Prepared for the Election Assistance Commission

Draft Voluntary Voting System Guidelines Version 1.1

May 27, 2009 draft

This document has been prepared by the National Institute of Standards and Technology (NIST) and represents draft materials for the Election Assistance Commission (EAC). It does not represent a consensus view or recommendation from NIST, nor does it represent any policy decisions of NIST.

Volume I: *Voting System Performance Guidelines*

Draft VVSG 1.1

May 27, 2009

This document represents a draft revision of the Election Assistance Commission's (EAC) 2005 Voluntary Voting System Guidelines (VVSG) Version 1.0. It has been prepared by the National Institute of Standards and Technology (NIST) for the EAC, and does not represent a consensus view or recommendation from NIST, nor does it represent any policy positions of NIST.

This document consists of the VVSG Version 1.0, revised with new material mostly from the Technical Guidelines Development Committee (TGDC) VVSG Recommendations to the EAC of August 31, 2007. It also contains changes to the 2005 VVSG material as a result of EAC decisions on Requests for Interpretation (RFI) of requirements in the 2005 VVSG. This document has been highlighted in places where changes have been made, new material has been added, or previous material has been deleted. Typos and formatting issues in the previous material that have been corrected are not highlighted.

Background

The Election Assistance Commission (EAC) requested that NIST investigate whether certain requirements in the 2007 TGDC Recommendations could be integrated with or replace current requirements in the 2005 VVSG in order to improve the overall quality and uniformity of testing for voting systems and to make key improvements in the 2005 VVSG while the TGDC Recommendations is in public review. The EAC requested also that the requirements also be accompanied by tests being developed by NIST as part of its test suites for the TGDC Recommendations. Other criteria used to identify candidate requirements from the TGDC Recommendations included that

- would not require hardware changes to current voting systems,
- would not require complex changes in software to current voting systems, and
- would not substantially change the structure of the VVSG 2005.

The EAC, with initial input from NIST (see http://vote.nist.gov/EACResearch-AmendedVVSG-2005-20081030.pdf), selected the requirements from the TGDC Recommendations to include in the 2005 VVSG revision. The EAC and NIST then reviewed comments received from the public review of the TGDC Recommendations (which ended in April, 2008) and revised the TGDC Recommendations requirements accordingly. Using this material, NIST then revised the 2005 VVSG Version 1.0.

Overview of Revisions

The following list identifies the major sections of material in this draft that are revised with updated material from the TGDC Recommendations. Items 10, Cryptography, and 11, External Interface Requirement, identify newly developed material.

1. **Hardware and Software Performance Benchmarks and Test Method**

    - **Volume I Section 4.1.1** of the 2005 VVSG is replaced by Part 1 Section 6.3.2 (Accuracy) of the TGDC Recommendations.
    - **Volume I Section 4.1.5.1.e.ii (under Ballot Handling) and 4.1.5.2.f** (under Ballot Reading Accuracy) of the 2005 VVSG are replaced by Part 1 Section 6.3.3 (Misfeed Rate) of the TGDC Recommendations.
    - **Volume I Section 4.3.3** of the 2005 VVSG is replaced by a condensed version of Part 1 Section 6.3.1 (Reliability) of the TGDC Recommendations.
    - To update the test method,

        - **Volume II Appendix C** of the 2005 VVSG is completely replaced by Part 3 Section 5.3 of the TGDC Recommendations.
        - **Volume II Sections 4.7.1.1 and 4.7.3** of the 2005 VVSG are deleted.
        - **Volume II Sections 1.8.2.3 and 4.5** of the 2005 VVSG are harmonized with Part 3 Section 2.5.3 of the TGDC Recommendations.

2. **Software Workmanship**

    - **Volume I Section 5.2** of the 2005 VVSG is replaced by Part 1 Sections 6.4.1 through 6.4.1.8 of the TGDC Recommendations.
    - **Volume II Section 5.4** of the 2005 VVSG is replaced by Part 3 Section 4.5.1 of the TGDC Recommendations.
    - **Volume II Section 1.8.2.6** (Certification Test Practices) of the 2005 VVSG is harmonized with Part 3 Section 2.5.5 of the TGDC Recommendations to clarify the handling of logic defects.

3. **Test Plan and Test Report - Appendices A and B of Volume II** of the 2005 VVSG are harmonized with the current EAC manuals and NOC 09-001.

4. **TDP and Voting Equipment User Documentation – Volume II Section 2.1.1.1** of the 2005 VVSG is revised to include an outline of the TDP and the Voting Equipment User Documentation that is based on the TGDC Recommendations. Miscellaneous TDP requirements are added or modified to correct problems.

5. **(Non-EMC) Environmental Hardware**

    - **Volume I Section 4.1.2.13** (Environmental Control – Operating Environment) of the 2005 VVSG is revised with an operational temperature and humidity test requirement, with temperatures ranging from 41 °F to 104 °F (5 °C to 40 °C) and relative humidity from 5% to 85%, non-condensing.

- **Volume II Section 4.7.1** (Temperature and Power Variation Tests is replaced with requirements for testing according to appropriate procedures of MIL-STD-810D. Most of the previous text in this section was devoted to test materials, including detailed test scenarios, which will be included in the test materials for the final version of the VVSG 1.1.

6. **Human Factors Requirements** – The usability and accessibility requirements in **Volume I Section 3 of the 2005 VVSG** are replaced with requirements from Part 1 Chapter 3 of the TGDC Recommendations, with the exception of Chapter 3's performance benchmark requirements. Part 1 Chapter 3 of the TGDC Recommendations is primarily a maintenance level upgrade to the 2005 VVSG with minor modifications, clarifications, and a few additions including performance and poll worker usability requirements. (The 2005 VVSG Section 3 was mostly new material based on research, best practices, and standards relating to human factors and the design of user interfaces as they apply to voting systems.)

7. **System Security Documentation Requirements -** Security documentation requirements in **Volume II Section 2.6** (Security Documentation) of the 2005 VVSG are revised with requirements from Part 2 Section 3.5 (System Security Specification) of the TGDC Recommendations. The new requirements include high-level security descriptions of the voting system and specific areas including

   - Access control,
   - Software installation security,
   - System event logging,
   - Physical security,
   - Setup inspection, and
   - Cryptography.

8. **Electronic Records - Section 2.4.4** (Electronic Records) has been added to **Volume I Section 2** (Functional Requirements) of the 2005 VVSG; it contains requirements from Part 1 Chapter 4.3 (Electronic Records) of the TGDC Recommendations. These requirements cover the electronic reports generated by the voting system, including specific reports for tabulators and Election Management Systems (EMS).

9. **Voter Verified Paper Audit Trails (VVPAT)** - VVPAT requirements in **Volume I Sections 7.9.1 through 7.9.4** (Voter Verifiable Paper Audit Trail Requirements) are replaced with requirements from Part 1 Chapter 4.4.2 (VVPAT) of the TGDC Recommendations.

10. **Cryptography** - Cryptography requirements in the 2005 VVSG are revised with requirements from Part 1 Section 5.1 (Cryptography) of the TGDC Recommendations. When cryptography is used in a voting system, the requirements call for the use of a level 1 FIPS 140 validated cryptographic module (which allows

software as well as hardware implementations, whereas the TGDC Recommendations allowed only hardware implementations). In addition, the new requirements require the use of NIST approved cryptographic algorithms at the 112-bit security strength or higher.

11. **External Interface Requirement - Volume I Section 7.4.6** (Software Setup Validation) of the 2005 VVSG are revised with newly developed requirements to allow an alternative method to validate software on voting systems. The requirements state that voting systems must support one of the two verification methods specified in the requirements. The current software verification method allows software to be verified after software has been installed. The alternative software verification method verifies software as it is being installed on the voting system and requires voting systems to have mechanisms to protect the software once installed.

12. **EAC Requests for Interpretation (RFI) decisions** - Requirements and discussion throughout the 2005 VVSG are revised based on the current set of EAC RFI decisions, from 2007-01 through 2008-12, located at http://www.eac.gov/program-areas/voting-systems/voting-system-certification/interpretations.

Voluntary Voting System Guidelines Version 1.1

Table of Contents

Volume I Voting System Performance Guidelines

Volume II National Certification Testing Guidelines

VOLUNTARY VOTING SYSTEM GUIDELINES

Volume I

Voting System Performance Guidelines

Voluntary Voting System Guidelines Overview

Table of Contents

Voluntary Voting System Guidelines Overview

The United States Congress passed the Help America Vote Act of 2002 (HAVA) to modernize the administration of federal elections, marking the first time in our nation's history that the federal government has funded an election reform effort. HAVA provides federal funding to help the states meet the law's uniform and non-discretionary administrative requirements, which include the following new programs and procedures: 1) provisional voting, 2) voting information, 3) statewide voter registration lists and identification requirements for first-time registrants, 4) administrative complaint procedures, and 5) updated and upgraded voting equipment.

HAVA also established the U.S. Election Assistance Commission (EAC) to administer the federal funding and to provide guidance to the states in their efforts to comply with the HAVA administrative requirements. Section 202 directs the EAC to adopt voluntary voting system guidelines, and to provide for the testing, certification, decertification, and recertification of voting system hardware and software. The purpose of the guidelines is to provide a set of specifications and requirements against which voting systems can be tested to determine if they provide all the basic functionality, accessibility, and security capabilities required of voting systems.

This document, the *Voluntary Voting System Guidelines* (referred to herein as the *Guidelines* and/or *VVSG*), is the third iteration of national level voting system standards that has been developed. The Federal Election Commission published the *Performance and Test Standards for Punchcard, Marksense and Direct Recording Electronic Voting Systems* in 1990. This was followed by the *Voting Systems Standards* in 2002.

Version 1.0 of the VVSG was adopted by a vote of EAC on December 13, 2005. Version 1.1 of the VVSG was created by the EAC in an effort to update and improve version 1.0 of the VVSG. Specifically Version 1.1 provides updates to requirements in the areas of security, reliability, usability, and accessibility. These improvements enhance the testability and clarity of several of the requirements contained in version 1.0 of the VVSG.

~~As required by HAVA, the EAC formed the Technical Guidelines Development Committee (TGDC) to develop an initial set of recommendations for the *Guidelines*. This committee of 15 experts began their work in July 2004 and submitted their recommendations to the EAC in the 9-month timeline prescribed by HAVA. The TGDC was provided with technical support by the National Institute for Standards and Technology (NIST), which was given nearly $3 million dollars by the EAC to complete this work.~~

~~The EAC reviewed and revised the TGDC recommendations and, as required by HAVA, published the proposed *Guidelines* for a 90 day public comment period. The document was also provided to both the Board of Advisors and the Standards Board for their review and comment. During the comment period the EAC conducted 3 public hearings on the *Guidelines* in New York City, Pasadena and Denver. Over 6000 comments were received from the public and the Boards. Each of these comments was reviewed and considered by the EAC in consultation with NIST in the development of this final version.~~

Purpose and Scope of the *Guidelines*

The purpose of the *Voluntary Voting System Guidelines* is to provide a set of specifications and requirements against which voting systems can be tested to determine if they provide all the basic functionality, accessibility and security capabilities required to ensure the integrity of voting systems. The *VVSG* specifies the functional requirements, performance characteristics, documentation requirements, and test evaluation criteria for the national certification of voting systems. The *VVSG* is composed of two volumes: Volume I, *Voting System Performance Guidelines* and Volume II, *National Certification Testing Guidelines.*

Effective Date

The ~~2005~~ *Voluntary Voting System Guidelines Version 1.1* will take effect ~~24 months~~ after their final adoption ~~in December 2005~~ by the EAC. At that time, all new systems submitted for national certification will be tested for conformance with these guidelines. In addition, if a modification to a system qualified or certified to a previous standard is submitted for national certification after this date, every component of the modified system will be tested against the ~~2005~~ *VVSG Version 1.1*. All previous versions of national standards will become obsolete at this time. ~~This effective date provision does not have any impact on the mandatory January 1, 2006, deadline for states to comply with the HAVA Section 301 requirements.~~

This *VVSG* effective date provision has no effect on the mandatory voting system requirements prescribed in HAVA Section 301(a), which states must comply with on or before January 1, 2006. The EAC issued Advisory 2005-004 to assist states in determining if a voting system is compliant with Section 301(a). This advisory is available on the EAC website at www.eac.gov.

Summary of Changes

Volume I of the *Guidelines*, entitled *Voting System Performance Guidelines*, includes ~~new~~ updated requirements for usability, accessibility, voting system software distribution, generation of software reference information, validation of software during voting system setup, and the use of wireless communications. System functional requirements have been revised to comply with HAVA Section 301 requirements. Environmental criteria have been updated. This volume also includes requirements for a voter verifiable paper audit trail component for direct-recording electronic voting systems for use by states that require this feature. In addition, this volume includes an updated glossary and a conformance clause.

Volume II of the *Guidelines*, entitled *National Certification Testing Guidelines*, has been revised to reflect the ~~new EAC process for national certification of voting systems~~ program requirements of the EAC's Testing and Certification Program. ~~This process was initiated in 2005 and replaces the voting system qualification process conducted by the National Association of State Election Directors (NASED) since 1994.~~ In addition, revisions have been made to the testing procedures to reflect new requirements for the conduct of usability and accessibility testing. Terminology in both volumes has been revised to reflect new terminology introduced by HAVA.

Volume I: *Voting System Performance Guidelines Summary*

Volume I, the *Voting System Performance Guidelines*, describes the requirements for the electronic components of voting systems. It is intended for use by the broadest audience, including voting system developers, manufacturers and suppliers; voting system testing labs (VSTL); state organizations that certify systems prior to procurement; state and local election officials who procure and deploy voting systems; and public interest organizations that have an interest in voting systems and voting system standards. It contains the following sections:

Section I describes the purpose and scope of the *Voting System Performance Guidelines.*

Section 2 describes the functional capabilities required of voting systems. This section has been revised to reflect HAVA Section 301 requirements.

Section 3 describes new standards that make voting systems more usable and accessible for as many eligible citizens as possible, whatever their physical abilities, language skills, or experience with technology. This section reflects the HAVA 301 (a)(3) accessibility requirements.

Sections 4 through 6 describe specific performance standards for election system hardware, software, telecommunications, and security. Environmental criteria have been updated in Section 4.

Section 7 describes voting system security requirements and includes new requirements for voting system software distribution, generation of software reference information, validation of software during system setup, and the use of wireless. It also includes requirements for voter verifiable paper audit trail components for direct-recording electronic voting systems.

Sections 8 and 9 describe requirements for manufacturer quality assurance and configuration management practices and the documentation about these practices required for the EAC certification process.

Appendix A contains a glossary of terms.

Appendix B provides a list of related standards documents incorporated into the *Guidelines* by reference, documents used in the preparation of the *Guidelines*, and referenced legislation.

Appendix C presents an introductory discussion of independent verification systems as a potential concept for future voting system security design.

Appendix D contains technical guidance on color, contrast and text size adjustment for individuals with low vision or color blindness.

Volume II: *National Certification Testing Guidelines Summary*

Volume II, the *National Certification Testing Guidelines*, is a complementary document to Volume I. Volume II provides an overview and specific detail of the national certification testing process, which is performed by independent voting system test labs (VSTL) accredited by the EAC. It is intended principally for use by manufacturers: VSTLs: and election officials who certify, procure, and accept voting systems. This volume contains the following sections:

Guide to Section Locations

Section 1 describes the purpose of the National Certification Testing Guidelines.

Section 2 provides a description of the Technical Data Package that manufacturers are required to submit with their system for certification testing.

Section 3 describes the basic functionality testing requirements.

Sections 4 through 6 define the requirements for hardware, software and system integration testing. Section 6 has been revised to reflect new requirements for usability and accessibility testing.

Section 7 describes the required examination of manufacturer quality assurance and configuration management practices.

Appendix A provides the requirements for the National Certification Test Plan that is prepared by the VSTL and provided to the EAC for review.

Appendix B describes the scope and content of the National Certification Test Report which is prepared by the VSTL and delivered to the EAC along with a recommendation for certification.

Appendix C describes the guiding principles used to design the voting system certification testing process. It also contains a revised section on testing system error rates.

1 Introduction

Table of Contents

1 Introduction

1.1 Purpose and Scope of the Voluntary Voting System Guidelines

The purpose of the *Voting System Performance Guidelines*) is to provide a set of specifications and requirements against which voting systems can be tested to determine if they provide all the basic functionality, accessibility, and security capabilities required of voting systems. ~~The VVSG specifies the functional requirements, performance characteristics, documentation requirements, and test evaluation criteria for the national certification of voting systems.~~ The performance guidelines specify the functional requirements, performance characteristics, documentation requirements, and test evaluation criteria for the national certification of voting systems. To the extent possible, these requirements and specifications are described so they can be assessed by a series of defined, objective tests. ~~The VVSG is composed of two volumes: Volume 1, Voting System Performance Guidelines; and Volume 2, National Certification Testing Guidelines.~~

~~The *VVSG* is one of several inter-related EAC promulgated guidelines and programs concerned with maintaining the reliability and security of voting systems and the integrity of the overall election process. The performance of national certification testing of voting systems is restricted to testing labs that have been formally accredited to be technically competent to evaluate systems for conformance to the *Voting System Performance Guidelines*. The National Association of State Election Directors (NASED) initiated the independent testing authority accreditation program for test labs in 1994, applying the standards and procedures in NASED Program Handbook 9201 (Revision A). With the passage of the Help America Vote Act (HAVA), this responsibility transitioned to the Election Assistance Commission (EAC) with support from the National Voluntary Laboratory Accreditation Program (NVLAP). This program is operated by the National Institute of Standards and Technology (NIST), applying the standards and procedures in NIST Handbook 150-22, NVLAP Voting System Testing.~~

~~The *VVSG* and the test lab accreditation process are essential components of the EAC National Certification Program for voting systems. This program applies the standards and procedures documented in the EAC voting system certification manual. HAVA Section 231 charges EAC with providing for the certification, decertification and recertification of voting systems. Under this program national certification is just the first step of the life cycle process of maintaining the reliability and security of the voting systems used in the nation's elections. To carry out this mandate, the EAC program will include monitoring of voting system performance through incident reporting by election officials and others. The certification program will maintain information on the quality assurance practices associated with the development and manufacturing of voting systems. When a system has successfully completed the certification process, the EAC program requires a copy of the certified voting system software to be provided to the~~

~~National Software Reference Library operated by NIST. This will enable election officials to validate that the software received by their jurisdictions is the same as the certified version.~~

~~The *VVSG* notes the need for appropriate procedures to complement and supplement the technical requirements for voting system performance. It is well known that deficiencies in election management and administration procedures can have just as much impact on the enfranchisement of voters and the outcome of elections as the functioning of the voting machines. The overall integrity of the election process depends on both of these elements working together. EAC and NASED have instituted a multi-year effort to develop a comprehensive set of election management guidelines that will complement the technical system guidelines, as well as cover other elements of the election process.~~

Except as noted below, Volume I of the *Guidelines* applies to all system hardware, software, telecommunications, and documentation intended for use to:

- Prepare the voting system for use in an election
- Produce the appropriate ballot formats
- Test that the voting system and ballot materials have been properly prepared and are ready for use
- Record and count votes
- Consolidate and report election results
- Display results on-site or remotely
- Produce and maintain comprehensive audit trail data

Some voting systems use one or more commercial off-the-shelf (COTS) devices (such as card readers, printers, and personal computers) or software products (such as operating systems, programming language compilers, and database management systems). These devices and products are exempt from certain portions of system certification testing, as long as they are not modified for use in the voting system.

~~Volume 2 describes the testing process to provide a documented independent verification by an accredited testing laboratory that a voting system has been demonstrated to conform to the Volume 1 requirements and therefore should receive national certification. It provides the specific detail about the testing process and documentation requirements required to support the national certification program.~~

1.2 Use of the Voluntary Voting System Guidelines

The *Guidelines* are intended for use by multiple audiences to support their respective roles in the development, testing, and acquisition of voting systems:

- The accredited testing laboratories who use this information to develop test plans and procedures for the analysis and testing of systems in support of the national certification testing process
- State and local election officials who are evaluating voting systems for potential use in their jurisdictions

- Voting system designers and manufacturers who need to ensure that their products fulfill all these requirements so they can be certified

1.3 Evolution of Voting System Standards

1.3.1 Federal Election Commission

The first voting system standards were issued in January 1990, by the Federal Election Commission (FEC). This document included performance standards and testing procedures for Punchcard, Marksense, and Direct-Recording Electronic (DRE) voting systems. These standards did not cover paper ballot and mechanical lever systems because paper ballots are sufficiently self-explanatory not to require technical standards and mechanical lever systems are no longer manufactured or sold in the United States. The FEC also did not incorporate requirements for mainframe computer hardware because it was reasonable to assume that sufficient engineering and performance criteria already governed the operation of mainframe computers. However, vote tally software installed on mainframes was covered.

A national testing effort was initiated by NASED in 1994. As the system qualification process matured and qualified systems were used in the field, the NASED Voting Systems Board, in consultation with the testing labs, identified certain testing issues that needed to be resolved. Moreover, rapid advancements in information and personal computer technologies introduced new voting system development and implementation scenarios not contemplated by the 1990 Standards.

In 1997, NASED briefed the FEC on the importance of keeping the Standards up to date. Following a requirements analysis completed in 1999, the FEC initiated an effort to revise the 1990 Standards to reflect the evolving needs of the elections community. This resulted in the 2002 Voting Systems Standards.

Voters and election officials who use voting systems represent a broad spectrum of the population, and include individuals with disabilities who may have difficulty using traditional voting systems. In developing accessibility provisions for the 2002 Voting System Standards, the FEC requested assistance from the Access Board, the federal agency in the forefront of promulgating accessibility provisions. The Access Board submitted technical standards to meet the diverse needs of voters with a broad range of disabilities. The FEC adopted the entirety of the Access Board's recommendations and incorporated them into the 2002 Voting Systems Standards.

1.3.2 Election Assistance Commission

In 2002, Congress passed the Help America Vote Act, which established the U.S. Election Assistance Commission (EAC). EAC was mandated to develop and adopt new voluntary voting system guidelines and to provide for the testing, certification, and decertification of voting systems. HAVA also established the Technical Guidelines Development Committee (TGDC) with the duty of assisting the EAC in the development of the new guidelines. The Director of NIST chairs the TGDC, and NIST was tasked to provide technical support to their work. ~~The TGDC delivered their initial set of recommendations to the EAC in May, 2005.~~

~~The TGDC built on the foundation of the 2002 Voting Systems Standards and the accessibility provisions of HAVA to expand requirements for voting system usability and accessibility. HAVA mandates that voting systems shall be accessible for individuals with disabilities in a manner that provides the same opportunity for access and participation (including privacy and independence) as for other voters. To facilitate the ability of jurisdictions to meet these requirements, HAVA allows for the use of at least one direct- recording electronic or other voting system equipped for individuals with disabilities at each polling place. Implementing this provision, however, will not entirely eliminate the necessity of accommodating the needs of some disabled voters by human assistance, given the limitations of current technology.~~

~~The 2005 *VVSG* is the culmination of sixteen months of effort by the TGDC, NIST and the EAC. There is still much to be done to further develop the technical guidelines for voting system performance, accessibility and usability features, and security. Further work is also needed for the specification of comprehensive standard test suites for certification testing, to include testing for usability and accessibility features and expanded security testing.~~

~~Overview of Voting System Testing~~

1.3.3 The ~~National Certification Program for Voting Systems~~ EAC’s Voting System Testing and Certification Program

The purpose of the Voting System Testing and Certification Program is to validate and document, through an independent testing process, that voting systems meet the requirements set forth in *VVSG* Volume 1 - *Voting System Performance Guidelines*, and perform according to the manufacturer’s specifications for the system. Volume 1 specifies the minimum functional requirements, performance characteristics, documentation requirements, and test evaluation criteria that voting systems must meet in order to receive national certification. At this time, 39 states either require national certification or utilize the national standards when certifying voting systems. [need to fact check this statement] The EAC Testing and Certification Program Manual Version 1.0 (OMB Control Number 3265-0004) documents the procedural requirements for this program.

~~The purpose of the national certification program is to validate and document, through an independent testing process, that voting systems meet the requirements set forth in *VVSG* Volume 1 - *Voting System Performance Guidelines*, and perform according to the vendor’s specifications for the system. Volume 1 specifies the minimum functional~~

~~requirements, performance characteristics, documentation requirements, and test evaluation criteria that voting systems must meet in order to receive national certification. At the time of VVSG 2005 publication, 39 states either require national certification or utilize the national standards when certifying voting systems.~~

Certification Testing under the EAC's program can only be performed by EAC accredited Voting System Test Labs (VSTLs). These VSTLs have been accredited for demonstrated technical competence to test voting systems using the *Guidelines*. Volume 2 of the *VVSG - National Testing and Certification Guidelines* - provides guidance on the testing process and describes the associated documentation requirements. These tests encompass the examination of software; the inspection and evaluation of system documentation; tests of hardware under conditions simulating the intended storage, operation, transportation, and maintenance environments; operational tests to validate system performance and function under normal and abnormal conditions; and examination of the manufacturer's system development, testing, quality assurance, and configuration management practices. Certification tests address individual system components or elements, as well as the integrated system as a whole. The [Lab Manual reference] sets out the procedures for the accreditation of testing laboratories.

~~National certification testing can only be performed by testing labs that have been accredited for demonstrated technical competence to test voting systems using these *Guidelines*. Volume 2 of the *VVSG – National Certification Testing Guidelines* – provides guidance on the testing process and describes the associated documentation requirements. These tests encompass the examination of software; the inspection and evaluation of system documentation; tests of hardware under conditions simulating the intended storage, operation, transportation, and maintenance environments; operational tests to validate system performance and function under normal and abnormal conditions; and examination of the vendor's system development, testing, quality assurance, and configuration management practices. Certification tests address individual system components or elements, as well as the integrated system as a whole.~~

Since 1994, testing of voting systems has been performed by Independent Test Authorities (ITAs) certified by NASED. Upon the successful completion of testing, the ITA issued a Qualification Test Report to the manufacturer and NASED. The Technical Committee of the NASED Voting Systems Board would review the test report and, if satisfactory, issue a Qualification Number. The Qualification Number remains valid for as long as the voting system remains unchanged.

HAVA mandated that the certification testing process be transferred from NASED to EAC. National certification testing complements and evaluates the manufacturer's developmental testing and beta testing. The VSTL is expected to evaluate the completeness of the manufacturer's developmental test program, including the sufficiency of manufacturer tests conducted to demonstrate compliance with the *Guidelines* as well as the system's performance specifications. The VSTL undertakes sample testing of the manufacturer's test modules and also designs independent system-level tests to supplement and check those designed by the manufacturer. Although some of the certification tests are based on those prescribed in the Military Standards, in most cases the test conditions are less stringent, reflecting commercial, rather than military, practice.

Upon review of test reports and a determination that satisfactory results were achieved that address the full scope of testing, EAC will issue a certification number that indicates the system has successfully completed testing by a VSTL for compliance with the *Guidelines*. The certification number applies to the system as a whole and does not apply to individual system components or untested configurations.

After a system has completed initial certification testing, further examination of the system is required if modifications are made to hardware, software, or telecommunications, including the installation of software on different hardware. Manufacturers request review of modifications by the VSTL based on the nature and scope of changes made. The VSTL will assess whether the modified system should be resubmitted for certification testing and the extent of testing to be conducted, and then it will provide an appropriate recommendation to the EAC and the manufacturer.

~~Generally, a voting system remains certified under the standards against which it was tested as long as no modifications requiring recertification have been made to the system. However, if a new threat to a particular voting system is discovered, it is the prerogative of EAC to determine which certified voting systems are vulnerable, whether those systems need to be retested, and the specific tests to be conducted. In addition, when new requirements supersede the requirements under which the system was certified, it is the prerogative of EAC to determine when systems that were certified under the earlier requirements will need to be re-tested to meet current guidelines.~~

1.3.4 State Certification Testing

State certification tests are performed by individual states, with or without the assistance of outside consultants, to:

- Confirm that the voting system presented is the same as the one certified under the *Guidelines*
- Test for the proper implementation of state-specific requirements
- Establish a baseline for future evaluations or tests of the system, such as acceptance testing or state review after modifications have been made
- Define acceptance tests

State certification test scripts are not included in the *Guidelines,* as they must be defined by the state, with its laws, election practices, and needs in mind. However, it is recommended that they not duplicate the national certification tests, but instead focus on functional tests and qualitative assessment to ensure that the system operates in a manner that is acceptable under state law. If a voting system is modified after state certification is completed, it is recommended that states reevaluate the system to determine if further certification testing is warranted.

Certification tests performed by individual states typically rely on information contained in documentation provided by the manufacturer for system design, installation, operations, required facilities and supplies, personnel support and other aspects of the voting system. States and jurisdictions may define information and documentation requirements additional to those defined in the *Guidelines*. By design, the *Guidelines* do not address these additional requirements. However, national certification testing will address all the capabilities of a voting system stated by the manufacturer in the system documentation submitted with the testing application to the EAC, including additional capabilities that are not required by the states.

1.3.5 Acceptance Testing

Acceptance tests are performed at the state or local jurisdiction level upon system delivery by the manufacturer to:

- Confirm that the system delivered is the specific system certified by EAC and, when applicable, certified by the state
- Evaluate the degree to which delivered units conform to both the system characteristics specified in the procurement documentation, and those demonstrated in the national and state certification tests
- Establish a baseline for any future required audits of the system

Some of the operational tests conducted during certification may be repeated during acceptance testing.

1.4 Definitions, References, and Types of Voting Systems

1.4.1 Definitions and References

The *Guidelines* contain terms describing function, design, documentation, and testing attributes of voting system hardware, software and telecommunications. Unless otherwise specified, the intended sense of technical terms is that which is commonly used by the information technology industry. In some cases terminology is specific to elections or voting systems. A glossary of terms is contained in Appendix A. Non-technical terms not listed in Appendix A shall be interpreted according to their standard dictionary definitions.

There are a number of technical standards that are incorporated in the *Guidelines* by reference. These are referred to by title in the body of the document. The full citations for these publications are provided in Appendix B. In addition, this appendix includes other references that may be useful for understanding and interpretation.

1.4.2 Types of Voting Systems

HAVA Section 301 defines a voting system as the total combination of mechanical, electromechanical, or electronic equipment (including the software, firmware, and documentation required to program, control, and support the equipment), that is used to define ballots; to cast and count votes; to report or display election results; and to maintain and produce any audit trail information. In addition, a voting system includes the practices and associated documentation used to identify system components and versions of such components; to test the system during its development and maintenance; to maintain records of system errors and defects; to determine specific system changes made after initial certification; and to make available any materials to the voter (such as notices, instructions, forms, or paper ballots).

Traditionally, a voting system has been defined by the mechanism the system uses to cast votes and further categorized by the location where the system tabulates ballots. In addition to defining a common set of requirements that apply to all voting systems, the *VVSG* states requirements specific to a particular type of voting system, where appropriate. However, the *Guidelines* recognize that as the industry develops new solutions and the technology continues to evolve, the distinctions between voting system types may become blurred. The fact that the *VVSG* refers to specific system types is not intended to stifle innovations that may be based on a more fluid understanding of system types. However, appropriate procedures must be in place to ensure new developments provide the necessary integrity and can be properly evaluated in the certification process.

Consequently, manufacturers that submit a system that integrates components from more than one traditional system type or a system that includes components or technology not addressed in the *Guidelines* shall submit the results of all beta tests of the new system when applying for national certification. Manufacturers shall also submit a proposed test plan to the EAC for use in national certification testing. The *Guidelines* permit manufacturers to produce or utilize interoperable components of a voting system that are tested within the full voting system configuration.

The listing below summarizes the functional requirements that HAVA Section 301 mandates to assist voters. While these requirements may be implemented in a different manner for different types of voting systems, all types of voting systems must provide these capabilities:

- permit the voter to verify (in a private and independent manner) the vote selected by the voter on the ballot before the ballot is cast and counted
- provide the voter with the opportunity (in a private and independent manner) to change the ballot or correct any error before the ballot is cast and counted
- notify the voter if he or she has selected more than one candidate for a single office, inform the voter of the effect of casting multiple votes for a single office, and provide the voter an opportunity to correct the ballot before it is cast and counted
- be accessible for individuals with disabilities in a manner that provides the same opportunity for access and participation (including privacy and independence) as for other voters
- provide alternative language accessibility pursuant to Section 203 of the Voting Rights Act

1.4.2.1 Paper-Based Voting System

A paper-based voting system records votes, counts votes, and produces a tabulation of the vote count from votes cast on paper cards or sheets. A marksense (also known as optical scan) voting system allows a voter to record votes by making marks directly on the ballot, usually in voting response locations. Additionally, a paper-based system may allow for the voter's selections to be indicated by marks made on a paper ballot by an electronic input device, as long as such an input device does not independently record, store, or tabulate the voter selections.

1.4.2.2 Direct-Recording Electronic Voting System

A direct-recording electronic (DRE) voting system records votes by means of a ballot display provided with mechanical or electro-optical components that can be activated by the voter; that processes data by means of a computer program; and that records voting data and ballot images in memory components. It produces a tabulation of the voting data stored in a removable memory component and as printed copy. The system may also provide a means for transmitting individual ballots or vote totals to a central location for consolidating and reporting results from precincts at the central location.

1.4.2.3 Public Network Direct-Recording Electronic Voting System

A public network DRE voting system is an election system that uses electronic ballots and transmits vote data from the polling place to another location over a public network. Vote data may be transmitted as individual ballots as they are cast, periodically as batches of ballots throughout the election day, or as one batch at the close of voting. For purposes of the *Guidelines*, public network DRE voting systems are considered a form of DRE voting system and are subject to the standards applicable to DRE voting systems. However, because transmitting vote data over public networks relies on equipment beyond the control of the election authority, the system is subject to additional threats to system integrity and availability. Therefore, additional requirements are applied to provide appropriate security for data transmission.

The use of public networks for transmitting vote data must provide the same level of integrity as other forms of voting systems, and must be accomplished in a manner that precludes three risks to the election process: automated casting of fraudulent votes, automated manipulation of vote counts, and disruption of the voting process such that the system is unavailable to voters during the time period authorized for system use.

1.4.2.4 Precinct Count Voting System

A precinct count voting system is a voting system that tabulates ballots at the polling place. These systems typically tabulate ballots as they are cast and print the results after the close of polling. For DREs and some paper-based systems these systems provide electronic storage of the vote count and may transmit results to a central location over public telecommunication networks.

1.4.2.5 Central Count Voting System

A central count voting system is a voting system that tabulates ballots from multiple precincts at a central location. Voted ballots are typically placed into secure storage at the polling place. Stored ballots are transported or transmitted to a central counting location. The system produces a printed report of the vote count, and may produce a report stored on electronic media.

1.5 Conformance Clause

This section provides information and requirements relating to how manufacturers and VSTLs use this document to assess whether a voting system conforms to the VVSG.

1.5.1 Structure of Requirements

Each part of the VVSG is organized into sections that address topics of interest. Sections typically begin with prose explaining the general purpose, etc. This is informative background to help understand the requirements. Sections also contain requirements, which are the hard and fast rules to be followed for conformance. The VVSG carefully distinguish normative requirements from informative context by using normative keywords as defined below.

Each voting system requirement in Volume I is identified according to a hierarchical scheme in which higher-level requirements (such as “provide accessibility for visually impaired voters”) are supported by lower-level requirements (e.g., “provide an audio-tactile interface”). Thus, requirements are nested. When the nesting hierarchy has reached four levels (i.e., 1.1.1.1), further nested requirements are designated with lowercase letters, then roman numerals. Therefore, all requirements are traceable by a distinct reference.

Some requirements are directly testable and some are not. The latter tend to be higher-level and are included because (1) they are testable indirectly insofar as their lower-level requirements are testable, and (2) they often provide the structure and rationale for the lower-level requirements. Satisfying the lower-level requirements will result in satisfying the higher-level requirement.

~~1.6.1 Scope and Applicability~~

~~The *Voluntary Voting System Guidelines* define requirements for conformance of voting systems that voting system vendors shall meet. The *Guidelines* also provide the framework, procedures, and requirements that testing labs responsible for the certification testing of voting systems shall follow. The requirements and procedures in the *Guidelines* may also be used by states to certify voting systems. To ensure that correct voting system software has been distributed without modification, the *Guidelines* include requirements for certified voting system software to be deposited in a national software repository. This provides an independent means for election officials to verify the software they purchase.~~

~~The *Guidelines* define the minimum requirements for voting systems and the process of testing voting systems. The guidelines are intended for use by:~~

- ~~Designers and manufacturers of voting systems~~
- ~~Test labs performing the analysis and testing of voting systems in support of the EAC national certification process~~
- ~~Software repositories designated by EAC or by a state~~
- ~~Election officials, including ballot designers and officials responsible for the installation, operation, and maintenance of voting machines~~
- ~~Test labs and consultants performing the state certification of voting systems~~

~~Minimum requirements specified in these guidelines include:~~

- ~~Functional capabilities~~
- ~~Performance characteristics, including security~~
- ~~Documentation~~
- ~~Test evaluation criteria~~

~~1.6.2 Conformance Framework~~

~~This section provides the framework in which conformance is defined. It identifies the entities to which these guidelines apply, the relationships among the various entities, the structure of the requirements, and the terminology used to indicate conformance.~~

1.5.1.1 ~~Conformance~~ Normative Language

The following keywords are used to convey conformance requirements:

- **Shall –** indicates a mandatory requirement in order to conform. Synonymous with "is required to."

- Shall not, **is prohibited** –indicates a mandatory requirement that indicates something that is not permitted (allowed) in order to conform. ~~Synonymous with "shall not."~~

- **Should, is encouraged -** indicates an optional recommended action, one that is particularly suitable, without mentioning or excluding others. Synonymous with "is permitted and recommended."
- **May** - indicates an optional, permissible action. Synonymous with "is permitted."

Informative parts of this document include examples, extended explanations, and other matter that contain information necessary for proper understanding of the *Guidelines* and conformance to it.

1.5.1.2 Applicability ~~Applicable Entities~~

The requirements, prohibitions, options, and guidance specified in these guidelines apply to voting systems, voting system manufacturers, VSTLs, and software repositories. In general, requirements for voting systems in these guidelines apply to all types of voting systems, unless prefaced with explanatory narrative that applicability is limited to a specific type of system or device. ~~Other terms in these guidelines shall be construed as synonymous with "voting systems." They are: "systems", "the system", "the voting system", and "each voting system."~~

The term "manufacturer" ~~"vendor"~~ imposes documentation or testing requirements for the manufacturer. Other terms in these guidelines shall be construed as synonymous with "manufacturer," including "vendor," "voting system designers," and "implementer."

The terms used to designate requirements and procedural guidelines for accredited national certification testing laboratories are indicated by referring to "VSTL" (Voting System Test Lab). Other terms in these guidelines shall be construed as synonymous with "VSTL," including "accredited test labs," and "test labs." The term "repository" will be used to designate requirements levied on the National Software Reference Library repository maintained at NIST or any other designated repository.

These *Guidelines* are voluntary in that each of the states can decide whether to require the voting systems used in their state to have a national certification. States may decide to adopt these *Guidelines* in whole or in part at any time, irrespective of the effective date. In addition, states may specify additional requirements that voting systems in their jurisdiction must meet. The national certification program does not in any way pre-empt the ability of the states to have their own system certification process.

~~1.6.2.2 Relationships Among Entities~~

~~It is the voting system vendor that needs to implement these requirements and provide the necessary documentation for the system. In order to claim conformance to the Guidelines, the voting system vendor shall satisfy the specified requirements, including implementation of functionality, prescribed software coding and assurance practices, and preparation of the Technical Data Package. The voting system vendor shall successfully complete the prescribed test campaign with an EAC accredited test lab.~~

~~The accredited test lab shall satisfy the requirements for conducting certification testing. The test lab may use an operational environment emulating that used by election officials as part of their testing to ensure that the voting system can be configured and operated in a secure and reliable manner according to the vendor's documentation and as specified by the Guidelines. The test lab shall coordinate and deliver the requisite documentation and test report to the EAC for review. Upon issuance of a certification number by the EAC, the test lab shall deposit a copy of the certified voting system software with the National Software Reference Library.~~

~~The EAC shall review the test results and associated documentation and make a determination that all requirements have been appropriately tested and the test results are acceptable. The EAC will issue a national certification number that indicates conformance of the specified system with these Guidelines.~~

~~The National Software Reference Library (NSRL) shall create a digital signature of the voting system software provided by the test lab. This information will be posted to a website so election officials can compare the digital signature of the software provided to them by the voting system vendor with this certified reference. The NSRL shall maintain this reference information until notified by the EAC that it can be archived.~~

1.5.1.3 Categorizing Requirements

The *Guidelines* set forth a common set of requirements for national certification that apply to all types of electronic voting systems. They also provide requirements that are applicable for particular circumstances, such as alternative language capability or disability accessibility. The requirements implementing the HAVA Section 301(a) mandates, except for disability accessibility, must be met by all voting systems. The alternative language capability mandated by Section 301(a)(4) must be met by all systems intended for use in jurisdictions subject to Section 203 of the Voting Rights Act. The Section 301(a)(3) disability accessibility requirements must be met by all systems intended to fulfill the one per polling place disability equipped voting system provision of Section 301(a)(3)(B).

In addition, the *Guidelines* categorize some requirements into related groups or classes of functionality to address equipment type, ballot tabulation location, and voting system component (e.g., election management system, voting machine). Hence, all of the requirements contained in the *Guidelines* do not apply to all elements of all voting systems. For example, requirements categorized as applying to DRE systems are not applicable to paper-based voting. The requirements implementing disability accessibility are not required of all voting systems, only by those systems the manufacturer designates as accessible voting systems.

Among the categories defined in the *VVSG* are two types of voting systems with respect to mechanisms to cast votes – paper-based voting systems and DRE voting systems. Additionally, voting systems are further categorized by the locations where ballots are tabulated – precinct count voting systems, which tabulate ballots at the polling place, and central count voting systems, which tabulate ballots from multiple precincts at a central location. The *Guidelines* define specific requirements for systems that fall within these four categories as well as various combinations of these categories.

1.5.1.4 Extensions

Extensions are additional functions, features, and/or capabilities included in a voting system that are not required by the *Guidelines*. To accommodate the needs of states that may impose additional requirements and to accommodate changes in technology, these guidelines allow extensions. For example, the requirements for a voter verifiable paper audit trail feature will only be applied to those systems designated by the manufacturer as providing this feature. The use of extensions shall not contradict nor cause the nonconformance of functionality required by the *Guidelines*.

1.5.2 Implementation Statement

The manufacturer shall provide an implementation statement with their application to the EAC for national certification testing.

An implementation statement documents the requirements that have been implemented by the voting system, the optional features and capabilities supported by the voting system, and any extensions (i.e., additional functionality beyond what is defined in the VVSG) that it implements.

An implementation statement may take the form of a checklist to be completed for each voting system submitted for conformity assessment. It is used by VSTLs to identify the conformity assessment activities that are applicable.

a. An implementation statement SHALL include:
   i. Full product identification of the voting system, including version number or timestamp;
   ii. Separate identification of each device that is part of the voting system;
   iii. Version of VVSG to which conformity assessment is desired;
   iv. Device capacities and limits
   v. List of languages supported; and
   vi. Signed attestation that the foregoing accurately characterizes the system submitted for testing.

Discussion: This requirement addresses many issues about the scope of conformity assessment and uncertainty whether particular features have been implemented in voting systems.

A keyboard, mouse or printer connected to a programmed voting device, as well as any optical drive, hard drive or similar component installed within it, are considered components of the voting device, not separate devices. The voting device is "responsible" for these components—e.g., a DRE must prevent unauthorized flashing of the firmware in its optical drive or other components that could be subverted to manipulate vote outcomes.

Specified capacities and limits should include the limit (if any) on the length of a candidate name that the system can process and display without truncation and similar limits for any other text fields whose usable or practically usable sizes are bounded. If the system provides a way to access the entirety of a long name even when it does not fit the width of the display and does not use any data structures that would force truncation, such a limit might not apply.

Manufacturers may wish to contact their intended testing labs in advance to determine if those labs can supply them with an implementation statement pro forma to facilitate meeting this requirement.

~~The voting system implementation statement describes the voting system and documents the *VVSG* Volume 1 requirements that have been implemented by the voting system. It can also identify optional features and capabilities supported by the voting system, as well as any extensions (i.e., additional functionality beyond what is required in the guidelines). The implementation statement must include a checklist identifying all the requirements for which a claim of conformance is made.~~

~~The implementation statement must be submitted with the vendor's application to the EAC for national certification testing. It must provide a concise summary and narrative description of the voting system's capabilities. It shall include identifying information about the voting system, including the hardware and software components, version number and date.~~

~~1.7 Effective Date~~

~~The *Voluntary Voting System Guidelines (VVSG)* shall become effective for national certification testing 24 months after their final adoption in December, 2005 by EAC. At that time, all new systems submitted for national certification shall be tested for conformance with these *Guidelines*. In addition, if a modification to a system certified or qualified to a previous standard is submitted for national certification after this date, every component of the modified system shall be tested using these *Guidelines*. All previous versions of national voting system standards will become obsolete upon this effective date.~~

2 Functional Requirements

Table of Contents

2 Functional Requirements

This section contains requirements detailing the functional capabilities required of a voting system. This section sets out precisely what a voting system is required to do. In addition, it sets forth the minimum actions a voting system must be able to perform to be eligible for certification.

For organizational purposes, functional capabilities are categorized as follows by the phase of election activity in which they are required:

> **2.1 Overall System Capabilities**: These functional capabilities apply throughout the election process. They include security, accuracy, integrity, system auditability, election management system, vote tabulation, ballot counters, telecommunications, and data retention.
>
> **2.2 Pre-voting Capabilities**: These functional capabilities are used to prepare the voting system for voting. They include ballot preparation, the preparation of election-specific software (including firmware), the production of ballots, the installation of ballots and ballot counting software (including firmware), and system and equipment tests.
>
> **2.3 Voting System Capabilities**: These functional capabilities include all operations conducted at the polling place by voters and officials including the generation of status messages.
>
> **2.4 Post-voting Capabilities**: These functional capabilities apply after all votes have been cast. They include closing the polling place; obtaining reports by voting machine, polling place, and precinct; obtaining consolidated reports; and obtaining reports of audit trails.
>
> **2.5 Maintenance, Transportation and Storage Capabilities**: These capabilities are necessary to maintain, transport, and store voting system equipment.

In recognition of the diversity of voting systems, the *Guidelines* apply specific requirements to specific technologies. Some of the guidelines apply only if the system incorporates certain optional functions (for example, voting systems employing telecommunications to transmit voting data). For each functional capability, common requirements are specified. Where necessary, these are followed by requirements applicable to specific technologies (i.e., paper-based or DRE) or intended use (i.e., central or precinct count).

2.1 Overall System Capabilities

This section defines required functional capabilities that are system-wide in nature and not unique to pre-voting, voting, and post-voting operations. All voting systems shall provide the following functional capabilities, further outlined in this section:

2.1.1 Security
2.1.2 Accuracy
2.1.3 Error Recovery
2.1.4 Integrity
2.1.5 System Audit
2.1.6 Election Management System
2.1.7 Vote Tabulating Program
2.1.8 Ballot Counter
2.1.9 Telecommunications
2.1.10 Data Retention

Voting systems may also include telecommunications components. Technical standards for these capabilities are described in Sections 3 through 6 of the *Voluntary Voting System Guidelines.*

2.1.1 Security

System security is achieved through a combination of technical capabilities and sound administrative practices. To ensure security, all systems shall:

a. Provide security access controls that limit or detect access to critical system components to guard against loss of system integrity, availability, confidentiality, and accountability
b. Provide system functions that are executable only in the intended manner and order, and only under the intended conditions
c. Use the system's control logic to prevent a system function from executing if any preconditions to the function have not been met
d. Provide safeguards in response to system failure to protect against tampering during system repair or interventions in system operations
e. Provide security provisions that are compatible with the procedures and administrative tasks involved in equipment preparation, testing, and operation
f. Incorporate a means of implementing a capability if access to a system function is to be restricted or controlled
g. Provide documentation of mandatory administrative procedures for effective system security

2.1.2 Accuracy

Memory hardware, such as semiconductor devices and magnetic storage media, must be accurate. The design of equipment in all voting systems shall provide for the highest possible levels of protection against mechanical, thermal, and electromagnetic stresses that impact system accuracy. Section 4 provides additional information on susceptibility requirements.

To ensure vote accuracy, all systems shall:

h. Record the election contests, candidates, and issues exactly as defined by election officials
i. Record the appropriate options for casting and recording votes
j. Record each vote precisely as indicated by the voter and produce an accurate report of all votes cast;
k. Include control logic and data processing methods incorporating parity and check-sums (or equivalent error detection and correction methods) to demonstrate that the system has been designed for accuracy
l. Provide software that monitors the overall quality of data read-write and transfer quality status, checking the number and types of errors that occur in any of the relevant operations on data and how they were corrected

In addition, DRE systems shall:

a. As an additional means of ensuring accuracy in DRE systems, voting devices shall record and retain redundant copies of the original ballot image. A ballot image is an electronic record of all votes cast by the voter, including undervotes.

2.1.3 Error Recovery

To recover from a non-catastrophic failure of a device, or from any error or malfunction that is within the operator's ability to correct, the system shall provide the following capabilities:

a. Restoration of the device to the operating condition existing immediately prior to the error or failure, without loss or corruption of voting data previously stored in the device
b. Resumption of normal operation following the correction of a failure in a memory component, or in a data processing component, including the central processing unit
c. Recovery from any other external condition that causes equipment to become inoperable, provided that catastrophic electrical or mechanical damage due to external phenomena has not occurred

2.1.4 Integrity

Integrity measures ensure the physical stability and function of the vote recording and counting processes.

To ensure system integrity, all systems shall:

a. Protect against a single point of failure that would prevent further voting at the polling place
b. Protect against the interruption of electrical power
c. Protect against generated or induced electromagnetic radiation
d. Protect against ambient temperature and humidity fluctuations
e. Protect against the failure of any data input or storage device
f. Protect against any attempt at improper data entry or retrieval
g. Record and report the date and time of normal and abnormal events
h. Maintain a permanent record of all original audit data that cannot be modified or overridden but may be augmented by designated authorized officials in order to adjust for errors or omissions (e.g., during the canvassing process)
i. Detect and record every event, including the occurrence of an error condition that the system cannot overcome, and time-dependent or programmed events that occur without the intervention of the voter or a polling place operator
j. Include built-in measurement, self-test, and diagnostic software and hardware for detecting and reporting the system's status and degree of operability

In addition to the common requirements, DRE systems shall:

k. Maintain a record of each ballot cast using a process and storage location that differs from the main vote detection, interpretation, processing, and reporting path
l. Provide a capability to retrieve ballot images in a form readable by humans

2.1.5 System Audit

This subsection describes the context and purpose of voting system audits and sets forth specific functional requirements. Election audit trails provide the supporting documentation for verifying the accuracy of reported election results. They present a concrete, indestructible archival record of all system activity related to the vote tally, and are essential for public confidence in the accuracy of the tally, for recounts, and for evidence in the event of criminal or civil litigation.

These requirements are based on the premise that system-generated creation and maintenance of audit records reduces the chance of error associated with manually generated audit records. Because most audit capability is automatic, the system operator has less information to track and record, and is less likely to make mistakes or omissions. The subsections that follow present operational requirements critical to acceptable performance and reconstruction of an election. Requirements for the content of audit records are described in Section 5.

The requirements for all system types, both precinct and central count, are described in generic language. Because the actual implementation of specific characteristics may vary from system to system, it is the responsibility of the manufacturer to describe each system's characteristics in sufficient detail so that VSTLs and system users can evaluate the adequacy of the system's audit trail. This description shall be incorporated in the System Operating Manual, which is part of the Technical Data Package.

Documentation of items such as paper ballots delivered, paper ballots collected, administrative procedures for system security, and maintenance performed on voting equipment are also part of the election audit trail, but are not covered in these technical standards. Useful guidance is provided by the *Innovations in Election Administration #10; Ballot Security and* Accountability, available on the EAC's website.

2.1.5.1 Operational Requirements

Audit records shall be prepared for all phases of election operations performed using devices controlled by the jurisdiction or its contractors. These records rely upon automated audit data acquisition and machine-generated reports, with manual input of some information. These records shall address the ballot preparation and election definition phase, system readiness tests, and voting and ballot-counting operations. The software shall activate the logging and reporting of audit data as described below.

a. The timing and sequence of audit record entries is as important as the data contained in the record. All voting systems shall meet the requirements for time, sequence and preservation of audit records outlined below.
    i. Except where noted, systems shall provide the capability to create and maintain a real-time audit record. This capability records and provides the operator or precinct official with continuous updates on machine status. This information allows effective operator identification of an error condition requiring intervention, and contributes to the reconstruction of election-related events necessary for recounts or litigation.
    ii. All systems shall include a real-time clock as part of the system's hardware. The system shall maintain an absolute record of the time and date or a record relative to some event whose time and data are known and recorded.
    iii. All audit record entries shall include the time-and-date stamp.
    iv. The audit record shall be active whenever the system is in an operating mode. This record shall be available at all times, though it need not be continually visible.
    v. The generation of audit record entries shall not be terminated or altered by program control, or by the intervention of any person. The physical security and integrity of the record shall be maintained at all times.
    vi. Once the system has been activated for any function, the system shall preserve the contents of the audit record during any interruption of power to the system until processing and data reporting have been completed.
    vii. The system shall be capable of printing a copy of the audit record. A separate printer is not required for the audit record, and the record may be produced on the standard system printer if all the following conditions are met:

- The generation of audit trail records does not interfere with the production of output reports
- The entries can be identified so as to facilitate their recognition, segregation, and retention
- The audit record entries are kept physically secure

b. All voting systems shall meet the requirements for error messages below.
    i. The voting system shall generate, store, and report to the user all error messages as they occur.
    ii. All error messages requiring intervention by an operator or precinct official shall be displayed or printed clearly in easily understood language text, or by means of other suitable visual indicators.
    iii. When the voting system uses numerical error codes for trained technician maintenance or repair, the text corresponding to the code shall be self-contained or affixed inside the voting machine. This is intended to reduce inappropriate reactions to error conditions, and to allow for ready and effective problem correction.
    iv. All error messages for which correction impacts vote recording or vote processing shall be written in a manner that is understandable to an election official who possesses training on system use and operation, but does not possess technical training on system servicing and repair.
    v. The message cue for all voting systems shall clearly state the action to be performed in the event that voter or operator response is required.
    vi. Voting system design shall ensure that erroneous responses will not lead to irreversible error.
    vii. Nested error conditions shall be corrected in a controlled sequence such that voting system status shall be restored to the initial state existing before the first error occurred.

c. The *Guidelines* provide latitude in software design so that manufacturers can consider various user processing and reporting needs. The jurisdiction may require some status and information messages to be displayed and reported in real-time. Messages that do not require operator intervention may be stored in memory to be recovered after ballot processing has been completed.

The voting system shall display and report critical status messages using clear indicators or English language text. The voting system need not display non-critical status messages at the time of occurrence. Voting systems may display non-critical status messages (i.e., those that do not require operator intervention) by means of numerical codes for subsequent interpretation and reporting as unambiguous text.

Voting systems shall provide a capability for the status messages to become part of the real-time audit record. The voting system shall provide a capability for a jurisdiction to designate critical status messages.

2.1.5.2 Use of ~~*Shared Computing Platforms*~~ *Multitasking Operating Systems*[1]

To ensure completeness and integrity of audit data for election software, further requirements must be applied to *voting devices that use multitasking operating systems (including COTS operating systems)* ~~*Commercial-off-the-Shelf operating systems to ensure completeness and integrity of audit data for election software. These operating systems are*~~ capable of executing multiple application programs simultaneously. These *operating* systems ~~include~~ *support* both servers and workstations~~, including~~ and *include* the many varieties of UNIX and Linux, and those offered by Microsoft and Apple. Election software *(including any COTS or other software applications used in the voting system)* running on these systems is vulnerable to unintended effects from other user sessions, applications, and utilities executing on the same platform at the same time as the election software.

~~“~~Simultaneous processes~~”~~ of concern include: unauthorized network connections, unplanned user logins, and unintended execution or termination of operating system processes. An unauthorized network connection or unplanned user login can host unintended processes and user actions, such as the termination of operating system audit, the termination of election software processes, or the deletion of election software audit and logging data. The execution of an operating system process could be a full system scan at a time when that process would adversely affect the election software processes. Operating system processes improperly terminated could be system audit or malicious code detection.

To counter these vulnerabilities, three operating system protections are required on all ~~such~~ *multitasking operating* systems ~~*on which election software is hosted*~~. First, authentication shall be configured on the local terminal (*e.g.,* display screen and keyboard) and on all external connection devices *(e.g.,* ~~“~~network cards~~”~~ and ~~“~~ports~~”~~). This ensures that only authorized and identified users affect the system while election software is running.

Second, operating system audit shall be enabled for all session openings and closings, for all connection openings and closings, for all process executions and terminations, and for the alteration or deletion of any memory or file object. This ensures the accuracy and completeness of election data stored on the system. It also ensures the existence of an audit record of any person or process altering or deleting system data or election data.

Third, the system shall be configured to execute only intended and necessary processes during the execution of election software. The system shall also be configured to halt election software processes upon the termination of any critical system process (such as system audit) during the execution of election software.

[1] The italicized text in Section 2.1.5.2 is based on EAC Decision on Request for Interpretation 2008-03, http://www.eac.gov/program-areas/voting-systems/docs/eac-decision-on-request-for-interpretation-2008-03-os-configuration-final.pdf/attachment_download/file.

The manufacturer may use whatever metrics it wishes to establish the correct configuration of multitasking operating systems. To ensure that these metrics are complete and consistent with current best practices for operating system security, the VSTL shall evaluate the configuration documentation provided by the manufacturer in order to determine completeness, clarity, and consistency with best practice checklist criteria. The VSTL shall provide additional information if any inconsistency exists with the checklist criteria. This information must include any rationale supporting the contention that any inconsistencies with the checklist are either not applicable or have been mitigated.

Discussion: *In its review of the VSTL evaluation of the operating system(s) configuration, the EAC will designate appropriate checklists from the National Vulnerability Database (NVD) System Content Automation Protocol (SCAP) checklist repository as the benchmark for appropriate settings. If the operating system configuration is at variance to the designated SCAP checklist, a justification for the variance shall be requested. It is recognized that in some cases variances may be justifiable for optimum security and functionality.*

Discussion: *For a given system, some requirements may appropriately be determined to be not applicable to a specific device (e.g., ballot marking devices), depending specifically how the design of a device is implemented and what features are included. Those determinations will be decided on a case-by-case, model by model, revision by revision basis, primarily by the VSTL, and then presented to the EAC for approval.*[2]

2.1.6 Election Management System

The Election Management System (EMS) is used to prepare ballots and programs for use in casting and counting votes, and to consolidate, report, and display election results. An EMS shall generate and maintain a database, or one or more interactive databases, that enables election officials or their designees to perform the following functions:

- Define political subdivision boundaries and multiple election districts as indicated in the system documentation
- Identify contests, candidates, and issues
- Define ballot formats and appropriate voting options
- Generate ballots and election-specific programs for voting equipment
- Install ballots and election-specific programs
- Test that ballots and programs have been properly prepared and installed
- Accumulate vote totals at multiple reporting levels as indicated in the system documentation
- Generate the post-voting reports required by Subsection 2.4

[2] This italicized discussion text is based on EAC Decision on Request for Interpretation 2008-12, http://www.eac.gov/program-areas/voting-systems/docs/eac-decision-on-request-for-interpretation-2008-12-vat-scope-of-testing-final/attachment_download/file.

- Process and produce audit reports of the data as indicated in Subsection 5.5

2.1.7 Vote Tabulating Program

Each voting system shall have a vote tabulation program that will meet specific functional requirements.

2.1.7.1 Functions

The vote tabulating program software resident in each voting machine, vote count server, or other devices shall include all software modules required to:

a. Monitor system status and generate machine-level audit reports
b. Accommodate device control functions performed by polling place officials and maintenance personnel
c. Register and accumulate votes
d. Accommodate variations in ballot counting logic

2.1.7.2 Voting Variations

There are significant variations among state election laws with respect to permissible ballot contents, voting options, and the associated ballot counting logic. The Technical Data Package accompanying the system shall specifically identify which of the following items *can* and *cannot* be supported by the voting system, as well as *how* the voting system can implement the items supported:

- Closed primaries
- Open primaries
- Partisan offices
- Non-partisan offices
- Write-in voting
- Primary presidential delegation nominations
- Ballot rotation
- Straight party voting
- Cross-party endorsement
- Split precincts
- Vote for N of M
- Recall issues, with options
- Cumulative voting
- Ranked order voting
- Provisional or challenged ballots

2.1.8 Ballot Counter

For all voting systems, each piece of voting equipment that tabulates ballots shall provide a counter that:

a. Can be set to zero before any ballots are submitted for tally
b. Records the number of ballots cast during a particular test cycle or election
c. Increases the count only by the input of a ballot
d. Prevents or disables the resetting of the counter by any person other than authorized persons at authorized points
e. Is visible to designated election officials

2.1.9 Telecommunications

For all voting systems that use telecommunications for the transmission of data during pre-voting, voting or post-voting activities, capabilities shall be provided that ensure data are transmitted with no alteration or unauthorized disclosure during transmission. Such transmissions shall not violate the privacy, secrecy, and integrity demands of the *Guidelines*. Section 6 describes telecommunications standards that apply to, at a minimum, the following types of data transmissions:

Voter Authentication: Coded information that confirms the identity of a voter for security purposes for a system that transmit votes individually over a public network

Ballot Definition: Information that describes to voting equipment the content and appearance of the ballots to be used in an election

Vote Transmission to Central Site: For voting systems that transmit votes individually over a public network, the transmission of a single vote to the county (or contractor) for consolidation with other county vote data

Vote Count: Information representing the tabulation of votes at any one of several levels: polling place, precinct, or central count

List of Voters: A listing of the individual voters who have cast ballots in a specific election

2.1.10 Data Retention

United States Code Title 42, Sections 1974 through 1974e state that election administrators shall preserve for 22 months “all records and paper that came into (their) possession relating to an application, registration, payment of poll tax, or other act requisite to voting.” This retention requirement applies to systems that will be used at anytime for voting of candidates for federal offices (e.g., Member of Congress, United

States Senator, and/or Presidential Elector). Therefore, all voting systems shall provide for maintaining the integrity of voting and audit data during an election and for a period of at least 22 months thereafter.

Because the purpose of this law is to assist the federal government in discharging its law enforcement responsibilities in connection with civil rights and elections crimes, its scope must be interpreted in keeping with that objective. The appropriate state or local authority must preserve all records that may be relevant to the detection and prosecution of federal civil rights or election crimes for the 22-month federal retention period, if the records were generated in connection with an election that was held in whole or in part to select federal candidates. It is important to note that Section 1974 does not require that election officials generate any specific type or classification of election record. However, if a record is generated, Section 1974 comes into force and the appropriate authority must retain the records for 22 months.

For 22-month document retention, the general rule is that all printed copy records produced by the election database and ballot processing systems shall be so labeled and archived. Regardless of system type, all audit trail information spelled out in Subsection 5.5 shall be retained in its original format, whether that be real-time logs generated by the system, or manual logs maintained by election personnel. The election audit trail includes not only in-process logs of election-night and subsequent processing of absentee or provisional ballots, but also time logs of baseline ballot definition formats, and system readiness and testing results.

In many voting systems, the source of election-specific data (and ballot formats) is a database or file. In precinct count voting systems, this data is used to program each machine, establish ballot layout, and generate tallying files. It is not necessary to retain this information on electronic media if there is an official, authenticated printed copy of all final database information. However, it is recommended that the state or local jurisdiction also retain electronic records of the aggregate data for each voting machine so that reconstruction of an election is possible without data re-entry. The same requirement and recommendation applies to vote results generated by each precinct count voting machine.

2.2 Pre-voting Capabilities

This subsection defines capabilities required to support functions performed prior to the opening of polls. All voting systems shall provide capabilities to support:

- Ballot preparation
- Election programming
- Ballot and program installation and control
- Readiness testing
- Verification at the polling place
- Verification at the central counting place

The standards also include requirements to ensure compatible interfaces with the ballot definition process and the reporting of election results.

2.2.1 Ballot Preparation

Ballot preparation is the process of using election databases to define the specific contests, questions, and related instructions to be contained in ballots and to produce all permissible ballot layouts. Ballot preparation requirements include:

- General capabilities
- Ballot formatting
- Ballot production

2.2.1.1 General Capabilities

All systems shall provide the general capabilities for ballot preparation. All systems shall be capable of:

a. Enabling the automatic formatting of ballots in accordance with the requirements for offices, candidates, and measures qualified to be placed on the ballot for each political subdivision and election district
b. Collecting and maintaining the following data
    i. Offices and their associated labels and instructions
    ii. Candidate names and their associated labels
    iii. Issues or measures and their associated text
c. Supporting the maximum number of potentially active voting positions as indicated in the system documentation
d. For a primary election, generating ballots that segregate the choices in partisan contests by party affiliation
e. Generating ballots that contain identifying codes or marks uniquely associated with each format
f. Ensuring that vote response fields, selection buttons, or switches properly align with the specific candidate names and/or issues printed on the ballot display, ballot card or sheet, or separate ballot pages

Paper-based voting systems shall also meet the following requirements applicable to the technology used:

a. Enable voters to make selections by making a mark in areas designated for this purpose upon each ballot sheet
b. For marksense systems, ensure that the timing marks align properly with the vote response fields

2.2.1.2 Ballot Formatting

Ballot formatting is the process by which election officials or their designees use election databases and voting system software to define the specific contests and related instructions contained on the ballot and present them in a layout permitted by state law. All voting systems shall provide a capability for:

a. Creation of newly defined elections
b. Rapid and error-free definition of elections and their associated ballot layouts
c. Uniform allocation of space and fonts used for each office, candidate, and contest such that the voter perceives no active voting position to be preferred to any other
d. Simultaneous display of the maximum number of choices for a single contest as indicated by the manufacturer in the system documentation
e. Retention of previously defined formats for an election
f. Prevention of unauthorized modification of any ballot formats
g. Modification by authorized persons of a previously defined ballot format for use in a subsequent election

2.2.1.3 Ballot Production

Ballot production is the process of converting ballot formats to a media ready for use in the physical ballot production or electronic presentation.

The voting system shall provide a means of printing or otherwise generating a ballot display that can be installed in all voting equipment for which it is intended. All voting systems shall provide the capabilities below.

a. The electronic display or printed document on which the user views the ballot is capable of rendering an image of the ballot in any of the languages required by the Voting Rights Act of 1965, as amended.
b. The electronic display or printed document on which the user views the ballot does not show any advertising or commercial logos of any kind, whether public service, commercial, or political, unless specifically provided for in state law. Electronic displays shall not provide connection to such material through hyperlink.
c. The ballot conforms to manufacturer specifications for type of paper stock, weight, size, shape, size and location of mark field used to record votes, folding, bleed-through, and ink for printing if paper ballot documents or paper displays are part of the system.

Basic Test Methodology[3]

Voting systems shall be tested to validate their ability to format and display voter targeted messages in a form consistent with all covered languages. (Incorporate the accents and special characters for Spanish or other languages, display translated text as an image, etc.) The VSTL shall also provide a statement in the test report that identifies the level to which the language testing was performed. When appropriate, the VSTL shall insert a disclaimer in the report that the translation content was not validated and that jurisdictions need to validate the content and accuracy of all translations. For DREs, basic functional testing of the ballot logic shall be repeated for at least one of the set of languages in each of the significant language groups where the manufacturer supports such language groups. For the purpose of this test procedure, the functional language groups are:

b. *The default language (English)*
c. *A secondary language using a Western European font (usually Spanish)*
d. *Ideographic language (such as Chinese or Korean)*
e. *Non-written languages requiring audio support*

In addition, a sample of audio ballots in each group should be checked with at least one audio set exercising full ballot logic and navigational choices including shortcuts to exit or skip candidates or races.

For mark sense/paper ballots, the additional functional tests may be waived if one of the following is true:

f. *The operational test deck contains all ballot styles including the alternate language ballots as separate styles.*
g. *It can be demonstrated that the ballot layout is not altered due to a change in language choice. (i.e., all ballot coding and voting mark sense target locations are the same regardless of ballot choices.)*

Discussion: *While the voting system need not offer every language covered by Section 203 of the Voting Rights Act, the system must be tested and shown to have the capability to present or display any of the covered languages noted above.*

Manufacturer documentation for marksense systems shall include specifications for ballot materials to ensure that vote selections are read from only a single ballot at a time, without detection of marks from multiple ballots concurrently (e.g., reading of bleed-through from other ballots).

[3] The italicized text in Section 2.2.1.3 is based on EAC Decision on Request for Interpretation 2008-04, http://www.eac.gov/program-areas/voting-systems/docs/eac-decision-on-request-for-interpretation-2008-04/attachment_download/file.

2.2.2 Election Programming

Election programming is the process by which election officials or their designees use election databases and manufacturer system software to logically define the voter choices associated with the contents of the ballots. All systems shall provide for the:

a. Logical definition of the ballot, including the definition of the number of allowable choices for each office and contest
b. Logical definition of political and administrative subdivisions, where the list of candidates or contests varies between polling places
c. Exclusion of any contest on the ballot in which the voter is prohibited from casting a ballot because of place of residence, or other such administrative or geographical criteria
d. Ability to select from a range of voting options to conform to the laws of the jurisdiction in which the system will be used
e. Generation of all required master and distributed copies of the voting program, in conformance with the definition of the ballots for each voting device and polling place, and for each tabulating device

2.2.3 Ballot and Program Installation and Control

All systems shall provide a means of installing ballots and programs on each piece of polling place or central count equipment in accordance with the ballot requirements of the election and the requirements of the jurisdiction in which the equipment will be used. All systems shall include the following at the time of ballot and program installation:

a. A detailed work plan or other documentation providing a schedule and steps for the software and ballot installation, which includes a table outlining the key dates, events and deliverables
b. A capability for automatically verifying that the software has been properly selected and installed in the equipment or in programmable memory devices, and for indicating errors
c. A capability for automatically validating that software correctly matches the ballot formats that it is intended to process, for detecting errors, and for immediately notifying an election official of detected errors

2.2.4 Readiness Testing

Election personnel conduct voting equipment and voting system readiness tests prior to the start of an election to ensure that the voting system functions properly, to confirm that voting equipment has been properly integrated, and to obtain equipment status reports. All voting systems shall provide the capabilities to:

d. Verify that voting equipment and precinct count equipment is properly prepared for an election, and collect data that verifies equipment readiness

e. Obtain status and data reports from each set of equipment
f. Verify the correct installation and interface of all voting equipment
g. Verify that hardware and software function correctly
h. Generate consolidated data reports at the polling place and higher jurisdictional levels
i. Segregate test data from actual voting data, either procedurally or by hardware/software features

Resident test software, external devices, and special purpose test software connected to or installed in voting equipment to simulate operator and voter functions may be used for these tests provided that the following standards are met:

j. These elements shall be capable of being tested separately, and shall be proven to be reliable verification tools prior to their use
k. These elements shall be incapable of altering or introducing any residual effect on the intended operation of the voting device during any succeeding test and operational phase

Paper-based systems shall:

l. Support conversion testing that uses all potential ballot positions as active positions
m. Support conversion testing of ballots with active position density for systems without pre-designated ballot positions

2.2.5 Verification at the Polling Place

Election officials perform verification at the polling place to ensure that all voting systems and voting equipment function properly before and during an election. All voting systems shall provide a formal record of the following, in any media, upon verification of the authenticity of the command source:

a. The election's identification data
b. The identification of all equipment units
c. The identification of the polling place
d. The identification of all ballot formats
e. The contents of each active candidate register by office and of each active measure register at all storage locations (showing that they contain only zeros)
f. A list of all ballot fields that can be used to invoke special voting options
g. Other information needed to confirm the readiness of the equipment, and to accommodate administrative reporting requirements

To prepare voting devices to accept voted ballots, all voting systems shall provide the capability to test each device prior to opening to verify that each is operating correctly. At a minimum, the tests shall include:

h. Confirmation that there are no hardware or software failures

i. Confirmation that the device is ready to be activated for accepting votes

If a precinct count system includes equipment for the consolidation of polling place data at one or more central counting locations, it shall have means to verify the correct extraction of voting data from transportable memory devices, or to verify the transmission of secure data over secure communication links.

2.2.6 Verification at the Central Location

Election officials perform verification at the central location to ensure that vote counting and vote consolidation equipment and software function properly before and after an election. Upon verification of the authenticity of the command source, any system used in a central count environment shall provide a printed record of the following:

a. The election's identification data
b. The contents of each active candidate register by office and of each active measure register at all storage locations (showing that they contain all zeros)
c. Other information needed to ensure the readiness of the equipment and to accommodate administrative reporting requirements

2.3 Voting Capabilities

All voting systems shall support:

- Opening the polls
- Casting a ballot

Additionally, all DRE systems shall support:

- Activating the ballot
- Augmenting the election counter
- Augmenting the life-cycle counter

2.3.1 Opening the Polls

The capabilities required for opening the polls are specific to individual voting system technologies. At a minimum, the systems shall provide the functional capabilities indicated below.

2.3.1.1 Precinct Count Systems

To allow voting devices to be activated for voting, all precinct count systems shall provide:

a. An internal test or diagnostic capability to verify that all of the polling place tests specified in Subsection 2.2.5 have been successfully completed
b. Automatic disabling of any device that has not been tested until it has been tested

2.3.1.2 Paper-based System Requirements

To facilitate opening the polls, all paper-based systems shall include:

a. A means of verifying that ballot marking devices are properly prepared and ready to use
b. A voting booth or similar facility, in which the voter may mark the ballot in privacy
c. Secure receptacles for holding voted ballots

In addition to the above requirements, all paper-based precinct count equipment shall include a means of:

d. Activating the ballot counting device
e. Verifying that the device has been correctly activated and is functioning properly
f. Identifying device failure and corrective action needed

2.3.1.3 DRE System Requirements

To facilitate opening the polls, all DRE systems shall include:

a. A security seal, a password, or a data code recognition capability to prevent the inadvertent or unauthorized actuation of the poll-opening function
b. A means of enforcing the execution of steps in the proper sequence if more than one step is required
c. A means of verifying the system has been activated correctly
d. A means of identifying system failure and any corrective action needed

If a device has a non-zero counter or residual votes, this is a failure to activate correctly and thus a device or system failure[4]*. Therefore the device shall disable itself from use in the voting system and election officials shall be advised of the proper corrective action. The occurrence shall be recorded in the device audit log. In addition, a clear, unambiguous warning that an attempt has been made to initiate an election with non-zero totals and that the device has been disabled from the system shall be documented and communicated to an election official.*

[4] The italicized text in Section 2.3.1.3 is based on EAC Decision on Request for Interpretation 2008-07, http://www.eac.gov/program-areas/voting-systems/docs/eac-decision-on-request-for-interpretation-2008-07/attachment_download/file.

The testing of the components and system readiness by the VSTL shall include attempts to initiate an election with non-zero totals on counters or residual ballots, validating that the "zero" report procedure will correctly identify and warn the election officials of the presence of any previously stored results which are in a form that may be deliberately or accidentally processed.

Discussion: *The standard requires more than a simple pre-election "zero report" for the voting system. It requires that all memory locations that contain counters and residual votes be reset before the election. If a unit or system has a non-zero counter or residual votes, this is considered a failure to activate correctly. The requirements of this section are to be interpreted to mean that such a failure to activate correctly is a device or system failure and therefore requires both that the device be disabled from use in the voting system and that election officials are advised of the proper corrective action.*

2.3.2 Activating the Ballot (DRE Systems)

To activate the ballot, all DRE systems shall:

a. Enable election officials to control the content of the ballot presented to the voter, whether presented in printed form or electronic display, such that each voter is permitted to record votes only in contests in which that voter is authorized to vote
b. Allow each eligible voter to cast a ballot
c. Prevent a voter from voting on a ballot to which he or she is not entitled
d. Prevent a voter from casting more than one ballot in the same election
e. Activate the casting of a ballot in a general election
f. Enable the selection of the ballot that is appropriate to the party affiliation declared by the voter in a primary election
g. Activate all portions of the ballot upon which the voter is entitled to vote
h. Disable all portions of the ballot upon which the voter is not entitled to vote

2.3.3 Casting a Ballot

Some required capabilities for casting a ballot are common to all systems. Others are specific to individual voting technologies or intended use. Systems must provide additional functional capabilities that enable accessibility to disabled voters as defined in Subsection 3.2.

2.3.3.1 Common Requirements

To facilitate casting a ballot, all systems shall:

a. Provide text that is at least 3 millimeters high and provide the capability to adjust or magnify the text to an apparent size of 6.3 millimeters
b. Protect the secrecy of the vote such that the system cannot reveal any information about how a particular voter voted, except as otherwise required by individual state law
c. Record the selection and non-selection of individual vote choices for each contest and ballot measure
d. Record the voter's selection of candidates whose names do not appear on the ballot, if permitted under state law, and record as many write-in votes as the number of candidates the voter is allowed to select
e. In the event of a failure of the main power supply external to the voting system, provide the capability for any voter who is voting at the time to complete casting a ballot, allow for the successful shutdown of the voting system without loss or degradation of the voting and audit data, and allow voters to resume voting once the voting system has reverted to back-up power
f. Provide the capability for voters to continue casting ballots in the event of a failure of a telecommunications connection within the polling place or between the polling place and any other location

2.3.3.2 Paper-based System Requirements

All paper-based systems shall:

a. Allow the voter to easily identify the voting field that is associated with each candidate or ballot measure response
b. Allow the voter to mark the ballot to register a vote
c. Allow either the voter or the appropriate election official to place the voted ballot into the ballot counting device (for precinct count systems) or into a secure receptacle (for central count systems)
d. Protect the secrecy of the vote throughout the process

In addition to the above requirements, all paper-based precinct count systems shall:

e. Provide feedback to the voter that identifies specific contests for which he or she has made no selection or fewer than the allowable number of selections (e.g., undervotes)
f. Notify the voter if he or she has made more than the allowable number of selections for any contest (e.g., overvotes)
g. Notify the voter before the ballot is cast and counted of the effect of making more than the allowable number of selections for a contest
h. Provide the voter opportunity to correct the ballot for either an undervote or overvote before the ballot is cast and counted

2.3.3.3 DRE System Requirements

In addition to the above common requirements, DRE systems shall:

a. Prohibit the voter from accessing or viewing any information on the display screen that has not been authorized by election officials and preprogrammed into the voting system (i.e., no potential for display of external information or linking to other information sources)
b. Enable the voter to easily identify the selection button or switch, or the active area of the ballot display, that is associated with each candidate or ballot measure response
c. Allow the voter to select his or her preferences on the ballot in any legal number and combination
d. Indicate that a selection has been made or canceled
e. Indicate to the voter when no selection, or an insufficient number of selections, has been made for a contest (e.g., undervotes)
f. Notify the voter if he or she has made more than the allowable number of selections for any contest (e.g., overvotes)
g. Notify the voter before the ballot is cast and counted of the effect of making more than the allowable number of selections for a contest
h. Provide the voter opportunity to correct the ballot for either an undervote or overvote before the ballot is cast and counted
i. Notify the voter when the selection of candidates and measures is completed
j. Allow the voter, before the ballot is cast, to review his or her choices and, if the voter desires, to delete or change his or her choices before the ballot is cast
k. For electronic image displays, prompt the voter to confirm the voter's choices before casting his or her ballot, signifying to the voter that casting the ballot is irrevocable and directing the voter to confirm the voter's intention to cast the ballot
l. Notify the voter after the vote has been stored successfully that the ballot has been cast
m. Notify the voter that the ballot has not been cast successfully if it is not stored successfully, including storage of the ballot image, and provide clear instruction as to the steps the voter should take to cast his or her ballot should this event occur
n. Provide sufficient computational performance to provide responses back to each voter entry in no more than three seconds
o. Ensure that the votes stored accurately represent the actual votes cast
p. Prevent modification of the voter's vote after the ballot is cast
q. Provide a capability to retrieve ballot images in a form readable by humans [in accordance with the requirements of Subsections 2.1.2 (f) and 2.1.4 (k) and (l)]
r. Increment the proper ballot position registers or counters
s. Protect the secrecy of the vote throughout the voting process
t. Prohibit access to voted ballots until after the close of polls
u. Provide the ability for election officials to submit test ballots for use in verifying the end-to-end integrity of the voting system
v. Isolate test ballots such that they are accounted for accurately in vote counts and are not reflected in official vote counts for specific candidates or measures

2.4 Post-Voting Capabilities

All voting systems shall provide capabilities to accumulate and report results for the jurisdiction and to generate audit trails. In addition, precinct count voting systems must provide a means to close the polls including generating appropriate reports. If the system provides the capability to broadcast results, additional standards apply.

2.4.1 Closing the Polls

These requirements for closing the polls and locking voting systems against future voting are specific to precinct count systems. The voting system shall provide the means for:

a. Preventing the further casting of ballots once the polls have closed
b. Providing an internal test that verifies that the prescribed closing procedure has been followed, and that the device status is normal
c. Incorporating a visible indication of system status
d. Producing a diagnostic test record that verifies the sequence of events, and indicates that the extraction of voting data has been activated
e. Precluding the unauthorized reopening of the polls once the poll closing has been completed for that election

2.4.2 Consolidating Vote Data

All systems shall provide a means to consolidate vote data from all polling places, and optionally from other sources such as absentee ballots, provisional ballots, and voted ballots requiring human review (e.g., write-in votes).

2.4.3 Producing Reports

All systems shall be able to create reports summarizing the vote data on multiple levels.

All systems shall provide capabilities to:

a. Support geographic reporting, which requires the reporting of all results for each contest at the precinct level and additional jurisdictional levels
b. Produce a printed report of the number of ballots counted by each tabulator
c. Produce a printed report for each tabulator of the results of each contest that includes the votes cast for each selection, the count of undervotes, and the count of overvotes
d. Produce a consolidated printed report of the results for each contest of all votes cast (including the count of ballots from other sources supported by the system as specified by the manufacturer) that includes the votes cast for each selection, the count of undervotes, and the count of overvotes

e. Be capable of producing a consolidated printed report of the combination of overvotes for any contest that is selected by an authorized official (e.g., the number of overvotes in a given contest combining candidate A and candidate B, combining candidate A and candidate C, etc.)
f. Produce all system audit information required in Subsection 5.4 in the form of printed reports, or in electronic memory for printing centrally
g. Prevent data from being altered or destroyed by report generation, or by the transmission of results over telecommunications lines

For all systems, there shall be a complete accounting of undervotes for N of M contests as well as races involving only one voting choice[5]*. In a "vote for N" contest, where L votes are recorded and L<M, the undervotes = N-L. In a "vote for 3" contest, votes would be recorded as follows:*

a. *A vote for no candidates = 3 undervotes.*
b. *A vote for 1 candidate = 2 undervotes.*
c. *A vote for 2 candidates = 1 undervote.*

Discussion: *The VVSG and HAVA are based on the premise that a voter's choices (or non-choices, as the case may be) need to be accounted for in full. Undervotes are absent selections governed by the "vote for…" limit. If, for example, a contest requires the voter to "vote for two" it is possible to have either one or two absent selections. For the vote cast by the voter to be precisely and accurately reported, each undervote must be considered separately. As a testable criterion, the total vote count for a contest shall equal the sum of the selections voted, the undervote count, and the overvote count (if the voting method permits overvoting). To enable effective audit checking, the undervote count must be an independent count and not simply the difference between the total count and the sum of the voted selections and the overvotes*

In addition, all precinct count voting systems shall:

a. Prevent the printing of reports and the unauthorized extraction of data prior to the official close of the polls
b. Provide a means to extract information from a transportable programmable memory device or data storage medium for vote consolidation
c. Consolidate the data contained in each unit into a single report for the polling place when more than one voting machine or precinct tabulator is used
d. Prevent data in transportable memory from being altered or destroyed by report generation, or by the transmission of official results over telecommunications lines

[5] The italicized text in Section 2.4.3 is based on EAC Decision on Request for Interpretation 2007-06, http://www.eac.gov/program-areas/voting-systems/docs/interpretation-2007-06-undervotes.pdf/attachment_download/file.

2.4.4 Electronic Reports

Electronic reports for voting systems are used to support audits. Typically, the electronic reports needed include: vote counts, counts of ballots recorded, information that identifies the electronic record, event logs and other records of important events or details of how the election was run on this device, and election archive information. The following requirements specify what information needs to be captured in electronic reports used to support voting system audits and how to protect the electronic reports from modification and verify their source and authenticity.

2.4.4.1 Voting system Electronic Reports

The following requirements apply to electronic reports produced by the voting system for any exchange of information between devices, support of auditing procedures, or reporting of final results.

The voting system shall provide the capability to export electronic reports to files formatted in a non-restrictive, publicly-available format. Manufacturers shall provide a specification describing how they have implemented the format with respect to the manufacturer’s specific voting devices and data, including such items as descriptions of elements, attributes, constraints, extensions, syntax and semantics of the format, and definitions for data fields and schemas.

The voting system shall provide the ability to produce printed forms of electronic reports. The printed forms of the electronic reports shall retain all required information as specified for each report type other than digital signatures. The printing of the electronic reports MAY be done from a different component of the voting system that produced the electronic report. It shall be possible to print electronic reports produced by the central tabulator or EMS on a different device.

Voting systems shall digitally sign electronic reports using FIPS approved algorithms with a security strength of at least 112 bits implemented within a FIPS 140-2 level 1 or higher validated cryptographic module operating in FIPS mode.

Discussion: NIST approved is “ An algorithm or technique that meets at least one of the following: 1) is specified in a FIPS or NIST Recommendation, 2) is adopted in a FIPS or NIST Recommendation or 3) is specified in a list of NIST approved security functions (e.g., specified as approved in the annexes of FIPS 140-2/3)”. The security strengths of cryptographic algorithms can be found in NIST Special Publication 800-57: Recommendation for Key Management – Part 1 General.

2.4.4.2 Tabulator electronic reports

The following requirements apply to electronic reports produced by tabulators, such as DREs and optical scanners, for exchange of information between devices, transmission of results to the EMS, support of auditing procedures, or reporting of intermediate election results.

Each tabulator shall produce a Tabulator Summary Count report including the following information:

a. Identifier of the tabulator;
b. Time and date of summary record;
c. The following, both in total and broken down by ballot configuration and precinct:
    i. Number of read ballots;
    ii. Number of counted ballots;
    iii. Number of rejected electronic CVRs; and
    iv. For each N-of-M (including 1-of-M) or cumulative voting contest appearing in any ballot configuration handled by the tabulator:
        1. Number of counted ballots that included that contest;
        2. Vote totals for each non-write-in contest choice;
        3. Number of write-in votes;
        4. Number of overvotes; and
        5. Number of undervotes.

In producing the Tabulator Summary Count report, the tabulator shall assume that no provisional or challenged ballots are accepted.

The tabulator shall:

a. Transmit the summary count report to the EMS with the other electronic reports;
b. Store the summary count report in the election archive, if available; and
c. Store the summary count report in the voting systems event log.

Tabulators should produce a report of ballot images that includes:

a. Time and date of creation of complete ballot image report; and
b. Ballot images recorded in randomized order by the DRE for the election. For each voted ballot, this includes:
    i. Ballot configuration and reporting context;
    ii. For each contest:
        1. The choice recorded, including undervotes and write-ins; and
        2. Any information collected electronically about each write-in;
    iii. Information specifying whether the ballot is provisional, type of provisional ballot, and providing a unique identifier for the ballot.

Discussion: NIST Special Publication 800-90: Recommendation for Random Number Generation Using Deterministic Random Bit Generators specifies techniques for the generation of random numbers that can be used to randomize the order of ballot images in a cryptographically sound way. Types of provisional ballots (such as “regular provisional”, “extended hours provisional”, and “regular extended hours”) are jurisdiction-dependent.

DREs shall produce a report of ballot images that includes:

a. Time and date at poll closing; and
b. Ballot images recorded in randomized order by the DRE for the election. For each voted ballot, this includes:
    i. Ballot configuration and reporting context;
    ii. For each contest:
        1. The choice recorded, including undervotes and write-ins; and
        2. Any information collected electronically about each write-in;
    iii. Information specifying whether the ballot is provisional, type of provisional ballot, and providing a unique identifier for the ballot.

Discussion: NIST Special Publication 800-90: Recommendation for Random Number Generation Using Deterministic Random Bit Generators specifies techniques for the generation of random numbers that can be used to randomize the order of ballot images in a cryptographically sound way. Types of provisional ballots (such as “regular provisional”, “extended hours provisional”, and “regular extended hours”) are jurisdiction-dependent.

Tabulators that produce the collection of ballot images report shall:

a. Transmit the collection of ballot images report to the EMS with the other electronic reports;
b. Store the collection of ballot images report in the election archive, if available; and
c. Store the collection of ballot images report in the voting systems event log.

The tabulator shall digitally sign the event log, transmit the signed event log to an EMS, and retain a record of the transmission. The tabulator digital signature shall be generated using a FIPS approved algorithm with a security strength of at least 112 bits implemented within a FIPS 140-2 level 1 or higher validated cryptographic module operating in FIPS mode.

Discussion: NIST approved is " An algorithm or technique that meets at least one of the following: 1) is specified in a FIPS or NIST Recommendation, 2) is adopted in a FIPS or NIST Recommendation or 3) is specified in a list of NIST approved security functions (e.g., specified as approved in the annexes of FIPS 140-2/3)". The security strengths of cryptographic algorithms can be found in NIST Special Publication 800-57: Recommendation for Key Management – Part 1 General.

2.4.4.3 EMS electronic reports

The following requirements apply to the reports produced by an EMS. EMSs include both DREs used as accumulators in the polling place, called a Precinct EMS, as well as EMSs used as jurisdiction-wide accumulators. All of the requirements for tabulators apply to EMSs. This section addresses additional requirements based on an EMSs role as an accumulator of ballot counts and vote totals.

Each EMS shall produce a Tabulator Summary Count report including the following information:

a. Identifiers for each tabulator contained in the summary;
b. For tabulators with public keys:
    i. The public key for each tabulator in the summary and
    ii. Signed tabulator summary count report.
c. Summary ballot counts and vote totals by tabulator, precinct, and polling place.
    i. Precinct totals include subtotals from each tabulator used in the precinct.

The EMS shall be capable of combining tabulator reports to protect voter privacy in cases when there are tabulators with few votes.

The EMS shall produce a report for each precinct including:

a. Each tabulator included in the precinct with its identifier;
b. Number of read ballots;
c. Number of counted ballots; and
d. For each N-of-M (including 1-of-M) or cumulative voting contest appearing in any ballot configuration handled by the tabulator:
    i. Number of counted ballots that included that contest;
    ii. Vote totals for each non-write-in contest choice; and
    iii. Number of write-in votes

The EMS shall produce a report showing the changes made to each contest based on the resolution of provisional ballots, challenged ballots, write-in choices, and the date and time of the report.

For each tabulator producing electronic reports, the EMS shall verify the digital signature on the report is correct using the public key associated with the tabulator.

2.4.5 Broadcasting Results

Some voting systems offer the capability to make unofficial results available to external organizations such as the news media, political party officials, and others. Although this capability is not required, systems that make unofficial results available shall:

a. Provide only aggregated results, and not data from individual ballots
b. Provide no access path from unofficial electronic reports or files to the storage devices for official data
c. Clearly indicate on each report or file that the results it contains are unofficial

2.5 Maintenance, Transportation, and Storage

All systems shall be designed and manufactured to facilitate preventive and corrective maintenance, conforming to the hardware standards described in Subsection 4.1. All vote casting and tally equipment designated for storage between elections shall:

a. Function without degradation in capabilities after transit to and from the place of use, as demonstrated by meeting the performance standards described in Subsection 4.1
b. Function without degradation in capabilities after storage between elections, as demonstrated by meeting the performance standards described in Subsection 4.1

3 Usability and Accessibility Requirements

Table of Contents

3 Usability, Accessibility, and Privacy Requirements

3.1 Overview

The importance of usability and accessibility in the design of voting systems has become increasingly apparent. It is not sufficient that the internal operation of these systems be correct; in addition, voters and poll workers must be able to use them effectively. There are some particular considerations for the design of usable and accessible voting systems:

- The voting task itself can be fairly complex; the voter may have to navigate an electronic ballot, choose multiple candidates in a single contest, or decide on abstrusely worded referenda
- Voting is performed infrequently, so there is limited opportunity for voters and poll workers to gain familiarity with the process
- Jurisdictions may change voting equipment, thus obviating whatever familiarity the voter might have acquired
- Usability and accessibility requirements include a broad range of factors, including physical abilities, language skills, and technology experience

3.1.1 Purpose

The challenge, then, is to provide a voting system that voters can use comfortably, efficiently, and with confidence that they have cast their votes correctly. The requirements within this section are intended to serve that goal. Three broad principles motivate this section:

1. All eligible voters shall have access to the voting process without discrimination.

The voting process shall be accessible to individuals with disabilities. The voting process includes access to the polling place, instructions on how to vote, initiating the voting session, making ballot selections, review of the ballot, final submission of the ballot, and getting help when needed.

2. Each cast ballot shall accurately capture the selections made by the voter.

The ballot shall be presented to the voter in a manner that is clear and usable. Voters should encounter no difficulty or confusion regarding the process for recording their selections.

3. The voting process shall preserve the secrecy of the ballot.

The voting process shall preclude anyone else from determining the content of a voter's ballot, without the voter's cooperation. If such a determination is made against the wishes of the voter, then his or her privacy has been violated.

All the requirements in this section have the purpose of improving the quality of interaction between voters and voting systems.

Note that these principles refer to the entire voting process. The VVSG applies only to voting systems; other aspects of the process (such as administrative rules and procedures) are outside the scope of the VVSG, but are nonetheless crucial for the full achievement of the principles.

3.1.2 Special terminology

The following terms are used frequently in this chapter; they are defined in Appendix A of Volume 1:

- Accessible Voting Station (Acc-VS)
- Alert time
- Audio-Tactile Interface (ATI)
- Common Industry Format (CIF)
- Completed system response time
- Direct Record Electronic (DRE)
- Initial system response time
- Precinct Count Optical Scanner (PCOS)
- Precinct Tabulator
- Summative Usability Testing
- Voter-Editable Ballot Device (VEBD)
- Voter inactivity time

~~Several uncommon terms are used in this section. For the convenience of the reader, they are defined below, in addition to being included in the Glossary. Other terms frequently used here and throughout this document are defined in the Glossary. Note in particular the distinctions between these terms: voting system, voting equipment, voting machine and voting station.~~

- ~~Common Industry Format (CIF) – the format to be used for usability testing reporting, described in ANSI/INCITS 354-2001 "Common Industry Format (CIF) for Usability Test Reports"~~
- ~~Accessible Voting Station – the voting station equipped for individuals with disabilities referred to in HAVA 301 (a)(3)(B).~~
- ~~Audio-Tactile Interface – a voter interface designed not to require visual reading of a ballot. Audio is used to convey information to the voter and sensitive tactile controls allow the voter to convey information to the voting system.~~

3.1.3 Interaction of usability and accessibility requirements

All the requirements in Section 3 have the purpose of improving the quality of interaction between voters and voting systems. Please note how Sections 3.2 and 3.3 work together:

- The requirements for general usability in Section 3.2 apply to ALL voting systems, including the Acc-VS. They cover the features that are applicable both to the general population and to voters with disabilities. In particular, note that the Acc-VS is classified as a Voter-Editable Ballot Device and therefore all VEBD requirements apply to the Acc-VS. Requirements for any alternative languages required by state or federal law are also included under Section 3.2.
- The requirements for accessibility in Section 3.3 cover only those features that are mandatory for the accessible voting station (Acc-VS) in addition to the general usability requirements. For instance, an audio interface would be of interest mainly to those with vision or other reading disabilities, but not to those who can use a visual interface. Therefore, to determine what usability features are required of the Acc-VS, one must examine both Sections 3.2 and 3.3. *The features of the Acc-VS may also assist those not usually described as having a disability, e.g., voters with poor reading vision or somewhat limited dexterity*[6].

- ~~Requirements for general usability apply to all voting systems. Requirements for any alternative languages required by state or federal law are included under this heading.~~
- ~~Requirements to assist voters with physical, sensory, or cognitive disabilities apply, as a minimum, to the accessible voting stations required by HAVA Section 301 (a)(3)(B). They may also assist those not usually described as having a disability, e.g., voters with poor eyesight or limited dexterity.~~

3.2 General Usability Requirements

The voting process shall provide a high level of usability for voters. Accordingly, voters shall be able to negotiate the process effectively, efficiently, and comfortably. The goal is that the resulting ballot accurately reflects the intention of the voter. The mandatory voting system standards mandated in HAVA Section 301 relate to the interaction between the voter and the voting system:

a. Requirements.--Each voting system used in an election for federal office shall meet the following requirements:

[6] The italicized text in Section 3.1.3 is based on EAC Decision on Request for Interpretation 2007-01, http://www.eac.gov/program-areas/voting-systems/docs/certification-docs-eac-decision-on-request-for-interpretation-2007-01-rev-2.pdf/attachment_download/file.

1. In general.--

A. Except as provided in subparagraph (B), the voting system (including any lever voting system, optical scanning voting system, or direct recording electronic system) shall--

i. Permit the voter to verify (in a private and independent manner) the votes selected by the voter on the ballot before the ballot is cast and counted;

ii. Provide the voter with the opportunity (in a private and independent manner) to change the ballot or correct any error before the ballot is cast and counted (including the opportunity to correct the error through the issuance of a replacement ballot if the voter was otherwise unable to change the ballot or correct any error); and

iii. If the voter selects votes for more than one candidate for a single office -

I. Notify the voter that the voter has selected more than one candidate for a single office on the ballot;

II. Notify the voter before the ballot is cast and counted of the effect of casting multiple votes for the office; and

III. Provide the voter with the opportunity to correct the ballot before the ballot is cast and counted.

B. A state or jurisdiction that uses a paper ballot voting system, a punch card voting system, or a central count voting system (including mail-in absentee ballots and mail-in ballots), may meet the requirements of subparagraph (A)(iii) by -

i. Establishing a voter education program specific to that voting system that notifies each voter of the effect of casting multiple votes for an office; and

ii. Providing the voter with instructions on how to correct the ballot before it is cast and counted (including instructions on how to correct the error through the issuance of a replacement ballot if the voter was otherwise unable to change the ballot or correct any error).

C. The voting system shall ensure that any notification required under this paragraph preserves the privacy of the voter and the confidentiality of the ballot.

The requirements of this section are intended to support these basic usability standards of HAVA.

~~Usability is defined generally as a measure of the effectiveness, efficiency, and satisfaction achieved by a specified set of users with a given product in the performance of specified tasks. In the context of voting, the primary user is the voter, the product is the voting system, and the task is the correct recording of the voter ballot selections. Additional requirements for task performance are independence and privacy: the voter should normally be able to complete the voting task without assistance from others, and the voter selections should be private. Lack of independence or privacy may adversely affect effectiveness (e.g., by possibly inhibiting the voter's free choice) and efficiency (e.g., by slowing down the process).~~

~~Among the basic metrics for usability are:~~

- ~~low error rate for marking the ballot (the voter selection is correctly conveyed to and represented within the voting system)~~
- ~~efficient operation (time required to vote is not excessive)~~
- ~~satisfaction (voter experience is safe, comfortable, free of stress, and instills confidence)~~

It is the intention of the EAC that in future revisions to the Guidelines, usability will be addressed by high-level performance-based requirements. That is, the requirements will directly address metrics for effectiveness (e.g., correct capture of voter selections), efficiency (e.g., time taken to vote), and satisfaction. Until the supporting research is completed, however, the contents of this subsection are limited to a basic set of widely accepted design requirements and lower-level performance requirements. The reasons for this approach are:

- ~~These are to serve as interim requirements, pending the issuance of high-level performance requirements~~
- ~~The actual benefit of numerous detailed design guidelines is difficult to prove or measure~~
- ~~The technical complexity and costs of a large set of detailed requirements may not be justified~~
- ~~Guidelines that are difficult to test because of insufficient specificity have been omitted~~

~~While the scope of usability applies to the entire voting process, the emphasis in these requirements is on the voter interface with the voting machine, which is assumed to be a visual-tactile interface.~~

~~The outline for this subsection is:~~

~~3.1.1 Usability Testing~~

~~3.1.2 Functional Capabilities~~

~~3.1.3 Alternative Languages~~

~~3.1.4 Cognitive Issues~~

~~3.1.5 Perceptual Issues~~

~~3.1.6 Interaction Issues~~

~~3.1.7 Privacy~~

3.2.1 General Usability

The voting system shall support voters in the task of effectively and accurately casting their ballots. The features of the voting system shall not contribute to the commission of voter error within the voting session.

a. The manufacturer shall conduct summative usability tests on the voting system using individuals who are representative of the general population and shall report the test results, using the Common Industry Format, *as part of the Technical Data Package (TDP). In addition, the usability test report shall be submitted to the EAC as part of the documentation manufacturers are required to file with the application to test a voting system*[7].

Discussion: Voting system developers are required to conduct realistic usability tests on their product before submitting the system to conformance testing. This is to encourage early detection and resolution of usability problems. *The manufacturer must submit the usability test report to the VSTL as part of their TDP. The VSTL will then check the technical data package to ensure that the report is present and reported in the Common Industry Format and contains the results from a summative usability test.*

~~3.1.1 Usability Testing~~

~~The vendor shall conduct summative usability tests on the voting system using individuals representative of the general population. The vendor shall document the testing performed and report the test results using the Common Industry Format. This documentation shall be included in the Technical Data Package submitted to the EAC for national certification.~~

[7] The italicized text in Section 3.2.1 is based on EAC Decision on a Request for Interpretation 2007-03, http://www.eac.gov/program-areas/voting-systems/docs/certification-docs-eac-decision-on-request-for-interpretation-2007-03.pdf-1/attachment_download/file.

~~Discussion: Voting system developers are required to conduct realistic usability tests on the final product. For the present, vendors can define their own testing protocols. Future revisions to the Guidelines will include requirements for usability testing that will provide specific performance benchmarks.~~

3.2.2 Functional capabilities

The usability of the voting process is enhanced by the presence of certain functional capabilities. These capabilities differ somewhat depending on whether or not the system presents an editable interface within which voters can easily change their votes (typically an electronic screen) or an interface in which voters must obtain a new ballot to make changes (typically a manually-marked paper ballot).

a. If the voter selects more than the allowable number of choices within a contest, the voting system shall notify the voter of the effect of this action before the ballot is cast and counted.

Discussion: In the case of manual systems, this may be achieved through appropriately placed instructions. This requirement has no force for VEBD systems, since they prevent overvoting in the first place.

b. The voting system shall allow the voter, at the voter's choice, to submit an undervoted ballot without correction.

c. The voting system shall provide the voter the opportunity to correct the ballot for either an undervote or overvote before the ballot is cast and counted.

Discussion: In the case of manual systems, this may be achieved through appropriately placed written instructions. Some corrections may require the voter to obtain a new paper ballot from a poll worker. Also, note the requirements on precinct-count optical scanners in Section 3.2.2.2 below.

d. If and only if the voter successfully casts the ballot, then the DRE or PCOS system shall so notify the voter.

Discussion: The purpose of this requirement is to provide feedback to voters to assure them that the voting session has been completed. Note that either a false notification of success or a missing confirmation of actual success violates this requirement.

~~3.1.2 Functional Capabilities~~

~~The voting process shall provide certain functional capabilities to support voter usability.~~

a. ~~The voting system shall provide feedback to the voter that identifies specific contests or ballot issues for which he or she has made no selection or fewer than the allowable number of selections (e.g., undervotes)~~
b. ~~The voting system shall notify the voter if he or she has made more than the allowable number of selections for any contest (e.g., overvotes)~~
c. ~~The voting system shall notify the voter before the ballot is cast and counted of the effect of making more than the allowable number of selections for a contest~~
d. ~~The voting system shall provide the voter the opportunity to correct the ballot for either an undervote or overvote before the ballot is cast and counted~~
e. ~~The voting system shall allow the voter, at his or her choice, to submit an undervoted ballot without correction~~
f. ~~DRE voting machines shall allow the voter to change a vote within a contest before advancing to the next contest.~~

~~Discussion: The point here is that voters using a DRE should not have to wait for the final ballot review screen in order to change a vote.~~

g. ~~DRE voting machines should provide navigation controls that allow the voter to advance to the next contest or go back to the previous contest before completing a vote on the contest currently being presented (whether visually or aurally).~~

~~Discussion: For example, the voter should not be forced to proceed sequentially through all the contests before going back to check his or her selection for a previous contest.~~

3.2.2.1 Editable interfaces

Voting systems such as DREs and EBMs present voters with an editable interface, allowing them to easily change their votes prior to final casting of the ballot.

a. The VEBD shall prevent voters from selecting more than the allowable number of choices for each contest.

Discussion: This requirement does not specify exactly how the system must respond when a voter attempts to select an "extra" candidate. For instance, the system may prevent the selection and issue a warning, or, in the case of a single-choice contest, simply change the vote.

b. The VEBD shall provide feedback to the voter, before final casting of the ballot that identifies specific contests for which the voter has selected fewer than the allowable number of choices (i.e., undervotes).

Discussion: For VEBD systems, no allowance is made for disabling this feature. Also, see the plain language requirement below on clarity of warnings 3.2.4c.i."

c. The VEBD shall provide the voter the opportunity to correct the ballot before it is cast and counted. This correction process shall not require external assistance. The corrections to be supported include modifying an undervote and changing a vote from one candidate to another.
d. The VEBD shall allow the voter to change a vote within a contest before advancing to the next contest.

Discussion: The point here is that voters using an editable interface should not have to wait for a final ballot review screen in order to change a vote.

e. The VEBD shall provide navigation controls that allow the voter to advance to the next contest or go back to the previous contest before completing a vote on the contest(s) currently being presented (whether visually or aurally).

Discussion: For example, voters should not be forced to proceed sequentially through all the contests before going back to check their votes within a previous contest.

f. If the voter takes the appropriate action to cast a ballot, but the DRE system does not accept and record it successfully, including failure to store the ballot image, then the DRE shall so notify the voter and provide clear instruction as to the steps the voter should take to cast the ballot.

Discussion: If a DRE fails at the point of casting a ballot, it must clearly indicate to the voter and to election officials responding to the failure whether or not the ballot was cast. Otherwise, election officials may be unable to provide substantial confirmation that the vote was or was not counted, possibly resulting in disenfranchisement or the casting of two ballots by a single voter. A device that "freezes" when the voter attempts to cast the ballot, providing no evidence one way or the other whether the ballot was cast would violate this requirement.

3.2.2.2 Non-Editable interfaces

Non-Editable interfaces, such as manually-marked paper ballots, do not have the same flexibility as do editable interfaces. Nonetheless, certain features are required, especially in the case of precinct-based optical scanners. Basically, a marginal mark is one that, according the manufacturer specifications, is neither clearly countable as a vote nor clearly countable as a non-vote.

a. The PCOS system shall be capable of providing feedback to the voter that identifies specific contests for which the voter has made more than the allowable number of votes (i.e.,. overvotes).
b. The PCOS system shall be capable of providing feedback to the voter that identifies specific contests for which the voter has made fewer than the allowable number of votes (i.e., undervotes). The system shall provide a means for an

authorized election official to deactivate this capability entirely and by contest. However, if a ballot is submitted with all the contests on one side left blank, notification to the voter is performed as described in requirement 3.2.2.2 c

c. The PCOS system shall be capable of notifying the voter that he or she has submitted a paper ballot that is blank on one or both sides. The system shall provide a means for an authorized election official to deactivate this capability.

Discussion: One purpose of this feature is to detect situations in which the voter might be unaware that the ballot is two-sided. This feature is distinct from the ability to detect and warn about undervoting.

d. If the PCOS system has notified the voter that a potential error condition (such as an overvote, undervote, or blank ballot) exists, the system shall then allow the voter to correct the ballot or to submit it as is.

Discussion: This requirement mandates that the system be capable of allowing either correction or immediate submission. For instance, a questionable paper ballot might be physically ejected for possible correction. This requirement does not constrain the procedures that jurisdictions might adopt for handling such situations (e.g., whether poll worker intervention is required).

e. Paper-based precinct tabulators should be able to identify a ballot containing marginal marks. When such a ballot is detected, the tabulator shall:

- Return the ballot to the voter;
- Provide feedback to the voter that identifies the specific contests for which a marginal mark was detected; and
- Allow the voter either to correct the ballot or to submit the ballot "as is" without correction.

Discussion: The purpose of this requirement is to provide more certainty about the handling of poorly-marked ballots. If a given candidate or option is clearly marked as chosen, or left completely unmarked, then there is no ambiguity to resolve. However, each manufacturer should define a "gray zone" (with respect to location, darkness, etc.) in which marks will be actively flagged as ambiguous.

f. If the voter takes the appropriate action to cast a ballot, but the PCOS system does not accept and record it successfully, including failure to read the ballot or to transport it into the ballot box, the PCOS shall so notify the voter.

Discussion: This requirement means that PCOS systems must detect and report electrical and mechanical failures within the system itself. It does not require the detection of errors on the part of the voter.

3.2.3 Privacy

The voting process must preclude anyone else from determining the content of a voter's ballot without the voter's cooperation. Privacy ensures that the voter can cast votes based solely on his or her own preferences without intimidation or inhibition.

3.2.3.1 Privacy at the polls

a. The voting system shall prevent others from determining the contents of a ballot.

Discussion: The voting system itself provides no means by which others can "determine" how one has voted. Of course voters could simply tell someone else for whom they voted, but the system provides no evidence for such statements, and therefore voters cannot be coerced into providing such evidence. It is assumed that the system is deployed according to the installation instructions provided by the manufacturer. Whether the configuration of the voting system protects privacy may well depend on proper setup.

b. The voting system shall support ballot privacy during the voting session and ballot submission.

Discussion: This requirement may involve different approaches for electronic and paper interfaces. In both cases, appropriate shielding of the voting station is important. When a paper record with ballot information needs to be transported by the voter, devices such as privacy sleeves may be necessary. This requirement applies to all records with information on votes (such as a vote verification record) even if that record is not itself a ballot.

c. During the voting session, the audio interface of the voting system shall be audible only to the voter.

Discussion: Voters who are hard of hearing but need to use an audio interface may also need to increase the volume of the audio. Such situations require headphones with low sound leakage.

d. The voting system shall issue all warnings in a way that preserves the privacy of the voter and the confidentiality of the ballot.

Discussion: HAVA 301 (a)(1)(C) mandates that the voting system must notify the voter of an attempted overvote in a way that preserves the privacy of the voter and the confidentiality of the ballot. This requirement generalizes that mandate.

e. The voting system shall not issue a receipt to the voter that would provide proof to another of how the voter voted.

3.2.3.2 No recording of alternative format usage

When voters use non-typical ballot interfaces, such as large print or alternative languages, their anonymity may be vulnerable. To the extent possible, only the logical contents of their ballots should be recorded, not the special formats in which they were rendered. However, in the case of paper ballots, where the interface is the record, some format information is unavoidably preserved.

a. No information shall be kept within an electronic cast voter record that identifies any alternative language feature(s) used by a voter.
b. No information shall be kept within an electronic cast voter record that identifies any accessibility feature(s) used by a voter.

~~3.1.7 Privacy~~

~~The voting process shall preclude anyone else from determining the content of a voter's ballot, without the voter's cooperation.~~

~~Discussion: Privacy ensures that the voter can make selections based solely on his or her own preferences without intimidation or inhibition. Among other practices, this forbids the issuance of a receipt to the voter that would provide proof of how he or she voted.~~

~~3.1.7.1 Privacy at the Polls~~

~~When deployed according to the installation instructions provided by the vendor, the voting station shall prevent others from observing the contents of a voter's ballot.~~

~~a. The ballot and any input controls shall be visible only to the voter during the voting session and ballot submission.~~
~~b. The audio interface shall be audible only to the voter.~~

~~Discussion: Voters who are hard of hearing but need to use an audio interface may also need to increase the volume of the audio. Such situations require headphones with low sound leakage.~~

~~c. As mandated by HAVA 301 (a)(1)(C), the voting system shall notify the voter of an attempted overvote in a way that preserves the privacy of the voter and the confidentiality of the ballot.~~

~~3.1.7.2 No Recording of Alternate Format Usage~~

~~Voter anonymity shall be maintained for alternative format ballot presentation.~~

~~d. No information shall be kept within an electronic cast vote record that identifies any alternative language feature(s) used by a voter.~~
~~e. No information shall be kept within an electronic cast vote record that identifies any accessibility feature(s) used by a voter.~~

3.2.4 Cognitive issues

The features specified in this section are intended to minimize cognitive difficulties for voters. They should always be able to operate the voting system and understand the effect of their actions.

a. The voting system shall provide instructions for all its valid operations.

Discussion: If an operation is available to the voter, it must be documented. Examples include how to change a vote, how to navigate among contests, how to cast a straight party vote, how to cast a write-in vote, and how to adjust display and audio characteristics.

b. The voting system shall provide a means for the voter to get help directly from the system at any time during the voting session.

Discussion: The voter should always be able to get context-sensitive help from the system when needed. The purpose is to minimize the need for assistance from the poll worker. VEBD voting systems may provide this with a distinctive "help" button. In addition to context-sensitive help, any voting system may provide written instructions that are separate from the ballot.

c. Instructional material for the voter shall conform to norms and best practices for plain language.

Discussion: Although part of general usability, the use of plain language is also expected to assist voters with cognitive disabilities. The plain language requirements apply to instructions that are inherent to the voting system or that are generated by default. To the extent that instructions are determined by election officials designing the ballot, they are beyond of the scope of this requirement. For specific guidance on how to implement this requirement, see: “Guidelines for Writing Clear Instructions and Messages for Voters and Poll Workers” at http://vote.nist.gov/032906PlainLanguageRpt.pdf .

i. Warnings and alerts issued by the voting system shall be distinguishable from other information and should clearly state:

- The nature of the problem;
- Whether the voter has performed or attempted an invalid operation or whether the voting system itself has malfunctioned in some way; and
- The set of responses available to the voter.

Discussion: For instance, “Do you need more time? Select ‘Yes’ or “No’.” rather than “System detects imminent timeout condition.” In case of an equipment failure, the only action available to the voter might be to get assistance from a poll worker.

ii. When an instruction is based on a condition, the condition should be stated first, and then the action to be performed.

Discussion: For instance, use "In order to change your vote, do X", rather than "Do X, in order to change your vote."

iii. The voting system should use familiar, common words and avoid technical or specialized words that voters are not likely to understand.

Discussion: For instance, "... there are more contests on the other side ..." rather than "...additional contests are presented on the reverse ..."

iv. Each distinct instruction should be separated spatially from other instructions for visual or tactile interfaces, and temporally for auditory interfaces.

Discussion: This implies not "burying" several unrelated instructions in a single long paragraph.

v. The voting system should issue instructions on the correct way to perform actions, rather than telling voters what not to do.

Discussion: For example, “Fill in the oval for your write-in vote to count” rather than “If the oval is not marked, your write-in vote cannot be counted.”

vi. The system's instructions should address the voter directly rather than use passive voice constructions.

Discussion: For example, "remove and retain this ballot stub" rather than "this ballot stub must be removed and retained by the voter."

vii. The voting system should avoid the use of gender-based pronouns.

Discussion: For example, "...write in your choice directly on the ballot..." rather than "... write in his name directly on the ballot..."

d. Consistent with election law, the voting system shall support a process that does not introduce bias for or against any of the contest choices to be presented to the voter. In both visual and aural formats, the choices shall be presented in an equivalent manner.

Discussion: Certain differences in presentation are mandated by state law, such as the order in which candidates are listed and provisions for voting for write-in candidates. However, comparable characteristics such as font size or voice volume and speed must be the same for all choices.

e. The voting system shall provide the capability to design a ballot with a high level of clarity and comprehensibility.
   i. The voting system should not visually present a single contest spread over two pages or two columns.

Discussion: Such a visual separation poses the risk that the voter may perceive one contest as two, or fail to see additional choices. If a contest has a large number of candidates, it may be infeasible to observe this guideline.

   ii. The ballot shall clearly indicate the maximum number of candidates for which one can vote within a single contest.
   iii. The relationship between the name of a candidate and the mechanism used to vote for that candidate shall be consistent throughout the ballot.

Discussion: For example, the response field where voters indicate their votes must not be located to the left of some candidates' names, and to the right of others'.

   iv. The voting system should present instructions near to where they are needed.

Discussion: For instance, only general instructions should be grouped at the beginning of the ballot; those pertaining to specific situations should be presented where and when needed.

f. The use of color by the voting system shall agree with common conventions: (a) green, blue or white is used for general information or as a normal status indicator; (b) amber or yellow is used to indicate warnings or a marginal status; (c) red is used to indicate error conditions or a problem requiring immediate attention.

g. When an icon is used to convey information, indicate an action, or prompt a response, it shall be accompanied by a corresponding linguistic label.

Discussion: While icons can be used for emphasis when communicating with the voter, they must not be the sole means by which information is conveyed, since there is no widely accepted "iconic" language and therefore not all voters may understand a given icon.

~~3.1.4 Cognitive Issues~~

~~The voting process shall be designed to minimize cognitive difficulties for the voter.~~

~~a. Consistent with election law, the voting system should support a process that does not introduce any bias for or against any of the selections to be made by the voter. In both visual and aural formats, contest choices shall be presented in an equivalent manner.~~

~~Discussion: Certain differences in presentation are mandated by state law, such as the order in which candidates are listed and provisions for voting for write-in candidates. But comparable characteristics such as font size or voice volume and speed must be the same for all choices.~~

~~b. The voting machine or related materials shall provide clear instructions and assistance to allow voters to successfully execute and cast their ballots independently.~~

~~Discussion: Voters should not routinely need to ask for human assistance.~~

~~i. Voting machines or related materials shall provide a means for the voter to get help at any time during the voting session.~~

~~Discussion: The voter should always be able to get help if needed. DRE voting machines may provide this with a distinctive “help” button. Any type of voting equipment may provide written instructions that are separate from the ballot.~~

~~ii. The voting machine shall provide instructions for all its valid operations.~~

~~Discussion: If an operation is available to the voter, it must be documented. Examples include how to change a vote, how to navigate among contests, how to cast a straight party vote, and how to cast a write-in vote.~~

~~c. The voting system shall provide the capability to design a ballot for maximum clarity and comprehension.~~

~~i. The voting equipment should not visually present a single contest spread over two pages or two columns.~~

~~Discussion: Such a visual separation poses the risk that the voter may perceive one contest as two. If a contest has a large number of candidates, it may be infeasible to observe this guideline.~~

ii. ~~The ballot shall clearly indicate the maximum number of candidates for which one can vote within a single contest.~~
iii. ~~There shall be a consistent relationship between the name of a candidate and the mechanism used to vote for that candidate.~~

~~Discussion: For example, if the response field where voters indicate their selections is located to the left of a candidate's name, then each response field shall be located to the left of the associated candidates' names.~~

~~Warnings and alerts issued by the voting system should clearly state the nature of the problem and the set of responses available to the voter. The warning should clearly state whether the voter has performed or attempted an invalid operation or whether the voting equipment itself has malfunctioned in some way.~~

~~Discussion: In case of an equipment failure, the only action available to the voter might be to get assistance from a poll worker.~~

d. ~~The use of color by the voting system should agree with common conventions: (a) green, blue or white is used for general information or as a normal status indicator; (b) amber or yellow is used to indicate warnings or a marginal status; (c) red is used to indicate error conditions or a problem requiring immediate attention.~~

3.2.5 Perceptual issues

The requirements of this section are designed to minimize perceptual difficulties for the voter. Some of these requirements are designed to assist voters with poor reading vision. These are voters who might have some difficulty in reading normal text, but are not typically classified as having a visual disability and thus might not be inclined to use the accessible voting station.

a. If the voting system uses an electronic display screen as the primary visual interface for the voter, the display shall have the following characteristics:

- Flicker frequency NOT between 2 Hz and 55 Hz.
- Minimum display brightness: 130 cd/m^2
- Minimum display darkroom 7×7 checkerboard contrast: 150:1
- Minimum display pixel pitch: 85 pixels/inch (0.3 mm/pixel)
- Minimum display area 700 cm^2
- Antiglare screen surface that shows no distinct virtual image of a light source
- Minimum uniform diffuse ambient contrast for 500 1× illuminance: 10:1

Discussion: Aside from usability concerns, this requirement protects voters from having visually-induced seizures.

b. Any aspect of the voting system that is adjustable by either the voter or poll worker, including font size, color, contrast, audio volume, or rate of speech, shall automatically reset to a standard default value upon completion of that voter's session. For the Acc-VS, the aspects include synchronized audio/video mode and non-manual input mode.

Discussion: This ensures that the voting system presents the same initial appearance to every voter.

c. If any aspect of a voting system is adjustable by either the voter or poll worker, there shall be a mechanism to allow the voter to reset all such aspects to their default values while preserving the current votes.

Discussion: The purpose is to allow a voter or poll worker who has adjusted the system into an undesirable state to reset all the aspects and begin again.

d. For all text intended for voters or poll workers, the voting system shall provide a font with the following characteristics

- Height of capital letters at least: 3.0 mm
- x-height of a least: 70% of cap height
- Stroke width at least: 0.35 mm.

e. A voting system that uses an electronic image display shall be capable of showing all information in at least two font sizes:

- 3.0-4.0 mm cap height, with a corresponding x-height at least 70% of the cap height and a minimum stroke width of 0.35 mm;
- 6.3-9.0 mm cap height, with a corresponding x-height at least 70% of the cap height and a minimum stroke width of 0.7 mm; under control of the voter. The system shall allow the voter to adjust font size throughout the voting session while preserving the current votes.

Discussion: While larger font sizes may assist most voters with poor vision, certain disabilities such as tunnel vision are best addressed by smaller font sizes. Larger font sizes may also assist voters with cognitive disabilities. This requirement mandates the availability of at least two font sizes, but additional choices (including continuous variability) are allowed.

f. Text intended for the voter should be presented in a sans serif font.

Discussion: In general, sans serif fonts are easier to read on-screen, they look reasonably good when their size is reduced, and they tend to retain their visual appeal across different platforms.

g. Voting systems using paper ballots or paper verification records shall provide features that assist in the reading of such ballots and records by voters with poor reading vision.

Discussion: While this requirement may be satisfied by one of its sub-requirements, other innovative solutions are not precluded.

i. The voting system may achieve legibility of paper records by supporting the printing of those records in at least two font sizes, 3.0-4.0mm and 6.3-9.0mm.

Discussion: Although the system may be capable of printing in several font sizes, the use of various font sizes in an actual election may be governed by local or state laws and regulations.

ii. The system may achieve legibility of paper records by supporting magnification of those records. This magnification may be done by optical or electronic devices. The manufacturer may either: 1) provide the magnifier itself as part of the system, or 2) provide the make and model number of readily available magnifiers that are compatible with the system.

Discussion: The magnifier(s) either provided or cited must, of course, provide legibility for the paper as actually presented on the system. For instance, if the paper record is under a transparent cover to prevent the voter from touching it, the means of magnification must be compatible with this configuration. "Straight edge" magnifiers, which allow the user to read an entire line, may be especially suitable for the voting task.

h. The minimum figure-to-ground ambient contrast ratio for all text and informational graphics (including icons) intended for voters or poll workers shall be 10:1. For paper ballots, contrast is measured based on ambient lighting of at least 300 l×.

i. A voting station with an electronic display screen shall be capable of showing all information in high contrast either by default or under the control of the voter. If the system allows the voter to adjust contrast during the voting session it shall preserve the current votes. High contrast is a figure-to-ground ambient contrast ratio for text and informational graphics of at least 50:1.

Discussion: Systems may, but need not, offer a lower contrast option, as long as high contrast is available.

j. The default color coding shall support correct perception by voters with color blindness.

Discussion: There are many types of color blindness and no color coding can, by itself, guarantee correct perception for everyone. However, designers should take into account such factors as: red-green color blindness is the most common form; high luminosity contrast will help colorblind voters to recognize visual features; and color-coded graphics can also use shape to improve the ability to distinguish certain features. For specific guidance on how to implement this requirement, please see: "NISTIR 7537: Guidelines for Using Color in Voting Systems" at http://vote.nist.gov/NISTIR-7537.pdf.

i. Ordinary information presented to the voter by the voting system should be in the form of black text on a white background. The use of color should be reserved for special cases, such as warnings or alerts.

ii. No information presented to the voter by the voting system shall be in the form of colored text on a colored background. Either the text or background shall be black or white.

iii. If text is colored other than black or white:

1. The background shall be black or white.
2. The text shall be presented in a bold font (minimum 0.6 mm stroke width).
3. If the background is black, the text color shall be yellow or light cyan.
4. If the background is white, the text color shall be dark enough to maintain a 10:1 contrast ratio.

Discussion: Any sufficiently dark yellow will appear brown or olive.

iv. If the background is colored other than black or white, the presentation shall follow these guidelines:

1. The text color shall be black.
2. The background color shall be yellow or light cyan.

k. Color coding shall not be used as the sole means of conveying information, indicating an action, prompting a response, or distinguishing a visual element.

Discussion: While color can be used for emphasis, some other non-color mode must also be used to convey the information, such as a shape or text style. For example, red can be enclosed in an octagon shape.

~~3.1.5 Perceptual Issues~~

~~The voting process shall be designed to minimize perceptual difficulties for the voter.~~

~~a. No voting machine display screen shall flicker with a frequency between 2 Hz and 55 Hz.~~

~~Discussion: Aside from usability concerns, this requirement protects voters with epilepsy.~~

~~b. Any aspect of the voting machine that is adjustable by the voter or poll worker, including font size, color, contrast, and audio volume, shall automatically reset to a standard default value upon completion of that voter's session.~~

~~Discussion: The voting machine must present the same initial appearance to every voter.~~

~~c. If any aspect of a voting machine is adjustable by the voter or poll worker, there shall be a mechanism to reset all such aspects to their default values.~~

~~Discussion: The purpose is to allow a voter who has adjusted the machine into an undesirable state to reset all the aspects to begin again.~~

~~d. All electronic voting machines shall provide a minimum font size of 3.0 mm (measured as the height of a capital letter) for all text.~~

~~e. All voting machines using paper ballots should make provisions for voters with poor reading vision.~~

~~Discussion: Possible solutions include: (a) providing paper ballots in at least two font sizes, 3.0-4.0mm and 6.3-9.0mm and (b) providing a magnifying device.~~

~~f. The default color coding shall maximize correct perception by voters with color blindness.~~

~~Discussion: There are many types of color blindness and no color coding can, by itself, guarantee correct perception for everyone. However, designers should take into account such factors as: red-green color blindness is the most common form; high luminosity contrast will help colorblind voters to recognize visual features; and color-coded graphics can also use shape to improve the ability to distinguish certain features.~~

~~g. Color coding shall not be used as the sole means of conveying information, indicating an action, prompting a response, or distinguishing a visual element.~~

~~Discussion: While color can be used for emphasis, some other non-color mode must also be used to convey the information, such as a shape or text style. For example, red can be enclosed in an octagon shape.~~

~~h. All text intended for the voter should be presented in a sans serif font.~~

~~Discussion: Experimentation has shown that users prefer such a font and the legibility of serif and sans serif fonts is equivalent.~~

~~i. The minimum figure-to-ground ambient contrast ratio for all text and informational graphics (including icons) intended for the voter shall be 3:1.~~

3.2.6 Interaction issues

The requirements of this section are designed to minimize interaction difficulties for the voter.

a. The VEBD shall not require page scrolling by the voter.

Discussion: That is, the page of displayed information must fit completely within the physical screen presenting it. Scrolling is not an intuitive operation for those unfamiliar with the use of computers. Even those experienced with computers often do not notice a scroll bar and miss information at the bottom of the "page." Voting systems may require voters to move to the next or previous "page."

b. The voting system shall provide unambiguous feedback regarding the voter's selection, such as displaying a checkmark beside the selected option or conspicuously changing its appearance.
c. Voting system input mechanisms shall be designed to prevent accidental activation.

Discussion: There are at least two kinds of accidental activation. One is when a control is activated as it is being "explored" by the voter because the control is overly sensitive to the touch. A second issue is the problem of having a control in a location where it can easily be activated unintentionally. An example would be a button in the very bottom left corner of the screen where a voter might hold the unit for support.

i. On touch screens, the sensitive touch areas shall have a minimum height of 0.5 inches and minimum width of 0.7 inches. The vertical distance between the centers of adjacent areas shall be at least 0.6 inches, and the horizontal distance at least 0.8 inches. Touch areas shall not overlap.
ii. No key or control on a voting system shall have a repetitive effect as a result of being held in its active position.

Discussion: This is to preclude accidental activation. For instance, if a voter is typing in the name of a write-in candidate, depressing and holding the "e" key results in only a single "e" added to the name.

~~3.1.6 Interaction Issues~~

~~The voting process shall be designed to minimize interaction difficulties for the voter.~~

a. ~~Voting machines with electronic image displays shall not require page scrolling by the voter.~~

~~Discussion: This is not an intuitive operation for those unfamiliar with the use of computers. Even those experienced with computers often do not notice a scroll bar and miss information at the bottom of the "page." Voting systems may require voters to move to the next or previous "page."~~

b. ~~The voting machine shall provide unambiguous feedback regarding the voter's selection, such as displaying a checkmark beside the selected option or conspicuously changing its appearance.~~
c. ~~If the voting machine requires a response by a voter within a specific period of time, it shall issue an alert at least 20 seconds before this time period has expired and provide a means by which the voter may receive additional time.~~
d. ~~Input mechanisms shall be designed to minimize accidental activation.~~
    i. ~~On touch screens, the sensitive touch areas shall have a minimum height of 0.5 inches and minimum width of 0.7 inches. The vertical distance between the centers of adjacent areas shall be at least 0.6 inches, and the horizontal distance at least 0.8 inches.~~
    ii. ~~No key or control on a voting machine shall have a repetitive effect as a result of being held in its active position.~~

~~Discussion: This is to preclude accidental activation. For instance, if a voter is typing in the name of a write-in candidate, depressing and holding the "e" key results in only a single "e" added to the name.~~

3.2.6.1 Timing issues

These requirements address how long the system and voter wait for each other to interact.

a. The initial system response time of the VEBD shall be no greater than 0.5 seconds.

Discussion: This is so the voter can very quickly perceive that an action has been detected by the system and is being processed. The voter never gets the sense of dealing with an unresponsive or "dead" system. Note that this requirement applies to VEBD-A (audio) as well as to VEBD-V (visual) systems.

b. When the voter performs an action to record a single vote, the completed system response time of the VEBD shall be no greater than one second in the case of a visual response, and no greater than five seconds in the case of an audio response.

Discussion: For example, if the voter touches a button to indicate a vote for a candidate, a visual system might display an "X" next to the candidate's name, and an audio system might announce, "You have voted for John Smith for Governor".

c. The completed system response time of the VEBD-V shall be no greater than 10 seconds.

Discussion: Even for "large" operations such as initializing the ballot or painting a new screen, the system must never take more than 10 seconds. In the case of audio systems, no upper limit is specified, since certain operations may take longer, depending on the length of the text being read (e.g., reading out a long list of candidates running in a contest).

d. If the VEBD-V has not completed its visual response within one second, it shall present to the voter, within 0.5 seconds of the voter's action, some indication that it is preparing its response.

Discussion: For instance, the system might present a progress bar indicating that it is "busy" processing the voter's request. This requirement is intended to preclude the "frozen screen" effect, in which no detectible activity is taking place for several seconds. There need not be a specific "activity" icon, as long as some visual change is apparent (such as progressively "painting" a new screen).

e. The VEBD shall detect and warn about lengthy voter inactivity during a voting session. Each VEBD shall have a defined and documented voter inactivity time, and that time shall be between two and five minutes.

Discussion: Each type of system must have a given inactivity time that is consistent among and within all voting sessions. This ensures that all voters are treated equitably.

f. Upon expiration of the voter inactivity time, the VEBD shall issue an alert and provide a means by which the voter may receive additional time. The alert time shall be between 20 and 45 seconds. If the voter does not respond to the alert within the alert time, the VEBD shall go into an inactive state requiring poll worker intervention.

3.2.7 Alternative languages

HAVA Section 301 (a)(4) states that the voting system shall provide alternative language accessibility pursuant to the requirements of Section 203 of the Voting Rights Act of 1965 (42 U.S.C. 1973aa-1a). Ideally every voter would be able to vote independently and privately, regardless of language. As a practical matter, alternative language access is mandated under the Voting Rights Act of 1975, subject to certain thresholds (e.g., if the language group exceeds 5% of the voting age population). Thus, election officials must ensure that the voting system they deploy is capable of handling the languages meeting the legal threshold within their districts.

While the following requirements support this process, it should be noted that they are requirements only for voting systems to be certified. It is anticipated that jurisdictions will apply additional requirements appropriate for their particular circumstances for procurement and deployment.

a. *The voting system shall be capable of presenting the ballot, contest choices, review screens, vote verification records, and voting instructions in any language declared by the manufacturer to be supported by the system*[8].

Discussion: *For example, if the manufacturer claims that a given system is capable of supporting Spanish and Chinese, then it must do so. Presentation of the ballot includes both visual and audio formats. Both written and unwritten languages are within the scope of this requirement.*

i. The VEBD shall allow the voter to select among the available languages throughout the voting session while preserving the current votes. When presenting a choice of languages to the voter, the VEBD shall use the native name of each language.

Discussion: For instance, a voter may initially choose an English version of the ballot, but then wish to switch to another language in order to read a referendum question.

ii. Information presented to the voter in the typical case of English-literate voters (including instructions, warnings, messages, contest choices, and vote verification information) shall also be presented when an alternative language is being used, whether the language is written or spoken.

Discussion: Therefore, it may not be sufficient simply to present the ballot per se in the alternative language, especially in the case of VEBD systems. All the supporting information must also be available in the alternative language.

iii. Any records, including paper ballots and paper verification records, shall have the information required to support auditing by poll workers and others who can read only English.

[8] The italicized text in Section 3.2.7 is based on EAC Decision on Request for Interpretation 2007-04, http://www.eac.gov/program-areas/voting-systems/docs/certification-docs-rfi2007-04.pdf/attachment_download/file.

Discussion: Even though the system must be easily available to voters without a command of English, any persistent records of the vote must also be fully available to English-only readers for auditing purposes. In the case of paper, this does not imply a fully bi-lingual ballot. For instance, the full text of a referendum question might appear only in the alternative language, but the content of the vote (e.g., "yes" on ballot question 106) needs to be readable by English-only readers.

iv. The manufacturer shall conduct summative usability tests for each of the voting system's supported languages, using subjects who are fluent in those languages but not fluent in English and shall report the test results, using the Common Industry Format, as part of the TDP. In addition, the usability test report shall be submitted to the EAC as part of the documentation manufacturers are required to file with the application to test a voting system.

~~3.1.3 Alternative Languages~~

~~The voting equipment shall be capable of presenting the ballot, ballot selections, review screens and instructions in any language required by state or federal law.~~

~~Discussion: HAVA Section 301 (a)(4) states that the voting system shall provide alternative language accessibility pursuant to the requirements of section 203 of the Voting Rights Act of 1965 (42 U.S.C. 1973aa-1a). Ideally every voter would be able to vote independently and privately, regardless of language. As a practical matter, alternative language access is mandated under the Voting Rights Act of 1975, subject to certain thresholds, e.g., if the language group exceeds 5% of the voting age population. The audio interface provided for blind voters may also assist voters who speak English, but who are unable to read it (See Subsection 3.2.2.2).~~

3.2.8 Usability for poll workers

Voting systems are used not only by voters to record their votes, but also by poll workers who are responsible for set-up, operation while polls are open, light maintenance, and poll closing. Because of the wide variety of implementations, it is impossible to specify detailed design requirements for these functions. The requirements below describe general capabilities that all systems must support.

a. Messages generated by the voting system for poll workers in support of the operation, maintenance, or safety of the system shall adhere to the requirements for clarity in Section 3.2.4 "Cognitive issues".

3.2.8.1 Operation

Poll workers are responsible for opening polls, keeping the polls open and running smoothly during voting hours, and closing the polls afterwards. Operations may be categorized in three phases:

Setup includes all the steps necessary to take the system from its state as normally delivered to the polling place, to the state in which it is ready to record votes. It does not include ballot definition.

Polling includes such functions as:

- voter identification and authorization;
- preparing the system for the next voter;
- assistance to voters who wish to change their ballots or need other help;
- system recovery in the case of voters who abandon the voting session without having cast a ballot; and routine hardware operations, such as installing a new roll of paper.

Shutdown includes all the steps necessary to take the system from the state in which it is ready to record votes to its normal completed state in which it has captured all the votes cast and the voting information cannot be further altered.

a. The procedures for voting system setup, polling, and shutdown, as documented by the manufacturer, shall be reasonably easy for the typical poll worker to learn, understand, and perform.

Discussion: This requirement covers procedures and operations for those aspects of system operation normally performed by poll workers and other "non-expert" operators. It does not address inherently complex operations such as ballot definition or system repair. While a certain amount of complexity is unavoidable, these "normal" procedures should not require any special expertise. The procedures may require a reasonable amount of training.

b. The manufacturer shall conduct summative usability tests on the voting system using individuals who are representative of the general population and shall report the test results, using the Common Industry Format, as part of the TDP. The tasks to be covered in the test shall include setup, operation, and shutdown. In addition, the usability test report shall be submitted to the EAC as part of the documentation manufacturers are required to file with the application to test a voting system.
c. The voting system shall include clear, complete, and detailed instructions and messages for setup, polling, and shutdown.

Discussion: This requirement covers documentation for those aspects of system operation normally performed by poll workers and other "non-expert" operators. It does not address inherently complex operations such as ballot definition. The instructions would usually be in the form of a written manual, but could also be presented on other media, such as a DVD or videotape. In the context of this requirement, "message" means information delivered by the system to the poll worker as he or she attempts to perform a setup, polling, or shutdown operation. For specific guidance on how to implement this requirement, please see: “NISTIR 7519: Style Guide for Voting System Documentation” at http://vote.nist.gov/NISTIR-7519.pdf.

i. The documentation required for normal voting system operation shall be presented at a level appropriate for poll workers who are not experts in voting system and computer technology.

Discussion: For instance, the documentation should not presuppose familiarity with personal computers.

ii. The documentation shall be in a format suitable for use in the polling place.

Discussion: For instance, a single large reference manual that simply presents details of all possible operations would be difficult to use, unless accompanied by aids such as a simple "how-to" guide.

iii. The instructions and messages shall enable the poll worker to verify that the voting system

- Has been set up correctly (setup);
- Is in correct working order to record votes (polling); and
- Has been shut down correctly (shutdown).

Discussion: The poll worker should not have to guess whether an operation has been performed correctly. The documentation should make it clear what the system "looks like" when correctly configured.

3.2.8.2 Safety

All voting systems and their components must be designed so as to eliminate hazards to personnel or to the equipment itself. Hazards include, but are not limited to:

- fire hazards;
- electrical hazards;
- potential for equipment tip-over (stability);
- potential for cuts and scrapes (e.g., sharp edges);

- potential for pinching (e.g., tight, spring-loaded closures); and
- potential for hair or clothing entanglement.

a. Devices associated with the voting system shall be certified in accordance with the requirements of UL 60950-1, Information Technology Equipment – Safety – Part 1 by a certification organization accredited by the Department of Labor, Occupational Safety and Health Administration's Nationally Recognized Testing Laboratory program. The certification organization's scope of accreditation shall include IEC/UL 60950-1.

Discussion: IEC/UL 60950 is a comprehensive standard for IT equipment and addresses all the hazards discussed above under Safety.

3.3 Accessibility requirements

HAVA Section 301 (a) (3) [HAVA02] reads, in part:

ACCESSIBILITY FOR INDIVIDUALS WITH DISABILITIES.--The voting system shall--

(A) be accessible for individuals with disabilities, including nonvisual accessibility for the blind and visually impaired, in a manner that provides the same opportunity for access and participation (including privacy and independence) as for other voters;

(B) satisfy the requirement of subparagraph (A) through the use of at least one direct recording electronic voting system or other voting system equipped for individuals with disabilities at each polling place;

The voting process is to be accessible to voters with disabilities through the use of a specially equipped voting station. A machine so equipped is referred to herein as an accessible voting station (Acc-VS).

The requirements in this section are intended to address this HAVA mandate. Ideally, every voter would be able to vote independently and privately. As a practical matter, there may be some number of voters who, because of the nature of their disabilities, will need personal assistance with any system. Nonetheless, these requirements are meant to make the voting system independently accessible to as many voters as possible. This includes access across all voting processes: capabilities to generate, verify and cast an official ballot must be provided.

This section is organized according to the type of disability being addressed. For each type, certain appropriate design features are specified. Note, however, that a feature intended primarily to address one kind of disability may very well assist voters with other kinds. Moreover, this organization in no way implies that the various sets of requirements are optional or mutually exclusive. In order to conform, an Accessible Voting Station must fulfill all the requirements of all the sub-sections of Chapter 3.3.

There are many other requirements, such as the general usability requirements, that apply to the Acc-VS besides those in this section. Please see Section 3.1.3 “Interaction of usability and accessibility requirements” for a full explanation.

~~The voting process shall be accessible to voters with disabilities. As a minimum, every polling place shall have at least one voting station equipped for individuals with disabilities, as provided in HAVA 301 (a)(3)(B). A machine so equipped is referred to herein as an accessible voting station.~~

~~HAVA Section 301 (a) (3) reads, in part:~~

> ~~ACCESSIBILITY FOR INDIVIDUALS WITH DISABILITIES.--The voting system shall—~~
>
> ~~(A) be accessible for individuals with disabilities, including nonvisual accessibility for the blind and visually impaired, in a manner that provides the same opportunity for access and participation (including privacy and independence) as for other voters;~~
>
> ~~(B) satisfy the requirement of subparagraph (A) through the use of at least one direct recording electronic voting system or other voting system equipped for individuals with disabilities at each polling place~~

~~The requirements in Subsection 3.2 are intended to address this mandate. Ideally, every voter would be able to vote independently and privately. As a practical matter, there may be some number of voters whose disabilities are so severe that they will need personal assistance. Nonetheless, these requirements are meant to make the voting system independently accessible to as many voters as possible. These requirements are in addition to those described in Subsection 3.1 Usability Requirements.~~

~~The outline for this subsection is:~~

3.3.1 General

The requirements of this section are relevant to a wide variety of disabilities.

a. The Acc-VS shall be integrated into the manufacturer's complete voting system so as to support accessibility for disabled voters throughout the voting session.

Discussion: This requirement ensures accessibility to the voter throughout the entire session. Not only must individual system components (such as ballot markers, paper records, and optical scanners) be accessible, but also they must work together to support this result.

i. The manufacturer shall supply documentation describing 1) recommended procedures that fully implement accessibility for voters with disabilities and 2) how the Acc-VS supports those procedures.

Discussion: The purpose of this requirement is for the manufacturer not simply to deliver system components, but also to describe the accessibility scenarios they are intended to support.

b. When the provision of accessibility for Acc-VS involves an alternative format for ballot presentation, then all information presented to non-disabled voters, including instructions, warnings, error and other messages, and contest choices, shall be presented in that alternative format.

c. The support provided to voters with disabilities shall be intrinsic to the accessible voting station. It shall not be necessary for the accessible voting station to be connected to any personal assistive device of the voter in order for the voter to operate it correctly.

Discussion: This requirement does not preclude the accessible voting station from providing interfaces to assistive technology. (See definition of "personal assistive devices" in Appendix A.) Its purpose is to assure that disabled voters are not required to bring special devices with them in order to vote successfully. The requirement does not assert that the accessible voting station will eliminate the need for a voter's ordinary non-interfacing devices, such as eyeglasses or canes.

d. If a voting system provides for voter identification or authentication by using biometric measures that require a voter to possess particular biological characteristics, then Acc-VS shall provide a secondary means that does not depend on those characteristics.

Discussion: For example, if fingerprints are used for voter identification, another mechanism must be provided for voters without usable fingerprints.

e. If the Acc-VS generates a paper record (or some other durable, human-readable record) for the purpose of allowing voters to verify their votes, then the system shall provide a means to ensure that the verification record is accessible to all voters with disabilities, as identified in 3.3 “Accessibility requirements”.

Discussion: While paper records generally provide a simple and effective means for technology-independent vote verification, their use can present difficulties for voters with certain types of disabilities. The purpose of this requirement is to ensure that all voters have a similar opportunity for vote verification. Note that this requirement addresses the special difficulties that may arise with the use of paper. Verification is part of the voting process, and all the other general requirements apply to verification, in particular those dealing with dexterity (e.g. 3.3.4 c), blindness (e.g. 3.3.3 e) and poor vision issues (e.g. 3.2.5 g).

i. If the Acc-VS generates a paper record (or some other durable, human-readable record) for the purpose of allowing voters to verify their votes, then the system shall provide a mechanism that can read that record and generate an audio representation of its contents.

Discussion: Sighted voters can directly verify the contents of a paper record. The purpose of this requirement is to allow voters with visual disabilities to verify, even if indirectly, the contents of the record. It is recognized that the verification depends on the integrity of the mechanism that reads the record to the voter. The audio must be generated via the paper record and therefore not depend on any electronic or other "internal" record of the ballot. Note that the paper record and its audio representation may be rendered in an alternative language.

~~3.2.1 General~~

~~The voting process shall incorporate the following features that are applicable to all types of disabilities:~~

~~a. When the provision of accessibility involves an alternative format for ballot presentation, then all information presented to voters including instructions, warnings, error and other messages, and ballot choices shall be presented in that alternative format.~~

~~b. The support provided to voters with disabilities shall be intrinsic to the accessible voting station. It shall not be necessary for the accessible voting station to be connected to any personal assistive device of the voter in order for the voter to operate it correctly.~~

~~Discussion: This requirement does not preclude the accessible voting station from providing interfaces to assistive technology. [See definition of "personal assistive devices" in the Glossary.] Its purpose is to assure that disabled voters are not required to bring special devices with them in order to vote successfully. The requirement does not assert that the accessible voting station will obviate the need for a voter's ordinary non-interfacing devices, such as eyeglasses or canes. Jurisdictions should ensure that an accessible voting station provides clean and sanitary devices for voters with dexterity disabilities.~~

~~c. When the primary means of voter identification or authentication uses biometric measures that require a voter to possess particular biological characteristics, the voting process shall provide a secondary means that does not depend on those characteristics.~~

~~Discussion: For example, if fingerprints are used for voter identification, another mechanism shall be provided for voters without usable fingerprints.~~

3.3.2 Low vision

These requirements specify the features of the accessible voting station designed to assist voters with low vision.

In general, low vision is defined as having a visual acuity worse than 20/70. Low (or partial) vision also includes dimness of vision, haziness, film over the eye, foggy vision, extreme near-sightedness or far-sightedness, distortion of vision, color distortion or blindness, visual field defects, spots before the eyes, tunnel vision, lack of peripheral vision, abnormal sensitivity to light or glare and night blindness.

People with tunnel vision can see only a small part of the ballot at one time. For these users it is helpful to have letters at the lower end of the font size range in order to allow them to see more letters at the same time. Thus, there is a need to provide font sizes at both ends of the range.

People with low vision or color blindness benefit from high contrast and from a selection of color combinations appropriate for their needs. Between 7% and 10% of all men have color vision deficiencies. Certain color combinations in particular cause problems. Therefore, use of color combinations with good contrast is required. Note also the general Requirement 3.2.5 j.

However, some users are very sensitive to very bright displays and cannot use them for long. An overly bright background causes a visual white-out that makes these users unable to distinguish individual letters. Thus, use of non-saturated color options is an advantage for some people.

It is important to note that some of the requirements in 3.2.5 "Perceptual issues" also provide support for voters with certain kinds of vision problems.

a. The manufacturer shall conduct summative usability tests on Acc-VS using individuals with low vision and shall report the test results, using the Common Industry Format, as part of the TDP. In addition, the usability test report shall be submitted to the EAC as part of the documentation manufacturers are required to file with the application to test a voting system.
b. An accessible voting station with a color electronic image display shall allow the voter to adjust the color saturation throughout the voting session while preserving the current votes. Two options shall be available: 1) black text on white background and 2) white text on black background.
c. *Buttons and controls on accessible voting stations shall be distinguishable by both shape and color. This applies to buttons and controls implemented either "on-screen" or in hardware. This requirement does not apply to sizeable groups of keys, such as a conventional 4x3 telephone keypad or a full alphabetic keyboard*[9].

Discussion: *The redundant cues assist those with low vision. They also help individuals who may have difficulty reading the text on the screen, those who are blind but have some residual vision, and those who using the controls on an accessible voting station because of limited dexterity. While this requirement is primarily focused on those with low vision, a feature intended primarily to address one kind of disability may very well assist voters with other kinds.*

d. The Acc-VS shall provide synchronized audio output to convey the same information as that which is displayed on the screen. There shall be a means by which the voter can disable either the audio or the video output, resulting in a video-only or audio-only presentation, respectively. The system shall allow the voter to switch among the three modes (synchronized audio/video, video-only, or audio-only) throughout the voting session while preserving the current votes.

Discussion: This feature may also assist voters with cognitive disabilities.

~~3.2.2 Vision~~

~~The voting process shall be accessible to voters with visual disabilities.~~

~~Discussion: Note that all aspects of the voting process are to be accessible, not just the voting machine.~~

[9] The italicized text in Section 3.3.2 is based on EAC Decision on Request for Interpretation 2007-01, http://www.eac.gov/program-areas/voting-systems/docs/certification-docs-eac-decision-on-request-for-interpretation-2007-01-rev-2.pdf/attachment_download/file.

~~3.2.2.1 Partial Vision~~

~~The accessible voting station shall be accessible to voters with partial vision.~~

~~a. The vendor shall conduct summative usability tests on the voting system using partially sighted individuals. The vendor shall document the testing performed and report the test results using the Common Industry Format. This documentation shall be included in the Technical Data Package submitted to the EAC for national certification.~~

~~Discussion: Voting system developers are required to conduct realistic usability tests on the final product. For the present, vendors can define their own testing protocols. Future revisions to the Guidelines will include requirements for usability testing that will provide specific performance benchmarks.~~

~~b. The accessible voting station with an electronic image display shall be capable of showing all information in at least two font sizes, (a) 3.0-4.0 mm and (b) 6.3-9.0 mm, under control of the voter.~~

~~Discussion: All millimeters will be calculated using Hard Metric Conversion. [See Glossary for definition.] While larger font sizes may assist most voters with poor vision, certain disabilities such as tunnel vision are best addressed by smaller font sizes.~~

~~c. An accessible voting station with a monochrome-only electronic image display shall be capable of showing all information in high contrast either by default or under the control of the voter or poll worker. High contrast is a figure-to-ground ambient contrast ratio for text and informational graphics of at least 6:1.~~

~~d. An accessible voting station with a color electronic image display shall allow the voter to adjust the color or the figure-to-ground ambient contrast ratio.~~

~~Discussion: See Technical Guide for Color, Contrast and Text Size in Appendix D for examples of how a voting station may meet this requirement by offering a limited number of discrete choices. In particular, it is not required that the station offer a continuous range of color or contrast values.~~

~~e. Buttons and controls on accessible voting stations shall be distinguishable by both shape and color.~~

~~Discussion: The redundant cues are helpful to those with low vision. They are also helpful to individuals who may have difficulty reading the text on the screen.~~

~~f. An accessible voting station using an electronic image display shall provide synchronized audio output to convey the same information as that which is displayed on the screen~~

3.3.3 Blindness

These requirements specify the features of the accessible voting station designed to assist voters who are blind.

a. The manufacturer shall conduct summative usability tests on the Acc-VS using individuals who are blind and shall report the test results, using the Common Industry Format, as part of the TDP. In addition, the usability test report shall be submitted to the EAC as part of the documentation manufacturers are required to file with the application to test a voting system.
b. The accessible voting station shall provide an audio-tactile interface (ATI) that supports the full functionality of the visual ballot interface.

Discussion: Note the necessity of both audio output and tactilely discernible controls for voter input. Full functionality includes at least:

- Instructions and feedback on initial activation of the ballot (such as insertion of a smart card), if applicable;
- Instructions and feedback to the voter on how to operate the accessible voting station, including settings and options (e.g., volume control, repetition);
- Instructions and feedback for navigation of the ballot;
- Instructions and feedback for contest choices, including write-in candidates;
- Instructions and feedback on confirming and changing votes; and
- Instructions and feedback on final submission of ballot.

i. The ATI of VEBD-A of the accessible voting station shall provide the same capabilities to vote and cast a ballot as are provided by its visual interface.

Discussion: For example, if a visual ballot supports voting a straight party ticket and then changing the vote for a single contest, so must the ATI.

ii. The ATI shall allow the voter to have any information provided by the voting system repeated.

Discussion: This feature may also be useful to voters with cognitive disabilities.

iii. The ATI shall allow the voter to pause and resume the audio presentation.

Discussion: This feature may also be useful to voters with cognitive disabilities.

iv. The ATI shall allow the voter to skip to the next contest or return to previous contests.

Discussion: This is analogous to the ability of sighted voters to move on to the next contest once they have made a selection or to abstain from voting on a contest altogether.

v. The ATI shall allow the voter to skip over the reading of a referendum so as to be able to vote on it immediately.

Discussion: This is analogous to the ability of sighted voters to skip over the wording of a referendum on which they have already made a decision prior to the voting session (e.g., "Vote yes on proposition #123").

c. Voting stations that provide audio presentation of the ballot shall do so in a usable way, as detailed in the following sub-requirements.

Discussion: These requirements apply to all voting system audio output, not just to the ATI of an accessible voting station.

i. The ATI shall provide its audio signal through an industry standard connector for private listening using a 3.5mm stereo headphone jack to allow voters to use their own audio assistive devices.

ii. When VEBD-A utilizes a telephone style handset or headphone to provide audio information, it shall provide a wireless T-Coil coupling for assistive hearing devices so as to provide access to that information for voters with partial hearing. That coupling shall achieve at least a category T4 rating as defined by [ANSI01] American National Standard for Methods of Measurement of Compatibility between Wireless Communications Devices and Hearing Aids, ANSI C63.19.

Discussion: Note that Requirement 3.3.6 c protects the use of hearing devices.

iii. A sanitized headphone or handset shall be made available to each voter.

Discussion: This requirement can be achieved in various ways, including the use of "throwaway" headphones, or of sanitary coverings.

iv. VEBD-A shall set the initial volume for each voting session between 40 and 50 dB SPL.

Discussion: A voter does not "inherit" the volume as set by the previous user of the voting station. See requirement 3.2.5 b.

v. The audio system shall allow the voter to control the volume throughout the voting session while preserving the current votes. The volume shall be adjustable from a minimum of 20dB SPL up to a maximum of 100 dB SPL, in increments no greater than 10 dB.

vi. The audio system shall be able to reproduce frequencies over the audible speech range of 315 Hz to 10 KHz.

Discussion: The required frequencies include the range of normal human speech. This allows the reproduced speech to sound natural.

vii. The audio presentation for VEBD-A of verbal information should be readily comprehensible by voters who have normal hearing and are proficient in the language. This includes such characteristics as proper enunciation, normal intonation, appropriate rate of speech, and low background noise. Candidate names should be pronounced as the candidate intends.

Discussion: This requirement covers both recorded and synthetic speech. It applies to those aspects of the audio content that are inherent to the voting system or that are generated by default. To the extent that the audio presentation is determined by election officials designing the ballot, it is beyond of the scope of this requirement.

viii. The audio system shall allow the voter to control the rate of speech throughout the voting session while preserving the current votes. The range of speeds supported shall include 75% to 200% of the nominal rate. Adjusting the rate of speech shall not affect the pitch of the voice.

Discussion: Many blind voters are accustomed to interacting with accelerated speech. This feature may also be useful to voters with cognitive disabilities.

d. If Acc-VS supports ballot activation for non-blind voters, then it shall also provide features that enable voters who are blind to perform this activation.

Discussion: For example, smart cards might provide tactile cues so as to allow correct insertion.

e. If Acc-VS supports ballot submission or vote verification for non-blind voters, then it shall also provide features that enable voters who are blind to perform these actions.

Discussion: For example, if voters using this station normally perform paper-based verification, or if they feed their own optical scan ballots into a reader, blind voters must also be able to do so.

f. Mechanically operated controls or keys, or any other hardware interface on Acc-VS available to the voter shall be tactilely discernible without activating those controls or keys.

Discussion: A blind voter should be able to operate the Acc-VS by “feel” alone. This means that vision should not be necessary for such operations as inserting a smart card or plugging into a headphone jack. Note also the more general Requirement 3.2.5 c. against accidental activation of controls.

g. The status of all locking or toggle controls or keys (such as the "shift" key) for Acc-VS shall be visually discernible, and also discernible through either touch or sound.

~~3.2.2.2 Blindness~~

~~The accessible voting station shall be accessible to voters who are blind.~~

~~a. The vendor shall conduct summative usability tests on the voting system using individuals who are blind. The vendor shall document the testing performed and report the test results using the Common Industry Format. This documentation shall be included in the Technical Data Package submitted to the EAC for national certification.~~

~~Discussion: Voting system developers are required to conduct realistic usability tests on the final product. For the present, vendors can define their own testing protocols. Future revisions to the Guidelines will include requirements for usability testing that will provide specific performance benchmarks.~~

~~b. The accessible voting station shall provide an audio-tactile interface (ATI) that supports the full functionality of the visual ballot interface, as specified in Subsection 2.3.3.~~

~~Discussion: Note the necessity of both audio output and tactilely discernible controls for voter input. Full functionality includes at least:~~

- ~~Instructions and feedback on initial activation of the ballot (such as insertion of a smart card), if this is normally performed by the voter on comparable voting stations~~
- ~~Instructions and feedback to the voter on how to operate the accessible voting station, including settings and options (e.g., volume control, repetition)~~
- ~~Instructions and feedback for navigation of the ballot~~
- ~~Instructions and feedback for contest choices, including write-in candidates~~
- ~~Instructions and feedback on confirming and changing selections~~
- ~~Instructions and feedback on final submission of ballot~~

~~i. The ATI of the accessible voting station shall provide the same capabilities to vote and cast a ballot as are provided by other voting machines or by the visual interface of the standard voting machine.~~

~~Discussion: For example, if a visual ballot supports voting a straight party ticket and then changing the choice in a single contest, so must the ATI.~~

~~ii. The ATI shall allow the voter to have any information provided by the voting system repeated.~~
~~iii. The ATI shall allow the voter to pause and resume the audio presentation.~~
~~iv. The ATI shall allow the voter to skip to the next contest or return to previous contests.~~

~~Discussion: This is analogous to the ability of sighted voters to move on to the next contest once they have made a selection or to abstain from voting on a contest altogether.~~

~~v. The ATI shall allow the voter to skip over the reading of a referendum so as to be able to vote on it immediately.~~

~~Discussion: This is analogous to the ability of sighted voters to skip over the wording of a referendum on which they have already made a decision prior to the voting session (e.g., "Vote yes on proposition #123").~~

~~c. All voting stations that provide audio presentation of the ballot shall conform to the following requirements:~~

~~Discussion: These requirements apply to all voting machine audio output, not just to the ATI of an accessible voting station.~~

~~i. The ATI shall provide its audio signal through an industry standard connector for private listening using a 3.5mm stereo headphone jack to allow voters to use their own audio assistive devices.~~
~~ii. When a voting machine utilize es a telephone style handset or headphone to provide audio information, it shall provide a wireless T-Coil coupling for assistive hearing devices so as to provide access to that information for voters with partial hearing. That coupling shall achieve at least a category T4 rating as defined by American National Standard for Methods of Measurement of Compatibility between Wireless Communications Devices and Hearing Aids, ANSI C63.19.~~
~~iii. No voting equipment shall cause electromagnetic interference with assistive hearing devices that would substantially degrade the performance of those devices. The voting equipment, considered as a wireless device, shall achieve at least a category T4 rating as defined by American National Standard for Methods of Measurement of Compatibility between Wireless Communications Devices and Hearing Aids, ANSI C63.19.~~

~~Discussion: "Hearing devices" include hearing aids and cochlear implants.~~

~~iv. A sanitized headphone or handset shall be made available to each voter.~~

~~Discussion: This requirement can be achieved in various ways, including the use of "throwaway" headphones, or of sanitary coverings.~~

v. ~~The voting machine shall set the initial volume for each voter between 40 and 50 dB SPL.~~

~~Discussion: A voter does not "inherit" the volume as set by the previous user of the voting station.~~

vi. ~~The voting machine shall provide a volume control with an adjustable volume from a minimum of 20dB SPL up to a maximum of 100 dB SPL, in increments no greater than 10 dB.~~

vii. ~~The audio system shall be able to reproduce frequencies over the audible speech range of 315 Hz to 10 KHz.~~

viii. ~~The audio presentation of verbal information should be readily comprehensible by voters who have normal hearing and are proficient in the language. This includes such characteristics as proper enunciation, normal intonation, appropriate rate of speech, and low background noise. Candidate names should be pronounced as the candidate intends.~~

ix. ~~The audio system shall allow voters to control the rate of speech. The range of speeds supported should be at least 75% to 200% of the nominal rate.~~

~~Discussion: Many blind voters are accustomed to interacting with accelerated speech.~~

d. ~~If the normal procedure is to have voters initialize the activation of the ballot, the accessible voting station shall provide features that enable voters who are blind to perform this activation.~~

~~Discussion: For example, smart cards might provide tactile cues so as to allow correct insertion.~~

e. ~~If the normal procedure is for voters to submit their own ballots, then the accessible voting station shall provide features that enable voters who are blind to perform this submission.~~

~~Discussion: For example, if voters normally feed their own optical scan ballots into a reader, blind voters should also be able to do so.~~

f. ~~All mechanically operated controls or keys on an accessible voting station shall be tactilely discernible without activating those controls or keys.~~

g. ~~On an accessible voting station, the status of all locking or toggle controls or keys (such as the "shift" key) shall be visually discernible, and discernible either through touch or sound.~~

3.3.4 Dexterity

These requirements specify the features of the accessible voting station designed to assist voters who lack fine motor control or use of their hands.

a. The manufacturer shall conduct summative usability tests on Acc-VS using individuals lacking fine motor control and shall report the test results, using the Common Industry Format, as part of the TDP. In addition, the usability test report shall be submitted to the EAC as part of the documentation manufacturers are required to file with the application to test a voting system.
b. The accessible voting station shall provide a mechanism to enable non-manual input that is functionally equivalent to tactile input. All the functionality of the accessible voting station (e.g., straight party voting, write-in candidates) that is available through the conventional forms of input, such as tactile, shall also be available through the non-manual input mechanism.

Discussion: This requirement ensures that the accessible voting station is operable by individuals who do not have the use of their hands. Examples of non-manual controls include mouth sticks and "sip and puff" switches. While it is desirable that the voter be able to independently initiate use of the non-manual input mechanism, this requirement guarantees only that the voter can vote independently once the mechanism is enabled.

c. If Acc-VS supports ballot submission or vote verification for non-disabled voters, then it shall also provide features that enable voters who lack fine motor control or the use of their hands to perform these actions.

Discussion: For example, if voters using this station normally perform paper-based verification, or if they feed their own optical scan ballots into a reader, voters with dexterity disabilities must also be able to do so. Note that the general requirement for privacy when voting (Requirement part 1:3.2.3.1 a.) still applies.

d. Keys, controls, and other manual operations on the accessible voting station shall be operable with one hand and shall not require tight grasping, pinching, or twisting of the wrist. The force required to activate controls and keys shall be no greater 5 lbs. (22.2 N).

Discussion: Controls are to be operable without excessive force. This includes operations such as inserting an activation card, and inserting and removing ballots.

e. The accessible voting station controls shall not require direct bodily contact or for the body to be part of any electrical circuit.

Discussion: This requirement ensures that controls are operable by individuals using prosthetic devices.

~~3.2.3 Dexterity~~

~~The voting process shall be accessible to voters who lack fine motor control or use of their hands.~~

a. ~~The vendor shall conduct summative usability tests on the voting system using individuals lacking fine motor control. The vendor shall document the testing performed and report the test results using the Common Industry Format. This documentation shall be included in the Technical Data Package submitted to the EAC for national certification.~~

~~Discussion: Voting system developers are required to conduct realistic usability tests on the final product. For the present, vendors can define their own testing protocols. Future revisions to the Guidelines will include requirements for usability testing that will provide specific performance benchmarks.~~

b. ~~All keys and controls on the accessible voting station shall be operable with one hand and shall not require tight grasping, pinching, or twisting of the wrist. The force required to activate controls and keys shall be no greater 5 lbs. (22.2 N).~~

~~Discussion: Controls are to be operable without excessive force.~~

c. ~~The accessible voting station controls shall not require direct bodily contact or for the body to be part of any electrical circuit.~~

~~Discussion: This requirement ensures that controls are operable by individuals using prosthetic devices.~~

d. ~~The accessible voting station shall provide a mechanism to enable non-manual input that is functionally equivalent to tactile input.~~

~~Discussion: This requirement ensures that the accessible voting station is operable by individuals who do not have the use of their hands. All the functionality of the accessible voting station (e.g., straight party voting, write-in candidates) that is available through the other forms of input, such as tactile, must also be available through a non-manual input mechanism if it is provided by the accessible voting station.~~

e. ~~If the normal procedure is for voters to submit their own ballots, then the accessible voting station shall provide features that enable voters who lack fine motor control or the use of their hands to perform this submission.~~

3.3.5 Mobility

These requirements specify the features of the accessible voting station designed to assist voters who use mobility aids, including wheelchairs. Many of the requirements of this section are based on the ADA Accessibility Guidelines for Buildings and Facilities (ADAAG).

a. The accessible voting station shall provide a clear floor space of 30 inches minimum by 48 inches minimum for a stationary mobility aid. The clear floor space shall be designed for a forward approach or a parallel approach.
b. When deployed according to the installation instructions provided by the manufacturer, Acc-VS shall allow adequate room for an assistant to the voter. This includes clearance for entry to and exit from the area of the voting station.

Discussion: Disabled voters sometimes prefer to have an assistant help them vote. The setup of the voting station should not preclude this.

c. Labels, displays, controls, keys, audio jacks, and any other part of the accessible voting station necessary for the voter to operate the voting system shall be legible and visible to a voter in a wheelchair with normal eyesight (no worse than 20/40, corrected) who is in an appropriate position and orientation with respect to the accessible voting station.

Discussion: There are a number of factors that could make relevant parts of the accessible voting station difficult to see, such as: small lettering; controls and labels tilted at an awkward angle from the voter's viewpoint; and glare from overhead lighting.

3.3.5.1 Controls within reach

The requirements of this section ensure that the controls, keys, audio jacks and any other part of the accessible voting station necessary for its operation are within easy reach. Note that these requirements have meaningful application mainly to controls in a fixed location. A hand-held tethered control panel is another acceptable way of providing reachable controls.

a. If the accessible voting station has a forward approach with no forward reach obstruction then the high reach shall be 48 inches maximum and the low reach shall be 15 inches minimum. See Part 1: Figure 3-1.
b. If the accessible voting station has a forward approach with a forward reach obstruction, the following sub-requirements shall apply. (See Part 1: Figure 3-2).
    i. The forward obstruction for Acc-VS shall be no greater than 25 inches in depth, its top no higher than 34 inches and its bottom surface no lower than 27 inches.
    ii. If the obstruction for Acc-VS is no more than 20 inches in depth, then the maximum high reach shall be 48 inches, otherwise it shall be 44 inches.

iii. Space under the obstruction between the finish floor or ground and 9 inches above the finish floor or ground shall be considered toe clearance and shall comply with the following provisions for Acc-VS:

1. Toe clearance depth shall extend 25 inches maximum under the obstruction;
2. The minimum toe clearance depth under the obstruction shall be either 17 inches or the depth required to reach over the obstruction to operate the accessible voting station, whichever is greater; and
3. Toe clearance width shall be 30 inches minimum.

iv. Space under the obstruction between 9 inches and 27 inches above the finish floor or ground shall be considered knee clearance and shall comply with the following provisions:

1. Knee clearance depth shall extend 25 inches maximum under the obstruction at 9 inches above the finish floor or ground;
2. The minimum knee clearance depth at 9 inches above the finish floor or ground shall be either 11 inches or 6 inches less than the toe clearance, whichever is greater;
3. Between 9 inches and 27 inches above the finish floor or ground, the knee clearance depth shall be permitted to reduce at a rate of 1 inch in depth for each 6 inches in height. (It follows that the minimum knee clearance at 27 inches above the finish floor or ground shall be 3 inches less than the minimum knee clearance at 9 inches above the floor.); and
4. Knee clearance width shall be 30 inches minimum.

c. If the accessible voting station has a parallel approach with no side reach obstruction then the maximum high reach shall be 48 inches and the minimum low reach shall be 15 inches. See Part 1: Figure 3-3.

d. If the accessible voting station has a parallel approach with a side reach obstruction, the following sub-requirements shall apply. See Part 1: Figure 3-4.

Discussion: Since this is a parallel approach, no clearance under the obstruction is required.

i. The side obstruction for Acc-VS shall be no greater than 24 inches in depth and its top no higher than 34 inches.

ii. If the obstruction is no more than 10 inches in depth, then the maximum high reach shall be 48 inches, otherwise it shall be 46 inches.

Figures 1-4 Unobstructed reach measurements

Dimensions shown in inches above the line, SI units (in millimeters) below the line

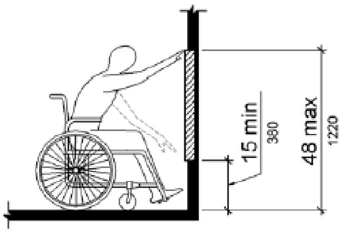


Figure 1: Unobstructed forward reach

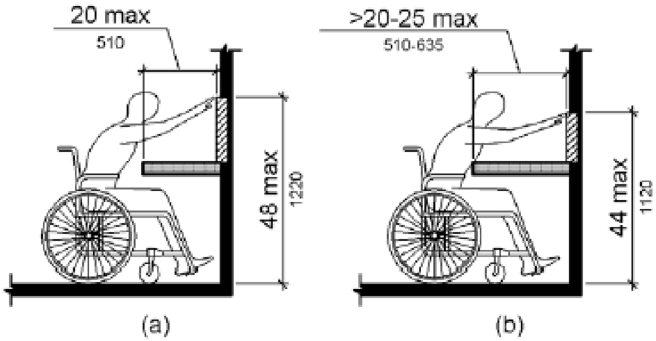


Figure 2: Obstructed forward reach

(a) for an obstruction depth of up to 20 inches
(b) for an obstruction depth of up to 25 inches

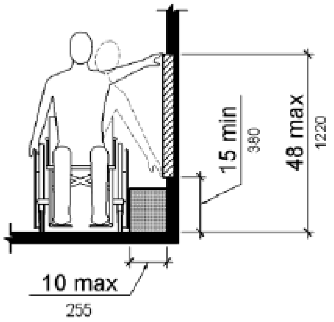


Figure 3: Unobstructed side reach with an allowable obstruction less than 10 inches deep

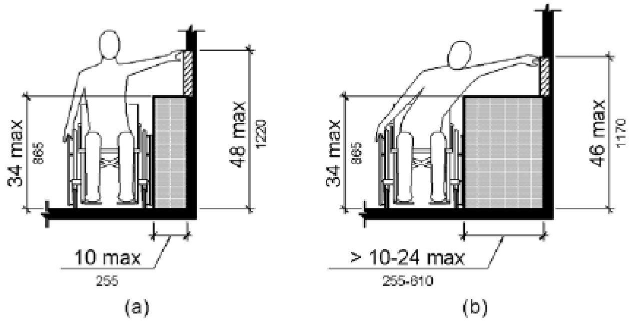


Figure 4: Obstructed side reach

(a) for an obstruction depth of up to 10 inches
(b) for an obstruction depth of up to 24 inches

~~3.2.4 Mobility~~

~~The voting process shall be accessible to voters who use mobility aids, including wheelchairs.~~

a. ~~The accessible voting station shall provide a clear floor space of 30 inches (760 mm) minimum by 48 inches (1220 mm) minimum for a stationary mobility aid. The clear floor space shall be level with no slope exceeding 1:48 and positioned for a forward approach or a parallel approach.~~
b. ~~All controls, keys, audio jacks and any other part of the accessible voting station necessary for the voter to operate the voting machine shall be within reach as specified under the following sub-requirements:~~

~~Discussion: Note that these requirements have meaningful application mainly to controls in a fixed location. A hand-held tethered control panel is another acceptable way of providing reachable controls.~~

i. ~~If the accessible voting station has a forward approach with no forward reach obstruction then the high reach shall be 48 inches maximum and the low reach shall be 15 inches minimum. See Figure 1.~~

ii. ~~If the accessible voting station has a forward approach with a forward reach obstruction, the following requirements apply (See Figure 2):~~

- ~~The forward obstruction shall be no greater than 25 inches in depth, its top no higher than 34 inches and its bottom surface no lower than 27 inches.~~
- ~~If the obstruction is no more than 20 inches in depth, then the maximum high reach shall be 48 inches, otherwise it shall be 44 inches.~~

iii. ~~Space under the obstruction between the finish floor or ground and 9 inches (230 mm) above the finish floor or ground shall be considered toe clearance and shall comply with the following provisions:~~

- ~~Toe clearance shall extend 25 inches (635 mm) maximum under the obstruction~~
- ~~The minimum toe clearance under the obstruction shall be either 17 inches (430 mm) or the depth required to reach over the obstruction to operate the accessible voting station, whichever is greater~~
- ~~Toe clearance shall be 30 inches (760 mm) wide minimum~~

iv. ~~Space under the obstruction between 9 inches (230 mm) and 27 inches (685 mm) above the finish floor or ground shall be considered knee clearance and shall comply with the following provisions:~~

- ~~Knee clearance shall extend 25 inches (635 mm) maximum under the obstruction at 9 inches (230 mm) above the finish floor or ground.~~
- ~~The minimum knee clearance at 9 inches (230 mm) above the finish floor or ground shall be either 11 inches (280 mm) or 6 inches less than the toe clearance, whichever is greater.~~
- ~~Between 9 inches (230 mm) and 27 inches (685 mm) above the finish floor or ground, the knee clearance shall be permitted to reduce at a rate of 1 inch (25 mm) in depth for each 6 inches (150 mm) in height.~~

~~Discussion: It follows that the minimum knee clearance at 27 inches above the finish floor or ground shall be 3 inches less than the minimum knee clearance at 9 inches above the floor.~~

- ~~Knee clearance shall be 30 inches (760 mm) wide minimum.~~

~~v. If the accessible voting station has a parallel approach with no side reach obstruction then the maximum high reach shall be 48 inches and the minimum low reach shall be 15 inches. See Figure 3.~~

~~vi. If the accessible voting station has a parallel approach with a side reach obstruction, the following sub-requirements apply. See Figure 4.~~

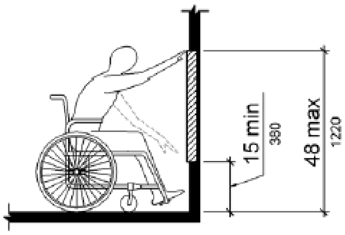
- ~~The side obstruction shall be no greater than 24 inches in depth and its top no higher than 34 inches.~~
- ~~If the obstruction is no more than 10 inches in depth, then the maximum high reach shall be 48 inches, otherwise it shall be 46 inches.~~

~~Discussion: Since this is a parallel approach, no clearance under the obstruction is required.~~

~~c. All labels, displays, controls, keys, audio jacks, and any other part of the accessible voting station necessary for the voter to operate the voting machine shall be easily legible and visible to a voter in a wheelchair with normal eyesight (no worse than 20/40, corrected) who is in an appropriate position and orientation with respect to the accessible voting station~~

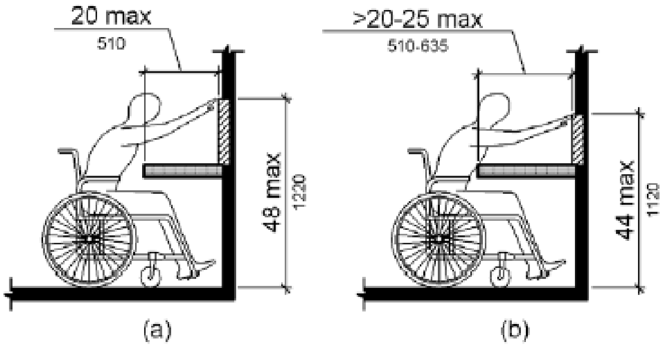
~~Discussion: There are a number of factors that could make relevant parts of the accessible voting station difficult to see such as; small lettering, controls and labels tilted at an awkward angle from the voter's viewpoint, and glare from overhead lighting.~~

~~**Figure 1**~~



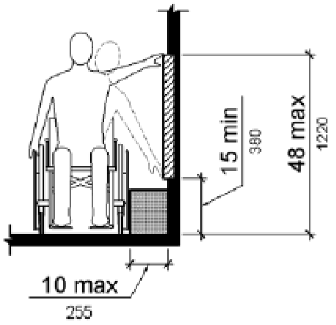
~~Unobstructed forward reach~~

~~**Figure 2**~~



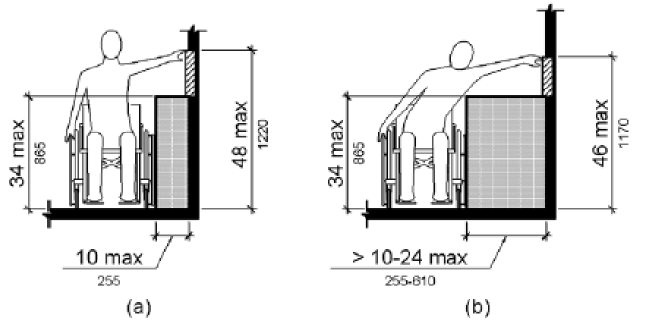
~~Obstructed forward reach~~
~~(a) for an obstruction depth of up to 20 inches (508 mm)~~
~~(b) for an obstruction depth of up to 25 inches (635 mm)~~

~~**Figure 3**~~



~~Unobstructed side reach with an allowable obstruction less than 10 inches (254 mm) deep.~~

~~**Figure 4**~~



~~Obstructed side reach~~
~~(a) for an obstruction depth of up to 10 inches (254 mm)~~
~~(b) for an obstruction depth of up to 24 inches (610 mm)~~

3.3.6 Hearing

These requirements specify the features of the accessible voting station designed to assist voters with hearing disabilities.

a. The accessible voting station shall incorporate the features listed under Requirement 3.3.3-C for voting systems that provide audio presentation of the ballot.

Discussion: Note especially the requirements for volume initialization and control.

b. If the accessible voting system provides sound cues as a method to alert the voter, the tone shall be accompanied by a visual cue, unless the station is in audio-only mode.

Discussion: For instance, the voting equipment might beep if the voter attempts to overvote. If so, there would have to be an equivalent visual cue, such as the appearance of an icon, or a blinking element. If the voting system has been set to audio-only mode, there would be no visual cue.

c. No voting device shall cause electromagnetic interference with assistive hearing devices that would substantially degrade the performance of those devices. The voting device, measured as if it were a wireless device, shall achieve at least a category T4 rating as defined by [ANSI01] American National Standard for Methods of Measurement of Compatibility between Wireless Communications Devices and Hearing Aids, ANSI C63.19.

Discussion: "Hearing devices" include hearing aids and cochlear implants.

~~3.2.5 Hearing~~

~~The voting process shall be accessible to voters with hearing disabilities.~~

~~a. The accessible voting station shall incorporate the features listed under requirement 3.2.2.2 (c) for voting equipment that provides audio presentation of the ballot to provide accessibility to voters with hearing disabilities.~~

~~Discussion: Note especially the requirements for volume initialization and control.~~

~~b. If voting equipment provides sound cues as a method to alert the voter, the tone shall be accompanied by a visual cue, unless the station is in audio-only mode.~~

~~Discussion: For instance, the voting equipment might beep if the voter attempts to overvote. If so, there would have to be an equivalent visual cue, such as the appearance of an icon, or a blinking element. Some voting equipment may have an audio-only mode, in which case, there would be no visual cue.~~

3.3.7 Cognition

These requirements specify the features of the accessible voting station designed to assist voters with cognitive disabilities.

a. The accessible voting station should provide support to voters with cognitive disabilities.

Discussion: Because of the highly varied nature of disabilities falling within the "cognitive" category, there are no design features uniquely aimed at helping those with such disabilities. However, many of the features designed primarily for other disabilities and for general usability are also highly relevant to these voters:

- The synchronization of audio with the displayed screen information (Requirement 3.3.2 d.);
- The general cognitive usability requirements (Requirement 3.2.4) and, in particular, the use of plain language (Requirement 3.2.4 c.);
- Large font sizes and legibility of paper (Requirement 3.2.5 e and 3.2.5 g.); and
- The ability to control various aspects of the audio presentation (Requirement 3.3.3 b. and 3.3.3 c) such as pausing, repetition, and speed.

~~3.2.8 Cognition~~

~~The voting process should be accessible to voters with cognitive disabilities.~~

~~At present there are no design features specifically aimed at helping those with cognitive disabilities. Requirements 3.2.2.1 (f), the synchronization of audio with the screen in a DRE, is helpful for some cognitive disabilities such as dyslexia. Requirements in Subsection 3.1.4 also address cognitive issues relative to voting system usability.~~

3.3.8 English proficiency

These requirements specify the features of the accessible voting station designed to assist voters who lack proficiency in reading English.

a. For voters who lack proficiency in reading English, Acc-VS shall provide an audio interface for instructions and ballots as described in 3.3.3 b.

~~3.2.7 English Proficiency~~

~~For voters who lack proficiency in reading English, or whose primary language is unwritten, the voting equipment shall provide spoken instructions and ballots in the preferred language of the voter, consistent with state and federal law. The requirements of 3.2.2.2 (c) shall apply to this mode of interaction.~~

3.3.9 Speech

a. The voting system shall not require voter speech for its operation.

Discussion: This does not preclude voting systems from offering speech input as an option, but speech must not be the only means of input.

~~3.2.6 Speech~~

~~The voting process shall be accessible to voters with speech disabilities.~~

~~a. No voting equipment shall require voter speech for its operation.~~

~~Discussion: This does not preclude voting equipment from offering speech input as an option, but speech must not be the only means of input.~~

4 Hardware Requirements

Table of Contents

4 Hardware Requirements

This section contains the requirements for the machines and manufactured devices that are part of a voting system. It specifies minimum values for certain performance characteristics; physical characteristics; and design, construction, and maintenance characteristics for the hardware and selected related components of all voting systems, such as:

- Ballot printers
- Ballot cards and sheets
- Ballot displays
- Voting devices, including ballot marking devices and DRE recording devices
- Voting booths and enclosures
- Ballot boxes and ballot transfer boxes
- Ballot readers
- Computers used to prepare ballots, program elections, consolidate and report votes, and perform other elections management activities
- Electronic ballot recorders
- Electronic precinct vote control units
- Removable electronic data storage media
- Servers
- Printers

This section applies to the combination of software and hardware to accomplish specific performance and system control requirements. Standards that are specific to software alone are provided in Section 5.

The requirements of this section apply generally to all hardware used in voting systems, including:

- Hardware provided by the voting system manufacturer and its suppliers
- Hardware furnished by an external provider (for example, providers of commercial-off-the-shelf equipment) where the hardware may be used in any way during voting system operation
- Hardware provided by the voting jurisdiction

The requirements presented in this section are organized as follows:

Performance Requirements: These requirements address the combined operational capabilities of the voting system hardware and software across a broad range of parameters

Physical Requirements: These requirements address the size, weight and transportability of the voting system

Design, Construction, and Maintenance Requirements: These requirements address the reliability and durability of materials, product marking, quality of system workmanship, safety, and other attributes to ensure smooth system operation in the voting environment

4.1 Performance Requirements

The performance requirements address a broad range of parameters, encompassing:

- Accuracy requirements, where requirements are specified for distinct processing functions of paper-based and DRE systems
- Environmental requirements, where no distinction is made between requirements for paper-based and DRE systems, but requirements for precinct and central count are described
- Vote data management requirements, where no differentiation is made between requirements for paper-based and DRE systems
- Vote recording requirements, where separate and distinct requirements are delineated for paper-based and DRE systems
- Conversion requirements, which apply only to paper-based systems
- Processing requirements, where separate and distinct requirements are delineated for paper-based and DRE systems
- Reporting requirements, where no distinction is made between requirements for paper-based and DRE systems, but where differences between precinct and central count systems are readily apparent based on differences of their reporting

The performance requirements include such attributes as ballot reading and handling requirements; system accuracy; memory stability; and the ability to withstand specified environmental conditions. These characteristics also encompass system-wide requirements for shelter, electrical supply, and compatibility with data networks.

Performance requirements for voting systems represent the combined operational capability of both system hardware and software. Accuracy, as measured by data error rate, and operational failure are treated as distinct attributes in performance testing. All systems shall meet the performance requirements under operating conditions and after storage under non-operating conditions.

4.1.1 Accuracy Requirements

All systems shall achieve a report total error rate of no more than one in 125,000 (8×10^{-6}).

Given a set of vote data reports resulting from the execution of tests, the observed cumulative report total error rate shall be calculated as follows.

a. Define a “report item” as any one of the numeric values (totals or counts) that must appear in any of the vote data reports. Each ballot count, each vote, overvote, and undervote total for each contest, and each vote total for each contest choice in each contest is a separate report item. The required report items are detailed in Volume I Chapters 2 and 4.

b. For each report item, compute the "report item error" as the absolute value of the difference between the correct value and the reported value. Special cases: If a value is reported that should not have appeared at all (spurious item), or if an item that should have appeared in the report does not (missing item), assess a report item error of one. Additional values that are reported as a manufacturer extension to the standard are not considered spurious items.
c. Compute the "report total error" as the sum of all of the report item errors from all of the reports.
d. Compute the "report total volume" as the sum of all of the correct values for all of the report items that are supposed to appear in the reports. Special cases: When the same logical contest appears multiple times, e.g. when results are reported for each ballot configuration and then combined or when reports are generated for multiple reporting contexts, each manifestation of the logical contest is considered a separate contest with its own correct vote totals in this computation.
e. Compute the observed cumulative report total error rate as the ratio of the report total error to the report total volume. Special cases: If both values are zero, the report total error rate is zero. If the report total volume is zero but the report total error is not, the report total error rate is infinite.

The benchmark of one in 125,000 (8×10^{-6}) is derived from the "maximum acceptable error rate" used as the lower test benchmark in the 2005 Voluntary Voting System Guidelines Version 1.0. That benchmark was defined as a ballot position error rate of one in 500,000 (2×10^{-6}). The benchmark of one in 125,000 is expressed in terms of votes[10], however it is consistent with the previous benchmark in that the estimated ratio of votes to ballot positions is ¼.

The estimated ratio was derived as follows: given that there is no "typical" ratio of votes to ballot positions with such diversity among the many jurisdictions, it is nevertheless necessary to base the benchmark on some rough estimates in order that it may be in the correct order of magnitude, albeit not optimal for every case. The rough estimates are as follows. In a presidential election, there will be approximately 20 contests with a vote for 1 on each ballot with an average of 4 candidates, including the write-in position, per contest. (Some states will have fewer contests and some more. A few contests, like President, would have 8–13 candidates; most have 3 candidates including the write-in, and a few have 2 candidates.) Thus, the estimated ratio of votes to ballot positions is ¼.

~~Voting system accuracy addresses the accuracy of data for each of the individual ballot positions that could be selected by a voter, including the positions that are not selected. For a voting system, accuracy is defined as the ability of the system to capture, record, store, consolidate and report the specific selections and absence of selections, made by the voter for each ballot position without error. Required accuracy is defined in terms of an error rate that for testing purposes represents the maximum number of errors allowed while processing a specified volume of data. This rate is set at a sufficiently stringent~~

[10] The error rate was originally defined in Volume 1 of the 2002 Voting System Standards and is prescribed by Sec. 301(a)(5) of the Help America Vote Act of 2002. Expressing this benchmark in terms of votes instead of ballot positions provides a more precise metric for the evaluation of accuracy.

~~level that the likelihood of voting system errors affecting the outcome of an election is exceptionally remote even in the closest of elections.~~

~~The error rate is defined using a convention that recognizes differences in how vote data is processed by different types of voting systems. Paper-based and DRE systems have different processing steps. Some differences also exist between precinct count and central count systems. Therefore, the acceptable error rate applies separately and distinctly to each of the following functions:~~

- ~~a. For all paper-based voting systems:~~
  - ~~i. Scanning ballot positions on paper ballots to detect selections for individual candidates and contests~~
  - ~~ii. Conversion of selections detected on paper ballots into digital data~~
- ~~b. For all DRE voting systems:~~
  - ~~i. Recording the voter selections of candidates and contests into voting data storage~~
  - ~~ii. Recording voter selections of candidates and contests into ballot image storage independently from voting data storage~~
- ~~c. For precinct-count voting systems (paper-based and DRE):~~
  - ~~i. Consolidation of vote selection data from multiple precinct-based voting machines to generate jurisdiction-wide vote counts, including storage and reporting of the consolidated vote data~~
- ~~d. For central-count voting systems (paper-based and DRE):~~
  - ~~i. Consolidation of vote selection data from multiple counting devices to generate jurisdiction-wide vote counts, including storage and reporting of the consolidated vote data~~

~~For testing purposes, the acceptable error rate is defined using two parameters: the desired error rate to be achieved, and the maximum error rate that should be accepted by the test process.~~

~~For each processing function indicated above, the voting system shall achieve a target error rate of no more than one in 10,000,000 ballot positions, with a maximum acceptable error rate in the test process of one in 500,000 ballot positions.~~

4.1.2 Environmental Requirements

The environmental requirements for voting systems include shelter, space, furnishings and fixtures, supplied energy, environmental control, and external telecommunications services. Environmental conditions applicable to the design and operation of voting systems consist of the following categories:

- Natural environment, including temperature, humidity, and atmospheric pressure
- Induced environment, including proper and improper operation and handling of the system and its components during the election processes
- Transportation and storage

- Electromagnetic signal environment, including exposure to and generation of radio frequency energy

All voting systems shall be designed to withstand the environmental conditions contained in the appropriate test procedures of the *Guidelines*. These procedures will be applied to all devices for casting, scanning and counting ballots, except those that constitute COTS devices that have not been modified in any manner to support their use as part of a voting system and that have a documented record of performance under conditions defined in the *Guidelines.*

The Technical Data Package supplied by the manufacturer shall include a statement of all requirements and restrictions regarding environmental protection, electrical service, recommended auxiliary power, telecommunications service, and any other facility or resource required for the proper installation and operation of the system.

4.1.2.1 Shelter Requirements

All precinct count systems shall be designed for storage and operation in any enclosed facility ordinarily used as a warehouse or polling place, with prominent instructions as to any special storage requirements.

4.1.2.2 Space Requirements

There is no restriction on space allowed for the installation of voting systems, except that the arrangement of these systems shall not impede performance of their duties by polling place officials, the orderly flow of voters through the polling place or the ability for the voter to vote in private.

4.1.2.3 Furnishings and Fixtures

Any furnishings or fixtures provided as a part of voting systems, and any components provided by the manufacturer that are not a part of the voting system but that are used to support its storage, transportation or operation, shall comply with the safety design of Subsection 4.3.8.

4.1.2.4 Electrical Supply

Components of voting systems that require an electrical supply shall meet the following standards:

a. Precinct count voting systems shall operate with the electrical supply ordinarily found in polling places (Nominal 120 Vac/60Hz/1 phase)

b. Central count voting systems shall operate with the electrical supply ordinarily found in central tabulation facilities or computer room facilities (Nominal 120 Vac/60Hz/1, nominal 208 Vac/60Hz/3 or nominal 240 Vac/60Hz/2)

a. *~~All~~ Precinct count*[11] voting machines shall also be capable of operating for a period of at least 2 hours on backup power, such that no voting data is lost or corrupted nor normal operations interrupted. When backup power is exhausted the voting machine shall retain the contents of all memories intact

Discussion: *All forms of voting equipment, including optical scan, shall include battery backup*[12].

The backup power capability is not required to provide lighting of the voting area.

Central count systems are not required to have a 2 hour battery backup. A central count system shall provide for a graceful shutdown to allow switching to an alternate power source. The graceful shutdown shall meet the following requirements:[13]

d. *All ballots shall reside in either the input or output hopper with no ballots in process at the end of the shutdown process.*
e. *All ballots in the output hopper shall be fully read and saved.*
f. *A report, including the final state of all ballots, timestamps and of the final state of the unit, shall be printed or saved in a file. The report shall be part of the permanent election record and shall be available when power is restored to the system.*
g. *The system shall be capable of resuming operation from the point it stopped once power is restored.*

Testing for the graceful shutdown shall maintain ballots in the input hopper through the shutdown process. The purpose of this requirement is to confirm that the system will stop processing further ballots, complete ballots in process and save a report that accurately identifies the final state of the ballots and the system. The second part of the test shall restore power to the system and confirm that the system restarts properly and that the status report reflects accurately the state of the ballots and the system.

[11] The italicized text in Section 4.1.2.4 is based on EAC Decision on Request for Interpretation 2008-06, http://www.eac.gov/program-areas/voting-systems/docs/eac-decision-on-request-for-interpretation-2008-06/attachment_download/file.

[12] The italicized text in the discussion box is based specifically on EAC Decision on Request for Interpretation 2008-02, http://www.eac.gov/program-areas/voting-systems/docs/request-for-interpretation-2008-02-battery-back-up-for-op-scan.pdf/attachment_download/file.

[13] The remaining italicized text is based on EAC Decision on Request for Interpretation 2008-06, http://www.eac.gov/program-areas/voting-systems/docs/eac-decision-on-request-for-interpretation-2008-06/attachment_download/file.

4.1.2.5 Electrical Power Disturbance

Vote scanning and counting equipment for paper-based voting systems, and all DRE voting equipment, shall be able to withstand, without disruption of normal operation or loss of data:

a. Voltage dip of 30% of nominal @10 ms;
b. Voltage dip of 60% of nominal @100 ms & 1 sec
c. Voltage dip of >95% interrupt @5 sec
d. Surges of ±15% line variations of nominal line voltage
e. Electric power increases of 7.5% and reductions of 12.5% of nominal specified power supply for a period of up to four hours at each power level

4.1.2.6 Electrical Fast Transient

Vote scanning and counting equipment for paper-based systems, and all DRE equipment, shall be able to withstand, without disruption of normal operation or loss of data, electrical fast transients of:

a. +2 kV and −2 kV on External Power lines (both AC and DC)
b. +1 kV and −1 kV on Input/Output lines(signal, data, and control lines) longer than 3 meters
c. Repetition Rate for all transient pulses will be 100 kHz

4.1.2.7 Lightning Surge

Vote scanning and counting equipment for paper-based systems, and all DRE equipment, shall be able to withstand, without disruption of normal operation or loss of data, surges of:

a. ±2 kV AC line to line
b. ±2 kV AC line to earth
c. + or – 0.5 kV DC line to line >10m
d. + or – 0.5 kV DC line to earth >10m
e. ±1 kV I/O sig/control >30m

4.1.2.8 Electrostatic Disruption

Vote scanning and counting equipment for paper-based systems, and all DRE equipment, shall be able to withstand ±15 kV air discharge and ±8 kV contact discharge without damage or loss of data. The equipment may reset or have momentary interruption so long as normal operation is resumed without human intervention or loss of data. Loss of data means votes that have been completed and confirmed to the voter.

4.1.2.9 Electromagnetic Emissions

Vote scanning and counting equipment for paper-based systems, and all DRE equipment, shall comply with the Rules and Regulations of the Federal Communications Commission, Part 15; Class B requirements for both radiated and conducted emissions.

4.1.2.10 Electromagnetic Susceptibility

Vote scanning and counting equipment for paper-based systems, and all DRE equipment, shall be able to withstand an electromagnetic field of 10 V/m modulated by a 1 kHz 80% AM modulation over the frequency range of 80 MHz to 1000 MHz, without disruption of normal operation or loss of data.

4.1.2.11 Conducted RF Immunity

Vote scanning and counting equipment for paper-based systems, and all DRE equipment, shall be able to withstand, without disruption of normal operation or loss of data, conducted RF energy of:

a. 10V rms over the frequency range 150 KHz to 80 MHz with an 80% amplitude modulation with a 1 KHz sine wave AC & DC power
b. 10V sig/control >3 m over the frequency range 150 KHz to 80 MHz with an 80% amplitude modulation with a 1 KHz sine wave

4.1.2.12 Magnetic Fields Immunity

Vote scanning and counting equipment for paper-based systems, and all DRE equipment, shall be able to withstand, without disruption of normal operation or loss of data, AC magnetic fields of 30 A/m at 60 Hz.

4.1.2.13 Environmental Control - Operating Environment

Voting systems shall be capable of operation in temperatures ranging from 41 °F to 104 °F (5 °C to 40 °C) and relative humidity from 5% to 85%, non-condensing.

For testing information, see Volume II, section 4.7.1.

~~Equipment used for election management activities or vote counting (including both precinct and central count systems) shall be capable of operation in temperatures ranging from 50 to 95 degrees Fahrenheit.~~

4.1.2.14 Environmental Control - Transit and Storage

Equipment used for vote casting or for counting votes in a precinct count system, shall meet these specific minimum performance standards that simulate exposure to physical shock and vibration associated with handling and transportation by surface and air common carriers, and to temperature conditions associated with delivery and storage in an uncontrolled warehouse environment:

a. High and low storage temperatures ranging from -4 to +140 degrees Fahrenheit, equivalent to MIL-STD-810D, Methods 501.2 and 502.2, Procedure I-Storage
b. Bench handling equivalent to the procedure of MIL-STD-810D, Method 516.3, Procedure VI
c. Vibration equivalent to the procedure of MIL-STD-810D, Method 514.3, Category 1- Basic Transportation, Common Carrier
d. Uncontrolled humidity equivalent to the procedure of MIL-STD-810D, Method 507.2, Procedure I-Natural Hot-Humid

4.1.2.15 Data Network Requirements

Voting systems may use a local or remote data network. If such a network is used, then all components of the network shall comply with the telecommunications requirements described in Section 6 and the Security requirements described in Section 7.

4.1.3 Election Management System Requirements

The Election Management System (EMS) requirements address electronic hardware and software used to conduct the pre-voting functions defined in Section 2 with regard to ballot preparation, election programming, ballot and program installation, readiness testing, verification at the polling place, and verification at the central location.

4.1.3.1 Recording Requirements

Voting systems shall accurately record all election management data entered by the user, including election officials or their designees.

For recording accuracy, all systems shall:

a. Record every entry made by the user
b. Add permissible voter selections correctly to the memory components of the device
c. Verify the correctness of detection of the user selections and the addition of the selections correctly to memory
d. Add various forms of data entered directly by the election official or designee, such as text, line art, logos, and images

e. Verify the correctness of detection of data entered directly by the user and the addition of the selections correctly to memory
f. Preserve the integrity of election management data stored in memory against corruption by stray electromagnetic emissions, and internally generated spurious electrical signals
g. Log corrected data errors by the voting system

4.1.3.2 Memory Stability

Memory devices used to retain election management data shall have demonstrated error-free data retention for a period of 22 months.

4.1.4 Vote Recording Requirements

The vote recording requirements address the enclosure, equipment, and supplies used by voters to vote.

4.1.4.1 Common Requirements

All voting systems shall provide voting booths or enclosures for poll site use. Such booths or enclosures may be integral to the voting system or supplied as components of the voting system, and shall:

a. Be integral to, or make provision for, the installation of the voting machine
b. Ensure by its structure stability against movement or overturning during entry, occupancy, and exit by the voter
c. Provide privacy for the voter, and be designed in such a way as to prevent observation of the ballot by any person other than the voter
d. Be capable of meeting the accessibility requirements of Subsection 3.2

4.1.4.2 Paper-based Recording Requirements

The paper-based recording requirements govern:

- Ballot cards or sheets, and pages or assemblies of pages containing ballot field identification data
- Ballot marking devices
- Frames or fixtures to hold the ballot while it is being marked
- Compartments or booths where voters record selections
- Secure containers for the collection of voted ballots

a. Paper ballots used by paper-based voting systems shall meet the following standards:

   i. Marks that identify the unique ballot format shall be outside the area in which votes are recorded, so as to minimize the likelihood that these marks will be mistaken for vote responses and the likelihood that recorded votes will obliterate these marks
   ii. If printed alignment marks are used to locate the vote response fields on the ballot, these marks shall be outside the area in which votes are recorded, so as to minimize the likelihood that these marks will be mistaken for vote responses and the likelihood that recorded votes will obliterate these marks
   iii. The Technical Data Package shall specify the required paper stock, size, shape, opacity, color, watermarks, field layout, orientation, size and style of printing, size and location of mark fields used for vote response fields and to identify unique ballot formats, placement of alignment marks, ink for printing, and folding and bleed-through limitations for preparation of ballots that are compatible with the system

b. The Technical Data Package shall specify marking devices, which, if used to make the prescribed form of mark, produce readable marked ballots such that the system meets the performance requirements for accuracy in Subsection 4.1.1. Marking devices can be either manual (such as pens or pencils) or electronic. These specifications shall identify:
   i. Specific characteristics of marking devices that affect readability of marked ballots
   ii. Performance capabilities with regard to each characteristic
   iii. For marking devices manufactured by multiple external sources, a listing of sources and model numbers that are compatible with the system

c. A frame or fixture for printed ballot cards is optional. However, if such a device is provided, it shall:
   i. Be of any size and shape consistent with its intended use
   ii. Position the card properly
   iii. Hold the ballot card securely in its proper location and orientation for voting
   iv. Comply with the requirements for design and construction contained in Subsection 4.3

d. Ballot boxes and ballot transfer boxes, which serve as secure containers for the storage and transportation of voted ballots, shall:
   i. Be of any size, shape, and weight commensurate with their intended use
   ii. Incorporate locks or seals, the specifications of which are described in the system documentation
   iii. Provide specific points where ballots are inserted, with all other points on the box constructed in a manner that prevents ballot insertion
   iv. For precinct count systems, contain separate compartments for the segregation of unread ballots, ballots containing write-in votes or any irregularities that may require special handling or processing. In lieu of compartments, the conversion processing may mark such ballots with an identifying spot or stripe to facilitate manual segregation

4.1.4.3 DRE System Recording Requirements

The DRE system recording requirements address the detection and recording of votes, including the logic and data processing functions required to determine the validity of voter selections, to accept and record valid selections, and to reject invalid selections. The requirements also address the physical environment in which ballots are cast.

a. DRE systems shall include an audible or visible activity indicator providing the status of each voting device. This indicator shall:
   i. Indicate whether the device has been activated for voting
   ii. Indicate whether the device is in use
b. To ensure vote recording accuracy and integrity while protecting the anonymity of the voter, all DRE systems shall:
   i. Contain all mechanical, electromechanical, and electronic components; software; and controls required to detect and record the activation of selections made by the voter in the process of voting and casting a ballot
   ii. Incorporate redundant memories to detect and allow correction of errors caused by the failure of any of the individual memories
   iii. Provide at least two processes that record the voter’s selections that:

      - To the extent possible, are isolated from each other
      - Designate one process and associated storage location as the main vote detection, interpretation, processing and reporting path

   iv. Use a different process to store ballot images, for which the method of recording may include any appropriate encoding or data compression procedure consistent with the regeneration of an unequivocal record of the ballot as cast by the voter
   v. Provide a capability to retrieve ballot images in a form readable by humans
   vi. Ensure that all processing and storage protects the anonymity of the voter
c. DRE systems shall meet the following requirements for recording accurately each vote and ballot cast:
   i. Detect every selection made by the voter
   ii. Correctly add permissible selections to the memory components of the device
   iii. Verify the correctness of the detection of the voter selections and the addition of the selections to memory
   iv. Achieve an error rate not to exceed the requirement indicated in Subsection 4.1.1
   v. Preserve the integrity of voting data and ballot images (for DRE machines) stored in memory for the official vote count and audit trail purposes against corruption by stray electromagnetic emissions, and internally generated spurious electrical signals
   vi. Maintain a log of corrected data

Recording reliability refers to the ability of the DRE system to record votes accurately at its maximum rated processing volume for a specified period of time. The DRE system shall record votes reliably in accordance with the requirements of Subsection 4.3.3.

4.1.5 Paper-based Conversion Requirements

The paper-based conversion requirements address the ability of the system to read the ballot card and to translate its pattern of marks into electronic signals for later processing. These capabilities may be built into the voting system in an integrated fashion, or may be provided by one or more components that are not unique to the system, such as a general purpose data processing card reader or read head suitably interfaced to the system. These requirements address two major functions: ballot handling and ballot reading.

4.1.5.1 Ballot Handling

Ballot handling consists of a ballot card's acceptance, movement through the read station, and transfer into a collection station or receptacle.

a. The capacity to convert the marks on individual ballots into signals is uniquely important to central count systems. The capacity for a central count system shall be documented by the manufacturer. This documentation shall include the capacity for individual components that impact the overall capacity
b. When ballots are unreadable or some condition is detected requiring that the cards be segregated from normally processed ballots for human review (e.g. write-ins), all central count paper-based systems shall do one of the following:
    i. Outstack the ballot
    ii. Stop the ballot reader and display a message prompting the election official or designee to remove the ballot
    iii. Mark the ballot with an identifying mark to facilitate its later identification
c. Additionally, the system shall provide a capability that can be activated by an authorized election official to identify ballots containing overvotes, blank ballots, and ballots containing undervotes in a designated contest. If enabled, these capabilities shall perform one of the above actions in response to the indicated condition.
d. When ballots are unreadable or when some condition is detected requiring that the cards be segregated from normally processed ballots for human review (e.g. write-in votes) all precinct count systems shall:
    i. In response to an unreadable or blank ballot, return the ballot and provide a message prompting the voter to examine the ballot
    ii. In response to a ballot with a write-in vote, segregate the ballot or mark the ballot with an identifying mark to facilitate its later identification
    iii. In response to a ballot with an overvote the system shall:

        - Provide a capability to identify an overvoted ballot
        - Return the ballot
        - Provide an indication prompting the voter to examine the ballot
        - Allow the voter to correct the ballot
        - Provide a means for an authorized election official to deactivate this capability entirely and by contest

    iv. In response to a ballot with an undervote, the system shall:

- Provide a capability to identify an undervoted ballot
- Return the ballot
- Provide an indication prompting the voter to examine the ballot
- Allow the voter to correct the ballot
- Allow the voter to submit the ballot with the undervote
- Provide a means for an authorized election official to deactivate this capability

e. Ballot readers shall prevent multiple feed or detect and provide an alarm indicating multiple feed. Multiple feed occurs when a ballot reader attempts to read more than one ballot at a time.

i. If multiple feed is detected, the card reader shall halt in a manner that permits the operator to remove the unread cards causing the error, and reinsert them in the card input hopper

~~ii.~~ The frequency of multiple feeds with ballots intended for use with the system shall not exceed l in 10,000

Multiple feeds, misfeeds (jams), and rejections of ballots that meet all manufacturer specifications are all treated collectively as “misfeeds” for benchmarking purposes; i.e., only a single count is maintained.

All paper-based tabulators and EBMs shall achieve a misfeed rate of no more than 0.002 (1/500).

The observed cumulative misfeed rate shall be calculated as follows:

Compute the “misfeed total” as the number of times that unforced multiple feed, misfeed (jam), or rejection of a ballot that meets all manufacturer specifications has occurred during the execution of tests. It is possible for a given ballot to misfeed more than once; each misfeed would be counted.

Compute the “total ballot volume” as the number of successful feeds of ballot pages or cards during the execution of tests. (If the pages of a multi-page ballot are fed separately, each page counts; but if both sides of a two-sided ballot are read in one pass through the tabulator, it only counts once.)

Compute the observed cumulative misfeed rate as the ratio of the misfeed total to the total ballot volume. Special cases: If both values are zero, the misfeed rate is zero. If the total ballot volume is zero but the misfeed total is not, the misfeed rate is infinite.

4.1.5.2 Ballot Reading Accuracy

This paper-based system requirement governs the conversion of the physical ballot into electronic data. Reading accuracy for ballot conversion refers to the ability to:

a. Recognize vote punches or marks, or the absence thereof, for each possible selection on the ballot
b. Discriminate between valid punches or marks and extraneous perforations, smudges, and folds
c. Convert the vote punches or marks, or the absence thereof, for each possible selection on the ballot into digital signals

To ensure accuracy, paper-based systems shall:

d. Detect punches or marks that conform to manufacturer specifications with an error rate not exceeding the requirement indicated in Subsection 4.1.1
e. Ignore, and not record, extraneous perforations, smudges, and folds

~~f. Reject ballots that meet all vendor specifications at a rate not to exceed 2 percent~~

4.1.6 Tabulation Processing Requirements

Tabulation processing requirements apply to the hardware and software required to accumulate voting data for all candidates and measures within voting machines and polling places, and to consolidate the voting data at a central level or multiple levels. These requirements also address the generation and maintenance of audit records, the detection and disabling of improper use or operation of the system, and the monitoring of overall system status. Separate and distinct requirements for paper-based and DRE voting systems are presented below.

4.1.6.1 Paper-based System Processing Requirements

The paper-based processing requirements address all mechanical devices, electromechanical devices, electronic devices, and software required to perform the logical and numerical functions of interpreting the electronic image of the voted ballot, and assigning votes to the proper memory registers.

a. Processing accuracy refers to the ability of the system to receive electronic signals produced by punches for punchcard systems and vote marks and timing information for marksense systems; perform logical and numerical operations upon these data; and reproduce the contents of memory when required, without error. Specific requirements are detailed below:
    i. Processing accuracy shall be measured by vote selection error rate, the ratio of uncorrected vote selection errors to the total number of ballot positions that could be recorded across all ballots when the system is operated at its nominal or design rate of processing
    ii. The vote selection error rate shall include data that denotes ballot style or precinct as well as data denoting a vote in a specific contest or ballot proposition
    iii. The vote selection error rate shall include all errors from any source

   iv. The vote selection error rate shall not exceed the requirement indicated in Subsection 4.1.1

b. Paper-based system memory devices, used to retain control programs and data, shall have demonstrated error-free data retention for a period of 22 months, under the environmental conditions for operation and non-operation (i.e., storage).

4.1.6.2 DRE System Processing Requirements

The DRE voting systems processing requirements address all mechanical devices, electromechanical devices, electronic devices, and software required to process voting data after the polls are closed.

a. DRE voting systems shall meet the following requirements for processing speed:
   i. Operate at a speed sufficient to respond to any operator and voter input without perceptible delay (no more than three seconds)
   ii. If the consolidation of polling place data is done locally, perform this consolidation in a time not to exceed five minutes for each device in the polling place
b. Processing accuracy is defined as the ability of the system to process voting data stored in DRE voting devices or in removable memory modules installed in such devices. Processing includes all operations to consolidate voting data after the polls have been closed. DRE voting systems shall:
   i. Produce reports that are completely consistent, with no discrepancy among reports of voting device data produced at any level
   ii. Produce consolidated reports containing absentee, provisional or other voting data that are similarly error-free. Any discrepancy, regardless of source, is resolvable to a procedural error, to the failure of a non-memory device or to an external cause
c. DRE system memory devices used to retain control programs and data shall have demonstrated error-free data retention for a period of 22 months. Error-free retention may be achieved by the use of redundant memory elements, provided that the capability for conflict resolution or correction among elements is included.

4.1.7 Reporting Requirements

The reporting requirements govern all mechanical, electromechanical, and electronic devices required for voting systems to print audit record entries and results of the tabulation. These requirements also address data storage media for transportation of data to other sites.

4.1.7.1 Removable Storage Media

In voting systems that use storage media that can be removed from the system and transported to another location for readout and report generation, these media shall use devices with demonstrated error-free retention for a period of 22 months under the environmental conditions for operation and non-operation contained in Subsection 4.1.2. Examples of removable storage media include: programmable read-only memory (PROM), random access memory (RAM) with battery backup, magnetic media or optical media.

4.1.7.2 Printers

All printers used to produce reports of the vote count shall be capable of producing:

a. Alphanumeric headers
b. Election, office and issue labels
c. Alphanumeric entries generated as part of the audit record

4.1.8 Vote Data Management Requirements

The vote data management requirements for all systems address capabilities that manage, process, and report voting data after the data has been consolidated at the polling place or other jurisdictional levels.

These capabilities allow the system to:

- Consolidate voting data from polling place data memory or transfer devices
- Report polling place summaries
- Process absentee ballots, data entered manually, and administrative ballot definition data

The requirements address all hardware and software required to generate output reports in the various formats required by the using jurisdiction.

4.1.8.1 Data File Management

All voting systems shall provide the capability to:

a. Integrate voting data files with ballot definition files
b. Verify file compatibility
c. Edit and update files as required

4.1.8.2 Data Report Generation

All voting systems shall include report generators for producing output reports at the device, polling place, and summary level, with provisions for administrative and judicial subdivisions as required by the using jurisdiction.

4.2 Physical Characteristics

This subsection covers physical characteristics of all voting systems and components that affect their general utility and suitability for election operations.

4.2.1 Size

There is no numerical limitation on the size of any voting equipment, but the size of each voting machine should be compatible with its intended use and the location at which the equipment is to be used.

4.2.2 Weight

There is no numerical limitation on the weight of any voting equipment, but the weight of each voting machine should be compatible with its intended use and the location at which the equipment is to be used.

4.2.3 Transport and Storage of Precinct Systems

All precinct voting systems shall:

a. Provide a means to safely and easily handle, transport, and install voting equipment, such as wheels or a handle or handles
b. Be capable of using, or be provided with, a protective enclosure rendering the equipment capable of withstanding:
    i. Impact, shock and vibration loads associated with surface and air transportation
    ii. Stacking loads associated with storage

4.3 Design, Construction, and Maintenance Characteristics

This subsection covers voting system materials, construction workmanship, and specific design characteristics important to the successful operation and efficient maintenance of the voting system.

4.3.1 Materials, Processes, and Parts

The approach to system design is unrestricted, and may incorporate any form or variant of technology capable of meeting the voting systems requirements and standards.

Precinct count systems shall be designed in accordance with best commercial practice for microcomputers, process controllers, and their peripheral components. Central count voting systems and equipment used in a central tabulating environment shall be designed in accordance with best commercial and industrial practice.

All voting systems shall:

a. Be designed and constructed so that the frequency of equipment malfunctions and maintenance requirements are reduced to the lowest level consistent with cost constraints
b. Include, as part of the accompanying Technical Data Package, an approved parts list
c. Exclude parts or components not included in the approved parts list

4.3.2 Durability

All voting systems shall be designed to withstand normal use without deterioration and without excessive maintenance cost for a period of ten years.

4.3.3 Reliability

For the purpose of demonstrating compliance with this requirement, a failure is defined as any event that results in (a) loss of one or more functions, (b) degradation of performance such that the device is unable to perform its intended function for longer than 10 seconds, (c) automatic reset, restart or reboot of the voting device, operating system or application software, (d) a requirement for an unanticipated intervention by a person in the role of poll worker or technician before the test can continue, or (e) error messages and/or audit log entries indicating that a failure has occurred.

In plain language, failures are equipment breakdowns, including software crashes, such that continued use without service or replacement is worrisome to impossible. Normal, routine occurrences like running out of paper are not considered failures. Misfeeds of ballots into optical scanners are handled by a separate benchmark (see Volume I, Section 4.1.5.1), so these are not included as failures for the general reliability benchmark.

A “user-serviceable” failure is one that can be remedied by a troubleshooter and/or election official using only knowledge found in voting equipment user documentation; a “non-user-serviceable” failure is one that requires the manufacturer or highly trained personnel to repair.

Any failure that results in all cast vote records pertaining to a given ballot becoming unusable or that makes it impossible to determine whether or not a ballot was cast is called disenfranchisement. It is unacceptable for even one ballot to become unrecoverable or to end up in an unknown state. For example, an optical scanner that shreds a paper ballot, rendering it unreadable by human or machine, is assessed a disenfranchisement type failure; so is a DRE that is observed to "freeze," providing no evidence one way or the other whether the ballot was cast, when the voter attempts to cast the ballot.

All voting devices shall achieve failure rates not exceeding those indicated in the following table.

Device class	Failure type	Unit of volume	Benchmark
voting device (all)	Disenfranchisement		0
central tabulator	All	ballot	1.237×10^{-6}
EMS	Non-user-serviceable	transaction	2.093×10^{-5}
EMS	User-serviceable (10 minutes)	transaction	9.084×10^{-4}
precinct tabulator	Non-user-serviceable	ballot	1.237×10^{-6}
precinct tabulator	User-serviceable	ballot	6.860×10^{-6}
DRE	Non-user-serviceable	voting session	1.941×10^{-5}
DRE	User-serviceable	voting session	8.621×10^{-5}
EBM	Non-user-serviceable	voting session	8.013×10^{-5}
EBM	User-serviceable	voting session	3.058×10^{-4}
Other vote-capture device	Non-user-serviceable	voting session	1.941×10^{-5}
Other vote-capture device	User-serviceable	voting session	8.621×10^{-5}
activation device	Media/token	ballot activation	2.027×10^{-4}
activation device	Main unit	ballot activation	1.237×10^{-6}
audit device	All	ballot	1.237×10^{-6}

More than one of the device classes listed in the table might apply to a given device. For example, if a DRE takes on the role of EMS before polls are opened and/or after polls are closed, its performance as a vote-capture device while polls are open would be evaluated under the DRE benchmark (voting session failure rate) while its performance as an EMS at other times would be evaluated under the EMS benchmark (transaction failure rate).

~~The reliability of voting system devices shall be measured as Mean Time Between Failure (MTBF) for the system submitted for testing. MBTF is defined as the value of the ratio of operating time to the number of failures which have occurred in the specified time interval. A typical system operations scenario consists of approximately 45 hours of equipment operation, consisting of 30 hours of equipment set-up and readiness testing~~

~~and 15 hours of elections operations. For the purpose of demonstrating compliance with this requirement, a failure is defined as any event which results in either the:~~

- ~~Loss of one or more functions~~
- ~~Degradation of performance such that the device is unable to perform its intended function for longer than 10 seconds~~

~~The MTBF demonstrated during certification testing shall be at least 163 hours.~~

4.3.4 Maintainability

Maintainability represents the ease with which maintenance actions can be performed based on the design characteristics of equipment and software and the processes the manufacturer and election officials have in place for preventing failures and for reacting to failures. Maintainability includes the ability of equipment and software to self-diagnose problems and make non-technical election workers aware of a problem. Maintainability addresses all scheduled and unscheduled events, which are performed to:

- Determine the operational status of the system or a component
- Adjust, align, tune or service components
- Repair or replace a component having a specified operating life or replacement interval
- Repair or replace a component that exhibits an undesirable predetermined physical condition or performance degradation
- Repair or replace a component that has failed
- Verify the restoration of a component or the system to operational status

Maintainability shall be determined based on the presence of specific physical attributes that aid system maintenance activities, and the ease with which system maintenance tasks can be performed by the VSTL. Although a more quantitative basis for assessing maintainability, such as the Mean Time to Repair the system is desirable, the certification of a system is conducted before it is approved for sale and thus before a broader base of maintenance experience can be obtained.

4.3.4.1 Physical Attributes

The following physical attributes will be examined to assess reliability:

a. Presence of labels and the identification of test points
b. Provision of built-in test and diagnostic circuitry or physical indicators of condition
c. Presence of labels and alarms related to failures
d. Presence of features that allow non-technicians to perform routine maintenance tasks (such as update of the system database)

4.3.4.2 Additional Attributes

The following additional attributes will be considered to assess system maintainability:

a. Ease of detecting that equipment has failed by a non-technician
b. Ease of diagnosing problems by a trained technician
c. Low false alarm rates (i.e., indications of problems that do not exist)
d. Ease of access to components for replacement
e. Ease with which adjustment and alignment can be performed
f. Ease with which database updates can be performed by a non-technician
g. Adjust, align, tune or service components

4.3.5 Availability

The availability of a voting system is defined as the probability that the equipment (and supporting software) needed to perform designated voting functions will respond to operational commands and accomplish the function. The voting system shall meet the availability standard for each of the following voting functions:

a. For all paper-based systems:
   i. Recording voter selections (such as by ballot marking or punch)
   ii. Scanning the punches or marks on paper ballots and converting them into digital data
b. For all DRE systems, recording and storing voter ballot selections
c. For precinct count systems (paper-based and DRE), consolidation of vote selection data from multiple precinct based systems to generate jurisdiction-wide vote counts, including storage and reporting of the consolidated vote data
d. For central-count systems (paper-based and DRE), consolidation of vote selection data from multiple counting devices to generate jurisdiction-wide vote counts, including storage and reporting of the consolidated vote data

System availability is measured as the ratio of the time during which the system is operational (up time) to the total time period of operation (up time plus down time). Inherent availability (Ai) is the fraction of time a system is functional, based upon Mean Time Between Failure (MTBF) and Mean Time To Repair (MTTR), that is:

$$Ai = (MTBF)/(MTBF + MTTR)$$

MTTR is the average time required to perform a corrective maintenance task during periods of system operation. Corrective maintenance task time is active repair time, plus the time attributable to other factors that could lead to logistic or administrative delays, such as travel notification of qualified maintenance personnel and travel time for such personnel to arrive at the appropriate site.

Corrective maintenance may consist of substitution of the complete device or one of its components, as in the case of precinct count and some central count systems, or it may consist of on-site repair.

The voting system shall achieve at least 99 percent availability during normal operation for the functions indicated above. This standard encompasses for each function the combination of all devices and components that support the function, including their MTTR and MTBF attributes.

Manufacturers shall specify the typical system configuration that is to be used to assess availability, and any assumptions made with regard to any parameters that impact the MTTR. These factors shall include at a minimum:

e. Recommended number and locations of spare devices or components to be kept on hand for repair purposes during periods of system operation
f. Recommended number and locations of qualified maintenance personnel who need to be available to support repair calls during system operation
g. Organizational affiliation (i.e., jurisdiction, manufacturer) of qualified maintenance personnel

4.3.6 Product Marking

All voting systems shall:

a. Identify all devices by means of a permanently affixed nameplate or label containing the name of the manufacturer or manufacturer, the name of the device, its part or model number, its revision letter, its serial number, and if applicable, its power requirements
b. Display on each device a separate data plate containing a schedule for and list of operations required to service or to perform preventive maintenance
c. Display advisory caution and warning instructions to ensure safe operation of the equipment and to avoid exposure to hazardous electrical voltages and moving parts at all locations where operation or exposure may occur

4.3.7 Workmanship

To help ensure proper workmanship, all manufacturers of voting systems shall:

a. Adopt and adhere to practices and procedures to ensure that their products are free from damage or defect that could make them unsatisfactory for their intended purpose
b. Ensure that components provided by external suppliers are free from damage or defect that could make them unsatisfactory for their intended purpose

4.3.8 Safety

All voting systems shall meet the following requirements for safety:

a. All voting systems and their components shall be designed to eliminate hazards to personnel or to the equipment itself
b. Defects in design and construction that can result in personal injury or equipment damage must be detected and corrected before voting systems and components are placed into service
c. Equipment design for personnel safety shall be equal to or better than the appropriate requirements of the Occupational Safety and Health Act, Code of Federal Regulations, Title 29, Part 1910

In order to meet these safety requirements, voting system manufacturers shall submit their systems for review to a Nationally Recognized Testing Laboratory (NRTL.)[14]

Discussion: *NRTL laboratories are specifically accredited by OSHA to identify relevant safety standards for a product and to conduct testing that ensures specific products meet the requirements of the product safety standards identified. Although this standard does not require that a voting system carry a Product Safety Listing (Label), voting system manufacturers may voluntarily choose to implement such labeling in order to meet such requirements implemented by State or local election jurisdictions. EAC accredited VSTLs remain responsible for non-core testing performed by third party laboratories as noted in Section 2.10.4.3 of the EAC Voting System Test Laboratory Program Manual, Version 1.0*

[14] The italicized text in Section 4.3.8 is based on EAC Decision on the Request for Interpretation 2008-09, http://www.eac.gov/program-areas/voting-systems/docs/eac-decision-on-request-for-interpretation-2008-09/attachment_download/file.

5 Software Requirements

Table of Contents

5 Software Requirements

5.1 Scope

This section describes essential design and performance characteristics of the software used in voting systems, addressing both system level software, such as operating systems, and voting system application software, including firmware. The requirements of this section are intended to ensure that voting system software is reliable, robust, testable, and maintainable. The requirements in this section also support system accuracy, logical correctness, privacy, security and integrity.

The general requirements of this section apply to software used to support the entire range of voting system activities described in Section 2. More specific requirements are defined for ballot counting, vote processing, creating an audit trail, and generating output reports and files. Although this section emphasizes software, the guidelines described also influence hardware design considerations.

This section recognizes that there is no best way to design software. Many programming languages are available for which modern programming practices are applicable, such as the use of rigorous program and data structures, data typing, and naming conventions. Other programming languages exist for which such practices are not easily applied.

The *Guidelines* are intended to guide the design of software written in any of the programming languages commonly used for mainframe, mini-computer, and microprocessor systems. They are not intended to preclude the use of other languages or environments, such as those that exhibit declarative structure, object-oriented languages, functional programming languages, or any other combination of language and implementation that provides appropriate levels of performance, testability, reliability, and security. The manufacturer makes specific software selections. However, the use of widely recognized and proven software design methods will facilitate the analysis and testing of voting system software in the certification process.

5.1.1 Software Sources

The requirements of this section apply generally to all software used in voting systems, including:

- Software provided by the voting system manufacturer and its component suppliers
- Software furnished by an external provider (for example, providers of COTS operating systems and web browsers) where the software may be used in any way during voting system operation
- Software developed by the voting jurisdiction

Compliance with the software requirements is assessed by several formal tests, including code examination. Unmodified software is not subject to code examination; however, source code provided by third parties and embedded in software modules for compilation or interpretation shall be provided in human readable form to the VSTL. The VSTL may inspect source code units to determine testing requirements or to verify that the code is unmodified and that the default configuration options have not been changed.

Configuration of software, both operating systems and applications, is critical to proper system functioning. Correct test design and sufficient test execution must account for the intended and proper configuration of all system components. Therefore, the manufacturers shall submit a record of all user selections made during software installation as part of the Technical Data Package. The manufacturer shall also submit a record of all configuration changes made to the software following its installation. The VSTL shall confirm the propriety and correctness of these user selections and configuration changes.

5.1.2 Management of Software and Hardware

The requirements of this section apply to all software used in any manner to support any voting-related activities, regardless of the ownership of the software or the ownership and location of the hardware on which the software is installed or operates. These requirements apply to:

- Software that operates on voting devices and vote counting devices installed at polling places under the control of the voting jurisdiction
- Software that operates on ballot printers, vote counting devices, and other hardware typically installed at central or precinct locations (including contractor facilities)
- Election management software

However, some requirements apply only in specific situations indicated in this section. In addition to the requirements of this section, all software used in any manner to support any voting-related activities shall meet the requirements for security described in Section 7.

5.1.3 Exclusions

Some voting systems use computers that also may be used for other purposes. General purpose software such as operating systems, programming language compilers, database management systems, and Web browsers may be installed on these computers. Such software is governed by the *Guidelines* unless:

a. The software provides no support of voting system capabilities
b. The software is removable, disconnectable or switchable such that it cannot function while voting system functions are enabled

c. Procedures are provided that confirm that the software has been removed, disconnected or switched

5.2 Software Design and Coding Standards

This section describes essential design and performance characteristics of the logic used in voting systems. The requirements of this section are intended to ensure that voting system logic is reliable, robust, testable, and maintainable.

The general requirements of this section apply to logic used to support the entire range of voting system activities. Although this section emphasizes software, the standards described also influence hardware design considerations.

While there is no best way to design logic, the use of outdated and ad hoc practices is a risk factor for unreliability, unmaintainability, etc. Consequently, these guidelines require the use of modern programming practices. The use of widely recognized and proven logic design methods will facilitate the analysis and testing of voting system logic.

5.2.1 Scope

The requirements of this section that constrain programming practices—design requirements—apply to all application logic, regardless of the ownership of the logic or the ownership and location of the hardware on which the logic is installed or operates. Although it would be desirable for COTS software to conform to the design requirements on software workmanship, its conformity to those requirements could not be assessed without access to the source code; hence, the design requirements are scoped to exclude COTS software. However, where there are purely functional requirements, such as the ability to detect and respond to invalid input without crashing, the behaviors of COTS software and hardware are equally constrained. (N.B., the definition of COTS precludes any application logic from receiving a COTS designation.)

Third-party logic, border logic, and configuration data are not required to conform to the design requirements on software workmanship, but manufacturers are required to supply that source code and data to the VSTL to enable a complete review of the application logic.

5.2.2 Selection of programming languages

Application logic shall be produced in a high-level programming language that has all of the following control constructs:

a. Sequence;
b. Loop with exit condition (e.g., for, while, and/or do-loops);

c. If/Then/Else conditional;
d. Case conditional; and
e. Block-structured exception handling (e.g., try/throw/catch).

The intent of this requirement is clarified in Volume I Section 5.2.5 with discussion and examples of specific programming languages.

By excluding border logic, this requirement allows the use of assembly language for hardware-related segments, such as device controllers and handler programs. It also allows the use of an externally-imposed language for interacting with an Application Program Interface (API) or database query engine. However, the special code should be insulated from the bulk of the code, e.g. by wrapping it in callable units expressed in the prevailing language, to minimize the number of places that special code appears. C.f. MISRA-C:2004[15] Rule 2.1: "Assembly language shall be encapsulated and isolated."

Acceptable programming languages are also constrained by Requirements 5.2.7.a.iii and iv, which effectively prohibit the invention of new languages.

The above requirement may be satisfied by using COTS extension packages to add missing control constructs to languages that could not otherwise conform. For example, C99[16] does not support block-structured exception handling, but the construct can be retrofitted using (e.g.) cexcept[17] or another COTS package.

The use of non-COTS extension packages or manufacturer-specific code for this purpose is not acceptable, as it would place an unreasonable burden on the VSTL to verify the soundness of an unproven extension (effectively a new programming language). The package must have a proven track record of performance supporting the assertion that it would be stable and suitable for use in voting systems, just as the compiler or interpreter for the base programming language must.

5.2.3 Selection of general coding standard

Note: The requirements of this section attempt to clarify the "published, reviewed, and industry-accepted" language appearing in previous iterations of the Guidelines, but the intent of the requirements is unchanged.

Application logic shall adhere to a published, credible set of coding rules, conventions or standards (herein simply called the "coding standard") that enhance the workmanship, security, integrity, testability, and maintainability of applications. Coding standards that are excessively specialized or simply inadequate may be rejected on the grounds that they

[15] MISRA-C:2004: Guidelines for the use of the C language in critical systems, MIRA Limited, U.K., 2004-10.

[16] ISO/IEC 9899:1999, Programming languages—C. Available from ISO, http://www.iso.org/.

[17] CEXCEPT (exception handling in C), software package, 2000. Available at http://cexcept.sourceforge.net/.

do not enhance one or more of workmanship, security, integrity, testability, and maintainability.

Coding standards shall be considered published if and only if they appear in a publicly available book, magazine, journal, or new media with analogous circulation and availability, or if they are publicly available on the Internet. Following are examples of published coding standards (links valid as of 2009-04). These are only examples and are not necessarily the best available for the purpose.

Ada: Christine Ausnit-Hood, Kent A. Johnson, Robert G. Pettit, IV, and Steven B. Opdahl, Eds., Ada 95 Quality and Style, Lecture Notes in Computer Science #1344, Springer-Verlag, 1995-06. Content available at http://www.iste.uni-stuttgart.de/ps/ada-doc/style_guide/cover.html and elsewhere.

C++: Mats Henricson and Erik Nyquist, Industrial Strength C++, Prentice-Hall, 1997. Content available at http://hem.passagen.se/erinyq/industrial/.

C#: "Design Guidelines for Class Library Developers," Microsoft. http://www.msdn.microsoft.com/library/default.asp?url=/library/en-us/cpgenref/html/cpconnetframeworkdesignguidelines.asp.

Java: "Code Conventions for the Java™ Programming Language," Sun Microsystems. http://java.sun.com/docs/codeconv/.

Coding standards shall be considered credible if and only if at least two different organizations with no ties to the creator of the rules or to the manufacturer seeking conformity assessment, and which are not themselves voting equipment manufacturers, independently decided to adopt them and made active use of them at some time within the three years before conformity assessment was first sought.

Coding standards evolve, and it is desirable for voting systems to be aligned with modern practices. If the "three year rule" was satisfied at the time that a system was first submitted for testing, it is considered satisfied for the purpose of subsequent reassessments of that system. However, new systems must meet the three year rule as of the time that they are first submitted for testing, even if they reuse parts of older systems.

5.2.4 Software modularity and programming

a. Application logic shall be designed in a modular fashion. Each module shall have a specific function that can be tested and verified independently of the remainder of the code. In practice, some additional modules (such as library modules) may be needed to compile the module under test, but the modular construction allows the supporting modules to be replaced by special test versions that support test objectives.
b. Callable units shall have cyclomatic complexity less than 20.

5.2.5 Structured programming

Discussion: Specific programming languages are identified to support the discussion. In no case does such identification imply recommendation or endorsement, nor does it imply that the programming languages identified are necessarily the best or only languages acceptable for voting system use.

Concept	**VSS[18], [19] / VVSG[20]**	**Ada[21], [22]**	**C[23], [24]**	**C++[25], [26]**	**C#[27], [28]**	**Java[29]**	**Visual Basic 2005 (VB 8.0)[30]**
Sequence	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Loop with exit condition	Yes	Yes	Yes	Yes	Yes	Yes	Yes
If/Then/Else conditional	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Case conditional	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Named block exit	No	Yes	No	No	No	Yes	No[31]
Block-structured exception handling	No	Yes	No	Yes	Yes	Yes	Yes

[18] Performance and Test Standards for Punchcard, Marksense, and Direct Recording Electronic Voting Systems, January 1990 edition with April 1990 revisions, in Voting System Standards, U.S. Government Printing Office, 1990. Available at http://josephhall.org/fec_vss_1990_pdf/1990_VSS.pdf.

[19] 2002 Voting Systems Standards, available from http://www.eac.gov/voting systems/voluntary-voting-guidelines/2002-voting-system-standards.

[20] 2005 Voluntary Voting System Guidelines, Version 1.0, 2006-03-06, available from http://www.eac.gov/program-areas/voting-systems/voting-system-certification/2005-vvsg.

[21] ISO/IEC 8652:1987, Programming languages—Ada.

[22] ISO/IEC 8652:1995, Information technology—Programming languages—Ada. Available from ISO, http://www.iso.org/.

[23] ISO/IEC 9899:1990, Programming languages—C.

[24] ISO/IEC 9899:1999, Programming languages—C. Available from ISO, http://www.iso.org/.

[25] ISO/IEC 14882:1998, Programming languages—C++.

[26] ISO/IEC 14882:2003, Programming languages—C++. Available from ISO, http://www.iso.org/.

[27] ISO/IEC 23270:2003, Information technology—C# language specification.

[28] ISO/IEC 23270:2006, Information technology—Programming languages—C#. Available from ISO, http://www.iso.org/.

[29] The Java Language Specification, Third Edition, 2005. Available at http://java.sun.com/docs/books/jls/index.html.

[30] Paul Vick, The Microsoft® Visual Basic® Language Specification, Version 8.0, 2005. Available from Microsoft Download Center, http://go.microsoft.com/fwlink/?linkid=62990.

[31] Visual Basic 8 does not support named block exit, but it does support specifying the kind of block (do loop, for loop, while loop, select, subroutine, function, etc.) from which to exit, which need not be the innermost block.

The requirement to follow a coding standard serves two purposes. First, by requiring specific risk factors to be mitigated, coding standards support integrity and maintainability of voting system logic. Second, by making the logic more transparent to a reviewer, coding standards facilitate VSTL evaluation of the logic's correctness to a level of assurance beyond that provided by operational testing.

Prominent among the requirements addressing logical transparency is the requirement to use high-level control constructs and to refrain from using the low-level arbitrary branch (a.k.a. goto). As is reflected in the above table, most high-level concepts for control flow were established by the time the first edition of the Guidelines was published and are supported by all of the programming languages that were examined as probable candidates for voting system use as of this iteration. However, two additional concepts have been slower to gain universal support.

The first additional concept, called here the "named block exit," is the ability to exit a specific block from within an arbitrary number of nested blocks, as opposed to only being able to exit the innermost block, without resorting to goto. The absence of named block exit from some languages is not cause for concern here because deeply nested blocks are themselves detrimental to the transparency of logic and most coding standards encourage restructuring them into separate callable units.

The second additional concept, called here "block-structured exception handling," is the ability to associate exception handlers with blocks of logic, and implicitly, the presence of the exception concept in the programming language. (This simply means try/throw/catch or equivalent statements, and should not be confused with the specific implementation known as Structured Exception Handling (SEH).[32]) Unlike deeply nested blocks, exceptions cannot be eliminated by restructuring logic. "When exceptions are not used, the errors cannot be handled but their existence is not avoided."[33]

Previous Guidelines required voting systems to handle such errors by some means, preferably using programming language exceptions (2005 VVSG I.5.2.3.e), but there was no unambiguous requirement for the programming language to support exception handling. These Guidelines require programming language exceptions because without them, the programmer must check for every possible error condition in every possible location, which both obfuscates the application logic and creates a high likelihood that some or many possible errors will not be checked for. Additionally, these Guidelines require block-structured exception handling because, like all unstructured programming, unstructured exception handling obfuscates logic and makes its verification by the VSTL more difficult. "One of the major difficulties of conventional defensive programming is that the fault tolerance actions are inseparably bound in with the normal processing which

[32] Matt Pietrek, "A Crash Course on the Depths of Win32™ Structured Exception Handling," Microsoft Systems Journal, 1997-01. Available at http://www.microsoft.com/msj/0197/exception/exception.aspx.

[33] ISO/IEC TR 15942:2000, Information technology—Programming languages—Guide for the use of the Ada programming language in high integrity systems. Available from ISO, http://www.iso.org/.

the design is to provide. This can significantly increase design complexity and, consequently, can compromise the reliability and maintainability of the software."[34]

Existing voting system logic implemented in programming languages that do not support block-structured exception handling can be brought into compliance either through migration to a newer programming language (most likely, a descendant of the same language that would require minimal changes) or through the use of a COTS package that retrofits block-structured exception handling onto the previous language with minimal changes. While the latter path may at first appear to be less work, it should be noted that many library functions may need to be adapted to throw exceptions when exceptional conditions arise, whereas in a programming environment that had exceptions to begin with the analogous library functions would already do this (see Requirement a below).

a. Application logic shall handle exceptions using block-structured exception handling constructs. If application logic makes use of any COTS or third-party logic callable units that do not throw exceptions when exceptional conditions occur, those callable units shall be wrapped in callable units that check for the relevant error conditions and translate them into exceptions, and the remainder of application logic shall use only the wrapped version. For example, if an application written in C99 + cexcept used the malloc function of libc, which returns a null pointer in case of failure instead of throwing an exception, the malloc function would need to be wrapped. Here is one possible implementation:

```
void *checkedMalloc (size_t size) {
  void *ptr = malloc (size);
  if (!ptr)
    Throw bad_alloc;
  return ptr;
}
#define malloc checkedMalloc
```

Wrapping legacy functions avoids the need to check for errors after every invocation, which both obfuscates the application logic and creates a high likelihood that some or many possible errors will not be checked for.

In C++, it would be preferable to use one of the newer mechanisms that already throw exceptions on failure and avoid use of legacy functions altogether.

b. Application logic shall contain no unstructured control constructs.
   i. Arbitrary branches (a.k.a. gotos) are prohibited.
   ii. Exceptions shall only be used for abnormal conditions. Exceptions shall not be used to redirect the flow of control in normal ("non-exceptional") conditions. "Intentional exceptions" cannot be used as a substitute for arbitrary branch. Normal, expected events, such as reaching the end of a file that is being read from beginning to end or receiving invalid input from

[34] M. R. Moulding, "Designing for high integrity: the software fault tolerance approach," Section 3.4. In C. T. Sennett, ed., High-Integrity Software, Plenum Press, New York and London, 1989.

a user interface, are not exceptional conditions and should not be implemented using exception handlers.

iii. Unstructured exception handling (e.g., On Error GoTo, setjmp/longjmp, or explicit tests for error conditions after every executable statement) is prohibited. The internal use of such constructs by a COTS extension package that adds block-structured exception handling to a programming language that otherwise would not have it, as described in Requirement a, is allowed. Analogously, it is not a problem that source code written in a high-level programming language is compiled into low-level machine code that contains arbitrary branches. It is only the direct use of low-level constructs in application logic that presents a problem.

c. Application logic shall not compile or interpret configuration data or other input data as a programming language. Distinguishing what is a programming language from what is not requires some professional judgment. However, in general, sequential execution of imperative instructions is a characteristic of conventional programming languages that should not be exhibited by configuration data. Configuration data must be declarative or informative in nature, not imperative. For example: it is permissible for configuration data to contain a template that informs a report generating application as to the form and content of a report that it should generate, but it is not permissible for configuration data to contain instructions that are executed or interpreted to generate a report, essentially embedding the logic of the report generator inside the configuration data. The reasons for this requirement are (1) mingling code and data is bad design, and (2) embedding logic within configuration data is an evasion of the conformity assessment process for application logic.

5.2.6 Header comments

Header comments and other commenting standards should be specified by the selected coding standard in a manner consistent with the idiom of the programming language chosen. If the coding standard specifies a coding style and commenting standard that make header comments redundant, then they may be omitted. Otherwise, in the event that the coding standard fails to specify the content of header comments, application logic modules should include header comments that provide at least the following information for each callable unit (function, method, operation, subroutine, procedure, etc.):

a. The purpose of the unit and how it works (if not obvious);
b. A description of input parameters, outputs and return values, exceptions thrown, and side-effects;
c. Any protocols that must be observed (e.g., unit calling sequences);
d. File references by name and method of access (read, write, modify, append, etc.);
e. Global variables used (if applicable);
f. Audit event generation;
g. Date of creation; and
h. Change log (revision record). Change logs need not cover the nascent period, but they must go back as far as the first baseline or release that is submitted for testing, and should go back as far as the first baseline or release that is deemed reasonably coherent.

5.2.7 Executable code and data integrity[35]

a. Subrequirements i through iv apply to application logic (and only to application logic):
   i. Self-modifying code is prohibited.
   ii. Application logic shall be free of race conditions, deadlocks, livelocks, and resource starvation.
   iii. If compiled code is used, it shall only be compiled using a COTS compiler. This prohibits the use of arbitrary, nonstandard compilers and consequently the invention of new programming languages.
   iv. If interpreted code is used, it shall only be run under a specific, identified version of a COTS runtime interpreter. This ensures (1) that no arbitrary, nonstandard interpreted languages are used, and (2) that the software tested and approved during the conformity assessment process does not change behavior because of a change to the interpreter.

b. All programmed devices shall prevent replacement or modification of executable or interpreted code (e.g., by other programs on the system, by people physically replacing the memory or medium containing the code, or by faulty code) except where this access is necessary to conduct the voting process. This requirement may be partially satisfied through a combination of read-only memory (ROM), the memory protection implemented by most popular COTS operating systems, error checking as described in Volume I Section 5.2.8, and access and integrity controls.

c. All voting devices shall prevent access to or manipulation of configuration data, vote data or audit records (e.g., by physical tampering with the medium or mechanism containing the data, by other programs on the system, or by faulty code) except where this access is necessary to conduct the voting process. This requirement may be partially satisfied through a combination of the memory protection implemented by most popular COTS operating systems, error checking as described in Volume I Section 5.2.8, and access and integrity controls. Systems using mechanical counters to store vote data must protect the counters from tampering. If vote data are stored on paper, the paper must be protected from tampering. Modification of audit records after they are created is never necessary.

d. All programmed devices shall provide the capability to monitor the transfer quality of I/O operations, reporting the number and types of errors that occur and how they were corrected.

e. Application logic and border logic shall contain no inaccessible code (dead code) other than defensive code (including exception handlers) that is provided to defend against the occurrence of failures and "can't happen" conditions.

[35] Portions of this section are derived from Section 5.6.2.2 of IEEE Draft Standard for the Evaluation of Voting Equipment, draft P1583/D5.3.2b, 2005-01-04. This material is from an unapproved draft of a proposed IEEE Standard, P1583. As such, the material is subject to change in the final standard. Because this material is from an unapproved draft, the IEEE recommends that it not be utilized for any conformance/compliance purposes. It is used at your own risk.

5.2.8 Error checking[36]

This section contains requirements for application logic to avoid, detect, and prevent well-known types of errors that could compromise voting integrity and security. Additional advice from the security perspective is available at the CERT® Coordination Center, Secure Coding homepage, http://www.cert.org/secure-coding/, and related sites, esp. Department of Homeland Security, Build Security In homepage, https://buildsecurityin.us-cert.gov/.

a. All programmed devices shall check information inputs for completeness and validity and ensure that incomplete or invalid inputs do not lead to irreversible error.

b. All application logic that is vulnerable to the following types of errors shall check for these errors at run time and respond defensively (as specified by Requirement f) when they occur: (1) out-of-bounds accesses of arrays or strings (includes buffers used to move data); (2) stack overflow errors; (3) CPU-level exceptions such as address and bus errors, dividing by zero, and the like; (4) variables that are not appropriately handled when out of expected boundaries; (5) numeric overflows; (6) known programming language specific vulnerabilities.

   i. If the application logic uses arrays, vectors, or any analogous data structures and the programming language does not provide automatic run-time range checking of the indices, the indices shall be ranged-checked on every access. Range checking code should not be duplicated before each access. Clean implementation approaches include: (1) consistently using dedicated accessors (functions, methods, operations, subroutines, procedures, etc.) that range-check the indices; (2) defining and consistently using a new data type or class that encapsulates the range-checking logic; (3) declaring the array using a template that causes all accessors to be range-checked; or (4) declaring the array index to be a data type whose enforced range is matched to the size of the array. Range-enforced data types or classes may be provided by the programming environment or they may be defined in application logic. If acceptable values of the index do not form a contiguous range, a map structure may be more appropriate than a vector.

   ii. If stack overflow does not automatically result in an exception, the application logic shall explicitly check for and prevent stack overflow. Embedded system developers use a variety of techniques for avoiding stack overflow. Commonly, the stack is monitored and warnings and exceptions are thrown when thresholds are crossed. In non-embedded contexts, stack overflow often manifests as a CPU-level exception related to memory segmentation, in which case it can be handled pursuant to Requirement b.iii.

   iii. The application logic shall implement such handlers as are needed to detect and respond to CPU-level exceptions. For example, under Unix a CPU-level exception would manifest as a signal, so a signal handler is needed. If

[36] Portions of this section are derived from Sections 5.6.2.2 and 6.6.4.2 of IEEE Draft Standard for the Evaluation of Voting Equipment, draft P1583/D5.3.2b, 2005-01-04. This material is from an unapproved draft of a proposed IEEE Standard, P1583. As such, the material is subject to change in the final standard. Because this material is from an unapproved draft, the IEEE recommends that it not be utilized for any conformance/compliance purposes. It is used at your own risk.

the platform supports it, it is preferable to translate CPU-level exceptions into software-level exceptions so that all exceptions can be handled in a consistent fashion within the voting application; however, not all platforms support it.

iv. All scalar or enumerated type parameters whose valid ranges as used in a callable unit (function, method, operation, subroutine, procedure, etc.) do not cover the entire ranges of their declared data types shall be range-checked on entry to the unit. This applies to parameters of numeric types, character types, temporal types, and any other types for which the concept of range is well-defined. In cases where the restricted range is frequently used and/or associated with a meaningful concept within the scope of the application, the best approach is to define a new class or data type that encapsulates the range restriction, eliminating the need for range checks on each use. This requirement differs from Requirement a. Requirement a deals with user input, which is expected to contain errors, while this requirement deals with program internal parameters, which are expected to conform to the expectations of the designer. User input errors are a normal occurrence; the errors discussed here are grounds for throwing exceptions.

v. If the programming language does not provide automatic run-time detection of numeric overflow, all arithmetic operations that could potentially overflow the relevant data type shall be checked for overflow. This requirement should be approached in a manner similar to Requirement b.i. Overflow checking should be encapsulated as much as possible.

c. All application logic that is vulnerable to the following types of errors should check for these errors at run time and respond defensively (as specified by Requirement f) when they occur: (1) pointer variable errors; (2) dynamic memory allocation and management errors.

i. If application logic uses pointers or a similar mechanism for specifying absolute memory locations, the application logic should validate pointers or addresses before they are used. Improper overwriting should be prevented in general as required by Requirements 5.2.7.b and c. Nevertheless, even if read-only memory would prevent the overwrite from succeeding, an attempted overwrite indicates a logic fault that must be corrected. Pointer use that is fully encapsulated within a standard platform library is treated as COTS software.

d. If dynamic memory allocation is performed in application logic, the application logic should be instrumented and/or analyzed with a COTS tool for detecting memory management errors. Dynamic memory allocation that is fully encapsulated within a standard platform library is treated as COTS software.

e. If pointers are used, any pointer variables that remain within scope after the memory they point to is deallocated shall be set to null or marked as invalid (pursuant to the idiom of the programming language used) after the memory they point to is deallocated. If this is not done automatically by the programming environment, a callable unit should be dedicated to the task of deallocating memory and nullifying pointers. Equivalently, “smart pointers” like the C++ std::auto_ptr can be used to avoid the problem. One should not add assignments after every deallocation in the source code. In languages using garbage collection, memory is not deallocated until all pointers to it have gone out of scope, so this requirement is moot.

f. The detection of any of the errors enumerated in Requirements b and c shall be treated as a complete failure of the callable unit in which the error was detected. An appropriate exception shall be thrown and control shall pass out of the unit forthwith.

g. Error checks detailed in Requirements b and c shall remain active in production code. These errors are incompatible with voting integrity, so masking them is unacceptable. Manufacturers should not implement error checks using the C/C++ assert() macro. It is often disabled, sometimes automatically, when software is compiled in production mode. Furthermore, it does not appropriately throw an exception, but instead aborts the program.

h. Exceptions resulting from failed error checks or CPU-level exceptions shall require intervention by an election official or administrator before voting can continue. These errors are incompatible with voting integrity, so masking them is unacceptable.

i. Electronic devices shall include a means of identifying device failure and any corrective action needed.

j. Electronic devices should proactively detect equipment failures and alert an election official or administrator when they occur.

k. To the extent possible, electronic devices shall proactively detect or prevent basic violations of election integrity (e.g., stuffing of the ballot box or the accumulation of negative votes) and alert an election official or administrator if they occur. Equipment can verify only those conditions that are within the scope of what the equipment does. However, insofar as the equipment can detect something that is blatantly wrong, it should do so and raise the alarm. This provides defense-in-depth to supplement procedural controls and auditing practices.

~~The software used by voting systems is selected by the vendor and not prescribed by the Guidelines. This section provides requirements for voting system software with regard to:~~

- ~~Selection of programming languages~~
- ~~Software integrity~~
- ~~Software modularity and programming~~
- ~~Control constructs~~
- ~~Naming conventions~~
- ~~Coding conventions~~
- ~~Comment conventions~~

~~5.2.1 Selection of Programming Languages~~

~~Software associated with the logical and numerical operations of vote data shall use a high-level programming language, such as: Pascal, Visual Basic, Java, C and C++. The requirement for the use of high-level language for logical operations does not preclude the use of assembly language for hardware-related segments, such as device controllers and handler programs. Also, operating system software may be designed in assembly language.~~

~~5.2.2 Software Integrity~~

~~Self-modifying, dynamically loaded or interpreted code is prohibited, except under the security provisions outlined in Subsection 7.4. This prohibition is to ensure that the software tested and approved during the certification process remains unchanged and retains its integrity. External modification of code during execution shall be prohibited. Where the development environment (programming language and development tools) includes the following features, the software shall provide controls to prevent accidental or deliberate attempts to replace executable code:~~

~~a. Unbounded arrays or strings (includes buffers used to move data)~~
~~b. Pointer variables~~
~~c. Dynamic memory allocation and management~~

~~5.2.3 Software Modularity and Programming~~

~~Voting system application software, including commercial off-the-shelf (COTS) software, shall be designed in a modular fashion. However, COTS software is not required to be inspected for compliance with this requirement. For the purpose of this requirement37, "modules" may be compiled or interpreted independently. Modules may also be nested. The modularity rules described here apply to the component sub-modules of a library. The principle to be followed is that the module contains all the elements to compile or interpret successfully and has limited access to data in other modules. The design concept is simple replacement with another module whose interfaces match the original module. A module is designed in accordance with the rules below.~~

~~a. Each module shall have a specific function that can be tested and verified independently of the remainder of the code. In practice, some additional modules (such as library modules) may be needed to compile the module under test, but the modular construction allows the supporting modules to be replaced by special test versions that support test objectives.~~
~~b. Each module shall be uniquely and mnemonically named, using names that differ by more than a single character. In addition to the unique name, the modules shall include a set of header comments identifying the module's purpose, design, conditions, and version history, followed by the operational code. Headers are optional for modules of fewer than ten executable lines where the subject module is embedded in a larger module that has a header containing the header information. Library modules shall also have a header comment describing the purpose of the library and version information.~~
~~c. All required resources, such as data accessed by the module, should either be contained within the module or explicitly identified as input or output to the module. Within the constraints of the programming language, such resources shall be placed at the lowest level where shared access is needed. If that shared access level is across multiple modules, the definitions should be defined in a~~

[37] ~~Some software languages and development environments use a different definition of module but this principle still applies.~~

~~single file (called header files in some languages, such as C) where any changes can be applied once and the change automatically applies to all modules upon compilation or activation.~~

d. ~~A module is small enough to be easy to follow and understand. Program logic visible on a single page is easy to follow and correct. Volume II, Section 5 provides testing guidelines for the accredited test lab to identify large modules subject to review under this requirement.~~

e. ~~Each module shall have a single entry point, and a single exit point, for normal process flow. For library modules or languages such as the object-oriented languages, the entry point is to the individual contained module or method invoked. The single exit point is the point where control is returned. At that point, the data that is expected as output must be appropriately set. The exception for the exit point is where a problem is so severe that execution cannot be resumed. In this case, the design must explicitly protect all recorded votes and audit log information and must implement formal exception handlers provided by the language.~~

f. ~~Process flow within the modules shall be restricted to combinations of the control structures defined in Volume II, Section 5. These structures support the modular concept, especially the single entry and exit rule above. They apply to any language feature where program control passes from one activity to the next, such as control scripts, object methods or sets of executable statements, even though the language itself is not procedural~~

~~5.2.4 Control Constructs~~

~~Voting system software shall use the control constructs identified in Volume II, Section 5:~~

a. ~~Acceptable constructs are Sequence, If-Then-Else, Do-While, Do-Until, Case, and the General Loop (including the special case for loop).~~

   i. ~~If the programming language used does not provide these control constructs, the vendor shall provide comparable control structure logic. The constructs shall be used consistently throughout the code. No other constructs shall be used to control program logic and execution.~~

   ii. ~~While some programming languages do not create programs as linear processes, stepping from an initial condition through changes to a conclusion, the program components nonetheless contain procedures (such as “methods” in object-oriented languages). Even in these programming languages, the procedures must execute through these control constructs or their equivalents, as defined and provided by the vendor.~~

   iii. ~~Operator intervention or logic that evaluates received or stored data shall not re-direct program control within a program routine. Program control may be re-directed within a routine by calling subroutines, procedures, and functions, and by interrupt service routines and exception handlers (due to abnormal error conditions). Do-While (False) constructs and intentional exceptions (used as GoTos) are prohibited.~~

~~5.2.5 Naming Conventions~~

~~Voting system software shall use the naming conventions below.~~

a. ~~Object, function, procedure, and variable names shall be chosen to enhance the readability and intelligibility of the program. Insofar as possible, names shall be selected so that their parts of speech represent their use, such as nouns to represent objects and verbs to represent functions.~~
b. ~~Names used in code and in documentation shall be consistent.~~
c. ~~Names shall be unique within an application. Names shall differ by more than a single character. All single-character names are forbidden except those for variables used as loop indexes. In large systems where subsystems tend to be developed independently, duplicate names may be used where the scope of the name is unique within the application. Names should always be unique where modules are shared.~~
d. ~~Language keywords shall not be used as names of objects, functions, procedures, variables or in any manner not consistent with the design of the language.~~

~~5.2.6 Coding Conventions~~

~~Voting system software shall adhere to basic coding conventions. The coding conventions used shall meet one of the following conditions:~~

a. ~~The vendors shall identify the published, reviewed, and industry-accepted coding conventions used and the accredited test lab shall test for compliance~~
b. ~~The accredited test lab shall evaluate the code using the coding convention requirements specified in Volume II, Section 5~~

~~These guidelines reference conventions that protect the integrity and security of the code, which may be language-specific and language-independent conventions that significantly contribute to readability and maintainability. Specific style conventions that support economical testing are not binding unless adopted by the vendor.~~

~~5.2.7 Comment Conventions~~

~~Voting system software shall use the following comment conventions:~~

a. ~~All modules shall contain headers. For small modules of 10 lines or less, the header may be limited to identification of unit and revision information. Other header information should be included in the small unit headers if not clear from the actual lines of code. Header comments shall provide the following information:~~
    i. ~~The purpose of the unit and how it works~~
    ii. ~~Other units called and the calling sequence~~
    iii. ~~A description of input parameters and outputs~~

   iv. ~~File references by name and method of access (i.e., read, write, modify or append)~~
   v. ~~Global variables used~~
   vi. ~~Date of creation and a revision record~~

b. ~~Descriptive comments shall be provided to identify objects and data types. All variables shall have comments at the point of declaration clearly explaining their use. Where multiple variables that share the same meaning are required, the variables may share the same comment~~
c. ~~In-line comments shall be provided to facilitate interpretation of functional operations, tests, and branching~~
d. ~~Assembly code shall contain descriptive and informative comments , such that its executable lines can be clearly understood~~
e. ~~All comments shall be formatted in a uniform manner that makes it easy to distinguish them from executable code~~

5.3 Data and Document Retention

All systems shall:

a. Maintain the integrity of voting and audit data during an election, and for at least 22 months thereafter, a time sufficient to resolve most contested elections and support other activities related to the reconstruction and investigation of a contested election
b. Protect against the failure of any data input or storage device at a location controlled by the jurisdiction or its contractors, and against any attempt at improper data entry or retrieval

5.4 Audit Record Data

Audit trails are essential to ensure the integrity of a voting system. Operational requirements for audit trails are described in Subsection 2.5.1.1. Audit record data are generated by these procedures. The audit record data in the following subsections are essential to the complete recording of election operations and reporting of the vote tally. This list of audit records may not reflect the design constructs of some systems. Therefore, manufacturers shall supplement it with information relevant to the operation of their specific systems.

5.4.1 Pre-election Audit Records

During election definition and ballot preparation, the system shall audit the preparation of the baseline ballot formats and modifications to them, a description of these modifications, and corresponding dates.

The log shall include:

a. The allowable number of selections a contest
b. The combinations of voting patterns permitted or required by the jurisdiction
c. The inclusion or exclusion of contests as the result of multiple districting within the polling place
d. Any other characteristics that may be peculiar to the jurisdiction, the election or the polling place location
e. Manual data maintained by election personnel
f. Samples of all final ballot formats
g. Ballot preparation edit listings

5.4.2 System Readiness Audit Records

The following minimum requirements apply to system readiness audit records:

a. Prior to the start of ballot counting, a system process shall verify hardware and software status and generate a readiness audit record. This record shall include the identification of the software release, the identification of the election to be processed, and the results of software and hardware diagnostic tests
b. In the case of systems used at the polling place, the record shall include polling place identification
c. The ballot interpretation logic shall test and record the correct installation of ballot formats on voting devices
d. The software shall check and record the status of all data paths and memory locations to be used in vote recording to protect against contamination of voting data
e. Upon the conclusion of the tests, the software shall provide evidence in the audit record that the test data have been expunged
f. If required and provided, the ballot reader and arithmetic-logic unit shall be evaluated for accuracy, and the system shall record the results. It shall allow the processing or simulated processing of sufficient test ballots to provide a statistical estimate of processing accuracy
g. For systems that use a public network, provide a report of test ballots that includes:
   i. Number of ballots sent
   ii. When each ballot was sent
   iii. Machine from which each ballot was sent
   iv. Specific votes or selections contained in the ballot

5.4.3 In-process Audit Records

In-process audit records document system operations during diagnostic routines and the casting and tallying of ballots. At a minimum, the in-process audit records shall contain:

a. Machine generated error and exception messages to demonstrate successful recovery. Examples include, but are not necessarily limited to:

   i. The source and disposition of system interrupts resulting in entry into exception handling routines
   ii. All messages generated by exception handlers
   iii. The identification code and number of occurrences for each hardware and software error or failure
   iv. Notification of system login or access errors, file access errors, and physical violations of security as they occur, and a summary record of these events after processing
   v. Other exception events such as power failures, failure of critical hardware components, data transmission errors or other types of operating anomalies

b. Critical system status messages other than informational messages displayed by the system during the course of normal operations. These items include, but are not limited to:
   i. Diagnostic and status messages upon startup
   ii. The "zero totals" check conducted before opening the polling place or counting a precinct centrally
   iii. For paper-based systems, the initiation or termination of card reader and communications equipment operation
   iv. For DRE machines at controlled voting locations, the event (and time, if available) of activating and casting each ballot (i.e., each voter's transaction as an event). This data can be compared with the public counter for reconciliation purposes

c. Non-critical status messages that are generated by the machine's data quality monitor or by software and hardware condition monitors

d. System generated log of all normal process activity and system events that require operator intervention, so that each operator access can be monitored and access sequence can be constructed

5.4.4 Vote Tally Data

In addition to the audit requirements described above, other election-related data is essential for reporting results to interested parties, the press, and the voting public, and is vital to verifying an accurate count.

Voting systems shall meet these reporting requirements by providing software capable of obtaining data concerning various aspects of vote counting and producing printed reports. At a minimum, vote tally data shall include:

a. Number of ballots cast, using each ballot configuration, by tabulator, by precinct, and by political subdivision
b. Candidate and measure vote totals for each contest, by tabulator
c. The number of ballots read within each precinct and for additional jurisdictional levels, by configuration, including separate totals for each party in primary elections
d. Separate accumulation of overvotes and undervotes for each contest, by tabulator, precinct and for additional jurisdictional levels (no overvotes would be indicated for DRE voting devices)

e. For paper-based systems only, the total number of ballots both able to be processed and unable to be processed; and if there are multiple card ballots, the total number of cards read

For systems that produce an electronic file containing vote tally data, the contents of the file shall include the same minimum data cited above for printed vote tally reports.

5.5 Vote Secrecy on DRE Systems

All DRE systems shall ensure vote secrecy by:

a. Immediately after the voter chooses to cast his or her ballot, record the voter's selections in the memory to be used for vote counting and audit data (including ballot images), and erase the selections from the display, memory, and all other storage, including all forms of temporary storage
b. Immediately after the voter chooses to cancel his or her ballot, erase the selections from the display and all other storage, including buffers and other temporary storage

6 Telecommunications Requirements

Table of Contents

6 Telecommunications Requirements

6.1 Scope

This section contains the performance, design, and maintenance characteristics of the telecommunications components of voting systems and the acceptable levels of performance against these characteristics. For the purpose of the *Guidelines*, telecommunications is defined as the capability to transmit and receive data electronically using hardware and software components over distances both within and external to a polling place.

The requirements in this section represent acceptable levels of combined telecommunications hardware and software function and performance for the transmission of data that is used to operate the system and report election results. Where applicable, this section specifies minimum values for critical performance and functional attributes involving telecommunications hardware and software components.

This section does not apply to other means of moving data, such as the physical transport of data recorded on paper-based media or the transport of physical devices, such as memory cards, that store data in electronic form.

Voting systems may include network hardware and software to transfer data among systems. Major network components are local area networks (LANs), wide area networks (WANs), workstations (desktop computers), servers, data, and applications. Workstations include voting stations, precinct tabulation systems, and voting supervisory terminals. Servers include systems that provide registration forms and ballots and accumulate and process voter registrations and cast ballots.

Desirable network characteristics include simplicity, flexibility (especially in routing, to maintain good response times) and maintainability (including availability, provided primarily through redundancy of resources and connections, particularly of connections to public infrastructure).

A wide area network (WAN) public telecommunications component consists of the hardware and software to transport information, over shared public (i.e., commercial or governmental) circuitry or among private systems. For voting systems, the telecommunications boundaries are defined as the transport circuitry, on one side of which exists the public telecommunications infrastructure, outside the control of voting system supervisors. On the other side of the transport circuitry are the local area network (LAN) resources, workstations, servers, data and applications controlled by voting system supervisors.

Local area network (LAN) components consist of the hardware and software infrastructure used to transport information between users in a local environment, typically a building or group of buildings. Typically a LAN connects workstations with a local server.

An application may be a single program or a group of programs that work together to provide a function to an end user, who may be a voter or an election administrator. Voter programs may include voter registration, balloting, and status checking. Administrator programs may include ballot preparation, registration for preparation, registration approval, ballot vetting, ballot processing, and election processing.

This section is intended to complement the network security requirements found in Section 7, which include requirements for voter and administrator access, availability of network service, data confidentiality, and data integrity. Most importantly, security services must restrict access to local election system components from public resources, and these services must also restrict access to voting system data while it is in transit through public networks.

6.1.1 Types of Components

This section addresses telecommunications hardware and software across a broad range of technologies including, but not limited to:

- Dial-up communications technologies including standard landline, wireless, microwave, Very Small Aperture Terminal, Integrated Services Digital Network, Digital Subscriber Line
- Public and private high-speed telecommunications lines including FT-1, T-1, T-3; frame relay; private line
- Cabling technologies including Universal Twisted Pair cable (CAT 5 or higher) or Ethernet hub/switch
- Wireless including radio frequency and infrared
- Communications routers
- Modems, whether internal and external to personal computers, servers, and other voting system components installed at the polling place or central count location
- Modem drivers, dial-up networking software
- Channel service units and Data service units installed at the polling place or central count location
- Dial-up networking applications software

6.1.2 Telecommunications Operations and Providers

This section applies to voting-related transmissions over public networks, such as those provided by local distribution and long distance carriers. This section also applies to private networks regardless of whether the network is owned and operated by the election jurisdiction.

For systems that transmit official data over public networks, this section applies to telecommunications components installed and operated at locations supervised by election officials, such as polling places or central offices. This includes:

- Components acquired by the jurisdiction for the purpose of voting, including components installed at the polling place or a central office (including central site facilities operated by manufacturers or contractors)
- Components acquired by others (such as school systems, libraries, military installations and other public organizations) that are used at locations supervised by election officials, including minimum configuration components required by the manufacturer but that the manufacturer permits to be acquired from third party sources not under the manufacturer's control (e.g., router or modem card manufacturer or supplier)

6.1.3 Data Transmission

These requirements apply to the use of telecommunications to transmit data for the preparation of the system for an election, the execution of an election, and the preservation of the system data and audit trails during and following an election. While this section does not assume a specific model of voting system operations and does not assume a specific model for the use of telecommunications to support such operations, it does address the following types of data, where applicable:

Voter Authentication: Coded information that confirms the identity of a voter for security purposes for a system that transmits votes individually over a public network

Ballot Definition: Information that describes to a voting machine the content and appearance of the ballots to be used in an election

Vote Transmission: For systems that transmit votes individually over a public network, the transmission of a single vote within a network at a polling place and to the county (or contractor) for consolidation with other county vote data

Vote Count: Information representing the tabulation of votes at any level within the control of the jurisdiction, such as the polling place, precinct or central count

List of Voters: A listing of the individual voters who have cast ballots in a specific election

Additional data transmissions used to operate a voting system in the conduct of an election, but not explicitly listed above, are also subject to the requirements of this section.

For systems that transmit data using public networks, this section applies to telecommunications hardware and software for transmissions within and among all combinations of senders and receivers located at polling places, precinct count facilities and central count facilities (whether operated by the jurisdiction or a contractor).

6.2 Design, Construction, and Maintenance Requirements

Design, construction, and maintenance requirements for telecommunications represent the operational capability of both system hardware and software. These capabilities shall be considered basic to all data transmissions.

6.2.1 Accuracy

The telecommunications components of all voting systems shall meet the accuracy requirements of Subsection 4.1.1.

6.2.2 Durability

The telecommunications components of all voting systems shall meet the durability requirements of Subsection 4.3.2.

6.2.3 Reliability

The telecommunications components of all voting systems shall meet the reliability requirements of Subsection 4.3.3.

6.2.4 Maintainability

The telecommunications components of all voting systems shall meet the maintainability requirements of Subsection 4.3.4.

6.2.5 Availability

The telecommunications components of all voting systems shall meet the availability requirements of Subsection 4.3.5.

6.2.6 Integrity

For WANs using public telecommunications, boundary definition and implementation shall meet the requirements below.

a. Outside service providers and subscribers of such providers shall not be given direct access or control of any resource inside the boundary.

b. Voting system administrators shall not require any type of control of resources outside this boundary. Typically, an end point of a telecommunications circuit will be a subscriber termination on a Digital Service Unit/Customer Service Unit although the specific technology configuration may vary. Regardless of the technology used, the boundary point must ensure that everything on the voting system side is locally configured and controlled by the election jurisdiction while everything on the public network side is controlled by an outside service provider.

c. The system shall be designed and configured such that it is not vulnerable to a single point of failure in the connection to the public network which could cause total loss of voting capabilities at any polling place.

6.2.7 Confirmation

Confirmation occurs when the system notifies the user of the successful or unsuccessful completion of the data transmission, where successful completion is defined as accurate receipt of the transmitted data. To provide confirmation, the telecommunications components of a voting system shall notify the user of the successful or unsuccessful completion of the data transmission. In the event of unsuccessful transmission the user shall be notified of the action to be taken.

7 Security Requirements

Table of Contents

7 Security Requirements

7.1 Scope

This section describes essential security capabilities for a voting system, encompassing the system's hardware, software, communications and documentation. No predefined set of security standards will address and defeat all conceivable or theoretical threats. The *Guidelines* articulate requirements to achieve acceptable levels of integrity and reliability. The objectives of the security standards for voting systems are:

- To protect critical elements of the voting system
- To establish and maintain controls to minimize errors
- To protect the system from intentional manipulation, fraud and malicious mischief
- To identify fraudulent or erroneous changes to the voting system
- To protect secrecy in the voting process

The *Voting System Performance Guidelines* (Volume I of the *VVSG*) are intended to address a broad range of risks to the integrity of a voting system. While it is not possible to identify all potential risks, Volume I identifies several types of risks that must be addressed. These include:

- Unauthorized changes to system capabilities for:
    - Defining ballot formats
    - Casting and recording votes
    - Calculating vote totals consistent with defined ballot formats
    - Reporting vote totals
- Alteration of voting system audit trails
- Changing, or preventing the recording of, a vote
- Introducing data for a vote not cast by a registered voter
- Changing calculated vote totals
- Preventing access to vote data--including individual votes and vote totals--by unauthorized individuals
- Preventing access to voter identification data and data for votes cast by the voter such that an individual can determine the content of specific votes

This section describes specific capabilities that manufacturers shall integrate into a voting system to address the risks above. Several new elements have been added since the 2002 *Voting Systems Standards*:

- Requirements for software distribution to purchasing jurisdictions
- Generation of reference information to validate software
- Validation of software using the reference information

- Requirements regarding the use of wireless communications
- Requirements for DREs with voter verifiable paper trail components

The requirements apply to the broad range of hardware, software, communications components, and documentation that comprises a voting system. These requirements apply to those components that are:

- Provided by the voting system manufacturer and the manufacturer's suppliers
- Furnished by an external provider (i.e., providers of personal computers and COTS operating systems) where the components are capable of being used during voting system operation
- Developed by a voting jurisdiction

The requirements apply to all software used in any manner to support any voting-related activity, regardless of the ownership of the software or the ownership and location of the hardware on which the software is installed or operated. These requirements apply to software that operates on:

- Voting devices and vote counting devices installed at polling places under the control or authority of the voting jurisdiction
- Ballot printers, vote counting devices, and other hardware typically installed at central or precinct locations (including contractor facilities)

7.1.1 Elements of Security Outside Manufacturer Control

The requirements of this section apply to the capabilities of a voting system that must be provided by the manufacturer. However, an effective security program requires well-defined security practices by the purchasing jurisdiction and the personnel managing and operating the system. These practices include:

- Administrative and management controls for the voting system and election management--including access controls
- Internal security procedures
- Adherence to, and enforcement of, operational procedures (e.g., effective password management)
- Security of physical facilities
- Organizational responsibilities and personnel screening

Because implementation of these elements is not under the control of the manufacturer, they will be addressed in the forthcoming Management Guidelines that will address the procedural aspects of conducting elections and managing the operation of voting systems. However, manufacturers must provide appropriate system capabilities to enable the implementation of management controls.

7.1.2 Organization of This Section

The guidelines presented in this section are organized as follows:

Access Control: These standards address procedures and system capabilities that limit or detect access to critical system components in order to guard against loss of system integrity, availability, confidentiality, and accountability.

Physical Security: These standards address physical security measures and procedures that prevent disruption of the voting process at the polling place and corruption of voting data.

Software Security: These standards address the installation of software, including firmware, in the voting system and the protection against malicious software. It should be noted that computer-generated audit controls facilitate system security and are an integral part of software capability. These audit requirements are presented in Subsection 5.4.

Telecommunications and Data Transmission: These standards address security for the electronic transmission of data between system components or locations over private, public, and wireless networks.

Use of Public Communications Networks: These standards address security for systems that communicate individual votes or vote totals over public communications networks.

Wireless Communications: These standards address the security of the voting system and voting data when wireless is used.

Independent Verification Systems: This section provides an introduction to the concept of independent verification as a method to demonstrate voting system integrity. This discussion provides the context for the requirements for DREs with voter verifiable paper audit trails.

Direct-Recording Electronic Systems with Voter Verifiable Paper Audit Trails (optional): This capability is not required for national certification. These guidelines are provided for use by states that require this feature for DRE systems.

7.2 Access Control

Access controls are procedures and system capabilities that detect or limit access to system components in order to guard against loss of system integrity, availability, confidentiality, and accountability. Access controls provide reasonable assurance that system resources such as data files, application programs, and computer-related facilities and equipment are protected against unauthorized operation, modification, disclosure, loss or impairment. Unauthorized operations include modification of compiled or interpreted code, run-time alteration of flow control logic or of data, and abstraction of raw or processed voting data in any form other than a standard output report by an authorized operator.

Access controls may include physical controls, such as keeping computers in locked rooms to limit physical access, and technical controls, such as security software programs designed to prevent or detect unauthorized access to sensitive files. The access controls described in this section are limited to those controls required to be provided by system manufacturers.

7.2.1 General Access Control Policy

The manufacturer shall specify the general features and capabilities of the access control policy recommended to provide effective voting system security.

Although the jurisdiction in which the voting system is operated is responsible for determining the access policies for each election, the manufacturer shall provide a description of recommended policies for:

a. Software access controls
b. Hardware access controls
c. Communications
d. Effective password management
e. Protection abilities of a particular operating system
f. General characteristics of supervisory access privileges
g. Segregation of duties
h. Any additional relevant characteristics

7.2.1.1 Individual Access Privileges

Voting system manufacturers shall:

a. Identify each person to whom access is granted, and the specific functions and data to which each person holds authorized access
b. Specify whether an individual’s authorization is limited to a specific time, time interval or phase of the voting or counting operations
c. Permit the voter to cast a ballot expeditiously, but preclude voter access to all aspects of the vote counting processes

7.2.1.2 Access Control Measures

Manufacturers shall provide a detailed description of all system access control measures designed to permit authorized access to the system and prevent unauthorized access. Examples of such measures include:

a. Use of data and user authorization
b. Program unit ownership and other regional boundaries
c. One-end or two-end port protection devices

d. Security kernels
e. Computer-generated password keys
f. Special protocols
g. Message encryption
h. Controlled access security

Manufacturers also shall define and provide a detailed description of the methods used to prevent unauthorized access to the access control capabilities of the system itself.

7.3 Physical Security Measures

A voting system's sensitivity to disruption or corruption of data depends, in part, on the physical location of equipment and data media, and on the establishment of secure telecommunications among various locations. Most often, the disruption of voting and vote counting results from a physical violation of one or more areas of the system thought to be protected. Therefore, security procedures shall address physical threats and the corresponding means to defeat them.

7.3.1 Polling Place Security

For polling place operations, manufacturers shall develop and provide detailed documentation of measures to enable poll workers to physically protect and perform orderly shutdown of voting equipment to counteract vandalism, civil disobedience, and similar occurrences.

The measures shall allow the immediate detection of tampering with vote casting devices and precinct ballot counters. They also shall control physical access to a telecommunications link if such a link is used

7.3.2 Central Count Location Security

Manufacturers shall develop and document in detail the measures to be taken in a central counting environment. These measures shall include physical and procedural controls related to the handling of ballot boxes, preparing of ballots for counting, counting operations and reporting data.

7.4 Software Security

Voting systems shall meet specific security requirements for the installation of software and for protection against malicious software.

7.4.1 Software and Firmware Installation

The system shall meet the following requirements for installation of software, including hardware with embedded firmware.

a. If software is resident in the system as firmware, the manufacturer shall require and state in the system documentation that every device is to be retested to validate each ROM prior to the start of elections operations.
b. To prevent alteration of executable code, no software shall be permanently installed or resident in the voting system unless the system documentation states that the jurisdiction must provide a secure physical and procedural environment for the storage, handling, preparation, and transportation of the system hardware.
c. The voting system bootstrap, monitor, and device-controller software may be resident permanently as firmware, provided that this firmware has been shown to be inaccessible to activation or control by any means other than by the authorized initiation and execution of the vote counting program, and its associated exception handlers.
d. The election-specific programming may be installed and resident as firmware, provided that such firmware is installed on a component (such as a computer chip) other than the component on which the operating system resides.
e. After initiation of election day testing, no source code or compilers or assemblers shall be resident or accessible.

7.4.2 Protection Against Malicious Software

Voting systems shall deploy protection against the many forms of threats to which they may be exposed such as file and macro viruses, worms, Trojan horses, and logic bombs. Manufacturers shall develop and document the procedures to be followed to ensure that such protection is maintained in a current status.

7.4.3 Software Distribution and Setup Validation

Subsections 7.4.4, 7.4.5 and 7.4.6 specify requirements for the distribution of voting system software and the setup validation performed on voting system equipment. These requirements are applicable to voting systems that have completed certification testing. The goal of the software distribution requirements is to ensure that the correct voting system software has been distributed without modification. The goal of setup validation requirements, including requirements for verifying the presence of certified software and the absence of other software, is to ensure that voting system equipment is in a proper initial state before being used.

In general, a voting system can be considered to be composed of multiple associated systems including polling place systems, central counting/aggregation systems, and election management systems. These other systems may reside on different computer platforms at different locations and run different software. Voting system software is considered to be all executable code and associated configuration files critical for the proper operation of the voting system regardless of the location of installation and functionality provided. This includes third party software such as operating systems, drivers, and database management systems.

7.4.4 Software Distribution

a. The manufacturer shall document all software including voting system software, third party software (such as operating systems and drivers) to be installed on the certified voting system, and installation programs.
   i. The documentation shall have a unique identifier (such as a serial number or part number) for the following set of information: documentation, software manufacturer name, product name, version, the certification application number of the voting system, file names and paths or other location information (such as storage addresses) of the software.
   ii. The documentation shall designate all software files as static, semi-static or dynamic.

Discussion: Static voting system software such as executable code does not change based on the election being conducted or the voting equipment upon which it is installed. Semi-static voting system software contains configuration information for the voting system based on the voting equipment that is installed and the election being conducted. Semi-static software is only modified during the installation of (a) the voting system software on voting equipment or (b) the election-specific software such as ballot formats. Dynamic voting system software changes over time once installed on voting equipment. However, the specific time or value of the change in the dynamic software is usually unknown in advance, making it impossible to create reference information to verify the software.

b. The EAC accredited testing lab shall witness the final build of the executable version of the certified voting system software performed by the manufacturer.
   i. The testing lab shall create a complete record of the build that includes: a unique identifier (such as a serial number) for the complete record; a list of unique identifiers of unalterable storage media associated with the record; the time, date, location, names and signatures of all people present; the source code and resulting executable file names; the version of voting system software; the certification application number of the voting system; the name and versions of all (including third party) libraries; and the name, version, and configuration files of the development environment used for the build.
   ii. The record of the source code and executable files shall be made on unalterable storage media. Each piece of media shall have a unique identifier.

Discussion: Unalterable storage media includes technology such as a CD-R, but not CD-RW. The unique identifiers appear on indelibly printed labels and in a digitally signed file on the unalterable storage media.

   iii. The testing lab shall retain this record until notified by the EAC that it can be archived.

c. After EAC certification has been granted, the testing lab shall create a subset of the complete record of the build that includes a unique identifier (such as a serial number) of the subset, the unique identifier of the complete record, a list of unique identifiers of unalterable storage media associated with the subset, the manufacturer and product name, the version of voting system software, the certification number of the voting system, and all the files that resulted from the build and binary images of all installation programs.
   i. The record of the software shall be made on unalterable storage media. Each piece of media shall have a unique identifier.
   ii. The testing lab shall retain a copy, send a copy to the manufacturer, and send a copy to the NIST National Software Reference Library (NSRL)[38] and/or to any repository designated by a State.
   iii. The NSRL shall retain this software until notified by the EAC that it can be archived.

d. The manufacturer shall provide the NSRL and any repository designated by a state with a copy of the software installation disk, which the manufacturer will distribute to purchasers--including the executable binary images of all third party software.
   i. All voting system software, installation programs and third party software (such as operating systems and drivers) used to install or to be installed on voting system equipment shall be distributed using unalterable storage media.
   ii. The manufacturer shall document that the process used to verify the software distributed on unalterable storage media is the certified software by using the reference information provided by the NSRL or other designated repository before installing the software.

e. The voting system equipment shall be designed to allow the voting system administrator to verify that the software is the certified software by comparing it to reference information produced by the NSRL or other designated repository.

f. The manufacturers and testing labs shall document to whom they provide voting system software.

7.4.5 Software Reference Information

The NSRL or other repository designated by a state election office shall generate reference information using the binary images of the (a) certified voting system software received on unalterable storage media from testing labs and (b) election- specific software received on unalterable storage media from jurisdictions.

[38] The National Software Reference Library (NSRL) is a repository of software maintained by the National Institute of Standards and Technology. It was designed to meet the need for court admissible evidence in the identification of software files. The EAC has designated the NSRL as a repository for voting system software. Information is available at www.nsrl.nist.gov.

a. The NSRL or other designated repository shall generate reference information in at least one of the following forms: (a) complete binary images, (b) cryptographic hash values or (c) digital signatures of the software.

Discussion: Although binary images, cryptographic hashes, and digital signatures can detect a modification or alteration in the software, they cannot determine if the change to the software was accidental or intentional.

b. The NSRL or other designated repository shall create a record of the creation of reference information that includes: a unique identifier (such as a serial number) for the record; the file names of software and associated unique identifier(s) of the unalterable storage media from which reference information is generated; the time, date and name of people who generated reference information; the type of reference information created; the certification number of the voting system; the voting system software version; the product name; and the manufacturer name.
c. The NSRL or other designated repository shall retain the unalterable storage media used to generate the reference information until notified by the EAC that it can be archived.

7.4.5.1 Hashes and Digital Signatures

a. The NSRL or other designated repository that generates hash value and/or digital signature reference information shall use FIPS-approved algorithms for hashing and signing.
   i. The NSRL or other designated repository that generates hash values, digital signatures reference information or cryptographic keys shall use a FIPS 140-2 level 1 or higher validated cryptographic module.

Discussion: See http://www.csrc.nist.gov/cryptval/ for information on FIPS 140-2.

   ii. The NSRL or other designated repository that generates sets of hash values and digital signatures for reference information shall include a hash value or digital signature covering the set of reference information.
b. If the NSRL or other designated repository uses public key technology, the following requirements shall be met:

   i. Public and private key pairs used by the repository to generate digital signatures shall have security strength of at least 112 bits.

Discussion: The security strengths of cryptographic algorithms can be found in NIST Special Publication 800-57: Recommendation for Key Management – Part 1 General.~~be 2048 bits or greater in length~~

   i. The repository's private keys used to generate digital signature reference information shall be used for no more than three years

ii. Public keys used to verify digital signature reference information shall be placed on unalterable storage media if not contained in a signed non-proprietary format for distribution.

Discussion: Examples of non-proprietary standard formats include X.509 or PKCS#7.

iii. All copies of public key unalterable storage media made by the repository shall be labeled so that they are uniquely identifiable, including at a minimum: a unique identifier (such as a serial number) for the unalterable storage media; the time, date, location and name(s) of the repository owning the associated private keys; documentation about its creation; and an indication that the contents are public keys.

iv. The NSRL or other designated repository shall document to whom they provide unalterable storage media containing their public keys used to verify digital signature reference information including at a minimum: the uniquely identified public keys, the time and date provided, the name of the organization, and the name and contact information (phone, address, email address) of the recipient.

v. When a private key used to generate digital signature reference information becomes compromised, the NSRL or other designated repository shall provide notification to recipients of the associated public key that the private key has been compromised and the date on which it was compromised.

c. The NSRL or other designated repository shall make both the reference information available on unalterable storage media and its associated documentation that is labeled by the repository that created it uniquely identifiable by including at a minimum: a unique identifier (such as a serial number) for the storage media; the time, date, location and name of the creating repository; and an indication that the contents are reference information.

7.4.6 Software Setup Validation

The following requirements support the security of voting systems by providing methods to verify that only authorized software is present on voting systems. It includes requirements for two software verification techniques. One method verifies digital signatures on software prior to installation on pieces of voting system equipment. This is a useful mechanism that helps prevent accidental or malicious software from being installed and could be employed by any voting system to protect against unauthorized software. The second method provides an external interface to voting system software. A separate piece of equipment could use this interface to verify the software on the voting system. However, this method merely provides a mechanism for detecting unauthorized software and, by itself, does not help prevent the installation of accidental or malicious software.

a. Setup validation methods shall verify that no unauthorized software is present on the voting equipment.

b. The manufacturer shall provide a method to comprehensively list all software files that are installed on voting systems.
    i. This method shall list version names and numbers for all application software on the voting system.
    ii. This method should list of the date of installation for all application software on the voting system.

c. Setup validation methods shall include a software verification method that ensures that the voting system software has not been modified illegitimately.
    i. The voting systems shall include any supporting software and hardware necessary to conduct the software verification method.
    ii. The manufacturer shall document the process used to conduct the software verification method.
    iii. The software verification method shall not modify the voting system software on the voting system.

d. Voting systems shall include a software verification method that either verifies software prior to installation or a method that verifies software using an external interface. Voting systems may include both software verification methods. Voting systems may provide ancillary setup validation methods, including methods for verifying or identifying installed software, other than those described in this section. There are no specific requirements for ancillary setup validation methods. However, any method intended to serve as the voting system software verification method must meet the requirements outlined in this section.

e. Voting systems which implement a software verification method that verifies software prior to installation shall meet the following requirements.
    i. The voting system shall contain no more than one method for installing, updating, or removing software on a system. Voting system equipment shall prevent processes from installing software except for the one specific software installation process identified by the manufacturer.
        1. The voting system manufacturer shall document the procedures for installing, updating, and removing voting system software, configuration files, and data files.
        2. Voting system equipment shall prevent processes from installing, updating or removing software while the polls are open.
        3. Voting system equipment shall prevent the execution of software not installed using the specified software installation process.
    ii. The voting system shall only allow authenticated administrators to install software on voting equipment. The voting system shall present the administrator with a description of the software change being performed, including:
        1. A list of all applications and/or file names being updated.
        2. The type of action performed on each application and/or file (e.g., new application/file, deletion or overwriting of existing file)
    iii. Voting system equipment shall store the current version identification of all software installed on the voting system equipment.
        1. The current version identification shall be included as part of reports created by the voting system equipment.
        2. The current version identification shall be displayed as part of the voting system equipment start up process.

iv. The process for installing, updating and removing software shall make software changes based on information contained in software update packages. Software update packages shall minimally contain the following information:

1. A unique identifier for the software update package.
2. Names of the applications or files modified during the update process.
3. Version numbers of the applications or files modified during the update process.
4. Any software prerequisites or dependencies for the software involved in the update.
5. A description of the type of action performed on each application and/or file (e.g., new application/file, deletion or overwriting of existing file).
6. The binary data of any new or updated files involved in the update process.

v. The software update package shall be formatted in a non-restrictive, publicly-available format. Manufacturers shall provide a specification describing how they have implemented the format with respect to the manufacturer's specific voting devices and data, including such items as descriptions of elements, attributes, constraints, extensions, syntax and semantics of the format, and definitions for data fields and schemas.

vi. Software update packages shall be digitally signed by the National Software Reference Library (NSRL), the voting device owner, or designated notary repositories using a NIST approved algorithm with a security strength of at least 112 bits.

Discussion: NIST approved is " An algorithm or technique that meets at least one of the following: 1) is specified in a FIPS or NIST Recommendation, 2) is adopted in a FIPS or NIST Recommendation or 3) is specified in a list of NIST approved security functions (e.g., specified as approved in the annexes of FIPS 140-2/3)". The security strengths of cryptographic algorithms can be found in NIST Special Publication 800-57: Recommendation for Key Management – Part 1 General.

vii. The software installation process shall verify digital signatures, software version identification, software prerequisites and dependencies, and manufacturer specific authorization information associated with the software before the software is installed. The software installation process shall not install software with invalid digital signatures, version numbers, or manufacturer specific authorization information, and shall not install software on systems that do not meet the update requisites.

viii. The voting system shall have the capability to prevent the installation of previous versions of applications or files.

Discussion: Vulnerabilities may be discovered in older versions of software. This requirement protects against an attacker downgrading to an old version of software, seeking to exploit a known vulnerability. This could be accomplished with a flag in the software installation package which indicates whether or not it downgrades should be possible from a particular software version.

ix. The software installation process shall result in information being stored in the voting system equipment's log such that altering or deleting log entries or the log will be detected.

x. The minimum information to be included in the voting system equipment log shall be:

1. Success or failure of the software installation process;
2. Cause of a failed software installation (such as invalid version identification, digital signature, etc.);
3. Application or file name(s), and version number(s);
4. A description of the type of action performed on each application and/or file (e.g., new application/file, deletion or overwriting of existing file);
5. A cryptographic hash of the software update package using FIPS 140-2 level 1 or higher validated cryptographic module.

Discussion: The software installation process can be automated using a software program specifically designed to perform voting system equipment software installation. There are different technologies that allow log entries and logs to detect if they have been altered or deleted such as logs stored on write once media, logs stored in append only files, and logs that leverage cryptographic mechanisms.

f. If software is verified after being installed on the voting system equipment, the voting system equipment shall provide an external interface to the location of the voting system software for software verification purposes.

i. The external interface:

1. Shall be protected using tamper evident techniques,
2. Shall have a physical indicator showing when the interface is enabled and disabled
3. Shall be disabled during voting
4. Should provide a direct read-only access to the location of the voting system software without the use of installed software

ii. The verification process should be able to be performed using COTS software and hardware available from sources other than the voting system manufacturer.

1. If the process uses hashes or digital signatures, then the verification software shall use a FIPS 140-2 level 1 or higher validated cryptographic module.
2. The verification process shall either (a) use reference information on unalterable storage media received from the repository or (b) verify the digital signature of the reference information on any other media.

g. Setup validation methods shall verify that registers and variables of the voting system equipment contain the proper static and initial values.
   i. The manufacturer should provide a method to query the voting system to determine the values of all static and dynamic registers and variables including the values that jurisdictions are required to modify to conduct a specific election.
   ii. The manufacturer shall document the values of all static registers and variables, and the initial starting values of all dynamic registers and variables listed for voting system software, except for the values set to conduct a specific election.

~~a. Setup validation methods shall verify that no unauthorized software is present on the voting equipment.~~

~~b. The vendor shall have a process to verify that the correct software is loaded, that there is no unauthorized software, and that voting system software on voting equipment has not been modified, using the reference information from the NSRL or from a State designated repository.~~
   ~~i. The process used to verify software should be possible to perform without using software installed on the voting system.~~
   ~~ii. The vendor shall document the process used to verify software on voting equipment.~~
   ~~iii. The process shall not modify the voting system software on the voting system during the verification process.~~

~~c. The vendor shall provide a method to comprehensively list all software files that are installed on voting systems.~~

~~d. The verification process should be able to be performed using COTS software and hardware available from sources other than the voting system vendor.~~
   ~~i. If the process uses hashes or digital signatures, then the verification software shall use a FIPS 140-2 level 1 or higher validated cryptographic module.~~
   ~~ii. The verification process shall either (a) use reference information on unalterable storage media received from the repository or (b) verify the digital signature of the reference information on any other media.~~

~~e. Voting system equipment shall provide a means to ensure that the system software can be verified through a trusted external interface, such as a read-only external interface, or by other means.~~
   ~~i. The external interface shall be protected using tamper evident techniques~~
   ~~ii. The external interface shall have a physical indicator showing when the interface is enabled and disabled~~
   ~~iii. The external interface shall be disabled during voting~~
   ~~iv. The external interface should provide a direct read-only access to the location of the voting system software without the use of installed software~~

~~f. Setup validation methods shall verify that registers and variables of the voting system equipment contain the proper static and initial values.~~
   ~~i. The vendor should provide a method to query the voting system to determine the values of all static and dynamic registers and variables including the values that jurisdictions are required to modify to conduct a specific election.~~

~~ii. The vendor shall document the values of all static registers and variables, and the initial starting values of all dynamic registers and variables listed for voting system software, except for the values set to conduct a specific election.~~

7.5 Telecommunications and Data Transmission

There are four areas that must be addressed by telecommunications and data transmission security capabilities: access control, data integrity, detection and prevention of data interception, and protection against external threats.

7.5.1 Maintaining Data Integrity

Voting systems that use telecommunications to communicate between system components and locations are subject to the same security requirements governing access to any other system hardware, software, and data function.

a. Voting systems that use electrical or optical transmission of data shall ensure the receipt of valid vote records is verified at the receiving station. This should include standard transmission error detection and correction methods such as checksums or message digest hashes. Verification of correct transmission shall occur at the voting system application level and ensure that the correct data is recorded on all relevant components consolidated within the polling place prior to the voter completing casting of his or her ballot.

   i. Cryptography used to verify the receipt of vote records shall use NIST approved algorithms with security strength of at least 112 bits. Message Authentication Code (MAC) keys shall have a security strength of at least 112 bits.

b. Voting systems that use telecommunications to communicate between system components and locations before the polling place is officially closed shall:

   i. Implement ~~an~~ encryption using NIST approved algorithms with a security strength of at least 112 bits ~~standard currently documented and validated for use by an agency of the U.S. government~~ within a FIPS 140-2 level 1 or higher validated cryptographic module operating in FIPS mode

   ii. Provide a means to detect the presence of an intrusive process, such as an Intrusion Detection System

Discussion: NIST approved is " An algorithm or technique that meets at least one of the following: 1) is specified in a FIPS or NIST Recommendation, 2) is adopted in a FIPS or NIST Recommendation or 3) is specified in a list of NIST approved security functions (e.g., specified as approved in the annexes of FIPS 140-2/3)". The security strengths of cryptographic algorithms can be found in NIST Special Publication 800-57: Recommendation for Key Management – Part 1 General.

7.5.2 Protection Against External Threats

a. Voting systems that use public telecommunications networks shall implement protections against external threats to which commercial products used in the system may be susceptible.
b. Voting systems that use public telecommunications networks shall provide system documentation that clearly identifies all COTS hardware and software products and communications services used in the development and/or operation of the voting system, including operating systems, communications routers, modem drivers and dial-up networking software.
    i. Such documentation shall identify the name, manufacturer, and version used for each such component.
c. Voting systems that use public telecommunications networks shall use protective software at the receiving-end of all communications paths to:
    i. Detect the presence of a threat in a transmission
    ii. Remove the threat from infected files/data
    iii. Prevent against storage of the threat anywhere on the receiving device
    iv. Provide the capability to confirm that no threats are stored in system memory and in connected storage media
    v. Provide data to the system audit log indicating the detection of a threat and the processing performed
d. Manufacturers shall use multiple forms of protective software as needed to provide capabilities for the full range of products used by the voting system.

7.5.3 Monitoring and Responding to External Threats

Voting systems that use public telecommunications networks may become vulnerable, by virtue of their system components, to external threats to the accuracy and integrity of vote recording, vote counting, and vote consolidation and reporting processes. Therefore, manufacturers of such systems shall document how they plan to monitor and respond to known threats to which their voting systems are vulnerable. This documentation shall provide a detailed description, including scheduling information, of the procedures the manufacturer will use to:

a. Monitor threats, such as through the review of assessments, advisories, and alerts for COTS components issued by the Computer Emergency Response Team (CERT), for which a current listing can be found at http://www.cert.org, the

National Infrastructure Protection Center (NIPC), and the Federal Computer Incident Response Capability (FedCIRC), for which additional information can be found at www.us-cert.gov

b. Evaluate the threats and, if any, proposed responses
c. Develop responsive updates to the system and/or corrective procedures
d. Submit the proposed response to the VSTLs and appropriate states for approval, identifying the exact changes and whether or not they are temporary or permanent
e. After implementation of the proposed response is approved by the state, assist clients, either directly or through detailed written procedures, how to update their systems and/or to implement the corrective procedures within the timeframe established by the state
f. Address threats emerging too late to correct the system by:
    i. Providing prompt, emergency notification to the VSTLs and the affected states and user jurisdictions
    ii. Assisting client jurisdictions directly or advising them through detailed written procedures to disable the public telecommunications mode of the system
    iii. Modifying the system after the election to address the threat, submitting the modified system to a VSTL and the EAC or state certification authority for approval, and assisting client jurisdictions directly or advising them through detailed written procedures, to update their systems and/or to implement the corrective procedures after approval

7.5.4 Shared Operating Environment

Ballot recording and vote counting can be performed in either a dedicated or non-dedicated environment. If ballot recording and vote counting operations are performed in an environment that is shared with other data processing functions, both hardware and software features shall be present to protect the integrity of vote counting and of vote data.

Systems that use a shared operating environment shall:

a. Use security procedures and logging records to control access to system functions
b. Partition or compartmentalize voting system functions from other concurrent functions at least logically, and preferably physically as well
c. Control system access by means of passwords, and restrict account access to necessary functions only
d. Have capabilities in place to control the flow of information, precluding data leakage through shared system resources

7.5.5 Incomplete Election Returns

If the voting system provides access to incomplete election returns and interactive inquiries before the completion of the official count, the system shall:

a. Be designed to provide external access to incomplete election returns (for equipment that operates in a central counting environment), only if that access for these purposes is authorized by the statutes and regulations of the using agency. This requirement applies as well to polling place equipment that contains a removable memory module or that may be removed in its entirety to a central place for the consolidation of polling place returns
b. Design voting system software and its security environment such that data accessible to interactive queries resides in an external file or database created and maintained by the elections software under the restrictions applying to any other output report:
   i. The output file or database has no provision for write access back to the system
   ii. Persons whose only authorized access is to the file or database are denied write access, both to the file or database, and to the system

7.6 Use of Public Communications Networks

Voting systems that transmit data over public telecommunications networks face security risks that are not present in other voting systems. This section describes standards applicable to voting systems that use public telecommunications networks.

7.6.1 Data Transmission

All systems that transmit data over public telecommunications networks shall:

a. Preserve the secrecy of voter ballot selections and prevent anyone from violating ballot privacy
b. Employ digital signatures for all communications between the vote server and other devices that communicate with the server over the network
c. Require that at least two authorized election officials activate any critical operation regarding the processing of ballots transmitted over a public communications network, i.e. the passwords or cryptographic keys of at least two employees are required to perform processing of votes

Cryptography used to provide protection of data transmitted over public telecommunications networks shall use NIST approved algorithms with security strength of at least 112 bits. Message Authentication Code (MAC) keys shall have a security strength of at least 112 bits.

Discussion: The security strengths of cryptographic algorithms can be found in NIST Special Publication 800-57: Recommendation for Key Management – Part 1 General.

7.6.2 Casting Individual Ballots

Systems designed for transmission of telecommunications over public networks shall meet security standards that address the security risks attendant with the casting of ballots from polling places controlled by election officials using voting devices configured and installed by election officials and/or their manufacturer or contractor, and using in-person authentication of individual voters.

7.6.2.1 Documentation of Mandatory Security Activities

Manufacturers of voting systems that cast individual ballots over a public telecommunications network shall provide detailed descriptions of:

a. All activities mandatory to ensuring effective voting system security to be performed in setting up the system for operation, including testing of security before an election
b. All activities that should be prohibited during voting equipment setup and during the timeframe for voting operations, including both the hours when polls are open and when polls are closed

7.6.2.2 Ability to Operate During Interruption of Service

These systems shall provide the following capabilities to provide resistance to interruptions of telecommunications service that prevent voting devices at the polling place from communicating with external components via telecommunications:

a. Detect the occurrence of a telecommunications interruption at the polling place and switch to an alternative mode of operation that is not dependent on the connection between polling place voting devices and external system components
b. Provide an alternate mode of operation that includes the functionality of a conventional electronic voting system without losing any single vote
c. Create and preserve an audit trail of every vote cast during the period of interrupted communication and system operation in conventional electronic voting system mode
d. Upon reestablishment of communications, transmit and process votes accumulated while operating in conventional electronic voting system mode with all security safeguards in effect
e. Ensure that all safeguards related to voter identification and authentication are not affected by the procedures employed by the system to counteract potential interruptions of telecommunications capabilities

7.7 Wireless Communications

This section provides requirements for implementing and using wireless communications within a voting system. These requirements reduce, but do not eliminate, the risk of using wireless communications for voting systems.

Wireless is defined as any means of communications that occurs without wires. This normally covers the entire electromagnetic spectrum. For the purposes of this section, wireless includes radio frequency, infrared, and microwave. This section provides requirements and considerations that apply to external wireless communications capabilities existing on voting equipment or as a component within a voting system. These requirements may be applied to internal wireless communications, but this is not required when the physical container that houses the voting equipment or voting system is considered adequate to protect the internal wireless between or among voting system components.

Since the wireless communications path on which the signals travel is via the air and not a wire or cable, devices other than those intended to receive the wireless signal (e.g. voting data) can receive (intentionally and unintentionally) the wireless signals. Some of the wireless communications paths (i.e. signals) are weakened by walls and distance, but are not stopped. This makes it possible to eavesdrop from a distance as well as transmit wireless signals (e.g., interference or intrusive data) from a distance. In many cases, the wireless signals cannot be seen, heard, or felt, thus making the presence of wireless communication hard to determine by the human senses. The requirements in this section mitigate the risks associated with wireless by controlling and identifying usage, and protecting the transmitted data and path.

There are other concerns when evaluating wireless usage; specifically radio frequency (RF). A device’s radio frequencies usage and the power output are governed by Federal Communications Commission (FCC) regulations and therefore all RF wireless communications devices are subject to the applicable FCC requirements. However, these FCC regulations do not fully address RF wireless interference caused by multiple FCC compliant devices. That is, the RF wireless used in a voting system may be using the same radio frequency as another non-voting wireless system and which may potentially cause a degradation of the wireless performance or a complete wireless failure for the voting system.

Sometimes a particular wireless technology permits a power output range, which may be used to overcome interference received from another device. A radio emissions site test can determine the extent of potential existing interference at the location where the wireless voting system is to be used. A radio emission site test can also determine the extent that the RF wireless transmission of the voting system escapes the building in which the RF wireless voting system is used.

7.7.1 Controlling Usage

a. If wireless communications are used in a voting system, then the manufacturer shall supply documentation describing how to use all aspects of wireless communications in a secure manner. This documentation shall include:
   i. A complete description of the uses of wireless in the voting system including descriptions of the data elements and signals that are to be carried by the wireless mechanism
   ii. A complete description of the vulnerabilities associated with this proposed use of wireless, including vulnerabilities deriving from the insertion, deletion, modification, capture or suppression of wireless messages
   iii. A complete description of the techniques used to mitigate the risks associated with the described vulnerabilities including techniques used by the manufacturer to ensure that wireless cannot send or receive messages other than those situations specified in the documentation. Cryptographic techniques shall be carefully and fully described, including a description of cryptographic key generation, management, use, certification, and destruction
   iv. A rationale for the inclusion of wireless in the proposed voting system, based on a careful and complete description of the perceived advantages and disadvantages of using wireless for the documented uses compared to using non-wireless approaches

Discussion: In general, convenience is not a sufficiently compelling reason, on its own, to justify the inclusion of wireless communications in a voting system. Convenience must be balanced against the difficulty of working with cryptographic keys.

b. The details of all cryptographic protocols used for wireless communications, including the specific features and data, shall be documented.
c. The wireless documentation shall be closely reviewed for accuracy, completeness, and correctness.
d. There shall be no undocumented use of the wireless capability, nor any use of the wireless capability that is not entirely controlled by an election official.

Discussion: This can be tested by reviewing all of the software, hardware, and documentation, and by testing the status of wireless activity during all phases of testing.

e. If a voting system includes wireless capabilities, then the voting system shall be able to accomplish the same function if wireless capabilities are not available due to an error or no service.
   i. The manufacturer shall provide documentation how to accomplish these functions when wireless is not available.
f. The system shall be designed and configured so it is not vulnerable to a single point of failure using wireless communications that causes a total loss of any voting capabilities.

g. If a voting system includes wireless capabilities, then the system shall have the ability to turn on the wireless capability when it is to be used and to turn off the wireless capability when the wireless capability is not in use.
h. If a voting system includes wireless capabilities, then the system shall not activate the wireless capabilities without confirmation from an elections official.

7.7.2 Identifying Usage

Since there are a wide variety of wireless technologies (both standard and proprietary) and differing physical properties of wireless signals, it is important to identify some of the characteristics of the wireless technologies used in the voting system.

a. If a voting system provides wireless communications capabilities, then there shall be a method for determining the existence of the wireless communications capabilities.
b. If a voting system provides wireless communications capabilities, then there shall be an indication that allows one to determine when the wireless communications (such as radio frequencies) capability is active.
c. The indication shall be visual.
d. If a voting system provides wireless communications capabilities, then the type of wireless communications used (such as radio frequencies) shall be identified either via a label or via the voting system documentation.

7.7.3 Protecting Transmitted Data

The transmitted data, especially via wireless communications, needs to be protected to ensure confidentiality and integrity. Examples of election information that needs to be protected include: ballot definitions, voting device counts, precinct counts, opening of poll signal, and closing of poll signal. Examples of other information that needs to be protected include: protocol messages, address or device identification information, and passwords.

Since radio frequency wireless signals radiate in all directions and pass through most construction material, anyone may easily receive the wireless signals. In contrast, infrared signals are line of sight and do not pass through most construction material. However, infrared signals can still be received by other devices that are in the line of sight. Similarly, wireless signals can be transmitted by others to create unwanted signals. Thus, encryption is required to protect the privacy and confidentiality of the voting information.

a. All information transmitted via wireless communications shall be encrypted and authenticated--with the exception of wireless T-coil coupling--to protect against eavesdropping and data manipulation including modification, insertion, and deletion.

   i. Cryptography used for encryption and authentication shall use NIST approved algorithms with security strength of at least 112 bits. Message

Authentication Code (MAC) keys shall have a security strength of at least 112 bits. ~~The encryption shall be as defined in Federal Information Processing Standards (FIPS) 197, "Advanced Encryption Standard (AES)."~~

ii. The cryptographic modules used shall comply with FIPS 140-2, Security Requirements for Cryptographic Modules.

b. The capability to transmit non-encrypted and non-authenticated information via wireless communications shall not exist.
c. If audible wireless communication is used, and the receiver of the wireless transmission is the human ear, then the information shall not be encrypted.

Discussion: This specifically covers wireless T-Coil coupling for assistive devices used by people who are hard of hearing. NIST approved is " An algorithm or technique that meets at least one of the following: 1) is specified in a FIPS or NIST Recommendation, 2) is adopted in a FIPS or NIST Recommendation or 3) is specified in a list of NIST approved security functions (e.g., specified as approved in the annexes of FIPS 140-2/3)". Message Authentication Codes of 96 bits are conventional in standardized secure communications protocols, and acceptable to protect voting systems communications. The security strengths of cryptographic algorithms can be found in NIST Special Publication 800-57: Recommendation for Key Management – Part 1 General.

7.7.4 Protecting the Wireless Path

If wireless communications are used, then the following capabilities shall exist in order to mitigate the effects of a denial of service (DoS) attack:

a. The voting system shall be able to function properly throughout a DoS attack, since the DoS attack may continue throughout the voting period.
b. The voting system shall function properly as if the wireless capability were never available for use.
c. Alternative procedures or capabilities shall exist to accomplish the same functions that the wireless communications capability would have done.
d. If infrared is being used, the shielding shall be strong enough to prevent escape of the voting system signal, as well as strong enough to prevent infrared saturation jamming.

Discussion: Since infrared has the line-of-sight property, securing the wireless path can be accomplished by shielding the path between the communicating devices with an opaque enclosure. However, this is only practical for short distances. This shielding would also help prevent accidental eye damage from the infrared signal.

7.7.5 Protecting the Voting System

Physical security measures to prevent access to a voting system are not possible when using a wireless communications interface because there is no discrete physical communications path that can be secured.

a. The security requirements in Subsection 2.1.1 shall be applicable to systems with wireless communications.
b. The accuracy requirements in Subsection 2.1.2 shall be applicable to systems with wireless communications.
c. The use of wireless communications that may cause impact to the system accuracy through electromagnetic stresses is prohibited.
d. The error recovery requirements in Subsection 2.1.3 shall be applicable to systems with wireless communications.
e. All wireless communications actions shall be logged.
    i. The log shall contain at least the following entries: times when the wireless is activated and deactivated, services accessed, identification of device to which data was transmitted to or received from, identification of authorized user, and successful and unsuccessful attempts to access wireless communications or service.

> Discussion: Other information such as the number of frames or packets transmitted or received at various logical layers may be useful, but is dependent on the wireless technology used.

f. Device authentication shall occur before any access to, or services from, the voting system are granted through wireless communications.

> Discussion: Authentication is an important element to protect the security of wireless communications. Authentication verifies the identity and legitimacy of users, devices, and services.

    i. User authentication shall be at least level 2 as per NIST Special Publication 800-63 Version 1.0.1, Electronic Authentication Guideline.

7.8 Independent Verification Systems

7.8.1 Overview

Independent verification (IV) systems are electronic voting systems that produce multiple independent cast vote records of voter ballot selections, which can be audited to a high level of precision. For this to happen, the cast vote records must be handled according to the following protocol:

- At least two cast vote records of the voter's selections are produced and one of the records is then stored in a manner that it cannot be modified by the voting system. For example, the voting system creates a record of the voter's selections and then copies it to unalterable storage media.
- The voter must be able to verify that both cast vote records are correct and match before leaving the polling place, e.g., verify his or her selections on the voting machine summary screen and also verify the second record on the unalterable storage media.
- The verification processes for the two cast vote records must be independent of each other, and at least one of the records must be verified directly by the voter.
- The contents of the two cast vote records also can be checked later for consistency through the use of unique identifiers that allow the records to be linked.

The cast vote records would be formatted so that at least one set is usable in an efficient counting process by the electronic voting system and the other set is usable in an efficient process of auditing or verifying the agreement between the two sets.

Given these conditions, the multiple cast vote records are considered to be distinct and independently verifiable, that is, both records are not under the control of the same system processes. As a result of this independence, the audit records can be used to check the accuracy of the counted records. Because the records are separately stored, an attacker who can compromise one will also have to compromise the other.

The voter verifiable paper audit trail (VVPAT) methodology is one of several classes of IV systems. In this approach, the voter can directly compare the electronic summary screen of the voting machine with the printed paper audit record. (This is not to be confused with the paper ballot that is produced by optical scan voting systems that the voter visually verifies before placing it in the ballot box or tabulator.) Requirements for DREs with a VVPAT feature are provided below to reflect the fact that a number of States currently require this feature.

There are a variety of other IV approaches for the voter to verify his or her selections with systems that produce an electronic record for verification. Appendix C describes the characteristics of these systems in more detail. They include:

- Split process systems, which use separate devices for the voters to record and verify their ballot selections
- Cryptographic systems, which provide voters with coded receipts that can be used to verify their ballot selections
- Witness systems, which use an independent module to create the second record

7.8.2 Basic Characteristics of IV Systems

This section describes a preliminary set of basic characteristics that apply to all types of IV systems. This information is provided for the purpose of introducing these concepts for consideration in voting system design. It is anticipated that future voting systems will be required to provide some type of independent verification feature to enable voters to have confidence that their ballot selections are correctly recorded and counted.

An independent verification system produces at least two independent cast vote records of ballot selections via interactions with the voter, such that one record can be compared against the other to check their equality of content.

Discussion: This is the fundamental characteristic of IV systems. The records can be checked against one another to determine whether or not the voter selections are correctly recorded.

The voter verifies the content of each cast vote record and either (a) verifies at least one of the records directly or (b) verifies both records indirectly if the records are each under the control of independent processes.

Discussion: Direct verification involves using human senses; for example, directly reading a paper record via one's eyesight. Indirect verification involves using an intermediary to perform the verification; for example, verifying an electronic ballot image on the voting machine.

The creation, storage and handling of the cast vote records are sufficiently separate that the failure or compromise of one record does not cause the failure or compromise of another.

Discussion: The records must be stored on different media and handled independently of each other so that no one process could compromise all records. If an attack can alter one record, it should still be very difficult to alter the other record.

Both cast vote records are highly resistant to damage or alteration and capable of long-term storage.

Discussion: The records should be difficult to alter or damage so that they could be used in case the counted records are damaged or lost.

The processes of verification for the cast vote records do not all depend on the same device, software module, or system for their integrity, and are sufficiently separate that each record provides evidence of the voter's selections independently of its corresponding record.

Discussion: For example, the verification of the summary screen (electronic record) of a DRE is sufficiently separate from the verification of a paper record printed by a VVPAT component or a copy of the electronic record stored on a separate system.

The multiple cast vote records are linked to their corresponding audit records by including a unique identifier within each record.

Discussion: The identifier serves the purpose of uniquely identifying and linking the records for cross-checking.

Each cast vote record includes information identifying the following:

- An identification of the polling place and precinct
- Whether the balloting is provisional, early, or on election day
- Ballot style
- A timestamp generated when the voting machine is enabled to begin a voting session that can be used to correctly group the cast vote records
- A unique identifier associated with the voting machine

Discussion: The identifier could be a serial number or other unique ID.

The cryptographic software used in IV systems are NIST approved algorithms with a security strength of at least 112 bits, Message Authentication Codes (MAC) with keys having a security strength of at least 112 bits ~~is approved by the U.S. Government's Cryptographic Module Validation Program,~~ and be implemented in a FIPS 140-2 level 1 or higher validated cryptographic module operating in FIPS mode, as applicable.

Discussion: IV voting systems may use cryptographic software for a number of different purposes, including calculating checksums, encrypting records, authentication, generating random numbers, and for digital signatures. NIST approved is " An algorithm or technique that meets at least one of the following: 1) is specified in a FIPS or NIST Recommendation, 2) is adopted in a FIPS or NIST Recommendation or 3) is specified in a list of NIST approved security functions (e.g., specified as approved in the annexes of FIPS 140-2/3)". The security strengths of cryptographic algorithms can be found in NIST Special Publication 800-57: Recommendation for Key Management – Part 1 General. ~~This software should be reviewed and approved by the Cryptographic Module Validation Program (CMVP).~~ There may by cryptographic voting schemes where the cryptographic algorithms used are necessarily different from any algorithms that have approved CMVP implementations, thus CMVP-approved software shall be used where feasible. The CMVP website is http://csrc.nist.gov/cryptval.

7.9 Voter Verifiable Paper Audit Trail Requirements

This section contains requirements for DREs with a Voter Verifiable Paper Audit Trail (VVPAT) component, henceforth referred to as VVPAT voting systems. A VVPAT voting system shall consist minimally of the following fundamental components:

- A voting device, on which a voter makes selections and prepares to cast a ballot;

- A printer that prints a paper record summary of the voter's ballot selections, and that allows the voter to compare it with the electronic ballot selections;
- A mechanism by which the voter may indicate acceptance or rejection of the VVPR;
- Ballot box/cartridge to contain accepted and voided paper records; and
- A paper record for each electronic ballot image. The paper record may be printed on a separate sheet for each record ("cut-sheet VVPAT") or on a continuous paper roll ("paper-roll VVPAT").

VVPAT capability is not required for national certification. However, these requirements will be applied for certification testing of DRE systems that are intended for use in states that require DREs to provide this capability. The manufacturer's certification testing application to the EAC must indicate whether the system being presented for testing includes this capability, as provided under Subsection 1.6.2.5 extensions.

~~This section contains requirements for DREs with a Voter Verifiable Paper Audit Trail (VVPAT) component.~~

7.9.1 Display and Print a Paper Record

a. VVPAT voting systems shall provide capabilities for the voter to review a paper record of ballot selections and a summary of the voter's electronic ballot selections prior to casting a ballot.
b. VVPAT voting systems shall create a paper record that election officials can use to reconstruct the full set of totals from the election.
c. Each paper record shall contain a human-readable summary of the electronic ballot image record. In addition, all paper records shall contain audit-related information including:
    i. Polling place;
    ii. Reporting context, such as precinct or election district;
    iii. Ballot configuration;
    iv. Date of election; and
    v. Complete summary of voter's choices.

~~a. The voting system shall print and display a paper record of the voter ballot selections prior to the voter making his or her selections final by casting the ballot.~~

~~Discussion: This is the basic requirement for VVPAT capability. It requires the paper record to be created as a distinct representation of the voter ballot selections. It requires the paper record to contain the same information as the electronic record and be suitable for use in verifications of the voting machine's electronic records.~~

~~b. The paper record shall constitute a complete record of ballot selections that can be used to assess the accuracy of the voting machine's electronic record, to verify the election results, and, if required by state law, in full recounts.~~

~~Discussion: This requirement exists to make clear that it is possible to use the paper record for checks of the voting machine's accuracy in recording voter ballot selections, as well as usable for election audits (such as mandatory 1% recounts). The paper record shall also be suitable for use in full recounts of the election if required by state law.~~

~~c. The paper record shall contain all voter selection information stored in the electronic (ballot image) record.~~

~~Discussion: The electronic ballot image record cannot hide any information related to ballot selections; all information relating to voter selections must be equally present in both records. The electronic record may contain other items that don't necessarily need to be on the paper record, such as digital signature information.~~

7.9.2 Approve or Void the Paper Record

a. The VVPAT voting system format and presentation of the paper record and electronic summaries of ballot selections shall be designed to facilitate the voter's comparison between the electronic ballot selections and the paper record.

b. When a voter indicates that the paper record is to be accepted, the VVPAT voting system shall:
   i. Immediately print an indication that the vote has been accepted, in view of the voter;
   ii. Electronically store the electronic ballot image record as a cast vote; and
   iii. Deposit the paper record into a secure receptacle.

c. When a voter indicates that the paper record is to be rejected, the VVPAT voting system shall:
   i. Immediately print an unambiguous indication that the vote has been rejected, in view of the voter;
   ii. Electronically store a record that the paper record was rejected; and
   iii. Deposit the rejected paper record into the secure receptacle.

d. The VVPAT voting system shall have the capacity to be configured to limit the number of times a single voter may reject a paper record without election official intervention. The VVPAT voting system shall support limits between zero (any rejected paper record requires election official intervention) to five times, and may support an unlimited number of rejections without election official intervention.

e. The VVPAT voting system shall have the capacity to limit the total number of paper records that a machine may reject before election official intervention is required. The VVPAT voting system shall permit the setting of no limit, so that no number of total rejected paper records requires immediate election official intervention.

f. When a VVPAT voting system reaches a configured limit of rejected paper records per voter or per machine, it shall do the following:
   i. Remove any indication of the voter's choices from the screen;

ii. Place the paper record that has been rejected into the ballot box or other receptacle;
iii. Clearly display that a paper record has been rejected and indicate the need for election official intervention; and
iv. Suspend normal operations until re-enabled by an authorized election official.

~~a. The voting equipment shall allow the voter to approve or void the paper record.~~

~~Discussion: There are three possible scenarios regarding the voter's disposition of the paper record.~~

- ~~The voter can verify that the ballot selections displayed on the DRE summary screen and those printed on the paper record are the same. If they are, and the voter is satisfied with these selections, the voter can proceed to cast his or her ballot, thereby approving the paper record.~~
- ~~If the selections match, but the voter wishes to change one or more selections, the paper record must be voided so a new paper record can be created to compare to the new summary screen displayed after the voter changes his or her ballot selections.~~
- ~~In the event the selections do not match between the summary screen and the paper record, the voter shall immediately request assistance from a poll worker. A non-match could indicate a potential voting machine or printer malfunction.~~

~~b. The voting equipment shall, in the presence of the voter, mark the paper record as being approved by the voter if the ballot selections are accepted; or voided or if the voter decides to change one or more selections.~~
~~c. If the records do not match, the voting equipment shall mark and preserve the paper record and shall provide a means to preserve the corresponding electronic record so the source of error or malfunction can be analyzed.~~

~~Discussion: The voting machine shall be withdrawn from service immediately and its use discontinued in accordance with jurisdiction procedures.~~

~~d. The voting machine shall not record the electronic record until the paper record has been approved by the voter.~~
~~e. Vendor documentation shall include procedures to enable the election official to return a voting machine to correct operation after a voter has used it incompletely or incorrectly. This procedure shall not cause discrepancies between the tallies of the electronic and paper records.~~

7.9.3 Electronic and Paper Record Structure

a. Electronic ballot images shall be recorded in a randomized order by the voting system for the election. For each voted ballot, this includes:
i. Ballot configuration and counting context;

ii. For each contest:
   1. The choice recorded, including undervotes and write-ins; and
   2. Any information collected by the vote-capture device electronically about each write-in;

iii. Information specifying whether the ballot is provisional, early voting or election day voting.

iv. Information linking the electronic ballot image to a paper record, if such functionality is enabled in the voting system.

Discussion: NIST Special Publication 800-90: Recommendation for Random Number Generation Using Deterministic Random Bit Generators specifies techniques for the generation of random numbers that can be used to randomize the order of ballot images in a cryptographically sound way, Types of provisional ballots (such as "regular provisional", "extended hours provisional", and "regular extended hours") are jurisdiction-dependent.

b. The voting system shall provide the capability to export the collection of electronic ballot images in a publicly documented format, such as XML, or include a utility to export the records into a publicly documented format for offline viewing.

c. Electronic ballot images shall be digitally signed by the voting system. The digital signature shall be generated using a NIST-approved digital signature algorithm with a security strength of at least 112 bits implemented within a FIPS 140-2 validated cryptographic module operating in FIPS mode.

Discussion: NIST approved is " An algorithm or technique that meets at least one of the following: 1) is specified in a FIPS or NIST Recommendation, 2) is adopted in a FIPS or NIST Recommendation or 3) is specified in a list of NIST approved security functions (e.g., specified as approved in the annexes of FIPS 140-2/3)". The security strengths of cryptographic algorithms can be found in NIST Special Publication 800-57: Recommendation for Key Management – Part 1 General.

d. The human-readable contents of the paper record should be created in a manner that is machine-readable by optical character recognition.

e. Paper-roll VVPAT voting systems shall mark paper rolls with the following:
   i. Polling place;
   ii. Reporting context, such as precinct or election district;
   iii. Date of election;
   iv. If multiple paper rolls were produced during this election on this device, the number of the paper roll (e.g., Roll #2); and
   v. A final summary line specifying how many total paper records appear on the roll, and how many accepted paper records appear on the roll.

f. Paper-roll VVPAT voting systems shall include the following on each paper record:
   i. Ballot configuration;
   ii. Type of voting (e.g., provisional, early, etc.);

   iii. Complete summary of voter's choices;
   iv. For each ballot contest:
      1. Contest name (e.g., "Governor");
      2. Any additional information needed for unambiguous interpretation of the paper record;
      3. An indication, if the contest was undervoted; and
      4. An indication, if the choice is a write-in vote.
   v. An indication of whether the ballot has been accepted or rejected by the voter.

g. Paper-roll VVPAT voting systems shall not split paper records across rolls; each paper record must be contained in its entirety by the paper roll.

h. Cut-sheet VVPAT voting systems shall include the following on each paper record:
   i. Polling place;
   ii. Reporting context, such as precinct or election district;
   iii. Date of election;
   iv. Ballot configuration
   v. Type of voting (e.g., provisional, early, etc.);
   vi. Complete summary of voter's choices;
   vii. For each ballot contest:
      1. Contest name (e.g., "Governor");
      2. Any additional information needed for unambiguous interpretation of the paper record;
      3. An indication, if the contest was undervoted; and
      4. An indication, if the choice is a write-in vote.
   viii. An indication of whether each sheet has been accepted or rejected by the voter.

i. If a cut-sheet VVPAT voting system splits paper records across multiple sheets of paper, each sheet shall include:
   i. Page number of this sheet and total number of sheets (e.g., page 1 of 4);
   ii. Ballot configuration
   iii. Reporting context, such as precinct or election district
   iv. An indication that the sheet's contents have been accepted or rejected by the voter; and
   v. Any correspondence information included to link the paper record to its corresponding electronic ballot image record.

j. If a cut-sheet VVPAT voting system splits paper record across multiple sheets of paper, it shall not split ballot contests across sheets.

k. If a cut-sheet VVPAT voting system splits paper records across multiple sheets of paper, the ballot choices on each sheet shall be submitted to the voter for verification separately according to the following:
   i. The voter shall be presented a verification screen for the contents of each sheet separately at the same time as the voter is able to verify the contents of the part of the paper record on the sheet;
   ii. When a voter accepts or rejects the contents of a sheet, the votes contained on that sheet and verification screen shall be committed to memory, regardless of the verification of any other sheet by the same voter;
   iii. Configurable limits on rejected paper records per voter shall count each rejected sheet as a rejected paper record;

iv. Configurable limits on rejected paper records per machine shall not count more than one rejected paper record per voter; and

v. When a rejected paper record requires election official intervention, the VVPAT voting system shall indicate which sheets have been accepted and which rejected.

l. The VVPAT voting system shall provide a capability to print information on each paper record sufficient for auditors to identify from an electronic ballot image record its corresponding paper record and from a paper records its corresponding electronic ballot image. This capability shall be possible for election officials to enable or disable.

m. Any information on the paper record that identifies the corresponding electronic ballot image should not be practical for the voter to read or copy by hand.

n. The VVPAT voting system manufacturer shall include a capability for auditors to verify the correspondence between the electronic ballot image and paper record pairs, if the correspondence information is printed on the paper record.

~~a. All cryptographic software in the voting system shall be approved by the U.S. Government's Cryptographic Module Validation Program, as applicable.~~

~~Discussion: Cryptographic software may be used for a number of different purposes, including calculating checksums, encrypting records, authentication, generating random numbers, and digital signatures. This software should be reviewed and approved by the Cryptographic Module Validation Program (CMVP). There may be cryptographic voting schemes where the cryptographic algorithms used are necessarily different from any algorithms that have approved CMVP implementations, thus CMVP approved software should be used where feasible but is not required. The CMVP website is http://csrc.nist.gov/cryptval.~~

~~b. The electronic ballot image and paper records shall include information about the election.~~

~~i. The voting equipment shall be able to include an identification of the particular election, the voting site and precinct, and the voting machine.~~

~~Discussion: If the voting site and precinct are different, both should be included.~~

~~ii. The records shall include information identifying whether the balloting is provisional, early, or on election day, and information that identifies the ballot style in use.~~

~~iii. The records shall include a voting session identifier that is generated when the voting equipment is placed in voting mode, and that can be used to identify the records as being created during that voting session.~~

~~Discussion: If there are several voting sessions on the same voting machine on the same day, the voting session identifiers must be different. They should be generated from a random number generator.~~

~~c. The electronic ballot image and paper records shall be linked by including a unique identifier within each record that can be used to identify each record uniquely and each record's corresponding record.~~

~~Discussion: he identifier serves the purpose of uniquely identifying and linking the records for cross-checking.~~

~~d. The voting machine should generate and store a digital signature for each electronic record.~~

~~e. The electronic ballot image records shall be able to be exported for auditing or analysis on standards-based and /or COTS information technology computing platforms.~~

~~i. The exported electronic ballot image records shall be in a publicly available, non-proprietary format.~~

~~Discussion: It is advantageous when all electronic records, regardless of manufacturer, use the same format or can easily be converted to a publicly available, non-proprietary format; for example, the OASIS Election Markup Language (EML) Standard.~~

~~ii. The records should be exported with a digital signature, which shall be calculated on the entire set of electronic records and their associated digital signatures.~~

~~Discussion: This is necessary to determine if records are missing or substituted.~~

~~iii. The voting system vendor shall provide documentation as to the structure of the exported ballot image records and how they shall be read and processed by software.~~

~~iv. The voting system vendor shall provide a software program that will display the exported ballot image records and that may include other capabilities such as providing vote tallies and indications of undervotes.~~

~~v. The voting system vendor shall provide full documentation of procedures for exporting electronic ballot image records and reconciling those records with the paper audit records.~~

~~f. The paper record should be created in a format that may be made available across different manufacturers of electronic voting systems.~~

~~Discussion: There may be a future requirement for some commonality in the format of paper records.~~

~~g. The paper record shall be created such that its contents are machine readable.~~

~~Discussion: This can be done by using specific OCR fonts or barcodes.~~

i. ~~The paper record shall contain error correcting codes for the purpose of detecting read errors and for preventing other markings on the paper record from being misinterpreted when machine reading the paper record.~~

~~Discussion: This requirement is not mandatory if a state prohibits the paper record from containing any information that cannot be read and understood by the voter. This requirement serves the purpose of detecting scanning errors and preventing stray or deliberate markings on the paper from being interpreted as valid data.~~

h. ~~If barcode is used, the voting equipment shall be able to print a barcode with each paper record that contains the human-readable contents of the paper record.~~

~~Discussion: This requirement is not mandatory if a state prohibits the paper record from containing any information that cannot be read and understood by the voter.~~

i. ~~The barcode shall use an industry standard format and shall be able to be read using readily available commercial technology.~~

~~Discussion: Examples of such codes are Maxi Code or PDF417.~~

ii. ~~If the corresponding electronic record contains a digital signature, the digital signature shall be included in the barcode on the paper record.~~
iii. ~~The barcode shall not contain any information other than the paper record's human-readable content, error correcting codes, and digital signature information.~~

7.9.4 Equipment Security and Reliability

a. The VVPAT printer shall be physically connected via a standard, publicly documented printer port using a standard communications protocol.
b. Tamper-evident seals or physical security measures shall protect the connection between the printer and the voting machine.
c. If the connection between the voting machine and the printer has been broken, the voting machine shall detect this event and record it in the system event log.
d. The VVPAT voting system shall detect printer errors that may prevent paper records from being correctly displayed, printed or stored, such as lack of consumables such as paper, ink, or toner, paper jams/misfeeds, and memory errors.
e. If a printer error or malfunction is detected, the VVPAT voting system shall:
    i. Present a clear indication to the voter and election officials of the malfunction. This must indicate clearly whether the current voter's vote has been cast, discarded, or is waiting to be completed;
    ii. Suspend voting operations until the problem is resolved;

   iii. Allow canceling of the current voter's electronic ballot image by election officials in the case of an unrecoverable error; and
   iv. Protect the privacy of the voter while the error is being resolved.

f. Procedures for recovery from printer errors on paper-roll VVPAT voting systems shall not expose the contents of previously cast paper records.

g. Paper-roll VVPAT voting systems shall be designed so that when the rolls are removed from the voting device according to the following:
   i. All paper records are contained inside the secure container;
   ii. The container supports being tamper-sealed and locked; and
   iii. The container supports being labeled with the device serial number, precinct, and other identifying information to support audits and recounts.

h. If a continuous paper spool is used to store paper records, the manufacturer shall provide a mechanism for an auditor to unspool the paper, view each paper record in its entirety, and then respool the paper, without modifying the paper in any way.

i. The printer shall not be permitted to communicate with any system or machine other than the voting machine to which it is connected.

j. The printer shall only be able to function as a printer; it shall not contain any other services (e.g., provide copier or fax functions) or network capability.

k. Protective coverings intended to be transparent on voting equipment shall be maintainable via a predefined cleaning process. If the coverings become damaged such that they obscure the paper record, they shall be replaceable.

l. The paper record shall be of sufficient durability to remain unchanged for minimally 22 months to be used for verifications, reconciliations, and recounts conducted manually or by automated processing.

~~a. The voting machine shall provide a standard, publicly documented printer port (or the equivalent) using a standard communication protocol.~~

~~Discussion: Using a standard, publicly documented printer protocol assists in security evaluations of system software.~~

~~b. Tamper-evident seals or physical security measures shall protect the connection between the printer and the voting machine.~~

~~c. If the connection between the voting machine and the printer has been broken, the voting machine shall detect this event and record it in the DRE internal audit log.~~

~~d. The paper path between the printing, viewing and storage of the paper record shall be protected and sealed from access except by authorized election officials.~~

~~e. The printer shall not be permitted to communicate with any system or machine other than the voting machine to which it is connected.~~

~~f. The printer shall only be able to function as a printer; it shall not contain any other services (e.g., provide copier or fax functions) or network capability.~~

~~g. The voting machine shall detect errors and malfunctions such as paper jams or low supplies of consumables such as paper and ink that may prevent paper records from being correctly displayed, printed or stored.~~

~~Discussion: This could be accomplished in a variety of different ways; for example, a printer that is out of paper or jammed could issue audible alarms, with the alarm different for each condition.~~

~~h. If an error or malfunction occurs, the voting machine shall suspend voting operations and should present a clear indication to the voter and election officials of the malfunction.~~
~~i. The voting machine shall not record votes if an error or malfunction occurs.~~
~~j. Printing devices should contain sufficient supplies of paper and ink to avoid reloading or opening equipment covers or enclosures and thus potential circumvention of security features; or be able to reload paper and ink with minimal disruption to voting and without circumvention of security features such as seals.~~
~~k. Vendor documentation shall include procedures for investigating and resolving printer malfunctions including, but not limited to; printer operations, misreporting of votes, unreadable paper records, and power failures.~~
~~l. Vendor documentation shall include printer reliability specifications including Mean Time Between Failure estimates, and shall include recommendations for appropriate quantities of backup printers and supplies.~~
~~m. Protective coverings intended to be transparent on voting equipment shall be maintainable via a predefined cleaning process. If the coverings become damaged such that they obscure the paper record, they shall be replaceable.~~
~~n. The paper record shall be sturdy, clean, and of sufficient durability to be used for verifications, reconciliations, and recounts conducted manually or by automated processing.~~

7.9.5 Preserving Voter Privacy

VVPAT records can be printed and stored by two different methods:

- Printed and stored on a continuous spool-to-spool paper roll where the voter views the paper record in a window
- Printed on separate pieces of paper, which are deposited in a secure receptacle.

If a requirement applies to only one method, that will be specified. Otherwise, the requirement applies to both.

a. Voter privacy shall be preserved during the process of recording, verifying and auditing his or her ballot selections.

Discussion: The privacy requirements from Section 3 also apply to voting equipment with VVPAT.

b. When a VVPAT with a spool-to-spool continuous paper record is used, a means shall be provided to preserve the secrecy of the paper record of voter selections.

c. When a VVPAT with a spool-to-spool continuous paper record is used, no record shall be maintained of which voters used which voting machine or the order in which they voted.
d. The electronic and paper records shall be created and stored in ways that preserve the privacy of the voter.

Discussion: For VVPAT systems that use separate pieces of paper for the record, this can be accomplished in various ways including shuffling the order of the records or other methods to separate the order of stored records.

e. The privacy of voters whose paper records contain an alternative language shall be maintained.
f. Unique identifiers shall not be displayed in a way that is easily memorable by the voter.

Discussion: Unique identifiers on the paper record are displayed or formatted in such a way that they are not memorable to voters, such as by obscuring them in other characters.

g. Both paper rolls and paper record secure receptacles shall be controlled, protected, and preserved with the same security as a ballot box.

7.9.6 VVPAT Usability

a. All usability requirements from Subsection 3.1 shall apply to voting machines with VVPAT.

Discussion: The requirements in this section are in addition to those in Subsection 3.1.

b. The voting equipment shall be capable of showing the information on the paper in a font size of at least 3.0 mm and should be capable of showing the information in at least two font ranges; 3.0–4.0 mm, and 6.3–9.0 mm, under control of the voter or poll worker.

Discussion: In keeping with requirements in Subsection 3.1, the paper record should use the same font sizes as displayed by the voting machine, but at least be capable of 3.0 mm. While larger font sizes may assist voters with poor vision, certain disabilities such as tunnel vision are best addressed by smaller font sizes.

c. The voting equipment shall display, print and store the paper record in any of the written alternative languages chosen for the ballot.
    i. To assist with manual auditing, candidate names on the paper record shall be presented in the same language as used on the DRE summary screen.

ii. Information on the paper record not needed by the voter to perform verification shall be in English.

Discussion: In addition to the voter ballot selections, the marking of the paper record as accepted or void, and the indication of the ballot page number need to be printed in the alternative language. Other information, such as precinct and election identifiers, shall be in English to facilitate use of the paper record for auditing.

d. The paper and electronic records shall be presented to allow the voter to read and compare the records without the voter having to shift his or her position.
e. If the paper record cannot be displayed in its entirety on a single page, a means shall be provided to allow the voter to view the entire record.

Discussion: Possible solutions include scrolling the paper or printing a new sheet of paper. The voter should be notified if it is not possible to scroll in reverse, so they will know to complete verification in one pass.

f. If the paper record cannot be displayed in its entirety on a single page, each page of the record shall be numbered and shall include the total count of pages for the record.

Discussion: Possible numbering schemes include "Page X of Y."

g. The instructions for performing the verification process shall be made available to the voter in a location on the voting machine.

Discussion: All instructions must meet the usability requirements contained in Subsection 3.1.

7.9.7 VVPAT Accessibility

a. All accessibility requirements from Subsection 3.2 shall apply to voting machines with VVPAT.
b. If the normal voting procedure includes VVPAT, the accessible voting equipment should provide features that enable voters who are visually impaired and voters with an unwritten language to perform this verification. If state statute designates the paper record produced by the VVPAT to be the official ballot or the determinative record on a recount, the accessible voting equipment shall provide features that enable visually impaired voters and voters with an unwritten language to review the paper record.

Discussion: For example, the accessible voting equipment might provide an automated reader that converts the paper record contents into audio output.

8 Quality Assurance Requirements

Table of Contents

8 Quality Assurance Requirements

8.1 Scope

Quality assurance provides continuous confirmation that a voting system conforms with the *Guidelines* and to the requirements of state and local jurisdictions. Quality assurance is a manufacturer function that is initiated prior to system development and continues throughout the maintenance life cycle of the voting system. Quality assurance focuses on building quality into a voting system and reducing dependence on system tests at the end of the life cycle to detect deficiencies, thus helping ensure the system:

- Meets stated requirements and objectives
- Adheres to established standards and conventions
- Functions consistently with related components and meets dependencies for use within the jurisdiction
- Reflects all changes approved during its initial development, internal testing, national certification, and, if applicable, state certification processes

8.2 General Requirements

The voting system manufacturer is responsible for designing and implementing a quality assurance program to ensure that the design, workmanship, and performance requirements are achieved in all delivered systems and components. At a minimum, this program shall:

a. Include procedures for specifying, procuring, inspecting, accepting, and controlling parts and raw materials of the requisite quality
b. Require the documentation of the hardware and software development process
c. Identify and enforce all requirements for:
   i. In-process inspection and testing that the manufacturer deems necessary to ensure proper fabrication and assembly of hardware
   ii. Installation and operation of software and firmware
d. Include plans and procedures for post-production environmental screening and acceptance testing
e. Include a procedure for maintaining all data and records required to document and verify the quality inspections and tests

8.3 Components from Third Parties

A manufacturer who does not manufacture all the components of its voting system, but instead procures components as standard commercial items for assembly and integration into a voting system, shall verify that the supplier manufacturers follow documented quality assurance procedures that are at least as stringent as those used internally by the voting system manufacturer.

8.4 Responsibility for Tests

The manufacturer or manufacturer shall be responsible for performing all quality assurance tests, acquiring and documenting test data, and providing test reports for examination by the VSTL as part of the national certification process. These reports shall also be provided to the purchaser upon request.

8.5 Parts and Materials Special Tests and Examinations

In order to ensure that voting system parts and materials function properly, manufacturers shall:

a. Select parts and materials to be used in voting systems and components according to their suitability for the intended application. Suitability may be determined by similarity of this application to existing standard practice or by means of special tests
b. Design special tests, if needed, to evaluate the part or material under conditions accurately simulating the actual voting system operating environment
c. Maintain the resulting test data as part of the quality assurance program documentation

8.6 Quality Conformance Inspections

The manufacturer performs conformance inspections to ensure the overall quality of the voting system and components delivered to the VSTL for national certification testing and to the jurisdiction for implementation.

To meet the conformance inspection requirements the manufacturer or manufacturer shall:

a. Inspect and test each voting system or component to verify that it meets all inspection and test requirements for the system
b. Deliver a record of tests or a certificate of satisfactory completion with each system or component

8.7 Documentation

Manufacturers are required to produce documentation to support the independent testing required for their products to be granted national certification. Volume II, Section 2, Description of the Technical Data Package, identifies the documentation required for the national certification testing process. This documentation shall be sufficient to serve the needs of the VSTL, election officials, and maintenance technicians. It shall be prepared and published in accordance with standard commercial practice for information technology and electronic and mechanical equipment. It shall include, at a minimum, the following:

- System overview
- System functionality description
- System hardware specification
- Software design and specifications
- System security specification
- System test and verification specification
- System operations procedures
- System maintenance procedures
- Personnel deployment and training requirements
- Configuration management plan
- Quality assurance program
- System change notes

9 Configuration Management Requirements

Table of Contents

9 Configuration Management Requirements

9.1 Scope

This section contains specific requirements for configuration management of voting systems. For the purpose of the *Guidelines*, configuration management is defined as a set of activities and associated practices that ensures full knowledge and control of the components of a system, starting with its initial development and progressing through its ongoing maintenance and enhancement. This section describes activities in terms of their purposes and outcomes. It does not describe specific procedures or steps to be employed to accomplish them. Specific steps and procedures are left to the manufacturer to select.

Manufacturers are required to submit these procedures as part of the Technical Data Package for system certification. State or local election legislation, regulations, or contractual agreements may require the manufacturer to conform to additional requirements for configuration management or to adopt specific required procedures. EAC and state and local election officials reserve the right to inspect manufacturer facilities and operations to determine conformance with the manufacturer's reported procedures and with these requirements.

9.1.1 Configuration Management Requirements

Configuration management addresses a broad set of record keeping, auditing, and reporting activities that contribute to full knowledge and control of a system and its components. These activities include:

- Identifying discrete system components
- Creating records of a formal baseline and later versions of components
- Controlling changes made to the system and its components
- Releasing new versions of the system
- Auditing the system, including its documentation, against configuration management records
- Controlling interfaces to other systems
- Identifying tools used to build and maintain the system

9.1.2 Organization of Configuration Management Requirements

The requirements for configuration management include:

- Application of configuration management requirements

- Configuration management policy
- Configuration identification
- Baseline, promotion, and demotion procedures
- Configuration control procedures
- Release process
- Configuration audits
- Configuration management resources

9.1.3 Application of Configuration Management Requirements

Requirements for configuration management apply to all components of voting systems regardless of the specific technologies employed. These components include:

- Software
- Hardware
- Communications
- Documentation
- Identification and naming conventions (including changes to these conventions) for software programs and data files
- Development and testing artifacts such as test data and scripts
- File archiving and data repositories

9.2 Configuration Management Policy

The manufacturer shall describe its policies for configuration management in the Technical Data Package. This description shall address the following elements:

- Scope and nature of configuration management program activities
- Breadth of application of the manufacturer's policies and practices to the voting system, i.e., extent to which policies and practices apply to the total system, and extent to which policies and practices of suppliers apply to particular components, subsystems or other defined system elements

9.3 Configuration Identification

Configuration identification is the process of identifying, naming, and acquiring configuration items. Configuration identification encompasses all system components.

9.3.1 Classification and Naming Configuration Items

The manufacturer shall describe the procedures and conventions used to classify configuration items into categories and subcategories, uniquely number or otherwise identify configuration items and name configuration items.

9.3.2 Versioning Conventions

When a system component is part of a higher level system element such as a subsystem, the manufacturer shall describe the conventions used to:

a. Identify the specific versions of individual configuration items and sets of items that are incorporated in higher level system elements such as subsystems
b. Uniquely number or otherwise identify versions
c. Name versions

9.4 Baseline and Promotion Procedures

The manufacturer shall establish formal procedures and conventions for establishing and providing a complete description of the procedures and related conventions used to:

a. Establish a particular instance of a component as the starting baseline
b. Promote subsequent instances of a component to baseline status as development progresses through to completion of the initial completed version released to the VSTL for testing
c. Promote subsequent instances of a component to baseline status as the component is maintained throughout its life cycle until system retirement (i.e., the system is no longer sold or maintained by the manufacturer)

9.5 Configuration Control Procedures

Configuration control is the process of approving and implementing changes to a configuration item to prevent unauthorized additions, changes or deletions. The manufacturer shall establish such procedures and related conventions, providing a complete description of those procedures used to:

a. Develop and maintain internally developed items
b. Acquire and maintain third-party items
c. Resolve internally identified defects for items regardless of their origin
d. Resolve externally identified and reported defects (i.e., by customers and VSTLs)

9.6 Release Process

The release process is the means by which the manufacturer installs, transfers or migrates the system to the VSTL and, eventually, to its customers. The manufacturer shall establish such procedures and related conventions, providing a complete description of those used to:

a. Perform a first release of the system to a VSTL

b. Perform a subsequent maintenance or upgrade release of the system or particular components, to a VSTL
c. Perform the initial delivery and installation of the system to a customer, including confirmation that the installed version of the system matches exactly the certified system version
d. Perform a subsequent maintenance or upgrade release of the system or a particular component to a customer, including confirmation that the installed version of the system matches exactly the certified system version

9.7 Configuration Audits

The *Guidelines* require two types of configuration audits: Physical Configuration Audits (PCA) and Functional Configuration Audits (FCA).

9.7.1 Physical Configuration Audit

The Physical Configuration Audit is conducted by the VSTL to compare the voting system components submitted for certification to the manufacturer's technical documentation.

For the PCA, a manufacturer shall provide:

a. Identification of all items that are to be a part of the software release
b. Specification of compiler (or choice of compilers) to be used to generate executable programs
c. Identification of all hardware that interfaces with the software
d. Configuration baseline data for all hardware that is unique to the system
e. Copies of all software documentation intended for distribution to users, including program listings, specifications, operations manual, voter manual, and maintenance manual
f. User acceptance test procedures and acceptance criteria
g. Identification of any changes between the physical configuration of the system submitted for the PCA and that submitted for the FCA, with a certification that any differences do not degrade the functional characteristics
h. Complete descriptions of its procedures and related conventions used to support this audit by:
   i. Establishing a configuration baseline of the software and hardware to be tested
   ii. Confirming whether the system documentation matches the corresponding system components

9.7.2 Functional Configuration Audit

The Functional Configuration Audit is conducted by the VSTL to verify that the system performs all the functions described in the system documentation. The manufacturer shall:

a. Completely describe its procedures and related conventions used to support this audit for all system components
b. Provide the following information to support this audit:
    i. Copies of all procedures used for module or unit testing, integration testing, and system testing
    ii. Copies of all test cases generated for each module and integration test, and sample ballot formats or other test cases used for system tests
    iii. Records of all tests performed by the procedures listed above, including error corrections and retests

In addition to such audits performed by the VSTL during the national certification process, elements of this audit may also be performed by state election organizations during the system certification process and individual jurisdictions during system acceptance testing.

9.8 Configuration Management Resources

Often, configuration management activities are performed with the aid of automated tools. Assuring that such tools are available throughout the system life cycle--including whether the manufacturer is acquired by or merged with another organization--is critical to effective configuration management. Manufacturers may choose the specific tools they use to perform the record keeping, auditing, and reporting activities of the configuration management standards. The resources documentation requirements focus on assuring that procedures are in place to record information about the tools to help ensure that they, and the data they contain, can be transferred effectively and promptly to a third party should the need arise. Within this context, a manufacturer is required to develop and provide a complete description of the procedures and related practices for maintaining information about:

a. Specific tools used, current version, and operating environment specifications
b. Physical location of the tools, including designation of computer directories and files
c. Procedures and training materials for using the tools

Appendix A Glossary

Table of Contents

Appendix A: Glossary

This glossary contains terms needed to understand voting systems and related areas such as security, human factors, and testing. Sources consulted in preparing the definitions are listed in section A.2.

A.1 Glossary

A

abandoned ballot: Ballot that the voter did not place in the ballot box or record as cast on DRE before leaving the polling place

absentee ballot: Ballot cast by a voter unable to vote in person at his or her polling place on election day

acceptance testing: Examination of a voting system and its components by the purchasing election authority (usually in a simulated-use environment) to validate performance of delivered units in accordance with procurement requirements, and to validate that the delivered system is, in fact, the certified system purchased

Access Board: Independent federal agency whose primary mission is accessibility for people with disabilities and a leading source of information on accessible design

accessibility: Measurable characteristics that indicate the degree to which a system is available to, and usable by, individuals with disabilities. The most common disabilities include those associated with vision, hearing and mobility, as well as cognitive disabilities.

Accessible Voting Station (Acc-VS): Voting station specially equipped for individuals with disabilities referred to in HAVA 301 (a)(3)(B).

accreditation: Formal recognition that a laboratory is competent to carry out specific tests or calibrations

accreditation body: (1) Authoritative body that performs accreditation (2) An independent organization responsible for assessing the performance of other organizations against a recognized standard, and for formally confirming the status of those that meet the standard

accuracy: (1) Extent to which a given measurement agrees with an accepted standard for that measurement (2) Closeness of the agreement between the result of a measurement and a true value of the particular quantity subject to measurement. Accuracy is a qualitative concept and is not interchangeable with precision.

accuracy for voting systems: Ability of the system to capture, record, store, consolidate and report the specific selections and absence of selections, made by the voter for each ballot position without error. Required accuracy is defined in terms of an error rate that for testing purposes represents the maximum number of errors allowed while processing a specified volume of data.

adequate security: Security commensurate with the risk and the magnitude of harm resulting from the loss, misuse, unauthorized access to, or modification of, information. This includes ensuring that systems and applications operate effectively and provide appropriate confidentiality, integrity, and availability, through the use of cost-effective management, personnel, operational, and technical controls.

alert time: The amount of time the system will wait for detectible voter activity after issuing an alert before going into an inactive state requiring poll worker intervention.

alternative format: The ballot or accompanying information is said to be in an alternative format if it is in a representation other than the standard ballot language and format. Examples include, but are not limited to languages other than English, Braille, ASCII text, large print, recorded audio.

application logic: Software, firmware, or hardwired logic from any source that is specific to the voting system, with the exception of border logic.

audio ballot: a ballot in which a set of offices is presented to the voter in spoken, rather than written, form

audio-tactile interface (ATI): Voter interface designed to not require visual reading of a ballot. Audio is used to convey information to the voter and sensitive tactile controls allow the voter to convey information ~~communicate ballot selections~~ to the voting system.

audit: Systematic, independent, documented process for obtaining records, statements of fact or other relevant information and assessing them objectively to determine the extent to which specified requirements are fulfilled

audit trail: Recorded information that allows election officials to review the activities that occurred on the voting equipment to verify or reconstruct the steps followed without compromising the ballot or voter secrecy

audit trail for direct-recording equipment: Paper printout of votes cast, produced by direct-recording electronic (DRE) voting machines, which election officials may use to crosscheck electronically tabulated totals

availability: The percentage of time during which a system is operating properly and available for use

B

ballot: The official presentation of all of the contests to be decided in a particular election. See also**, audio ballot, ballot image, video ballot, electronic voter interface.**

ballot configuration: Particular set of contests to appear on the ballot for a particular election district, their order, the list of ballot positions for each contest, and the binding of candidate names to ballot positions

ballot counter: Process in a voting device that counts the votes cast in an election

ballot counting logic: The software logic that defines the combinations of voter choices that are valid and invalid on a given ballot and that determines how the vote choices are totaled in a given election

ballot format: The concrete presentation of the contents of a ballot appropriate to the particular voting technology being used. The contents may be rendered using various methods of presentation (visual or audio), language or graphics.

ballot image: Electronically produced record of all votes cast by a single voter. See also **cast vote record**.

ballot instructions: Information provided to the voter during the voting session that describes the procedure for executing a ballot. Such material may (but need not) appear directly on the ballot.

ballot measure: (1) A question that appears on the ballot for approval or rejection. (2) A contest on a ballot where the voter may vote yes or no.

ballot position: A specific place in a ballot where a voter's selection for a particular contest may be indicated. Positions may be connected to row and column numbers on the face of a voting machine or ballot, particular bit positions in a binary record of a ballot (for example, an electronic ballot image), the equivalent in some other form. Ballot positions are bound to specific contests and candidate names by the ballot configuration.

ballot preparation: Selecting the specific contests and questions to be contained in a ballot format and related instructions; preparing and testing election-specific software containing these selections; producing all possible ballot formats; and validating the correctness of ballot materials and software containing these selections for an upcoming election

ballot production: Process of generating ballots for presentation to voters, e.g., printing paper ballots or configuring the ballot presentation on a DRE

ballot rotation: Process of varying the order of the candidate names within a given contest

ballot scanner: Device used to read the voter selection data from a paper ballot or ballot card

ballot style: See **ballot configuration**

border logic: Software, firmware, or hardwired logic that is developed to connect application logic to COTS or third-party logic.

Discussion: Although it is typically developed by the voting system manufacturer, border logic is constrained by the requirements of the third-party or COTS interface with which it must interact. It is not always possible for border logic to achieve its function while conforming to coding standards. For this reason, border logic should be minimized relative to application logic and where possible, wrapped in a conforming interface. An example of border logic that could not be so wrapped is a customized boot manager that connects a bootable voting application to a COTS BIOS.

C

callable unit: (Of a software program or analogous logical design) Function, method, operation, subroutine, procedure, or analogous structural unit that appears within a module.

candidate: Person contending in a contest for office. A candidate may be explicitly presented as one of the choices on the ballot or may be a write-in candidate.

candidate register: Record that reflects the total votes cast for the candidate. This record is augmented as each ballot is cast on a DRE or as digital signals from the conversion of voted paper ballots are logically interpreted and recorded.

canvass: Compilation of election returns and validation of the outcome that forms the basis of the official results by political subdivision

cast ballot: Ballot that has been deposited by the voter in the ballot box or electronically submitted for tabulation

Cast Vote Record (CVR): Permanent record of all votes produced by a single voter whether in electronic, paper or other form. Also referred to as ballot image when used to refer to electronic ballots.

catastrophic system failure: Total loss of function or functions, such as the loss or unrecoverable corruption of voting data or the failure of an on board battery of volatile memory

central count voting system: A voting system that tabulates ballots from multiple precincts at a central location. Voted ballots are placed into secure storage at the polling place. Stored ballots are transported or transmitted to a central counting place which produces the vote count report.

certification: Procedure by which a third party gives written assurance that a product, process or service conforms to specified requirements. See also **state certification** and **national certification.**

certification testing: Testing performed under either national or state certification processes to verify voting system conformance to requirements

challenged ballot: Ballot provided to an individual who claim they are registered and eligible to vote but whose eligibility or registration status cannot be confirmed when they present themselves to vote. Once voted, such ballots must be kept separate from other ballots and are not included in the tabulation until after the voter's eligibility is confirmed. Michigan is an exception in that they determine voter eligibility before a ballot is issued. See also **provisional ballot**

checksum: Value computed from the content of a document or data record. Typically this is the sum of the numeric representations of all the characters in the text. Checksums are used to aid in detecting errors or alterations during transmission or storage.

claim of conformance: Statement by a manufacturer declaring that a specific product conforms to a particular standard or set of standard profiles; for voting systems, NASED qualification or EAC certification provides independent verification of a claim

closed primary: Primary election in which voters receive a ballot listing only those candidates running for office in the political party with which the voters are affiliated. In some states, non-partisan contests and ballot issues may be included. In some cases, political parties may allow unaffiliated voters to vote in their party's primary

commercial off-the-shelf (COTS): Commercial, readily available hardware devices (such as card readers, printers or personal computers) or software products (such as operating systems, programming language compilers, or database management systems)

Common Industry Format (CIF): Format to be used for summative usability test reporting, described in ISO/IEC 25062:2006 "Common Industry Format (CIF) for Usability Test Reports" ~~Refers to the format described in ANSI/INCITS 354-2001 "Common Industry Format (CIF) for Usability Test Reports~~

completed system response time: The time taken from when the voter performs some detectible action to when the voting system completes its response and settles into a stable state (e.g., finishes "painting" the screen with a new page).

component: Element within a larger system; a component can be hardware or software. For hardware, it is a physical part of a subsystem that can be used to compose larger systems (e.g., circuit boards, internal modems, processors, computer memory). For software, it is a module of executable code that performs a well-defined function and interacts with other components.

confidentiality: Prevention of unauthorized disclosure of information

configuration management: Discipline applying technical and administrative direction and surveillance to identify and document functional and physical characteristics of a configuration item, control changes to these characteristics, record and report change processing and implementation status, and verify compliance with specified requirements

configuration management plan: Document detailing the process for identifying, controlling and managing various released items (such as code, hardware and documentation)

configuration status accounting: An element of configuration management, consisting of the recording and reporting of information needed to manage a configuration effectively. This includes a listing of the approved configuration identification, the status of proposed changes to the configuration, and the implementation status of approved changes.

conformance: Fulfillment of specified requirements by a product, process or service

conformance testing: Process of testing an implementation against the requirements specified in one or more standards. The outcomes of a conformance test are generally a pass or fail result, possibly including reports of problems encountered during the execution. Also known as certification testing.

contest: Decision to be made within an election, which may be a contest for office or a referendum, proposition and/or question. A single ballot may contain one or more contests.

COTS: Software, firmware, device or component that is used in the United States by many different people or organizations for many different applications and that is incorporated into the voting system with no manufacturer- or application-specific modification.

Discussion: (1) The expansion of COTS as Commercial Off-The-Shelf is no longer helpful, since much of what satisfies the requirements is non-commercial software that is not available in stores. The acronym COTS is used here only because it is familiar to the audience. (2) By requiring “many different applications,” this definition deliberately prevents any application logic from receiving a COTS designation.

count: Process of totaling votes. See **tabulation.**

counted ballot: Ballot that has been processed and whose votes are included in the candidates and measures vote totals

corrective action: Action taken to eliminate the causes of an existing deficiency or other undesirable situation in order to prevent recurrence

cross filing: Endorsement of a single candidate or slate of candidates by more than one political party. The candidate or slate appears on the ballot representing each endorsing political party. Also referred to as cross-party endorsement.

cryptographic key: Value used to control cryptographic operations, such as decryption, encryption, signature generation or signature verification

cryptography: Discipline that embodies the principles, means, and methods for the transformation of data in order to hide their semantic content, prevent their unauthorized use, prevent their undetected modification and establish their authenticity

cumulative voting: A method of voting exclusive to multi-member district election (e.g. county board) in which each voter may cast as many votes as there are seats to be filled and may cast two or more of those votes for a single candidate

D

data accuracy: (1) Data accuracy is defined in terms of ballot position error rate. This rate applies to the voting functions and supporting equipment that capture, record, store, consolidate and report the specific selections, and absence of selections, made by the voter for each ballot position. (2) The system's ability to process voting data absent internal errors generated by the system. It is distinguished from data integrity, which encompasses errors introduced by an outside source.

data integrity: Invulnerability of the system to accidental intervention or deliberate, fraudulent manipulation that would result in errors in the processing of data. It is distinguished from data accuracy that encompasses internal, system-generated errors.

decertification: Revocation of national or state certification of voting system hardware and software

decryption: Process of changing encrypted text into plain text

device: Functional unit that performs its assigned tasks as an integrated whole

digital signature: An asymmetric key operation where the private key is used to digitally sign an electronic document and the public key is used to verify the signature. Digital signatures provide data authentication and integrity protection

direct-recording electronic (DRE) voting system: ~~An electronic voting system that utilizes electronic components for the functions of ballot presentation, vote capture, vote recording, and tabulation which are logically and physically integrated into a single unit.~~ Combination Voter-Editable Ballot Device (VEBD) and tabulator that gathers votes via an electronic voter interface, records voting data and ballot images in memory components, and produces a tabulation of the voting data. ~~A DRE produces a tabulation of the voting data stored in a removable memory component and in printed hardcopy.~~

Discussion: A typical DRE presents contest choices to the voter on an electronic monitor, and after the voter finishes the ballot the voter's votes are stored locally on the computer.

directly verifiable: Voting system feature that allows the voter to verify at least one representation of his or her ballot with his/her own senses, not using any software or hardware intermediary. Examples include a marksense paper ballot and a DRE with a voter verifiable paper record feature.

disability: With respect to an individual; (1) a physical or mental impairment that substantially limits one or more of the major life activities of such individual; (2) a record of such an impairment; (3) being regarded as having such an impairment (definition from the Americans with Disabilities Act).

dynamic voting system software: Software that changes over time once it is installed on the voting equipment. See also voting system software.

E

EAC: Election Assistance Commission (www.eac.gov)

early voting: Broadly, voting conducted before election day where the voter completes the ballot in person at a county office or other designated polling place or ballot drop site prior to election day

election: A formal process of selecting a person for public office or of accepting or rejecting a political proposition by voting

election databases: Data file or set of files that contain geographic information about political subdivisions and boundaries, all contests and questions to be included in an election, and the candidates for each contest

election definition: Definition of the contests and questions that will appear on the ballot for a specific election

election district: Contiguous geographic area represented by a public official who is elected by voters residing within the district boundaries. The district may cover an entire state or political subdivision, may be a portion of the state or political subdivision, or may include portions of more than one political subdivision.

election management system: Set of processing functions and databases within a voting system that defines, develops and maintains election databases, performs election definitions and setup functions, format ballots, count votes, consolidates and report results, and maintains audit trails

election officials: The people associated with administering and conducting elections, including government personnel and poll workers

election programming: Process by which election officials or their designees use voting system software to logically define the ballot for a specific election

electronic cast vote record: An electronic version of the cast vote record

electronic voter interface: Subsystem within a voting system which communicates ballot information to a voter in video, audio or other alternative format which allows the voter to select candidates and issues by means of vocalization or physical actions

electronic voting machine: Any system that utilizes an electronic component. Term is generally used to refer to DREs. See also voting equipment, voting system.

electronic voting system: An electronic voting system is one or more integrated devices that utilize an electronic component for one or more of the following functions: ballot presentation, vote capture, vote recording, and tabulation. A DRE is a functionally and physically integrated electronic voting system which provides all four functions electronically in a single device. An optical scan (also known as marksense) system where the voter marks a paper ballot with a marking instrument and then deposits the ballot in a tabulation device is partially electronic in that the paper ballot provides the presentation, vote capture and vote recording functions. An optical scan system employing a ballot marking device adds a second electronic component for ballot presentation and vote capture functions.

Electronically-assisted Ballot Marker (EBM): VEBD that produces an executed, human-readable paper ballot as a result, and that does not make any other lasting record of the voter's votes.

Discussion: One kind of EBM presents contest choices to the voter on an electronic monitor; after the voter finishes the ballot, the voter's choices are printed on a paper ballot that is the only record of the voter's choices. However, vote-by-telephone systems that are in use at the time of this writing are also EBMs. The voter uses an audio interface (remotely) and a paper ballot is produced (centrally). An EBM may mark ballot positions on a pre-printed ballot or it may print an entire ballot; however, in any event, the ballot produced is assumed to be human-readable and comparable to an MMPB.

encryption: Process of obscuring information by changing plain text into ciphertext for the purpose of security or privacy. See also **cryptography** and **decryption**.

error correcting code: coding system that allows data being read or transmitted to be checked for errors and, when detected, corrects those errors

F

Federal Information Processing Standards: Standards for federal computer systems developed by NIST. These standards are developed when there are no existing industry standards to address federal requirements for system interoperability, portability of data and software, and computer security.

firmware: Computer programming stored in programmable read-only memory thus becoming a permanent part of the computing device. It is created and tested like software.

Functional Configuration Audit (FCA): Exhaustive verification of every system function and combination of functions cited in the manufacturer's documentation. The FCA verifies the accuracy and completeness of the system's Voter Manual, Operations Procedures, Maintenance Procedures, and Diagnostic Testing Procedures.

functional test: Test performed to verify or validate the accomplishment of a function or a series of functions

G

general election: Election in which voters, regardless of party affiliation, are permitted to select candidates to fill public office and vote on ballot issues

guidelines: See **product standard**

H

hash: Algorithm that maps a bit string of arbitrary length to a fixed-length bit string.

hash function: A function that maps a bit string of arbitrary length to a fixed length bit string. Approved hash functions satisfy the following properties: 1. (One-way) It is computationally infeasible to find any input that maps to any pre-specified output, and 2. (Collision resistant) It is computationally infeasible to find any two distinct inputs that map to the same output.

hardwired logic: Logic implemented through the design of an integrated circuit; the programming of a Programmable Logic Device (PLD), Field-Programmable Gate Array (FPGA), Peripheral Interface Controller (PIC), or similar; the integration of smaller hardware components; or mechanical design (e.g., as in lever machines).

I

indirectly verifiable: Voting system feature that allows a voter to verify his or her selections via a hardware or software intermediary. An example is a touch screen DRE where the voter verifies the ballot selections through the assistance of audio stimuli.

implementation statement: Statement by a manufacturer indicating the capabilities, features, and optional functions as well as extensions that have been implemented. Also known as implementation conformance statement.

Independent Testing Authority (ITA): Replaced by "accredited testing laboratories" and "VSTL" (Voting System Test Lab). Prior usage referred to independent testing organizations accredited by the National Association of State Election Directors (NASED) to perform voting system qualification testing.

information security: Protecting information and information systems from unauthorized access, use, disclosure, disruption, modification, or destruction in order to provide integrity, confidentiality, and availability

initial system response time: The time taken from when the voter performs some detectible action (such as pressing a button) to when the voting system begins responding in some obvious way (such as an audible response or any change on the screen).

inspection: Examination of a product design, product, process or installation and determination of its conformity with specific requirements or, on the basis of professional judgment, with general requirements. Inspection of a process may include inspection of staffing, facilities, technology and methodology.

integrity: Guarding against improper information modification or destruction, and ensuring information non-repudiation and authenticity

internal audit log: A human readable record, resident on the voting machine, used to track all activities of that machine. This log records every activity performed on or by the machine indicating the event and when it happened.

K

key management: Activities involving the handling of cryptographic keys and other related security parameters (e.g., passwords) during the entire life cycle of the keys, including their generation, storage, establishment, entry and output, and zeroization.

L

logic and accuracy testing: Testing of the tabulator setups of a new election definition to ensure that the content correctly reflects the election being held (i.e., contests, candidates, number to be elected, ballot styles) and that all voting positions can be voted for the maximum number of eligible candidates and that results are accurately tabulated and reported.

logical correctness: Condition signifying that, for a given input, a computer program will satisfy the program specification and produce the required output

M

marksense: System by which votes are recorded by means of marks made in voting response fields designated on one or both faces of a ballot card or series of cards. Marksense systems may use an optical scanner or similar sensor to read the ballots. Also known as optical scan.

measure register: Record that reflects the total votes cast for and against a specific ballot issue. This record is augmented as each ballot is cast on a DRE or as digital signals from the conversion of voted paper ballots are logically interpreted and recorded.

mechanical lever voting machine: Machine that directly records a voter's choices via mechanical lever-actuated controls into a counting mechanism that tallies the votes without using a physical ballot

module: Structural unit of software or analogous logical design, typically containing several callable units that are tightly coupled.

Discussion: Modular design requires that inter-module coupling be loose and occur over defined interfaces. A module should contain all elements needed to compile or interpret successfully and have limited access to data in other modules. A module should be substitutable with another module whose interfaces match the original module. In software, a module typically corresponds to a single source code file or a source code / header file pair. In object-oriented languages, this typically corresponds to a single class of object.

multi-seat contest: Contest in which multiple candidates can run, up to a specified number of seats. Voters may vote for no more than the specified number of candidates

N

NASED: National Association of State Election Directors**, (**www.nased.org**)**

national certification testing: Examination and testing of a voting system to determine if the system complies with the performance and other requirements of the national certification standards and with its own specifications

national certification test report: Report of results of independent testing of a voting system by a VSTL delivered to the EAC with a recommendation regarding granting a certification number

NIST: National Institute of Standards and Technology

non-partisan office: Elected office for which candidates run without political party affiliation

nonvolatile memory: Memory in which information can be stored indefinitely with no power applied. ROMs and PROMs are examples of nonvolatile memory.

NVLAP: The National Voluntary Laboratory Accreditation Program operated by NIST

O

open primary: Primary election in which any voters can participate, regardless of their political affiliation. Some states require voters to publicly declare their choice of party ballot at the polling place, after which the poll worker provides or activates the appropriate ballot. Other states allow the voters to make their choice of party ballot within the privacy of the voting booth.

operational environment: All software, hardware (including facilities, furnishings and fixtures), materials, documentation, and the interface used by the election personnel, maintenance operator, poll worker, and voter, required for voting equipment operations.

optical scan, optical scan system: System by which votes are recorded by means of marks made in voting response fields designated on one or both faces of a ballot card or series of cards. An optical scan system reads and tabulates ballots, usually paper ballots, by scanning the ballot and interpreting the contents. Also known as **marksense**.

overvote: Voting for more than the maximum number of selections allowed in a contest

P

paper-based voting system: Voting system that records votes, counts votes, and tabulates the vote count, using one or more ballot cards or paper ballots

paper record: Paper cast vote record that can be directly verified by a voter. See also **ballot image, cast vote record**.

partisan office: An elected office for which candidates run as representatives of a political party

personal assistive device: A device that is carried or worn by an individual with some physical impairment whose primary purpose is to help compensate for that impairment

Physical Configuration Audit (PCA): Inspection by a VSTL that compares the voting system components submitted for certification testing to the manufacturer's technical documentation and confirms that the documentation submitted meets the national certification requirements. Includes witnessing of the build of the executable system to ensure that the certified release is built from the tested components.

political subdivision: Any unit of government, such as counties and cities, school districts, and water and conservation districts having authority to hold elections for public offices or on ballot issues

polling location: Physical address of a polling place

polling place: Facility to which voters are assigned to cast in-person ballots

precinct: Election administration division corresponding to a contiguous geographic area that is the basis for determining which contests and issues the voters legally residing in that area are eligible to vote on

precinct count: Counting of ballots in the same precinct in which those ballots have been cast

Precinct Count Optical Scanner (PCOS): Optical scanner used as a precinct tabulator.

Discussion: A PCOS is a special purpose scanner designed to enable the voter to feed his or her own paper ballot—one ballot at a time.

precinct count voting system: A voting system that tabulates ballots at the polling place. These systems typically tabulate ballots as they are cast and print the results after the close of polling. For DREs, and for some paper-based systems, these systems provide electronic storage of the vote count and may transmit results to a central location over public telecommunication networks.

precinct tabulator: Tabulator that counts votes at the polling place.

Discussion: These devices typically tabulate ballots as they are cast and print the results after the close of polls. For DREs and some paper-based systems, these devices provide electronic storage of the vote count and may transmit results to a central location over public telecommunication networks. A tabulator that may be configured for use either in the precinct or in the central location may satisfy the requirements for both Precinct tabulator and Central tabulator.

precision: (1) Extent to which a given set of measurements of the same sample agree with their mean. Thus, precision is commonly taken to be the standard deviation estimated from sets of duplicate measurements made under conditions of repeatability, that is, independent test results obtained with the same method on identical test material, in the same laboratory or test facility, by the same operator using the same equipment within short intervals of time. (2) Degree of refinement in measurement or specification, especially as represented by the number of digits given.

primary election: Election held to determine which candidate will represent a political party for a given office in the general election. Some states have an open primary, while others have a closed primary. Sometimes elections for nonpartisan offices and ballot issues are held during primary elections.

primary presidential delegation nomination: Primary election in which voters choose the delegates to the presidential nominating conventions allotted to their states by the national party committees

privacy: The ability to prevent others from determining how an individual voted

private key: The secret part of an asymmetric key pair that is typically used to digitally sign or decrypt data

product standard: Standard that specifies requirements to be fulfilled by a product or a group of products, to establish its fitness for purpose

provisional ballot: Ballot provided to individuals who claim they are registered and eligible to vote but whose eligibility or registration status cannot be confirmed when they present themselves to vote. Once voted, such ballots must be kept separate from other ballots and are not included in the tabulation until after the voter's eligibility is confirmed. In some jurisdictions called an affidavit ballot. See also **challenged ballot**.

public key: Public part of an asymmetric key pair that is typically used to verify digital signatures or encrypt data

public network direct-recording electronic (DRE) voting system: A DRE that transmits vote counts to a central location over a public telecommunication network

Q

qualification number: A number issued by NASED (National Association of State Election Directors) to a system that has been tested by an accredited Independent Testing Authority for compliance with the voting system standards. Issuance of a qualification number indicates that the system conforms to the national standards.

qualification test report: Report of results of independent testing of a voting system by an Independent Test Authority documenting the specific system configuration tested, the scope of tests conducted and when testing was completed.

qualification testing: Examination and testing of a voting system by a NASED-accredited Independent Test Authority to determine if the system conforms to the performance and other requirements of the national certification standards and the manufacturer's own specifications.

R

ranked order voting: Practice that allows voters to rank candidates in a contest in order of choice: 1, 2, 3 and so on. A candidate receiving a majority of the first choice votes wins that election. If no candidate receives a majority, the last place candidate is deleted, and all ballots are counted again, with each ballot cast for the deleted candidate applied to the next choice candidate listed on the ballot. The process of eliminating the last place candidate and recounting the ballots continues until one candidate receives a majority of the vote. The practice is also known as instant runoff voting, preferences or preferential voting, or choice voting.

recall issue with options: Process that allows voters to remove elected representatives from office prior to the expiration of their terms of office. The recall may involve not only the question of whether a particular officer should be removed, but also the question of naming a successor in the event that there is an affirmative vote for the recall.

recertification: Re-examination, and possibly retesting of a voting system that was modified subsequent to receiving national and/or state certification. The object of is to determine if the system as modified still conforms to the requirements.

recount: Retabulation of the votes cast in an election

referendum: Process whereby a state law or constitutional amendment may be referred to the voters before it goes into effect.

reporting context: Scope within which reported totals or counts are calculated (e.g., precinct or election district).

reproducibility: Ability to obtain the same test results by using the same test method on identical test items in different testing laboratories with different operators using different equipment

requirement: Provision that conveys criteria to be fulfilled

residual vote: Total number of votes that cannot be counted for a specific contest. There may be multiple reasons for residual votes (e.g., declining to vote for the contest, overvoting in a contest).

risk assessment: The process of identifying the risks to system security and determining the probability of occurrence, the resulting impact, and safeguards that would mitigate this impact

runoff election: Election to select a winner following a primary or a general election, in which no candidate in the contest received the required minimum percentage of the votes cast. The two candidates receiving the most votes for the contest in question proceed to the runoff election.

S

secure receptacle: The container for storing VVPAT paper audit records

security analysis: An inquiry into the potential existence of security flaws in a voting system. Includes an analysis of the system's software, firmware, and hardware, as well as the procedures associated with system development, deployment, operation and management.

security controls: Management, operational, and technical controls (i.e., safeguards or countermeasures) prescribed for an information system to protect the confidentiality, integrity, and availability of the system and its information.

security strength: A number associated with the amount of work (that is, the number of operations) that is required to break a cryptographic algorithm or system.

semi-static voting system software: Software that may change in response to the voting equipment on which it is installed or to election-specific programming.

split precinct: A precinct that contains an election district subdivision, e.g., a water district or school board district, requiring an additional ballot configuration

spoiled ballot: Ballot that has been voted but will not be cast

state certification: State examination and possibly testing of a voting system to determine its compliance with state requirements for voting systems

static voting system software: Software that does not change based on the election being conducted or the voting equipment upon which it is installed, e.g., executable code

straight party voting: Mechanism that allows voters to cast a single vote to select all candidates on the ballot from a single political party

summative usability testing: Evaluation of a product with representative users and tasks designed to measure the usability (defined as effectiveness, efficiency and satisfaction) of the complete product. The purpose of a summative test is to evaluate a product through defined measures, rather than diagnosis and correction of specific design problems, as in formative testing.

support software: Software that aids in the development, maintenance, or use of other software, for example, compilers, loaders and other utilities

symmetric (secret) encryption algorithm: Encryption algorithms using the same secret key for encryption and decryption

T

tabulation: Process of totaling votes**.** See also **count.**

tabulator: Device that counts votes

Discussion: Any distinction between processing individual votes and processing vote totals that resulted from a previous step is not relevant; both of these constitute “counting votes”.

t-coil: Inductive coil used in some hearing aids to allow reception of an audio band magnetic field signal, instead of an acoustic signal. The magnetic or inductive mode of reception is commonly used in conjunction with telephones, auditorium loop systems and other systems that provide the required magnetic field output.

technical data package: Manufacturer documentation relating to the voting system required to be submitted with the system as a precondition of certification testing

telecommunications: Transmission, between or among points specified by the user, of information of the user's choosing, without change in the form or content of the information as sent and received

test: Technical operation that consists of the determination of one or more characteristics of a given product, process or service according to a specified procedure

test campaign: Sum of the work by a VSTL on a single product or system from contract through test plan, conduct of testing for each requirement (including hardware, software, and systems), reporting, archiving, and responding to issues afterwards

testing standard: Standard that is concerned with test methods, sometimes supplemented with other provisions related to testing, such as sampling, use of statistical methods or sequence of tests

test method: Specified technical procedure for performing a test

test plan: Document created prior to testing that outlines the scope and nature of testing, items to be tested, test approach, resources needed to perform testing, test tasks, risks and schedule

third-party logic: Software, firmware, or hardwired logic that is neither application logic nor COTS; e.g., general-purpose software developed by a third party that is either customized (e.g., ported to a new platform, as is Windows CE[39]) or not widely used, or source code generated by a COTS package.

[39] Specific equipment and materials are identified in order to describe certain procedures. In no case does such identification imply recommendation or endorsement, nor does it imply that the materials or equipment identified are necessarily the best available for the purpose.

touch screen voting machine: A voting machine that utilizes a computer screen to display the ballot and allows the voter to indicate his or her selections by touching designated locations on the screen

U

undervote: Occurs when the number of choices selected by a voter in a contest is less than the maximum number allowed for that contest or when no selection is made for a single choice contest

usability: Effectiveness, efficiency and satisfaction with which a specified set of users can achieve a specified set of tasks in a particular environment. Usability in the context of voting refers to voters being able to cast valid votes as they intended quickly, without errors, and with confidence that their ballot choices were recorded correctly. It also refers to the usability of the setup and operation in the polling place of voting equipment.

usability testing: Encompasses a range of methods that examine how users in the target audience actually interact with a system, in contrast to analytic techniques such as usability inspection

V

valid vote: Vote from a ballot or ballot image that is legally acceptable according to state law

validation: Process of evaluating a system or component during or at the end of the development process to determine whether it satisfies specified requirements

verification: Process of evaluating a system or component to determine whether the products of a given development phase satisfy the conditions (such as specifications) imposed at the start of the phase

video ballot: Electronic voter interface which presents ballot information and voting instructions as video images. See also **ballot**.

vote for N of M: A ballot choice in which voters are allowed to vote for a specified number (“N”) of candidates in a multi-seat (“M”) contest

voted ballot: Ballot that contains all of a voter's selections and has been cast

Voter-Editable Ballot Device (VEBD): Vote-capture device that gathers votes via an electronic voter interface and allows the voter to alter previously made votes without spoiling the ballot.

Discussion: "VEBD-V" denotes the visual interface of such systems and "VEBD-A" denotes the audio interface.

voter inactivity time: The amount of time from when the system completes its response until there is detectible voter activity. In particular, note that audio prompts from the system may take several minutes and that this time does not count as voter inactivity.

voter verifiable: A voting system feature that provides the voter an opportunity to verify that his or her ballot selections are being recorded correctly, before the ballot is cast

voter verifiable audit record: Human-readable printed record of all of a voter's selections presented to the voter to view and check for accuracy

voting device: Device that is part of the voting system.

Discussion: Components and materials that are vital to the function of the voting device within the voting system, such as smart cards and ballot printers, are considered parts of the device for the purpose of conformity assessment.

voting equipment: All devices, including the voting machine, used to display the ballot, accept voter selections, record voter selections, and tabulate the votes

voting machine: The mechanical, electromechanical and electric components of a voting system that the voter uses to view the ballot, indicate their selections, verify their selections. In some instances, the voting machine also casts and tabulates the votes. See **voting equipment**.

voting officials: Term used to designate the group of people associated with elections, including election personnel, poll workers, ballot designers and those responsible for the installation, operation and maintenance of the voting systems.

voting position: Specific response field on a ballot where the voter indicates the selection of a candidate or ballot proposition response

voting station: The location within a polling place where voters may record their votes. A voting station includes the area, location, booth or enclosure where voting takes place as well as the voting machine. See **voting machine.**

voting system: The total combination of mechanical, electromechanical or electronic equipment (including the software, firmware, and documentation required to program, control, and support the equipment) that is used to define ballots; to cast and count votes; to report or display election results; and to maintain and produce any audit trail information; and the practices and associated documentation used to identify system components and versions of such components; to test the system during its development and maintenance; to maintain records of system errors and defects; to determine specific system changes to be made to a system after the initial qualification of the system; and to make available any materials to the voter (such as notices, instructions, forms or paper ballots).

Discussion: *An Automatic Bar Code Reader is considered part of a voting system based on the definition of a voting system. Specifically, the Automatic Bar Code Reader "supports" the system and is used to produce audit trail information, therefore it must be included as part of the testing of a voting system.*[40]

voting system software: All the executable code and associated configuration files needed for the proper operation of the voting system. This includes third party software such as operating systems, drivers, and database management tools. See also **dynamic voting system software, semi-static voting system software**, and **static voting system software**.

voting system testing: Examination and testing of a computerized voting system by using test methods to determine if the system complies with the requirements in the *Voluntary Voting System Guidelines* and with its own specifications.

~~**voting system test laboratory:** Test laboratory accredited by the National Voluntary Laboratory Accreditation Program (NVLAP) to be competent to test voting systems. When NVLAP has completed its evaluation of a test lab, the Director of NIST will forward a recommendation to the EAC for the completion of the accreditation process.~~

Voting System Test Lab (VSTL): Test laboratory accredited by the Election Assistance Commission under the EAC's Voting System Testing and Certification Program.

W

write-in voting: To make a selection of an individual not listed on the ballot. In some jurisdictions, voters may do this by using a marking device to physically write their choice on the ballot or they may use a keypad, touch screen or other electronic means to enter the name.

A.2 Sources

Definitions in this glossary are either extracted from or based on the following sources:

44 U.S.C. 35	United States Code, Title 44, Chapter 35, Information Security, Section 3542, Definitions.

[40] The italicized test is based on EAC Decision on Request for Interpretation 2008-08, http://www.eac.gov/program-areas/voting-systems/docs/eac-decision-on-request-for-interpretation-2008.08/attachment_download/file.

ACM SIGCHI	ACM's Special Interest Group on Computer-Human Interaction, http://www.acm.org/sigchi/ (February 2005).
ADA	Americans with Disabilities Act of 1990.
ANSI Dictionary	American National Dictionary for Information Processing Systems, American National Standards Committee X3, Information Processing Systems, 1982.
ANSI 354	American National Standards Institute, International Committee for Information Technology Standards, Common Industry Format for Usability Test Reports, ANSI/INCITS 354-2001
ANSI C63.19	American National Standards for Methods of Measurement of Compatibility between Wireless Communications Devices and Hearing Aids, 2001.
electionline	http://electionline.org/, (March 2005).
FIPS 81	Federal Information Processing Standard 81, DES Modes of Operations, December, 1980.
FIPS 140-2	Federal Information Processing Standard 140-2, Security Requirements for Cryptographic Modules, May 2001.
FIPS 199	Federal Information Processing Standard 199, Standards for Security Categorization of Federal Information and Information Systems, December 2003.
FIPS 201	Federal Information Processing Standard 201, Personal Identity Verification for Federal Employees and Contractors, February 2005.
HAVA	Help America Vote Act of 2002 - Public Law 107-252.
IEA	International Ergonomics Association, http://www.iea.cc/, (February 2005).
IEEE 1583	IEEE P1583/D5.3.2 Draft Standard for the Evaluation of Voting Equipment, December 6, 2004.
ISO 5725	ISO/IEC 5725:1994 Accuracy (trueness and precision) of measurement methods and results.
ISO 9241	ISO/IEC 9241:1997 Ergonomic requirements for office work with visual display terminals (VDT).

ISO 17000	ISO/IEC 17000:2004 Conformity assessment -- Vocabulary and general principles.
ISO Guide 2-4	ISO/IEC Guide 2:2004 Standardization and related activities - General vocabulary.
ISO Guide 2-6	ISO/IEC Guide 2:1996 Standardization and related activities - General vocabulary.
NASS	National Association of Secretaries of State Election Reform Key Terms, http://www.nass.org/Election%20Reform%20Key%20Terms.pdf (February 2005).
NIST HB 143	NIST Handbook 143 State Weights and Measures Laboratories Program Handbook.
NIST HB 150	NIST Handbook 150:2001 NVLAP Procedures and General Requirements.
NIST HF Rpt.	NIST Special Publication 500-256 Improving the Usability and Accessibility of Voting Systems and Products, May 2004.
NIST SP 800-30	NIST Special Publication 800-30 Risk Management Guide for Information Technology Systems, July 2002.
NIST SP 800-49	NIST Special Publication 800-49 Federal S/MIME V3 Client Profile, November 2002.
NIST SP 800-53	NIST Special Publication 800-53 Recommended Security Controls for Federal Information Systems, Appendix B, Glossary.
NIST SP 800-59	NIST Special Publication 800-59 Guideline for Identifying an Information System as a National Security System, August 2003.
NIST SP 800-63	NIST Special Publication 800-63 Electronic Authentication Guideline: Recommendations of the National Institute of Standards and Technology, June 2004.
OMB A130	OMB Circular A-130, Appendix III.
Section 508 of the Rehabilitation Act of 1973, as amended.	Electronic and Information Technology Accessibility Standards (2002) Architectural and Transportation Barriers Compliance Board, 36 CRF Part 1194, http://www.accessboard.gov/sec508/508standards.htm

Usability Glossary	Usability First Usability Glossary, http://www.usabilityfirst.com/glossary/main.cgi, (February 2005).
VIM	The ISO International Vocabulary of Basic and General Terms in Metrology (VIM), 1994.
VSS	2002 Voting Systems Standards, Volumes I and II. Federal Election Commission.
Whatis.com	http://whatis.com, IT Encyclopedia

Appendix B References

Table of Contents

Appendix B: References

B.1 Documents Incorporated in the Guidelines

The following publications have been incorporated into the Guidelines. When specific provisions from these publications have been incorporated, specific references are made in the body of the Guidelines.

Federal Regulations

Code of Federal Regulations, Title 29, Part 1910, Occupational Safety and Health Act

Code of Federal Regulations, Title 36, Part 1194, Architectural and Transportation Barriers Compliance Board, Electronic and Information Technology Standards - Final Rule

Code of Federal Regulations, Title 47, Parts 15 and 18, Rules and Regulations of the Federal Communications Commission

Code of Federal Regulations, Title 47, Part 15, "Radio Frequency Devices", Subpart J, "Computing Devices", Rules and Regulations of the Federal Communications Commission

American National Standards Institute (ANSI)

ANSI C63.4	Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9Khz to 40 GHz
ANSI C63.19	American National Standard for Methods of Measurement of Compatibility between Wireless Communication Devices and Hearing Aids
ANSI-NCITS	Industry Usability Reporting and the Common Industry Format 354-2001

International Electrotechnical Commission (IEC)

IEC 61000-4-2 (1995-01)	Electromagnetic Compatibility (EMC) Part 4: Testing and Measurement Techniques. Section 2 Electrostatic Discharge Immunity Test (Basic EMC publication).
IEC 61000-4-3 (1996)	Electromagnetic Compatibility (EMC) Part 4: Testing and Measurement Techniques. Section 3 Radiated Radio-Frequency Electromagnetic Field Immunity Test.

IEC 61000-4-4 (1995-01)	Electromagnetic Compatibility (EMC) Part 4: Testing and Measurement Techniques. Section 4 Electrical Fast Immunity Test.
IEC 61000-4-5 (1995-02)	Electromagnetic Compatibility (EMC) Part 4: Testing and Measurement Techniques. Section 5 Surge Immunity Test.
IEC 61000-4-6 (1996-04)	Electromagnetic Compatibility (EMC) Part 4: Testing and Measurement Techniques. Section 6 Immunity to Conducted Disturbances Induced by Radio-Frequency Fields.
IEC 61000-4-8 (1993-06)	Electromagnetic Compatibility (EMC) Part 4: Testing and Measurement Techniques. Section 8 Power-Frequency Magnetic Field Immunity Test. (Basic EMC publication).
IEC 61000-4-11 (1994-06)	Electromagnetic Compatibility (EMC) Part 4: Testing and Measurement Techniques. Section 11. Voltage Dips, Short Interruptions and Voltage Variations Immunity Tests.
IEC 61000-5-7 Ed. 1.0 b:2001	Electromagnetic compatibility (EMC) Part 5-7: Installation and mitigation guidelines—Degrees of protection provided by enclosures against electromagnetic disturbances

National Institute of Standards and Technology

FIPS 140-2	Security Requirements for Cryptographic Modules
FIPS 180-2	Secure Hash Standard, August 2002
FIPS 186-2	Digital Signature Standard, February 2000
FIPS 188	Standard Security Label for Information Transfer
FIPS 196	Entity Authentication Using Public Key Cryptography
FIPS 197	Advanced Encryption Standard (AES)
SP 800-63	Electronic Authentication Guideline, Version 1.0.1

Military Standards

MIL-STD-498	Software Development and Documentation Standard, 1989
MIL-STD-810D(2)	Environmental Test Methods and Engineering Guidelines, 19 July 1983

B.2 Other Documents Used in Developing the Guidelines

The following publications have been used for guidance in the revision of the *Guidelines*.

American National Standards Institute (ANSI), International Organization for Standardization (ISO), International Electro-technical Commission (IEC)

ANSI/ISO/IEC R 9294.1990	Information Technology Guidelines for the Management of Software Documentation
IEC/UL 60950-1	
ISO/IEC 60950-1	Information technology— Safety—Part 1: General Requirements
ISO/IEC TR 13335-4:2000	Information technology—Guidelines for the management of IT Security—Part 4: Selection of safeguards
ISO/IEC TR 13335-3:1998	Information technology—Guidelines for the management of IT Security—Part 3 Techniques for the management of IT security
ISO/IEC TR 13335-2:1997	Information technology—Guidelines for the management of IT Security—Part 2: Managing and planning IT security
ISO/IEC TR 13335-1:1996	Information technology—Guidelines for the management of IT Security—Part 1: Concepts and models for IT security
ISO/IEC 2506206	ISO/IEC 25062:2006 Common Industry Format (CIF) for Usability Test Reports.
ISO 10007:1995	Quality Management Guidelines for Configuration Management
ISO 10005-1995	Quality Managment Guidelines for Quality Plans
ANSI/ISO/ASQC QS9000-3-1997	QM and QA standards Part 3: Guidelines for the application of ANSI/ISO/ASQC Q9000-1994 to the Development, Supply, Installation, and Maintenance of Computer Software

Electronic Industries Alliance Standards

MB2, MB5, MB9	Maintainability Bulletins
EIA 157	Quality Bulletin
EIA QB2-QB5	Quality Bulletins
EIA RB9	Failure Mode and Effect Analysis, Revision 71

EIA SEB1—SEB4	Safety Engineering Bulletins
RS-232-C	Interface Between Data Terminal Equipment and Data Communications Equipment Employing Serial Binary Data Interchange
RS-366-A Calling	Interface Between Data Terminal Equipment and Automatic Equipment for Data Communication
RS-404	Standard for Start-Stop Signal Quality Between Data Terminal Equipment and Non-synchronous Data Communication Equipment

National Institute of Standards and Technology

NIST SP 800-57	NIST Special Publication 800-57: Recommendation for Key Management – Part 1: General
NISTIR 7519	Style Guide for Voting System Documentation, http://vote.nist.gov/NISTIR-7519.pdf
NISTIR 7537	Guidelines for Using Color in Voting Systems, http://vote.nist.gov/NISTIR-7537.pdf
NISTIR 4909	Software Quality Assurance: Documentation and Reviews

Institute of Electrical and Electronics Engineers

610.12-1990	IEEE Standard Glossary of Software Engineering Terminology
730-1998	IEEE Standard for Software Quality Assurance Plans
828-1998	IEEE Standard for Software Configuration Management Plans
829-1998	IEEE Standard for Software Test Documentation
830-1998	IEEE Recommended Practice for Software Requirements Specifications

Military Standards

MIL-STD-498	Software Development and Documentation, 27 May 1998

B.3 Legislation References

Help America Vote Act, Pub. L. 107-252, 42 USC Sections 15301-15545

Americans With Disabilities Act of 1990, Pub. L. 101-336, 42 USC Sections 12101-12213

42 USC 1974

Occupational Safety and Health Act, Pub. L. 91-596, 29 USC Sections 651-678, 42 USC Section 3142-1

Architectural Barriers Act of 1968, Pub. L. 90-480, 42 USC Sections 4151-4157

Voting Rights Act of 1965, Pub. L. 89-110, 42 USC Sections 1973; 1973a-p; 1973aa; 1973aa-1-6; 1973bb; 1973bb-1

B.4 Additional References

The following publications contain information that is useful in understanding and complying with the *Guidelines*.

American National Standards Institute (ANSI), International Organization for Standardization (ISO), International Electro-technical Commission (IEC)

ANSI/ISO/IEC TR 10176.1998	Information Technology Guidelines for the Preparation of Programming Language Standards
ANSI/ISO/IEC 6592.2000	Information Technology Guidelines for the Documentation of Computer Based Application Systems
ANSI/ISO/ASQC Q9000-3- 1997	Quality management and quality assurance standards Part 3: Guidelines for the application of ANSI/IAO/ASQC Q9001-1994 to the Development, supply, installation and maintenance of computer software
ANSI/ISO/ASQC Q9000-1-1994	Quality Management and Quality Assurance Standards—Guidelines for Selection and Use
ANSI/ISO/ASQC Q10007-1995	Quality Management Guidelines for Configuration Management
ANSI X9.31-1998	Digital Signatures Using Reversible Public Key Cryptography for the Financial Services Industry, 1998
ANSI X9.62-1998	Public Key Cryptography for Financial Services Industry: The Elliptic Curve Digital Signature Algorithm, 1998
ISO/IEC 9594-	ITU-T Recommendation X.509 (2000), Information technology -

8:2001	Open Systems Interconnection - The Directory: Public-key and attribute certificate frameworks

National Institute of Standards and Technology

FIPS 102	Guideline for Computer Security Certification and Accreditation
FIPS 112	Password Usage (3)
FIPS 113	Computer Data Authentication

Institute of Electrical and Electronics Engineers

488-1987	IEEE Standard Digital Interface for Programmable Instrumentation
796-1983	IEEE Standard Microcomputer System Bus IEEE/ANSI Software Engineering Standards
750.1-1995	IEEE Guide for Software Quality Assurance Planning
1008-1987	IEEE Standard for Software Unit Testing
1016-1998	IEEE Recommended Practice for Software Design Descriptions
1012-1998	IEEE Guide for Software Verification and Validation Plans

Military *Standards*

MIL-HDBK-454	Standard General Requirements for Electronic Equipment
MIL-HDBK-470	Maintainability Program for Systems & Equipment
MIL-HDBK-781A for	Handbook for Reliability Test Methods, Plans, and Environments Engineering, Development Qualification, and Production
MIL-STD-882	Systems Safety Program Requirements
MIL-STD-1472	Human Engineering Design Criteria for Military Systems, Equipment and Facilities
MIL-STD-973	Configuration Management, 30 September 2000

Other References

Designing for the Color-Challenged: A Challenge, by Thomas G. Wolfmaier (March 1999); http://www.sandia.gov/itg/newsletter/mar99/accessibility_color_challenged.html;

Effective Color Contrast: Designing for People with Partial Sight and Color Deficiencies, by Aries Arditi, Ph.D; http://www.lighthouse.org/color_contrast.htm

Electronic Markup Language (EML), Version 4.0, (Committee Draft) Organization for the Advancement of Structured Information Standards (OASIS), January 24, 2005

Guidelines for Writing Clear Instructions and Messages for Voters and Poll Workers, http://vote.nist.gov/032906PlainLanguageRpt.pdf

NIST Special Publication 500-256, Improving the Usability and Accessibility of Voting Systems and Products, http://vote.nist.gov

RSA Laboratories Technical Note, Public Key Cryptographic Standard (PKCS) #7: Cryptographic Message Syntax Standard, November 1, 1993

RSA Laboratories Technical Note, Extensions and Revisions to PKCS #7, May 13, 1997

The Americans with Disabilities Act Accessibility Guidelines (ADAAG 2202), Access Board; http://www.access-board.gov/adaag/html/adaag.htm

Appendix C Independent Verification Systems

Table of Contents

Appendix C: Independent Verification Systems

Appendix C is an informative section that describes Independent Verification systems followed by characteristics of the types of Independent Verification systems which will be used as the basis for future requirements. This information is preliminary and will be evolving with further research.

C.1 Independent Verification Systems

A primary objective for using electronic voting systems is the production of voting records that are highly precise, highly reliable, and easily counted - in essence, an accurate representation of ballot selections whose handling requirements are reasonable. To meet this objective, there are many factors to consider in an electronic voting system design, including:

- the environment provided for voting, including the physical and environmental factors
- the ease with which voters can use the voting system, i.e., its usability
- the robustness and reliability of the voting equipment
- the capability of the records to be used in audits

Independent Verification (IV) systems have as their primary objective the production of independent records of voter ballot selections that are capable of being used in audits in which their correctness can be audited to a very high level of precision. The primary voting security and integrity issues addressed by IV systems are:

- whether electronic voting systems are accurately recording ballot selections
- whether the ballot record contents can be audited precisely post-election

The threats addressed by IV systems are those that could cause a voting system to inaccurately record the voter's selections or cause damage to the voting system records. These threats could occur via any number of means including human error, accident or fraudulent activity. The threats are addressed mainly by providing, in the voting system design, the capability for ballot record audits to detect precisely whether specific records are correct as recorded or damaged, missing, or fraudulent.

C.1.1 Improved Accuracy in Independent Verification Audits

Independent Verification is the top-level categorization for electronic voting systems that produce multiple records of ballot selections that can be audited to a high level of precision. For this to happen, the records must be produced and made verifiable by the voter, and then subsequently handled according to the following protocol:

- At least two records of voter selections are produced and one of the records is then stored such that it cannot be modified by the voting system, e.g., the voting system creates a record of voter selections and then copies it to some unalterable media
- The voter must be able to verify that both records are correct, e.g., verify his or her selections on the voting system's display and also verify the second record of selections stored on the unalterable storage media
- The verification processes for the two records must be independent of each other and (a) at least one of the records must be verified directly by the voter, or (b) it is acceptable for the voter to indirectly verify both records if they are stored on independent systems
- The content of the two records can be checked later for consistency through the use of identifiers that allow the records to be linked

An assumption is made that at least one set of records is usable in an efficient counting process such as an automated tabulator, and the other set of records is usable in an efficient process of verifying its agreement with the other set of records used in the counting process. The sets of records would preferentially be different in form and thus have more resistance to accidental or deliberate damage.

Given these conditions, the multiple records are said to be distinct and independently verifiable; that is, both records are not under the control of the same processes. As a result of this independence, one record can be used to audit or check the accuracy of the other record. Because the storage of the records is separate, an attacker who can compromise one of the records still will face a difficult task in compromising the other.

C.1.2 Example Independent Verification Systems

The following sections present overviews of several types of IV systems. Some of these systems have not been marketed as yet but are included here to help clarify approaches to independent verification systems. The Independent Verification systems discussed are:

- voting systems with a split process architecture[41]
- end-to-end voting systems that include cryptographic audit schemes
- witness systems that take a picture of or otherwise capture an indirect verification of ballot selections
- direct independent verification, including voting systems that produce an optically scanned ballot or that produce a voter verifiable paper audit trail

[41] The split process architecture is otherwise known as the frog protocol, which was first described in the Caltech – MIT report: *Voting: What Is, What Could Be*, as part of a modular voting architecture. The frog term, i.e., the token, was chosen specifically to convey no information about the physical form of the object used to carry vote information between two separate modules of the voting station. The report is available for download at http://www.vote.caltech.edu/.

C.1.2.1 The Split Process Architecture for IV Systems

A voting machine with a split process architecture consists of vote capture and verification stations that are separate, i.e., two physical devices. A voter inserts an object called a token into the capture station to make ballot selections and then takes the token object to the verification station to review and store his or her votes. The token object could be paper or unalterable media. Two records of the vote are created: one on the token object and one by the verification station. Either could be used in the final count.

For any split process voting system, the interaction between the voter and the split process operates as follows:

- A voter is given a token object that has been initialized to be blank
- Supporting information is written to the token object including the ballot and identification information about the election and precinct
- The voter inserts the token object into a capture station such as a DRE, which reads the ballot information from the token and then displays the ballot to the voter by some means such as a touch screen. The voter makes his or her ballot selections, which causes a record of the vote to be recorded on the token object
- The voter takes the token object to a separate verification station, which reads the recorded votes from the token object, makes an electronic copy, and displays it to the voter
- The voter verifies that the information is correct and then deposits the token object in a secure container so it can be archived and used later for recounts or audits against the electronic records

Two sets of records are produced: the electronic records and the token records. Typically, the electronic records recorded by the verification station would be counted in the election. The records should be different in form and be resistant to accidental or deliberate damage to be useful for audits and recounts.

In theory, the physical separation of vote capture from vote verification may make analysis of the capture and verification devices easier or less costly. The rationale is that the user interface software on the capture station is expected to be complex and difficult to verify for correctness. On the other hand, the verification station's software is expected to be less complicated because it need only copy the contents of the token, display it to the voter, and store the ballot selections. In general, segregating functions by placing them on physically different systems is a standard computer security practice for making those functions easier to test for correctness and easier to manage securely.

C.1.2.2 End to End Cryptographic IV Systems

End to end systems use cryptographic techniques to store an encrypted copy of the voter's ballot selections. In this way, ballot selections can be audited and demonstrated to have been included in the election count.

End to end systems in existence today generally operate as follows:

- A voter uses a voting machine such as a DRE to make ballot selections
- The DRE issues a paper receipt to the voter that contains information that permits the voter to verify that the choices were recorded correctly. The information does not permit the voter to reveal his or her selections
- The voter may have the option to check that his or her ballot selections were included in the election count, e.g., by checking a web site of values that (should) match the information on the voter's paper receipt

End to end systems are sometimes referred to as receipt-based systems. They may provide an assurance not only that the correct set of ballot choices was recorded, but that those selections were included in the election count. Some analyses of auditing and cryptographic systems assert that very small numbers of self-audits are required to verify the correctness of an election.

C.1.2.3 Witness IV Systems

A witness system creates the second record of ballot choices by using a separate module to record or witness the voter's verification of the first record. The primary feature of a witness system is that the creation of the record does not require action by the voter. This may result in quicker voting times or voting systems that are simpler to use than other approaches that involve multiple, direct verifications by the voter.

An example of a witness system is a DRE with a camera mounted above its screen. The camera takes pictures and saves them independently of the DRE. It would operate as follows:

- A voter makes ballot selections at the DRE and then presses a button to record his or her vote
- The DRE records the ballot selections and uses them in the election count
- At the time the button is pressed, the camera takes a picture of the DRE summary screen and saves the image. The voter would not be included in the picture.
- This collection of images constitutes a second ballot record that can be used in audits and recounts

As can be seen by this example, the voter's interactions are reduced to making ballot selections at the DRE and pressing a button to make the selections final. If the DRE were to be compromised such that it secretly recorded the ballot choices incorrectly, the stored photographic images would reflect what the voter had seen and verified at the DRE summary screen.

Because the voter may not be able to verify that the creation of the second record was performed accurately, it is important that the creation process be highly reliable and very resistant to accidental or deliberate damage. Also, the suitability of the records for manual or automated auditing is a factor when considering this approach.

C.1.2.4 Direct IV Systems

Direct Independent Verification systems produce a record that the voter may verify directly with the voter's senses and which is then preserved for auditing or counting. Some optical scan voting systems fit this category, as well as DREs with VVPAT capability.

The optical scan voting systems in this category are those in which two records are created: a paper and an electronic record. This system uses Optical Scan Recognition (OCR) to create an electronic record from the paper record after the paper record has been directly verified by the voter. The general operation of this system is:

- A voter uses a marking device such as a DRE to mark a ballot and then presses a button to print the marked ballot
- The voter directly reviews the printed paper record to ensure its correctness, and if correct, places the paper record into a scanner. A procedure would be needed to handle voided ballots.
- The scanner converts the paper record into an electronic format. To reduce errors that may result from scanning the paper record, the paper records might contain a barcode representation of the human readable portion of the ballot.
- The paper record is deposited in a secure receptacle

No verification of the scanned paper record is performed in the above approach. One may assume that the scanning process is highly accurate and can be trusted to create the electronic record correctly; however it would be preferential for the voter to somehow verify that the record was, in fact, created correctly.

A DRE with VVPAT capability is similar to that of the optical scan above but consists typically of a DRE that both creates and records an electronic record, and a printer that creates a paper record of the voter's selections. Like the optical scan system, it creates two distinct representations of the voter's ballot selections: an electronic record and a paper record.

Typically, a voter would use the voting system as follows:

- A voter makes ballot selections and indicates that his or her selections are complete
- A paper record is printed of the voter's ballot selections as displayed on the summary screen. An alternative approach is to print the voter's ballot selections as they are made.
- The voter inspects and directly verifies that the paper record matches the displayed electronic record
- The paper record is deposited in a secure receptacle

Both approaches described here produce paper records that are verified directly by the voter through visual inspection. Voters with sight impairments would require an accessible device for verification that can produce an audible representation of the paper record.

C.1.3 Handling Multiple Records Produced by IV Systems

There are several fundamental questions that need to be addressed when designing the structure and selecting the physical characteristics of IV system records, including:

- how to tell if the records are authentic and not forged
- how to tell if the integrity of the records has remained intact from the time they were recorded
- the suitability of the records for various types of auditing
- how best to address problems if there are errors in the records

Whenever an electronic voting system produces multiple records of votes, there is some possibility that one or more of the records may not match. Records can be lost, or deliberately or accidentally damaged, or stolen, or fabricated. Keeping the two records in correspondence with each other can be made more or less difficult depending on the technologies used for the records and the procedures used to handle the records.

It is important to structure the records so that errors and other anomalies can be readily detected during audits. There are a number of techniques that can be used:

- associating unique identifiers with corresponding records, e.g., an individual paper record sharing a unique identifier with its corresponding electronic record
- including an identification of the specific voting system that produced the records, such as a serial number identifier, or by having the voting system digitally sign the records
- including other information about the election and the precinct or location where the records were created
- creating checksums of the electronic records and having the voting system digitally sign the entire sets of records so that missing or inserted records can be detected
- structuring the records in open, publicly documented formats that can be readily analyzed on different computing platforms

The ease with which records can be handled is a factor in the practical capability to conduct precise audits, given that some types of records are better suited to auditing and different voting environments than others. The factors that make certain types of records more suitable than others could vary greatly depending upon many other criteria, both objective and subjective. For example, paper records may require manual handling by poll workers and thus be more susceptible to accidental or deliberate damage, loss, and theft. At the same time, the extent to which the paper records must be handled will vary depending on the type of voting system in use. Electronic records may by their nature be more suitable for automated audits; however electronic records are still subject to accidental or deliberate damage, loss, and theft.

C.2 Core Characteristics for Independent Verification Systems

This section contains a preliminary set of characteristics for IV systems. These characteristics are fundamental in nature and apply to all categories of IV systems. They will form the basis for future requirements for independent verification systems.

- A voting machine equipped with independent verification produces two independent records of ballot selections via interactions with the voter such that one record can be compared against the other to check their equality of content.

Discussion: This is the fundamental characteristic of IV systems. The records can be checked against one another to determine whether or not the voter's selections were correctly recorded.

- The voter verifies the content of each record and either (a) verifies at least one of the records directly or (b) verifies both records indirectly if the records are each under the control of independent processes.
- The creation, storage, and handling of the records are sufficiently separate such that the failure or compromise of one record does not cause the failure or compromise of another.

Discussion: The records must be stored on different media and handled independently of each other, so that no one process could compromise all records. If an attack can alter one record, it should still be very difficult to alter the other record.

- Both records are highly resistant to damage or alteration and should be capable of long-term storage.

- The records are linked to their corresponding records by including a unique identifier within each record that can be used to identify the corresponding record.
- The processes of verification for the multiple records do not all depend for their integrity on the same device or software module, and are sufficiently separate such that each record provides evidence of the voter's selections independently of the corresponding record.
- The records can be used in checks of one another, such that if one set of records can be used in an efficient counting process, the other set of records can be used for checking its agreement with the first set of records.

Discussion: For example, an electronic record can be used in an efficient counting process. A paper record can be used to verify the accuracy of the electronic record. However, it is less suitable for efficient counting unless it can be corrected by an automated scan process.

- Each record includes an identification of the polling place and precinct.

Discussion: If the voting site and precinct are different, both should be included.

- The records include information identifying whether the balloting is provisional, early, or on election day, and information that identifies the ballot style in use.
- The records include a voting session identifier that is generated when the voting station is placed in voting mode and that can be used to identify the records as being created during that voting session.

Discussion: If there are several voting sessions on the same voting station on the same day, the voting session identifiers must be different. They should be generated from a random number generator.

- The records include a unique identifier associated with the voting station.

Discussion: The identifier could be a serial number or other unique ID.

- The cryptographic software in voting systems with independent verification is approved by the U.S. Government's Cryptographic Module Validation Program (CMVP) as applicable.

Discussion: Cryptographic software may be used for a number of different purposes, including calculating checksums, encrypting records, authentication, generating random numbers, and for digital signatures. This software should be reviewed and approved by the Cryptographic Module Validation Program. There may be cryptographic voting schemes where the cryptographic algorithms used are necessarily different from any algorithms that have approved CMVP implementations, thus CMVP approved software shall be used where feasible. The CMVP web site is http://csrc.nist.gov/cryptval.

C.3 Split Process Independent Verification Systems

This section contains characteristics specific to split process IV systems. The characteristics build on and are in addition to the core characteristics for IV systems. Split process systems consist of separate vote capture and verification stations, i.e., two physical devices. A voter inserts an object called a token into the capture station to make ballot selections and then takes the token object to the verification station to review and store his or her votes. Two records of the vote are created: one on the token object and one by the verification station.

C.3.1 Capture and Verification Stations

- The verification station is able to add information to the token object but cannot change prior recorded information.
- The capture and verification stations do not permit any communications between them except via the token object.
- The verification station shall log all rejected votes, including the precise contents of the votes and the identifier of the token object.

Discussion: The voter could reject and thereby void his or her ballot. This is to prevent the verification station from recording ballot selections that are different from what was entered at the capture station.

- The capture and verification stations could be purchased from different manufacturers and could use different operating systems.

Discussion: The greater the independence of the capture and verification stations, the less likely they could be compromised by the same threats, e.g., software viruses, or by a single conspiracy.

C.3.2 Data Formats for Token Objects

- The format for data written to the token object is specified and publicly available for use without licensing fees.
- The verification station verifies the correctness of the data on the token object and provides an indication of any errors to the voter.

Discussion: The verification station needs to verify that the data written to the token object was formatted properly according to the format specification and reject improperly formatted data. It also checks that the votes are consistent with the voting instructions, e.g., “vote for one, vote for two.”

- The record on the token object is digitally signed using a private key known only to the vote capture station and whose public key is distributed in an authenticated way to auditing systems and the verification station.
- The record created by the verification station is digitally signed using a private key known only to the verification station and whose public key is distributed in an authenticated way to auditing systems.
- The capture station associates a unique identifier with each record of voter selections to identify that record and link it to the corresponding record created by the verification station.

Discussion: The identifier serves the purpose of uniquely identifying the record to identify duplicates and/or for cross-checking two record types.

- The records from the verification station are randomly shuffled in memory when exported, so that the order of the records cannot be used to relate the votes to a specific voter.
- Rejected token objects are stored separately from accepted token objects for later auditing.

C.3.3 Storage and Communications of Records

- The verification station exports its records of voter choices accompanied by a digital signature on the entire set of electronic records and their associated digital signatures.

Discussion: This is necessary to determine if records are missing or substituted.

- The token objects are stored and transported in a physically secure way, using chain-of-custody mechanisms to ensure their integrity.
- The records from each station are randomly shuffled, so that an attacker learning the contents of those records at any point in the voting process can learn nothing about the order of votes cast.

C.4 Witness IV Systems

Witness IV systems are composed of two physically separate devices: the vote capture station that captures and stores records of voter selections, and the witness device that captures voter verifications of the records at the vote capture station. Because there are two devices, a number of the definitions for split verification systems apply equally well to witness systems. Because the vote capture station is in essence a DRE, a number of the definitions for DREs with VVPAT also apply to vote capture stations. A witness system fits somewhat loosely in the independent verification category because the voter performs only an indirect verification of ballot choices at the DRE. It is important that the witness device be tested extensively for accuracy and reliability and that malfunctions of the device be made immediately obvious to the voter and poll workers.

- A witness device records only a voter's verification at the vote capture station and stores the record so that it can be used for audit.
- A witness device acts as a passive device that cannot perform any operation with respect to the voting station other than to capture voter ballot selections as the voter verifies them.

Discussion: The witness device is synchronized with the voter verification of the ballot selections.

- A witness device, if attached to the vote capture station, is attached such that it can capture only the voter’s verification of ballot selections.

Discussion: For example, the witness device could be connected only to the display unit and not the vote capture station's memory or disk drive.

- The vote capture station is able to detect whether the witness device is connected or in operation.

Discussion: If the witness device is not in operation, the vote capture station should cease recording voter selections.

- The vote capture station and the witness device are connected using a publicly available, published communications interface, such as RS232 or USB.
- Because voters must trust that the witness device records their verifications accurately, assessments of its software and functionality are straightforward, readily performed, and include extensive evaluation and penetration testing above and beyond what may be performed on voting systems that do not contain witness devices.

Discussion: Witness device manufacturers will be required to fully document their systems and conduct stringent testing.

- A voter should be able to inspect the record of his or her verification upon request.

Discussion: It is desirable that a voter have the ability to verify that the witness device is operating as specified.

- The witness device clearly indicates any malfunction in a way that is obvious to the voter and poll workers.
- The records captured by the witness device are able to be used in highly accurate verifications of the voting records of the voting station.
- The records contain unique identifiers that correspond to records stored by the vote capture station.
- The records are digitally signed by the witness device so that the integrity and authenticity of its records can be verified.
- A witness device is able to export its records in an open, nonproprietary format such that the records can be used in automated audits.
- The records are stored in the witness device and exported such that voter privacy is protected, e.g., by randomizing the order of the records.

C.5 End to End Cryptographic IV Systems

This section contains very preliminary definitions for end to end cryptographic-based IV systems. They are consistent with the characteristics of IV systems and build on the core characteristics of IV systems.

End to end voting systems use cryptographic mechanisms as a substitute for some physical, computer-security, or procedural mechanisms used to secure other types of voting systems. These cryptographic mechanisms can be used by a voter to verify that ballot selections were recorded correctly and counted in the election. Some auditing procedures normally performed by voting officials at the tabulation center can be done by voters or their designated representatives, using receipts issued by the voting system that work in conjunction with the cryptographic mechanisms. Typically, multiple individuals, known as designated trustees, hold key information that is combined to form encryption and decryption keys; thus, no one person is able to encrypt or decrypt. Several types of cryptographic voting approaches have been proposed or implemented, with varying properties. There are many cryptographic techniques (such as secure multiparty computation and homomorphic) that could be applied in novel ways in future voting systems.

- End to end systems record voters ballot selections at electronic voting machines and encrypt the records of votes for later counting by designated trustees.

Discussion: The voting station would operate much as a DRE.

- End to end systems produce a receipt that can be used by the voter in a process defined by voting officials that would enable the voter to verify that the voter's ballot selections were recorded correctly and counted in the election.

Discussion: The receipt could have a variety of different forms but likely would be printed on paper for the voter’s ease of handling.

- No one designated trustee is able to decrypt the records; decryption of the records is performed by a process that involves multiple designated trustees.
- The receipt preserves voter privacy by not containing any information that can be used to show the voter’s selections.
- The process used to verify that ballot selections were recorded correctly and counted preserves voter privacy by not revealing any information that can be used to identify the voter's selections.
- End to end systems store backup records of voter ballot selections that can be used in contingencies such as damage or loss of its counted records.

Discussion: This is necessary because the handling of the encrypted records requires the same chain of custody procedures as records produced by other voting systems and are thus subject to loss or damage. This could be paper for example.

- The backup records contain unique identifiers that correspond to unique identifiers in its counted records, and the backup records are digitally signed so that they can be verified for their authenticity and integrity in audits.
- Cryptographic software in end to end systems is documented thoroughly and subject to extensive verification testing for correctness. The documentation

includes extensive discussion of how cryptographic keys are to be generated, distributed, managed, used, certified, and destroyed.

- Vote capture stations used in end to end systems must meet all the security, usability, and accessibility requirements.
- Reliability, usability, and accessibility requirements for printers in other voting systems apply as well to receipt printers used in end to end systems.
- Trustee systems are subject to the same evaluations and assessments as other voting systems.
- Systems for verifying that voter ballot selections were recorded properly and counted are implemented in a robust secure manner.

Discussion: Many of the cryptographic approaches have a "public append-only bulletin board" as a component; this is an important part of the system and needs to be implemented in a robust secure manner.

Appendix D Technical Guidance for Color, Size and Text

Table of Contents

Appendix D: Technical Guidance for Color, Contrast, and Text Size

Note: This appendix is provided for guidance only. See Volume 1, Section 3 for detailed requirements.

Although estimates vary, it is generally agreed that there are approximately 10 million visually impaired people in the United States. This estimate includes the 600,000 people who are legally blind. 8.1 million people were estimated to have a functional limitation in seeing in 1994, including both those with "non-severe limitation" (e.g., difficulty seeing words and letters) and those with "severe limitation" (e.g., unable to see words and letters). Approximately 1.8 million people in the U.S. have severe visual impairments but are not legally blind.[42] Low vision includes dimness of vision, haziness, film over the eye, foggy vision, extreme near-sightedness or far-sightedness, distortion of vision, color distortion or blindness, visual field defects, spots before the eyes, tunnel vision, lack of peripheral vision, abnormal sensitivity to light or glare and night blindness. For the purposes of this discussion low vision is defined as having a visual acuity greater than 20/70.

People with low vision or color blindness will benefit from high contrast and selection of color combinations that are appropriate for their needs. Between 7% and 10% of all men have color vision deficiencies. Certain color combinations in particular cause problems. Therefore, use of color combinations with good contrast is required.

However, some users are very sensitive to very bright displays and cannot use them for long. An overly bright background causes a visual “white-out” which makes these users unable to distinguish individual letters. Contrast ratio between 6:1 and 15:1 is optimal[43].

When color selection is provided the 16-color pallet as used in Microsoft Windows for 16 color displays and recognized by HTML 4.0 provides a sufficient range of both saturated and non-saturated color options. Use of non-saturated color options is an advantage for some people. The use of the 16-color palette or a larger color palette is suggested when voter adjustment of color is provided.

#	**Color Name** (Color names are per HTML 4.0)	**RGB Value** (Hexadecimal)
1	Black	#000000
2	Blue	#0000FF

[42] See the following sites for further detail:
http://blue.census.gov/hhes/www/disable
http://www.afb.org/info_document_view.asp?documentid=1367
http://www.brailleinstitute.org

[43] Cushman, W.H. and Rosenberg, D. J., Human Factors in Product Design. New York: Elsevier, 1991.

3	Lime	#00FF00
4	Red	#FF0000
5	Aqua	#00FFFF
6	Fuchsia	#FF00FF
7	Yellow	#FFFF00
8	White	#FFFFFF
9	Navy	#000080
10	Green	#008000
11	Maroon	#800000
12	Teal	#008080
13	Purple	#800080
14	Olive	#808000
15	Grey	#808080
16	Silver	#C0C0C0

Large fonts provide significant help to users with low or impaired vision. A voting system is required to provide letters of at least 6.3 mm, for capital letters. A capital "X" is often used to make this measurement. It is not the size per se, but visual angle that is of primary importance. Visual angle is a measure, in degrees, of the size of the retinal image subtended by a viewed object. It represents the apparent size of an object based on the relationship between an object's distance from the viewer and its size (perpendicular to the viewer's line of sight). An object of constant size will subtend a smaller visual angle as it is moved farther from the viewer. Visual angle is typically defined in terms of minutes of visual arc. For people with normal vision, it is recommended that the height of characters in displayed text or labels be at least 16 minutes of arc (4.6 milliradians), and the preferred character height should be 22 minutes of arc (6.4 milliradians), which is preferred for reading tasks.

The size required for low vision accessibility is somewhat arbitrary, in that the larger the size the greater the number of low vision voters who can be accommodated. The Usability/Accessibility Task Group for IEEE P1583 recommends 30 minutes of arc, depending upon the presumed viewing distance. A table in the usability section of IEEE P1583 provides the following recommendations based on three possible viewing distances:

- for a distance of 51 cm (20 in): 4.43 mm (.17 in)
- for a distance of 64 cm (25 in): 5.54 mm (.22 in)
- for a distance of 76 cm (30 in): 6.65 mm (.26 in)

People with tunnel vision can only see a small part of the ballot at one time. For these users it is helpful to have letters at the lower end of the font size range in order to allow them to see more letters at the same time. Thus, there is a need to provide font sizes at both ends of the recommended range.

Use of sans serif fonts is also recommended for computer displays. Sans serif fonts have proven to be easier to read on computer screens than stylized fonts.