



# Securing Your SCADA and Industrial Control Systems

Version 1.0



Additional copies of this guide are available from the Government Printing Office. To order, cite stock number 008-022-00338-0, ISBN 0-16-075115-8. Orders may be placed via the Internet, phone, fax, and mail.

For secure ordering via the Internet, visit the U.S. Government Online Bookstore at <http://bookstore.gpo.gov>.

Phone: (202) 512-1800

Monday through Friday, 7:30 a.m.-5:00 p.m., eastern standard time

Fax: (202) 512-2250 at any time

Mail: send to:

Superintendent of Documents

P.O. Box 371954

Pittsburgh, PA 15250-7954

All orders require prepayment, either by check, money order, VISA, MasterCard, Discover/NOVUS, or GPO Deposit Account.

## **Disclaimer**

The information in this guide is for informational purposes only and is not legal advice. The information is general and may or may not reflect the most current legal or technical developments. It does not constitute legal advice or substitute for obtaining legal advice from an attorney licensed in your state.

Copyright © 2005, Technical Support Working Group. All rights reserved.

Permission is granted to display, copy, publish, and distribute this document in its entirety, provided that the copies are not used for commercial advantage and that the present copyright notice is included in all copies, so that the recipients of such copies are equally bound to abide by the present conditions.

Unlimited release – Approved for public release.

## Purpose

This guidebook, developed by the Technical Support Working Group (TSWG), provides information for enhancing the security of Industrial Control Systems (ICS). The information is a comprehensive overview of industrial control system security, including administrative controls, architecture design, and security technology. This guide is intended for all sectors that use ICS technology. This is a guide for enhancing security, not a how-to manual for building an ICS, and its purpose is to teach ICS managers, administrators, operators, engineers, and other ICS staff what security concerns they should be taking into account.

## Scope

This guide does not constitute a standard, and it is not a substitute for standards documents. Neither is this guide a comprehensive security manual. It does not go into detail about any specific technologies; it covers ICS security too broadly to be used as a standalone document. Standards and vendor documents should be consulted for help in properly securing a specific ICS configuration.

## To Whom This Guide Applies

ICS is one term for a broader set of control systems, which include

- SCADA (Supervisory Control and Data Acquisition)
- DCS (Digital Control System)
- PCS (Process Control System)
- EMS (Energy Management System)
- AS (Automation System)
- Any other automated control system

Each industry has its own culture and set of terms. This guide is useful for any industry employing networked automation systems, regardless of the terms used.

# Table of Contents

<b>1. Start Here</b>		
• Disclaimer	1	
• Purpose	2	
• Scope	2	
• To Whom This Guide Applies	2	
• Table of Contents	3	
• How to Use This Guidebook	7	
• A Note on Anecdotes	7	
• Guidebook User Roles	8	
• Icons	9	
• How to Use Frequently Requested Help	10	
• Frequently Requested Help	10	
<b>2. Setting the Foundation</b>	12	
• Sustainable Security	13	
• Effective Security Documentation	14	
• Enforcement	15	
• The Secure Design Process	16	
• Secure Implementation	17	
• Legal Obligations of Critical Infrastructure	18	
• Critical Infrastructure Liability	19	
<b>3. The Secure Design Process</b>	20	
• The Secure Design Process Introduction	22	
• Identify	23	
• Object-Role Modeling	24	
• ICS Reference Model	26	
◦ How to Use	28	
◦ General Types of Functionality	28	
• External Entities	29	
• Architecture and Design Suggestions	30	
• Determine Adversarial Threat Models		
and Consequences of Concern	31	
◦ Capabilities and Motivation to		
Initiate an Attack	32	
• Data Types and Categories	33	
◦ Data Protection	34	
• Data Classification	35	
• Risk Assessment	36	
<b>4. Security Documentation</b>	40	
• Security Documentation Introduction	41	
• Documentation Relationships	42	
• Types of Security Documentation	43	
• Security Plan Elements	45	
• Implementation Guidance	46	

## Table of Contents (cont.)

<b>5. Policy</b>		
• Policy Introduction	47	49
• How to Write Policy		49
• What Goes into a Policy?		50
• ICS Security Policy Framework		52
◦ ICS Security Program		54
◦ Data Security Policy		56
◦ Platform Security Policy		57
◦ Communication Security Policy		58
◦ Personnel Security Policy		60
◦ Configuration Management Policy		61
◦ Audit Policy		62
◦ Application Policy		64
◦ Physical Security Policy		65
◦ Manual Operations Policy		66
<b>6. Enforcement</b>		67
• Enforcement Introduction		69
• The Enforcement Cycle		69
• Aspects of Enforcement		70
• Configuration Management		71
◦ Why is Configuration Management Necessary?		71
◦ Configuration Management:		
◦ Step 1		72
◦ Configuration Management:		
◦ Step 2		73
◦ Configuration Management:		
◦ Step 3		73
• Changes		74
◦ Change Request/Approval Process		74
• Test Labs		75
◦ Essential Elements of a Test Lab		76
• Auditing Versus Assessment		77
• Types of Audit and Assessment		78
• Steps for Using Audit and Assessment Results		79
• What to Look for in an Assessment Company		80

<b>7. ICS Best Practices</b>	<b>81</b>		
• Defense in Depth	83	• Manual Operations	100
• Security Program Best Practices	83	• Physical Protection	101
• Policy Best Practices	84	• Physical Asset Disposal	103
• Organizational Best Practices	84	• Other Security Suggestions	104
• Data Security	85		
• Malicious Software Protection	85		
• Platform Security	86		
• Security for RTUs, PLCs, or IEDs	88		
• Communication Security	88		
• Wireless Security	89		
• Virtual Private Networks	89		
• Firewalls	90		
• Demilitarized Zones	91		
• Proxies	91		
• Remote Access	92		
• External or Third Party Access	93		
• Remote Access Servers (RAS)	94		
• Personnel Security	94		
• Accounts and Passwords	95		
• Training	96		
o What to Look for In a Training Class	96		
• Assessment	97		
• Auditing	97		
• Intrusion Detection Systems	98		
• Intrusion Prevention Systems	99		
• Logging	99		
• Applications	100		
<b>8. Finding Your Vulnerabilities</b>	<b>105</b>		
• Vulnerabilities and Threats	107		
• ICS Security	108		
o Historical ICS Security	108		
o Current Issues	108		
o Security Limitations of Legacy Equipment	108		
• Poor ICS Practices	109		
o Poor Account Maintenance	109		
o Unprotected Network Connections	109		
o Poor Application Implementation	109		
o Lack of Maintenance and Monitoring	110		
• Lack of ICS Security Documentation and Enforcement	110		
• Lack of Physical Controls	111		
• Inadequate Physical Protection of Equipment	112		
• Remote Access	112		
• Types of Remote Access	113		
• Lack of Data Categorization and Sensitivity Guidance	114		
• Protocol Vulnerabilities	114		

## Table of Contents (cont.)

<b>9. Incident Handling and Response</b>		
• How to Recover When Something Goes Wrong	115	
• Incident Handling	116	
• The Incident Handling Process	117	
• After The Fact	118	
• Indications of Incidents	119	
• What to Do About Unusual Activity	120	
o Malicious Code Resources	121	
o Hoax Investigation Sites	121	
o Detection and Recovery Sites	121	
• Digital Forensics	122	
• Threat Response	124	
<b>10. Resources and References</b>		
• References for each section	125	
o Section 1	125	
o Section 2	126	
o Section 3	127	
o Section 4	127	
o Section 5	128	
o Section 6	128	
o Section 7	129	
o Section 8	130	
o Section 9	130	
• Resources	132	
• Definitions	135	
• Acronyms	141	
• Standards and Association Links	145	
• ICS Primer	150	
o Two Categories of ICS	150	
o Manufacturing or Chemical	151	
o Electric Power, Oil and Gas, and Water	151	
o Automation Systems in Electric Power	152	
• Related Works in Progress	153	

## How to Use This Guidebook

This guide provides a foundation to help implement secure systems, secure existing systems, and make security a process rather than an afterthought. Working knowledge of ICS and basic cyber security is assumed.

Small colored boxes appear on the right-hand side of any page that implicitly refers to another section of the guide. Each such box contains the name of the section referred to and is that section's color.

The related TSWG website, <http://www.tswg.gov/tswg/ip/scada.htm>, contains more detailed information, updates, and job aids. Job aids include examples, templates, and references. A training support package will also be available with more detailed information for each section of the guide.



## A Note on Anecdotes

Many sections in this guide begin with short anecdotes. These anecdotes provide examples of actual ICS security incidents, and are meant to demonstrate potential consequences of inadequate security practices. The anecdotes are in italic font with colored backgrounds for easy recognition.

## Guidebook User Roles

This guide was written for a wide range of ICS staff. The roles defined below need not correlate perfectly with actual positions at a given ICS; they are meant to encapsulate job functions that must be performed by ICS staff in general. The icons appear at the beginning of each section, denoting the roles most applicable. All ICS staff, however, will benefit from reading each section.



ICS Engineer/Technician – Designs and maintains the ICS; participates in testing and designing security response guidelines (e.g. manual operations, incident response); maintains the system hardware.



ICS Operator – Maintains the day-to-day operations of the ICS; and administers users' accounts and applications.



ICS Security Administrator – Maintains security documentation; oversees the implementation of all security controls; evaluates and implements the results of security audits and assessments; investigates security incidents; and administers users' accounts and application security.



ICS Information Security Officer – Maintains all data contained in the system, and ensures that security controls are adequate for the protection of data.



ICS Manager – Approves all changes to the ICS, including exceptions to policy, purchases, new equipment, acquisitions, and ensures all security requirements are met.

## Icons

The following icons are used throughout the guidebook to indicate other documents promoting the same recommendations, or cases where the TSWG website contains more detailed information.



See TSWG website for more information

<http://www.tswg.gov/tswg/ip/scada.htm>



See "21 Steps to Improve Cyber Security of SCADA Networks"

[http://www.tswg.gov/tswg/ip/21\\_Steps\\_SCADA.pdf](http://www.tswg.gov/tswg/ip/21_Steps_SCADA.pdf)



See "NERC Critical Infrastructure Protection Standards CIP-002-1 through CIP-009-1"

<http://www.nerc.com/~filez/standards-cyber.html>

<http://www.nerc.com/~filez/standards/Cyber-Security-Permanent.html>



See "AGA-12: Cryptographic Protection of SCADA Communications General Recommendations"

[http://www.gastechology.org/webroot/downloads/en/1ResearchCap/1\\_1GasOps/AGASCADANews.pdf](http://www.gastechology.org/webroot/downloads/en/1ResearchCap/1_1GasOps/AGASCADANews.pdf)



See "NRC: Criteria for use of Computers in Safety Systems of Nuclear Power Plants"

<http://www.nrc.gov/reading-rm/doc-collections/reg-guides/power-reactors/active/01-152/>



See API's "Security Vulnerability Assessment Methodology for the Petroleum and Petrochemical Industries" and "Security Guidelines for the Petroleum Industry"

[http://www.npra.org/publications/general/SVA\\_2nd\\_Edition.pdf](http://www.npra.org/publications/general/SVA_2nd_Edition.pdf)

## How to Use Frequently Requested Help

The Frequently Requested Help section lists common scenarios ICS engineers encounter that may require security knowledge and solutions. The list includes the page numbers of this guidebook that will assist the engineer in solving these problems with security in mind.

Not all issues can be covered by this guide. Every attempt has been made to cite the proper references where applicable.

## Frequently Requested Help

Responding to:

An Incident **115-124**

Cyber Attack **118-119**

Forensic Analysis **122-123**

Observed Unusual Activity  
or Incident **120**

A Threat **124**

New Regulations **18-19, 42**

Security-Related Upgrade

Decisions **17, 22-23, 30-39, 81-104**

Need an Audit/Assessment?: **80, 100**

What Type of Audit/Assessment

Do You Need? **78**

Why Audit/Assess? **62-63, 77**

System Benchmarking **72-73**

Using the Results of an

Audit/Assessment **42, 79**

Need to Write Documentation? **14, 40-46**

Security Policy **43, 47-66**

Security Plan **44, 45**

Incident Response Guide **43, 116**

Configuration Management  
Plan **43, 71-73**

## Frequently Requested Help (cont.)

Need to Know If Something's Secure? **81-104**

- Evaluate the Security of a Design **24-28, 38-39**
- Select a Security Product **81-104**

Need Implementation Help? **81-104**

- Security **22-30, 81-104**
- Add-On Security Device **90-92**

Best Practices for:

- Network Connections **90-95**
- Communication Interfaces **89**
- Monitoring Tools **99-100**
- Using Equipment **87-92**
- Changing Equipment **74-76**

How to Manage:

- Equipment Failure **66, 101**
- Data Loss **33-35, 56, 86**
- Using Equipment with Security **46, 89**
- Changing Equipment **74-76**

Where to Find More Information on:

- Regulations **132-134**
- Training **97**
- User Groups **145-149**
- Government Standards **132-134**

## References

### Section 1: Start Here

1. TSWG SCADA Security website  
<http://www.tswg.gov/tswg/ip/scada.htm>
2. "21 Steps to Improve Cyber Security of SCADA Networks"  
[http://www.tswg.gov/tswg/ip/21\\_Steps\\_SCADA.pdf](http://www.tswg.gov/tswg/ip/21_Steps_SCADA.pdf)
3. NERC Critical Infrastructure Protection Standards CIP-002-1 through CIP-009-1  
<http://www.nerc.com/~filez/standards-cyber.html>  
<http://www.nerc.com/~filez/standards/Cyber-Security-Permanent.html>
4. "AGA-12: Cryptographic Protection of SCADA Communications General Recommendations"  
[http://www.gastechnology.org/webroot/downloads/en/1ResearchCap/1\\_1GasOps/AGASCADANews.pdf](http://www.gastechnology.org/webroot/downloads/en/1ResearchCap/1_1GasOps/AGASCADANews.pdf)
5. "NRC: Criteria for use of Computers in Safety Systems of Nuclear Power Plants"  
<http://www.nrc.gov/reading-rm/doc-collections/reg-guides/power-reactors/active/01-152/>
6. API's "Security Vulnerability Assessment Methodology for the Petroleum and Petrochemical Industries" and "Security Guidelines for the Petroleum Industry"  
[http://www.npra.org/publications/general/SVA\\_2nd\\_Edition.pdf](http://www.npra.org/publications/general/SVA_2nd_Edition.pdf)

## Section 2: Setting the Foundation

1. HIPAA (Health Insurance Portability and Accountability Act of 1996)  
<http://www.cms.hhs.gov/hipaa/>
2. Gramm-Leach-Bliley Act  
<http://www.ftc.gov/privacy/glbact/>
3. Federal Information Security management Act (FISMA)  
<http://csrc.nist.gov/sec-cert/>
4. California Senate Bill 1386  
[http://info.sen.ca.gov/pub/01-02/bill/sen/sb\\_1351-1400/sb\\_1386\\_bill\\_20020926\\_chaptered.html](http://info.sen.ca.gov/pub/01-02/bill/sen/sb_1351-1400/sb_1386_bill_20020926_chaptered.html)
5. National Strategy to Secure CyberSpace  
<http://www.whitehouse.gov/pcipb/>
6. National Strategy for the Physical Protection of Critical Infrastructures and Key Assets  
<http://www.whitehouse.gov/pcipb/physical.html>
7. The Freedom of Information Act (FOIA)  
<http://www.usdoj.gov/04foia/>
8. Stamp, Campbell, Depoy, Dillinger, Young. "Sustainable Security for Infrastructure SCADA," SAND2003-4670C  
<http://www.sandia.gov/scada/documents.htm>
9. AMWA. Atkins, Cathy and Morandi, Larry. "Protecting Water System Security Information." September 2003. - Summarizes applicable legislation and lists FOIA exemptions  
[http://www.amwa.net/security/NCSL\\_FOIA.pdf](http://www.amwa.net/security/NCSL_FOIA.pdf)

## Section 3: The Secure Design Process

1. Stamp and Berg. "A Reference Model for Control and Automation Systems in Electric Power," SAND 2005-1000C  
<http://www.sandia.gov/scada/documents.htm>
2. Campbell and Stamp. "A Classification Scheme for Risk Assessment Methods," SAND 2004-4233  
<http://www.sandia.gov/scada/documents.htm>
2. American Gas Association. AGA 12 - Cryptographic Protection of SCADA Communications General Recommendations. 2004  
<http://www.gti的乐趣.org/security/AGA12Draft3r6.pdf>
3. Government Classification  
<http://en.wikipedia.org/wiki/Classified>
4. Data Classification  
[http://www.yourwindow.to/information-security/gl\\_dataclassification.htm](http://www.yourwindow.to/information-security/gl_dataclassification.htm)

## Section 4: Security Documentation

1. NIST 800-18 - Guide for Developing Security Plans for Information Technology Systems  
<http://csrc.nist.gov/publications/nistpubs/>
2. SANS System Security Plan  
<http://www.sans.org/projects/systemsecurity.php>
3. SANS Security Policy Project  
<http://www.sans.org/resources/policies/>

## Section 5: Policy

1. Kilman and Stamp. "Framework for SCADA Security Policy," SAND 2005-1002C  
<http://www.sandia.gov/scada/documents.htm>
2. SANS Security Policy Project  
<http://www.sans.org/resources/policies/>
3. CobIT Control Objectives for Information and related Technology  
<http://www.isaca.org/cobit.htm>
4. BS7799  
<http://www.thewindow.to/bs7799/>
5. Anecdote  
<http://www.computerworld.com/printthis/2004/0,4814,95615,00.htm>

## Section 6: Enforcement

1. API's "Security Vulnerability Assessment Methodology for the Petroleum and Petrochemical Industries" and "Security Guidelines for the Petroleum Industry"  
[http://www.npra.org/publications/general/SVA\\_2nd\\_Edition.pdf](http://www.npra.org/publications/general/SVA_2nd_Edition.pdf)
2. Sandia National Laboratories. SCADA Assessment Training Course  
[http://www.sandia.gov/scada/training\\_courses.htm](http://www.sandia.gov/scada/training_courses.htm)

## Section 7: ICS Best Practices

1. American Gas Association. AGA 12 - Cryptographic Protection of SCADA Communications General Recommendations. 2004  
<http://www.gtiservices.org/security/AGA12Draft3r6.pdf>
2. National Institute of Standards and Technology FIPS PUB 140-2 "Security Requirements for Cryptographic Modules"  
<http://csrc.nist.gov/publications/fips/fips140-2/fips1402.pdf>
3. SANS SCORE  
<http://www.sans.org/score/>
4. SANS/FBI Top 20  
<http://www.sans.org/top20/>
5. NIST – National Institute of Standards and Technology  
<http://csrc.nist.gov/publications/nistpubs/>
6. CobIT Control Objectives for Information and related Technology  
<http://www.isaca.org/cobit.htm>
7. BS7799  
<http://www.thewindow.to/bs7799/>
8. NSA Guidelines  
<http://nsa2.www.conexion.com/support/download.htm>
9. Anecdote  
<http://archives.openflows.org/electronetwork-l/msg00013.html>

## Section 8: Common Vulnerabilities

1. Stamp, Dillinger, Young, and Depoy. "Common Vulnerabilities in Critical Infrastructure Control Systems," SAND2003-1772C, May 2003  
<http://www.sandia.gov/scada/documents.htm>
2. Anecdote  
<http://www.securityfocus.com/news/6767>
3. FBI/SANS Top 20 Vulnerabilities  
<http://www.sans.org/top20/>

## Section 9: Incident Handling and Response

1. NIST 800-61 Computer Security Incident Handling Guide  
<http://csrc.nist.gov/publications/nistpubs/>
2. DOE EIA  
<http://www.nerc.com/~dawg/append-a.html>
3. F-Secure Computer Virus Info Center  
<http://www.f-secure.com/v-descs/>
4. McAfee Virus Information Library  
<http://vil.mcafee.com/>
5. Sophos Virus Information  
<http://www.sophos.com/virusinfo/>
6. Symantec AntiVirus Research Center  
<http://www.symantec.com/avcenter/>

## Section 9: Incident Handling and Response (cont.)

7. TrendMicro Virus Encyclopedia  
<http://www.trendmicro.com/vinfo/virusencyclo/>
8. Virus Bulletin VGrep Database  
<http://www.virusbtn.com/resources/vgrep/>
9. Vmyths Hoax  
<http://www.vmyths.com/hoax.cfm>
10. CIAC Hoaxbusters  
<http://hoaxbusters.ciac.org/>
11. DOE EIA  
<http://www.nerc.com/~dawg/append-a.html>
12. U.S. Department of Justice. Forensic Examination of Digital Evidence: A Guide for Law Enforcement:  
<http://www.ncjrs.org/pdffiles1/nij/199408.pdf>

## Resources

### Presidential Information

Homeland Security Presidential Directive on Critical Infrastructure:  
Identification, Prioritization, and Protection - HSPD-7

<http://www.whitehouse.gov/news/releases/2003/12/20031217-5.html>

Executive Order 13231: Critical Infrastructure Protection

<http://www.fas.org/irp/offdocs/eo/eo-13231.htm>

Presidential Decision Directive 63: Critical Infrastructure Protection

<http://www.fas.org/irp/offdocs/pdd-63.htm>

The National Strategy to Secure Cyberspace

<http://www.whitehouse.gov/pcipb/>

The National Strategy for the Physical Protection of Critical Infrastructures and Key Assets

<http://www.whitehouse.gov/pcipb/physical.html>

### General Information

Cybersecurity for the Homeland DHS - December 2004

<http://hsc.house.gov/files/cybersecurityreport12.06.04.pdf>

Critical Infrastructure Protection: Improving Information Sharing with Infrastructure Sectors GAO - July 2004

<http://www.gao.gov/cgi-bin/getrpt?GAO-04-780>

## General Standards

System Protection Profile for Industrial Control Systems NIST

<http://www.isd.mel.nist.gov/projects/processcontrol/>

IT Security for Industrial Control Systems NIST and PCSRF

<http://www.isd.mel.nist.gov/documents/falco/ITSecurityProcess.pdf>

## General Guidance

21 Steps to Improve Cyber Security of SCADA Networks.

DOE and the President's Critical Infrastructure Protection Board

<http://www.ea.doe.gov/pdfs/21stepsbooklet.pdf>

Common Vulnerabilities in Critical Infrastructure Control Systems. Sandia National Laboratories

<http://www.ea.doe.gov/pdfs/vulnerabilities.pdf>

Sustainable Security for Infrastructure SCADA. Sandia National Laboratories

<http://www.sandia.gov/scada/documents/SustainableSecurity.pdf>

## Applicable Laws

The Freedom of Information Act (FOIA)

<http://www.usdoj.gov/04foia/>

## Control Frameworks

"CobiT Executive Summary," "CobiT Control Objectives," "CobiT Quickstart,"

<http://www.isaca.org/cobit.htm>

ISO-17799: Information Technology - Code of Practice for Information Security Management

<http://www.iso-17799.com/>

## Implementation Best Practices

Threat Alert System and Cyber Response Guidelines for the Electricity Sector NERC and CIPAG

[ftp://www.nerc.com/pub/sys/all\\_updl/cip/tas\\_cyber\\_v2.pdf](ftp://www.nerc.com/pub/sys/all_updl/cip/tas_cyber_v2.pdf)

NERC CIPC Guides

<http://www.nerc.com/~filez/cipfiles.html>

NERC Urgent Action Standard 1200-Cyber Security

<http://www.nerc.com/~filez/standards-cyber.html>

NERC Urgent Action Standard 1300-Cyber Security

<http://www.nerc.com/~filez/standards/Cyber-Security-Permanent.html>

FERC Security Standards for Electric Market Participants

<http://elibrary.ferc.gov/idmws/common/opennat.asp?fileID=9538944>

ISA-SP99, Manufacturing and Control Systems Security

<http://www.isa.org/MSTemplate.cfm?MicrositeID=988&CommitteeID=6821>

## Definitions

**Access Control** - Any method or technology used to control which hosts and/or users have access to a given resource.

**Access Control List (ACL)** - A table used by the computer system to identify access rights for each user to a particular system resource, such as a file directory, an individual file, or a device. In networking, the term refers to a list of the computing services available on a server, each with a list of hosts permitted to use the service.

**Assets** - Resources contributing to an organization achieving its mission. Assets may be tangible or intangible.

**Authentication** - The process of verifying the identity of a user or process attempting to access systems or resources.

**Availability** - The assurance that authorized users can access the information necessary to complete their jobs.

**Bastion Host** - A gateway between an inside network and an outside network designed to defend against attacks aimed at the inside network.

**Classified** - Data that is not to be released outside of the organization; release could result in harm to the organization (and could harm national security).

**Company confidential** - Private company information; release could damage the company.

**Confidentiality** - Protects information against unauthorized access or disclosure.

## Definitions (cont.)

**Configuration Management** - Enforces the security plan and implementation guidance.

**Cyber Security** - The protection of information system assets and data by all means necessary, including physical protections.

**DMZ (Demilitarized Zone)** - Security enclaves, usually located logically between the inside and outside interface at a firewall, also called extranets.

**Engineer/Technician** - Designs and maintains the ICS, participates in testing and designing security response guidelines (manual operations, incident response), maintains the system hardware.

**Event** - An action or occurrence that can exploit a vulnerability.

**Finger** - Displays information about a user or users on a specified remote computer (typically a computer running UNIX).

**For Official Use Only (FOUO)** - Unclassified information exempt from public release and restricted to need-to-know access.

**Implementation Guidance** - A set of directives for the configuration, installation, and maintenance of specific technologies.

## **Definitions (cont.)**

**Information Security Officer** - Responsible for all data contained in the system, responsible for ensuring that security controls are adequate for the protection of data.

**In-Band** - The technique of transmitting controlling information over the same LAN the information is controlling.

**Integrity** - Ensures the correctness and appropriateness of a piece of information content.

**Intelligent Electronic Device (IED)** - Consolidates data from field devices.

**Link Encryption** - Encrypts data as it is transmitted between two hosts in a network.

**Manager** - Responsible for approving all changes to the ICS, exceptions to policy, purchasing, and new equipment; ensures all security requirements are met.

**Need-To-Know (NTK)** - The business requirement that allows an individual to only have access to and knowledge of specific, protected information necessary to fulfill their work duties.

**Operator** - Maintains the day-to-day operations of the ICS.

**Packet Encryption** - Encrypts data between two applications running on different hosts.

**Physical Security** - The protection of assets using physical devices and entities (such as guns, gates, and guards), allowing access only to authorized individuals.

## Definitions (cont.)

**Principle of Least Privilege** - A user or process is given no more privilege than necessary to perform a job.

**Procedures** - Document appropriate behavior for repeatable situations.

**Programmable Logic Controller (PLC)** - Devices that provide hardware interface for input sensors and output actuators.

**Public** - Data is not sensitive; release of this information poses no threat.

**Reliability** - Ensures that users can depend on the information and resources of a system to be accurate and available when needed.

**Remote Access** - Any access to a device that originates outside of the system's network.

**Remote Access Server (RAS)** - A server that is dedicated to handling users not on a LAN but needing remote access to it.

**Remote Terminal Unit (RTU)** - Data interface between a control station and remote control equipment and field devices.

**Risk** - The possibility that a particular threat will exploit a vulnerability resulting in a consequence of concern.

## **Definitions (cont.)**

**Risk Assessment** - The determination of risks and risk levels acceptable by a system. This type of assessment must take into account expected adversaries and their capabilities, as well as the vulnerabilities of the system.

**Security Administrator** - Maintains security documentation; oversees the implementation of all security controls; evaluates and implements the results of security audits and assessments; investigates security incidents; and administers users' accounts and application security.

**Security Enclave** - An enclave is the container for data elements of like security characteristics. Security enclaves can be implemented as perimeters or as access controls on storage media or platforms.

**Security Plan** - Enumerates security guidelines for systems, or groups of systems, based on fundamental concepts from the security policy.

**Security Policy** - Translates the desired security and reliability control objectives for the overall business into enforceable staff directions and behaviors to ensure secure ICS design, implementation, and operation. Security Policy bridges the control framework to enforcement.

**Single Point of Failure** - Any component of a system that upon failure will cause a malfunction in the entire system.

**Split Tunneling** - The process of allowing a remote VPN user to access a public network (most commonly the Internet) at the same time that the user is allowed to access resources on the VPN.

## Definitions (cont.)

**Threat** - A threat is a circumstance or event that can potentially cause harm to a system.

**Virtual Private Network (VPN)** - Any technology that allows confidential sharing of network resources across an insecure channel.

**Vulnerability** - A point of weakness in a system.

**Vulnerability Assessment** - The determination of possible security holes in a system. This type of assessment must take into account current technology and its possible uses and misuses.

**Wipe (wiping software)** - A method of removing data from electronic media. This method involves overwriting the existing data, usually multiple times.

## Acronyms

ACL	Access Control List
AEPR	Alarm and Event Processing Routine
AES	Advanced Encryption Standard
AGC	Automatic Generation Control
AS	Automation Systems
AV	Antivirus
BOOTP	Bootstrap Protocol
CI	Critical Infrastructures
CM	Configuration Management
DCS	Digital Control Systems
DHS	Department of Homeland Security
DHCP	Dynamic Host Configuration Protocol
DMZ	Demilitarized Zone
DoD	Department of Defense
EMS	Energy Management Systems
FIPS	Federal Information Processing Standards
FISMA	Federal Information Security Management Act

## Acronyms (cont.)

FOIA	Freedom of Information Act
FOUO	For Official Use Only
FTP	File Transfer Protocol
HIDS	Host-based Intrusion Detection Systems
HIPAA	Health Insurance Portability and Accountability Act
HMI	Human Machine Interface
HTTP	Hypertext Transfer Protocol (world wide web protocol)
I/O	Input/Output
ICCP	Inter-Control Center Communications Protocol
ICS	Industrial Control Systems
IDS	Intrusion Detection System
IED	Intelligent Electronic Device
IP	Internet Protocol
ISAC	Information Sharing and Analysis Center
ISO	Independent System Operators
IT	Information Technology
LAN	Local Area Network

## Acronyms (cont.)

MAC	Media Access Control
MAN	Metropolitan Area Network
NERC	North American Electric Reliability Council
NIDS	Network-based Intrusion Detection System
NIST	National Institute of Standards and Technology
NTK	Need-To-Know
PCS	Process Control Systems
PCSRF	Process Control Security Requirements Forum
PLC	Programmable Logic Controller
PX	Power Exchange
RAS	Remote Access Services
RF	Radio Frequency
RFQ	Request for Quote
RTO	Regional Transmission Operator
RTU	Remote Terminal Unit
SCADA	Supervisory Control and Data Acquisition
SMTP	Simple Mail Transfer Protocol (Internet email)

## Acronyms (cont.)

<b>SNMP</b>	Simple Network Management Protocol
<b>SPAN</b>	Switch Port Analyzer
<b>SSID</b>	Service Set Identification (IEEE 802.11 wireless networks)
<b>SSH</b>	Secure Shell
<b>TCP</b>	Transmission Control Protocol
<b>TFTP</b>	Trivial File Transfer Protocol
<b>TSWG</b>	Technical Support Working Group
<b>UPS</b>	Uninterruptible Power Supply
<b>VPN</b>	Virtual Private Network
<b>WAN</b>	Wide Area Network
<b>WAP</b>	Wide Area Protection

## Standards and Association Links

### Broad Based Links

- Instrumentation, Systems, and Automation Society  
<http://www.isa.org/>
- National Association of Regulatory Utility Commissioners  
<http://www.naruc.org/>
- Sandia National Labs Center for SCADA Security  
<http://www.sandia.gov/scada/home.htm>
- Process Control Systems Forum (PCSF)  
<http://www.pcsforum.org/>
- NIST Process Control Security Requirements Forum (PCSRF)  
<http://www.isd.mel.nist.gov/projects/processcontrol/>

### Chemical Links

- Chemical Industry Data Exchange  
<http://www.cidx.org/>
- American Institute of Chemical Engineers  
<http://www.aiche.org/>

## Standards and Association Links (cont.)

### Electrical Links

- North American Electric Reliability Council (NERC)  
<http://www.nerc.com/>
- Electric Power Research Institute  
<http://www.epri.com/>
- Office of Energy Assurance  
<http://www.ea.doe.gov/>
- Electricity Sector Information Sharing and Analysis Center  
<http://www.esisac.com/>
- International Council on Large Electric Utilities  
<http://www.cigre.org/> -or- <http://www.cigre-usnc.org/>
- National Council on Electricity Policy:  
<http://www.ncouncil.org/>

### Energy Links

- Energy Information Sharing and Analysis Center  
<http://www.energyisac.com/>
- American Public Power Association  
<http://www.appanet.org/>
- National Association of State Energy Officials  
<http://www.naseo.org/>

## Manufacture Links

- National Center for Manufacturing Sciences  
<http://www.ncms.org/>

## Nuclear Links

- Nuclear Regulatory Commission  
<http://www.nrc.gov/>

## Oil & Gas Standards Links

- Security Vulnerability Assessment Methodologies for the Petroleum and Petrochemical Industries API, May 2003  
[http://api-ec.api.org/filelibrary/SVA\\_2003.pdf](http://api-ec.api.org/filelibrary/SVA_2003.pdf)
- Security Guidelines for the Petroleum Industry - American Petroleum Institute  
[http://api-ec.api.org/filelibrary/Security\\_Guidance2003.pdf](http://api-ec.api.org/filelibrary/Security_Guidance2003.pdf)

## Standards and Association Links (cont.)

### Oil and Gas Links

- Gas Technology Institute (GTI)  
<http://www.gastechnology.org/>
- American Gas Association  
<http://www.agae.org/>
- American Petroleum Institute  
<http://api-ec.api.org/>
- National Petroleum Council  
<http://www.npc.org/>
- National Petrochemical & Refiners Association  
<http://www.npra.org/>

### Security Links

- Infragard  
<http://www.infragard.net/>
- Information System Security Association  
<http://www.issa.org/>
- Partnership for Critical Infrastructure Security  
<http://www.pcis.org/>
- Information Systems Audit and Control Association  
<http://www.isaca.org/>

## Standards and Association Links (cont.)

### Water Links

- Water Information Sharing and Analysis Center  
<http://www.waterisac.org/>
- Association of Metropolitan Water Agencies  
<http://www.amwa.net/>
- American Public Works Association  
<http://www.apwa.net/>
- Water Quality Association  
<http://www.wqa.org/>
- Water Environment Federation  
<http://www.wef.org/>
- National Rural Water Association  
<http://www.nrwa.org/>
- Association of State Drinking Water Administrators  
<http://www.asdwa.org/>
- Ground Water Protection Council  
<http://www.gwpc.org/>
- Association of Metropolitan Sewage Agencies  
<http://www.amsa-cleanwater.org/>
- American Water Works Association  
<http://www.awwa.org/>

## ICS Primer

An ICS monitors and controls critical infrastructure equipment both locally and remotely. The system can be viewed as a collection of interconnecting devices and automated and human actions working together to monitor and control a particular infrastructure. The function and efficiency of an ICS depends on the types of equipment controlled and the communication methods employed by the ICS.

Local controls primarily protect equipment from damage by removing from service when set thresholds (temperature, pressure, current, etc.) are exceeded. Well-defined local control functions regulate and respond to system conditions within a specified range. Remote controls at control centers consolidate data from local equipment using automated and human actions.

## Two Categories of ICS

Control systems can be broken into two broad categories: those deployed in a single location, such as those used in manufacturing or chemical plants, and those spread out over multiple locations, such as those used in electric power, oil and gas, or water systems.

## Manufacturing and Chemical

In the manufacturing and chemical industries, ethernet or modem networks typically transmit control data between local equipment and several distributed control areas or centralized control areas. These industries refer to ICSs as Process Control Systems (PCSSs) or Distributed Control Systems (DCSs) rather than as Supervisory Control and Data Acquisition (SCADA) systems. A typical system has an interconnected network of programmable logic controllers (PLCs) and control centers that communicate via local area network (LAN) fibers or wires, supplemented with gateways and modems or serial lines to carry out the monitoring and control functions of the field devices. Because Ethernet is high-speed and the serial devices are relatively close to the PLCs, monitoring and control of devices can be very rapid.

## Electric Power, Oil and Gas, and Water

In the electric power, oil and gas, and water infrastructures, ICSs have one or a few centralized control stations to communicate with a multitude of remote stations, each with a Remote Terminal Unit (RTU) or PLC to concentrate data from the remote station devices. The remote station connections can be as simple as an RTU connected with direct hardwires to panels and field devices, or a more modern configuration with RTU connections to serial or Ethernet intelligent electronic devices (IEDs) (which consolidate data from the field devices). RTUs, PLCs, and individual IEDs can also be Internet Protocol (IP) addressable, allowing for direct monitor and control.

## Automation Systems in Electric Power

- SCADA – Supervisory Control and Data Acquisition (All-encompassing government term for automation systems)
- EMS – Energy Management System
- Protection – Relaying
- AGC – Automatic Generation Control
- WAP – Wide Area Protection
- DMS – Distribution Management System

## Related Works in Progress

We refer readers to the future publication of NIST 800-82 – “Guide to Supervisory Control and Data Acquisition (SCADA) and Industrial Control System Security” to be released as a public draft in September 2005 and as a final publication in January 2006. This publication may be found on the Internet at:

- NIST Special Publications: Computer Security Resource Center - CSD  
<http://csrc.nist.gov/publications/nistpubs/>

Additional resources that will be valuable for SCADA security may be found on the Internet at:

- NIST Process Control Security Requirements Forum (PCSRF)  
<http://www.isd.mel.nist.gov/projects/processcontrol/>
- Institute for Information Infrastructure Protection (The I3P)  
<http://www.thei3p.org/>

**TSWG Mission:** Conduct the National Interagency Research and Development program for Combating Terrorism through rapid research, development and prototyping.

Please contact TSWG at [ipsubgroup@TSWG.gov](mailto:ipsubgroup@TSWG.gov) to provide comments or suggestions on this publication or to request further information on the TSWG and its programs.

**TSWG**