes a user to execute malicious code in an AMI component resource asset in order to gain access to an asset it is not authorized to access.
T.Malicious_Code.Res.6	Medium	<i>Likely</i>	An entity causes a user to execute malicious code in an AMI component resource asset in order to exfiltrate information assets to a potential covert channel.
T.Malicious_Code.Res.7	Low	<i>Unlikely</i>	An entity causes a user to execute malicious code in an AMI component resource asset in order to launch a denial of service attack.

Network Threats

Network threats are those threats that directly involve the network in some manner other than eavesdropping (which is covered in the Eavesdropping Threats section). The specific threats are listed below in Table 1-36.

**Table 1-36
Threat Descriptions - Network Threats**

THREAT NAME	SEVERITY	LIKELIHOOD	DESCRIPTION
T.Network.Denial.1	High	Likely	An entity performs a denial of service attack on the Backhaul network (e.g. jamming, malicious code, distributed denial-of-service) resulting in a denial of service for assets.
T.Network.Filter.1	High	Likely	An entity uses IP-level access to a Backhaul network and uses the AMI system security domain network interface to gain IP-level access to another Backhaul network that the AMI system security domain is interfacing with.
T.Network.Modify.1	High	Likely	An entity modifies data on the Backhaul network in an attempt to modify that information asset.
T.Network.Modify.2	High	Likely	An AMI entity without proper access to an information asset inserts data onto the AMI Virtual Network in an attempt to modify that information asset.
T.Network.Replay.1	Medium	Likely	An entity attempts to replay a previous AMI network message sent over the Backhaul network.

THREAT NAME	SEVERITY	LIKELIHOOD	DESCRIPTION
T.Network.Replay.2	Medium	Likely	An entity attempts to replay a previous AMI network message sent over the AMI Virtual Network.
T.Network.Unauth.1	High	Likely	An AMI entity with access adds unauthorized network interfaces to AMI system security domain.

Operational Denial of Service Threats

Operational denial of service threats are those threats that affect availability of the system and may be caused by operational users of the system. The specific threats are listed below in Table 1-37.

**Table 1-37
Threat Descriptions - Operational Denial of Service**

THREAT NAME	SEVERITY	LIKELIHOOD	DESCRIPTION
T.Op.Denial.1	<i>Low</i>	<i>Likely</i>	An entity enters access control attributes related to specific content resulting in denying access to consumers who should be authorized for that information object.
T.Op.Denial.2	<i>Low</i>	<i>Likely</i>	An entity enters improper value in the priority attribute related to specific content resulting in reduced distribution efficiency for that information object.
T.Op.Denial.3	<i>High</i>	Likely	An entity creates excessive volume of information objects resulting in resource exhaustion (e.g., storage space) resulting in a denial of service.
T.Op.Denial.4	Medium	Likely	An entity removes or changes endorsements on an information object in an unauthorized manner with the intent to stop the publication of the information object.
T.Op.Denial.5	High	Unusual	An entity creates excessive volume of endorsements resulting in resource exhaustion (e.g., storage space) resulting in a denial of service.
T.Op.Denial.6	High	Unlikely	An entity copies the information object to an excessive volume of ownership types resulting in resource exhaustion (e.g., storage space).
T.Op.Denial.7	High	Unlikely	An entity copies an excessive volume of the information object to the same ownership type resulting in resource exhaustion (e.g., storage space, processor resources [race condition]).
T.Op.Denial.8	Low	Likely	An entity enters (regrades to) incorrect values in the access control attributes that overly restrict access to the information content resulting in denial of service. Incorrect values could be as a result of: <ul style="list-style-type: none"> • Negligence • Hidden or malicious content • Content different than what was displayed
T.Op.Denial.9	High	Unlikely	An entity publishes the information object to an excessive volume of ownership types resulting in resource exhaustion (e.g., storage space).

THREAT NAME	SEVERITY	LIKELIHOOD	DESCRIPTION
T.Op.Denial.10	High	Unlikely	An entity publishes an excessive volume of the information object to the same ownership type resulting in resource exhaustion (e.g., storage space, processor resources [race condition]).
T.Op.Denial.11	Medium	Likely	An entity deletes an object it is not authorized to delete resulting in denial of service.
T.Op.Denial.12	Low	Likely	An AMI entity deletes an object it is authorized to delete resulting in denial of service.
T.Op.Denial.13	Low	Unlikely	An AMI entity mounts an attack against AMI computing resources that results in task overloading.
T.Op.Denial.14	Medium	Unlikely	An entity prevents the decryption of information objects resulting in no information being displayed, resulting in denial of service.
T.Op.Denial.15	Medium	Unusual	An entity prevents display content from being displayed resulting in denial of service.
T.Op.Denial.16	Low	Unusual	An entity causes an authorized user to view an improper/incorrect AMI directory structure resulting in denial by failing to connect to the intended AMI directory.

Operational Disclosure Threats

Operational disclosure threats are those threats that affect confidentiality of the system and may be caused by operational users of the system. The specific threats are listed below in Table 1-38.

**Table 1-38
Threat Descriptions - Operational Disclosure**

THREAT NAME	SEVERITY	LIKELIHOOD	DESCRIPTION
T.Op.Disclosure.1	Medium	Likely	An entity views an information asset it is not authorized to view.
T.Op.Disclosure.2	<i>Medium</i>	Likely	An entity enters, edits, or imports content with attributes it does not have access to resulting in unauthorized disclosure.
T.Op.Disclosure.3	Medium	Likely	An entity improperly copies to the wrong ownership resulting in disclosure to a different set of entities prior to obtaining authorization to disseminate.
T.Op.Disclosure.4	Medium	Likely	An entity regard to incorrect values in the access control attributes resulting in the unauthorized access to the information content resulting in disclosure. Incorrect values could be as a result of: <ul style="list-style-type: none"> • Negligence • Hidden or malicious content • Content different than what was displayed
T.Op.Disclosure.5	Medium	Likely	An entity improperly publishes a document resulting in disclosure or exfiltration of information assets.
T.Op.Disclosure.6	Medium	Likely	An AMI entity improperly publishes a document to the wrong location resulting in disclosure or exfiltration of information assets.

THREAT NAME	SEVERITY	LIKELI-HOOD	DESCRIPTION
T.Op.Disclosure.7	Medium	Likely	An AMI entity fails to delete all copies of an information object resulting in disclosure of information that may have been distributed (e.g., after publishing a document with incorrect information, he tries to delete, but the genie is out of the bottle; or had a bad delete list; or user forgot to select all objects that he intended to delete).
T.Op.Disclosure.8	High	Likely	An entity collects (e.g., signals intelligence SIGINT) unprotected (plaintext) content and unprotected object attributes and endorsements resulting in unauthorized disclosure.
T.Op.Disclosure.9	Medium	Likely	An entity executes a view function (decryption) on an object they are not authorized to access resulting in unauthorized disclosure.
T.Op.Disclosure.10	High	Likely	An entity collects (e.g., signals intelligence SIGINT, human intelligence HUMINT) unprotected (plaintext) content and unprotected object attributes and endorsements resulting in unauthorized disclosure.
T.Op.Disclosure.11	Medium	Likely	An entity executes an export function on an information object they are not authorized to export resulting in unauthorized disclosure.
T.Op.Disclosure.12	Medium	Likely	An entity executes an export function on an information object they are authorized to export to the wrong non-AMI network resulting in unauthorized disclosure.
T.Op.Disclosure.13	High	Likely	An AMI entity with access in a remote information system attempts to access AMI information objects in an unauthorized manner.
T.Op.Disclosure.14	Low	Unusual	An entity views unauthorized AMI directory structure resulting in unauthorized disclosure. (e.g. an unauthorized user is presented unauthorized directory names)
T.Op.Disclosure.15	Medium	Likely	An entity views an information asset it is not authorized to view because an authorized user viewed the information on an unauthorized component.

Operational Integrity Threats

Operational integrity threats are those threats that affect integrity of the system or information in the system and may be caused by operational users of the system. The specific threats are listed below in Table 1-39.

Table 1-39
Threat Descriptions - Operational Integrity

THREAT NAME	SEVERITY	LIKELI-HOOD	DESCRIPTION
T.Op.Integrity.1	High	Likely	An entity modifies an information asset it is not authorized to modify.
T.Op.Integrity.2	Medium	Likely	An entity modifies information content it is not authorized to modify (see T.Integrity.1).

T.Op.Integrity.3	High	Likely	An entity modifies access control attributes when it does not have degrade function access (see T.Integrity.1).
T.Op.Integrity.4	High	Likely	An entity modifies information attributes it is not authorized to modify (see T.Integrity.1).
T.Op.Integrity.5	High	Likely	An entity modifies policy it is not authorized to modify (see T.Integrity.1).
T.Op.Integrity.6	High	Unusual	An entity modifies display signals resulting in incorrect information being displayed.
T.Op.Integrity.7	High	Likely	An AMI entity with access in a remote information system attempts to modify AMI information objects in an unauthorized manner.
T.Op.Integrity.8	High	Likely	An entity modifies a AMI component software or operating system resource asset in an unauthorized manner.

Operational Non-repudiation Threats

Operational non-repudiation threats are those threats that affect the ability to perform non-repudiation of information in the system and may be caused by operational users of the system. The specific threats are listed below in Table 1-40.

**Table 1-40
Threat Descriptions - Operational Non-repudiation**

THREAT NAME	SEVERITY	LIKELIHOOD	DESCRIPTION
T.Op.Non-Repudiation.1	Medium	Likely	An entity enters, edits unauthorized values in the information attributes resulting in false attribution of the content creator.
T.Op.Non-Repudiation.2	Low	Unlikely	An entity improperly enters, edits unauthorized values in the information attributes resulting in false repudiation of the content endorser. (X deletes X or Y signatures)
T.Op.Non-Repudiation.3	Low	Unlikely	An entity enters, edits unauthorized values in the information attributes resulting in repudiation of the information object copier. (X says X did not do it)
T.Op.Non-Repudiation.4	Medium	Likely	An entity enters, edits unauthorized values in the information attributes resulting in false attribution of the information object copier. (X says Y did it)
T.Op.Non-Repudiation.5	Low	Unlikely	An entity enters, edits unauthorized values in the information attributes resulting in repudiation of the information object publisher. (X says X did not do it)
T.Op.Non-Repudiation.6	Low	Unlikely	An entity enters, edits unauthorized values in the information attributes resulting in false attribution of the information object publisher. (X says Y did it).

THREAT NAME	SEVERITY	LIKELIHOOD	DESCRIPTION
T.Op.Non-Repudiation.7	Medium	Likely	An entity improperly enters, edits unauthorized values in the information attributes resulting in false attribution of the content endorser. (X says Y signed it).

Physical Threats

Physical threats are those threats that directly involve the physical hardware/software of the system. The specific threats are listed below in Table 1-41.

**Table 1-41
Threat Descriptions - Physical**

THREAT NAME	SEVERITY	LIKELIHOOD	DESCRIPTION
T.Physical.Capture.1	High	Likely	Without warning, an entity captures (e.g., with troops) a AMI System security domain in order to access assets.
T.Physical.Capture.2	High	Likely	With warning, an entity captures (e.g., with troops) a AMI System security domain in order to access assets.
T.Physical.Denial.1	Medium	Likely	An entity causes the physical to cease functioning (e.g., cables are cut, a router fails, a network component loses power) causing a denial of service.
T.Physical.Destruction.IA.1	Low	Likely	An entity destroys a AMI token resource asset. (see T.Physical.Destruction.Res.1 and T.Physical.Destruction.Res.2)
T.Physical.Destruction.IA.2	Low	Likely	An entity renders a AMI biometric source unusable (e.g., a body part is lost or damaged).
T.Physical.Destruction.Info.1	Medium	Unusual	A natural disaster destroys the media that contains an information asset.
T.Physical.Destruction.Info.2	Medium	Likely	An entity destroys the media that contains an information asset.
T.Physical.Destruction.Res.1	Medium	Likely	A natural disaster destroys a resource asset.
T.Physical.Destruction.Res.2	Medium	Likely	An entity destroys a resource asset.
T.Physical.Destruction.Serv.1	Medium	Likely	A natural disaster renders a service asset physically inoperable.
T.Physical.Destruction.Serv.2	Medium	Likely	An entity renders a service asset physically inoperable.
T.Physical.Destruction.Total.1	High	Unusual	A natural disaster destroys a AMI System security domain.
T.Physical.Destruction.Total.2	High	Likely	An entity destroys an AMI System security domain.
T.Physical.Extract.IA.1	High	Likely	An entity gains physical access to an AMI token resource asset containing a user authentication information in order to extract that information via intrusive physical means.

THREAT NAME	SEVERITY	LIKELIHOOD	DESCRIPTION
T.Physical.Extract.IA.2	High	Likely	An entity eavesdrops on compromising emanations from an AMI token resource asset to discover user authentication information.
T.Physical.Extract.NonAMI.1	High	Likely	An entity collects emanations from the unprotected side of the non-AMI interface to discover information assets.
T.Physical.Extract.Res.1	High	Likely	An entity gains physical access to an AMI component resource asset containing an information asset in order to extract that information asset via intrusive physical means.
T.Physical.Extract.Res.2	High	Likely	An entity eavesdrops on compromising emanations from a AMI component resource asset to discover an information asset (e.g., to learn information content or perform traffic analysis).
T.Physical.Extract.Res.3	High	Likely	An entity eavesdrops on compromising emanations from a AMI component resource asset to receive covert channel communications.
T.Physical.HWFailure.1	Medium	Likely	An AMI component resource asset experiences a hardware failure that places AMI in a non-operational state.
T.Physical.HWFailure.2	Medium	Likely	An AMI component resource asset experiences a hardware failure that places AMI in an insecure state.
T.Physical.HWFailure.3	Medium	Likely	An AMI component resource asset experiences a hardware failure that alters an information asset.
T.Physical.MechFailure.1	Medium	Likely	An AMI component resource asset experiences a mechanical failure that places AMI in a non-operational state.
T.Physical.Modification.Info.1	Medium	<i>Unlikely</i>	An entity gains physical access to an AMI component resource asset containing an information asset in order to modify that information asset via physical means.
T.Physical.Modification.Input.1	High	Likely	An entity installs a recording device into a user's input device so as to gain the user's access or discover information.
T.Physical.Modification.Res.1	<i>High</i>	Likely	An entity physically modifies a AMI component resource asset in order to gain access to an asset.
T.Physical.Modification.Res.2	High	Likely	An entity physically modifies a AMI component resource asset to exfiltrate information assets to a potential covert channel.
T.Physical.Obsolete.1	High	Likely	AMI component hardware resource assets become obsolete and are no longer in production.
T.Physical.Obsolete.2	High	Likely	AMI component software resource assets become obsolete and are no longer available, resulting in denial of service.

THREAT NAME	SEVERITY	LIKELIHOOD	DESCRIPTION
T.Physical.ReverseEng.1	Medium	Likely	An entity procures a piece of AMI hardware to perform reverse engineering so as to capture advanced technology.
T.Physical.ReverseEng.2	Medium	Likely	An entity procures a piece of AMI hardware to perform reverse engineering to exploit discovered flaws.
T.Physical.ReverseEng.3	Medium	Likely	An entity with physical access to AMI equipment at the remote AMI system reverse engineers the AMI equipment to improve that country's technology.
T.Physical.ReverseEng.4	Medium	Likely	An entity with physical access to AMI equipment at the remote AMI system reverse engineers the AMI equipment to use it against us.
T.Physical.SWFailure.1	Medium	Likely	An AMI component resource asset experiences a software failure that places AMI in a non-operational state.
T.Physical.SWFailure.2	Medium	Likely	An AMI component resource asset experiences a software failure that places AMI in an insecure state.

Social Engineering Threats

Social engineering threats are those threats that involve human-to-human breaches in security. Specific threats are listed below in Table 1-42.

**Table 1-42
Threat Descriptions - Social Engineering**

THREAT NAME	SEVERITY	LIKELIHOOD	DESCRIPTION
T.Social_Eng.Access.1	High	Likely	An entity co-opts a AMI user to grant the entity system access.
T.Social_Eng.Access.2	High	Likely	An entity persuades a user of a non-AMI system with some level of access to AMI to divulge his AMI credentials.
T.Social_Eng.Access.3	High	Likely	An entity persuades a user of a different AMI system with some level of access to the AMI to divulge his AMI credentials.
T.Social_Eng.AdminLeak.1	High	Likely	An entity persuades an administrator of a non-AMI system to reveal information about system operational procedures, auditing or known flaws so as to enable the entity to access AMI.
T.Social_Eng.Authorize.1	Medium	Likely	An AMI entity co-opts a AMI user to grant the entity authorization to an asset.
T.Social_Eng.Info.1	Medium	Likely	An entity co-opts a AMI user to access information assets. The attacking entity may then access the information via the co-opted user (e.g., read over the shoulder of user, have user verbally tell content).
T.Social_Eng.Info.2	High	Likely	An entity co-opts a AMI user to exfiltrate information assets to a potential covert channel.

THREAT NAME	SEVERITY	LIKELIHOOD	DESCRIPTION
T.Social_Eng.Info.3	High	Likely	An entity co-opts a AMI user to modify information assets.
T.Social_Eng.Info.4	High	Likely	An entity attempts to guess a user passphrase based upon knowledge of the user.

Trust Threats

Trust threats are those threats which involve either impersonation of a known entity or creation of trusted assets. Specific threats are listed below in Table 1-43.

**Table 1-43
Threat Descriptions - Trust**

THREAT NAME	SEVERITY	LIKELIHOOD	DESCRIPTION
T.Trust.Impersonate.1	High	Likely	An entity impersonates a policy authority entity and is recognized by the AMI System security domain as a valid policy authority.
T.Trust.Impersonate.2	<i>High</i>	Likely	An entity impersonates the Key Management System and is recognized by the AMI System security domain as the Key Management System.
T.Trust.Impersonate.3	High	Likely	An entity impersonates a known AMI System and is recognized by the AMI System security domain as that AMI System.
T.Trust.Impersonate.4	High	Likely	An entity impersonates a known non-AMI System and is recognized by the AMI System security domain as that non-AMI System.
T.Trust.Impersonate.5	High	Likely	An entity impersonates the Download Source and is recognized by the AMI System security domain as the Download Source.
T.Trust.Impersonate.6	High	Likely	An entity impersonates a user and is recognized by the AMI System security domain as that user.
T.Trust.Impersonate.7	High	Likely	An entity impersonates an application, and that application is recognized by the AMI System security domain as a valid application.
T.Trust.Impersonate.8	Medium	Unlikely	An entity impersonates the network infrastructure in order to analyze or affect IP datagram transmissions.
T.Trust.Info.1	High	Likely	An entity creates trusted information assets in an unauthorized manner.
T.Trust.Res.1	High	Likely	An entity creates trusted resource assets in an unauthorized manner.
T.Trust.Serv.1	High	Likely	An entity is able to impersonate trusted service assets in an unauthorized manner.

Organizational Security Policies

The following statements identify and explain organizational policies that are relevant to AMI. These policies define the operation, management, personnel responsibilities, and guidelines that must be used to provide security for the AMI system. Table 1-44 describes these policies.

Table 1-44
Organizational Security Policies

POLICY NAME	DEFINITION
P.Access	Access to TOE information will be limited to authorized users within the limits of their credentials and need-to-know.
P.Accountability	Authorized administrators and users are held accountable for security relevant actions they perform.
P.Admin_Security	A Security Administrator interprets, maintains, and oversees site security policy and develops and implements procedures assuring secure operation of the TOE.
P.Admin_Split	Administrative responsibilities are split between System Administrator and Security Administrator roles that together competently administer the TOE. The assignment of split administrative authorization is established in order to prevent unrestricted system control and to provide for "checks and balances".
P.Admin_System	A System Administrator is responsible for installing, configuring, managing, and monitoring the performance of the TOE in accordance with its evaluated configuration and ensuring its conformance to applicable security policies.
P.Audit_Review	Administrators will review audit reports and take appropriate action.
P.Cross_Domain_Filtering	Information domains will not be directly connected without application of appropriate cross-domain filtering techniques.
P.Distribution	A Security Administrator will issue security relevant TOE hardware and software, and will maintain all records regarding distribution of these items.
P.Due_Care	The level of security afforded the TOE will be in accordance with what is considered prudent by the organization's accrediting authority.
P.Info_Senders	TOE users and processes must be explicitly authorized to transfer information outside the TOE.
P.Info_Sources	U.S. and partner personnel and processes that transfer information into the TOE must be explicitly authorized to do so.
P.Integrity	Data collected and produced by the TOE will be protected from modification.

POLICY NAME	DEFINITION
P.Protect	The TOE will be protected from unauthorized accesses and disruptions of TOE data and functions.
P.Security_Admin_Restricted	Only authorized System Administrators, Security Administrators, and their representatives may administer or repair security mechanisms in the TOE.
P.Users	Only personnel authorized by the sponsoring U.S. Command, Service, Agency, or Coalition Organization may have access to or utilize TOE resources.

Security Objectives of the System

This section defines the security objectives of the AMI system and its supporting environment. Security objectives reflect the stated intent to counter identified threats and/or comply with any organizational security policies identified.

Table 1-45
Security Objectives of the System

OBJECTIVE NAME	DESCRIPTION
O.Admin_Roles_Access	Design administrative functions such that administrative responsibilities of the system will be well defined and compartmentalized such that administrators do not automatically have access to assets, except for necessary exceptions.
O.Audit	Record in audit records: date and time of action, location of the action, and the entity responsible for the action.
O.Audit_Log_Maintenance	The audit log will be maintained in such a way as to prevent unauthorized access, modification, deletion or overflow conditions.
O.Trusted_Path&Channel	Provide a trusted path and channel between the system and a remote trusted system for the performance of security-critical operations.
O.Confidentiality	Provide high assurance that information is not disclosed to unauthorized individuals, processes, or devices.
O.Crypto_Comm_Channel	Provide secure session establishment between the system and remote systems using NSA approved confidentiality, integrity, authentication and non-repudiation of network transmissions. Restrict user access to cryptographic IT assets in accordance with a specified user access control policy. Provide complete separation between plaintext and encrypted data and between data and keys.
O.Crypto_Storage	Provide NSA approved confidentiality, integrity, authentication and non-repudiation of stored information content.
O.Crypto_Import_Export	Protect cryptographic data assets when they are being transmitted to and from the TOE, either through intervening untrusted components or directly to/from human users.
O.Import_Export_Control	Provide security services and labels on import/export data that is consistent with policy (i.e. user, data source, data content, and intended audience).
O.Fault_Tolerant	Provide fault tolerant operations for critical components and continue to operate in the presence of specific failures in one or more system components.
O.Integrity_Checks	Provide periodic integrity checks on system data, user data, and hardware/software functionality.
O.I&A	Uniquely identify and robustly authenticate each user that will support accountability and authorization.
O.Integ_Data	Ensure the integrity of system data, user data, and security attributes transferred or replicated within the system.

OBJECTIVE NAME	DESCRIPTION
O.Emanations	Limit system-produced unintended emanations (intelligible or not) to within a specified limit.
O.Isolate_Executables	Run executable code in a protected domain where the code's potential errors or malicious code will not significantly impact other system functions of other valid users of the system.
O.Maintain_Online	Provide online maintenance role with a limited capability to observe the usage of specified services or resources as necessary.
O.NonRepudiation	Provide accountability and non-repudiation of information transfer between entities.
O.Obj_Attr	Maintain object security attributes with integrity.
O.Priority_Of_Service	Control access to resources so that lower-priority activities do not unduly interfere with or delay higher-priority activities.
O.Resource_Quotas	Use resource quotas to limit user and service use of system resources to a level that will prevent degradation or denial of service to other critical users and services.
O.Rollback	Recover from user operations by undoing some user operations (i.e., "rolling back") to restore a previous known state.
O.SW_Download	Provide the ability to update the TOE software program to patch discovered security flaws or other flaws in the program that could be exploited by the adversary. SW download is implemented with High Robustness.
O.Session_Protection	Provide protection of a user or admin session to prevent an unauthorized user from using an unattended computer where a valid user has an active session.
O.Secure_State	Maintain and recover to a secure state without security compromise after power cycle, addition or removal of components, system error or other interruption of system operation.
O.Security_Mgt	Manage the initialization of, limits on, and allowable operations on security attributes, security-critical data, and security mechanisms.
O.Security_Roles	Maintain security-relevant roles and the association of users with those roles.
O.Sys_Assur_HW/SW/FW	Ensure that security-relevant software, hardware, and firmware are correctly functioning through features and procedures.
O.Tamper	Provide system features that prevent, detect, and resist physical tampering of a system component, and use those features to limit security breaches.
O.User_Attributes	Maintain a set of security attributes (which may include group membership, clearance, access rights, etc.) associated with individual users in addition to user identity.
O.Secure_via_Cryptography	Ensure the protection provided to data in the system is predicated on the secrecy of the keys not in the secrecy of the design.
O.Malicious_Code	Incorporate malicious code prevention procedures and mechanisms.
O.Comp_Attributes	Maintain a set of security attributes associated with individual components in addition to component identity.
O.Attr_based_Policy	Provide policy based access control via security attributes on Users, Components, and Objects.

Security Objectives of the Environment

Security Objectives of the Environment encompass environment countermeasures that are necessary to protect assets. The environment is defined as the "aggregate of external procedures, conditions, and objects affecting the development, operation, and maintenance of an information system" or alternatively environment can also be defined as that which is not being built.

Security objectives of the environment can contribute to overall defense-in-depth strategies that result in high-assurance protections with respect to privacy, integrity, availability, and authenticity. The AMI system is being specified to result in only modest levels for environment

countermeasures, and therefore, the security objectives of the environment can be identified by addressing broad categories of countermeasures with only modest needs for environment countermeasures (e.g., a remote AMI User should be able to operate on sea, land, or air in a boat, tent, or small airborne vehicle).

**Table 1-46
Security Objectives of the Environment**

OBJECTIVE NAME	DESCRIPTION
OE.Admin_Guidance	Deter administrator errors by providing adequate administrator guidance.
OE.Config_Management	Implement a configuration management plan. Implement configuration management to assure storage integrity, identification of system connectivity (software, hardware, and firmware), and identification of system components (software, hardware, and firmware).
OE.Crypto_Key_Man	Fully define cryptographic components, functions, and interfaces. Ensure appropriate protection for cryptographic keys throughout their lifecycle, covering generation, distribution, storage, use, and destruction.
OE.Secure_Configuration	Manage and update system security policy data and enforcement functions, and other security-relevant configuration data, in accordance with organizational security policies.
OE.Evaluated_System	Evaluate system via Common Criteria methods for proper implementation including examination for accidental or deliberate flaws in code made by the developer. The accidental flaws could be lack of engineering detail or bad design. Where the deliberate flaws would include building trapdoors for later entry as an example.
OE.Sys_Backup_Procs	Provide backup procedures to ensure that the system can be reconstructed.
OE.User_Auth_Management	Manage and update user authorization and privilege data in accordance with organizational security and personnel policies.
OE.User_Guidance	Provide documentation for the general user.
OE.Component_Engineering	Manage lifecycle maintenance such that when component hardware becomes obsolete the AMI hardware/software is redesigned to support production
OE.Admin_Available	Provide at least one Security Administrator (authorized by the U.S. or the host country) to respond to administrative issues including fixing enrollment/I&A issues.
OE.Trusted_Facility	Provide a trusted facility for initialization.
OE.Physical_Security	Provide an appropriate level of physical security.
OE.BackhaulSLA	Negotiate an SLA with the Backhaul network that meets the operational needs of the mission. This includes required fault-tolerant aspects of the Backhaul's system including but not limited to routers, switch, and even "back-hoe" protection.
OE.Enrollment_Process	Provide a registration/enrollment procedure that includes both a chain of trust of user identity to enroll (e.g. DoD PKI or a US Passport) plus a chain of trust of access and authorization to those domains to grant access.

Coverage

Coverage of Administrative Threats

Table 1-47
Coverage of Administrative Threats

THREATS	OBJECTIVES
T.Admin.Cred.1	O.Admin_Roles_Access O.Confidentiality O.Rollback O.Session_Protection O.Security_Mgt O.Security_Roles O.Attr_based_Policy OE.Secure_Configuration
T.Admin.Cred.2	O.Admin_Roles_Access O.Rollback O.Security_Mgt O.Security_Roles OE.Secure_Configuration
T.Admin.Cred.3	O.Admin_Roles_Access O.Rollback O.Security_Mgt O.Security_Roles OE.Secure_Configuration
T.Admin.Enroll.1	O.Admin_Roles_Access O.Confidentiality O.Rollback O.Security_Mgt O.Security_Roles OE.User_Auth_Management OE.Enrollment_Process
T.Admin.Enroll.2	O.Admin_Roles_Access O.Confidentiality O.Rollback O.Security_Mgt O.Security_Roles OE.User_Auth_Management OE.Enrollment_Process
T.Admin.Enroll.3	O.Admin_Roles_Access O.Rollback O.Security_Mgt O.Security_Roles OE.User_Auth_Management OE.Enrollment_Process
T.Admin.Enroll.4	O.Admin_Roles_Access O.Rollback O.Security_Mgt O.Security_Roles OE.User_Auth_Management OE.Enrollment_Process

THREATS	OBJECTIVES
T.Admin.Enroll.5	O.Admin_Roles_Access O.Confidentiality O.I&A O.Rollback O.Session_Protection O.Security_Mgt O.Security_Roles O.Attr_based_Policy OE.User_Auth_Management
T.Admin.Enroll.6	O.Admin_Roles_Access O.Confidentiality O.Rollback O.Security_Mgt O.Security_Roles OE.User_Auth_Management OE.Enrollment_Process
T.Admin.Enroll.7	O.Admin_Roles_Access O.Security_Mgt O.Security_Roles OE.User_Auth_Management OE.Enrollment_Process
T.Admin.Lockout.1	O.Admin_Roles_Access O.I&A O.Rollback O.Session_Protection O.Security_Mgt O.Security_Roles O.Attr_based_Policy OE.User_Auth_Management
T.Admin.Lockout.2	O.Admin_Roles_Access O.I&A O.Rollback O.Session_Protection O.Security_Mgt O.Security_Roles O.Attr_based_Policy OE.User_Auth_Management
T.Admin.Policy.1	O.Admin_Roles_Access O.Confidentiality O.I&A O.Session_Protection O.Security_Mgt O.Security_Roles O.Attr_based_Policy OE.User_Auth_Management
T.Admin.Policy.2	O.Admin_Roles_Access O.Rollback O.Security_Mgt O.Security_Roles OE.Secure_Configuration
T.Admin.Policy.3	O.Admin_Roles_Access O.Confidentiality O.Rollback O.Security_Mgt O.Security_Roles OE.Secure_Configuration

THREATS	OBJECTIVES
T.Admin.Policy.4	O.Admin_Roles_Access O.Confidentiality O.Import_Export_Control O.I&A O.Rollback O.Session_Protection O.Security_Mgt O.Security_Roles O.Attr_based_Policy OE.Secure_Configuration
T.Admin.Policy.5	O.Admin_Roles_Access O.Resource_Quotas O.Rollback O.Security_Mgt O.Security_Roles OE.Secure_Configuration
T.Admin.Policy.6	O.Admin_Roles_Access O.Rollback O.Security_Mgt O.Security_Roles OE.Secure_Configuration
T.Admin.Policy.7	O.Admin_Roles_Access O.Confidentiality O.Security_Mgt O.Security_Roles
T.Admin.Policy.8	O.Admin_Roles_Access O.Confidentiality O.Rollback O.Session_Protection O.Security_Mgt O.Security_Roles O.Attr_based_Policy OE.Secure_Configuration
T.Admin.Policy.9	O.Admin_Roles_Access O.Confidentiality O.Rollback O.Security_Mgt O.Security_Roles OE.Secure_Configuration
T.Admin.Policy.10	O.Admin_Roles_Access O.Confidentiality O.Rollback O.Security_Mgt O.Security_Roles OE.Secure_Configuration
T.Admin.Policy.11	O.Admin_Roles_Access O.Rollback O.Security_Mgt O.Security_Roles OE.Secure_Configuration
T.Admin.Policy.12	O.Admin_Roles_Access O.Confidentiality O.Rollback O.Security_Mgt O.Security_Roles OE.Secure_Configuration

THREATS	OBJECTIVES
T.Admin.Policy.13	O.Admin_Roles_Access O.Confidentiality O.Rollback O.Security_Mgt O.Security_Roles OE.Secure_Configuration
T.Admin.Policy.14	O.Admin_Roles_Access O.Confidentiality O.Import_Export_Control O.NonRepudiation O.Rollback O.Security_Mgt O.Security_Roles OE.Secure_Configuration
T.Admin.Policy.15	O.Admin_Roles_Access O.Confidentiality O.Import_Export_Control O.NonRepudiation O.Security_Mgt O.Security_Roles OE.Secure_Configuration
T.Admin.Policy.16	O.Admin_Roles_Access O.Confidentiality O.Security_Mgt O.Security_Roles OE.Secure_Configuration
T.Admin.Policy.17	O.Admin_Roles_Access O.Rollback O.Security_Mgt O.Security_Roles OE.Secure_Configuration
T.Admin.PolicyImp.1	O.Admin_Roles_Access O.Fault_Tolerant O.Rollback O.Security_Mgt O.Security_Roles OE.Secure_Configuration
T.Admin.PolicyImp.2	O.Admin_Roles_Access O.Confidentiality O.I&A O.Rollback O.Session_Protection O.Security_Mgt O.Security_Roles O.Attr_based_Policy OE.Secure_Configuration

Coverage of Audit Threats

Table 1-48
Coverage of Audit Threats

THREATS	OBJECTIVES
T.Audit.1	O.Audit_Log_Maintenance O.Import_Export_Control O.Maintain_Online
T.Audit.2	O.Audit_Log_Maintenance O.Import_Export_Control O.Maintain_Online
T.Audit.3	O.Audit_Log_Maintenance O.Import_Export_Control O.Maintain_Online
T.Audit.4	O.Audit O.Confidentiality O.Import_Export_Control O.I&A O.Maintain_Online O.Attr_based_Policy
T.Audit.5	O.Audit O.Confidentiality O.Import_Export_Control O.Maintain_Online O.Attr_based_Policy
T.Audit.6	O.Audit O.Import_Export_Control O.Maintain_Online O.Attr_based_Policy
T.Audit.7	O.Audit O.Audit_Log_Maintenance O.Import_Export_Control O.I&A O.Maintain_Online O.Attr_based_Policy
T.Audit.8	O.Audit O.Import_Export_Control O.Maintain_Online OE.Admin_Guidance
T.Audit.9	O.Audit O.Import_Export_Control O.Maintain_Online OE.Admin_Guidance
T.Audit.10	O.Audit O.Import_Export_Control O.Maintain_Online
T.Audit.11	O.Audit O.Import_Export_Control O.Maintain_Online

Coverage of Crypto Threats

Table 1-49
Coverage of Crypto Threats

THREATS	OBJECTIVES
T.Crypto.Break.1	O.Confidentiality O.Crypto_Comm_Channel O.Crypto_Storage
T.Crypto.Break.2	O.Confidentiality O.Crypto_Comm_Channel O.Crypto_Storage
T.Crypto.Invalid_Keys.1	O.Trusted_Path&Channel O.Confidentiality OE.Crypto_Key_Man
T.Crypto.Invalid_Keys.2	O.Trusted_Path&Channel O.Confidentiality OE.Crypto_Key_Man
T.Crypto.Weak_Keys.1	O.Trusted_Path&Channel O.Confidentiality O.Crypto_Comm_Channel O.Crypto_Storage OE.Crypto_Key_Man

Coverage of Download Threats

Table 1-50
Coverage of Download Threats

THREATS	OBJECTIVES
T.Download.1	O.Fault_Tolerant O.Import_Export_Control O.Integrity_Checks O.SW_Download
T.Download.2	O.Confidentiality O.Import_Export_Control O.Integrity_Checks O.SW_Download
T.Download.3	O.Import_Export_Control O.Integrity_Checks O.SW_Download
T.Download.4	O.Confidentiality O.Import_Export_Control O.Integrity_Checks O.SW_Download O.Comp_Attributes
T.Download.5	O.Import_Export_Control O.Integrity_Checks O.SW_Download

Coverage of Eavesdropping Threats

Table 1-51
Coverage of Eavesdropping Threats

THREATS	OBJECTIVES
T.Eavesdrop.Apps.1	O.Confidentiality O.Import_Export_Control
T.Eavesdrop.Comm.1	O.Confidentiality O.Crypto_Comm_Channel O.Import_Export_Control
T.Eavesdrop.Comm.2	O.Confidentiality O.Crypto_Comm_Channel O.Import_Export_Control
T.Eavesdrop.Comm.3	O.Confidentiality O.Crypto_Comm_Channel O.Import_Export_Control
T.Eavesdrop.Comm.4	O.Confidentiality O.Crypto_Comm_Channel O.Import_Export_Control
T.Eavesdrop.Comm.5	O.Confidentiality O.Crypto_Comm_Channel O.Import_Export_Control
T.Eavesdrop.Comm.6	O.Confidentiality O.Crypto_Comm_Channel O.Import_Export_Control
T.Eavesdrop.Comm.7	O.Confidentiality O.Crypto_Comm_Channel O.Import_Export_Control
T.Eavesdrop.HMI.1	O.Confidentiality O.Import_Export_Control O.Session_Protection
T.Eavesdrop.HMI.2	O.Confidentiality O.Session_Protection
T.Eavesdrop.HMI.3	O.Confidentiality O.Session_Protection
T.Eavesdrop.HMI.4	O.Security_Mgt O.Comp_Attributes OE.Physical_Security

Coverage of Flawed Implementation Threats

Table 1-52
Coverage of Flawed Implementation Threats

THREATS	OBJECTIVES
T.Flawed_Imp.Backdoor.1	O.Confidentiality O.SW_Download O.Malicious_Code OE.Evaluated_System
T.Flawed_Imp.Developer.1	O.Confidentiality O.SW_Download O.Malicious_Code OE.Evaluated_System
T.Flawed_Imp.Developer.2	O.SW_Download O.Malicious_Code OE.Evaluated_System

THREATS	OBJECTIVES
T.Flawed_Imp.Developer.3	O.Confidentiality O.SW_Download O.Malicious_Code OE.Evaluated_System

Coverage of I&A Threats

Table 1-53
Coverage of I&A Threats

THREATS	OBJECTIVES
T.Ident_Auth.1	O.Confidentiality O.I&A
T.Ident_Auth.2	O.Confidentiality O.I&A
T.Ident_Auth.3	OE.Admin_Available
T.Ident_Auth.4	O.Confidentiality O.I&A
T.Ident_Auth.5	O.Confidentiality O.I&A
T.Ident_Auth.6	O.Confidentiality O.I&A
T.Ident_Auth.7	O.Confidentiality O.I&A
T.Ident_Auth.8	O.Confidentiality O.I&A

Coverage of Information Systems Threats

Table 1-54
Coverage of Information System Threats

THREATS	OBJECTIVES
T.InfoSys.1	O.Confidentiality OE.Evaluated_System
T.InfoSys.2	O.Confidentiality O.Import_Export_Control O.I&A O.NonRepudiation
T.InfoSys.Filter.1	O.Confidentiality OE.Evaluated_System
T.InfoSys.Printer.1	O.Confidentiality O.User_Attributes OE.User_Guidance OE.Physical_Security

Coverage of Initialization Threats

Table 1-55
Coverage of Initialization Threats

THREATS	OBJECTIVES
T.Initialize.Configuration.1	O.Confidentiality OE.Trusted_Facility
T.Initialize.Configuration.2	O.Confidentiality OE.Trusted_Facility
T.Initialize.Configuration.3	O.Confidentiality O.SW_Download
T.Initialize.Distribution.1	O.Confidentiality O.Integrity_Checks O.SW_Download
T.Initialize.Distribution.2	O.Confidentiality O.Integrity_Checks O.SW_Download O.Malicious_Code

Coverage of Insider Threats

Table 1-56
Coverage of Insider Threats

THREATS	OBJECTIVES
T.Insider.Aggregation.1	O.Audit O.Confidentiality O.User_Attributes
T.Insider.Confusion.1	O.Confidentiality O.Rollback
T.Insider.Confusion.2	O.Confidentiality O.Import_Export_Control
T.Insider.Confusion.3	O.Confidentiality O.Import_Export_Control O.Rollback
T.Insider.Misinfo.1	O.Import_Export_Control
T.Insider.Mislabel.1	O.Confidentiality O.Import_Export_Control
T.Insider.Mislabel.2	O.Confidentiality O.Import_Export_Control O.I&A
T.Insider.Misuse.Info.1	O.Confidentiality O.Import_Export_Control
T.Insider.Misuse.Info.2	O.Confidentiality OE.Physical_Security
T.Insider.Misuse.Res.1	O.Maintain_Online O.Priority_Of_Service O.Resource_Quotas

Coverage of Key Management Threats

Table 1-57
Coverage of Key Management Threats

THREATS	OBJECTIVES
T.KeyMan.Deliver.1	O.Confidentiality OE.Admin_Guidance OE.Crypto_Key_Man
T.KeyMan.Deliver.2	O.Confidentiality OE.Admin_Guidance OE.Crypto_Key_Man
T.KeyMan.Deliver.3	O.Confidentiality OE.Admin_Guidance OE.Crypto_Key_Man
T.KeyMan.Deliver.4	O.Fault_Tolerant OE.Crypto_Key_Man
T.KeyMan.Membership.1	O.Admin_Roles_Access O.Confidentiality OE.Admin_Guidance OE.User_Auth_Management
T.KeyMan.Membership.2	O.Admin_Roles_Access OE.Admin_Guidance OE.User_Auth_Management
T.KeyMan.Membership.3	O.Admin_Roles_Access O.Confidentiality OE.Admin_Guidance OE.Crypto_Key_Man OE.User_Auth_Management
T.KeyMan.Obsolescence.1	OE.Crypto_Key_Man
T.KeyMan.Order.1	OE.Admin_Guidance OE.Crypto_Key_Man
T.KeyMan.Order.2	OE.Admin_Guidance OE.Crypto_Key_Man
T.KeyMan.Order.3	O.Fault_Tolerant OE.Admin_Guidance OE.Crypto_Key_Man
T.KeyMan.TrackControl.1	O.Fault_Tolerant OE.Admin_Guidance OE.Crypto_Key_Man

Coverage of Malicious Code Threats

Table 1-58
Coverage of Malicious Code Threats

THREATS	OBJECTIVES
T.Malicious_Code.App.1	O.Confidentiality O.Integrity_Checks O.Isolate_Executables O.Malicious_Code O.Attr_based_Policy
T.Malicious_Code.App.2	O.Confidentiality O.Integrity_Checks O.Isolate_Executables O.Malicious_Code O.Attr_based_Policy

THREATS	OBJECTIVES
T.Malicious_Code.App.3	O.Confidentiality O.Integrity_Checks O.Isolate_Executables O.Malicious_Code O.Attr_based_Policy
T.Malicious_Code.App.4	O.Confidentiality O.Integrity_Checks O.Isolate_Executables O.Malicious_Code O.Attr_based_Policy
T.Malicious_Code.Info.1	O.Confidentiality O.Integrity_Checks O.Isolate_Executables O.Malicious_Code O.Attr_based_Policy
T.Malicious_Code.Info.2	O.Confidentiality O.Integrity_Checks O.Isolate_Executables O.Malicious_Code O.Attr_based_Policy
T.Malicious_Code.Info.3	O.Integrity_Checks O.Isolate_Executables O.Malicious_Code O.Attr_based_Policy
T.Malicious_Code.Info.4	O.Integrity_Checks O.Isolate_Executables O.Malicious_Code O.Attr_based_Policy
T.Malicious_Code.Info.5	O.Integrity_Checks O.Isolate_Executables O.Malicious_Code
T.Malicious_Code.Info.6	O.Confidentiality O.Integrity_Checks O.Isolate_Executables O.Malicious_Code
T.Malicious_Code.Info.7	O.Confidentiality O.Integrity_Checks O.Isolate_Executables O.Malicious_Code
T.Malicious_Code.Info.8	O.Integrity_Checks O.Isolate_Executables O.Malicious_Code
T.Malicious_Code.Proxy.1	O.Confidentiality O.Integrity_Checks O.Isolate_Executables O.Malicious_Code O.Attr_based_Policy
T.Malicious_Code.Res.1	O.Confidentiality O.Integrity_Checks O.Isolate_Executables O.Malicious_Code O.Attr_based_Policy
T.Malicious_Code.Res.2	O.Confidentiality O.Integrity_Checks O.Isolate_Executables O.Malicious_Code O.Attr_based_Policy

THREATS	OBJECTIVES
T.Malicious_Code.Res.3	O.Integrity_Checks O.Isolate_Executables O.Malicious_Code O.Attr_based_Policy
T.Malicious_Code.Res.4	O.Integrity_Checks O.Isolate_Executables O.Malicious_Code O.Attr_based_Policy
T.Malicious_Code.Res.5	O.Integrity_Checks O.Isolate_Executables O.Malicious_Code
T.Malicious_Code.Res.6	O.Integrity_Checks O.Isolate_Executables O.Malicious_Code
T.Malicious_Code.Res.7	O.Integrity_Checks O.Isolate_Executables O.Malicious_Code

Coverage of Network Threats

Table 1-59
Coverage of Network Threats

THREATS	OBJECTIVES
T.Network.Denial.1	O.Trusted_Path&Channel O.Fault_Tolerant O.Maintain_Online O.Resource_Quotas
T.Network.Filter.1	O.Confidentiality O.Trusted_Path&Channel O.Maintain_Online
T.Network.Modify.1	O.Crypto_Comm_Channel
T.Network.Modify.2	O.Crypto_Comm_Channel O.Maintain_Online
T.Network.Replay.1	O.Maintain_Online
T.Network.Replay.2	O.Maintain_Online
T.Network.Unauth.1	O.Admin_Roles_Access O.Confidentiality O.Audit O.User_Attributes OE.Admin_Guidance OE.User_Guidance

Coverage of Denial of Service Threats

Table 1-60
Coverage of Denial of Service Threats

THREATS	OBJECTIVES
T.Op.Denial.1	O.Import_Export_Control O.I&A O.Integrity_Checks O.Integ_Data O.NonRepudiation O.Obj_Attr O.Session_Protection O.User_Attributes O.Attr_based_Policy OE.User_Guidance
T.Op.Denial.2	O.Import_Export_Control O.I&A O.NonRepudiation O.Priority_Of_Service O.Session_Protection O.User_Attributes O.Attr_based_Policy OE.User_Guidance
T.Op.Denial.3	O.I&A O.NonRepudiation O.Resource_Quotas O.Session_Protection O.User_Attributes O.Attr_based_Policy
T.Op.Denial.4	O.Import_Export_Control O.I&A O.Integrity_Checks O.Obj_Attr O.Session_Protection O.User_Attributes O.Attr_based_Policy
T.Op.Denial.5	O.Import_Export_Control O.I&A O.Obj_Attr O.Resource_Quotas O.Session_Protection O.User_Attributes O.Attr_based_Policy
T.Op.Denial.6	O.Import_Export_Control O.I&A O.Obj_Attr O.Resource_Quotas O.Session_Protection O.User_Attributes O.Attr_based_Policy
T.Op.Denial.7	O.I&A O.Obj_Attr O.Resource_Quotas O.Session_Protection O.User_Attributes O.Attr_based_Policy

THREATS	OBJECTIVES
T.Op.Denial.8	O.Import_Export_Control O.I&A O.Integrity_Checks O.Obj_Attr O.Session_Protection O.User_Attributes OE.User_Guidance O.Attr_based_Policy
T.Op.Denial.9	O.Import_Export_Control O.I&A O.Obj_Attr O.Resource_Quotas O.Session_Protection O.User_Attributes O.Attr_based_Policy
T.Op.Denial.10	O.Import_Export_Control O.I&A O.Obj_Attr O.Resource_Quotas O.Session_Protection O.User_Attributes O.Attr_based_Policy
T.Op.Denial.11	O.I&A O.Integrity_Checks O.Obj_Attr O.Priority_Of_Service O.Session_Protection O.User_Attributes O.Attr_based_Policy
T.Op.Denial.12	O.I&A O.NonRepudiation O.User_Attributes OE.User_Guidance O.Attr_based_Policy
T.Op.Denial.13	O.I&A O.Integrity_Checks O.Resource_Quotas O.Session_Protection O.User_Attributes O.Attr_based_Policy
T.Op.Denial.14	O.I&A O.Integrity_Checks O.User_Attributes O.Attr_based_Policy
T.Op.Denial.15	O.I&A O.Integrity_Checks O.Obj_Attr O.User_Attributes O.Attr_based_Policy
T.Op.Denial.16	O.I&A O.Integrity_Checks O.Obj_Attr O.User_Attributes O.Attr_based_Policy

Coverage of Operational Disclosure Threats

Table 1-61
Coverage of Operational Disclosure Threats

THREATS	OBJECTIVES
T.Op.Disclosure.1	O.Admin_Roles_Access O.Confidentiality O.Import_Export_Control O.I&A O.Obj_Attr O.Session_Protection O.User_Attributes O.Attr_based_Policy
T.Op.Disclosure.2	O.Admin_Roles_Access O.Confidentiality O.Import_Export_Control O.I&A O.Integrity_Checks O.Obj_Attr O.Session_Protection O.User_Attributes O.Attr_based_Policy
T.Op.Disclosure.3	O.Admin_Roles_Access O.Confidentiality O.Import_Export_Control O.I&A O.Obj_Attr O.Session_Protection O.User_Attributes O.Attr_based_Policy OE.User_Guidance
T.Op.Disclosure.4	O.Admin_Roles_Access O.Confidentiality O.Import_Export_Control O.I&A O.Obj_Attr O.Session_Protection O.User_Attributes O.Attr_based_Policy OE.User_Guidance
T.Op.Disclosure.5	O.Admin_Roles_Access O.Confidentiality O.Import_Export_Control O.I&A O.Obj_Attr O.Session_Protection O.User_Attributes O.Attr_based_Policy OE.User_Guidance
T.Op.Disclosure.6	O.Admin_Roles_Access O.Confidentiality O.Import_Export_Control O.I&A O.Obj_Attr O.Session_Protection O.User_Attributes O.Attr_based_Policy OE.User_Guidance

THREATS	OBJECTIVES
T.Op.Disclosure.7	O.Admin_Roles_Access O.Confidentiality O.Import_Export_Control O.I&A O.Obj_Attr OE.User_Guidance
T.Op.Disclosure.8	O.Admin_Roles_Access O.Confidentiality O.Import_Export_Control O.I&A O.Obj_Attr O.Emanations O.User_Attributes O.Attr_based_Policy
T.Op.Disclosure.9	O.Admin_Roles_Access O.Confidentiality O.Import_Export_Control O.I&A O.Obj_Attr O.Session_Protection O.User_Attributes O.Attr_based_Policy
T.Op.Disclosure.10	O.Admin_Roles_Access O.Confidentiality O.Import_Export_Control O.I&A O.Obj_Attr O.Session_Protection O.Emanations
T.Op.Disclosure.11	O.Admin_Roles_Access O.Confidentiality O.Import_Export_Control O.I&A O.Obj_Attr O.Session_Protection O.User_Attributes O.Attr_based_Policy
T.Op.Disclosure.12	O.Admin_Roles_Access O.Confidentiality O.Import_Export_Control O.I&A O.Obj_Attr O.Session_Protection O.User_Attributes OE.User_Guidance O.Attr_based_Policy
T.Op.Disclosure.13	O.Admin_Roles_Access O.Confidentiality O.Import_Export_Control O.I&A O.Obj_Attr
T.Op.Disclosure.14	O.Admin_Roles_Access O.Confidentiality O.Import_Export_Control O.I&A O.Obj_Attr O.Session_Protection O.User_Attributes O.Attr_based_Policy

THREATS	OBJECTIVES
T.Op.Disclosure.15	O.Sys_Assur_HW/SW/FW O.Comp_Attributes OE.Config_Management OE.Evaluated_System

Coverage of Operational Integrity Threats

Table 1-62
Coverage of Operational Integrity Threats

THREATS	OBJECTIVES
T.Op.Integrity.1	O.I&A O.Integrity_Checks O.Integ_Data O.Obj_Attr O.Session_Protection O.User_Attributes O.Attr_based_Policy
T.Op.Integrity.2	O.I&A O.Integrity_Checks O.Integ_Data O.Obj_Attr O.Session_Protection O.User_Attributes O.Attr_based_Policy
T.Op.Integrity.3	O.I&A O.Integrity_Checks O.Integ_Data O.Obj_Attr O.Session_Protection O.User_Attributes O.Attr_based_Policy
T.Op.Integrity.4	O.I&A O.Integrity_Checks O.Integ_Data O.Obj_Attr O.Session_Protection O.User_Attributes O.Attr_based_Policy
T.Op.Integrity.5	O.I&A O.Integrity_Checks O.Integ_Data O.Obj_Attr O.Session_Protection O.User_Attributes O.Attr_based_Policy
T.Op.Integrity.6	O.I&A O.Integrity_Checks O.Integ_Data O.Obj_Attr O.Session_Protection O.User_Attributes O.Attr_based_Policy
T.Op.Integrity.7	O.I&A O.Integrity_Checks O.Integ_Data O.Obj_Attr O.Session_Protection

THREATS	OBJECTIVES
T.Op.Integrity.8	O.I&A O.Integrity_Checks O.Integ_Data O.Obj_Attr O.Session_Protection O.User_Attributes O.Attr_based_Policy

Coverage of Operational Non-repudiation Threats

Table 1-63
Coverage of Operational Non-repudiation Threats

THREATS	OBJECTIVES
T.Op.Non-Repudiation.1	O.Import_Export_Control O.I&A O.NonRepudiation O.Session_Protection O.User_Attributes O.Attr_based_Policy
T.Op.Non-Repudiation.2	O.Import_Export_Control O.I&A O.NonRepudiation O.Session_Protection O.User_Attributes O.Attr_based_Policy
T.Op.Non-Repudiation.3	O.Import_Export_Control O.I&A O.NonRepudiation O.Session_Protection O.User_Attributes O.Attr_based_Policy
T.Op.Non-Repudiation.4	O.Import_Export_Control O.I&A O.NonRepudiation O.Session_Protection O.User_Attributes O.Attr_based_Policy
T.Op.Non-Repudiation.5	O.Import_Export_Control O.I&A O.NonRepudiation O.Session_Protection O.User_Attributes O.Attr_based_Policy
T.Op.Non-Repudiation.6	O.Import_Export_Control O.I&A O.NonRepudiation O.Session_Protection O.User_Attributes O.Attr_based_Policy

Coverage of Physical Threats

Table 1-64
Coverage of Physical Threats

THREATS	OBJECTIVES
T.Physical.Capture.1	O.Confidentiality O.Fault_Tolerant O.Secure_State O.Tamper
T.Physical.Capture.2	O.Confidentiality O.Fault_Tolerant O.Secure_State O.Tamper
T.Physical.Denial.1	O.Secure_State
T.Physical.Destruction.IA.1	O.Fault_Tolerant O.I&A OE.Admin_Available
T.Physical.Destruction.IA.2	O.Fault_Tolerant O.I&A OE.Admin_Available
T.Physical.Destruction.Info.1	O.Secure_State OE.Sys_Backup_Procs
T.Physical.Destruction.Info.2	O.Secure_State OE.Sys_Backup_Procs
T.Physical.Destruction.Res.1	O.Secure_State
T.Physical.Destruction.Res.2	O.Secure_State
T.Physical.Destruction.Serv.1	O.Secure_State
T.Physical.Destruction.Serv.2	O.Secure_State
T.Physical.Destruction.Total.1	O.Secure_State
T.Physical.Destruction.Total.2	O.Secure_State
T.Physical.Extract.IA.1	O.Confidentiality O.Tamper
T.Physical.Extract.IA.2	O.Confidentiality O.Emanations
T.Physical.Extract.NonAMI.1	O.Confidentiality O.Emanations
T.Physical.Extract.Res.1	O.Confidentiality O.Tamper
T.Physical.Extract.Res.2	O.Confidentiality O.Emanations
T.Physical.Extract.Res.3	O.Confidentiality O.Emanations
T.Physical.HWFailure.1	O.Secure_State O.Sys_Assur_HW/SW/FW
T.Physical.HWFailure.2	O.Confidentiality O.Secure_State O.Sys_Assur_HW/SW/FW
T.Physical.HWFailure.3	O.Secure_State O.Sys_Assur_HW/SW/FW
T.Physical.MechFailure.1	O.Secure_State O.Sys_Assur_HW/SW/FW
T.Physical.Modification.Info.1	O.Tamper
T.Physical.Modification.Input.1	O.Confidentiality O.Tamper
T.Physical.Modification.Res.1	O.Confidentiality O.Tamper
T.Physical.Modification.Res.2	O.Confidentiality O.Tamper
T.Physical.Obsolete.1	OE.Component_Engineering

THREATS	OBJECTIVES
T.Physical.Obsolete.2	OE.Component_Engineering
T.Physical.ReverseEng.1	O.Confidentiality O.Secure_via_Cryptography
T.Physical.ReverseEng.2	O.Confidentiality O.Secure_via_Cryptography
T.Physical.ReverseEng.3	O.Confidentiality O.Secure_via_Cryptography
T.Physical.ReverseEng.4	O.Confidentiality O.Secure_via_Cryptography
T.Physical.SWFailure.1	O.Secure_State O.Sys_Assur_HW/SW/FW
T.Physical.SWFailure.2	O.Confidentiality O.Secure_State O.Sys_Assur_HW/SW/FW

Coverage of Social Engineering Threats

Table 1-65
Coverage of Social Engineering Threats

THREATS	OBJECTIVES
T.Social_Eng.Access.1	O.Confidentiality O.I&A OE.Physical_Security
T.Social_Eng.Access.2	O.Confidentiality
T.Social_Eng.Access.3	O.Confidentiality
T.Social_Eng.AdminLeak.1	O.Confidentiality OE.Secure_Configuration OE.Evaluated_System
T.Social_Eng.Authorize.1	O.Confidentiality O.I&A OE.Physical_Security
T.Social_Eng.Info.1	O.Confidentiality O.User_Attributes OE.User_Auth_Management OE.Physical_Security
T.Social_Eng.Info.2	O.Confidentiality OE.User_Auth_Management OE.Secure_Configuration OE.User_Auth_Management
T.Social_Eng.Info.3	OE.User_Auth_Management OE.Secure_Configuration OE.User_Auth_Management
T.Social_Eng.Info.4	O.Confidentiality O.I&A OE.User_Auth_Management

Coverage of Trust Threats

Table 1-66
Coverage of Trust Threats

THREATS	OBJECTIVES
T.Trust.Impersonate.1	O.Confidentiality O.I&A
T.Trust.Impersonate.2	O.Confidentiality O.I&A OE.Crypto_Key_Man
T.Trust.Impersonate.3	O.Confidentiality O.I&A
T.Trust.Impersonate.4	O.Confidentiality O.I&A
T.Trust.Impersonate.5	O.Confidentiality O.I&A
T.Trust.Impersonate.6	O.Confidentiality O.I&A
T.Trust.Impersonate.7	O.Confidentiality O.I&A O.Session_Protection
T.Trust.Impersonate.8	O.Confidentiality O.I&A
T.Trust.Info.1	O.I&A O.Session_Protection
T.Trust.Res.1	O.Confidentiality O.I&A O.Session_Protection
T.Trust.Serv.1	O.Confidentiality O.I&A O.Session_Protection

Coverage of Assumptions

Table 1-67
Coverage of Assumptions

ASSUMPTIONS	OBJECTIVES
A.Admin_Available	O.Admin_Roles_Access
A.Audit_Analysis	O.Audit O.Maintain_Online OE.Admin_Guidance
A.Back_Up	O.Admin_Roles_Access
A.Clearance	OE.Admin_Guidance
A.Comms_Available	O.Fault_Tolerant OE.Config_Management
A.Environment	O.Secure_State
A.External_Networks	O.Fault_Tolerant
A.KeyMat_Source	OE.Crypto_Key_Man

ASSUMPTIONS	OBJECTIVES
A.Personnel_Untrusted	O.Audit O.Crypto_Comm_Channel O.Crypto_Storage O.Crypto_Import_Export O.Import_Export_Control O.I&A O.Isolate_Executables O.NonRepudiation O.Obj_Attr O.Priority_Of_Service O.Resource_Quotas O.Rollback O.Session_Protection O.Security_Mgt O.Security_Roles O.Sys_Assur_HW/SW/FW O.Tamper O.User_Attributes O.Malicious_Code O.Comp_Attributes O.Attr_based_Policy OE.Config_Management OE.Crypto_Key_Man OE.Secure_Configuration OE.Evaluated_System OE.Sys_Backup_Procs OE.User_Auth_Management OE.Physical_Security
A.Physical_Protection	O.Secure_State OE.Physical_Security
A.Partial_Physical_Security	O.Tamper OE.Physical_Security
A.Policy_MoA	O.Audit O.Crypto_Comm_Channel O.Crypto_Storage O.Crypto_Import_Export O.Import_Export_Control O.I&A O.Isolate_Executables O.NonRepudiation O.Obj_Attr O.Priority_Of_Service O.Resource_Quotas O.Rollback O.Session_Protection O.Security_Mgt O.Security_Roles O.Sys_Assur_HW/SW/FW O.Tamper O.User_Attributes O.Malicious_Code O.Comp_Attributes O.Attr_based_Policy OE.Config_Management OE.Crypto_Key_Man OE.Secure_Configuration OE.Evaluated_System OE.Sys_Backup_Procs OE.User_Auth_Management OE.Physical_Security

ASSUMPTIONS	OBJECTIVES
A.Printer_Security	OE.User_Guidance OE.Physical_Security
A.TOE_Design	OE.Admin_Guidance OE.Config_Management OE.Crypto_Key_Man OE.Secure_Configuration OE.Evaluated_System OE.Sys_Backup_Procs OE.User_Auth_Management OE.User_Guidance OE.Component_Engineering OE.Admin_Available OE.Trusted_Facility OE.Physical_Security OE.BackhaulSLA
A.TOE_Maintenance	O.I&A O.Maintain_Online OE.Admin_Guidance OE.Secure_Configuration
A.TOE_Operation	O.I&A O.Maintain_Online OE.Admin_Guidance OE.Secure_Configuration OE.BackhaulSLA
A.TOE_User	O.I&A OE.Secure_Configuration OE.User_Auth_Management OE.User_Guidance
A.Trained	O.I&A OE.User_Auth_Management OE.User_Guidance
A.Trusted_Source	OE.Crypto_Key_Man OE.Trusted_Facility
A.Visual_Security	OE.Secure_Configuration OE.Physical_Security

Coverage of Policy

Table 1-68
Coverage of Policy

POLICY	OBJECTIVES
P.Access	O.Admin_Roles_Access O.I&A
P.Accountability	O.Admin_Roles_Access O.Audit O.I&A O.NonRepudiation OE.Admin_Guidance
P.Admin_Security	O.Admin_Roles_Access O.I&A O.Maintain_Online
P.Admin_Split	O.Admin_Roles_Access
P.Admin_System	O.Admin_Roles_Access O.I&A O.Maintain_Online

POLICY	OBJECTIVES
P.Audit_Review	O.Admin_Roles_Access O.Audit O.Audit_Log_Maintenance O.Maintain_Online OE.Admin_Guidance
P.Cross_Domain_Filtering	O.Import_Export_Control O.I&A OE.Admin_Guidance
P.Distribution	O.Integrity_Checks O.Integ_Data O.Maintain_Online
P.Due_Care	O.Trusted_Path&Channel OE.Admin_Guidance OE.Config_Management
P.Info_Senders	O.Import_Export_Control O.I&A
P.Info_Sources	O.Import_Export_Control O.I&A
P.Integrity	O.Integrity_Checks O.Integ_Data O.Obj_Attr
P.Protect	O.Trusted_Path&Channel O.Crypto_Comm_Channel O.Crypto_Storage O.Obj_Attr OE.Crypto_Key_Man
P.Security_Admin_Restricted	O.Admin_Roles_Access O.I&A OE.Admin_Guidance
P.Users	O.Import_Export_Control O.I&A

Coverage of Objectives for Target (System)

Table 1-69
Coverage of Objectives for Target (System)

OBJECTIVES	THREATS / POLICIES / ASSUMPTIONS
O.Admin_Roles_Access	T.Admin.Cred.1 T.Admin.Cred.2 T.Admin.Cred.3 T.Admin.Enroll.1 T.Admin.Enroll.2 T.Admin.Enroll.3 T.Admin.Enroll.4 T.Admin.Enroll.5 T.Admin.Enroll.6 T.Admin.Enroll.7 T.Admin.Lockout.1 T.Admin.Lockout.2 T.Admin.Policy.1 T.Admin.Policy.2 T.Admin.Policy.3 T.Admin.Policy.4 T.Admin.Policy.5 T.Admin.Policy.6 T.Admin.Policy.7 T.Admin.Policy.8

OBJECTIVES	THREATS / POLICIES / ASSUMPTIONS
	T.Admin.Policy.9 T.Admin.Policy.10 T.Admin.Policy.11 T.Admin.Policy.12 T.Admin.Policy.13 T.Admin.Policy.14 T.Admin.Policy.15 T.Admin.Policy.16 T.Admin.Policy.17 T.Admin.PolicyImp.1 T.Admin.PolicyImp.2 T.KeyMan.Membership.1 T.KeyMan.Membership.2 T.KeyMan.Membership.3 T.Network.Unauth.1
O.Admin_Roles_Access (cont.)	T.Op.Disclosure.1 T.Op.Disclosure.2 T.Op.Disclosure.3 T.Op.Disclosure.4 T.Op.Disclosure.5 T.Op.Disclosure.6 T.Op.Disclosure.7 T.Op.Disclosure.8 T.Op.Disclosure.9 T.Op.Disclosure.10 T.Op.Disclosure.11 T.Op.Disclosure.12 T.Op.Disclosure.13 T.Op.Disclosure.14 A.Admin_Available A.Back_Up P.Access P.Accountability P.Admin_Security P.Admin_Split P.Admin_System P.Audit_Review P.Security_Admin_Restricted
O.Audit	T.Audit.4 T.Audit.5 T.Audit.6 T.Audit.7 T.Audit.8 T.Audit.9 T.Audit.10 T.Audit.11 T.Insider.Aggregation.1 T.Network.Unauth.1 A.Audit_Analysis A.Personnel_Untrusted A.Policy_MoA P.Accountability P.Audit_Review
O.Audit_Log_Maintenance	T.Audit.1 T.Audit.2 T.Audit.3 T.Audit.7 P.Audit_Review
O.Trusted_Path&Channel	T.Crypto.Invalid_Keys.1

OBJECTIVES	THREATS / POLICIES / ASSUMPTIONS
	T.Crypto.Invalid_Keys.2 T.Crypto.Weak_Keys.1 T.Network.Denial.1 T.Network.Filter.1 P.Due_Care P.Protect
O.Confidentiality	T.Admin.Cred.1 T.Admin.Enroll.1 T.Admin.Enroll.2 T.Admin.Enroll.5 T.Admin.Enroll.6 T.Admin.Policy.1 T.Admin.Policy.2 T.Admin.Policy.3 T.Admin.Policy.4 T.Admin.Policy.7 T.Admin.Policy.8 T.Admin.Policy.9 T.Admin.Policy.10 T.Admin.Policy.12 T.Admin.Policy.13 T.Admin.Policy.14 T.Admin.Policy.15 T.Admin.Policy.16 T.Admin.PolicyImp.2 T.Audit.4 T.Audit.5
O.Confidentiality (cont.)	T.Crypto.Break.1 T.Crypto.Break.2 T.Crypto.Invalid_Keys.1 T.Crypto.Invalid_Keys.2 T.Crypto.Weak_Keys.1 T.Download.2 T.Download.4 T.Eavesdrop.Apps.1 T.Eavesdrop.Comm.1 T.Eavesdrop.Comm.2 T.Eavesdrop.Comm.3 T.Eavesdrop.Comm.4 T.Eavesdrop.Comm.5 T.Eavesdrop.Comm.6 T.Eavesdrop.Comm.7 T.Eavesdrop.HMI.3 T.Flawed_Imp.Backdoor.1 T.Flawed_Imp.Developer.1 T.Flawed_Imp.Developer.3 T.Ident_Auth.1 T.Ident_Auth.2 T.Ident_Auth.4 T.Ident_Auth.5 T.Ident_Auth.8 T.InfoSys.1 T.InfoSys.2 T.InfoSys.Filter.1 T.InfoSys.Printer.1 T.Initialize.Configuration.1 T.Initialize.Configuration.2 T.Initialize.Configuration.3 T.Initialize.Distribution.1 T.Initialize.Distribution.2
O.Confidentiality (cont.)	T.Insider.Aggregation.1

OBJECTIVES	THREATS / POLICIES / ASSUMPTIONS
	T.Insider.Confusion.1 T.Insider.Confusion.2 T.Insider.Confusion.3 T.Insider.Mislabel.1 T.Insider.Mislabel.2 T.Insider.Misuse.Info.1 T.Insider.Misuse.Info.2 T.KeyMan.Deliver.1 T.KeyMan.Deliver.2 T.KeyMan.Deliver.3 T.KeyMan.Membership.1 T.KeyMan.Membership.3 T.Malicious_Code.App.1 T.Malicious_Code.App.2 T.Malicious_Code.App.3 T.Malicious_Code.App.4 T.Malicious_Code.Info.1 T.Malicious_Code.Info.2 T.Malicious_Code.Info.6 T.Malicious_Code.Info.7 T.Malicious_Code.Proxy.1 T.Malicious_Code.Res.1 T.Malicious_Code.Res.2 T.Malicious_Code.Res.5 T.Malicious_Code.Res.6 T.Network.Filter.1 T.Network.Unauth.1
O.Confidentiality (cont.)	T.Op.Disclosure.1 T.Op.Disclosure.2 T.Op.Disclosure.3 T.Op.Disclosure.4 T.Op.Disclosure.5 T.Op.Disclosure.6 T.Op.Disclosure.7 T.Op.Disclosure.8 T.Op.Disclosure.9 T.Op.Disclosure.10 T.Op.Disclosure.11 T.Op.Disclosure.12 T.Op.Disclosure.13 T.Op.Disclosure.14 T.Physical.Capture.1 T.Physical.Capture.2 T.Physical.Extract.IA.1 T.Physical.Extract.IA.2 T.Physical.Extract.NonAMI.1 T.Physical.Extract.Res.1 T.Physical.Extract.Res.2 T.Physical.Extract.Res.3 T.Physical.HWFailure.2 T.Physical.Modification.Input.1 T.Physical.Modification.Res.1 T.Physical.Modification.Res.2 T.Physical.ReverseEng.1 T.Physical.ReverseEng.2 T.Physical.ReverseEng.3 T.Physical.ReverseEng.4 T.Physical.SWFailure.2
O.Confidentiality (cont.)	T.Social_Eng.Access.1 T.Social_Eng.Access.2 T.Social_Eng.Access.3

OBJECTIVES	THREATS / POLICIES / ASSUMPTIONS
	T.Social_Eng.AdminLeak.1 T.Social_Eng.Authorize.1 T.Social_Eng.Info.1 T.Social_Eng.Info.2 T.Social_Eng.Info.4 T.Trust.Impersonate.1 T.Trust.Impersonate.2 T.Trust.Impersonate.3 T.Trust.Impersonate.4 T.Trust.Impersonate.5 T.Trust.Impersonate.6 T.Trust.Impersonate.7 T.Trust.Impersonate.8 T.Trust.Res.1 T.Trust.Serv.1
O.Crypto_Comm_Channel	T.Crypto.Break.1 T.Crypto.Break.2 T.Crypto.Weak_Keys.1 T.Eavesdrop.Comm.1 T.Eavesdrop.Comm.2 T.Eavesdrop.Comm.3 T.Eavesdrop.Comm.4 T.Eavesdrop.Comm.5 T.Eavesdrop.Comm.6 T.Eavesdrop.Comm.7 T.Network.Modify.1 T.Network.Modify.2 A.Personnel_Untrusted A.Policy_MoA P.Protect
O.Crypto_Storage	T.Crypto.Break.1 T.Crypto.Break.2 T.Crypto.Weak_Keys.1 A.Personnel_Untrusted A.Policy_MoA P.Protect
O.Crypto_Import_Export	A.Personnel_Untrusted A.Policy_MoA
O.Fault_Tolerant	T.Admin.PolicyImp.1 T.Download.1 T.KeyMan.Deliver.4 T.KeyMan.Order.3 T.KeyMan.TrackControl.1 T.Network.Denial.1 T.Physical.Capture.1 T.Physical.Capture.2 T.Physical.Destruction.IA.1 T.Physical.Destruction.IA.2 A.Comms_Available A.External_Networks
O.Import_Export_Control	T.Admin.Policy.4 T.Admin.Policy.14 T.Admin.Policy.15 T.Audit.1 T.Audit.2 T.Audit.3 T.Audit.4 T.Audit.5 T.Audit.6 T.Audit.7 T.Audit.8

OBJECTIVES	THREATS / POLICIES / ASSUMPTIONS
	T.Audit.9 T.Audit.10 T.Audit.11 T.Download.1 T.Download.2 T.Download.3 T.Download.4 T.Download.5
O.Import_Export_Control (cont.)	T.Eavesdrop.Apps.1 T.Eavesdrop.Comm.1 T.Eavesdrop.Comm.2 T.Eavesdrop.Comm.3 T.Eavesdrop.Comm.4 T.Eavesdrop.Comm.5 T.Eavesdrop.Comm.6 T.Eavesdrop.Comm.7 T.Eavesdrop.HMI.1 T.InfoSys.2 T.Insider.Confusion.2 T.Insider.Confusion.3 T.Insider.Misinfo.1 T.Insider.Mislabel.1 T.Insider.Mislabel.2 T.Insider.Misuse.Info.1 T.Op.Denial.1 T.Op.Denial.2 T.Op.Denial.4 T.Op.Denial.5 T.Op.Denial.6 T.Op.Denial.8 T.Op.Denial.9 T.Op.Denial.10 T.Op.Disclosure.1 T.Op.Disclosure.2 T.Op.Disclosure.3 T.Op.Disclosure.4 T.Op.Disclosure.5 T.Op.Disclosure.6 T.Op.Disclosure.7 T.Op.Disclosure.8 T.Op.Disclosure.9 T.Op.Disclosure.10 T.Op.Disclosure.11 T.Op.Disclosure.12 T.Op.Disclosure.13 T.Op.Disclosure.14
O.Import_Export_Control (cont.)	T.Op.Non-Repudiation.1 T.Op.Non-Repudiation.2 T.Op.Non-Repudiation.3 T.Op.Non-Repudiation.4 T.Op.Non-Repudiation.5 T.Op.Non-Repudiation.6 A.Personnel_Untrusted A.Policy_MoA P.Cross_Domain_Filtering P.Info_Senders P.Info_Sources P.Users
O.I&A	T.Admin.Enroll.5 T.Admin.Lockout.1 T.Admin.Lockout.2

OBJECTIVES	THREATS / POLICIES / ASSUMPTIONS
	T.Admin.Policy.1 T.Admin.Policy.4 T.Admin.PolicyImp.2 T.Audit.4 T.Audit.7 T.Ident_Auth.1 T.Ident_Auth.2 T.Ident_Auth.4 T.Ident_Auth.5 T.Ident_Auth.6 T.Ident_Auth.7 T.Ident_Auth.8 T.InfoSys.2 T.Insider.Mislabel.2
O.I&A (cont.)	T.Op.Denial.1 T.Op.Denial.2 T.Op.Denial.3 T.Op.Denial.4 T.Op.Denial.5 T.Op.Denial.6 T.Op.Denial.7 T.Op.Denial.8 T.Op.Denial.9 T.Op.Denial.10 T.Op.Denial.11 T.Op.Denial.12 T.Op.Denial.13 T.Op.Denial.14 T.Op.Denial.15 T.Op.Denial.16 T.Op.Disclosure.1 T.Op.Disclosure.2 T.Op.Disclosure.3 T.Op.Disclosure.4 T.Op.Disclosure.5 T.Op.Disclosure.6 T.Op.Disclosure.7 T.Op.Disclosure.8 T.Op.Disclosure.9 T.Op.Disclosure.10 T.Op.Disclosure.11 T.Op.Disclosure.12 T.Op.Disclosure.13 T.Op.Disclosure.14 T.Op.Integrity.1 T.Op.Integrity.2 T.Op.Integrity.3 T.Op.Integrity.4 T.Op.Integrity.5 T.Op.Integrity.6 T.Op.Integrity.7 T.Op.Integrity.8
O.I&A (cont.)	T.Op.Non-Repudiation.1 T.Op.Non-Repudiation.2 T.Op.Non-Repudiation.3 T.Op.Non-Repudiation.4 T.Op.Non-Repudiation.5 T.Op.Non-Repudiation.6 T.Physical.Destruction.IA.1 T.Physical.Destruction.IA.2 T.Social_Eng.Access.1

OBJECTIVES	THREATS / POLICIES / ASSUMPTIONS
	T.Social_Eng.Authorize.1 T.Social_Eng.Info.4 T.Trust.Impersonate.1 T.Trust.Impersonate.2 T.Trust.Impersonate.3 T.Trust.Impersonate.4 T.Trust.Impersonate.5 T.Trust.Impersonate.6 T.Trust.Impersonate.7 T.Trust.Impersonate.8 T.Trust.Info.1 T.Trust.Res.1 T.Trust.Serv.1 A.Personnel_Untrusted A.Policy_MoA A.TOE_Maintenance A.TOE_Operation A.TOE_User A.Trained P.Access P.Accountability P.Admin_Security P.Admin_System P.Cross_Domain_Filtering P.Info_Senders P.Info_Sources P.Security_Admin_Restricted P.Users
O.Integrity_Checks	T.Download.1 T.Download.2 T.Download.3 T.Download.4 T.Download.5 T.Initialize.Distribution.1 T.Initialize.Distribution.2 T.Malicious_Code.App.1 T.Malicious_Code.App.2 T.Malicious_Code.App.3 T.Malicious_Code.App.4 T.Malicious_Code.Info.1 T.Malicious_Code.Info.2 T.Malicious_Code.Info.3 T.Malicious_Code.Info.4 T.Malicious_Code.Info.5 T.Malicious_Code.Info.6 T.Malicious_Code.Info.7 T.Malicious_Code.Info.8 T.Malicious_Code.Proxy.1 T.Malicious_Code.Res.1 T.Malicious_Code.Res.2 T.Malicious_Code.Res.3 T.Malicious_Code.Res.4 T.Malicious_Code.Res.5 T.Malicious_Code.Res.6 T.Malicious_Code.Res.7 T.Op.Denial.1 T.Op.Denial.4 T.Op.Denial.8 T.Op.Denial.11 T.Op.Denial.13 T.Op.Denial.14

OBJECTIVES	THREATS / POLICIES / ASSUMPTIONS
	T.Op.Denial.15 T.Op.Denial.16
O.Integrity_Checks (cont.)	T.Op.Disclosure.2 T.Op.Integrity.1 T.Op.Integrity.2 T.Op.Integrity.3 T.Op.Integrity.4 T.Op.Integrity.5 T.Op.Integrity.6 T.Op.Integrity.7 T.Op.Integrity.8 P.Distribution P.Integrity
O.Integ_Data	T.Op.Denial.1 T.Op.Integrity.1 T.Op.Integrity.2 T.Op.Integrity.3 T.Op.Integrity.4 T.Op.Integrity.5 T.Op.Integrity.6 T.Op.Integrity.7 T.Op.Integrity.8 P.Distribution P.Integrity
O.Isolate_Executables	T.Malicious_Code.App.1 T.Malicious_Code.App.2 T.Malicious_Code.App.3 T.Malicious_Code.App.4 T.Malicious_Code.Info.1 T.Malicious_Code.Info.2 T.Malicious_Code.Info.3 T.Malicious_Code.Info.4 T.Malicious_Code.Info.5 T.Malicious_Code.Info.6 T.Malicious_Code.Info.7 T.Malicious_Code.Info.8 T.Malicious_Code.Proxy.1 T.Malicious_Code.Res.1 T.Malicious_Code.Res.2 T.Malicious_Code.Res.3 T.Malicious_Code.Res.4 T.Malicious_Code.Res.5 T.Malicious_Code.Res.6 T.Malicious_Code.Res.7 A.Personnel_Untrusted A.Policy_MoA
O.Maintain_Online	T.Audit.1 T.Audit.2 T.Audit.3 T.Audit.4 T.Audit.5 T.Audit.6 T.Audit.7 T.Audit.8 T.Audit.9 T.Audit.10 T.Audit.11 T.Insider.Misuse.Res.1 T.Network.Denial.1 T.Network.Filter.1 T.Network.Modify.2

OBJECTIVES	THREATS / POLICIES / ASSUMPTIONS
	T.Network.Replay.1 T.Network.Replay.2 A.Audit_Analysis A.TOE_Maintenance A.TOE_Operation P.Admin_Security P.Admin_System P.Audit_Review P.Distribution
O.NonRepudiation	T.Admin.Policy.14 T.Admin.Policy.15 T.InfoSys.2 T.Op.Denial.1 T.Op.Denial.2 T.Op.Denial.3 T.Op.Denial.12 T.Op.Non-Repudiation.1 T.Op.Non-Repudiation.2 T.Op.Non-Repudiation.3 T.Op.Non-Repudiation.4 T.Op.Non-Repudiation.5 T.Op.Non-Repudiation.6 A.Personnel_Untrusted A.Policy_MoA P.Accountability
O.Obj_Attr	T.Op.Denial.1 T.Op.Denial.4 T.Op.Denial.5 T.Op.Denial.6 T.Op.Denial.7 T.Op.Denial.8 T.Op.Denial.9 T.Op.Denial.10 T.Op.Denial.11 T.Op.Denial.15 T.Op.Denial.16 T.Op.Disclosure.1 T.Op.Disclosure.2 T.Op.Disclosure.3 T.Op.Disclosure.4 T.Op.Disclosure.5 T.Op.Disclosure.6 T.Op.Disclosure.7 T.Op.Disclosure.8 T.Op.Disclosure.9 T.Op.Disclosure.10 T.Op.Disclosure.11 T.Op.Disclosure.12 T.Op.Disclosure.13 T.Op.Disclosure.14 T.Op.Integrity.1 T.Op.Integrity.2 T.Op.Integrity.3 T.Op.Integrity.4 T.Op.Integrity.5 T.Op.Integrity.6 T.Op.Integrity.7 T.Op.Integrity.8 A.Personnel_Untrusted A.Policy_MoA P.Integrity

OBJECTIVES	THREATS / POLICIES / ASSUMPTIONS
	P.Protect
O.Priority_Of_Service	T.Insider.Misuse.Res.1 T.Op.Denial.2 T.Op.Denial.11 A.Personnel_Untrusted A.Policy_MoA
O.Resource_Quotas	T.Admin.Policy.5 T.Insider.Misuse.Res.1 T.Network.Denial.1 T.Op.Denial.3 T.Op.Denial.5 T.Op.Denial.6 T.Op.Denial.7 T.Op.Denial.9 T.Op.Denial.10 T.Op.Denial.13 A.Personnel_Untrusted A.Policy_MoA
O.Rollback	T.Admin.Cred.1 T.Admin.Cred.2 T.Admin.Cred.3 T.Admin.Enroll.1 T.Admin.Enroll.2 T.Admin.Enroll.3 T.Admin.Enroll.4 T.Admin.Enroll.5 T.Admin.Enroll.6 T.Admin.Lockout.1 T.Admin.Lockout.2 T.Admin.Policy.2 T.Admin.Policy.3 T.Admin.Policy.4 T.Admin.Policy.5 T.Admin.Policy.6 T.Admin.Policy.8 T.Admin.Policy.9 T.Admin.Policy.10 T.Admin.Policy.11 T.Admin.Policy.12 T.Admin.Policy.13 T.Admin.Policy.14 T.Admin.Policy.17 T.Admin.PolicyImp.1 T.Admin.PolicyImp.2 T.Insider.Confusion.1 T.Insider.Confusion.3 A.Personnel_Untrusted A.Policy_MoA
O.SW_Download	T.Download.1 T.Download.2 T.Download.3 T.Download.4 T.Download.5 T.Flawed_Imp.Backdoor.1 T.Flawed_Imp.Developer.1 T.Flawed_Imp.Developer.2 T.Flawed_Imp.Developer.3 T.Initialize.Configuration.3 T.Initialize.Distribution.1 T.Initialize.Distribution.2
O.Session_Protection	T.Admin.Cred.1

OBJECTIVES	THREATS / POLICIES / ASSUMPTIONS
	T.Admin.Enroll.5 T.Admin.Lockout.1 T.Admin.Lockout.2 T.Admin.Policy.1 T.Admin.Policy.4 T.Admin.Policy.8 T.Admin.PolicyImp.2 T.Eavesdrop.HMI.1 T.Eavesdrop.HMI.2 T.Eavesdrop.HMI.3 T.Op.Denial.1 T.Op.Denial.2 T.Op.Denial.3 T.Op.Denial.4 T.Op.Denial.5 T.Op.Denial.6 T.Op.Denial.7 T.Op.Denial.8 T.Op.Denial.9 T.Op.Denial.10 T.Op.Denial.11 T.Op.Denial.13 T.Op.Disclosure.1 T.Op.Disclosure.2 T.Op.Disclosure.3 T.Op.Disclosure.4 T.Op.Disclosure.5 T.Op.Disclosure.6 T.Op.Disclosure.9 T.Op.Disclosure.10 T.Op.Disclosure.11 T.Op.Disclosure.12 T.Op.Disclosure.14
O.Session_Protection (cont.)	T.Op.Integrity.1 T.Op.Integrity.2 T.Op.Integrity.3 T.Op.Integrity.4 T.Op.Integrity.5 T.Op.Integrity.6 T.Op.Integrity.7 T.Op.Integrity.8 T.Op.Non-Repudiation.1 T.Op.Non-Repudiation.2 T.Op.Non-Repudiation.3 T.Op.Non-Repudiation.4 T.Op.Non-Repudiation.5 T.Op.Non-Repudiation.6 T.Trust.Impersonate.7 T.Trust.Info.1 T.Trust.Res.1 T.Trust.Serv.1 A.Personnel_Untrusted A.Policy_MoA
O.Secure_State	T.Physical.Capture.1 T.Physical.Capture.2 T.Physical.Denial.1 T.Physical.Destruction.Info.1 T.Physical.Destruction.Info.2 T.Physical.Destruction.Res.1 T.Physical.Destruction.Res.2 T.Physical.Destruction.Serv.1

OBJECTIVES	THREATS / POLICIES / ASSUMPTIONS
	T.Physical.Destruction.Serv.2 T.Physical.Destruction.Total.1 T.Physical.Destruction.Total.2 T.Physical.HWFailure.1 T.Physical.HWFailure.2 T.Physical.HWFailure.3 T.Physical.MechFailure.1 T.Physical.SWFailure.1 T.Physical.SWFailure.2 A.Environment A.Physical_Protection
O.Security_Mgt	T.Admin.Cred.1 T.Admin.Cred.2 T.Admin.Cred.3 T.Admin.Enroll.1 T.Admin.Enroll.2 T.Admin.Enroll.3 T.Admin.Enroll.4 T.Admin.Enroll.5 T.Admin.Enroll.6 T.Admin.Enroll.7 T.Admin.Lockout.1 T.Admin.Lockout.2 T.Admin.Policy.1 T.Admin.Policy.2 T.Admin.Policy.3 T.Admin.Policy.4 T.Admin.Policy.5 T.Admin.Policy.6 T.Admin.Policy.7 T.Admin.Policy.8 T.Admin.Policy.9 T.Admin.Policy.10 T.Admin.Policy.11 T.Admin.Policy.12 T.Admin.Policy.13 T.Admin.Policy.14 T.Admin.Policy.15 T.Admin.Policy.16 T.Admin.Policy.17 T.Admin.PolicyImp.1 T.Admin.PolicyImp.2 T.Eavesdrop.HMI.4 A.Personnel_Untrusted A.Policy_MoA
O.Security_Roles	T.Admin.Cred.1 T.Admin.Cred.2 T.Admin.Cred.3 T.Admin.Enroll.1 T.Admin.Enroll.2 T.Admin.Enroll.3 T.Admin.Enroll.4 T.Admin.Enroll.5 T.Admin.Enroll.6 T.Admin.Enroll.7 T.Admin.Lockout.1 T.Admin.Lockout.2 T.Admin.Policy.1 T.Admin.Policy.2 T.Admin.Policy.3 T.Admin.Policy.4

OBJECTIVES	THREATS / POLICIES / ASSUMPTIONS
	T.Admin.Policy.5 T.Admin.Policy.6 T.Admin.Policy.7 T.Admin.Policy.8 T.Admin.Policy.9 T.Admin.Policy.10 T.Admin.Policy.11 T.Admin.Policy.12 T.Admin.Policy.13 T.Admin.Policy.14 T.Admin.Policy.15 T.Admin.Policy.16 T.Admin.Policy.17 T.Admin.PolicyImp.1 T.Admin.PolicyImp.2 A.Personnel_Untrusted A.Policy_MoA
O.Sys_Assur_HW/SW/FW	T.Op.Disclosure.15 T.Physical.HWFailure.1 T.Physical.HWFailure.2 T.Physical.HWFailure.3 T.Physical.MechFailure.1 T.Physical.SWFailure.1 T.Physical.SWFailure.2 A.Personnel_Untrusted A.Policy_MoA
O.Tamper	T.Physical.Capture.1 T.Physical.Capture.2 T.Physical.Extract.IA.1 T.Physical.Extract.Res.1 T.Physical.Modification.Info.1 T.Physical.Modification.Input.1 T.Physical.Modification.Res.1 T.Physical.Modification.Res.2 A.Personnel_Untrusted A.Partial_Physical_Security A.Policy_MoA
O.Emanations	T.Op.Disclosure.8 T.Op.Disclosure.10 T.Physical.Extract.IA.2 T.Physical.Extract.NonAMI.1 T.Physical.Extract.Res.2 T.Physical.Extract.Res.3
O.User_Attributes	T.InfoSys.Printer.1 T.Insider.Aggregation.1 T.Network.Unauth.1 T.Op.Denial.1 T.Op.Denial.2 T.Op.Denial.3 T.Op.Denial.4 T.Op.Denial.5 T.Op.Denial.6 T.Op.Denial.7 T.Op.Denial.8 T.Op.Denial.9 T.Op.Denial.10 T.Op.Denial.11 T.Op.Denial.12 T.Op.Denial.13 T.Op.Denial.14 T.Op.Denial.15

OBJECTIVES	THREATS / POLICIES / ASSUMPTIONS
	T.Op.Denial.16 T.Op.Disclosure.1 T.Op.Disclosure.2 T.Op.Disclosure.3 T.Op.Disclosure.4 T.Op.Disclosure.5 T.Op.Disclosure.6 T.Op.Disclosure.8 T.Op.Disclosure.9 T.Op.Disclosure.11 T.Op.Disclosure.12 T.Op.Disclosure.14 T.Op.Integrity.1 T.Op.Integrity.2 T.Op.Integrity.3 T.Op.Integrity.4 T.Op.Integrity.5 T.Op.Integrity.6 T.Op.Integrity.8
O.User_Attributes (cont.)	T.Op.Non-Repudiation.1 T.Op.Non-Repudiation.2 T.Op.Non-Repudiation.3 T.Op.Non-Repudiation.4 T.Op.Non-Repudiation.5 T.Op.Non-Repudiation.6 T.Social_Eng.Info.1 A.Personnel_Untrusted A.Policy_MoA
O.Secure_via_Cryptography	T.Physical.ReverseEng.1 T.Physical.ReverseEng.2 T.Physical.ReverseEng.3 T.Physical.ReverseEng.4
O.Malicious_Code	T.Flawed_Imp.Backdoor.1 T.Flawed_Imp.Developer.1 T.Flawed_Imp.Developer.2 T.Flawed_Imp.Developer.3 T.Initialize.Distribution.2 T.Malicious_Code.App.1 T.Malicious_Code.App.2 T.Malicious_Code.App.3 T.Malicious_Code.App.4 T.Malicious_Code.Info.1 T.Malicious_Code.Info.2 T.Malicious_Code.Info.3 T.Malicious_Code.Info.4 T.Malicious_Code.Info.5 T.Malicious_Code.Info.6 T.Malicious_Code.Info.7 T.Malicious_Code.Info.8 T.Malicious_Code.Proxy.1 T.Malicious_Code.Res.1 T.Malicious_Code.Res.2 T.Malicious_Code.Res.3 T.Malicious_Code.Res.4 T.Malicious_Code.Res.5 T.Malicious_Code.Res.6 T.Malicious_Code.Res.7 A.Personnel_Untrusted A.Policy_MoA
O.Comp_Attributes	T.Download.4 T.Eavesdrop.HMI.4

OBJECTIVES	THREATS / POLICIES / ASSUMPTIONS
	T.Op.Disclosure.15 A.Personnel_Untrusted A.Policy_MoA
O.Attr_based_Policy	T.Admin.Cred.1 T.Admin.Enroll.5 T.Admin.Lockout.1 T.Admin.Lockout.2 T.Admin.Policy.1 T.Admin.Policy.4 T.Admin.Policy.8 T.Admin.PolicyImp.2 T.Audit.4 T.Audit.5 T.Audit.6 T.Audit.7 T.Malicious_Code.App.1 T.Malicious_Code.App.2 T.Malicious_Code.App.3 T.Malicious_Code.App.4 T.Malicious_Code.Info.1 T.Malicious_Code.Info.2 T.Malicious_Code.Info.3 T.Malicious_Code.Info.4 T.Malicious_Code.Proxy.1 T.Malicious_Code.Res.1 T.Malicious_Code.Res.2 T.Malicious_Code.Res.3 T.Malicious_Code.Res.4 T.Op.Denial.1 T.Op.Denial.2 T.Op.Denial.3 T.Op.Denial.4 T.Op.Denial.5 T.Op.Denial.6 T.Op.Denial.7 T.Op.Denial.8 T.Op.Denial.9
O.Attr_based_Policy (cont.)	T.Op.Denial.10 T.Op.Denial.11 T.Op.Denial.12 T.Op.Denial.13 T.Op.Denial.14 T.Op.Denial.15 T.Op.Denial.16 T.Op.Disclosure.1 T.Op.Disclosure.2 T.Op.Disclosure.3 T.Op.Disclosure.4 T.Op.Disclosure.5 T.Op.Disclosure.6 T.Op.Disclosure.8 T.Op.Disclosure.9 T.Op.Disclosure.11 T.Op.Disclosure.12 T.Op.Disclosure.14 T.Op.Integrity.1 T.Op.Integrity.2 T.Op.Integrity.3 T.Op.Integrity.4 T.Op.Integrity.5 T.Op.Integrity.6

OBJECTIVES	THREATS / POLICIES / ASSUMPTIONS
	T.Op.Integrity.8 T.Op.Non-Repudiation.1 T.Op.Non-Repudiation.2 T.Op.Non-Repudiation.3 T.Op.Non-Repudiation.4 T.Op.Non-Repudiation.5 T.Op.Non-Repudiation.6 A.Personnel_Untrusted A.Policy_MoA

Coverage of Objectives for the Environment

Table 1-70
Coverage of Objectives for the Environment

OBJECTIVES	THREATS / POLICIES / ASSUMPTIONS
OE.Admin_Guidance	T.Audit.8 T.Audit.9 T.KeyMan.Deliver.1 T.KeyMan.Deliver.2 T.KeyMan.Deliver.3 T.KeyMan.Membership.1 T.KeyMan.Membership.2 T.KeyMan.Membership.3 T.KeyMan.Order.1 T.KeyMan.Order.2 T.KeyMan.Order.3 T.KeyMan.TrackControl.1 T.Network.Unauth.1 A.Audit_Analysis A.Clearance A.TOE_Design A.TOE_Maintenance A.TOE_Operation P.Accountability P.Audit_Review P.Cross_Domain_Filtering P.Due_Care P.Security_Admin_Restricted
OE.Config_Management	T.Op.Disclosure.15 A.Comms_Available A.Personnel_Untrusted A.Policy_MoA A.TOE_Design P.Due_Care
OE.Crypto_Key_Man	T.Crypto.Invalid_Keys.1 T.Crypto.Invalid_Keys.2 T.Crypto.Weak_Keys.1 T.KeyMan.Deliver.1 T.KeyMan.Deliver.2 T.KeyMan.Deliver.3 T.KeyMan.Deliver.4 T.KeyMan.Membership.3 T.KeyMan.Obsolescence.1 T.KeyMan.Order.1 T.KeyMan.Order.2 T.KeyMan.Order.3 T.KeyMan.TrackControl.1

OBJECTIVES	THREATS / POLICIES / ASSUMPTIONS
	T.Trust.Impersonate.2 A.KeyMat_Source A.Personnel_Untrusted A.Policy_MoA A.TOE_Design A.Trusted_Source P.Protect
OE.Secure_Configuration	T.Admin.Cred.1 T.Admin.Cred.2 T.Admin.Cred.3 T.Admin.Policy.2 T.Admin.Policy.3 T.Admin.Policy.4 T.Admin.Policy.5 T.Admin.Policy.6 T.Admin.Policy.8 T.Admin.Policy.9 T.Admin.Policy.10 T.Admin.Policy.11 T.Admin.Policy.12 T.Admin.Policy.13 T.Admin.Policy.14 T.Admin.Policy.15 T.Admin.Policy.16 T.Admin.Policy.17 T.Admin.PolicyImp.1 T.Admin.PolicyImp.2 T.Social_Eng.Access.2 T.Social_Eng.Access.3 T.Social_Eng.AdminLeak.1 A.Personnel_Untrusted A.Policy_MoA A.TOE_Design A.TOE_Maintenance A.TOE_Operation A.TOE_User A.Visual_Security
OE.Evaluated_System	T.Flawed_Imp.Backdoor.1 T.Flawed_Imp.Developer.1 T.Flawed_Imp.Developer.2 T.Flawed_Imp.Developer.3 T.InfoSys.1 T.InfoSys.Filter.1 T.Op.Disclosure.15 T.Social_Eng.AdminLeak.1 A.Personnel_Untrusted A.Policy_MoA A.TOE_Design
OE.Sys_Backup_Procs	T.Physical.Destruction.Info.1 T.Physical.Destruction.Info.2 A.Personnel_Untrusted A.Policy_MoA A.TOE_Design
OE.User_Auth_Management	T.Admin.Enroll.1 T.Admin.Enroll.2 T.Admin.Enroll.3 T.Admin.Enroll.4 T.Admin.Enroll.5 T.Admin.Enroll.6 T.Admin.Enroll.7 T.Admin.Lockout.1

OBJECTIVES	THREATS / POLICIES / ASSUMPTIONS
	T.Admin.Lockout.2 T.Admin.Policy.1 T.KeyMan.Membership.1 T.KeyMan.Membership.2 T.KeyMan.Membership.3 T.Social_Eng.Access.2 T.Social_Eng.Access.3 T.Social_Eng.Info.1 T.Social_Eng.Info.2 T.Social_Eng.Info.3 T.Social_Eng.Info.4 A.Personnel_Untrusted A.Policy_MoA A.TOE_Design A.TOE_User A.Trained
OE.User_Guidance	T.InfoSys.Printer.1 T.Network.Unauth.1 T.Op.Denial.1 T.Op.Denial.2 T.Op.Denial.8 T.Op.Denial.12 T.Op.Disclosure.3 T.Op.Disclosure.4 T.Op.Disclosure.5 T.Op.Disclosure.6 T.Op.Disclosure.7 T.Op.Disclosure.12 A.Printer_Security A.TOE_Design A.TOE_User A.Trained
OE.Component_Engineering	T.Physical.Obsolete.1 T.Physical.Obsolete.2 A.TOE_Design
OE.Admin_Available	T.Ident_Auth.3 T.Physical.Destruction.IA.1 T.Physical.Destruction.IA.2 A.TOE_Design
OE.Trusted_Facility	T.Initialize.Configuration.1 T.Initialize.Configuration.2 A.TOE_Design A.Trusted_Source
OE.Physical_Security	T.InfoSys.Printer.1 T.Insider.Misuse.Info.2 T.Eavesdrop.HMI.4 T.Social_Eng.Access.1 T.Social_Eng.Authorize.1 T.Social_Eng.Info.1 A.Personnel_Untrusted A.Physical_Protection A.Partial_Physical_Security A.Policy_MoA A.Printer_Security A.TOE_Design A.Visual_Security
OE.BackhaulSLA	A.TOE_Design A.TOE_Operation
OE.Enrollment_Process	T.Admin.Enroll.1 T.Admin.Enroll.2 T.Admin.Enroll.3

OBJECTIVES	THREATS / POLICIES / ASSUMPTIONS
	T.Admin.Enroll.4 T.Admin.Enroll.6 T.Admin.Enroll.7

AMI-SEC RA: Appendix E – Vulnerability Analysis Support

Table 1-71
Vulnerability Analysis Support

Vulnerability Name	Description	Assets Impacted (eg meter)	Nature of the vulnerability (e.g. Proximity)	Cost	Complexity	Type of compromise	trust level required	Business Impact	Frequency	Severity	Consequences description	Rating (Low, Med, High)	Comments	Provided by (Your Name)
SPP-ICS Vulnerabilities														
V.PLAINTEXT	Use of clear text protocols - The use of clear text protocols and the transmission of business and control data unencrypted over insecure communication channels (e.g. FTP, TELNET).													Neil Greenfield
V.SERVICES	Unnecessary services enabled on system components - The presence of unnecessary system services on key AMI system components and subsystems that may be exploited to negatively impact on system security (e.g. sendmail, finger services).													Neil Greenfield
V.REMOTE	Remote access vulnerabilities - Uncontrolled external access to the corporate network (e.g. through the Internet) allowing unauthorized entry to the interconnected AMI system network. Also includes vulnerabilities introduced through poor VPN configuration, exposed wireless access points, uncontrolled modem access (e.g. through networked faxes) and weak remote user authentication techniques.													Neil Greenfield

Vulnerability Name	Description	Assets Impacted (eg meter)	Nature of the vulnerability (e.g. Proximity)	Cost	Complexity	Type of compromise	trust level required	Business Impact	Frequency	Severity	Consequences description	Rating (Low, Med, High)	Comments	Provided by (Your Name)
V.ARCHITECTURE	<p>Poor system architecture design leading to weaknesses in system security posture - Business and operational requirements impacting on the effectiveness of deployed or planned security measures to protect the confidentiality, integrity and availability of the AMI system and its components. Poor security architecture may also lead to the bypass and tamper of AMI system security functions.</p>													Neil Greenfield
V.DEVELOPMENT	<p>Poor system development practices leading to weakness in system implementation - Lack of quality processes (e.g. configuration management, quality testing) leading to errors in system implementation and third party products such as buffer overflows and errors in control algorithms.</p>													Neil Greenfield
V.NOPOLICIES	<p>Inadequate system security policies, plans and procedures - Lack of formal system policies, plans and procedures (e.g. weak password policies, no incident response plans, irregular compliance audits, poor configuration management policies and procedures, poor system auditing practices, backup procedures etc).</p>													Neil Greenfield
V.SPOF	<p>Single Points of Failure - Poor security architecture design leading to one or more single points of failure in the AMI system and resulting in system unavailability.</p>													Neil Greenfield
V.NOTRAINING	<p>Inadequate user training - Inadequate training on system security issues leading to poor user security awareness.</p>													Neil Greenfield

Vulnerability Name	Description	Assets Impacted (eg meter)	Nature of the vulnerability (e.g. Proximity)	Cost	Complexity	Type of compromise	trust level required	Business Impact	Frequency	Severity	Consequences description	Rating (Low, Med, High)	Comments	Provided by (Your Name)
V.3RDPARTY	Unauthorized access to AMI system via 3rd party network - Unauthorized user access to the AMI system or its components via a 3rd party network connection.													Neil Greenfield
V.NORISK	Lack of risk assessment - Inadequate risk assessment activities performed on critical assets leading to a poor understanding of the security posture of the AMI system and the security controls needed to counter security risks to the organization.													Neil Greenfield
Policy and Procedure Vulnerabilities														
Inadequate security policy for the AMI system	Vulnerabilities are often introduced into AMI system due to inadequate policies or the lack of policies specifically for control system security.													Neil Greenfield
No formal AMI system security training and awareness program	A documented formal security training and awareness program is designed to keep staff up to date on organizational security policies and procedures as well as industry cyber security standards and recommended practices. Without training on specific AMI system policies and procedures, staff cannot be expected to maintain a secure AMI system environment.													Neil Greenfield
Inadequate security architecture and design	Control engineers have historically had minimal training in security and until relatively recently vendors have not included security features in their products													Neil Greenfield

Vulnerability Name	Description	Assets Impacted (eg meter)	Nature of the vulnerability (e.g. Proximity)	Cost	Complexity	Type of compromise	trust level required	Business Impact	Frequency	Severity	Consequences description	Rating (Low, Med, High)	Comments	Provided by (Your Name)
No specific or documented security procedures were developed from the security policy for the AMI system	Specific security procedures should be developed and employees trained for the AMI system. They are the roots of a sound security program.													Neil Greenfield
Absent or deficient AMI system equipment implementation guidelines	Equipment implementation guidelines should be kept up to date and readily available. These guidelines are an integral part of security procedures in the event of an AMI system malfunction.													Neil Greenfield
Lack of administrative mechanisms for security enforcement	Staff responsible for enforcing security should be held accountable for administering documented security policies and procedures.													Neil Greenfield
Few or no security audits on the AMI system	Independent security audits should review and examine a system's records and activities to determine the adequacy of system controls and ensure compliance with established AMI system security policy and procedures. Audits should also be used to detect breaches in AMI system security services and recommend changes as countermeasures which may include making existing security controls more robust and/or adding new security controls.													Neil Greenfield
No AMI system specific continuity of operations or disaster recovery plan (DRP)	A DRP should be prepared, tested and available in the event of a major hardware or software failure or destruction of facilities. Lack of a specific DRP for the AMI system could lead to extended downtimes and production loss.													Neil Greenfield

Vulnerability Name	Description	Assets Impacted (eg meter)	Nature of the vulnerability (e.g. Proximity)	Cost	Complexity	Type of compromise	trust level required	Business Impact	Frequency	Severity	Consequences description	Rating (Low, Med, High)	Comments	Provided by (Your Name)
Lack of AMI system specific configuration change management	A process for controlling modifications to hardware, firmware, software, and documentation should be implemented to ensure an AMI system is protected against inadequate or improper modifications before, during, and after system implementation. A lack of configuration change management procedures can lead to security oversights, exposures, and risks.													Neil Greenfield
OS and vendor software patches may not be developed until significantly after security vulnerabilities are found	Because of the complexity of AMI system software and possible modifications to the underlying OS, changes must undergo comprehensive regression testing. The elapsed time for such testing and subsequent distribution of updated software provides a long window of vulnerability													Neil Greenfield
Platform Configuration Vulnerabilities														
OS and application security patches are not maintained	Out-of-date OSs and applications may contain newly discovered vulnerabilities that could be exploited. Documented procedures should be developed for how security patches will be maintained.													Neil Greenfield
OS and application security patches are implemented without exhaustive testing	OS and application security patches deployed without testing could compromise normal operation of the AMI system. Documented procedures should be developed for testing new security patches.													Neil Greenfield
Default configurations are used	Using default configurations often leads to insecure and unnecessary open ports and exploitable services and applications running on hosts.													Neil Greenfield

Vulnerability Name	Description	Assets Impacted (eg meter)	Nature of the vulnerability (e.g. Proximity)	Cost	Complexity	Type of compromise	trust level required	Business Impact	Frequency	Severity	Consequences description	Rating (Low, Med, High)	Comments	Provided by (Your Name)
Critical configurations are not stored or backed up	Procedures should be available for restoring AMI system configuration settings in the event of accidental or adversary-initiated configuration changes to maintain system availability and prevent loss of data. Documented procedures should be developed for maintaining AMI system configuration settings.													Neil Greenfield
Data unprotected on portable device	If sensitive data (e.g., passwords, dial-up numbers) is stored in the clear on portable devices such as laptops and PDAs and these devices are lost or stolen, system security could be compromised. Policy, procedures, and mechanisms are required for protection.													Neil Greenfield
Lack of adequate password policy	Password policies are needed to define when passwords must be used, how strong they must be, and how they must be maintained. Without a password policy, systems might not have appropriate password controls, making unauthorized access to systems more likely. Password policies should be developed as part of an overall AMI system security program taking into account the capabilities of the AMI system to handle more complex passwords.													Neil Greenfield

Vulnerability Name	Description	Assets Impacted (eg meter)	Nature of the vulnerability (e.g. Proximity)	Cost	Complexity	Type of compromise	trust level required	Business Impact	Frequency	Severity	Consequences description	Rating (Low, Med, High)	Comments	Provided by (Your Name)
No password used	<p>Passwords should be implemented on AMI system components to prevent unauthorized access. Password-related vulnerabilities include having no password for:</p> <ul style="list-style-type: none"> • System login (if the system has user accounts) • System power-on (if the system has no user accounts) • System screen saver (if an AMI system component is unattended over time) <p>Password authentication should not hamper or interfere with emergency actions for AMI system.</p>													Neil Greenfield
Password disclosure	<p>Passwords should be kept confidential to prevent unauthorized access. Examples of password disclosures include:</p> <ul style="list-style-type: none"> • Posting passwords in plain sight, local to a system • Sharing passwords to individual user accounts with associates • Communicating passwords to adversaries through social engineering • Sending passwords that are not encrypted through unprotected communications 													Neil Greenfield
Password guessing	<p>Poorly chosen passwords can easily be guessed by humans or computer algorithms to gain unauthorized access. Examples include:</p> <ul style="list-style-type: none"> • Passwords that are short, simple (e.g., all lower-case letters), or otherwise do not meet typical strength requirements. <p>Password strength also depends on the specific AMI system capability to handle more stringent passwords</p> <ul style="list-style-type: none"> • Passwords that are set to the default vendor supplied value • Passwords that are not changed on a specified interval 													Neil Greenfield

Vulnerability Name	Description	Assets Impacted (eg meter)	Nature of the vulnerability (e.g. Proximity)	Cost	Complexity	Type of compromise	trust level required	Business Impact	Frequency	Severity	Consequences description	Rating (Low, Med, High)	Comments	Provided by (Your Name)
Inadequate access controls applied	Poorly specified access controls can result in giving an AMI system user too many or too few privileges. The following exemplify each case: <ul style="list-style-type: none"> • System configured with default access control settings gives an operator administrative privileges • System improperly configured results in an operator being unable to take corrective actions in an emergency situation Access control policies should be developed as part of an AMI system security program.													Neil Greenfield
Platform Hardware Vulnerabilities														
Inadequate testing of security changes	Many AMI system facilities, especially smaller facilities, have no test facilities, so security changes must be implemented using the live operational systems													Neil Greenfield
Inadequate physical protection for critical systems	Access to the control center, field devices, portable devices, media, and other AMI system components needs to be controlled. Many remote sites are often not staffed and it may not be feasible to physically monitor them.													Neil Greenfield

Vulnerability Name	Description	Assets Impacted (eg meter)	Nature of the vulnerability (e.g. Proximity)	Cost	Complexity	Type of compromise	trust level required	Business Impact	Frequency	Severity	Consequences description	Rating (Low, Med, High)	Comments	Provided by (Your Name)
Unauthorized personnel have physical access to equipment	Physical access to AMI system equipment should be restricted to only the necessary personnel, taking into account safety requirements, such as emergency shutdown or restarts. Improper access to AMI system equipment can lead to any of the following: <ul style="list-style-type: none"> Physical theft of data and hardware Physical damage or destruction of data and hardware Unauthorized changes to the functional environment (e.g., data connections, unauthorized use of removable media, adding/removing resources) Disconnection of physical data links Undetectable interception of data (keystroke and other input logging) 													Neil Greenfield
Insecure remote access on AMI system components	Modems and other remote access capabilities that enable control engineers and vendors to gain remote access to systems should be deployed with security controls to prevent unauthorized individuals from gaining access to the AMI system.													Neil Greenfield
Dual network interface cards (NIC) to connect networks	Machines with dual NAMI system connected to different networks could allow unauthorized access and passing of data from one network to another.													Neil Greenfield
Undocumented assets	To properly secure an AMI system, there should be an accurate listing of the assets in the system. An inaccurate representation of the control system and its components could leave an unauthorized access point or backdoor into the AMI system.													Neil Greenfield

Vulnerability Name	Description	Assets Impacted (eg meter)	Nature of the vulnerability (e.g. Proximity)	Cost	Complexity	Type of compromise	trust level required	Business Impact	Frequency	Severity	Consequences description	Rating (Low, Med, High)	Comments	Provided by (Your Name)
Radio frequency and electro-magnetic pulse (EMP)	The hardware used for control systems is vulnerable to radio frequency electro-magnetic pulses (EMP). The impact can range from temporary disruption of command and control to permanent damage to circuit boards.													Neil Greenfield
Lack of backup power	Without backup power to critical assets, a general loss of power will shut down the AMI system and could create an unsafe situation. Loss of power could also lead to insecure default settings.													Neil Greenfield
Loss of environmental control	Loss of environmental control could lead to processors overheating. Some processors will shut down to protect themselves; some may continue to operate but in a minimal capacity, producing intermittent errors; and some just melt if they overheat.													Neil Greenfield
Lack of redundancy for critical components	Lack of redundancy in critical components could provide single point of failure possibilities													Neil Greenfield
Platform Software Vulnerabilities														
Buffer overflow	Software used to implement an AMI system could be vulnerable to buffer overflows; adversaries could exploit these to perform various attacks.													Neil Greenfield
Installed security capabilities not enabled by default	Security capabilities that were installed with the product are useless if they are not enabled or at least identified as being disabled.													Neil Greenfield
Denial of service (DoS)	AMI system software could be vulnerable to DoS attacks, resulting in the prevention of authorized access to a system resource or delaying system operations and functions.													Neil Greenfield

Vulnerability Name	Description	Assets Impacted (eg meter)	Nature of the vulnerability (e.g. Proximity)	Cost	Complexity	Type of compromise	trust level required	Business Impact	Frequency	Severity	Consequences description	Rating (Low, Med, High)	Comments	Provided by (Your Name)
Mishandling of undefined, poorly defined, or "illegal" conditions	Some AMI system implementations are vulnerable to packets that are malformed or contain illegal or otherwise unexpected field values.													Neil Greenfield
OLE for Process Control (OPC) relies on Remote Procedure Call (RPC) and Distributed Component Object Model (DCOM)	Without updated patches, OPC is vulnerable to the known RPC/DCOM vulnerabilities.													Neil Greenfield
Use of insecure industry-wide AMI system protocols	Distributed Network Protocol (DNP) 3.0, Modbus, Profibus, and other protocols are common across several industries and protocol information is freely available. These protocols often have few or no security capabilities built in.													Neil Greenfield
Use of clear text	Many AMI system protocols transmit messages in clear text across the transmission media, making them susceptible to eavesdropping by adversaries.													Neil Greenfield
Unneeded services running	Many platforms have a wide variety of processor and network services defined to operate as a default. Unneeded services are seldom disabled and could be exploited.													Neil Greenfield

Vulnerability Name	Description	Assets Impacted (eg meter)	Nature of the vulnerability (e.g. Proximity)	Cost	Complexity	Type of compromise	trust level required	Business Impact	Frequency	Severity	Consequences description	Rating (Low, Med, High)	Comments	Provided by (Your Name)
Use of proprietary software that has been discussed at conferences and in periodicals	Proprietary software issues are discussed at international IT, AMI system and "Black Hat" conferences and available through technical papers, periodicals and listservers. Also, AMI system maintenance manuals are available from the vendors. This information can help adversaries create successful attacks against AMI systems.													Neil Greenfield
Inadequate authentication and access control for configuration and programming software	Unauthorized access to configuration and programming software could provide the ability to corrupt a device.													Neil Greenfield
Intrusion detection/prevention software not installed	Incidents can result in loss of system availability; the capture, modification, and deletion of data; and incorrect execution of control commands. IDS/IPS software may stop or prevent various types of attacks, including DoS attacks, and also identify attacked internal hosts, such as those infected with worms. IDS/IPS software must be tested prior to deployment to determine that it does not compromise normal operation of the AMI system.													Neil Greenfield
Logs not maintained	Without proper and accurate logs, it might be impossible to determine what caused a security event to occur.													Neil Greenfield
Incidents are not detected	Where logs and other security sensors are installed, they may not be monitored on a real-time basis and therefore security incidents may not be rapidly detected and countered.													Neil Greenfield

Vulnerability Name	Description	Assets Impacted (eg meter)	Nature of the vulnerability (e.g. Proximity)	Cost	Complexity	Type of compromise	trust level required	Business Impact	Frequency	Severity	Consequences description	Rating (Low, Med, High)	Comments	Provided by (Your Name)
Platform Malware Vulnerabilities														
Malware protection software not installed	Malicious software can result in performance degradation, loss of system availability, and the capture, modification, or deletion of data. Malware protection software, such as antivirus software, is needed to prevent systems from being infected by malicious software.													Neil Greenfield
Malware protection software or definitions not current	Outdated malware protection software and definitions leave the system open to new malware threats.													Neil Greenfield
Malware protection software implemented without exhaustive testing	Malware protection software deployed without testing could impact normal operation of the AMI system.													Neil Greenfield
Network Configuration Vulnerabilities														
Weak network security architecture	The network infrastructure environment within the AMI system has often been developed and modified based on business and operational requirements, with little consideration for the potential security impacts of the changes. Over time, security gaps may have been inadvertently introduced within particular portions of the infrastructure. Without remediation, these gaps may represent backdoors into the AMI system.													Neil Greenfield

Vulnerability Name	Description	Assets Impacted (eg meter)	Nature of the vulnerability (e.g. Proximity)	Cost	Complexity	Type of compromise	trust level required	Business Impact	Frequency	Severity	Consequences description	Rating (Low, Med, High)	Comments	Provided by (Your Name)
Data flow controls not employed	Data flow controls, such as access control lists (ACL), are needed to restrict which systems can directly access network devices. Generally, only designated network administrators should be able to access such devices directly. Data flow controls should ensure that other systems cannot directly access the devices.													Neil Greenfield
Poorly configured security equipment	Using default configurations often leads to insecure and unnecessary open ports and exploitable network services running on hosts. Improperly configured firewall rules and router ACLs can allow unnecessary traffic.													Neil Greenfield
Network device configurations not stored or backed up	Procedures should be available for restoring network device configuration settings in the event of accidental or adversary-initiated configuration changes to maintain system availability and prevent loss of data. Documented procedures should be developed for maintaining network device configuration settings.													Neil Greenfield
Passwords are not encrypted in transit	Passwords transmitted in clear text across transmission media are susceptible to eavesdropping by adversaries, who could reuse them to gain unauthorized access to a network device. Such access could allow an adversary to disrupt AMI system operations or to monitor AMI system network activity.													Neil Greenfield
Passwords exist indefinitely on network devices	Passwords should be changed regularly so that if one becomes known by an unauthorized party, the party has unauthorized access to the network device only for a short time. Such access could allow an adversary to disrupt AMI system operations or monitor AMI system network activity.													Neil Greenfield

Vulnerability Name	Description	Assets Impacted (eg meter)	Nature of the vulnerability (e.g. Proximity)	Cost	Complexity	Type of compromise	trust level required	Business Impact	Frequency	Severity	Consequences description	Rating (Low, Med, High)	Comments	Provided by (Your Name)
Inadequate access controls applied	Unauthorized access to network devices and administrative functions could allow a user to disrupt AMI system operations or monitor AMI system network activity.													Neil Greenfield
Network Hardware Vulnerabilities														
Inadequate physical protection of network equipment	Access to network equipment should be controlled to prevent damage or destruction.													Neil Greenfield
Unsecured physical ports	Unsecured universal serial bus (USB) and PS/2 ports could allow unauthorized connection of thumb drives, keystroke loggers, etc.													Neil Greenfield
Loss of environmental control	Loss of environmental control could lead to processors overheating. Some processors will shut down to protect themselves, and some just melt if they overheat.													Neil Greenfield
Non-critical personnel have access to equipment and network connections	Physical access to network equipment should be restricted to only the necessary personnel. Improper access to network equipment can lead to any of the following: <ul style="list-style-type: none"> • Physical theft of data and hardware • Physical damage or destruction of data and hardware • Unauthorized changes to the security environment (e.g., altering ACLs to permit attacks to enter a network) • Unauthorized interception and manipulation of network activity • Disconnection of physical data links or connection of unauthorized data links 													Neil Greenfield
Lack of redundancy for critical networks	Lack of redundancy in critical networks could provide single point of failure possibilities													Neil Greenfield

Vulnerability Name	Description	Assets Impacted (eg meter)	Nature of the vulnerability (e.g. Proximity)	Cost	Complexity	Type of compromise	trust level required	Business Impact	Frequency	Severity	Consequences description	Rating (Low, Med, High)	Comments	Provided by (Your Name)
Network Perimeter Vulnerabilities														
No security perimeter defined	If the control network does not have a security perimeter clearly defined, then it is not possible to ensure that the necessary security controls are deployed and configured properly. This can lead to unauthorized access to systems and data, as well as other problems.													Neil Greenfield
Firewalls nonexistent or improperly configured	A lack of properly configured firewalls could permit unnecessary data to pass between networks, such as control and corporate networks. This could cause several problems, including allowing attacks and malware to spread between networks, making sensitive data susceptible to monitoring/eavesdropping on the other network, and providing individuals with unauthorized access to systems.													Neil Greenfield
Control networks used for non-control traffic	Control and non-control traffic have different requirements, such as determinism and reliability, so having both types of traffic on a single network makes it more difficult to configure the network so that it meets the requirements of the control traffic. For example, non-control traffic could inadvertently consume resources that control traffic needs, causing disruptions in AMI system functions.													Neil Greenfield
Control network services not within the control network	Where IT services such as Domain Name System (DNS),and/or Dynamic Host Configuration Protocol (DHCP) are used by control networks, they are often implemented in the IT network, causing the AMI system network to become dependent on the IT network that may not have the reliability and availability requirements needed by the AMI system.													Neil Greenfield

Vulnerability Name	Description	Assets Impacted (eg meter)	Nature of the vulnerability (e.g. Proximity)	Cost	Complexity	Type of compromise	trust level required	Business Impact	Frequency	Severity	Consequences description	Rating (Low, Med, High)	Comments	Provided by (Your Name)
Network Monitoring and Logging Vulnerabilities														
Inadequate firewall and router logs	Without proper and accurate logs, it might be impossible to determine what caused a security incident to occur.													Neil Greenfield
No security monitoring on the AMI system network	Without regular security monitoring, incidents might go unnoticed, leading to additional damage and/or disruption. Regular security monitoring is also needed to identify problems with security controls, such as misconfigurations and failures.													Neil Greenfield
Communications Vulnerabilities														
Critical monitoring and control paths are not identified	Rogue and/or unknown connections into the AMI system can leave a backdoor for attacks.													Neil Greenfield
Standard, well-documented communication protocols are used in plain text	Adversaries that can monitor the AMI system network activity can use a protocol analyzer or other utilities to decode the data transferred by protocols such as telnet, File Transfer Protocol (FTP), and Network File System (NFS). The use of such protocols also makes it easier for adversaries to perform attacks against the AMI system and manipulate AMI system network activity.													Neil Greenfield
Authentication of users, data or devices is substandard or nonexistent	Many AMI system protocols have no authentication at any level. Without authentication, there is the potential to replay, modify, or spoof data or to spoof devices such as sensors and user identities.													Neil Greenfield

Vulnerability Name	Description	Assets Impacted (eg meter)	Nature of the vulnerability (e.g. Proximity)	Cost	Complexity	Type of compromise	trust level required	Business Impact	Frequency	Severity	Consequences description	Rating (Low, Med, High)	Comments	Provided by (Your Name)
Lack of integrity checking for communications	There are no integrity checks built into most industrial control protocols; adversaries could manipulate communications undetected. To ensure integrity, the AMI system can use lower-layer protocols (e.g., IPsec) that offer data integrity protection.													Neil Greenfield
Wireless Connection Vulnerabilities														
Inadequate authentication between clients and access points	Strong mutual authentication between wireless clients and access points is needed to ensure that clients do not connect to a rogue access point deployed by an adversary, and also to ensure that adversaries do not connect to any of the AMI system's wireless networks.													Neil Greenfield
Inadequate data protection between clients and access points	Sensitive data between wireless clients and access points should be protected using strong encryption to ensure that adversaries cannot gain unauthorized access to the unencrypted data.													Neil Greenfield

2

AMI SYSTEM SECURITY REQUIREMENTS

Introduction

As a key element in the evolution of the Smart Grid, AMI is the convergence of the power grid, the communications infrastructure, and the supporting information infrastructure. AMI security must exist in the real world with many interested parties and overlapping responsibilities. This chapter focuses on the security services that are important to secure the power grid, communications infrastructure and supporting information infrastructure.

Purpose

The purpose of the AMI Security Specification is to provide the utility industry along with supporting vendor communities and other stakeholders a set of security requirements that should be applied to AMI implementations to ensure the high level of information assurance, availability and security necessary to maintain a reliable system and consumer confidence. While this specification focuses on AMI, the security requirements contained in the document may be extended to other network-centric, Smart Grid solutions.

Strategic Importance

Utility companies of the future will deliver energy and information to customers through a “smart” energy supply chain created by the convergence of electric, communication and information technologies that are highly automated for responding to the changing environment, electricity demands and customer needs. The building blocks of this Smart Grid include AMI, advanced transmission and distribution automation, distributed generation, electric vehicle refueling infrastructure and renewable energy generation projects of today.

The emergence of this new class of Smart Grid systems holds tremendous promise and requires innovation and deployment of new technologies, processes and policies. Composed of many independent systems, the Smart Grid will evolve by integrating existing islands of automation to achieve value through the delivery of information to customers, grid operators, utility companies and other stakeholders. A reliable and secure Smart Grid holds the promise of enabling automated demand response, providing customers a myriad of options to manage their energy costs through technology enabled programs along with limiting outages with a self-healing resilient transmission and distribution network and other strategically important functions.

The challenge of providing both a reliable and secure AMI solution lies in the diversity of technologies, processes and approaches used to realize this vision. Managing change rising from the complexity of diverse solutions with an effective and efficient systems integration process will enable the AMI system. This requires a commitment to standards, best practices and a high degree of architectural discipline. This chapter specifies platform independent security requirements, services and guidance required to implement secure, resilient AMI solutions.

Problem Domain

As the utility industry's capabilities increase to serve the needs of a rapidly growing information society, the breadth and sophistication of the threat environment these Smart Grid solutions operate in also increases. By bridging heterogeneous networks capable of exchanging information seamlessly across the AMI older proprietary and often manual methods of securing utility services will disappear as each is replaced by more open, automated and networked solutions. The benefits of this increased connectivity depends upon robust security services and implementations that are necessary to minimize disruption of vital services and provide increased reliability, manageability and survivability of the electric grid.

Recognizing the unique challenges of AMI enabled Smart Grid solutions is imperative to deploying a secure and reliable solution. Unique characteristics of AMI implementations that set them apart from other utility project include the following:

- AMI touches every consumer
- AMI is a command and control system
- AMI has millions of nodes
- AMI touches almost every enterprise system
- Many current AMI solutions are narrowband solutions

These network-centric characteristics, coupled with a lack of a composite set of cross industry AMI security requirements and implementation guidance, is the primary motivation for the development of the content in this chapter. The problem domains needing to be addressed within AMI implementations are relatively new to the utility industry; however there is precedence for implementing large scale, network-centric solutions with high information assurance requirements. The defense, cable and telecommunication industries offer a number of examples of requirements, standards and best practices directly applicable to AMI implementations.

The challenge is to secure AMI in a holistic manner, noting that such an approach requires the buy-in of many stakeholders. Stakeholders can be viewed in three groups:

- Stakeholders within the enterprise who have an interest in generating value from technology investments:
 - Those who make investment decisions
 - Those who decide about requirements
 - Those who use technology services
- Internal and external stakeholders who provide technology services:
 - Those who manage the technology organization and processes
 - Those who develop capabilities
 - Those who operate the services
- Internal and external stakeholders who have a control/risk responsibility:
 - Those with security, privacy and/or risk responsibilities
 - Those performing compliance functions

- Those requiring or providing assurance services

To meet the requirements of the stakeholder community, a security framework for AMI technology governance and control should:

- Provide a business focus to enable alignment between business and technology objectives
- Establish a process orientation to define the scope and extent of coverage, with a defined structure enabling easy navigation of content
- Be generally acceptable by being consistent with accepted technology good practices and standards and independent of specific technologies
- Supply a common language with a set of terms and definitions that are generally understandable by all stakeholders
- Help meet regulatory requirements by being consistent with generally accepted corporate governance standards (e.g., Committee of Sponsoring Organizations of the Treadway Commission) and technology controls expected by regulators and external auditors.

As such, this chapter provides security requirements for the purposes of procurement, design input, validation and certification. It is not the intent in this chapter to describe AMI architecture. The satisfaction of requirements identified in this document implies a need for coherent architecture, policies, procedures, etc... none of which is prescribed in this document.

AMI security involves a system of systems approach in design and operations, and therefore security responsibility must extend to stakeholders and parties outside and in addition to the electric utility. While security requirements for the broader AMI may or may not be within the scope of a single utility's responsibility, imposing the requirements upon cooperating interconnecting systems and the corresponding capabilities will meet or support some aspects of AMI security objectives. Moreover, interdependencies among the power grid, the communications infrastructure, and the information infrastructure pose a particularly serious challenge to the design of a secure and survivable AMI.

Intended Audience

The intended audience for this chapter includes utility companies seeking AMI implementation and policy guidance; vendors seeking product design requirements and input; policy makers seeking to understand the requirements of reliable and secure AMI solutions; and any reader who wishes to find information related to AMI security requirements. While this document is intended for use by security professionals, solution architects and product designers, much of the document is written for a broader audience seeking to understand AMI security challenges, requirements and potential solutions. Lastly, this specification may provide a foundation for security requirements in the procurement and implementation of AMI solutions.

The content in this chapter is intended to be a living specification to be updated as the industry evolves, with a focus on AMI security functionality. As such, one of the benefits of this document is to create a baseline document for the utility industry that provides AMI security requirements and identifies gaps between current requirements and capabilities available in the

market. Ideally, the AMI security specification will be referenced and reused throughout the utility industry, providing a common set of semantics for enabling the development and implementation of robust, reliable AMI solutions.

Scope

AMI Security is simply defined as those means and measures concerned with securing an AMI system. For the purpose of this document, the definition of AMI is:

The communications hardware and software and associated system and data management software that creates a network between advanced meters and utility business systems and which allows collection and distribution of information to customers and other parties such as competitive retail providers, in addition to providing it to the utility itself. AMI is further defined as: 1) The hardware and software residing in, on, or closest to the customer premise for which the utility or its legal proxies are primarily responsible for proper operation; and 2) The hardware and software owned and operated by the utility or its legal proxies which has as its primary purpose the facilitation of Advanced Metering.

This chapter presents security requirements for AMI systems. The chapter does not address business functional or other non-security related requirements.

A further understanding of the scope requires an understanding of the utility business systems and associated functionality. In general, this specification is a tool that can be applied broadly as defined above and to peripheral systems using AMI communication services. Each individual utility should decide the boundary distinction. The boundary definition and document applicability includes system security maturity of the associated connecting system, organizational responsibility and procurement scope.

Home Area Network use cases were considered in the development of this document and it is reasonable to assume utility edge application requirements can be applied to HAN applications (e.g., requirements applied to utility applications can also be applied to consumer applications). Imposing requirements on the HAN requires additional considerations associated with control and ownership that are outside the scope of this chapter.

Chapter Overview

This section describes how this chapter relates to the Architectural Description, Risk Assessment, Component Catalog and Implementation Guide that is part of the AMI Security Acceleration Project (ASAP) Phase 1 Report (**EPRI Technical Update, Product 1020235, September 2009**).

The path that a particular utility follows through these documents (Risk Assessment, System Security Requirements, Architectural Description, Component Catalog and Implementation Guide) depends upon the level of resources the utility chooses to put toward the effort. In the drawing below, this level of resources tracks the “Entry Points” on the right side of the drawing. For the descriptions below (Figure 2-1), the utility will define Architectural Elements, i.e., hardware and software.

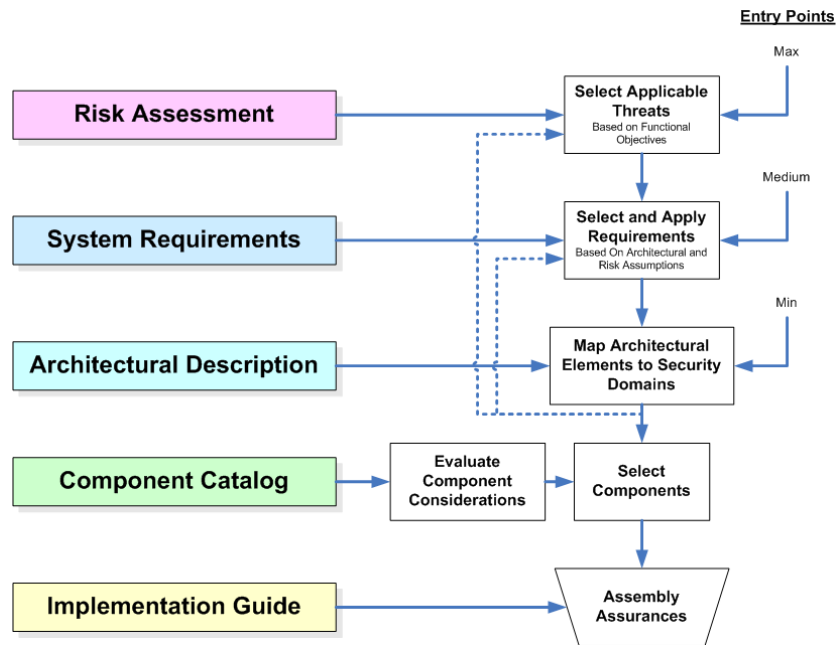


Figure 2-1
Deliverables Process Flow

Maximum Level of Resources. For a utility with the ability to apply the maximum level of resources, the process to take is the following:

- Step 1 The utility will tailor the AMI-SEC Risk Assessment to their particular environment, constraints, and risk acceptance limits.
- Step 2 The utility selects which requirements apply to their potential solution architecture by combing through the AMI-SEC System Security Requirements document and assigning priority to the requirements they need in order to adequately mitigate risks.
- Step 3 The utility maps the significant Architectural Elements of potential solutions against the defined Security Domains and places selected and prioritized requirements on Architectural Elements according to the elements' placement within the Security Domains.

Medium Level of Resources. For a utility with a moderate (“medium”) level of resources, the process to undertake is the following:

- Step 1 The utility will review the System Security Requirements document and select which requirements apply to their potential solution architecture.
- Step 2 The utility maps the significant Architectural Elements of potential solutions against the defined Security Domains.
- Step 3 The utility accepts the AMI-SEC Risk Assessment without any modification or customization, but bears the responsibility for combing through the AMI-SEC System Security Requirements document
- Step 4 The utility assigns priority to the requirements they need to adequately mitigate risks.
- Step 5 Once the utility has selected and prioritized requirements, the requirements are placed on Architectural Elements according to the elements' placement within the Security Domains.

Minimum Level of Resources. For a utility looking to utilize the minimal level of resources, the process to undertake is the following:

- Step 1 The utility will review the Architectural Description document and map the significant Architectural Elements of potential solutions against the defined Security Domains.
- Step 2 The utility accepts the AMI-SEC Risk Assessment without any modification or customization.
- Step 3 The utility accepts the AMI-SEC System Security Requirements as a whole without selecting any particular subset as applicable to their environment.
- Step 4 Requirements are placed on Architectural Elements according to the elements' placement within the Security Domains. In this scenario, the utility pushes the entire set of requirements on to the vendor. The onus lies with the vendor to push back and indicate where requirements are applicable and where they are not.

Definitions, acronyms, and abbreviations

Rather than produce an exhaustive list of AMI and security terms, links have been provided to well known, extensively used definitions, acronyms and abbreviations. Other terminology is addressed as encountered throughout this document.

**Table 2-1
Terminology References**

Resource	Location
SmartGridipedia	http://www.smartgridipedia.org
NIST IR 7298 - Glossary of Key Information Security Terms	http://csrc.nist.gov/publications/nistir/NISTIR-7298_Glossary_Key_Infor_Security_Terms.pdf
International Electrotechnical Commission 62351-2 Security Terms	http://std.iec.ch/terms/terms.nsf/ByPub?OpenView&Count=-1&RestrictToCategory=IEC%2062351-2
Electropedia	http://www.electropedia.org/

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General System Description

Use Cases

AMI Use Cases have been organized into five different categories consistent with the primary value streams they support. These five categories/value streams are:

- Billing
- Customer
- Distribution System
- Installation
- System

Reference

AMI-SEC SSR: Appendix B – Supplemental Material: Business Functions as Stakeholders in AMI Systems provides additional extensions to the use cases presented here, as well as describing business functions and scenarios.

Billing

There are four primary Use Cases in the Billing category.

1. Multiple Clients Read Demand and Energy Data Automatically from Customer Premises
2. Utility remotely limits usage and/or connects and disconnects customer
3. Utility detects tampering or theft at customer site
4. Contract Meter Reading (or Meter Reading for other Utilities)

Billing Use Cases 1 and 4 are directly related to the electronic capture and processing of time-based energy and demand data from customer meters to support the core Billing process of the electric utility (1) or, on a contract basis, for a gas or water utility (4). The other Billing Use Cases explore other functionality that can be leveraged from having installed AMI meters in the field. Use case 2 explores utilization of the remote connect/disconnect functionality of AMI meters. Use case 3 considers how AMI meters and the data they capture can be leveraged to support the detection of energy theft.

Business value in the Billing area is created in several different ways. By automating the collection of time-based energy usage and demand, the utility is able to significantly transform the process for collecting energy and demand information to support the billing process. The traditional process for collecting meter data (manually recording meter dial settings on a monthly basis) is replaced by a fully automated, electronic capture process. Because the energy data is captured in intervals of time (typically 15 minute intervals), AMI systems enable time-based rates. Time-based billing rates vary throughout the day, reflecting changes in the balance between energy supply and demand. Although the primary implementers of AMI have been electric utilities, the potential exists for the infrastructure to be leveraged to capture gas and water meter data as well – either for the host utility if they deliver those commodities or for another utility (on a contract basis).

Other business value accrues from functionality that the AMI meters can provide. AMI meters typically are outfitted with remote connect and remote disconnect capability. This allows the utility to initiate or terminate service remotely, without having to send a field technician. This functionality supports the routine Move-In/Move-Out processes as well as the credit/collections processes. Disconnects for non-payment (and subsequent reconnects) can be accomplished remotely rather than requiring on-site presence. AMI meters also come with functionality that can help utilities identify potential meter tampering or energy theft/diversion.

Finally, AMI provides a wealth of data that various entities within the utility to use to create additional business value. These areas include the following:

- Distribution system design – granular data on actual customer energy usage can be utilized for more optimal design of distribution system components

- Distribution planning – the utility has a wealth of usage and demand data by circuit that can be analyzed to better target investments in new distribution facilities to meet growth in demand
- Distribution operations and maintenance – the Distribution organization has a wealth of data for improved state estimation, contingency planning, and asset management
- Marketing – AMI data can be analyzed to develop energy services/products to meet customer needs

The following table summarizes the major business processes supported by the Billing Use Cases and the key areas of business value that they enable.

**Table 2-2
Billing Use Cases**

Use Case 1: Auto-Capture Customer Energy and Demand Data		
Major Processes Supported	Business Value	Security Concerns
<ul style="list-style-type: none"> • Read Meters • Validate Meter Reads • Generate Customer Bills 	<ul style="list-style-type: none"> • Eliminate meter reader labor cost and meter reading infrastructure cost • Increase billing accuracy • Enable time-based rates • Enable improved <ul style="list-style-type: none"> ○ Distribution system design ○ Distribution planning ○ Distribution operations and maintenance ○ Marketing 	Confidentiality (privacy) of customer data Integrity of meter data Availability of meter data (for remote read)
Use Case 2: Remote Connect/Disconnect		
Major Processes Supported	Business Value	Security Concerns
<ul style="list-style-type: none"> • Establish service • Terminate service • Manage credit/collection 	<ul style="list-style-type: none"> • Reduce field service truck rolls <ul style="list-style-type: none"> ○ Labor ○ Transportation • Reduce bad debt • Reduce energy losses 	Integrity of signal (correct message and location) Confidentiality (privacy) of signal Availability of connect/disconnect service
Use Case 3: Tamper Detection		
Major Processes Supported	Business Value	Security Concerns
<ul style="list-style-type: none"> • Protect revenue; reduce energy theft 	<ul style="list-style-type: none"> • Reduce lost revenue 	Integrity of tamper indication Availability of tamper indication Confidentiality (privacy) of location data
Use Case 4: Meter Reading for Other Utilities		
Major Processes Supported	Business Value	Security Concerns
<ul style="list-style-type: none"> • Read gas/water meters • Read gas/water meters (other utilities) • Transfer meter reading data to other utility 	<ul style="list-style-type: none"> • Eliminate meter reader labor cost and meter reading infrastructure cost • Create additional source of revenue • Leverage AMI investment 	Confidentiality (privacy) of customer data Integrity of meter data Availability of meter data (for remote read) Availability of meter data to contracting utility through B2B infrastructure

Customer

Four Use Cases have also been defined under the category of Customer:

5. Customer reduces their usage in response to pricing or voluntary load reduction events
6. Customer has access to recent energy usage and cost at their site
7. Customer prepays for electric services
8. External clients use the AMI to interact with devices at customer site

Customer Use Case 1 explores how the AMI system, working together with customers, can create mutually-beneficial programs to manage energy demand/consumption. Use Case 2 is related to 1 in that it describes ways that customers can access information about their energy costs and consumption, and how they can receive messaging from the utility informing the customer of an upcoming peak energy event, requiring/requesting customer load reductions. Customer Use Case 4 is directly related to the previous use cases as well in that it describes how a customer's energy cost/consumption data can be shared with a third party energy service provider to outsource the customer's energy consumption. Use Case 3 describes how AMI functionality can be leveraged to enable customer pre-payment for energy.

The primary business value in the Customer Use Cases comes from an enhanced ability to manage peak load on the distribution network. By communicating pricing signals and upcoming peak load events to customers, customers can modify their energy consumption behavior to reduce their energy costs. The utility benefits by reducing the potential for outages resulting from overload of the system and deferring new capital investments to provide increased capacity. Another source of business value unique to Use Case 3 (Customer Prepayment) accrues to the utility through reduction in bad debt and improved cash flow.

The following table summarizes the major business processes supported by the Customer Use Cases and the key areas of business value that they enable.

**Table 2-3
Customer Use Cases**

Use Case 1: Demand Response / Load Reduction		
Major Processes Supported	Business Value	Security Concerns
<ul style="list-style-type: none"> • Manage Energy Demand/Consumption 	<ul style="list-style-type: none"> • Reduce peak load <ul style="list-style-type: none"> ○ Defer new construction ○ Green benefits ○ Reduce outages 	Confidentiality (access control) of customer equipment Integrity of control messaging and message information Availability of customer devices
Use Case 2: Customer Access to Energy Data		
Major Processes Supported	Business Value	Security Concerns
<ul style="list-style-type: none"> • Provide Energy Information to Customers and Third Parties 	<ul style="list-style-type: none"> • Customer energy awareness • Reduce peak load 	Confidentiality (access control) of customer equipment via price signals and messages Integrity of control messaging and message information Availability of customer devices

Use Case 3: Customer Prepayment		
Major Processes Supported	Business Value	Security Concerns
<ul style="list-style-type: none"> • Collect Revenue from Energy Sales 	<ul style="list-style-type: none"> • Reduce bad debt • Improve cash flow • Improve customer convenience/satisfaction 	Confidentiality (privacy) of customer data and payments Integrity of control messaging and message information containing prepayment data Availability of customer payment data and usage balances
Use Case 4: Third Party Energy Management		
Major Processes Supported	Business Value	Security Concerns
<ul style="list-style-type: none"> • Manage Energy Demand/Consumption 	<ul style="list-style-type: none"> • Reduce peak load • Customer satisfaction 	Confidentiality (privacy) of customer data Integrity of usage data, rate information Availability of usage data, rate information

Distribution System

Four Use Cases have been defined for the Distribution System category:

9. Distribution Operations curtails customer load for grid management
10. Distribution Engineering or Operations optimize network based on data collected by the AMI system
11. Customer Provides Distributed Generation
12. Distribution Operator locates Outage Using AMI Data and Restores Service

Distribution System Use Case 1 is similar to Customer Use Case 1. Both use cases describe the process to send signals to customers for the purpose of reducing load on the system, typically during a system peak. Customer Use Case 1 describes demand response events that the customer can voluntarily participate in using a price signal or a load control signal that the customer may ignore. Distribution System Use Case 1 describes demand response events that are non-voluntary using load control signals or meter disconnection commands. Distribution Use Case 2 explores how data gathered by the AMI system can be utilized (either online or offline) to improve power quality and the overall performance of the distribution network. Distribution Use Case 3 describes how the AMI system can interface with distributed generation (small, customer-owned generation) to improve network operations and reduce off-system energy purchases. Use Case 4 investigates how the AMI system can be leveraged to support the identification of outages on the system and to facilitate the restoration of power following an outage.

The primary areas of business value in the Distribution System Use Cases are related to improving network operations. Optimizing network operations can result in reduced energy losses, reduced outage frequency, and increased customer satisfaction (improved power quality). In addition, Use Case 4 explicitly describes processes to reduce outage duration and, therefore, customer satisfaction.

The following table summarizes the major business processes supported by the Distribution System Use Cases and the key areas of business value that they enable.

**Table 2-4
Distribution Use Cases**

Use Case 1: Emergency Demand Response		
Major Processes Supported	Business Value	Security Concerns
<ul style="list-style-type: none"> • Manage Energy Demand/Consumption 	<ul style="list-style-type: none"> • Reduce peak load <ul style="list-style-type: none"> ○ Defer new construction ○ Reduce outages 	Confidentiality (access control) of customer equipment (including remote service switch and HAN devices) Integrity of control messaging and message information Availability of customer devices
Use Case 2: Distribution Network Optimization		
Major Processes Supported	Business Value	Security Concerns
<ul style="list-style-type: none"> • Manage Power Quality • Optimize Distribution Network • Manage Outages 	<ul style="list-style-type: none"> • Customer satisfaction • Reduce energy losses • Improve outage performance 	Integrity of system data Availability of system data Confidentiality of system data
Use Case 3: Distributed Generation		
Major Processes Supported	Business Value	Security Concerns
<ul style="list-style-type: none"> • Optimize Distribution Network • Manage/Dispatch Distributed Resources 	<ul style="list-style-type: none"> • Network Optimization • Reduced Off-System Energy Purchases 	Integrity of system data Availability of system data Confidentiality of system data
Use Case 4: Outage Location and Restoration		
Major Processes Supported	Business Value	Security Concerns
<ul style="list-style-type: none"> • Manage outages 	<ul style="list-style-type: none"> • Reduced outage duration • Customer satisfaction 	Availability of system data Integrity of system data Confidentiality of system data

Installation

Three Use Cases have been defined for the Installation category:

13. Utility installs, provisions, and configures the AMI system
14. Utility Manages End-to-End Lifecycle of the Meter System
15. Utility upgrades AMI to address future requirements.

Installation Use Case 1 describes the process for deploying an AMI system, including the initial deployment plan, the forecasting and procurement process, logistical support, and field installation/testing/configuration. Use Case 2 focuses on managing the AMI system components

through their life cycle, including maintenance and asset retirement. Use Case 3 explores future upgrades to the AMI system functionality and performance with particular attention to future deployment and integration of customer Home Area Network (HAN).

The key areas of business value in the Installation Use Cases include optimization of deployment costs and schedule for AMI system implementation, minimizing AMI operations and maintenance costs, maintaining billing accuracy, minimizing risk, and accommodating future growth and development within the AMI infrastructure.

The following table summarizes the major business processes supported by the Installation Use Cases and the key areas of business value that they enable.

**Table 2-5
Installation Use Cases**

Use Case 1: AMI System Deployment		
Major Processes Supported	Business Value	Security Concerns
<ul style="list-style-type: none"> • Deploy AMI system 	<ul style="list-style-type: none"> • Optimize deployment costs/schedule 	Integrity of system data for registration Availability of system data supporting deployment and registration Confidentiality of system data
Use Case 2: AMI System Maintenance		
Major Processes Supported	Business Value	Security Concerns
<ul style="list-style-type: none"> • Maintain AMI system 	<ul style="list-style-type: none"> • Minimize AMI O&M costs • Maintain billing accuracy 	Integrity of system data for remote diagnostics Availability of system data supporting maintenance and work orders Confidentiality of system data
Use Case 3: AMI System Upgrade		
Major Processes Supported	Business Value	Security Concerns
<ul style="list-style-type: none"> • Upgrade/enhance AMI system functionality/performance • Deploy/support customer HAN 	<ul style="list-style-type: none"> • Minimize risk • Accommodate growth and future functionality 	Integrity of system data for registration of new devices and remote firmware upgrades Availability of system data supporting deployment and remote upgrades Confidentiality of system data and customer data

System

The final Use Case category is System. Only one Use Case has been defined for this category:

16. AMI system recovers after outage, communications or equipment failure.

System Use Case 1 explores how the AMI system responds and recovers to individual component failures, communications failures, and broader outages/disasters. The primary

business value in this use case comes from maintaining AMI system integrity through unplanned equipment failures or distribution system outages.

Table 2-6
AMI System Use Cases

Use Case 1: AMI System Recovery		
Major Processes Supported	Business Value	Security Concerns
<ul style="list-style-type: none"> • Recover from AMI component and telecommunications failures • Recover from major area outages/disasters 	<ul style="list-style-type: none"> • Maintain system integrity 	<ul style="list-style-type: none"> Integrity of system data Availability of system data Confidentiality of system data

System Context

AMI is the convergence of the power grid, the communications infrastructure, and the supporting information infrastructure. However, AMI security must exist in the real world with many stakeholders, other interested parties and overlapping responsibilities.

Consider an individual system that is part of an AMI solution to be made up of: 1) Software; 2) Hardware; 3) People and; 4) Information. Now, consider the entire AMI solution to be made up of a collection of various systems, each made up of software, hardware, workers and information – a system of systems. Systems-of-Systems are hierarchical in nature, that is, they naturally break down into parts.

The value of a logical decomposition comes from its ability to view a complex system at multiple levels of abstraction (decomposition) while maintaining forward and reverse traceability through the different levels of decomposition. Logical decomposition can also be mapped to physical decomposition to correlate the model elements. The security domain model shown below (Figure 2-2) was developed to limit the complexity of specifying the security required to implement a robust, secure AMI solution as well as serve as a tool to guide utilities in applying the security requirements in this document to their AMI implementation.

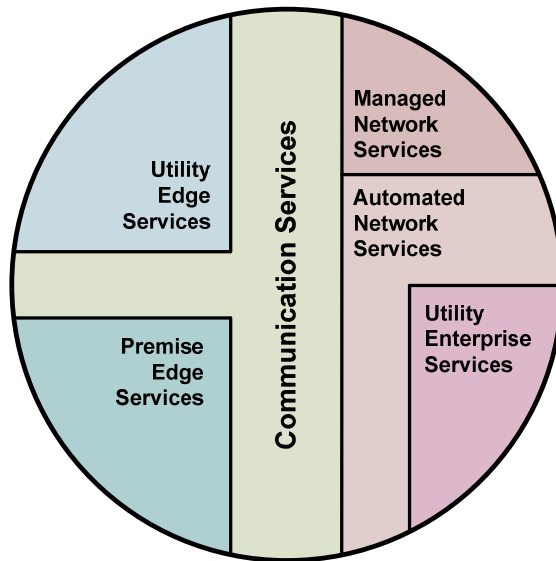


Figure 2-2
AMI Security Domain Model

The following “services” are a description of each of the six security domains shown in the model above.

Table 2-7
AMI Security Domain Descriptions

Security Domain	Description
Utility Edge Services	All field services applications including monitoring, measurement and control controlled by the Utility
Premise Edge Services	All field services applications including monitoring, measurement and control controlled by the Customer (Customer has control to delegate to third party)
Communications Services	are applications that relay, route, and field aggregation, field communication aggregation, field communication management information
Management Services	attended support services for automated and communication services (includes device management)
Automated Services	unattended collection, transmission of data and performs the necessary translation, transformation, response, and data staging
Business Services	core business applications (includes asset management)

Each utility’s AMI implementation will vary based on the specific technologies selected, the policies of the utility company and the deployment environment. The application of the security requirements should guide the AMI system’s capabilities.

AMI system use can be mapped across applicable security domains based on the collection of capabilities that enable use of the AMI. Security requirements in this document shall map to specific security domains based on the location of an enabling capability that enables a particular use for the AMI system. For any particular use of the AMI system, in the context of the enabling capability, the security requirements for that domain should be applied.

For example: If the use of the AMI system is “Remote Service Switch Operation” to support a customer “move-in” or “move-out” event then the analysis of which security requirements would apply for this use would be to map sequence of capabilities to domains.

(Note: there are a number of intermediate steps related to account updates, customer verification, policy enforcements and validations as well as error conditions not shown in this example.)

**Table 2-8
Mapping of AMI Security Domain Services to Utility Processes**

Process step	Enabling Capabilities (components)	Security Domain
Triggering event – Move-out request received from customer for a particular time and date	Request received via call center or via web (IVR or Company Website)	Utility Enterprise Services
Switch operation scheduled and validated	Customers Information System (CIS) or Meter Data Management Systems (MDMS)	Utility Enterprise Services
Command messages generated at scheduled time	CIS or MDMS	Utility Enterprise Services
Command received by head-end system	Network Management System (aka DCA or head-end)	Automated Network Services
Grid protection module validates command against rules (i.e. how many total service switch commands are pending in the next 10 min.)	Network Management System	Automated Network Services
Command transmitted to Meter	Network Management System	Automated Network Services
Command routed to the customer’s meter	Wide-Area Network, Neighborhood Area Network (aka LAN)	Communication Services
Command received by meter	Meter	Utility Edge Services
Service Switch “opened”	Meter	Utility Edge Services
Acknowledgement message created	Meter	Utility Edge Services
Acknowledgement message transmitted	Wide-Area Network, Neighborhood Area Network (aka LAN)	Communications Services
Acknowledgement message received	Network Management System	Automated Network Services
Account status updated	CIS and or MDMS	Utility Enterprise Services

It should be noted that this specification and the method of mapping security requirements to specific domains based on use is lifecycle agnostic. Meaning, some uses of the system (i.e. key placement in devices) may happen prior to the commencement of operations.

System Constraints

A number of system constraints need to be taken into account when satisfying security requirements found in this document. The requirements described do not prescribe which of a range of solutions (e.g., the use of narrow- or wide-band communications technologies) is most appropriate in a given setting. Such a decision is typically based on making prudent trade-offs among a collection of competing concerns, such as the following:

- Other business or non-functional requirements
 - Performance (e.g., response time)
 - Usability (e.g., complexity of interactions for users)
 - Upgradability (e.g., ease of component replacement)
 - Adaptability (e.g., ease of reconfiguration for use in other applications)
 - Effectiveness (e.g., information relevant and pertinent to the business process as well as being delivered in a timely, correct, consistent and usable manner)
 - Efficiency (e.g., the provision of information through the most productive and economical use of resources)
 - Confidentiality (e.g., protection of sensitive information from unauthorized disclosure)
 - Integrity (e.g., accuracy, completeness and validity of information in accordance with business values and expectations)
 - Availability (e.g., information being available when required by the business process)
 - Compliance – (e.g., complying with the laws, regulations and contractual arrangements)
 - Reliability (e.g., the provision of appropriate information for management to operate the entity and exercise its fiduciary and governance responsibilities)

It is important to consider system constraints when developing applying security requirements. The requirements themselves do not take into account the trade-offs involved with design phase of AMI. Therefore, satisfying these requirements should not be done in isolation from the design.

- Constraints
 - Computational (e.g., available computing power in remote devices)
 - Networking (e.g., bandwidth, throughput, or latency)
 - Storage (e.g., required capacity for firmware or audit logs)
 - Power (e.g., available power in remote devices)
 - Personnel (e.g., impact on time spent on average maintenance)
 - Financial (e.g., cost of bulk devices)
 - Temporal (e.g., rate case limitations)
 - Technology
 - Availability
 - Maturity
 - Integration / Interoperability (e.g., legacy systems)

- Lifecycle
- Interconnectedness of infrastructure
- Applications (e.g., the automated user systems and manual procedures that process the information)
- Information (e.g., the data, in all their forms, input, processed and output by the information systems in whatever form is used by the business)
- Infrastructure (e.g., the technology and facilities i.e., hardware, operating systems, database management systems, networking, multimedia, and the environment that houses and supports them, that enable the processing of the applications.)
- People (e.g., the personnel required to plan, organize, acquire, implement, deliver, support, monitor and evaluate the information systems and services. They may be internal, outsourced or contracted as required.)
- Time
- Financial
- Technical
- Operational
- Cultural
- Ethical
- Environmental
- Legal
- Ease of Use
- Regulatory requirements
 - Scope / sphere of influence
 - Acceptance vs. transference

Security States and Modes

This section discusses the states and modes that may apply to the system as a whole and/or the component level. A component may be a sub-system or individual element of the system. Security modes and states are considered in the evaluation of security requirements because they pose special circumstances for which the requirements may change. Evaluating these special circumstances is important because in any given state or mode the risk of a system or sub-system component may increase or decrease, thus needing supplemental requirement treatment (less or more).

Definitions of terms:

- State – a temporal condition of a system or component; implies a “snapshot”.
 - Typically within a time-based consideration
 - Sometimes overlap
- Mode – describes operational intent (implies action taken).

System States

The term *state* for the purposes of this document implies a snapshot of the system. The goal is to identify the state as they relate to security.

The System State Flow Diagram (Figure 2-3) assists in understanding the transition between states and the direction in which changes in state are allowed to occur. The System State Flow Diagram is used in defining the AMI system transitions. It is important to understand and control state flow in order to prevent an undesired, inadvertent system state. Transition of states for security components should be defined and understood with respect to defining requirements. The Sanitization State is also shown as a path where high assurance is required.

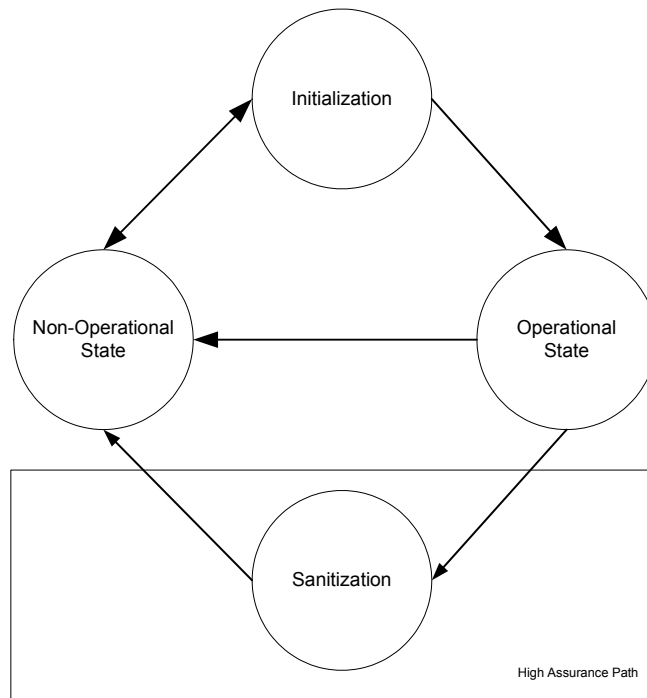


Figure 2-3
Example of a System State Flow Diagram

Table 2-9
System States

System State	Description
Operational	Includes all functionality supportive of on-going operations (set by policy)
Non-operational	Not performing functionality indicative of on-going operations
Initialization	Used to configure system prior to operation
Sanitization	Removal and/or storing of information representative or residual of any running condition (e.g., sensitive data)

System State Security Requirements

State.1 Activities allowed during non-operational state shall be limited to system activities needed to enter

- initialization. (Excludes interactions w/stakeholders, execution of business functions, etc.)
- State.2 Activities allowed during initialization state shall be limited to system activities needed to enter operations. (Excludes interactions w/stakeholders, execution of business functions, etc.)
- State.3 Activities allowed during initialization state shall include management functions necessary for element configuration.
- State.4 Activities allowed during the initialization state shall include policy establishment (i.e., creation and configuration).
- State.5 Activities allowed during the initialization state shall include security domain establishment.
- State.6 A system shall transition into the operational state only upon completion of the critical initialization activities.
- State.7 An operational system shall perform only those activities conformant to policy.
- State.8 A system shall be capable of operating in a degraded mode while in an operational state. In this mode, “degraded” refers to a system that has non-operational or impaired components/elements. While services may be denied to some components/elements in the degraded mode, critical functions and security features of the system are still in force for the remaining components/elements.
- State.9 A system shall transition into the non-operational state upon detection of a critical failure.
- State.10 Supporting activities pertaining to the health of the system (e.g., diagnostics, maintenance, training, etc.) shall only be allowed during the operational state. Support activities may be performed in other system states; however they will be performed by systems external to the SUD.

System Modes

At the highest level, a system or component can be placed into a “normal” or “limited” mode of operation. At a minimum, modes should be taken into consideration during Protection Profile development. In a Protection Profile, criteria for entering and exiting each mode should be defined (pay close attention to risk associated with transition between modes – i.e., target mode must be defined before leaving current mode). For a more granular analysis, one may consider the following refinement examples:

- On-Line/Off-Line – system or element is accessible (or non-accessible) from a communication point of view
- Lock – certain functions are not accessible / intentionally disabled
- Maintenance – configuring / patching
- Diagnostics – monitoring for purposes of problem resolution (i.e., debugging)
- Commissioning/Decommissioning – initialization/establishment of functionality or service (decommissioning is reverse)
- Learning – acquiring new parameters and/or functionality for purposes of optimization

- Training – utilizing system functions for purposes of familiarization and simulation. (“Real” outputs are not engaged.)
- Sleep/Power saving – certain functions are temporarily disabled or degraded for decreased energy consumption.
- Special/Emergency – configurations based on criticality of function and preferential and/or prioritized treatment of certain operations. (Example needed, i.e., impending natural disaster.)

Security Objectives

As currently envisioned, Smart Grid services promise unprecedented levels of automation, situational awareness, and fine-grained control of the generation, transmission, distribution and use of electric power. If fully realized, such services should significantly increase the effectiveness, efficiency and reliability of the electric power system providing lower operating costs associated with many of today's labor-intensive tasks and would provide the incentives and technical capability for customers to automatically manage their usage patterns. Customers would specify demand-response usage policies based on pricing signals from the market or would permit direct supplier control of end-user load (automatically shedding load to reduce peak demand or mitigate emergency situations). In conjunction with end-user control, demand response would make the most efficient use of available generating capacity, while supporting conservation and environmental efforts.

Smart Grid services typically require complex distributed applications (some with near real-time constraints), communication over highly-networked information infrastructures, that include a broad range of Internet technologies. For the vision of the Smart Grid to be realized, system security must be maintained at consistently high levels of assurance. Security concerns must be addressed from the outset of any Systems Development Life Cycle (SDLC) activity throughout every systems engineering, including architecture, acquisition, implementation, integration, deployment, operations, maintenance, and decommissioning. Security solutions must be comprehensive or *holistic* in nature (obligatory clichés: you're only as strong as your weakest line” and "the devil is in the details") and capable of evolving in response to changes in the threat or technological environment.

The Smart Grid's primary (cyber) security objectives are as follows:

- Protect all Smart Grid services from malicious attack¹ and unintended adverse cyber and physical events that threaten the mission of the service (i.e., *security events*).
 - Ensure that sufficient information about a security events are available when and where needed to support the decision making necessary to protect (or minimize the disruption to) the mission of the affected Smart Grid service. This includes the collection and delivery of the real-time data needed for situational awareness as well as the collection and protection of forensics data needed for post-mortem analysis to improve the security and survivability of the system in the face of future security events.

¹ Includes cyber and physical attacks, such as attempts to physically tamper with a meter, and disruption of the supporting communications infrastructure.

- Ensure the integrity, availability, and (where appropriate) the confidentiality of the information regarding security services, survivability services and mechanisms used to protect the Smart Grid services. These security and survivability services and mechanisms shall not provide an attack vector or incorrectly respond to malicious or benign stimuli in a manner that would create or worsen a security event.
- Prevent security incidents associated with a Smart Grid service from contributing to or complicating the safety and protection of personnel, stakeholders, stakeholder services and the electrical system.
 - Do not allow any Smart Grid service or its associated technology (e.g., communications networks and gateways) to be used as a stepping stone or conduit for attacks (or amplifying the effects of attacks) on other Smart Grid services, end users, external service providers (e.g., cell phone networks, ISPs), or any other interconnected entity.
 - Smart Grid services shall not amplify the adverse effects of any accident, natural disaster, or human error.
- Provide sufficient evidence to support the assurance of justifiable confidence (i.e., trust) in the integrity, confidentiality, and availability of Smart Grid services. (For example, provide evidence to support public trust in the accuracy of billing statements, the safety and reliability of electricity services, and the fairness of energy markets.)

Smart Grid security involves a system of systems approach in engineering design and operations, which require that security responsibility be extended beyond the Smart Grid. While security requirements for the broader Smart Grid may or may not be within the scope of a single utility's responsibility, imposing the requirements through agreements and/or regulatory mandates upon cooperating interconnecting systems and corresponding capabilities will meet and/or support some aspects of the Smart Grid security objectives. Moreover, interdependencies among the power grid, the communications infrastructure, and the information infrastructure pose a particularly serious challenge to the design of a secure and survivable Smart Grid.

As an example, AMI system security must protect the missions of all AMI business functions and must not be allowed to be used as a conduit for attacking some method of control of the grid. This does not imply that AMI security architects are solely responsible for ensuring this, but rather that responsibility must be assigned for a system of systems perspective wherein potential AMI impact on the larger grid is analyzed, anticipated, and defended against in some portion of the overall system of systems (SoS) architecture and implementation.

Here are a few examples of what the Smart Grid security objectives are meant to prevent:

- Reputational Loss - Attacks or accidents that destroy trust in Smart Grid services, including their technical and economic integrity
- Business Attack - Theft of money or services or falsifying business records
- Gaming the system - Ability to collect, delay, modify, or delete information to gain an unfair competitive advantage (e.g., in energy markets)
- Safety - Attack on safety of the grid, its personnel or users
- Assets - Damaging physical assets of the grid or assets of its users

- Short-term Denial or Disruption of Service
- Long-term Denial or Disruption of Service (including significant physical damage to the grid)
- Privacy violations
- Hijacking control of neighbor's equipment
- Physical and logical tampering
- Subverting situational awareness so that operators take fatal actions that disrupt the system
- Cause automated system to waste resources on false alarms.
- Hijacking services
- Using Smart Grid services or the supported communication mechanisms to attack end users residential or industrial networks (e.g., allowing end-users to compromise other end-users' networked systems.)

Holistic Security

The magnitude of the challenge posed by melding the complexity of the power grid with open, distributed, highly networked technologies, crossing multiple organizational and administrative boundaries, in the presence of intelligent adversaries, is such that traditional security approaches alone are insufficient to meet them.

The primary concern is with protecting the business missions embodied in each of the Smart Grid services individually and collectively, not merely in enforcing security requirements or protecting IT components. *Survivability* is the capability of a system to fulfill its mission in a timely manner despite attack, accident or subsystem failure. Survivability is a blend of security and business risk management that builds upon traditional security approach by adding domain-specific strategies and tactics to create a holistic perspective. The characteristics of a survivable system include its ability to prevent or resist attacks, accidents, other forms of stress, recognize a survivability event and the state of the system under stress and to recover from the adverse impact of a survivability event in a timely manner. Survivability is marked by graceful degradation under stress, with essential services maintained.

User Characteristics

Many of the security requirements within this document are written with respect to a generic notion of an actor or user, rather than identifying specific users such as a maintenance engineer or residential customer. When such a requirement is applied to an architectural element, it should be tailored to specific types of users by taking into account the characteristics of each type of user and how that informs the requirement.

Typical classes of users (at a high level) include (refer to the Contextual View for insight into these classes of users)

- Utility
- Customer
- Third-party

Some of the characteristics that distinguish these classes of users, and even different types of users within these classes, are:

- Organizational responsibility
- Organizational authority
- Ability to delegate authority
- Privileges within the domain
- Access of users

When tailoring a requirement, one might generate several versions of a requirement, each of which differs by identifying a different user and requiring slightly different responses (e.g., level of access control required for a given behavior).

Assumptions and Dependencies

This document is an ad hoc security specification, and as such does not contain requirements pertaining to business (functional) requirements or quality of service (non-functional) requirements (e.g., performance, usability, or maintainability issues). It is assumed that business requirements have already been established for deploying an AMI solution. It does contain a collection of security requirements that have been drawn from industry best practices and government sources documenting best practices for security.

It is not the intent of this document to specify the security requirements for any particular AMI system. Instead, the goal is to provide guidance likely to be suitable across a variety of different AMI implementations. No assumptions are made regarding context specific characteristics such as available computing, software and/or infrastructure resources, unless specifically cited. No assumptions are made regarding the presence or absence of specific business requirements.

This document contains high-level requirements, not detailed specifications. Details such as specific interfaces, algorithms, protocols, and technology solutions are not addressed. These requirements should provide the impetus for the creation of more detailed specifications for AMI systems, the specifics of which depend on each AMI system's context (e.g., actual assets and information flows, business requirements, and detailed risk assessments).

System Security Requirements

The requirements found throughout this section are fine grained. A given section may contain related requirements addressing the same need that differ in terms of the strength of mechanism, rigor and protection each offers.

Requirements are given a lettering scheme as follows:

- Requirements that begin with an “F” are functional requirements.
- Requirements that end with an “S” are supporting services to functional requirements.

- Requirements that begin with an “A” are assurance requirements.
- Remaining letters in the identifier help associate the requirement to its requirement class.

Primary Security Services

This area uses business/mission needs to define requirements. It answers the question, “What security is needed?”

Confidentiality and Privacy (FCP)

This class contains confidentiality and privacy requirements. These requirements provide a user, service or object protection against discovery and misuse of identity by other users/subjects.

FCP.1	The security function shall ensure that [assignment: set of unauthorized users and/or subjects] are unable to determine the real user name bound to [assignment: list of subjects and/or operations and/or objects].
FCP.2	The security function shall provide [selection: an authorized user, [assignment: list of trusted subjects]] a capability to determine the user identity based on the provided alias only under the following [assignment: list of conditions].
FCP.3	The security function shall be able to provide [assignment: number of aliases] aliases of the real identity (e.g., user name) to [assignment: list of subjects].
FCP.4	The security function shall [selection, choose one of: determine an alias for a user, accept the alias from the user] and verify that it conforms to the [assignment: alias metric].
FCP.5	The security function shall provide an alias to the real user name which shall be identical to an alias provided previously under the following [assignment: list of conditions] otherwise the alias provided shall be unrelated to previously provided aliases.
FCP.6	The security function shall ensure that [assignment: list of users and/or subjects] are unable to determine whether [assignment: list of operations][selection: were caused by the same user, are related as follows[assignment: list of relations]].
FCP.7	The security function shall ensure that [assignment: list of users and/or subjects] are unable to observe the operation [assignment: list of operations] on [assignment: list of objects] by [assignment: list of protected users and/or subjects].
FCP.8	The security function shall allocate the [assignment: unobservability related information] among different parts of the module such that the following conditions hold during the lifetime of the information: [assignment: list of conditions].
FCP.9	The security function shall provide [assignment: list of services] to [assignment: list of subjects] without soliciting any reference to [assignment: privacy related information (e.g., real username)].
FCP.10	The security function shall provide [assignment: list of authorized users] with the capability to observe the usage of [assignment: list of resources and/or services].
FCP.11	The security function shall prevent unauthorized and unintended information transfer via shared system resources.
FCP.12	The functions provided by the security function to recover from failure or service discontinuity shall ensure that the secure initial state is restored without exceeding [assignment: quantification] for loss of security function data or objects under the control of the module's security function.
FCP.13	The security function shall protect security function data from unauthorized disclosure when it is transmitted between separate parts of the system.
FCP.14	The security function shall identify and handle error conditions in an expeditious manner without providing information that could be exploited by adversaries.
FCP.15	The authentication mechanisms in the system shall obscure feedback of authentication information

	during the authentication process to protect the information from possible exploitation or use by unauthorized individuals.
FCP.16	The security function shall ensure that the security attributes, when exported outside the system, are unambiguously associated with the exported user data.

Integrity (FIN)

"Maintaining a control system, including information integrity, increases assurance that sensitive data have neither been modified nor deleted in an unauthorized or undetected manner. The security controls described under the system and information integrity family provide policy and procedure for identifying, reporting, and correcting control system flaws. Controls exist for malicious code detection, spam protection, and intrusion detection tools and techniques. Also provided are controls for receiving security alerts and advisories and the verification of security functions on the control system. In addition, there are controls within this family to detect and protect against unauthorized changes to software and data, restrict data input and output, check the accuracy, completeness, and validity of data, and handle error conditions." [DHS]

FIN.1	The security function shall preserve a secure state when the following types of failures occur: [List of types of failure in the module]
FIN.2	The security function shall provide the capability to detect modification of all security function data during transmission between the security function and another trusted IT product within the following metric: [assignment: a defined modification metric].
FIN.3	The security function shall provide the capability to verify the integrity of all security function data transmitted between the security function and another trusted IT product and perform [assignment: action to be taken] if modifications are detected.
FIN.4	The security function shall provide the capability to correct [assignment: type of modification] of all security function data transmitted between the security function and another trusted IT product.
FIN.5	The security function shall be able to detect [selection: modification of data, substitution of data, re-ordering of data, deletion of data, [assignment: other integrity errors]] for security function data transmitted between separate parts of the module.
FIN.6	Upon detection of a data integrity error, the security function shall take the following actions: [assignment: specify the action to be taken].
FIN.7	The security function shall provide detection of physical tampering that might compromise the module's security function.
FIN.8	The security function shall provide the capability to determine whether physical tampering with the module's security function's devices or module's security function's elements has occurred.
FIN.9	For [assignment: list of security function devices/elements for which active detection is required], the security function shall monitor the devices and elements and notify [assignment: a designated user or role] when physical tampering with the module's security function's devices or module's security function's elements has occurred.
FIN.10	The security function shall resist [assignment: physical tampering scenarios] to the [assignment: list of security function devices/elements] by responding automatically such that the integrity is maintained.
FIN.11	After [assignment: list of failures/service discontinuities] the security function shall enter a [assignment: mode (e.g., maintenance mode)] where the ability to return to a secure state is provided.
FIN.12	For [assignment: list of failures/service discontinuities], the security function shall ensure the return of

	the module to a secure state using automated procedures.
FIN.13	When automated recovery from [assignment: list of failures/service discontinuities] is not possible, the security function shall enter [assignment: mode (e.g., a maintenance mode)] where the ability to return to a secure state is provided.
FIN.14	The utility provided by the security function to recover from failure or service discontinuity shall ensure that the secure initial state is restored without exceeding [assignment: quantification] for loss of module's security function data or objects under the control of the module's security function.
FIN.15	If the security function and/or system experience failure or service discontinuity, the security function shall provide the capability to determine the objects that were or were not capable of being recovered; as a result, the following actions should be taken [assignment: action to be taken].
FIN.16	The security function shall detect replay for the following entities: [assignment: list entities].
FIN.17	The security function shall use [assignment: list of interpretation rules to be applied by the module's security function] to consistently interpret security function data from another trusted IT product.
FIN.18	The security function shall run a suite of tests [selection: during initial start-up, periodically during normal operation, at the request of an authorized user, [assignment: other conditions]] to check the fulfillment of [assignment: list of properties of the external entities]. If the test fails, the security function shall [assignment: action(s)].
FIN.19	The security function shall ensure that security function data is consistent when replicated between [assignment: parts of the system].
FIN.20	When parts of the module containing replicated security function data are disconnected, the security function shall ensure the consistency of the replicated security function data upon reconnection before processing any requests for [assignment: list of functions dependent on security function data replication consistency].
FIN.21	The security function shall run a suite of <i>self-tests</i> during initial start-up, periodically during normal operation, at the request of the authorized user, at the conditions [assignment: conditions under which self-test should occur] to demonstrate the correct operation of [selection: [assignment: parts of security function (e.g. key management)], the module's security function.
FIN.22	The security function shall provide authorized users with the capability to verify the integrity of [selection: [assignment: parts of module's security function], security function data].
FIN.23	The security function shall provide authorized users with the capability to verify the integrity of stored security function executable code.
FIN.24	The security function shall verify the correct operation of security utilities [Selection (one or more): upon system startup and restart, upon command by user with appropriate privilege, periodically every [Assignment: organization-defined time-period]] and [Selection (one or more): notifies [assignment: user, etc. (e.g., system administrator), shuts the system down, restarts the system] when anomalies are discovered.
FIN.25	The security function shall detect and protect against unauthorized changes to software and information.
FIN.26	The security function shall restrict the capability to input information to the information system to authorized personnel.
FIN.27	The security function shall check information for accuracy, completeness, validity, and authenticity.
FIN.28	The organization shall handle and retain output from the information system in accordance with applicable laws, Executive Orders, directives, policies, regulations, standards, and operational requirements.

FIN.29	The organization shall develop, disseminate, and periodically review/update: <ol style="list-style-type: none"> 1. Formal, documented, system and control integrity policy that addresses purpose, scope, roles, responsibilities, management commitment, coordination among organizational entities, and compliance; 2. Formal, documented procedures to facilitate the implementation of the system and information integrity policy and associated system and information integrity controls.
FIN.30	The organization shall identify, report, and remediate control system flaws per organizational, legal, and/or regulatory policies.
FIN.31	The security function employs malicious code protection.
FIN.32	The security function shall verify the correct operation of security functions within the control system upon system startup and restart; upon command by user with appropriate privilege; periodically; and/or at defined time periods. The security function notifies the [assignment: system administrator, system component, etc.] when anomalies are discovered.
FIN.33	The security function shall monitor and detect unauthorized changes to software and information.
FIN.34	The security function shall implement security measures to restrict information input to the control system to authorized personnel only.
FIN.35	The security function shall employ mechanisms to check information for accuracy, completeness, validity, and authenticity.
FIN.36	The organization shall handle and retain output from the security function in accordance with applicable laws, regulations, standards, and organizational policy, as well as operational requirements of the control process.
FIN.37	The security function shall protect the integrity of transmitted information.
FIN.38	The security function shall reliably associate [assignment: security parameters] with information exchanged between [assignment: information systems].
FIN.39	The security function that provides name/address resolution service for local clients shall perform data origin authentication and data integrity verification on the resolution responses it receives from authoritative sources when requested by client systems.
FIN.40	The security function that collectively provides name/address resolution service for an organization shall be fault tolerant and implement role separation.
FIN.41	The security function shall protect security function data from modification when it is transmitted between separate parts of the system.
FIN.42	The security function shall mark output using standard naming conventions to identify any special dissemination, handling, or distribution instructions.
FIN.43	The security function shall provide [assignment: list of subjects] with the ability to verify evidence of the validity of the indicated information and the identity of the [assignment: user, object, etc.] that generated the evidence.

Availability (FAV)

This involves the ability of the system to continue to operate and satisfy business/mission needs under diverse operating conditions, including but not limited to peak load conditions, attacks, maintenance operations, and normal operating conditions.

FAV.1	The security function shall ensure the operation of [assignment: list of system's capabilities] when the following failures occur: [assignment: list of type of failures].
FAV.2	The security function shall assign a priority to each subject in the system's security function in terms of availability.

FAV.3	The security function shall ensure that each access to [assignment: controlled resources] shall be mediated on the basis of the subjects assigned priority.
FAV.4	The security function shall ensure that each access to all shareable resources shall be mediated on the basis of the subjects assigned priority.
FAV.5	The security function shall enforce maximum quotas of the following resources: [assignment: controlled resources] that [selection: individual user, defined group of users, subjects] can use [selection: simultaneously, over a specified period of time].
FAV.6	The security function shall ensure the provision of minimum quantity of each [assignment: controlled resource] that is available for [selection: an individual user, defined group of users, subjects] to use [selection: simultaneously, over a specified period of time].
FAV.7	The security function shall protect against or limits the effects of the following types of denial of service attacks: [Assignment: organization-defined list of types of denial of service attacks or reference to source for current list].
FAV.8	The security function shall limit the use of resources by priority.
FAV.9	The functions provided by the security function to recover from failure or service discontinuity shall ensure that the secure initial state is restored without exceeding [assignment: quantification] for loss of security function data or objects under the control of the module's security function.
FAV.10	The security function shall ensure the availability of [assignment: list of types of security function data] provided to another trusted IT product within [assignment: a defined availability metric] given the following conditions [assignment: conditions to ensure availability].

Identification (FID)

This section covers requirements around who an actor claims to be.

FID.1	The security function shall require each user to be successfully identified before allowing any other system's security function-mediated actions on behalf of that user unless is one of the following: [list of system's security function-mediated actions] that may be allowed before the user is identified.
FID.2	The security function shall associate the following user security attributes with subjects acting on the behalf of that user: [assignment: list of user security attributes].
FID.3	The security function shall enforce the following rules on the initial association of user security attributes with subjects acting on the behalf of users: [assignment: rules for the initial association of attributes].
FID.4	The security function shall enforce the following rules governing changes to the user security attributes associated with subjects acting on the behalf of users: [assignment: rules for the changing of attributes].
FID.5	The security function shall uniquely identify (and authenticate) [assignment: users, processes acting on behalf of users, devices, etc.] before establishing a connection.
FID.6	The organization shall manage user identifiers by: <ol style="list-style-type: none"> 1. Uniquely identifying each user; 2. Verifying the identity of each user; 3. Receiving authorization to issue a user identifier from an appropriate organization official; 4. Issuing the user identifier to the intended party; 5. Disabling the user identifier after [Assignment: organization-defined time period] of inactivity; and 6. Archiving user identifiers.
FID.7	The security function shall have mechanisms to uniquely identify (and authenticate) [assignment: users, processes acting on behalf of users, etc.].
FID.8	The security function shall appropriately label information in storage, in process and in transmission.

Authentication (FAT)

This section covers requirements around the proof of identity of an actor.

FAT.1	After a predetermined period of inactivity, the system shall prevent further access to the system by initiating a session lock that remains in effect until the user reestablishes access using appropriate (identification and) authentication procedures.
FAT.2	The security function shall employ a mechanism to authenticate specific devices before establishing a connection.
FAT.3	The security function shall employ authentication methods that meet the requirements of applicable laws, Executive Orders, directives, policies, regulations, standards, and guidance for authentication to a cryptographic module.
FAT.4	The security function shall have mechanisms to authenticate users (or processes acting on behalf of users).
FAT.5	The security function enforces assigned authorizations for controlling access to the system in accordance with applicable policy.
FAT.6	The security function shall employ authentication methods that meet the requirements of applicable laws, Executive Orders, directives, policies, regulations, standards, and guidance for authentication to a cryptographic module.
FAT.7	The security function shall enforce assigned authorizations for controlling the flow of information within the system and between interconnected systems in accordance with applicable policy.
FAT.8	The security function shall enforce the most restrictive set of rights and privileges or accesses needed by [assignment: users, processes acting on behalf of users, etc.] for the performance of specified tasks.
FAT.9	The security function shall (identify and) authenticate specific devices before establishing a connection.
FAT.10	The security function shall obscure feedback of authentication information during the authentication process to protect the information from possible exploitation and unauthorized use.
FAT.11	The security function shall uniquely authenticate [assignment: users, processes acting on behalf of users, etc.].
FAT.12	The organization shall authorize all methods of remote access to the system.
FAT.13	The organization shall develop and enforce policies and procedures for system users concerning the generation and use of passwords. These policies stipulate rules of complexity, based on the criticality level of the systems to be accessed.
FAT.14	The organization shall develop, disseminate and periodically review and update: <ol style="list-style-type: none"> 1. A formal, documented, access control policy that addresses purpose, scope, roles, responsibilities, management commitment, coordination among organizational entities, and compliance; and 2. Formal, documented procedures to facilitate the implementation of the access control policy and associated access controls.
FAT.15	The organization shall develop, disseminate and periodically review and update: <ol style="list-style-type: none"> 1. A formal, documented, authentication policy that addresses purpose, scope, roles, responsibilities, management commitment, coordination among organizational entities, and compliance; and 2. Formal, documented procedures to facilitate the implementation of the identification and authentication policy and associated authentication controls.
FAT.16	The organization shall employ mechanisms in the design and implementation of a system to restrict

	public access to the system from the organization's enterprise network.
FAT.17	The organization shall establish terms and conditions for authorized individuals to: <ol style="list-style-type: none"> 1. Access the information system from an external information system; and 2. Process, store, and/or transmit organization-controlled information using an external information system.
FAT.18	The organization shall identify and document specific user actions (authorizations) that can be performed on the information system without identification or authentication.
FAT.19	The organization shall manage information system authenticators by: <ol style="list-style-type: none"> 1. Defining initial authenticator content; 2. Establishing administrative procedures for initial authenticator distribution, for lost/compromised, or damaged authenticators, and for revoking authenticators; 3. Changing default authenticators upon information system installation; and 4. Changing/refreshing authenticators periodically
FAT.20	The organization shall supervise and review the activities of users with respect to the enforcement and usage of system access controls.
FAT.21	The organization shall: <ol style="list-style-type: none"> 1. Establish usage restrictions and implementation guidance for [assignment: devices (e.g., wireless technologies, portable and mobile devices and media)]; and, 2. Authorize, monitor and control access to the system. 3. Document, monitor, log, and limit access of these devices to the organization's system. 4. Appropriate organizational officials shall authorize the use of these devices per organization's established security policy and procedures.
FAT.22	The security function authenticates specific devices before establishing a connection.
FAT.23	The security function shall [selection: detect, prevent] use of authentication data that has been copied or forged by any actor of the system.
FAT.24	The security function shall allow [assignment: list of security function mediated actions] on behalf of the user to be performed before the user is authenticated.
FAT.25	The security function shall allow the [assignment: the authorized identified roles] to specify alternative initial values to override the default values when an object or information is created.
FAT.26	The security function shall authenticate any user's claimed identity according to the [assignment: rules describing how the multiple authentication mechanisms provide authentication].
FAT.27	The security function shall be able to associate [assignment: users] with roles.
FAT.28	The security function shall be able to enforce the use of security function generated secrets for [assignment: list of functions].
FAT.29	The security function shall enforce the [assignment: access control security function policy] on [assignment: list of subjects and objects] and all operations among subjects and objects covered by the security function's policy.
FAT.30	The security function shall enforce the [assignment: access control security function policy] to objects based on the following: [assignment: list of subjects and objects controlled under the indicated security function policy, and for each, the security function policy-relevant security attributes, or named groups of security function policy-relevant security attributes].
FAT.31	The security function shall enforce the [assignment: access control security function policy(s), information flow control security function policy(s)] to restrict the ability to [selection: change, default, query, modify, delete, [assignment: other operations]] the security attributes [assignment: list of security attributes] to [assignment: the authorized identified roles].
FAT.32	The security function shall enforce the [assignment: access control security function policy, information flow control security function policy] to provide [selection, choose one of: restrictive, permissive, [assignment: other property]] default values for security attributes that are used to enforce the security function policy.

FAT.33	The security function shall enforce the following rules to determine if an operation among controlled subjects and controlled objects is allowed: [assignment: rules governing access among controlled subjects and controlled objects using controlled operations on controlled objects].
FAT.34	The security function shall enforce the rules [assignment: specification of revocation rules].
FAT.35	The security function shall ensure that all operations between any subject controlled by the security function and any object controlled by the security function are covered by an access control security function policy.
FAT.36	The security function shall ensure that the conditions [assignment: conditions for the different roles] are satisfied.
FAT.37	The security function shall explicitly [selection: authorize, deny] an information flow based on the following rules: [assignment: rules, based on security attributes that explicitly [selection: authorize, deny] information flows].
FAT.38	The security function shall explicitly deny access of subjects to objects based on the [assignment: rules, based on security attributes that explicitly deny access of subjects to objects].
FAT.39	The security function shall maintain the following list of security attributes belonging to individual users: [assignment: list of security attributes].
FAT.40	The security function shall maintain the roles: [assignment: authorized identified roles].
FAT.41	The security function shall prevent reuse of authentication data related to [assignment: identified authentication mechanism(s)].
FAT.42	The security function shall provide [assignment: list of multiple authentication mechanisms] to support user authentication.
FAT.43	The security function shall provide a mechanism to <i>generate</i> secrets that meet [assignment: a defined quality metric].
FAT.44	The security function shall provide a mechanism to <i>verify</i> that secrets meet [assignment: a defined quality metric].
FAT.45	The security function shall provide only [assignment: list of feedback] to the user while the authentication is in progress.
FAT.46	The security function shall re-authenticate the user under the conditions [assignment: list of conditions under which re-authentication is required].
FAT.47	The security function shall require an explicit request to assume the following roles: [assignment: the roles].
FAT.48	The security function shall require each user to be successfully authenticated before allowing any other system's security function-mediated actions on behalf of that user.
FAT.49	The security function shall restrict the ability to [selection: change, default, query, modify, delete, clear, [assignment: other operations]] the [assignment: list of security function data] to [assignment: the authorized identified roles].
FAT.50	The security function shall restrict the ability to [selection: determine the behavior of, disable, enable, modify the behavior of] the functions [assignment: list of functions] to [assignment: the authorized identified roles].
FAT.51	The security function shall restrict the ability to revoke [assignment: list of security attributes] associated with the [selection: users, subjects, objects, [assignment: other additional resources]] under the control of the security function to [assignment: the authorized identified roles].
FAT.52	The security function shall restrict the capability to specify an expiration time for [assignment: list of security attributes for which expiration is to be supported] to [assignment: the authorized identified roles].
FAT.53	The security function shall restrict the specification of the limits for [assignment: list of security function data] to [assignment: the authorized identified roles].

FAT.54	The security function shall use the following rules to set the value of security attributes: [assignment: rules for setting the values of security attributes]
FAT.55	Based on the criticality level of the systems to be accessed, the organization shall develop and enforce policies and procedures for system users concerning the generation, use and rules of complexity for passwords.
FAT.56	The security function shall prevent further access to the system by initiating a session lock after [Assignment: organization-defined time period] of inactivity, and the session lock remains in effect until the user reestablishes access using appropriate identification and authentication procedures.
FAT.57	When the defined number of unsuccessful authentication attempts has been [selection: met, surpassed], the security function shall [assignment: list of actions].

Authorization (FAZ)

Authorization is the approval of an actor to perform an action.

FAZ.1	The security function shall enforce assigned authorizations for controlling access to the system in accordance with applicable policy.
FAZ.2	The security function shall enforce separation of duties through assigned access authorizations.
FAZ.3	The security function shall enforce assigned authorizations for controlling the flow of information within the system and between interconnected systems in accordance with applicable policy.
FAZ.4	The organization shall document authorization and approval policies and procedures and maintains a list of personnel authorized to perform maintenance on the control system. Only authorized and qualified organization or vendor personnel perform maintenance on the system.
FAZ.5	The organization shall develop and keep current a list of personnel with authorized access to the facility where [assignment: type of system (e.g., control system, information system)] resides (except for those areas within the facility officially designated as publicly accessible) and issues appropriate authorization credentials (e.g., badges, identification cards, smart cards). Designated officials within the organization review and approve the access list and authorization credentials [Assignment: organization-defined frequency, at least annually].
FAZ.6	The organization shall control all physical access points (including designated entry/exit points) to the facility where the information system resides (except for those areas within the facility officially designated as publicly accessible) and verifies individual access authorizations before granting access to the facility. The organization shall control access to areas officially designated as publicly accessible, as appropriate, in accordance with the organization's assessment of risk.
FAZ.7	The organization shall review information system and facility access authorizations when personnel are reassigned or transferred to other positions within the organization and initiates appropriate actions
FAZ.8	The organization shall limits physical access to all control system facilities and assets and verifies individual access authorizations before granting access. The organization shall limit access to areas officially designated as publicly accessible, as appropriate, in accordance with the organization's assessment of risk.
FAZ.9	The organization shall authorize (i.e., accredit) the system for processing before operations and periodically update the authorization [assignment: organization-defined frequency] or when there is a significant change to the system. A senior organizational official shall sign and approve the security accreditation.
FAZ.10	The security function shall enforce the most restrictive set of rights, privileges or accesses needed by users or workstations (or processes acting on behalf of users) for the performance of specified tasks.
FAZ.11	The security function shall explicitly authorize access of subjects to objects based on the following additional rules: [assignment: rules, based on security attributes that explicitly authorize access of

	subjects to objects].
FAZ.12	The security function shall enforce a limit of [assignment: organization-defined number] consecutive invalid access attempts by a user during a [assignment: organization-defined time period] time period. The security function shall automatically [Selection: locks the account/node for an [assignment: organization-defined time period], delays next login prompt according to [assignment: organization-defined delay algorithm.]] when the maximum number of unsuccessful attempts is exceeded.
FAZ.13	The security function automatically terminates a remote session after [assignment: defined period of inactivity] for [assignment: workstations, servers, etc.] that are used for [assignment: system monitoring, maintenance activities, etc.] based on the risk assessment of the system and the organization's security policy.
FAZ.14	The security function shall limit the number of concurrent sessions for any user to [assignment: organization-defined number of sessions] on the system.

Non-Repudiation (FNR)

Non-repudiation is the ability to irrefutably, tie an actor to an action.

FNR.1	The security function shall be able to generate evidence of origin for transmitted [assignment: list of information types] at the request of the [selection: originator, recipient, [assignment: list of third parties]].
FNR.2	The security function shall be able to relate the [assignment: list of attributes] of the originator of the information, and the [assignment: list of information fields] of the information to which the evidence applies.
FNR.3	The security function shall provide a capability to verify the evidence of origin of information to [selection: originator, recipient, [assignment: list of third parties]] given [assignment: limitations on the evidence of origin].
FNR.4	The security function shall enforce the generation of evidence of origin for transmitted [assignment: list of information types] at all times.
FNR.5	The security function shall be able to generate evidence of receipt for received [assignment: list of information types] at the request of the [selection: originator, recipient, [assignment: list of third parties]].
FNR.6	The security function shall be able to relate the [assignment: list of attributes] of the recipient of the information, and the [assignment: list of information fields] of the information to which the evidence applies.
FNR.7	The security function shall provide a capability to verify the evidence of receipt of information to [selection: originator, recipient, [assignment: list of third parties]] given [assignment: limitations on the evidence of receipt].
FNR.8	The security function shall enforce the generation of evidence of receipt for received [assignment: list of information types] at all times.
FNR.9	The security function shall provide mechanisms to protect the authenticity of communications sessions.
FNR.10	The security function shall provide a capability to generate evidence that can be used as a guarantee of the validity of [assignment: list of objects or information types].
FNR.11	The security function shall provide the capability to determine whether a [assignment: given individual, system, etc.] took a particular [assignment: action].

Accounting (FAC)

This section covers the recording of activity by actors/elements throughout the system. Accounting requirements provide the means to perform a successful audit of events that occur on the system.

FAC.1	The security function shall take [assignment: list of actions] upon detection of a potential security violation.
FAC.2	The security function shall be able to generate an accounting record of the following auditable events: <ol style="list-style-type: none"> 1. Start-up and shutdown of the audit functions; 2. All auditable events for the [selection, choose one of: minimum, basic, detailed, not specified] level of audit; and 3. [assignment: other specifically defined auditable events]
FAC.3	The security function shall generate audit records, at a minimum, for the following events whether or not the attempts were successful: <ol style="list-style-type: none"> 1. Attempts to logon; 2. Attempts to change local account attributes such as privileges; 3. Attempts to change local security policy
FAC.4	The security function shall provide [assignment: authorized users] with the capability to read [assignment: list of audit information] from the audit records.
FAC.5	The security function shall prohibit all users read access to the audit records, except those users that have been granted explicit read-access.
FAC.6	The security function shall ensure that [assignment: metric for saving audit records] stored audit records will be maintained when the following conditions occur: [selection: audit storage exhaustion, failure, attack]
FAC.7	The security function shall generate audit records for the following events: [Assignment: organization-defined auditable events].
FAC.8	The security function shall record within each accounting record at least the following information: <ol style="list-style-type: none"> 1. Date and time of the event, type of event, subject identity and/or source of the event, and the outcome (e.g., success or failure) of the event; and 2. For each audit event type [assignment: other audit relevant information].
FAC.9	For audit events resulting from actions of identified users, the security function shall be able to associate each auditable event with the identity of the user that caused the event.
FAC.10	The security function shall be able to apply a set of rules in monitoring the audited events and based upon these rules indicate a potential violation of the enforcement of the security function requirements.
FAC.11	The security function shall enforce the following rules for monitoring audited events: <ol style="list-style-type: none"> 1. Accumulation or combination of [assignment: subset of defined auditable events] known to indicate a potential security violation; 2. [assignment: any other rules]
FAC.12	The security function shall be able to maintain profiles of system usage, where an individual profile represents the historical patterns of usage performed by the member(s) of [assignment: the profile target group].
FAC.13	The security function shall be able to maintain a suspicion rating associated with each user whose activity is recorded in a profile, where the suspicion rating represents the degree to which the user's current activity is found inconsistent with the established patterns of usage represented in the profile.
FAC.14	The security function shall be able to indicate a possible violation of the enforcement of the security function requirements when a user's suspicion rating exceeds the following threshold conditions [assignment: conditions under which anomalous activity is reported by the module's security function].

FAC.15	The security function shall be able to maintain an internal representation of the following signature events [assignment: a subset of system events] that may indicate a violation of the enforcement of the security function requirements.
FAC.16	The security function shall be able to compare the signature events against the record of system activity discernible from an examination of [assignment: the information used to determine system activity].
FAC.17	The security function shall be able to indicate a potential violation of the enforcement of the security function requirements when a system event is found to match a signature event or event sequence that indicates a potential violation of the enforcement of the security function requirements.
FAC.18	The security function shall be able to maintain an internal representation of the following event sequences of known intrusion scenarios [assignment: list of sequences of system events whose occurrence are representative of known penetration scenarios] and the following signature events [assignment: a subset of system events] that may indicate a potential violation of the enforcement of the security function requirements.
FAC.19	The security function shall be able to compare the signature events and event sequences against the record of system activity discernible from an examination of [assignment: the information to be used to determine system activity].
FAC.20	The security function shall provide the audit records in a manner suitable for the user to interpret the information.
FAC.21	The security function shall provide the ability to apply [assignment: methods of selection and/or ordering] of audit data based on [assignment: criteria with logical relations].
FAC.22	The security function shall be able to select the set of audited events from the set of all auditable events based on the following attributes: <ol style="list-style-type: none"> 1. [selection: object identity, user identity, subject identity, host identity, event type] 2. [assignment: list of additional attributes that audit selectivity is based upon]
FAC.23	The security function shall be able to [selection, choose one of: prevent, detect] unauthorized modifications to the stored audit records in the audit trail.
FAC.24	The security function shall protect audit information and audit tools from unauthorized access, modification, and deletion.
FAC.25	The security function shall [assignment: actions to be taken in case of possible audit storage failure] if the audit trail exceeds [assignment: pre-defined limit].
FAC.26	The security function shall [selection, choose one of: "ignore audited events", "prevent audited events, except those taken by the authorized user with special rights", "overwrite the oldest stored audit records"] and [assignment: other actions to be taken in case of audit storage failure] if the audit trail is full.
FAC.27	The organization shall allocate sufficient audit record storage capacity and configures auditing to reduce the likelihood of exceeding storage capacity.
FAC.28	The security function shall alert appropriate organizational officials in the event of an audit processing failure and takes the following additional actions: [Assignment: organization-defined actions to be taken (e.g., shut down information system, overwrite oldest audit records, stop generating audit records)].
FAC.29	The security function shall provide an audit reduction and report generation capability.
FAC.30	The security function shall provide time stamps for use in audit record generation.
FAC.31	The security function/system shall notify the user, upon successful logon, of the date and time of the last logon and the number of unsuccessful logon attempts since the last successful logon.

FAC.32	<p>The security function shall display an approved, system use notification message before granting system access informing potential users:</p> <ol style="list-style-type: none"> 1. That the user is accessing a [assignment: name of organization's information system]; 2. That system usage may be monitored, recorded, and subject to audit; 3. That unauthorized use of the system is prohibited and subject to criminal and civil penalties; and 4. That use of the system indicates consent to monitoring and recording. The system use notification message provides appropriate privacy and security notices (based on associated privacy and security policies or summaries) and remains on the screen until the user takes explicit actions to log on to the information system.
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Supporting Security Services

Supporting Security Services requirements are how security is realized for primary security requirements. Each requirement in this section maps to requirements in Chapter 3 of the AMI Security Acceleration Project Phase 1 Report (EPRI Technical Update Product ID 1020235 entitled “ **Error! Reference source not found.** ”. The mapping should indicate which requirements from the **Error! Reference source not found.** are satisfied (in whole or in part) given satisfaction of the identified requirement. The litmus test for inclusion in this section is simple. If any requirement in this section cannot be mapped to at least two requirements across confidentiality, integrity and availability (CIA), then it should appear in the **Error! Reference source not found.**

Policy requirements can appear in this section, so long as they are relevant to a specific supporting security service area.

Anomaly Detection Services (FAS)

Detection services detect events outside of the bounds of normally anticipated or desired behavior such as attacks, intrusions, or errors.

FAS.1	Upon detection of a data integrity error, the security function shall take the following actions: [assignment: specify the action to be taken].
FAS.2	The security function shall provide unambiguous detection of physical tampering that might compromise the module's security function.
FAS.3	For [assignment: list of security function devices/elements for which active detection is required], the security function shall monitor the devices and elements and notify [assignment: a designated user or role] when physical tampering with the module's security function's devices or module's security function's elements has occurred.
FAS.4	The security function shall take [assignment: list of actions] upon detection of a potential security violation.
FAS.5	The organization shall employ and maintain fire suppression and detection devices/systems that can be activated in the event of a fire.
FAS.6	The organization shall implement and maintain fire suppression and detection devices/systems that can be activated in the event of a fire.
FAS.7	The organization shall implement an incident handling capability for security incidents that includes preparation, detection and analysis, containment, eradication, and recovery.
FAS.8	The organization shall implement control system incident handling capabilities for security incidents that includes preparation, detection and analysis, containment, eradication, and recovery.

Boundary Services (FBS)

This section provides requirements around boundary services. Boundary services provide isolation between system elements or between the system and external entities. Boundary services explain what occurs at the transition between two separate security domains such as examination or changing constraints on the border relationship.

Boundary requirements are oriented towards maintaining the strength and integrity of the boundary (isolation) between inside and outside of the system boundary. The requirements for a firewall configuration are one set of examples.

FBS.1	The security function shall restrict the scope of the session security attributes [assignment: session security attributes], based on [assignment: attributes].
FBS.2	The security function shall restrict the maximum number of concurrent sessions that belong to the same user.
FBS.3	The security function shall enforce, by default, a limit of [assignment: default number] sessions per user.
FBS.4	The security function shall restrict the maximum number of concurrent sessions that belong to the same user according to the rules [assignment: rules for the number of maximum concurrent sessions].
FBS.5	The security function shall lock an interactive session after [assignment: time interval of user inactivity] by: a) clearing or overwriting display devices, making the current contents unreadable; b) disabling any activity of the user's data access/display devices other than unlocking the session.
FBS.6	The security function shall require the following events to occur prior to unlocking the session: [assignment: events to occur].
FBS.7	The security function shall allow user-initiated locking of the user's own interactive session, by: a) clearing or overwriting display devices, making the current contents unreadable; b) disabling any activity of the user's data access/display devices other than unlocking the session.
FBS.8	The security function shall terminate an interactive session after a [assignment: time interval of user inactivity].
FBS.9	The security function shall allow user-initiated termination of the user's own interactive session.
FBS.10	Before establishing a user session, the security function shall display an advisory warning message regarding unauthorized use of the module.
FBS.11	Upon successful session establishment, the security function shall display the [selection: date, time, method, location] of the last successful session establishment to the user.
FBS.12	Upon successful session establishment, the security function shall display the [selection: date, time, method, location] of the last unsuccessful attempt to session establishment and the number of unsuccessful attempts since the last successful session establishment.
FBS.13	The security function shall not erase the access history information from the user interface without giving the user an opportunity to review the information.
FBS.14	The security function shall be able to deny session establishment based on [assignment: attributes].
FBS.15	The security function shall provide a communication channel between itself and another trusted IT product that is logically distinct from other communication channels and provides assured identification of its end points and protection of the channel data from modification or disclosure.
FBS.16	The security function shall permit [selection: the module's security function, another trusted IT

	product] to initiate communication via the trusted channel.
FBS.17	The security function shall initiate communication via the trusted channel for [assignment: list of functions for which a trusted channel is required].
FBS.18	The security function shall provide a communication path between itself and [selection: remote, local] users that is logically distinct from other communication paths and provides assured identification of its end points and protection of the communicated data from [selection: modification, disclosure, [assignment: other types of integrity or confidentiality violation]].
FBS.19	The security function shall permit [selection: the module's security function, local users, remote users] to initiate communication via the trusted path.
FBS.20	The security function shall require the use of the trusted path for [selection: initial user authentication, [assignment: other services for which trusted path is required]].
FBS.21	The organization shall develop, implement, and periodically review and update: <ol style="list-style-type: none"> 1. A formal, documented, control system security policy that addresses: <ol style="list-style-type: none"> a. The purpose of the security program as it relates to protecting the organization's personnel and assets; b. The scope of the security program as it applies to all the organizational staff and third-party contractors; c. The roles, responsibilities, and management accountability structure of the security program to ensure compliance with the organization's security policy and other regulatory commitments. 2. Formal, documented procedures to implement the security policy and associated requirements. A control system security policy considers controls from each of the families contained in this document.
FBS.22	The organization shall establish policies and procedures to define roles, responsibilities, behaviors, and practices for the implementation of an overall security program.
FBS.23	The organization shall define a framework of management leadership accountability. This framework establishes roles and responsibilities to approve cyber security policy, assign security roles, and coordinate the implementation of cyber security across the organization.
FBS.24	Baseline practices that organizations employ for organizational security include, but are not limited to: <ol style="list-style-type: none"> 1. Executive management accountability for the security program; 2. Responsibility for control system security within the organization includes sufficient authority and an appropriate level of funding to implement the organization's security policy; 3. The organization's security policies and procedures that provide clear direction, accountability, and oversight for the organization's security team. The security team assigns roles and responsibilities in accordance with the organization's policies and confirms that processes are in place to protect company assets and critical information; 4. The organization's contracts with external entities that address the organization's security policies and procedures with business partners, third-party contractors, and outsourcing partners; 5. The organization's security policies and procedures ensure coordination or integration with the organization's physical security plan. Organization roles and responsibilities are established that address the overlap and synergy between physical and control system security risks.
FBS.25	The organization's security policies and procedures shall delineate how the organization implements its emergency response plan and coordinates efforts with law enforcement agencies, regulators, Internet service providers and other relevant organizations in the event of a security incident.
FBS.26	The organization shall hold external suppliers and contractors that have an impact on the security of the control center to the same security policies and procedures as the organization's own personnel; and shall ensure security policies and procedures of second- and third-tier suppliers comply with corporate cyber security policies and procedures if they will impact control system security.
FBS.27	The organization shall establish procedures to remove external supplier access at the conclusion/termination of the contract.

FBS.28	The security function shall monitor and control communications at the external boundary of the information system and at key internal boundaries within the system.
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Cryptographic Services (FCS)

Cryptographic services include encryption, signing, key management and key revocation.

The security function may employ cryptographic functionality to help satisfy several high-level security objectives. These include, but are not limited to identification and authentication, non-repudiation, trusted path, trusted channel and data separation. This class is used when the security component implements cryptographic functions, the implementation of which could be in hardware, firmware and/or software.

The FCS: Cryptographic support class is composed of two families: Cryptographic key management (FCS_CKM) and Cryptographic operation (FCS_COP). The Cryptographic key management (FCS_CKM) family addresses the management aspects of cryptographic keys, while the Cryptographic operation (FCS_COP) family is concerned with the operational use of those cryptographic keys. [DHS]

FCS.1	The security function shall generate cryptographic keys in accordance with a specified cryptographic key generation algorithm [assignment: cryptographic key generation algorithm] and specified cryptographic key sizes [assignment: cryptographic key sizes] that meet the following: [assignment: list of standards].
FCS.2	The security function shall distribute cryptographic keys in accordance with a specified cryptographic key distribution method [assignment: cryptographic key distribution method] that meets the following: [assignment: list of standards].
FCS.3	The security function shall perform [assignment: type of cryptographic key access] in accordance with a specified cryptographic key access method [assignment: cryptographic key access method] that meets the following: [assignment: list of standards].
FCS.4	The security function shall destroy cryptographic keys in accordance with a specified cryptographic key destruction method [assignment: cryptographic key destruction method] that meets the following: [assignment: list of standards].
FCS.5	The security function shall perform [assignment: list of cryptographic operations] in accordance with a specified cryptographic algorithm [assignment: cryptographic algorithm] and cryptographic key sizes [assignment: cryptographic key sizes] that meet the following: [assignment: list of standards].
FCS.6	For information requiring cryptographic protection, the information system shall implement cryptographic mechanisms that comply with applicable laws, Executive Orders, directives, policies, regulations, standards, and guidance.

Notification and Signaling Services (FNS)

Notification and signaling services are oriented towards providing system activity information and command result logging.

FNS.1	For [assignment: list of security function devices/elements for which active detection is required], the security function shall monitor the devices and elements and notify [assignment: a designated user or role] when physical or logical tampering with the module's security function's devices or module's security function's elements has occurred.
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FNS.2	The security function verifies the correct operation of security utility [Selection (one or more): upon system startup and restart, upon command by user with appropriate privilege, periodically every [Assignment: organization-defined time-period]] and [Selection (one or more): notifies system administrator, shuts the system down, restarts the system] when anomalies are discovered.
FNS.3	The organization shall verify the correct operation of security functions within the control system upon system startup and restart; upon command by user with appropriate privilege; periodically; and/or at defined time periods. The security function notifies the system administrator when anomalies are discovered.
FNS.4	The security function shall notify the user, upon successful logon, of the date and time of the last logon and the number of unsuccessful logon attempts since the last successful logon.
FNS.5	The security function shall display an approved, system use notification message before granting system access informing potential users: <ol style="list-style-type: none"> 1. That the user is accessing a [assignment: organization] information system; 2. That system usage may be monitored, recorded, and subject to audit; 3. That unauthorized use of the system is prohibited and subject to criminal and civil penalties; and 4. That use of the system indicates consent to monitoring and recording. The system use notification message provides appropriate privacy and security notices (based on associated privacy and security policies or summaries) and remains on the screen until the user takes explicit actions to log on to the information system.
FNS.6	The security function shall perform [assignment: list of specific actions] when replay is detected.

Resource Management Services (FRS)

This section covers resource management services requirements. Resources Management Services include management of runtime resources, such as network/communication paths, processors, memory or disk space (e.g., for audit log capacity), and other limited system resources.

FRS.1	The organization shall develop, disseminate, and periodically review and update: <ol style="list-style-type: none"> 1. A formal, documented system and communication protection policy that addresses: <ol style="list-style-type: none"> a. The purpose of the system and communication protection policy as it relates to protecting the organization's personnel and assets; b. The scope of the system and communication protection policy as it applies to all the organizational staff and third-party contractors; c. The roles, responsibilities and management accountability structure of the security program to ensure compliance with the organization's system and communications protection policy and other regulatory commitments; 2. Formal, documented procedures to facilitate the implementation of the control system and communication protection policy and associated systems and communication protection controls
FRS.2	The security function shall separate telemetry/data acquisition services from management port functionality.
FRS.3	The security function shall isolate security functions from non-security functions.
FRS.4	The security function shall prevent unauthorized or unintended information transfer via shared system resources.
FRS.5	The security function shall protect against or limits the effects of denial-of-service attacks based on an organization's defined list of types of denial-of-service attacks.
FRS.6	The security function shall limit the use of resources by priority.

FRS.7	The organization shall define the external boundary(ies) of the control system. Procedural and policy security functions define the operational system boundary, the strength required of the boundary, and the respective barriers to unauthorized access and control of system assets and components. The control system monitors and manages communications at the operational system boundary and at key internal boundaries within the system.
FRS.10	The security function shall establish a trusted communications path between the user and the system.
FRS.11	When cryptography is required and employed within the system, the organization shall establish and manage cryptographic keys using automated mechanisms with supporting procedures or manual procedures.
FRS.12	The organization shall develop and implement a policy governing the use of cryptographic mechanisms for the protection of control system information. The organization shall ensure all cryptographic mechanisms comply with applicable laws, regulatory requirements, directives, policies, standards, and guidance.
FRS.13	The use of collaborative computing mechanisms on control system is strongly discouraged and provides an explicit indication of use to the local users.
FRS.14	The system shall reliably associate security parameters (e.g., security labels and markings) with information exchanged between the enterprise information systems and the system.
FRS.15	The organization shall issue public key certificates under an appropriate certificate policy or obtains public key certificates under an appropriate certificate policy from an approved service provider.
FRS.16	The organization shall: <ol style="list-style-type: none"> 1. Establish usage restrictions and implementation guidance for mobile code technologies based on the potential to cause damage to the control system if used maliciously; 2. Document, monitor, and manage the use of mobile code within the control system. Appropriate organizational officials should authorize the use of mobile code.
FRS.17	The organization shall: <ol style="list-style-type: none"> 1. Establish usage restrictions and implementation guidance for Voice over Internet Protocol (VOIP) technologies based on the potential to cause damage to the information system if used maliciously; and 2. Authorize, monitor, and limit the use of VOIP within the control system.
FRS.18	All external system and communication connections shall be identified and adequately protected from tampering or damage.
FRS.19	The system design and implementation shall specify the security roles and responsibilities for the users of the system.
FRS.20	The system shall provide mechanisms to protect the authenticity of device-to-device communications.
FRS.21	The system's devices that collectively provide name/address resolution services for an organization shall be fault tolerant and implement address space separation.
FRS.22	The system resource (i.e., authoritative DNS server) that provides name/address resolution service shall provide additional artifacts (e.g., digital signatures and cryptographic keys) along with the authoritative DNS resource records it returns in response to resolution queries.
FRS.23	The system resource (i.e., resolving or caching name server) that provides name/address resolution service for local clients shall perform data origin authentication and data integrity verification on the resolution responses it receives from authoritative DNS servers when requested by client systems.
FRS.24	The security function shall restrict the ability to [selection: determine the behavior of, disable, enable, modify the behavior of] the functions [assignment: list of functions] to [assignment: the authorized identified roles].
FRS.25	The security function shall enforce the [assignment: access control security function policy(s), information flow control security function policy(s)] to restrict the ability to [selection: change, default, query, modify, delete, [assignment: other operations]] the security attributes [assignment: list of

	security attributes] to [assignment: the authorized identified roles].
FRS.26	The security function shall ensure that only secure values are accepted for [assignment: list of security attributes].
FRS.27	The security function shall enforce the [assignment: access control security function policy, information flow control security function policy] to provide [selection, choose one of: restrictive, permissive, [assignment: other property]] default values for security attributes that are used to enforce the security function policy.
FRS.28	The security function shall allow the [assignment: the authorized identified roles] to specify alternative initial values to override the default values when an object or information is created.
FRS.29	The security function shall use the following rules to set the value of security attributes: [assignment: rules for setting the values of security attributes]
FRS.30	The security function shall restrict the ability to [selection: change_default, query, modify, delete, clear, [assignment: other operations]] the [assignment: list of security function data] to [assignment: the authorized identified roles].
FRS.31	The security function shall restrict the specification of the limits for [assignment: list of security function data] to [assignment: the authorized identified roles].
FRS.32	The security function shall take the following actions, if the security function data are at, or exceed, the indicated limits: [assignment: actions to be taken].
FRS.33	The security function shall ensure that only secure values are accepted for [assignment: list of security function data].
FRS.34	The security function shall restrict the ability to revoke [assignment: list of security attributes] associated with the [selection: users, subjects, objects, [assignment: other additional resources]] under the control of the security function to [assignment: the authorized identified roles].
FRS.35	The security function shall enforce the rules [assignment: specification of revocation rules].
FRS.36	The security function shall restrict the capability to specify an expiration time for [assignment: list of security attributes for which expiration is to be supported] to [assignment: the authorized identified roles].
FRS.37	For each of these security attributes, the security function shall be able to [assignment: list of actions to be taken for each security attribute] after the expiration time for the indicated security attribute has passed.
FRS.38	The security function shall be capable of performing the following management functions: [assignment: list of management functions to be provided by the module's security function].
FRS.39	The security function shall maintain the roles [assignment: the authorized identified roles].
FRS.40	The security function shall be able to associate users with roles.
FRS.41	The security function shall maintain the roles: [assignment: authorized identified roles].
FRS.42	The security function shall ensure that the conditions [assignment: conditions for the different roles] are satisfied.
FRS.43	The security function shall require an explicit request to assume the following roles: [assignment: the roles].
FRS.44	The security function shall terminate the network session at the end of a session or after [Assignment: organization-defined time period] of inactivity.

Trust and Certificate Services (FTS)

Description of relationships between entities and the faith placed on the relationship certificates that have uses outside of cryptography for example, material relating to creation, storage, and revocation of certificates.

FTS.1	The security function shall issue public key certificates based on an appropriate certificate policy or obtain public key certificates under an appropriate certificate policy from an [assignment: approved service provider].
FTS.2	When cryptography is required and employed within the security function, the organization shall establish and manage cryptographic keys using automated mechanisms with supporting procedures or manual procedures.

Assurance

Development Rigor (ADR)

Not all solutions are created equal. Differing degrees of care and consideration can go into developing solutions that satisfy any given security requirement. This section contains requirements regarding the activities involved in developing smart grid system solutions. Topics including:

- acquisition issues
- configuration management
- development practices

This is about the creation of smart grid systems, not their deployment, operation, or maintenance.

ADR.1	The organization shall develop, disseminate, and periodically review/update: <ol style="list-style-type: none">1. A formal, documented, information system maintenance policy that addresses purpose, scope, roles, responsibilities, management commitment, coordination among organizational entities, and compliance; and2. Formal, documented procedures to facilitate the implementation of the information system maintenance policy and associated system maintenance controls.
ADR.2	The organization shall schedule, perform, document and reviews records of routine preventative and regular maintenance (including repairs) on the components of the information system in accordance with manufacturer or vendor specifications and/or organizational requirements.
ADR.3	The organization shall approve, control and monitor the use of information system maintenance tools and maintains the tools on an ongoing basis.
ADR.4	The organization shall authorize, monitor and control any remotely executed maintenance and diagnostic activities, if employed.
ADR.5	The organization shall allow only authorized personnel to perform maintenance on the information system.
ADR.6	The organization shall obtain maintenance support and spare parts for [Assignment: organization-defined list of key information system components] within [Assignment: organization-defined time period] of failure.

ADR.7	The organization shall develop, disseminate, and periodically review/update: <ol style="list-style-type: none"> 1. A formal, documented, system and services acquisition policy that includes information security considerations and that addresses purpose, scope, roles, responsibilities, management commitment, coordination among organizational entities, and compliance; and 2. Formal, documented procedures to facilitate the implementation of the system and services acquisition policy and associated system and services acquisition controls.
ADR.8	The organization shall determine, document and allocate as part of its capital planning and investment control process, the resources required to adequately protect the information system.
ADR.9	The organization shall manage the information system using a system development life cycle methodology that includes information security considerations.
ADR.10	The organization shall include security requirements and/or security specifications, either explicitly or by reference, in information system acquisition contracts based on an assessment of risk and in accordance with applicable laws, Executive Orders, directives, policies, regulations, and standards.
ADR.11	The organization shall obtain, protect as required, and make available to authorized personnel, adequate documentation for the information system.
ADR.12	The organization shall comply with software usage restrictions.
ADR.13	The organization shall enforce explicit rules governing the installation of software by users.
ADR.14	The organization shall design and implement the information system using security engineering principles.
ADR.15	The organization shall: <ol style="list-style-type: none"> 1. Requires that providers of external information system services employ adequate security controls in accordance with applicable laws, Executive Orders, directives, policies, regulations, standards, guidance, and established service-level agreements; and 2. Monitors security control compliance
ADR.16	The organization shall require that information system developers create and implement a configuration management plan that controls changes to the system during development, tracks security flaws, requires authorization of changes, and provides documentation of the plan and its implementation.
ADR.17	The organization shall require that information system developers create a security test and evaluation plan, implement the plan, and document the results.
ADR.18	The organization shall develop, disseminate and periodically review/update: <ol style="list-style-type: none"> 1. A formal, documented, system and services acquisition policy that addresses: <ol style="list-style-type: none"> a. The purpose of the security program as it relates to protecting the organization's personnel and assets; b. The scope of the security program as it applies to all the organizational staff and third-party contractors; c. The roles, responsibilities and management accountability structure of the security program to ensure compliance with the organization's security policy and other regulatory commitments. 2. Formal, documented procedures to facilitate the implementation of the system and services acquisition policy and associated system and services acquisition controls.
ADR.19	The organization shall implement a process to determine, document, approve, and allocate the resources required to adequately protect the control system as part of its capital planning and investment control process.
ADR.20	The organization shall manage the control system using a system development life-cycle methodology that includes control system security considerations.
ADR.21	The organization shall include security requirements and/or security specifications, either explicitly or by reference, in control system acquisition contracts based on an assessment of risk and in accordance with applicable laws, Executive Orders, directives, policies, regulations, and standards.
ADR.22	The organization shall ensure that adequate documentation for the control system and its constituent components are available, protected when required, and are accessible to authorized personnel.

ADR.23	The organization's security program shall deploy policy and procedures to enforce compliance with software license usage restrictions.
ADR.24	The organization shall implement policies and procedures to enforce explicit rules and management expectations governing user installation of software.
ADR.25	The organization shall design and implement the control system using security engineering principles and best practices.
ADR.26	The organization shall ensure that third-party providers of control system services employ adequate security mechanisms in accordance with established service-level agreements and monitor compliance.
ADR.27	The control system vendor shall create and implement a configuration management plan and procedures that limit changes to the control system during design and installation. This plan tracks security flaws. The vendor shall obtain the organization's written approval for any changes to the plan. The vendor shall provide documentation of the plan and its implementation.
ADR.28	The control system vendor shall develop a security test and evaluation plan. The vendor shall submit the plan to the organization for approval and implements the plan once written approval is obtained. The vendor shall then documents the results of the testing and evaluation and submits them to the organization for approval.
ADR.29	The control system vendor shall adopt appropriate software development life-cycle practices to eliminate common coding errors that affect security, particularly with respect to input data validation and buffer management.
ADR.30	The organization shall develop, disseminate, and periodically review and update: <ol style="list-style-type: none"> 1. A formal, documented Configuration Management policy that addresses: <ol style="list-style-type: none"> a. The purpose of the configuration management policy as it relates to protecting the organization's personnel and assets; b. The scope of the configuration management policy as it applies to all the organizational staff and third-party contractors; c. The roles, responsibilities and management accountability structure contained in the configuration management policy to ensure compliance with the organization's security policy and other regulatory commitments 2. Formal, documented procedures to facilitate the implementation of the configuration management policy and associated configuration management controls. 3. The personnel qualification levels required to make changes, the conditions under which changes are allowed, and what approvals are required for those changes.
ADR.31	The organization shall develop, document, and maintain a current baseline configuration of the control system and an inventory of the system's constituent components.
ADR.32	The organization shall authorize, document and manage changes to the control system.
ADR.33	The organization shall implement a process to monitor changes to the control system and conducts security impact analyses to determine the effects of the changes.
ADR.34	The organization shall: <ol style="list-style-type: none"> 1. Approves individual access privileges and enforces physical and logical access restrictions associated with configuration changes to the control system; 2. Generates, retains, and reviews records reflecting all such changes.
ADR.35	The organization shall: <ol style="list-style-type: none"> 1. Establishes mandatory configuration settings for IT products employed within the control system; 2. Configures the security settings of control systems technology products to the most restrictive mode consistent with control system operational requirements; 3. Documents the changed configuration settings.
ADR.36	The organization shall configure the control system to provide only essential capabilities and specifically prohibit and/or restrict the use of functions, ports, protocols, and/or services as defined in

	an organizationally generated “prohibited and/or restricted” list.
ADR.37	The organization shall create and maintains a list of all end-user configurable assets and the configurations of those assets used by the organization.
ADR.38	The organization shall implement policy and procedures to address the addition, removal, and disposal of all control system equipment. All control system assets and information shall be documented, identified and tracked so that their location and function are known.
ADR.39	The organization shall change all factory default authentication credentials on control system components and applications upon installation.
ADR.40	The organization shall develop, disseminate, and periodically review/update: <ol style="list-style-type: none"> 1. A formal, documented, control system maintenance policy that addresses purpose, scope, roles, responsibilities, management commitment, coordination among organizational entities, and compliance; 2. Formal, documented procedures to facilitate the implementation of the control system maintenance policy and associated system maintenance controls.
ADR.41	The organization shall develop policies and procedures to upgrade existing legacy control systems to include security mitigating measures commensurate with the organization’s risk tolerance and the risk to the system and processes controlled.
ADR.42	The organization shall conduct periodic security vulnerability assessments according to the risk management plan. Then, the control system shall be updated to address any identified vulnerabilities in accordance with organization’s control system maintenance policy.
ADR.43	The organization shall make and secure backups of critical system software, applications and data for use if the control system operating system software becomes corrupted or destroyed.
ADR.44	The organization shall review and follow security requirements for a control system before undertaking any unplanned maintenance activities of control system components (including field devices). Documentation includes the following: <ol style="list-style-type: none"> 1. The date and time of maintenance; 2. The name of the individual(s) performing the maintenance; 3. The name of the escort, if necessary; 4. A description of the maintenance performed; 5. A list of equipment removed or replaced (including identification numbers, if applicable).
ADR.45	The organization shall schedule, perform and document routine preventive and regular maintenance on the components of the control system in accordance with manufacturer or vendor specifications and/or organizational policies and procedures.
ADR.46	The organization shall approve, manage, protect and monitor the use of control system maintenance tools and maintains the integrity of tools on an ongoing basis.
ADR.47	The organization shall document authorization and approval policies and procedures and maintains a list of personnel authorized to perform maintenance on the control system. Only authorized and qualified organization or vendor personnel shall perform maintenance on the control system.
ADR.48	The organization shall authorize, manage, and monitor remotely executed maintenance and diagnostic activities on the control system. When remote maintenance is completed, the organization (or control system in certain cases) shall terminate all sessions and remote connections invoked in the performance of that activity. If password-based authentication is used to accomplish remote maintenance, the organization shall change the password following each remote maintenance service.
ADR.49	The organization shall acquire maintenance support and spare parts for key control system components within a specified time period of failure.
ADR.50	The organization shall: <ol style="list-style-type: none"> 1. Establish usage restrictions and implementation guidance for mobile code technologies based on the potential to cause damage to the information system if used maliciously; and 2. Authorize, monitor, and control the use of mobile code within the information system.

ADR.51	The security function shall separate user data from security function data when such data is transmitted between separate parts of the module.
ADR.52	The organization shall require that information system developers create and implement a configuration management plan that controls changes to the system during development, tracks security flaws, requires authorization of changes, and provides documentation of the plan and its implementation.

Organizational Rigor (AOR)

This section contains requirements regarding the policies employed by the organization(s) with access to assets of a deployed smart grid system. These requirements reflect on an organization's ability to continue to operate a smart grid system reliably over time. Topics include

- training procedures
- personnel security
- strategic planning
- monitoring and reviewing security policies

AOR.1	The organization shall develop, disseminate, and periodically review/update: <ol style="list-style-type: none"> 1. A formal, documented, security awareness and training policy that addresses purpose, scope, roles, responsibilities, management commitment, coordination among organizational entities, and compliance; and 2. Formal, documented procedures to facilitate the implementation of the security awareness and training policy and associated security awareness and training controls.
AOR.2	The organization shall provide basic security awareness training to all information system users (including managers and senior executives) before authorizing access to the system, when required by system changes, and [Assignment: organization-defined frequency, at least annually] thereafter.
AOR.3	The organization shall identify personnel that have significant information system security roles and responsibilities during the system development life cycle, documents those roles and responsibilities, and provides appropriate information system security training: <ol style="list-style-type: none"> 1. Before authorizing access to the system or performing assigned duties; 2. When required by system changes; and 3. [Assignment: organization-defined frequency] thereafter
AOR.4	The organization shall document and monitor individual information system security training activities including basic security awareness training and specific information system security training.
AOR.5	The organization shall establish and maintain contacts with special interest groups, specialized forums, professional associations, news groups, and/or peer groups of security professionals in similar organizations to stay up to date with the latest recommended security practices, techniques, and technologies and to share the latest security-related information including threats, vulnerabilities, and incidents.
AOR.6	The organization shall develop, disseminate, and periodically review/update: <ol style="list-style-type: none"> 1. A formal, documented, media protection policy that addresses purpose, scope, roles, responsibilities, management commitment, coordination among organizational entities, and compliance; and 2. Formal, documented procedures to facilitate the implementation of the media protection policy and associated media protection controls.
AOR.7	The organization shall restrict access to information system media to authorized individuals.

AOR.8	The organization shall: <ol style="list-style-type: none"> 1. Affix external labels to removable information system media and information system output indicating the distribution limitations, handling caveats and applicable security markings (if any) of the information; and 2. Exempt [Assignment: organization-defined list of media types or hardware components] from labeling so long as they remain within [Assignment: organization-defined protected environment].
AOR.9	The organization shall physically control and securely store information system media within controlled areas.
AOR.10	The organization shall protect and control information system media during transport outside of controlled areas and restricts the activities associated with transport of such media to authorized personnel.
AOR.11	The organization shall sanitize information system media, both digital and non-digital, prior to disposal or release for reuse.
AOR.12	The organization shall develop, disseminate, and periodically review/update: <ol style="list-style-type: none"> 1. A formal, documented, physical and environmental protection policy that addresses purpose, scope, roles, responsibilities, management commitment, coordination among organizational entities, and compliance; and 2. Formal, documented procedures to facilitate the implementation of the physical and environmental protection policy and associated physical and environmental protection controls.
AOR.13	The organization shall develop and keep a current a list of personnel with authorized access to the facility where the information system resides (except for those areas within the facility officially designated as publicly accessible) and issues appropriate authorization credentials. Designated officials within the organization shall review and approve the access list and authorization credentials [Assignment: organization-defined frequency, at least annually].
AOR.14	The organization shall control all physical access points (including designated entry/exit points) to the facility where the information system resides (except for those areas within the facility officially designated as publicly accessible) and verifies individual access authorizations before granting access to the facility. The organization shall control access to areas officially designated as publicly accessible, as appropriate, in accordance with the organization's assessment of risk.
AOR.15	The organization shall control physical access to information system distribution and transmission lines within organizational facilities.
AOR.16	The organization shall control physical access to information system devices that display information to prevent unauthorized individuals from observing the display output.
AOR.17	The organization shall monitor physical access to the information system to detect and respond to physical security incidents.
AOR.18	The organization shall control physical access to the information system by authenticating visitors before authorizing access to the facility where the information system resides other than areas designated as publicly accessible.
AOR.19	The organization shall maintain visitor access records to the facility where the information system resides (except for those areas within the facility officially designated as publicly accessible) that includes: <ol style="list-style-type: none"> 1. Name and organization of the person visiting; 2. Signature of the visitor; 3. Form of identification; 4. Date of access; 5. Time of entry and departure; 6. Purpose of visit; and 7. Name and organization of person visited. Designated officials within the organization shall review the visitor access records [Assignment: organization-defined frequency].
AOR.20	The organization shall protect power equipment and power cabling for the information system from

	damage and destruction.
AOR.21	The organization shall provide, for specific locations within a facility containing concentrations of information system resources, the capability of shutting off power to any information system component that may be malfunctioning or threatened without endangering personnel by requiring them to approach the equipment.
AOR.22	The organization shall provide a short-term uninterruptible power supply to facilitate an orderly shutdown of the information system in the event of a primary power source loss.
AOR.23	The organization shall employ and maintain automatic emergency lighting that activates in the event of a power outage or disruption and that covers emergency exits and evacuation routes.
AOR.24	The organization shall employ and maintain fire suppression and detection devices/systems that can be activated in the event of a fire.
AOR.25	The organization shall regularly maintain, within acceptable levels, and monitor the temperature and humidity within the facility where the information system resides.
AOR.26	The organization shall protect the information system from water damage resulting from broken plumbing lines or other sources of water leakage by providing master shutoff valves that are accessible, working properly, and known to key personnel.
AOR.27	The organization shall authorize and control information system-related items entering and exiting the facility and maintains appropriate records of those items.
AOR.28	The organization shall employ appropriate management, operational, and technical information system security controls at alternate work sites.
AOR.29	The organization shall position information system components within the facility to minimize potential damage from physical and environmental hazards and to minimize the opportunity for unauthorized access.
AOR.30	The organization shall protect the information system from information leakage due to electromagnetic signals emanations.
AOR.31	The organization shall develop, disseminate, and periodically review/update: <ol style="list-style-type: none"> 1. A formal, documented, security planning policy that addresses purpose, scope, roles, responsibilities, management commitment, coordination among organizational entities, and compliance; and 2. Formal, documented procedures to facilitate the implementation of the security planning policy and associated security planning controls.
AOR.32	The organization shall develop and implement a security plan for the information system that provides an overview of the security requirements for the system and a description of the security controls in place or planned for meeting those requirements. Designated officials within the organization shall review and approve the plan
AOR.33	The organization shall review the security plan for the information system [Assignment: organization-defined frequency, at least annually] and revises the plan to address system/organizational changes or problems identified during plan implementation or security control assessments.
AOR.34	The organization shall establish and make readily available to all information system users, a set of rules that describes their responsibilities and expected behavior with regard to information and information system usage. The organization shall receive signed acknowledgment from users indicating that they have read, understand, and agree to abide by the rules of behavior, before authorizing access to the information system and its resident information.
AOR.35	The organization shall conduct a privacy impact assessment on the information system in accordance with regulatory and the organization's policy.
AOR.36	The organization shall plan and coordinate security-related activities affecting the information system before conducting such activities in order to reduce the impact on organizational operations (i.e., mission, functions, image, and reputation), organizational assets, and individuals.

AOR.37	The organization shall develop, disseminate, and periodically review/update: <ol style="list-style-type: none"> 1. A formal, documented, personnel security policy that addresses purpose, scope, roles, responsibilities, management commitment, coordination among organizational entities, and compliance; and 2. Formal, documented procedures to facilitate the implementation of the personnel security policy and associated personnel security controls
AOR.38	The organization shall assign a risk designation to all positions and establishes screening criteria for individuals filling those positions. The organization shall review and revise position risk designations [Assignment: organization-defined frequency].
AOR.39	The organization shall screen individuals requiring access to organizational information and information systems before authorizing access.
AOR.40	The organization, upon termination of individual employment, shall terminate information system access, conducts exit interviews, retrieves all organizational information system-related property, and provide appropriate personnel with access to official records created by the terminated employee that are stored on organizational information systems.
AOR.41	The organization shall review information systems/facilities access authorizations when personnel are reassigned or transferred to other positions within the organization and initiates appropriate actions
AOR.42	The organization shall complete appropriate signed access agreements for individuals requiring access to organizational information and information systems before authorizing access and reviews/updates the agreements [Assignment: organization-defined frequency].
AOR.43	The organization shall establish personnel security requirements including security roles and responsibilities for third-party providers and monitors provider compliance.
AOR.44	The organization shall employ a formal sanctions process for personnel failing to comply with established information security policies and procedures.
AOR.45	The organization shall develop, disseminate, and periodically review and update: <ol style="list-style-type: none"> 1. A formal, documented, personnel security policy that addresses: <ol style="list-style-type: none"> a. The purpose of the security program as it relates to protecting the organization's personnel and assets; b. The scope of the security program as it applies to all the organizational staff and third-party contractors; c. The roles, responsibilities, and management accountability structure of the security program to ensure compliance with the organization's security policy and other regulatory commitments; 2. Formal, documented procedures to facilitate the implementation of the personnel security policy and associated personnel security controls. 3. Formal procedure to review and document list of approved personnel with access to control systems.
AOR.46	The organization shall assign a risk designation to all positions and establishes screening criteria for individuals filling those positions. The organization shall review and revise position risk designations periodically based on the organization's requirements or regulatory commitments.
AOR.47	The organization shall screen individuals requiring access to the control system before access is authorized.
AOR.48	When an employee is terminated, the organization shall revoke logical and physical access to control systems and facilities and ensure all organization-owned property is returned and that organization-owned documents and/or data files relating to the control system that are in the employee's possession be transferred to the new authorized owner within the organization. Complete execution of this control shall occur within 24 hours for employees or contractors terminated for cause.
AOR.49	The organization shall review logical and physical access permissions to control systems and facilities when individuals are reassigned or transferred to other positions within the organization and initiates appropriate actions. Complete execution of this control shall occur within 7 days for employees or contractors who no longer need to access control system resources.

AOR.50	The organization shall complete appropriate agreements for control system access before access is granted. This requirement applies to all parties, including third parties and contractors, who desire access to the control system. The organization shall review and update access agreements periodically.
AOR.51	The organization shall enforce security controls for third-party personnel and monitors service provider behavior and compliance.
AOR.52	The organization shall employ a formal accountability process for personnel failing to comply with established control system security policies and procedures and clearly documents potential disciplinary actions for failing to comply.
AOR.53	The organization shall provide employees and contractors with complete job descriptions and unambiguous and detailed expectations of conduct, duties, terms and conditions of employment, legal rights, and responsibilities.
AOR.54	The organization develops, implements, and periodically reviews and updates: <ol style="list-style-type: none"> 1. A formal, documented physical security policy that addresses: <ol style="list-style-type: none"> a. The purpose of the physical security program as it relates to protecting the organization's personnel and assets; b. The scope of the physical security program as it applies to all the organizational staff and third-party contractors; c. The roles, responsibilities and management accountability structure of the physical security program to ensure compliance with the organization's security policy and other regulatory commitments. 2. Formal, documented procedures to facilitate the implementation of the physical and environmental protection policy and associated physical and environmental protection controls.
AOR.55	The organization shall develop and maintain lists of personnel with authorized access to facilities containing control systems (except for areas within facilities officially designated as publicly accessible) and issue appropriate authorization credentials (e.g., badges, identification cards, smart cards). Designated officials within the organization shall review and approve the access list and authorization credentials at least annually.
AOR.56	The organization shall limit physical access to all control system facilities and assets and verify individual access authorizations before granting access. The organization shall limit access to areas officially designated as publicly accessible, as appropriate, in accordance with the organization's assessment of risk.
AOR.57	The organization shall monitor physical access to the control system facilities to detect and respond to physical security incidents.
AOR.58	The organization shall limit physical access to control systems by authenticating visitors before authorizing access to facilities or areas other than areas designated as publicly accessible.
AOR.59	The organization shall maintain visitor access records to the control system facility (except for those areas within the facility officially designated as publicly accessible) that include: <p>Name and organization of the person visiting;</p> <ol style="list-style-type: none"> 1. Signature of the visitor; 2. Form of identification; 3. Date of access; 4. Time of entry and departure; 5. Purpose of visit; 6. Name and organization of person visited.
AOR.60	The organization shall retain all physical access logs for as long as dictated by any applicable regulations or based on an organization-defined period by approved policy.
AOR.61	For specific locations within a facility containing concentrations of control system resources (e.g., control centers, server rooms), the organization shall provide the capability of shutting off power to any component that may be malfunctioning (e.g., due to an electrical fire) or threatened (e.g., due to a water leak) without compromising personnel safety.
AOR.62	The organization shall provide a short-term Uninterruptible Power Supply (UPS) to facilitate an

	orderly shutdown of non-critical control system components in the event of a primary power source loss.
AOR.63	The organization shall employ and maintain automatic emergency lighting systems that activate in the event of a power outage or disruption and includes lighting for emergency exits and evacuation routes.
AOR.64	The organization shall implement and maintain fire suppression and detection devices/systems that can be activated in the event of a fire.
AOR.65	The organization shall regularly monitors the temperature and humidity within facilities containing control system assets and ensures they are maintained within acceptable levels.
AOR.66	The organization shall protect the control systems from water damage resulting from broken plumbing lines, fire control systems or other sources of water leakage by ensuring that master shutoff valves are accessible, working properly, and known to key personnel.
AOR.67	The organization shall authorize and limit the delivery and removal of control system components (i.e., hardware, firmware, software) from control system facilities and maintain appropriate records and control of that equipment. The organization shall document policies and procedures governing the delivery and removal of control system assets in the control system security plan.
AOR.68	The organization shall establish an alternate control center with proper equipment and communication infrastructure to compensate for the loss of the primary control system worksite. The organization shall implement appropriate management, operational, and technical security measures at alternate control centers.
AOR.69	The organization shall monitor and prohibit the use of unapproved portable media use on the control system.
AOR.70	The organization shall implement asset location technologies to track and monitor the movements of personnel and vehicles within the organization's controlled areas to ensure they stay in authorized areas, to identify personnel needing assistance, and to support emergency response.
AOR.71	The organization shall locate control system assets to minimize potential damage from physical and environmental hazards and to minimize the opportunity for unauthorized access.
AOR.72	The organization shall protect the control system from information leakage.
AOR.73	The organization shall protect control system power equipment and power cabling from damage and destruction.
AOR.74	The organization shall employ hardware (cages, locks, cases, etc.) to detect and deter unauthorized physical access to control system devices.
AOR.75	The organization shall develop, disseminate, and periodically review and update: <ol style="list-style-type: none"> 1. A formal, documented, planning policy that addresses: <ol style="list-style-type: none"> a. The purpose of the strategic planning program as it relates to protecting the organization's personnel and assets; b. The scope of the strategic planning program as it applies to all the organizational staff and third-party contractors; c. The roles, responsibilities, and management accountability structure of the strategic planning program to ensure compliance with the organization's security policy and other regulatory commitments. 2. Formal, documented procedures to facilitate the implementation of the strategic planning policy and associated strategic planning controls.
AOR.76	The organization shall develop and implement a security plan for the control system that provides an overview of the security requirements for the system and a description of the security measures in place or planned for meeting those requirements. Designated officials within the organization shall review and approve the control system security plan.
AOR.77	The organization shall identify potential interruptions and classify them as to "cause," "effects," and "likelihood."
AOR.78	The organization's control system security plan shall define and communicate the specific roles and

	responsibilities in relation to various types of incidents.
AOR.79	The organization shall include training on the implementation of the control system security plans for employees, contractors, and stakeholders into the organization's planning process.
AOR.80	The organization shall regularly test security plans to validate the control system objectives.
AOR.81	The organization shall include investigation and analysis of control system incidents in the planning process.
AOR.82	The organization shall include processes and mechanisms in the planning to ensure that corrective actions identified as the result of a cyber security and system incidents are fully implemented.
AOR.83	Risk-reduction mitigation measures shall be planned and implemented and the results monitored to ensure effectiveness of the organization's risk management plan.
AOR.84	The organization shall regularly, at prescribed frequencies, review the security plan for the control system and revise the plan to address system/organizational changes or problems identified during system security plan implementation or security controls assessment.
AOR.85	The organization shall establish and make readily available to all control system users a set of rules that describes their responsibilities and expected behavior with regards to control system usage. The organization shall obtain signed acknowledgement from users indicating that they have read, understand, and agree to abide by the rules of behavior before authorizing access to the control system.
AOR.86	The organization shall plan and coordinate security-related activities affecting the control system before conducting such activities to reduce the impact on organizational operations (i.e., mission, functions, image, and reputation), organizational assets, or individuals.
AOR.87	The organization shall develop, disseminate, and periodically review/update: <ol style="list-style-type: none"> 1. A formal, documented, security awareness and training policy that addresses purpose, scope, roles, responsibilities, management commitment, coordination among organizational entities, and compliance; and 2. Formal, documented procedures to facilitate the implementation of the security awareness and training policy and associated security awareness and training controls.
AOR.88	The organization shall provide basic security awareness training to all control system users (including managers and senior executives) before authorizing access to the system, when required by system changes, and at least annually thereafter. The effectiveness of security awareness training, at the organization level, shall be reviewed at a minimum [assignment: once a year, etc.].
AOR.89	The organization shall identify and train personnel with significant control system security roles and responsibilities. The organization shall document the roles and responsibilities and provide appropriate control system security training before authorizing access to the system, when required by system changes, and with periodic training thereafter.
AOR.90	The organization shall document, maintain, and monitor individual control system security training activities, including basic security awareness training and specific information and control system security training in accordance with the organization's records retention policy.
AOR.91	The organization shall establish, participate with, and maintain contacts with special interest groups, industry vendor forums, specialized public or governmental forums, or professional associations to stay up to date with the latest recommended security practices, techniques, and technologies and to share the latest security-related information including threats, vulnerabilities, and incidents.
AOR.92	The organization shall document and test the knowledge of personnel on security policies and procedures based on their roles and responsibilities to ensure that they understand their responsibilities in securing the control system.
AOR.93	The organization shall develop, disseminate, and periodically review/update: <ol style="list-style-type: none"> 1. A formal, documented, media protection policy that addresses purpose, scope, roles, responsibilities, management commitment, coordination among organizational entities, and compliance; 2. Formal, documented procedures to facilitate the implementation of the media protection policy and associated media protection controls.

AOR.94	The organization shall ensure that only authorized users have access to information in printed form or on digital media, whether integral to or removed from the control system.
AOR.95	The organization shall review and classify all removable information storage media and the control system output to determine distribution limitations [assignment: public, confidential, classified, etc.].
AOR.96	The organization shall affix external labels to removable information system media and to the control system output that indicate the distribution limitations [assignment: public, confidential, classified, etc.] and handling caveats of the information. The organization may exempt specific types of media or hardware components from labeling as long as they remain within a secure environment (as defined by the organization).
AOR.97	The organization shall physically manage and securely store control system media within protected areas. The sensitivity of the material delineates how the media is stored.
AOR.98	The organization shall develop security measures for paper and digital media extracted from the control system and restricts the pickup, receipt, transfer, and delivery of such media to authorized personnel.
AOR.99	The organization shall sanitize control system digital and non-digital media, before disposal or release for reuse.
AOR.100	The organization shall develop, disseminate, and periodically review/update: <ol style="list-style-type: none"> 1. A formal, documented, monitoring and reviewing control system security management policy that addresses purpose, scope, roles, responsibilities, management commitment, coordination among organizational entities, and compliance; 2. Formal, documented procedures to facilitate the implementation of the monitoring and reviewing control system security management policy and associated audit and accountability controls.
AOR.101	The organization's security program shall implement continuous improvement practices to ensure that industry lessons-learned and best practices are incorporated into control system security policies and procedures.
AOR.102	The organization shall include a process for monitoring and reviewing the performance of their cyber security policy.
AOR.103	The organization shall incorporate industry best practices into the organization's security program for control systems.
AOR.104	The organization shall authorize (i.e., accredit) the control system for processing before operations and periodically updates the authorization based on organization-defined frequency or when there is a significant change to the system. A senior organizational official shall sign and approve the security accreditation.
AOR.105	The organization shall conduct an assessment of the security mechanisms in the control system to determine the extent to which the security measures are implemented correctly, operating as intended, and producing the desired outcome with respect to meeting the security requirements for the system.
AOR.106	The organization shall establish policies and procedures to define roles, responsibilities, behaviors, and practices for the implementation of an overall security program.
AOR.107	The organization shall define a framework of management leadership accountability. This framework establishes roles and responsibilities to approve cyber security policy, assign security roles, and coordinate the implementation of cyber security across the organization.

AOR.108	<p>Baseline practices that the organization shall employ for organizational security include, but are not limited to:</p> <ol style="list-style-type: none"> 1. Executive management accountability for the security program; 2. Responsibility for control system security within the organization includes sufficient authority and an appropriate level of funding to implement the organization's security policy; 3. The organization's security policies and procedures that provide clear direction, accountability, and oversight for the organization's security team. The security team assigns roles and responsibilities in accordance with the organization's policies and confirms that processes are in place to protect company assets and critical information; 4. The organization's contracts with external entities that address the organization's security policies and procedures with business partners, third-party contractors, and outsourcing partners; 5. The organization's security policies and procedures ensure coordination or integration with the organization's physical security plan. Organization roles and responsibilities are established that address the overlap and synergy between physical and control system security risks.
AOR.109	<p>The organization's security policies and procedures shall delineate how the organization implements its emergency response plan and coordinates efforts with law enforcement agencies, regulators, Internet service providers and other relevant organizations in the event of a security incident.</p>
AOR.110	<p>The organization shall hold external suppliers and contractors that have an impact on the security of the control center to the same security policies and procedures as the organization's own personnel. The organization shall ensure security policies and procedures of second- and third-tier suppliers comply with corporate cyber security policies and procedures if they will impact control system security.</p>
AOR.111	<p>The organization shall establish procedures to remove external supplier access at the conclusion/termination of the contract.</p>
AOR.112	<p>The organization shall:</p> <ol style="list-style-type: none"> 1. Establish usage restrictions and implementation guidance for Voice over Internet Protocol (VoIP) technologies based on the potential to cause damage to the information system if used maliciously; and 2. Authorize, monitor, and control the use of VoIP within the information system.
AOR.113	<p>The organization shall display an approved system use notification (message) before granting access to the system.</p>
AOR.114	<p>The organization shall develop a formal written policy and appropriate security procedures to address and protect against the risks of remote access to the system, field devices, and communication facilities.</p>
AOR.115	<p>The organization shall restrict the use of personally owned information copied to the system or system user workstation that is used for official organization business. This includes the processing, storage, or transmission of organization business and critical system information. The terms and conditions need to address, at a minimum:</p> <ol style="list-style-type: none"> 1. The types of applications that can be accessed from personally owned IT, either remotely or from within the organization's system; 2. The maximum security category of information that can processed, stored, and transmitted; 3. How other users of the personally owned system will be prevented from accessing organization information; 4. The use of virtual private networking (VPN) and firewall technologies; 5. The use of and protection against the vulnerabilities of wireless technologies; 6. The maintenance of adequate physical security mechanisms; 7. The use of virus and spyware protection software; and 8. How often the security capabilities of installed software are to be updated (e.g., operating system and other software security patches, virus definitions, firewall version updates, malware definitions).
AOR.116	<p>The organization shall develop, disseminate and periodically review and update:</p> <ol style="list-style-type: none"> 1. A formal, documented identification policy that addresses purpose, scope, roles, responsibilities, management commitment, coordination among organizational entities, and compliance; and

	<ol style="list-style-type: none"> 2. Formal, documented procedures to facilitate the implementation of the identification policy and associated identification controls.
AOR.117	<p>The organization shall develop, disseminate, and periodically review and update:</p> <ol style="list-style-type: none"> 1. A formal, documented, access control policy that addresses purpose, scope, roles, responsibilities, management commitment, coordination among organizational entities, and compliance; 2. Formal, documented procedures to facilitate the implementation of the access control policy and associated access controls.
AOR.118	<p>The organization shall manage system accounts, including establishing, activating, modifying, reviewing, disabling, and removing accounts. The organization reviews system accounts at least [assignment: period of time (e.g., annually)].</p>
AOR.119	<p>The organization shall develop, disseminate, and periodically review/update:</p> <ol style="list-style-type: none"> 1. A formal, documented, accountability policy that addresses purpose, scope, roles, responsibilities, management commitment, coordination among organizational entities, and compliance; and 2. Formal, documented procedures to facilitate the implementation of the accountability policy and associated audit and accountability controls.
AOR.120	<p>The organization shall regularly review and analyze information system audit records:</p> <ol style="list-style-type: none"> 1. For indications of inappropriate or unusual activity 2. To investigate suspicious activity or suspected violations 3. To report findings to appropriate officials, and 4. Take necessary actions.
AOR.121	<p>The organization shall conduct audits at planned intervals to determine whether the security objectives, measures, processes, and procedures:</p> <ol style="list-style-type: none"> 1. Conform to the requirements and relevant legislation or regulations; 2. Conform to the identified information security requirements; 3. Are effectively implemented and maintained; 4. Perform as expected; 5. Identify inappropriate activities.
AOR.122	<p>The organization's audit program shall specify auditor qualifications in accordance with the organization's documented training program.</p>
AOR.123	<p>The organization under the audit program shall specify strict rules and careful use of audit tools when auditing control system functions.</p>
AOR.124	<p>The organization shall demonstrate compliance to the organization's security policy through audits in accordance with the organization's audit program.</p>

Handling/Operating Rigor (AHR)

This section contains requirements regarding the activities involved in the day-to-day operation of deployed smart grid systems. Topics include

- information and document management policies
- incident response procedures
- maintenance procedures
- physical and environmental security
- media protection

AHR.1	The organization shall develop, disseminate, and periodically review/update: <ol style="list-style-type: none"> 1. A formal, documented, contingency planning policy that addresses purpose, scope, roles, responsibilities, management commitment, coordination among organizational entities, and compliance; and 2. Formal, documented procedures to facilitate the implementation of the contingency planning policy and associated contingency planning controls.
AHR.2	The organization shall develop and implement a contingency plan for the information system addressing contingency roles, responsibilities, assigned individuals with contact information, and activities associated with restoring the system after a disruption or failure. Designated officials within the organization shall review and approve the contingency plan and distribute copies of the plan to key contingency personnel.
AHR.3	The organization shall train personnel in their contingency roles and responsibilities with respect to the information system and provides refresher training [Assignment: organization-defined frequency, at least annually].
AHR.4	The organization shall: <ol style="list-style-type: none"> 1. Test and/or exercise the contingency plan for the information system [Assignment: organization-defined frequency, at least annually] using [Assignment: organization-defined tests and/or exercises] to determine the plan's effectiveness and the organization's readiness to execute the plan; and 2. Review the contingency plan test/exercise results and initiates corrective actions.
AHR.5	The organization shall review the contingency plan for the information system [Assignment: organization-defined frequency, at least annually] and revises the plan to address system/organizational changes or problems encountered during plan implementation, execution, or testing.
AHR.6	The organization shall identify an alternate storage site and initiates necessary agreements to permit the storage of information system backup information.
AHR.7	The organization shall identify an alternate processing site and initiates necessary agreements to permit the resumption of information system operations for critical mission/business functions within [Assignment: organization-defined time period] when the primary processing capabilities are unavailable.
AHR.8	The organization shall identify primary and alternate telecommunications services to support the information system and initiates necessary agreements to permit the resumption of system operations for critical mission/business functions within [Assignment: organization-defined time period] when the primary telecommunications capabilities are unavailable.
AHR.9	The organization shall conduct backups of user-level and system-level information (including system state information) contained in the information system [Assignment: organization-defined frequency] and protects backup information at the storage location.
AHR.10	The organization shall employ mechanisms with supporting procedures to allow the information system to be recovered and reconstituted to a known secure state after a disruption or failure.
AHR.11	The organization shall develop, disseminate, and periodically review/update: <ol style="list-style-type: none"> 1. A formal, documented, incident response policy that addresses purpose, scope, roles, responsibilities, management commitment, coordination among organizational entities, and compliance; and 2. Formal, documented procedures to facilitate the implementation of the incident response policy and associated incident response controls.
AHR.12	The organization shall train personnel in their incident response roles and responsibilities with respect to the information system and provides refresher training [Assignment: organization-defined frequency, at least annually].
AHR.13	The organization shall test and/or exercise the incident response capability for the information system [Assignment: organization-defined frequency, at least annually] using [Assignment: organization-defined tests and/or exercises] to determine the incident response effectiveness and documents the results.

AHR.14	The organization shall implement an incident handling capability for security incidents that includes preparation, detection and analysis, containment, eradication, and recovery.
AHR.15	The organization tracks and documents information system security incidents on an ongoing basis.
AHR.16	The organization promptly reports incident information to appropriate authorities.
AHR.17	The organization shall provide an incident response support resource that offers advice and assistance to users of the information system for the handling and reporting of security incident (The support resource is an integral part of the organization's incident response capability).
AHR.18	The organization shall develop, disseminate and periodically review/update: <ol style="list-style-type: none"> 1. A formal, documented, control system information and document management policy that addresses purpose, scope, roles, responsibilities, management commitment, coordination among organizational entities, and compliance. 2. Formal, documented procedures to facilitate the implementation of the control system information and document management policy and associated system maintenance controls.
AHR.19	The organization shall manage control system related data, including establishing retention policies and procedures for both electronic and paper data, and manages access to the data based on formally assigned roles and responsibilities.
AHR.20	Organization implemented policies and procedures detailing the handling of information shall be developed and periodically reviewed and updated.
AHR.21	All information shall be classified to indicate the protection required commensurate with its sensitivity and consequence.
AHR.22	Formal contractual and confidentiality agreements shall be established for the exchange of information and software between the organization and external parties.
AHR.23	The organization shall develop policies and procedures to classify data, including establishing: <ol style="list-style-type: none"> 1. Retention policies and procedures for both electronic and paper media; 2. Classification policies and methods, (e.g., restricted, classified, general, etc.); 3. Access and control policies, to include sharing, copying, transmittal, and distribution appropriate for the level of protection required; 4. Access to the data based on formally assigned roles and responsibilities for the control system.
AHR.24	The organization shall develop policies and procedures that provide details of the retrieval of written and electronic records, equipment, and other media for the control system in the overall information and document management policy.
AHR.25	The organization shall develop policies and procedures detailing the destruction of written and electronic records, equipment, and other media for the control system, without compromising the confidentiality of the data.
AHR.26	The organization shall perform periodic reviews of compliance with the control system information and document security management policy to ensure compliance with any laws and regulatory requirements.
AHR.27	The control system shall automatically marks data output using standard naming conventions to identify any special dissemination, handling, or distribution instructions.
AHR.28	The control system shall automatically label information in storage, in process and in transmission.
AHR.29	The organization shall develop, disseminate, and periodically review/update: <ol style="list-style-type: none"> 1. A formal, documented, incident response policy that addresses purpose, scope, roles, responsibilities, management commitment, coordination among organizational entities, and compliance; and 2. Formal, documented procedures to facilitate the implementation of the incident response policy and associated incident response controls.
AHR.30	The organization shall develop and implement a continuity of operations plan dealing with the overall issue of maintaining or re-establishing production in case of an undesirable interruption for a control

	system. The plan shall address roles, responsibilities, assigned individuals with contact information, and activities associated with restoring system operations after a disruption or failure. Designated officials within the organization shall review and approve the continuity of operations plan.
AHR.31	The organization's continuity of operations plan shall define and communicate the specific roles and responsibilities for each part of the plan in relation to various types of control system incidents.
AHR.32	The organization shall train personnel in their continuity of operations plan roles and responsibilities with respect to the control system. The organization shall provide refresher training at least annually. The training covers employees, contractors, and stakeholders in the implementation of the continuity of operations plan.
AHR.33	The organization shall test the continuity of operations plan to determine its effectiveness and documents the results. Appropriate officials within the organization shall review the documented test results and initiate corrective actions if necessary. The organization shall test the continuity of operations plan for the control system at least annually, using organization prescribed tests and exercises to determine the plan's effectiveness and the organization's readiness to execute the plan.
AHR.34	The organization shall review the continuity of operations plan for the control system at least annually and updates the plan to address system, organizational, and technology changes or problems encountered during plan implementation, execution, or testing.
AHR.35	The organization shall implement control system incident handling capabilities for security incidents that includes preparation, detection and analysis, containment, eradication, and recovery.
AHR.36	The organization shall track and document control system network security incidents on an ongoing basis.
AHR.37	The organization shall promptly report cyber and control system security incident information to the appropriate authorities.
AHR.38	The organization shall provide an incident response support resource that offers advice and assistance to users of the control system for the handling and reporting of security incidents (The support resource is an integral part of the organization's incident response capability).
AHR.39	The organization shall document its policies and procedures to show that investigation and analysis of incidents are included in the planning process. The procedures shall ensure that the control system is capable of providing event data to the proper personnel for analysis and for developing mitigation steps. The organization shall ensure that a dedicated group of personnel is assigned to periodically review the data at a minimum monthly.
AHR.40	The organization shall include processes and mechanisms in the planning to ensure that corrective actions identified as the result of a cyber security incident are fully implemented.
AHR.41	The organization shall identify an alternate storage site and initiates necessary agreements to permit the storage of control system configuration information.
AHR.42	The organization shall identify alternate command/control methods for the control system and initiates necessary agreements to permit the resumption of operations for the safe operation of the control system within an organization-defined time period when the primary system capabilities are unavailable.
AHR.43	The organization shall identify an alternate control center, necessary telecommunications, and initiates necessary agreements to permit the resumption of control system operations for critical functions within [assignment: an organization-prescribed time period] when the primary control center is unavailable.
AHR.44	The organization shall conduct backups of critical control system information, including state of the user-level and system level information, process formulas, system inventories, etc., contained in the control system, on a regular schedule as defined by the organization, and stores the information at an appropriately secured location.
AHR.45	The organization shall employ mechanisms with supporting procedures to allow the control system to be recovered and reconstituted to the system's original state after a disruption or failure.
AHR.46	The control system shall have the ability to execute an appropriate fail safe procedure upon the loss

	of communications with the control system or the loss of the control system itself.
AHR.47	The organization shall retain audit records for [Assignment: organization-defined time period] to provide support for after-the-fact investigations of security incidents and to meet regulatory and organizational information retention requirements.

Accountability (AAY)

"Security auditing involves recognizing, recording, storing, and analyzing information related to security relevant activities (i.e. activities controlled by the TSF). The resulting audit records can be examined to determine which security relevant activities took place and whom (which user) is responsible for them." [CC]

AAY.1	The organization shall manage control system accounts, including establishing, activating, modifying, reviewing, disabling, and removing accounts. The organization shall review control system accounts [assignment: time period (e.g., at least annually)].
AAY.3	The organization shall manage information system accounts, including establishing, activating, modifying, reviewing, disabling, and removing accounts. The organization shall review information system accounts [Assignment: organization-defined frequency, at least annually].
AAY.4	The information system shall enforce a limit of [Assignment: organization-defined number] consecutive invalid access attempts by a user during a [Assignment: organization-defined time period] time period. The information system automatically [Selection: locks the account/node for an [Assignment: organization-defined time period], delays next login prompt according to [Assignment: organization-defined delay algorithm.]] when the maximum number of unsuccessful attempts is exceeded.
AAY.5	The organization shall develop, disseminate, and periodically review/update: <ol style="list-style-type: none"> 1. A formal, documented, audit and accountability policy that addresses purpose, scope, roles, responsibilities, management commitment, coordination among organizational entities, and compliance; and 2. Formal, documented procedures to facilitate the implementation of the audit and accountability policy and associated audit and accountability controls.
AAY.6	The organization shall develop, disseminate, and periodically review/update: <ol style="list-style-type: none"> 1. A formal, documented, audit and accountability policy that addresses purpose, scope, roles, responsibilities, management commitment, coordination among organizational entities, and compliance; 2. Formal, documented procedures to facilitate the implementation of the audit and accountability policy and associated audit and accountability controls.
AAY.7	The control system shall generate audit records, at a minimum, for the following events whether or not the attempts were successful: <ol style="list-style-type: none"> 1. Attempts to logon; 2. Attempts to change local account attributes such as privileges; 3. Attempts to change local security policy.
AAY.8	The organization shall develop, implement, and periodically review and update: <ol style="list-style-type: none"> 1. A formal, documented, control system security policy that addresses: <ol style="list-style-type: none"> a. The purpose of the security program as it relates to protecting the organization's personnel and assets; b. The scope of the security program as it applies to all the organizational staff and third-party contractors; c. The roles, responsibilities, and management accountability structure of the security program to ensure compliance with the organization's security policy and other regulatory commitments. 2. Formal, documented procedures to implement the security policy and associated requirements. A control system security policy considers controls from each of the families

	contained in this document.
AAY.9	The organization shall define a framework of management leadership accountability. This framework establishes roles and responsibilities to approve cyber security policy, assign security roles, and coordinate the implementation of cyber security across the organization.
AAY.10	Baseline practices that organizations employ for organizational security shall include, but are not limited to: <ol style="list-style-type: none"> 1. Executive management accountability for the security program; 2. Responsibility for control system security within the organization includes sufficient authority and an appropriate level of funding to implement the organization's security policy; 3. The organization's security policies and procedures that provide clear direction, accountability, and oversight for the organization's security team. The security team assigns roles and responsibilities in accordance with the organization's policies and confirms that processes are in place to protect company assets and critical information; 4. The organization's contracts with external entities that address the organization's security policies and procedures with business partners, third-party contractors, and outsourcing partners; 5. The organization's security policies and procedures ensure coordination or integration with the organization's physical security plan. Organization roles and responsibilities are established that address the overlap and synergy between physical and control system security risks.
AAY.11	The organization shall develop, disseminate, and periodically review and update: <ol style="list-style-type: none"> 1. A formal, documented system and communication protection policy that addresses: <ol style="list-style-type: none"> a. The purpose of the system and communication protection policy as it relates to protecting the organization's personnel and assets; b. The scope of the system and communication protection policy as it applies to all the organizational staff and third-party contractors; c. The roles, responsibilities and management accountability structure of the security program to ensure compliance with the organization's system and communications protection policy and other regulatory commitments; 2. Formal, documented procedures to facilitate the implementation of the control system and communication protection policy and associated systems and communication protection controls.
AAY.12	The organization shall develop, disseminate, and periodically review/update: <ol style="list-style-type: none"> 1. A formal, documented, system and services acquisition policy that addresses: <ol style="list-style-type: none"> a. The purpose of the security program as it relates to protecting the organization's personnel and assets; b. The scope of the security program as it applies to all the organizational staff and third-party contractors; c. The roles, responsibilities and management accountability structure of the security program to ensure compliance with the organization's security policy and other regulatory commitments. 2. Formal, documented procedures to facilitate the implementation of the system and services acquisition policy and associated system and services acquisition controls.

AAY.13	<p>The organization shall develop, disseminate, and periodically review and update:</p> <ol style="list-style-type: none"> 1. A formal, documented Configuration Management policy that addresses: <ol style="list-style-type: none"> a. The purpose of the configuration management policy as it relates to protecting the organization's personnel and assets; b. The scope of the configuration management policy as it applies to all the organizational staff and third-party contractors; c. The roles, responsibilities and management accountability structure contained in the configuration management policy to ensure compliance with the organization's security policy and other regulatory commitments. 2. Formal, documented procedures to facilitate the implementation of the configuration management policy and associated configuration management controls. 3. The personnel qualification levels required to make changes, the conditions under which changes are allowed, and what approvals are required for those changes.
AAY.14	<p>The organization shall develop, disseminate, and periodically review and update:</p> <ol style="list-style-type: none"> 1. A formal, documented, personnel security policy that addresses: <ol style="list-style-type: none"> a. The purpose of the security program as it relates to protecting the organization's personnel and assets; b. The scope of the security program as it applies to all the organizational staff and third-party contractors; c. The roles, responsibilities, and management accountability structure of the security program to ensure compliance with the organization's security policy and other regulatory commitments; 2. Formal, documented procedures to facilitate the implementation of the personnel security policy and associated personnel security controls. 3. Formal procedure to review and document list of approved personnel with access to control systems.
AAY.15	<p>The organization shall employ a formal accountability process for personnel failing to comply with established control system security policies and procedures, and clearly document potential disciplinary actions for failing to comply.</p>
AAY.16	<p>The organization shall develop, implement, and periodically review and update:</p> <ol style="list-style-type: none"> 1. A formal, documented physical security policy that addresses: <ol style="list-style-type: none"> a. The purpose of the physical security program as it relates to protecting the organization's personnel and assets; b. The scope of the physical security program as it applies to all the organizational staff and third-party contractors; c. The roles, responsibilities and management accountability structure of the physical security program to ensure compliance with the organization's security policy and other regulatory commitments. 2. Formal, documented procedures to facilitate the implementation of the physical and environmental protection policy and associated physical and environmental protection controls.
AAY.17	<p>The organization shall develop, disseminate, and periodically review and update:</p> <ol style="list-style-type: none"> 1. A formal, documented, planning policy that addresses: <ol style="list-style-type: none"> a. The purpose of the strategic planning program as it relates to protecting the organization's personnel and assets; b. The scope of the strategic planning program as it applies to all the organizational staff and third-party contractors; c. The roles, responsibilities, and management accountability structure of the strategic planning program to ensure compliance with the organization's security policy and other regulatory commitments. 2. Formal, documented procedures to facilitate the implementation of the strategic planning policy and associated strategic planning controls.
AAY.18	<p>The organization shall develop, disseminate, and periodically review/update:</p> <ol style="list-style-type: none"> 1. A formal, documented, monitoring and reviewing control system security management policy that addresses purpose, scope, roles, responsibilities, management commitment, coordination among organizational entities, and compliance; 2. Formal, documented procedures to facilitate the implementation of the monitoring and reviewing control system security management policy and associated audit and

	accountability controls.
AAY.19	<p>Baseline practices that the organization employs for organizational security shall include, but are not limited to:</p> <ol style="list-style-type: none"> 1. Executive management accountability for the security program; 2. Responsibility for control system security within the organization includes sufficient authority and an appropriate level of funding to implement the organization's security policy; 3. The organization's security policies and procedures that provide clear direction, accountability, and oversight for the organization's security team. The security team assigns roles and responsibilities in accordance with the organization's policies and confirms that processes are in place to protect company assets and critical information; 4. The organization's contracts with external entities that address the organization's security policies and procedures with business partners, third-party contractors, and outsourcing partners; 5. The organization's security policies and procedures ensure coordination or integration with the organization's physical security plan. Organization roles and responsibilities are established that address the overlap and synergy between physical and control system security risks.

Access Control (AAC)

"The focus of access control is ensuring that resources are only accessed by the appropriate personnel and that personnel are correctly identified. The first step in access control is creating access control lists with access privileges for personnel. The next step is to implement security mechanisms to enforce the access control lists. Mechanisms also need to be put into place to monitor access activities for inappropriate activity. The access control lists need to be managed through adding, altering, and removing access rights as necessary.

Identification and authentication is the process of verifying the identity of a user, process, or device, as a prerequisite for granting access to resources in a control system. Identification could be a password, a token, or a fingerprint. Authentication is the challenge process to prove (validate) the identification provided. An example would be using a fingerprint (identification) to access a computer via a biometric device (authentication). The biometric device authenticates the identity of the fingerprint." [DHS]

AAC.1	<p>The organization shall develop, disseminate, and periodically review/update:</p> <ol style="list-style-type: none"> 1. A formal, documented, access control policy that addresses purpose, scope, roles, responsibilities, management commitment, coordination among organizational entities, and compliance; 2. Formal, documented procedures to facilitate the implementation of the access control policy and associated access controls.
AAC.2	The organization shall supervise and review the activities of users with respect to the enforcement and usage of control system access control.
AAC.3	The security function shall enforce the [assignment: access control security function policy] on [assignment: list of subjects, objects, and operations among subjects and objects covered by the security function policy].
AAC.4	The security function shall enforce the [assignment: access control security function policy] on [assignment: list of subjects and objects] and all operations among subjects and objects covered by the security function policy.
AAC.5	The security function shall ensure that all operations between any subject controlled by the security

	function and any object controlled by the security function are covered by an access control security function policy.
AAC.6	The security function shall enforce the [assignment: access control security function policy] to objects based on the following: [assignment: list of subjects and objects controlled under the indicated security function policy, and for each, the security function policy-relevant security attributes, or named groups of security function policy-relevant security attributes].
AAC.7	The security function shall enforce the [assignment: access control security function policy(s) and/or information flow control security function policy(s)] when exporting user data, controlled under the security function policy(s), outside of the module.
AAC.8	The organization shall develop, disseminate, and periodically review/update: <ol style="list-style-type: none"> 1. A formal, documented, access control policy that addresses purpose, scope, roles, responsibilities, management commitment, coordination among organizational entities, and compliance; and 2. Formal, documented procedures to facilitate the implementation of the access control policy and associated access controls.
AAC.9	The organization shall supervise and review the activities of users with respect to the enforcement and usage of information system access controls.
AAC.10	The security function shall enforce the [assignment: access control security function policy(s), information flow control security function policy(s)] to restrict the ability to [selection: change_default, query, modify, delete, [assignment: other operations]] the security attributes [assignment: list of security attributes] to [assignment: the authorized identified roles].
AAC.11	The security function shall enforce the [assignment: access control security function policy, information flow control security function policy] to provide [selection, choose one of: restrictive, permissive, [assignment: other property]] default values for security attributes that are used to enforce the security function policy.
AAC.12	The organization shall review logical and physical access permissions to control systems and facilities when individuals are reassigned or transferred to other positions within the organization and initiates appropriate actions. Complete execution of this control occurs within [Assignment: time period (e.g., 7 days)] for employees or contractors who no longer need to access control system resources.
AAC.13	The organization shall supervise and review the activities of users with respect to the enforcement and usage of system access control.

AMI-SEC RA: Appendix A – Architectural Description

This appendix contains information that is non-formative to the architecture of AMI security, but provides useful background and understanding.

Scope

AMI Security Architecture as defined by the AMI-SEC taskforce as:

The communications hardware and software and associated system and data management software that creates a network between advanced meters and utility business systems and which allows collection and distribution of information to customers and other parties such as competitive retail providers, in addition to providing it to the utility itself. AMI is further defined as: 1) The hardware and software residing in, on, or closest to the customer premise for which the utility or its legal proxies are primarily responsible for proper operation; and 2) The hardware and software owned and operated by the utility or its legal proxies which has as its primary purpose the facilitation of Advanced Metering.

The goal of this section is to describe the abstract (logical, platform-agnostic) mitigation plan for addressing requirements identified in the Risk Assessment / System Requirements in Chapters 1 and 2 respectively. The following approach has been taken in designing the system:

Approach

- Architectural Representation of Security Systems
- Logical Function Descriptions
- System, Subsystem, and Function Boundaries
- Reference: IEEE 1471-2000

This document is intended to focus on security architecture, and is not intended to cover enterprise level AMI architecture, except to describe a security concept. The objective of architecting is to decompose the system into its primary views in order to describe the system enough to complete the mission of AMI security. The architecture does not extend beyond the external visible properties of the elements of the system. That is, non-visible properties are left to the designers, implementers and integrators of the system.

The following image represents the 10,000 foot view of AMI. This document begins by explaining the interactions between external actors and the AMI system (see Chapter 3: **Error! Reference source not found.** in the *ASAP Phase 1 Report – EPRI Technical Update Product ID 1020235*). The next view zooms in on the AMI system by describing the system with a decomposition view. Each revision provides deeper granularity and traceability between views.

AMI-SEC Task Force is developing other relevant documentation in parallel that supports the Architectural Description (AD) including the AMI Risk Analysis and System Security Requirements (SSR) documents. The Risk Analysis walks the utility through a method of determining a risk-to-value of an asset. Assets in terms of these documents are considered to be the business level value streams to the utility. Appendix A of the AMI Risk Analysis includes catalogues for assets, vulnerabilities, and threats. The SSR document includes AMI-SEC's approach to conducting a requirements assessment and applying requirements. Traceability between views in the AD and requirements defined in the SSR are maintained for consistency and rationale.

This section develops security around commonly known AMI use cases selected from use cases shared by utilities to AMI-SEC. It is assumed that AMI will evolve supporting additional uses and variants, but these uses cannot be predicted. Therefore, a goal of this AD is to group use cases that possess commonality in security treatment in order to support the evolution of AMI.

Mission

The mission of the AMI Security Architecture is to provide understanding of AMI security, communication among stakeholders and serve as a basis for system analysis. It is important to understand that the task of this architecture is not to provide the groundwork to build the entire AMI system, but to secure it, which is inherently nontrivial.

The information contained in this section will provide an introduction to AMI Security to interested parties. Newcomers will find this document a starting point for understanding the elements, interfaces, and structure of AMI security.

This document will serve to provide communication among stakeholders including designers of the system, implementers, integrators, testers and operators. All architecture is design, but not all design is considered architecture. The mission in communication is to produce sufficient guidance for stakeholders so that they understand the architecture well enough to perform their role.

The architecture will also serve to provide information needed the support analysis performed for security objectives including availability, integrity, confidentiality, access control and accounting.

The architecture will cross-check with information contained in the Requirements document to provide reasoning for requirements selection.

Stakeholders & Concerns

This section describes the stakeholders and their concerns. A stakeholder is any individual or group of individuals with interests or concerns associated with the system. All actors of the system are stakeholders, but not all stakeholders are actors. For example, an investor may have a stake in the success of the AMI system, but may not interact directly with the AMI system.

Stakeholders identified to be relevant to the security architecture are:

- Customer Users of the system
- Operators of the system
- Responsible Entities of the systems
- Developers of the system
- Implementers of the system
- Maintainers of the system

Concerns that stakeholders may have from a security perspective for the entire AMI system

General Stakeholder Concerns:

- Integrity of the system
- Availability of the system
- Confidentiality of the system
- The purpose or missions of the system as pertains to security
- The appropriateness of the system for use in fulfilling its missions to security
- The feasibility of constructing the system
- The risks of system development and operation to users, acquirers, and developers of the system
- Maintainability, deploy-ability, and evolve-ability of the system

Each viewpoint defined for AMI security possesses specific concerns defined with each viewpoint under the following section.

Potential examples of AMI security concerns by stakeholders:

**Table 2-10
Stakeholder Security Concerns**

STAKEHOLDER	SECURITY CONCERN
Residential Customer	Privacy
Utility Operator	Integrity of information and system control
Regulators	Integrity of system and compliance with regulations
Telecom Provider	Compliance with contractual obligations and regulations

Security Analysis Approach

The security analysis approach is to evaluate each view under the security principles of availability, integrity, confidentiality, access control and accountability. The high level models are in the form of Use Cases. At least one security objective is identified with each Use Case by evaluating against these security principles.

- Availability
 - Ensure the desired resource is available at the time it is needed.
 - Ensure the desired resource is accessible in the intended manner by the appropriate entity.
- Integrity
 - Ensure the desired resource contains accurate information.
 - Ensure the desired resource performs precisely as intended.
- Confidentiality
 - Ensure the desired resource is only accessible to the desired targets.
 - Ensure the desired resource is only accessible under the designated conditions.
- Access Control
 - Ensure resource access follows the designated procedure.
 - Ensure access mechanisms provide sufficient management capabilities to establish, modify, and remove desired criteria.
- Accountability
 - Ensure system activities can be reconstructed, reviewed, and examined from transaction inception to output of final results.
 - Ensure system controls are provably compliant with established policy and procedures.

Architecture Description Approach

This section is an introduction to the approach of describing the AMI architecture based on IEEE 1471-2000, *IEEE Recommended Practice for Architectural Description of Software-Intensive Systems*. This section serves as a roadmap for Appendix A and provides a guide for where to locate information.

This section introduces templates and patterns that will be used in subsequent sections. Each view describes:

- What viewpoint it realizes
 - Name & definition of the viewpoint (external pointer or brief definition)
 - What stakeholders and concerns it addresses (and to what extent)
 - Language/notation to be used
- One or more models, where a model includes:
 - Context diagram (i.e., how it relates to AMI as a whole or to other models within the same view)
 - A picture or other primary presentation, always with a key or legend
 - Brief descriptions (or pointers to such) for each element and relation type in the primary presentation
 - Related models, such as scenarios related to the view
 - Known or anticipated variations (likely very important here)
 - Rationale, assumptions, or other background for the decisions depicted in the view

Viewpoints

IEEE 1471-2000 describes a viewpoint on a system as – “a form of abstraction achieved using a selected set of architectural constructs and structuring rules, in order to focus on particular concerns within a system. The relationship between viewpoint and view is analogous to that of a template and an instance of that template.” Therefore, a viewpoint may contain:

- Specifications of each viewpoint that has been selected to organize the representation of the architecture and the rationale for those selections
- One or more architectural views
- A record of all known inconsistencies among the architectural description’s required constituents
- A rationale for selection of the architecture

Each viewpoint shall be specified by:

17. A viewpoint name,
18. The stakeholders to be addressed by the viewpoint,
19. The concerns to be addressed by the viewpoint,

20. The language, modeling techniques, or analytical methods to be used in constructing a view based upon the viewpoint,
21. The source, for a library viewpoint (the source could include author, date, or reference to other documents, as determined by the using organization).

A viewpoint specification may include additional information on architectural practices associated with using the viewpoint, as follows:

- Formal or informal consistency and completeness tests to be applied to the models making up an associated view
- Evaluation or analysis techniques to be applied to the models
- Heuristics, patterns, or other guidelines to assist in synthesis of an associated view

Viewpoint specifications may be incorporated by reference (such as to a suitable recommended practice or previously defined practice). An architectural description shall include a rationale for the selection of each viewpoint. The rationale shall address the extent to which the stakeholders and concerns are covered by the viewpoints selected.

Views

An architectural description is organized into one or more constituents called (architectural) views. Each view addresses one or more of the concerns of the system stakeholders. The term view is used to refer to the expression of a system's architecture with respect to a particular viewpoint.

The relationship between viewpoint and view is analogous to that of a template and an instance of that template. The *viewpoint* is the template and the *view* is the instance of the template.

Contextual View

The primary goal of this view is to identify the external points of interaction (physical and logical/data) between AMI and anything outside of AMI. Once these points of interaction are defined, security architecture is developed to address the concerns of the stakeholders involved. Use cases are used to model customer, third party and utility interactions with AMI in Chapter 2 of this document.

Elaborations of the interactions in this view are unlikely to be complete; they should however provide representative examples of –

- Use cases of the outside world interacting with (stimulating) AMI
- Use cases of AMI interacting with (stimulating) the outside world
- Misuse or abuse cases in either direction; that is, specific uses that should be prevented
- Any actor sub-categories where the actor uses the system in a fashion that implies security needs that differ from major actors (e.g., leading to identification of access domains/privilege levels)
- Physical interactions (e.g., installing a meter or physical access to assets like collectors)

- Logical interactions (e.g., user monitors or modifies settings with the utility via web browser or utility initiates a demand-response interaction with a residence)

Elements of the view are the AMI system (as a black box), human actors, and connected systems. Relations of the view are vague - "interacts with", with elaboration in the prose.

Top Level Model

The top level model represents a high level view of the external stakeholders that interact with the AMI system. This model is used to provide an understanding of security concerns of interaction with AMI for these stakeholders.

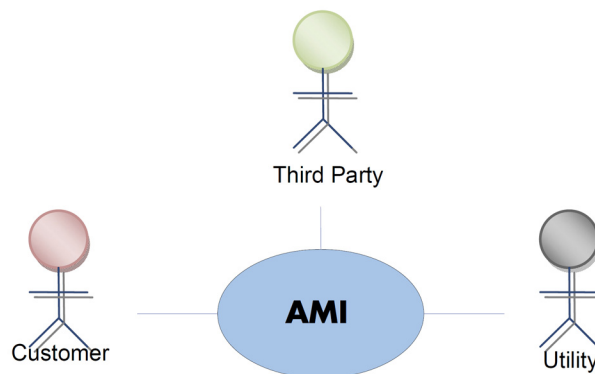


Figure 2-4
AMI Top Level Model

General security interaction needs:

- Customers are the consumers of AMI services and have a primary desire of availability and privacy from AMI and service value.
- Third Parties manage AMI resources with delegated authority from the Customer or Utility through an established trust relationship.
- Utilities provide AMI services and primary desire reliably gather information from the Customer to support the availability, resiliency and survivability of the electric grid.

Constraints:

- Bandwidth – current technologies have limited bandwidth for providing security services (examples: encryption, network management services).
- Latency – the time between when data is requested or generated and the time it is received. In many cases, data is only useful if received within a specific window of time.
- Storage – devices that store information either persistently or stage data temporarily are limited in the amount of data they are capable of storing at any given time.

- Processing – the rate at which a device can process information. It is important to keep in mind cryptographic functions require additional processing horsepower above normal processor usage.

Customer Model

The customer model focuses on the interactions between a customer and the AMI system. Customers may include sub-actors such as:

- Residential Customer (Private home owners)
- Commercial Customer (Office buildings, Apartment Complexes)
- Industrial Customer (Manufacturing plants)
- Municipalities Customer (Street lights, traffic lights, subways)

Sub-actors may be considered in the instance that there is different security treatment applied based on the role a sub-actor plays. If the security treatment of all sub-actors is the same or similar then the group is treated as a whole. The differentiating properties are identified in the cases where sub-actors only differ slightly in the treatment of security. The following diagram represents the relationship between the customer and AMI system where the customer may perform a stimulus on the AMI system or vice versa.

The following use cases are used to define the relationship between the customer and AMI:



**Figure 2-5
Customer Model**

Customer reduces their usage in response to pricing or voluntary load reduction event:

- The utility can notify customers through the AMI system that demand reduction is requested for the purposes of either improving grid reliability, performing economic dispatch (energy trading), or deferring buying energy.

There are two levels of advanced warning which are envisioned for AMI demand response systems as outlined in Distribution Use Case 2. The first being predicted energy shortages—a few hours notice in advanced—and the emergency shortages—minute to sub-minute notices.

Security Objective:

- Prevent false warnings from reaching the customer.

- Ensure that only people and/or systems that are authorized by the utility can send warnings to the customer
- Ensure that the system is resilient to periods of over-subscribed network utilization, especially in the case of emergency shortages.

Customer has access to recent energy usage and cost at their site:

- Customers can view a variety of information being gathered by their meter, permitting them to make energy-efficient choices and to shift demand to off-peak periods. Customers may access this information through a variety methods.

Security Objective:

- Protect the variety of methods of access from unauthorized access by unauthorized persons outside of the site.
- Protect the confidentiality of the usage and data associated with a particular customer or site.
- Protect the devices that communicate the usage and cost data from tampering.
- Validate that the communication of the usage and cost data is in a manner that is consistent with the utilities intent. For example, display only “need to know” data; ensure that all displayed data is consistent with respect to reality.

Customer prepays for electric services:

- Customers of the AMI system can prepay their accounts and read their current balance. Pre-pay may be done through the internet, phone, or other method.

Security Objective:

- Compliance with PCI or other applicable standard is required by utilities or financial entities
- Ensure that the AMI system and/or payment devices are resistant to payment fraud of many types
- Ensure that payment data confidentiality is maintained

External clients use the AMI system to interact with devices at customer site:

- The Advanced Meter Infrastructure (AMI) will enable third parties, such as energy management companies, to use the communication infrastructure as a gateway to monitor and control customer equipment located at the customer’s premise. The AMI will be required to enable on-demand requests and support a secure environment for the transmission of customer confidential information.

Security Objective:

- Ensure that all third-parties agree to some standard of data confidentiality agreement.
- Ensure that all third-parties agree to some standard of granting access to systems which allow access to monitor and control customer equipment at the premise.
- Ensure that all communications that result in an action with equipment at a customer premise is authorized, authenticated, non-repudiated, logged.
- Ensure that the communication path to a customer premise that allows control of equipment is secured and tamper proof.

- Ensure that customers are required to agree to specific third-party access to their premise gateway.

Third Party Model

The third party model represents the interaction between third parties and the AMI system. Third parties include utility contracted organizations such as a telecom provider, other utility, etc. Third parties may also include organizations that have established contracts with the customer for managing their premise devices within the home area network, for example an energy management system.

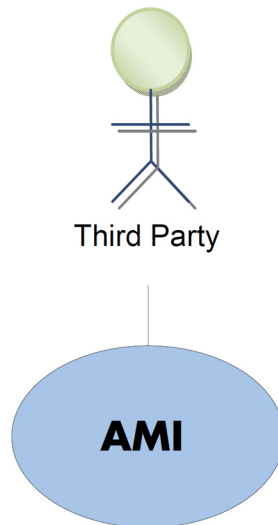


Figure 2-6
Third Party Model

The following are use cases describing the relationships between potential third parties and the AMI system.

Multiple Clients Read Demand and Energy Data Automatically from Customer Premises:

- The AMI system can be used to permit gas and water utilities, contract meter readers, aggregators and other third parties to read electrical meters, read gas and water meters, or control third-party equipment on customer premises.

Security Objective:

- To protect customer information. Customer grants the right to what information is disseminated and to whom.
- To maintain integrity of meter data. Meter data should be protected from manipulation or deletion.
- To establish timely availability of the meter data to the clients for direct scheduled and non-scheduled reads.

Utility Model

The utility model describes interactions between the Utility stakeholder and the AMI system in order to describe the security treatments that need to be applied.



Figure 2-7
Utility Model

Utility stakeholder security concerns about AMI:

- Loss of competitive advantage
- Loss of billing integrity
- Service degraded
- Increased cost
- Regulatory compliance

The following are use cases describing the relationships between the Utility and AMI.

Remote Meter Reads

- The AMI system permits the utility to remotely read meter data in intervals so that customers may be billed on their time of use, and demand can therefore be shifted from peak periods to off-peak periods, improving energy efficiency.

Security Objective:

- To maintain privacy of customer information in transit and within temporary and permanent memory storage.
- To protect meter data from manipulation or deletion.
- To provide timely availability of meter data.

Remote Connect / Disconnect

- The AMI system permits customers' electrical service to be remotely connected or disconnected for a variety of reasons, eliminating the need for utility personnel to visit the customer premises.

Security Objective:

- To protect integrity of connect/disconnect control messages; avoiding fake messages, fake senders, unintended receivers, manipulated messages

- To establish a secure connection in transporting connect/disconnect control messages
- To establish timely connectivity to connect/disconnect service
- It should also provide an efficient way in which to initiate/terminate a service agreement between customer and utility via remote switching service(on/off)

Security Objective:

- To establish timely connectivity to connect/disconnect service
- Posses the ability to remotely limit customer usage as a response to constrained supply as well as the customer's inability to pay the cost for the service

Security Objective:

- To protect integrity of connect/disconnect/limit control messages; avoiding fake messages, fake senders, unintended receivers, manipulated messages
- To establish a secure connection in transporting connect/disconnect/limit control messages
- In addition to the aforementioned the following business transactions should also be made available to the customer and utility:
 - Routine shut-off of service (move out)
 - Routine turn-on of service (move in)
 - Credit & Collections termination of service
 - Local/on site shut-off of service
 - Local/on site turn-on of service
 - Credit and Collection Service Limiting

Security Objective:

- To establish timely connectivity to connect/disconnect/limit service
- To produce historical, non-reputable record of event

Energy Theft

- The AMI system can be used to report when customers are stealing energy or tampering with their meter.

Security Objective:

- To produce reliable tamper indication
- To successfully transmit and receive a tamper signal
- To securely transmit tamper signal from a non-reputable source

Outage Management

- The AMI system can be used to report outages with greater precision than other sources, or verify outage reports from other sources.

Security Objective:

Power Quality Analysis

- The AMI system can be used to analyze the quality of electrical power by reporting harmonic data, RMS variations, Voltage and VARs, and can communicate directly with distribution automation networks to improve power quality and fault recovery times.

Security Objective:

- To maintain integrity of meter data sent; avoid manipulation and deletion
- To security meter data being transmitted; avoid customer's private data being released or intercepted
- To maintain availability of quality analysis information

Distributed Generation Management

- The AMI system can be used to dispatch, measure, regulate and detect distributed generation by customers.

Security Objective:

- To maintain integrity of AMI data being transmitted and stored to avoid manipulation and deletion
- To provide timely availability to system data
- Additional benefits include, but are not limited, to the following:
 - An increase in customer's willingness to participate in a load management program with the utilities
 - Provides a channel of communication from utility to load management devices
 - Reduction in the costs associated with the installation of AMI system components which would enable customer-provided distributed generation (this could increase customer's willingness to participate as well since there wouldn't be any out of pocket costs for the customer)
 - Creates an avenue for the utilities to dispatch and monitor those participants in distributed generation

Security Objective:

- To protect confidentiality of customer's data and maintain customer trust

Optimizing Lifetime of Network

- With the advent of new communications, in particular: wireless communication systems, PLC, and BPL, AMI devices would have the ability to interact with the critical physical infrastructure (e.g. IED's such as CBC (Capacitor Bank Controller) systems in order to improve: circuit efficiency, loss reduction, and energy savings). This will help optimize the lifetime of the physical infrastructure. (Ref: Distribution Use Case 2)

Security Objective:

- To protect integrity of data stored and in transit between AMI/Smart Grid devices

- To provide AMI/Smart Grid device information in a timely manner
- To protect AMI/Smart Grid communications from manipulation, deletion and interception

Management of the End-to-End Lifecycle of the Metering System

- An important requirement of such an AMI system would be the ability of the system to diagnose itself. The system should be able to: collect information about the status/health of certain devices, conduct remote diagnostics, and optimize operating parameters remotely.

Security Objective:

- To protect diagnostic data from being manipulated, deleted or masqueraded
- To validate the authenticity of the diagnostic messages being transmitted
- To provide timely availability to diagnostic data
- To secure diagnostic data from eavesdropping or capture

AMI System Adaptability

- The system should be able to adapt to anticipated changes that may or may not occur such as:
 - New physical communications methods
 - New features available from equipment vendors
 - New tariffs possibly with certain restrictions (e.g. number of rates or time)
 - Connections to new types of load control equipment
 - New communications protocols
 - Changes to operating parameters
 - New computing applications

Security Objective:

- The aforementioned should be accomplishable with minimal incremental cost in stark contrast to a wholesale system replacement

Security Objective:

- Objectives to be determined and prioritized based on technology implemented

Prepay

- Utilities use the AMI system to enforce disconnection when the prepayment balance reaches zero.

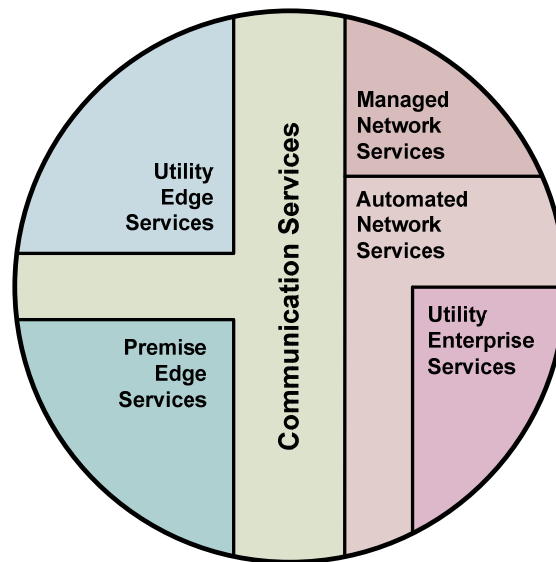
Security Objective:

- To provide confidentiality to customer payment and associated information; avoid eavesdropping, interception or collection of customer data stored (temporary or permanent) or in transit

- To provide integrity of data being transmitted including non-repudiation and validation of customer information transmitted
- To provide the customer availability to their respective account(s) within customer payment services

Security Domains View

This section describes the internal use cases; cases where activity is stimulated from entirely within AMI itself. Examples are automation and intelligent responses. The following diagram describes the internal services provided by AMI. Assumption is made that measurement, monitoring, and application control encompass all services.



**Figure 2-8
AMI Service Domains**

Legend:

- **Utility Edge Services** – All field services applications including monitoring, measurement and control controlled by the Utility
- **Premise Edge Services** – All field services applications including monitoring, measurement and control controlled by the Customer (Customer has control to delegate to third party)
- **Communications Services** – are applications that relay, route, and field aggregation, field communication aggregation, field communication distribution information.
- **Management Services** – attended support services for automated and communication services (includes device management)
- **Automated Services** – unattended collection, transmission of data and performs the necessary translation, transformation, response, and data staging
- **Business Services** – core business applications (includes asset management)

Stakeholders:

- Customer Users of the system
- Operators of the system

- Responsible Entities of the systems
- Implementers of the system
- Maintainers of the system

Concerns:

How is integrity maintained for processes?
 How is integrity maintained for data?
 How is confidentiality of customer data maintained (e.g. customer usage)?
 How is availability to utility assets maintained?

Viewpoint language:

Use Cases (Misuse Cases)
 Note: Potentially move down from business functions.

Analytic Methods:

Penetration Testing
 Auditing

Rationale:

This viewpoint was selected because it shows the relationship between AMI services requiring security measures. Drivers for this viewpoint include control, ownership, environmental, and functionality (capability) concerns.

Utility Edge Services Domain

Summary

The Utility Edge Services Domain allows the utility to interact with non-customer-owned edge assets, such a meter (electric, gas, or water) or other end-point device.

Assumptions

The Utility Edge Services Domain assumes a singular service endpoint (point of service).

Ownership and Control Concerns

The utility owns at least some of the assets within the Utility Edge Services Domain. Any asset not owned by the utility in question is owned by a peer entity, such as another utility.

The utility controls all assets within the Utility Edge Services Domain. Assets owned by another entity are controlled by the utility as a proxy for the owner.

Premise Edge Services Domain

Summary

The Premise Edge Services Domain allows the utility to interact with customer-owned edge assets, such as Home Area Network (HAN) devices.

Assumptions

The Premise Edge Services Domain assumes a singular customer.

Ownership and Control Concerns

The utility may own the assets within the Premise Edge Services Domain. Alternatively, assets in the Premise Edge Services Domain may be owned by the Customer or a Third Party Service Provider.

The utility controls all assets within the Premise Edge Services Domain. Control of assets owned by another entity is delegated to the utility as part of admission to the Premise Edge Services Domain.

Communication Services Domain

Summary

The Communication Services Domain facilitates communication between assets in adjacent service domains (Utility Edge, Premise Edge, Managed Network, and Automated Network) and may facilitate communication between assets within the same domain.

Assumptions

The Communication Services Domain assumes interfaces to multiple Utility Edge and Premise Edge Services Domains, and may include interfaces to multiple Managed Network and Automated Network Services Domains.

Ownership and Control Concerns

The utility may own the assets within the Communication Services Domain. Alternatively, assets in the Communication Services Domain may be owned by a Communication Services Provider.

The utility may control assets within the Communication Services Domain. Alternatively, assets in the Communication Services Domain may be controlled by a Communication Services Provider. Assets controlled by a Communication Services Provider may be included in a contractual services agreement with the utility.

Managed Network Services Domain

Summary

The Managed Network Services Domain allows the utility to manage communication configuration, settings, capabilities, and resources in each of the other service domains.

Assumptions

The utility primarily uses assets in the Managed Network Services Domain to manipulate configurations and settings in the Automated Network Services Domain (i.e., human interface).

Ownership and Control Concerns

The utility may own the assets within the Managed Network Services Domain. Alternatively, assets in the Managed Network Services Domain may be owned by a Communication Services Provider.

The utility controls all assets within the Managed Network Services Domain. Control of assets owned by another entity is delegated to the utility as part of admission to the Managed Network Services Domain.

Automated Network Services Domain

Summary

The Automated Network Services Domain allows the utility to implement the communication parameters specified using assets in the Managed Network Services Domain.

Assumptions

The utility primarily uses assets in the Automated Network Services Domain to perform routine and/or repetitive operations at high speed without manual intervention.

Ownership and Control Concerns

The utility may own the assets within the Automated Network Services Domain. Alternatively, assets in the Automated Network Services Domain may be owned by a Communication Services Provider.

The utility controls all assets within the Automated Network Services Domain. Control of assets owned by another entity is delegated to the utility as part of admission to the Automated Network Services Domain.

Utility Enterprise Services Domain

Summary

The Utility Enterprise Services Domain allows the utility to perform the business functions required by enterprise applications.

Assumptions

The assets in the Utility Enterprise Services Domain provide the interface to AMI systems and data for the remainder of the enterprise.

Ownership and Control Concerns

The utility owns all assets within the Utility Enterprise Services Domain.

The utility controls all assets within the Utility Enterprise Services Domain.

AMI-SEC SSR: Appendix B – Supplemental Material: Business Functions as Stakeholders in AMI Systems

Introduction

The information provided in this appendix provides supplemental background material for understanding potential business functions within AMI systems. Some of the business functions provide a forward-looking perspective into AMI systems. This information may be used in the development of a utility's specific use cases, but the information in this section is not intended to be regarded as security requirements for AMI.

Scope of AMI Systems

As Smart Grid requirements drive the development new technologies and the deployment of new systems, more and more new and existing Business Functions are becoming stakeholders in these new systems. Advanced Metering Infrastructure (AMI) systems are prime examples of these new technologies: they clearly can provide Smart Grid benefits. However, AMI systems are still a work in process, which can clearly benefit some business functions, but which appear potentially useful for others while not yet obviously beneficial. In addition, there will inevitably be business functions which are not yet foreseen that will suddenly become viable.

AMI systems consist of the hardware, software and associated system and data management applications that create a communications network between end systems at customer premises (including meters, gateways, and other equipment) and diverse business and operational systems of utilities and third parties. AMI systems provide the technology to allow the exchange of information between customer end systems and those other utility and third party systems. In order to protect this critical infrastructure, end-to-end security must be provided across the AMI systems, encompassing the customer end systems as well as the utility and third party systems which are interfaced to the AMI systems (see Figure 2-9).

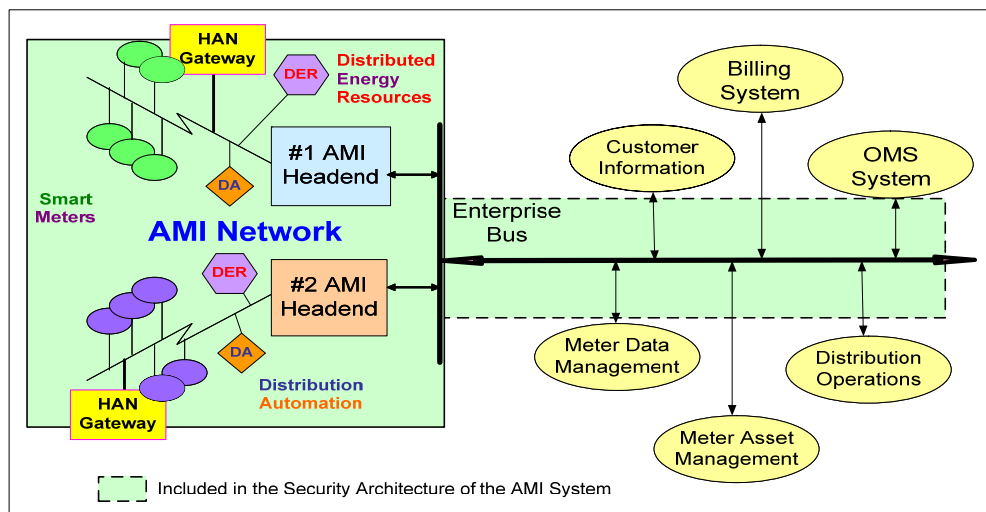


Figure 2-9
Scope of AMI Systems

Overview of Business Functions Utilizing AMI Systems

Identifying and describing Business Functions are the most effective methods for understanding the information exchange requirements. The range of Business Functions utilizing the AMI systems is shown in Figure 2-10.

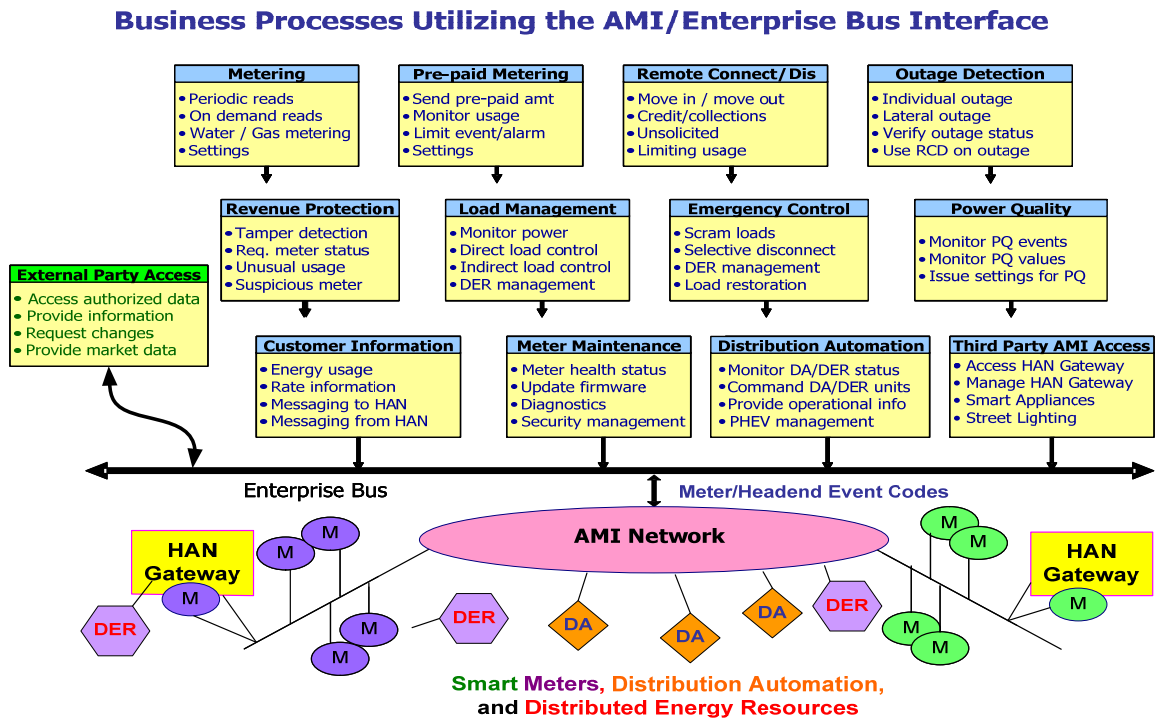


Figure 2-10
Business Functions Utilizing the AMI/Enterprise Bus Interface

The following sections expand on these Business Functions.

AMI Metering Business Functions

Metering Services

Metering services provide the basic meter reading capabilities for generating customer bills. Different types of metering services are usually provided, depending upon the type of customer (residential, smaller commercial, larger commercial, smaller industrial, larger industrial) and upon the applicable customer tariff.

Periodic Meter Reading

Traditionally for residential customers and the smaller C&I customers, periodic meter reading services are performed monthly via a meter reader, possibly using handheld or mobile meter reading tools. It takes the current index reading from the meter and records it for billing and other purposes. For Time-of-Use (TOU) data from net metering or other TOU meters, intervals can be established such as “on-peak” and “off-peak”, as defined in the utility’s tariffs. In some

utilities or under certain circumstances, actual meter reading is done less frequently, and bills rely on meter reading estimates which are “trued up” later.

In AMI systems, periodic meter reading will retrieve interval data (usually hourly data but possibly 15-minute or 5-minute data). The frequency of retrieving the data from the meter can vary from every 5 minutes, to hourly, to daily, and to monthly.

Among the benefits of AMI for periodic meter readings are the increased accuracy (fewer estimated reads, more exact reading dates/times), and the availability of the to-date meter readings during the billing cycle.

On-Demand Meter Reading

Traditionally, on-demand meter reading is performed by sending a meter reader to the meter site around the time requested for the meter reading. Typically reasons for on-demand meter readings include:

- Move in / move out
- Limited usage tariffs
- Billing questions by the customer
- Revenue protection concerns

AMI systems will permit on-demand reads to take place almost immediately or more precisely at the scheduled date and time.

Net Metering for DER

When customers have the ability to generate or store power as well as consume power, net metering is installed to measure not only the flow of power in each direction, but also when the net power flows occurred. Often Time of Use (TOU) tariffs are employed.

Today larger C&I customers and an increasing number of residential and smaller C&I customers have net metering installed for their photovoltaic systems, wind turbines, combined heat and power (CHP), and other DER devices. As plug-in hybrid electric vehicles (PHEVs) become available, net metering will increasingly be implemented in homes and small businesses, even parking lots.

AMI systems can facilitate the management of net metering, particularly if pricing becomes more dynamic and/or more fine-grained than currently used for TOU rates.

Paycheck Matching

Today, depending on the utility bills arrive monthly, quarterly or yearly and not on a schedule selected by the customer, rather they are based on a schedule that matches the meter reading schedules. Small scale trials have proven that for customers who are living on the margin and miss occasional payments, that matching the date and frequency of the customer’s paycheck reduces the number of late or missing payments significantly, cutting collection costs and reducing the cost to all customers.

AMI systems provide the flexibility to provide customers with bills when the customers prefer to receive them.

Pre-Paid Metering

Prepayment Tariffs

Customers who either want a lower rate or have a history of slow payment can benefit from prepayment of power. Smart metering makes it easier to deploy new types of prepayment to customers and provide them with better visibility on the remaining hours of power, as well as extending time of use rates to prepayment customers.

AMI systems can also trigger notifications when the pre-payment limits are close to being reached and/or have been exceeded.

Limited Energy Usage

Traditionally, customers who use pre-payment tariffs need to go through the utility customer representatives to learn about their current usage or to extend their energy limits. With AMI systems, customers can see their current usage and limits, and may be able to automatically extend their limits electronically (e.g. pay over the Internet with the AMI system then updating their energy limits).

Limited Demand

Customers can also have tariffs that limit demand. Some C&I customers have rates that depended on the peak 15-minute demand. Some other customers actually have current limiting equipment to ensure limited demand.

AMI systems can provide the customer with the information necessary to manage their demand limits more precisely and effectively.

Revenue Protection

Tamper Detection

Non-technical losses (or theft of power by another name) have long been the subject of an ongoing battle between utilities and certain customers. In a traditional meter, when the meter reader arrives, they can look for visual signs of tampering, such as broken seals and meters plugged in upside down. During the analysis of the data, tampering that is not visually obvious may be detected, such as anomalous low usage.

With AMI systems, smart meters can immediately issue “tampering” alarms that are set off by a number of different sensors and routines in the meter. These tampering actions can include meter removal, tilt, and unauthorized access attempts (smart meters cannot be plugged in upside down).

Anomalous Readings

Some anomalous readings in the meter can trigger warning events which can be immediately investigated to determine if they are legitimate (people are on vacation or the factory has shut down an assembly line) or if they are due to tampering, such as wiring around the meter.

Meter Status

Some theft of power has occurred by the bypassing of the meter for a few days between scheduled readings by a meter reader. AMI systems will permit the status of meters to be verified at any time during the reading cycle.

Suspicious Meter

Some theft of power has occurred by the replacement of a certified meter with a “slow run” meter. AMI systems with smart meters will have each meter “registered” with an identity that cannot be tampered with without showing evidence of that tampering.

Remote Connect / Disconnect

Remote Connect for Move-In

The customer initiates a request to move into a location that has electric service but is currently disconnected at the meter. The request can be for immediate action or for a connection at a specific date and time.

Traditionally, utilities send a metering service person to connect the meter. With an AMI system, the connection can be performed remotely by closing the remote connect/disconnect (RCD) switch, using the following steps:

- At the appropriate date and time, read the meter to get the latest reading and to verify that the meter is functional.
- Determine there is no backfeed current detected by the meter
- Issue the connect command to the meter
- Verify that the meter is connected

Remote Connect for Reinstatement on Payment

Once a customer pays who was disconnected due to non-payment (or works out some mutually accepted agreements), the meter needs to be reconnected by closing the remote connect/disconnect (RCD) switch. The same process as for a move-in would be used.

Remote Disconnect for Move-Out

Traditionally, move-outs are handled by performing a special meter read (“soft” disconnect) around the time of the move-out. Since the power is not actually disconnected, this method can lead to illegal use of power after the move-out and before the next move-in.

With an AMI system, a move-out can have a “hard” disconnect that opens the RCD switch, typically using the following steps:

- Verify that the meter can be disconnected remotely
- Issue the disconnect command at the appropriate date and time
- Verify that the meter is disconnected
- Read the meter for the final billing.

In conjunction with the next meter reading during a move-in connection, any delta between the readings can be detected as a possible tampering or illegal usage of power.

Remote Disconnect for Non-Payment

The cost of collections is high, typically higher yet is the cost of disconnecting a customer – not only the lost revenue, but the cost of two special trips to the location, one to turn the power off and eventually another to turn it back on again. While remote disconnects are still pricy today, they offer a much lower cost for turning the power off and once customers understand that a disconnect can be done immediately, collections costs also seem to decline.

Remote Disconnect for Emergency Load Control

Some customers could get special rates if they agree to the temporary suspension of electric service in support emergency load shed activities. This is an alternative to wide-scale rolling blackouts and circuit level interruptions. Customers who choose to participate in such a program are eligible to have their power cut during the critical periods.

This type of selective black-out provides the means for reducing power demands on the overall grid while selectively maintaining service to critical customers such as public infrastructure (i.e. traffic lights) and medical facilities.

Unsolicited Connect / Disconnect Event

Unsolicited connect/disconnect events can be caused by a number of activities, covered in the following Business Functions:

- Meter manually switched off by utility employee, including both valid and invalid switching
- Meter manually switched off by unknown party, including both valid and invalid switching
- Software/hardware failure switches meter off/on (also includes unauthorized command causing switch)
- Miscellaneous event causes meter to switch off/on
- Meter manually switched on by utility employee, including both valid and invalid switching
- Meter manually switched on by unknown party, including both valid and invalid switching

Meter Maintenance

Connectivity Validation

Determination that the customer is connected to the grid and even with the right signally which phase and circuit they are on. In several reviews of customer connectivity today for utilities the phase information is missing from many single phase connections and in some cases the circuit

information is missing or wrong. Validation helps with making sure the data analysis is correct for engineering studies and other purposes.

Geo-Location

In asset data bases today many meters are literally miles (kilometers) from their physical location in the real world. During the installation of the meters GPS or other geo-location techniques can be used to provide accurate information on the meter's location. If the location of the meter accidentally is changed in the database it is possible to flag the problem. This is possible since the location of the circuit is known, helping to eliminate problems that creep in over the long life of electric (gas and water) networks.

Battery Management

If there were no smart meters, there would be no need to do battery management, so the benefit only works for smart meter equipped networks. In an operational world the meters communicate more, running the battery down faster. It is important to have good battery management or the cost of maintaining the system will skyrocket. Remote battery monitoring (as part of the regular communications) can help deal with battery replacement planning and battery life extension.

Distribution Operations Business Functions

Distribution Automation (DA)

DA Equipment Monitoring and Control

Some utilities are planning to use the AMI system for distribution automation, as a minimum for direct monitoring and more sophisticated control of capacitor banks and voltage regulators on feeders, rather than relying on local actions triggered by time, current, or voltage levels. Others also would like to monitor and control automated switches and fault indicators if the AMI network were able to stay alive during grid power outages, presumably via battery backup for critical nodes.

Use of Smart Meters for Power System Information

If more sensors were available in the distribution network, it would be possible to do distribution SCADA, with the deployment of smart meters and a near real-time communications network, it is possible to pick a sub-set of the smart meters and use them as bell weather devices in the grid to provide a distribution SCADA like capability. In addition some utilities are installing smart meters in place of RTUs for extending their current SCADA system further into the grid.

Power System Security/Reliability

As interference with the operation of the distribution grid becomes more common, it becomes more and more important to monitor the integrity of the grid at all times. Smart meters offer a way to get a "heart beat" from the whole of the distribution system on a regular basis thus providing assurance that the grid is intact. That it has not been attacked by a mad man in a backhoe or a copper thief with a chainsaw.

Power System Protection

Overloads on the system once were not a big issue devices could operate at two or even three times their rated capacity for several hours on a peak day. Today devices have been engineered to run at loads much closer to their ratings, and overloads of several hours can cause degradation in the devices. By being able to monitor the load on the device and with the deployment of direct load control or disconnect switches, the load on the device can be managed until it can be replaced or upgraded, the same goes for other physical assets that may be de-rated, allowing at least some of the lights to stay on.

Site/Line Status

Tag out procedures are supposed to render a segment of the network dead and safe to work on, unfortunately with the addition of true distributed generation, it is possible to have an islanding failure and to have a line that the crew expects to be ready for work, to actually still be live. With the correct smart metering system and the right connectivity mapping, it is possible to use the smart meters to determine if any power is still flowing through the lines. With the potential for the sales of plug-in hybrids to ramp up quickly in the next decade and the lack of protection schemes currently this may become an even larger issue.

Automation of Emergency Response

Today in a fire, the fire department normally handles the disconnection of the power and other utilities from the involved structures. Often with a fire axe! With the advent of remote disconnects in the meters it will be possible to cut the power to the structure, as well as gas and other utilities. This makes it easier to restore service after small problems and to more rapidly remove a possible source of problems from the structure.

Dynamic Rating of Feeders

Operators can dynamically rate feeders based on the more accurate power system information retrieved via the AMI system from strategic locations. This permits the operators to decide when they can run feeders beyond their ostensible ratings or when to perform multi-level feeder reconfigurations to balance the loads and avoid overloads.

Outage Detection and Restoration

Outage Detection

Today the majority of real time information about a customer, comes from the customer, they pick up the phone and call about issues they have, such as an outage, and provide information to the utility. In the future, the smart meter will be able to provide up to date information about the customer and the status of their service.

Scheduled Outage Notification

For either scheduled outages for maintenance or for notification of a customer that the power is out in their home when they are at work or away from home, smart metering provides a needed piece. For scheduled outages, if there are in home displays deployed the metering system can provide the outage times and durations to the customers directly impacted and no others. This

minimizes possible security issues of the information getting into the wrong hands as security systems that require power stop functioning, etc. It also helps with the number of phone calls that have to be placed to customers to let them know that maintenance is happening. With the connectivity verification, it is possible to really know who is on a specific path and to accurately manage the outage. For unscheduled outages, it is possible to use the information coming from the meters to let customers know that they will be returning to a location with no power (water, gas) and that will let them make alternate plans, rather than walking into a surprise.

Street Lighting Outage Detection

Street lighting can be critical to safety and crime-prevention, and yet monitoring which street lights are out is currently performed haphazardly by civil servants and concerned citizens. AMI systems could be used to monitor these lights.

Outage Restoration Verification

Restoration verification has the metering system report in as the power it returned to the meters. This alert function is built into many meters that are being deployed as smart meters today and includes a timestamp for the restoration time. For some utilities this is improving their IEEE indices, since their crews may take several minutes to complete other actions before reporting the power back on. It can also be used to help isolate nested outages and help the field crews get to the root cause of those nested outages before they leave the scene.

Planned Outage Scheduling

Ideally, planned outages should be done at a time when they have the least impact on the customers. Today we use rules of thumb about when to take a planned outage, in the future with a complete data set it is possible to adjust the time of the outage to correspond with the lowest number of customers demanding power. This minimizes the impact to the customers.

Planned Outage Restoration Verification

In completing work orders, it is useful to know that all of the customers that were affected by the work order have power and that there are no outstanding issues that need to be corrected, prior to the crew leaving the area. The ability to “ping” every meter in the area that was affected by the work order and determine if there are any customers who are not communicating that they have power is useful to minimize return trips to the work area to restore single customers.

Calculation of IEEE Outage Indices

Today the IEEE indices are manually calculated in most utilities and they are not up to date, since the information needed to track them comes from field reports and other documents that do not feed into a central location. Additionally since not every single point is tracked in any system for outages, it is impossible to accurately determine the indices. Most utilities have gotten very good at the development of indices that are very close to the reality that their customers are seeing and to the limits of the information available.

Call Center Unloading

Today we rely on customers to call in when there is an outage; this normally is one of the factors in sizing call centers and staffing them. When smart metering is deployed in the right way, it is possible for the system to determine where the outages are and to let the utility call the customer with an outage message and an estimated time to repair. In the long run this will reduce the loading on the call center during periods of high outage levels.

Load Management

Direct Load Control

Direct Load Control provides active control by the utility of customer appliances (e.g. cycling of air conditioner, water heaters, and pool pumps) and certain C&I customer systems (e.g. plenum pre-cooling, heat storage management). Direct load control is thus a callable and schedulable resource, and can be used in place of operational reserves in generation scheduling. Customer like it (if it is invisible), because they do not have to think about it, they sign up, allow the installation and forget it.

AMI systems will enhance the ability of utilities to include more customers in (appropriate) programs of direct load control, since it will increase the number of appliances accessible for participation in load control, and will improve the “near-real-time” monitoring of the results of the load control actions.

Demand Side Management

Management of the use of energy is important in a number of ways. Demand Side Management is a step beyond just tariff based load reduction. It assumes that customer will setup or allow to be set up equipment to reduce load when signals are sent to the customer’s location. The customer is in charge of making demand side management decisions.

Load Shift Scheduling

Given the ability to get customers to shift load when requested, and to do bottom up simulation it becomes possible to work with customers who have the ability to shift load to different times of the day or week. This ability to do load scheduling could have an impact on transmission and other capital expenses.

Curtailment Planning

To do proper load reduction, for either de-rated equipment or for planned outage or even to deal with load growth that has gotten ahead of system upgrades takes having data on what the loads are and what can be curtailed. In California, load curtailment has been called rolling blackouts, the best that can be done without an ability to control the demand on the system in a more granular fashion. By using curtailment planning, notice can be given in advance to the impacted customers and they have enough time to respond if they have an option in their contract to keep the power on.

Selective Load Management through Home Area Networks

With the deployment of home area networks the utility can choose to manage the load on the grid, to manage peak, to manage customer bills, to allow for a generation or transmission issue to be corrected or other reasons. This can permit, with the right equipment the reduction in the need for reserve margin in generation and for rolling reserve, the selective load management becoming a virtual power plant that is a callable and schedulable asset.

Power Quality Management

Power Quality Monitoring

Today for some larger customers and at select locations on the grid we are able to monitor harmonics, wave form, phase angles and other power quality indicators. The need continues to grow as large screen televisions and other consumer electronics devices are increasingly adding harmonics to the system. With the newest metering technology some power quality monitoring is built into the meter and more is on the way. While not every house needs to monitor power quality, a percentage of the meters deployed should probably have this advanced capability.

Asset Load Monitoring

With Connectivity Verification and Geo-Location information it is possible to group the devices in a tree structure that correctly shows connection points in the grid. With the ability to read intervals from the meters it is then possible to build a picture of the load that each asset (e.g. transformers, conductors, etc.) are subjected to. This allows an operator to monitor heavily loaded assets and look for ways to off load some of the demand from that asset. It also allows a maintenance planner to prioritize what maintenance should be done to maximize the reliability of the grid, as part of a reliability centered maintenance program.

Phase Balancing

One of the least talked about issues with losses in the distribution grid today is single phase load and the imbalance it can cause between the phases. These losses have seldom been measured in the grid and little study has been done of the amount of phase imbalance on the grid today. In early studies the chronic phase imbalance in several circuits that were monitored averaged over 10 percent. While correction is hard when the circuit is run as single phase laterals, in many cases there is enough load on the feeder portion of the circuit to allow rebalancing of the circuit to eliminate more than half of the chronic phase imbalance.

Load Balancing

Where there is an option to move a portion of the load from one circuit to another, the instrumentation is not always available to make good choices or to be able to forecast the load in a way that makes the movement pro-active instead of reactive. Automated feeder switches, and segmentation devices are becoming more and more common in the grid. The ability to use metering data to support the operation of these devices will only increase their value to the grid operator. Today with information only at the substation end of the circuit, it is tough to determine where on the circuit the load really is and where to position segmentation and when to activate a

segmentation device when more than one is available. Operators today typically learn the right way by trial and error on the system.

Distributed Energy Resource (DER) Management

In the future, more and more of the resources on the grid will be connected to the distribution network and will complicate the operation of the grid for the future. Failure to integrate these resources into the grid and understand their impact will only degrade the operation of the grid and its reliability. It is no longer an option to deal with distributed resources, the time for refusing to allow them has passed. The only choice is to either embrace them and manage their impact or ignore them and suffer the consequences.

Direct Monitoring and Control of DER

Some DER units at customer sites could be monitored in “near-real-time” and possibly directly controlled by the utility or a third party (e.g. an aggregator) via the AMI system, in an equivalent manner to load control.

Shut-Down or Islanding Verification for DER

Each time an outage occurs that affects the power grid with DER, the DER should either shut down or island itself from the rest of the grid, only feeding the “microgrid” that is directly attached to. In many cases the shut-down or islanding equipment in smaller installations is poorly installed or poorly maintained. This leads to leakage of the power into the rest of the grid and potential problems for the field crews.

Each time an outage occurs, meters that are designed to monitor net power can tell if the islanding occurred correctly, if they are installed at the right point in the system. This reporting can minimize crew safety and allow the utility to let the customer know that maintenance is required on their DER system. In most cases when the islanding fails, other problems also exist that reduce the efficiency of the DER system, costing the customer the power that they expected to get from the system.

Plug-in Hybrid Vehicle (PHEV) Management

Depending on how plug-in hybrids are sold and how the consumers take to them, they may either become one of the largest new uses of power or they may not have an impact. A major problem is that planners are now assuming that they will be mobile generation plants, that the drivers will burn fuel and store power in the battery to be drawn during the peak times while parked in the company garage. Others have assumed that the cars will become the largest new consumer of power in the downtown grid, an overstressed part of the grid already.

How PHEVs are managed and how consumers will use them is a social experiment. What is not is that they will draw a large amount of power from somewhere and have the potential to store a lot of power for later use. How the power company measures which car provides or takes how many megawatt hours and proves it and bills for it, will be an interesting change. Smart meters can help with this if the right standards are place to deal with communication from the car to the meter.

Net and Gross DER Monitoring

There are two different generation results from distributed generation, the gross output of the device and the net input into the grid, after the owner takes their needed energy. The two can be very different at times when the DER is creating most power the owner may also be drawing so heavily that the net result to the grid is still negative. At other times, the demand from the owner may be less than the output, even though the output may be well under the design output of the device.

Some utilities have decided to reward renewable generation owners on the gross output, while other utilities have decided to reward them on the net output, possibly with TOU rates. But to manage a utility and the reliability of the grid it is important to know both the net and the gross output of the device for simulation, load forecasting and for engineering design.

Storage Fill/Draw Management

If someone has installed distributed storage, when should it be topped off, and when should the storage discharge? Today's answer is to use a timer in most cases or a phone based trigger. For one utility the use of electric thermal storage for winter heat and time of use tariffs that encouraged topping up at a specific time of the day resulted in the destruction of a number of pieces of equipment on the grid as demand exceeded the local ability to supply that demand. The attempt to improve the load factor on the grid with this storage system resulted instead with demand that exceeded all expectations.

Smart metering with a home area network capability can trigger each storage device based on the total load in the area, leveling out the peaks in the system and providing better use of generation resources that may be variable in nature.

Supply Following Tariffs

DER has a strong probability of having a large percentage of renewable generation which has a strong variable component. Since the supply will be variable and highly variable on short notice, it may be that to avoid either a large component of rolling reserve that uses fossil fuels, it may be that a supply following tariff could be possible. It would require a very high speed forecasting system, excellent weather information and near real time communications to devices in the homes and in businesses with almost instant response. This is a tall order in today's world, but the cable companies have proven that millions of devices are possible to broadcast to in near real-time, so it is possible.

Smart meters on the right communications network and with the right in home gateway could provide a piece of this supply following tariff system.

Small Fossil Source Management

There is a large amount of diesel generation that is installed on customer sites to deal with outages on the grid. Some companies are now forming to manage these resources, not for outage, but for peak power production, bidding into the market a few megawatts at a time. While the use of these resources is a good thing, the penetration of private companies will never be as complete as if the utility were to work with their customers to equip most of this generation with controls and monitoring equipment.

Whether the utility operates and maintains these resources or allows third parties to take responsibility is not important. What is important is that smart metering can reduce the cost and complexity of making these resources available. In California more than 2,000 Megawatts of generation are already installed, more than enough to end most rolling blackouts (if the resources are in the right areas).

Distribution Planning

Vegetation Management

Momentary outages normally increase as vegetation grows back in an area and starts to become potential issue for overhead lines. Smart metering allows the return of momentary outage information and allows the outage counts to be overlaid on a GIS system. This allows the planners to better target vegetation management people to the right locations. In the underground world, cable failures and splice failures can be found early, prior to a complete failure.

Regional and Local Load Forecasting

Given the ability to draw a full data set from the field, it is now possible to forecast regional and local loads and generation that can be used to prepare for and to set prices for both demand and supply.

Simulations of Responses to Pricing and Direct Control Actions

As more detailed information is available through AMI systems on regional and local loads and generation, it will be possible to assess the responses of both customers and the power system to price-related actions as well as direct control actions. This ability to simulate the market a day or more in advance should allow for better planning and for the system to run with smaller amounts of rolling reserve and ancillary services.

Asset Load Analysis

With the ability to have a real load history on a specific asset and to be able to do bottom up forecasting, the same can be done for assets in the connection tree. This should allow planners and others to see potential problem areas before they really exist.

Design Standards

Many of today's standards assume that complete data is not available so there are factors of safety built into the calculations at each step of the design process for the transmission and distribution grid to make sure that the design is useful for its full design life. The improvement in load and demand data from the smart meters will make it possible to remove many of the rules of thumb and design to the real needs of the customers.

Maintenance Standards

Maintenance is done with incomplete information. So the maintenance standards allow for this, in some cases too much maintenance is done and sometimes too little is done, standards call for the best possible maintenance planning that incomplete information can provide. The good news

is that the reliability of the system is very high, better than any other service (including telecommunications and cable TV) that is available to a customer. The bad news is with all the retirements in the industry, the experienced technicians that are required to make the judgment calls in the field will all be replaced in a few years. Improving the standards for maintenance with better information will mean that the new field workers will be routed to the highest priority work almost every time.

Rebuild Cycle

When is the right time to rebuild a circuit and how much of it really needs to be upgraded? Today with the information we have, we hang some recorders and use a few weeks or months of data from a few locations to determine what to rebuild, with the improved data set and the improved standards it is possible to actually determine the sections of the grid to rebuild and how much to reinforce them.

Replacement Planning

Equipment replacement is based on the estimated load or a load study that is normally conducted with less than perfect information. This has resulted in the engineering team being conservative and over sizing many of the replacement equipment. Smart metering offers better information to make better sizing decisions.

Work Management

Work Dispatch Improvement

Today we use manufacturers' recommendations, models, estimates, and visual inspection to determine when a lot of maintenance work should be done. While it works, in some utilities it means more maintenance than others think is required and in others it means less. In almost every case, some maintenance is performed that is not really required for reliability centered maintenance strategies. When smart metering information is available and used to do asset loading analysis and other data analysis, work can be more accurately dispatched to the crews in the field improving reliability in the system for the same number of jobs completed.

Order Completion Automation

Some utilities have the field crew log the completion of their job prior to packing up; others want the crew ready to roll prior to completion of the order. Some want the crews to look around before leaving, some want the crew to leave and let the customers call if there is still an issue in the area. With smart metering, as restoration alerts come in, it is possible to automate the time the job was completed and some of the closing paperwork, allowing the crew to stay in the field longer each day and to do less paperwork overall.

Field Worker Data Access

Today if a line worker wants to know the status of an area of the grid, she can measure power flow, she can look at meters or he can call dispatch. Access to near real time information on the status of the customers close to the worker's location is limited today. With the deployment of smart metering, depending on how the software is configured and the security setup, it may be

possible for a field worker to get access to the a near real-time map of the status of the customers in their working area, minimizing the need for dispatch to tell the worker where to go next and what to do.

With experience, field workers have proven to be very good at determining where in their work area a likely root cause is, based on outage information, reducing the time it takes to find the cause and start the repair work.

Reliability Centered Maintenance (RCM) Planning

Today we guess at the loading on devices using models, and use that information to develop a reliability centered maintenance plan. Based on that information we do our best to perform the maintenance that the system requires to make sure that people have power. With the ability to do load monitoring and load forecasting more accurately, preseason maintenance can be scheduled based on the facts that the system generates. While it will never prevent all failures in the system, use of this information and a well designed RCM plan can result in significantly less outage for non-natural disaster causes.

Customer Interactions Business Functions

Customer Services

Remote Issue Validation

When a customer calls today with a problem, other than twenty questions on the phone or rolling a truck to the location, there is no way to understand if the customer really knows what the problem is or if they do not understand the problem. Use of near real time information from smart meters can allow the customer service representative (CSR) to provide better information to the customer and to provide better advice on what to do with the current situation. It can also reduce the dispatch of trucks for customer complaints. In general it reduces both call volume and call handling times.

Customer Dispute Management

The most frequent customer dispute is a high bill. They complain about the meter reading being wrong. In truth there are enough meter reading errors that high bills are a fact of life. But the ability to check the current meter reading directly from the meter while the customer is on the phone and re-calculate the bill if the bill was high, and to end the post call investigation, by being able to directly validate the customer dispute reduces the time to clear a complaint that is non-phone time and it reduces the call handling time of the life of the dispute. It is not unusual that the initial call time goes up, since the CSR has to explain how they are getting the information and may have to have the customer walk to the meter while on the phone and verify the numbers that show on the meter. This has reduced monthly disputes with chronic callers over a period of 3 to 6 months in most utilities that have this ability.

Outbound Customer Issue Notification

Not only can customers be called at work for problems with outage, but other problems can be determined and customers notified, in one case, a meter looked like it had been tampered with,

but the customer had a complaint about low voltage on file. A review of the situation determined that one of the wires was probably loose in the customer's breaker panel. That call resulted in the customer hiring an electrician and fixing a number of electrical problems in their home that the electrician uncovered while fixing the loose wire in the panel. This is one example of a number of proactive actions that can be taken with the customer to help them be safe and know what is going on with their energy consumption. Similar work was undertaken on behalf of a water company and a number of beyond the meter leaks were identified with night time readings on homes with high water bill complaints.

Customer Energy Advisory

Some utilities have undertaken to provide a customer energy consumption advisory that allowed customers to indicate what they have for energy consuming devices and information about their home. In return, the utilities rank their consumption against similar homes and provide feedback on the equipment and appliances that were consuming significant energy.

This advisory can even suggest what should be replaced and the payback period on the replacement, based on energy usage. The comparison allows customers to see how they did against similar customers and where they ranked in energy consumption. This has been very useful in getting customers to pay more attention to their consumption.

Customer Price Display

To make a realistic decision about using or not using energy and water, customers need to know how much it will cost. As we have seen with Gasoline the global consumption decreased very little (in reality only the projection of growth in consumption declined, not the actual usage) when the price tripled at the pump in many countries. Electricity, gas and water today are in the noise of running a household for most families and for many businesses the cost does not enter the top five costs for the business. To this end, making a decision to consume energy and water is easy.

For a few businesses and a small percentage of residential customers this is not true and they have strong motivation to conserve power. With critical peak pricing or time of use pricing and rising prices for energy and water, the percentage of the average family income consumed by these utilities will no longer be noise and having information about pricing, will drive some conservation. Expect that customers will need to know the price to wash a load of clothes, not the price of a kilowatt hour.

Tariffs and Pricing Schemes

Tariff Design

Today a sample of the customers is used to determine what the customer profile should be and how that profile should be priced. In many cases the classification of the customers is very broad and does not really take into account the different ways that customers actually consume power.

For example, a young educated single male living in an apartment may have a lower usage than the young family across the hallway and they may both pay the same per kilowatt-hour of power.

However, the young male may actually cost the utility more to serve, since the load factor for that single male may be much lower than the load factor for the young family. By being able to provide accurate data, better tariffs can be designed and better segmentation done to support a fair power price.

Rate Case Support

Today to get almost any change in what can be charged to the customers or what is placed in the rate base, it requires a rate case. In some rate cases the documents filed fill rooms and rooms in a building, mostly because the issues can be handled in a black and white manner. Experts are required to testify on many aspects of the rate case using data from other locations, since the complete data set to answer the question does not exist at the utility. While experts will not go away, and there will still be a lot of estimating, it is important to realize that smart meters provide a large data set to assist with the rate cases.

Tariff Assessments

Do critical peak tariffs create the response expected, does it do it for all segments of customers, and does it impact some customer segments more harshly than others. Use of smart meter data allows a better review of how the customers are responding to the tariffs and how to re-work them to better fit the needs of the society.

Cross Subsidization

An issue that is raised over and over again is cross subsidization of customers, one group of customers paying part of the cost of another group of customers. With our example in Tariff Design, more than likely the young family is subsidizing the young male. Regulators want to know what the cross subsidization is, they do not always want to eliminate it (e.g. the long distance rates for the telephone companies for decades financed the ability of everyone to have a phone). By having complete data on each and every customer, subsidization arguments no longer fall on “I think” arguments, but fall into the “I know” allowing the regulator to only have intended subsidies.

Customer Segmentation

Customer segmentation has traditionally been done by industry or by business segment or by customer type, not by the actual needs or profile of the customers. Regulators have never had enough data to make segmentation decisions that really classify customers together by the way they consume power and their needs for power quality or their creation of power quality issues that the utility needs to fix. Smart metering can provide the data to make meaningful segmentation decisions.

Demand Response

Demand response is a general capability that could be implemented in many different ways. The primary focus is to provide the customer with pricing information for current or future time periods so they may respond by modifying their demand. This may entail just decreasing load or may involve shifting load by increasing demand during lower priced time periods so that they can decrease demand during higher priced time periods. The pricing periods may be real-time

based or may be tariff-based, while the prices may also be operationally-based or fixed or some combination. As noted below, real-time pricing inherently requires computer-based responses, while the fixed time-of-use pricing may be manually handled once the customer is aware of the time periods and the pricing.

Sub functions for demand response, which may or may not involve the AMI system directly, could include:

- Enroll Customer
- Enroll in Program
- Enroll Device
- Update Firmware in HAN Device
- Send Pricing to device
- Initiate Load Shedding event
- Charge/Discharge PHEV – storage device
- Commission HAN device
- HAN Network attachment verification (e.g. which device belongs to which HAN)
- Third Party enroll customer in program (similar to, but not the same as the customer enrolling directly)
- Customer self-enrollment
- Manage in home DG (e.g. MicroCHP)
- Enroll building network (C&I – e.g. Modbus)
- Decommission device
- Update security keys
- Validate device
- Test operational status of device

Real Time Pricing (RTP)

Use of real time pricing for electricity is common for very large customers affording them an ability to determine when to use power and minimize the costs of energy for their business, one aluminum company cut the cost of power by more than 70% with real time pricing and flexible scheduling. The extension of real time pricing to smaller customers and even residential customers is possible with smart metering and in home displays. Most residential customers will probably decline to participate individually because of the complexity of managing power consumption, but may be quite willing to participate if they are part of a community whose power usage is managed by an aggregator or energy service provider.

Time of Use (TOU) Pricing

Time of use pricing creates blocks of time and seasonal differences that allow smaller customers with less time to manage power consumption to gain some of the benefits of real time pricing. This is the favored regulatory method in most of the world for dealing with global warming.

Although Real Time Pricing is more flexible than Time of Use, it is likely that TOU will still provide many customers will all of the benefits that they can profitably use or manage.

Critical Peak Pricing

Critical Peak Pricing builds on Time of Use Pricing by selecting a small number of days each year where the electric delivery system will be heavily stressed and increasing the peak (and sometime shoulder peak) prices by up to 10 times the normal peak price. This is intended to reduce the stress on the system during these days.

California is the largest proponent of this tariff program at this time. Most of the California utilities would prefer an incentive program instead to encourage the same behavior. There is some question as to whether retailers in unregulated markets would have to pass thru the Critical Peak Pricing to customers or if they could offer a flat price and hedge the risk of the critical peak pricing.

External Parties Business Functions

Gas and Water Metering

Leak Detection

In the world of gas and water, non-revenue water and leaking gas pipes are important to track down. In the water industry, use of pressure transducers on smart meters has proven useful when doing minimum night flows to find unexpected pressure drops in the system. Normally the need is one pressure transducer meter per 500 to 1000 customers in an urban environment.

Water Meter Flood Prevention

With a disconnect in the water meter, it is possible if there is a sudden increase in flow and a drop in pressure that is sustained and unusual, that the disconnect can be activated and prevent flooding. Much work will have to be done in the control software algorithms to make this a useful benefit and not one the shuts off the water when the sprinkler system and the shower are both running.

Gas Leak Isolation

Similar to flood prevention, again the software needs to get much better or their needs to be a gas leak sensor in the structure that communicates with the meter.

Pressure Management

If there is a home area network, then shut off devices or throttling devices can be attached to specific water taps and the gas meter can communicate to thermostats and water heater controls to manage the rate of consumption in the location and help with pressure management on critical days.

Third Party Access

Third Party Access for Outsourced Utility Functions

For some utilities, many of the business functions listed in the previous sections may be provided by third parties, rather than by the utility. In these situations, messaging will come through the "external party access" avenue, rather than an internally-driven messaging. The business processes will be fundamentally the same, but the security requirements could be significantly different and probably requiring stronger authentication at each system handoff.

Some of the business functions provided by third parties could include:

- Prepaid metering
- Remote connect/disconnect
- Load management
- Emergency control
- Distribution automation
- Customer usage information
- HAN management

Third Party Security Management of HAN Applications

Customers will need access to HAN application accounts through a secure web portal where they can upload device and software security keys. Those keys will need to be sent through the AMI network to the meter to allow the HAN devices to provision and join with the meter.

Future functionality may include extraction of security keys out of the meter for storage in the utility's database. This will allow the keys to be downloaded back to a meter if it ever has to be replaced. This functionality will be required to eliminate the need to re-provision all the HAN devices in the house in the event of a meter replacement.

Appliance Monitoring

Appliances seldom last as long in the home as they do in the lab, part of this is that home owners do not do maintenance when they should, and part of it is that when small problems occur that are not handled, so they become big and expensive problems. Smart meters are a key part of an appliance monitoring solution, even for appliances that were installed long ago.

Home Security Monitoring

Today's security monitoring industry uses phone lines and other communications methods to monitor homes. The ability to hook security monitoring devices into a home area network and provide alerts and alarms over the smart metering network could lower the cost of home security monitoring making it more affordable to the people who live in areas most likely to need it.

Home Control Gateway

Home owners may want to control their home devices themselves or they may want a third party to do so, in either case, the smart metering system can be a method of providing that home area network gateway and allowing that control to be done.

Medical Equipment Monitoring

More and more medical equipment is being installed in homes as nursing homes and hospitals are getting too expensive to live in and more life support equipment is required for people who still can live at home unassisted most of the time. Today that equipment is only monitored by specialized companies and this seldom happens. It is a growing need especially for the elderly customers of the utility. While utilities may not wish to step into this role, the smart metering infrastructure can provide a way for authorized third parties to do so.

External Party Information

Regulatory Issues

There are a number of issues that regulators need to judge the performance of a utility and the fairness of a utility to its customers. Smart metering has a role to play in providing facts to the regulator to help them manage these issues.

Investment Decision Support

When a utility goes to the regulator for a major capital expense there is a need for proof that the expense is required. Today like other regulator interactions, the data is typically made up of sampled data and expert opinions. With smart metering the complete data set is available to support the decisions.

Education

Customer Education

Customers today call the call center and receive bills. They have little interaction with their utilities, less than 40% of the customer base interacts with the utility annually. The majority of the call volume is related to outage or other power quality issues. The second highest interaction reason is billing issues. If the industry is to be successful in changing people's habits and helping to reduce consumption, then there will need to be more interaction with customers, some on billing issues, some on power quality, but more on the way they consume power and what they have for appliances.

AMI systems will provide a means of interacting more with the customer, but only if the customer understands the capabilities – as well as being assured that AMI systems are not “Big Brother” watching over them.

Utility Worker Education

Utility workers will need significant education to learn not only their own roles in a utility with AMI, but also the issues of security and privacy that will become far more critical with the widespread scope of AMI systems.

Third Party Access for Certain Utility Functions

For some utilities, many of the business functions listed in the previous sections may be provided by third parties, rather than by the utility. In these situations, messaging will come through the "external party access" avenue, rather than an internally-driven messaging. The business processes will be fundamentally the same, but the security requirements could be significantly different and probably requiring stronger authentication at each system handoff.

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