

Draft Standard for Voter Verified Paper Audit Trails in DRE Voting Systems (DRE-VVPAT): Supplement to the 2002 Voting Systems Standard

Draft Version March 2, 2005

2 March 2005

National Institute of Standards and Technology (NIST)

Provided for consideration by the Technical Guidelines Development Committee (TGDC) and the Election Assistance Commission under the requirements of the Help America Vote Act (HAVA) of 2002.

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Credits

The National Institute of Standards and Technology (NIST) would like to acknowledge the individuals and groups who helped contribute to the preparation of this document. Members of the NIST voting team provided substantial assistance, especially Nelson Hastings, John Kelsey, Sharon Laskowski, and Alan Mink. Dr. Ronald L. Rivest, chair of the Security and Testing Subcommittee of the Technical Guidelines Development Committee (TGDC) provided strong leadership and guidance. NIST would also like to acknowledge Ms. Leslie Reynolds, executive director of the National Association of Secretaries of State (NASS) for her help in reviews of enacted State legislation, and the IEEE organization for permission to use excerpts from the IEEE P1583 Draft Standard for the Evaluation of Voting Equipment.

Authority

This document has been provided for consideration by the Technical Guidelines Development Committee (TGDC) and the Election Assistance Commission under the requirements of the Help America Vote Act (HAVA) of 2002.

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Executive Summary

This document has been provided for consideration by the Technical Guidelines Development Committee (TGDC) and the Election Assistance Commission under the requirements of the Help America Vote Act (HAVA) of 2002. It contains a discussion of requirements that are fundamental for providing VVPAT capability and that should be followed uniformly when providing Voter Verified Paper Audit Trail (VVPAT) capability in Direct Recording Electronic (DRE) voting systems. The requirements are intended to be usable by voting system manufacturers and election officials for the 2006 election cycle. It also contains a discussion of objectives, benefits, and issues involved in VVPAT and a summary of enacted State VVPAT-related legislation.

A DRE voting system with VVPAT capability, referred to as a *DRE-VVPAT*, consists of a DRE, mechanisms for printing a paper record of the voter's choices and for the voter to verify the paper record, and a ballot box for storing the paper records. Generally, a voter makes ballot selections at the DRE and then causes the paper record to be printed in. If the voter determines that the paper record matches the electronic record and is accurate, the voter can then finalize his or her vote. Otherwise, the voter may spoil the ballot and reenter ballot choices at the DRE. Once the vote is final, the paper record is stored and retained in the ballot box. The paper record is typically used to audit the accuracy of the electronic record as well as for recounts, but may be used as the official ballot of record.

The presence of the paper record can significantly increase voter satisfaction and trust in the accuracy of electronic voting systems and in elections. Electronic voting systems are inherently complex; consequently it is difficult to ascertain whether they are implemented correctly. The issue of whether the DRE-VVPAT voting system has accurately recorded the voter's intent is less important because the paper is a tangible, permanent record of voters' choices that can be manually audited or recounted or used in case of problems with the electronic voting system.

VVPAT capability introduces a number of issues that must be addressed carefully if the capability is to have value. These issues include inherent problems in handling paper records, the suitability and reliability of the VVPAT equipment, accessibility and usability issues in using the equipment, and complexities involved in handling and audit the correspondence between the electronic and paper records.

Analysis of these issues as well as current VVPAT-related legislation enacted by various States results in requirements for VVPAT capability affecting the design of VVPAT equipment and the specification of specific procedures to follow in handling the paper and electronic records. The requirements include such aspects as accessibility and usability of the DRE-VVPAT, audits, recounts, data formats, printer reliability, and procedures and training for election officials.

The core requirements fundamental to VVPAT capability are as follows:

- R1. The DRE-VVPAT shall show the voter a paper record of the voter's electronic ballot choices which constitutes a distinct record of the voter's ballot choices.
- R2. The DRE-VVPAT shall permit the voter to compare the paper and electronic records with maximum ease according to established accessibility and usability guidelines.
- R3. The method for voter verification shall be accessible to all voters.
- R4. The DRE-VVPAT shall permit the voter to accept or reject the paper record and reenter ballot choices at the DRE-VVPAT.
- R5. The voter's privacy and anonymity shall be preserved during the process of recording, verifying, and auditing ballot choices.
- R6. The DRE-VVPAT shall permit robust auditing, forensics analysis, and full recount capability of its electronic and paper records.
- R7. The DRE-VVPAT equipment shall be secure and resistant to failures, and shall be usable in its administration.
- R8. Trained personnel, procedures, and consumables shall be in place during elections to handle all aspects of VVPAT capability.

1. Introduction and Overview

This document provides requirements for voting system manufacturers and election officials for the purposes of providing a Voter Verified Paper Audit Trail (VVPAT) capability in Direct Recording Electronic (DRE) voting systems. It can be used as a supplement to the 2002 Voting Systems Standard (VSS). It is meant to provide requirements and guidance for voting systems for the 2006 election cycle.

This document is produced by NIST for consideration by the Technical Guidelines Development Committee (TGDC). This document has been produced at the request of the Election Assistance Commission (EAC) as well as by Resolution 12-5 authored by Ronald L. Rivest at the TGDC meeting in January, 2005 [4].

Certain U.S. States and some local voting jurisdictions are now mandating that voting system manufacturers provide DRE models that contain a ballot verification method, i.e., a DRE-VVPAT. The method that is generally specified is one in which a paper representation of a voter's choices as made on a DRE are printed on paper and the voter is then given the opportunity to verify that the paper representation is accurate before finalizing the choices made on the DRE's display. The paper representations are a distinct representation of the electronic ballots as maintained by the DRE and can be used for auditing and recounts. Typically, the DRE representations are the primary representation of the ballot, or ballot of record to be used in vote tallies and the paper record is used for audit and recounts. However, either representation could be used as the ballot of record.

Currently, State and local election officials and DRE manufacturers are responding in specific ways to State-legislated requirements for providing VVPAT, resulting in various different approaches that may or may not be appropriate. This is due in part to the lack of generally-accepted standards describing the fundamental requirements for VVPAT¹. Consequently, this document provides those fundamental, core requirements to be used as a uniform approach to providing VVPAT capability in DRE systems.

1.1 Audience

This document is produced for the TGDC, but is aimed at DRE manufacturers and State and local election officials. This document is also aimed towards the many parties who are concerned with fair, secure, and transparent elections.

1.2 Document Scope

This document discusses requirements pertaining to use of VVPAT involving DRE voting systems that create paper-based records of voter's choices. It does not

¹ The State of California has produced requirements for VVPAT [1] and various other States have enacted legislation that contains general requirements. The California standard and other States' legislation is very useful; however they do not provide detailed requirements.

discuss other methods for providing voter verification and additional transparency in elections².

Because this document is a supplement to the 2000 VSS and is meant to provide requirements and guidance in the near term for 2006, the requirements described in this document are intended to be achievable with current technology. NIST recognizes the need for next-generations standards that take into account new technologies, especially in the areas of accessibility and security.

1.3 Structure of the Document

Chapter 1 deals with introductory material.

Chapter 2 provides a definition of VVPAT, various benefits and disadvantages associated with VVPAT capability, issues involved in dealing with paper and electronic representations of voter's choices, and an analysis of existing requirements for VVPAT capability in legislation and from other authoritative sources.

Chapter 3 provides core requirements for VVPAT. The core requirements are followed by derived requirements and recommendations.

Chapter 4 provides other recommendations and suggestions for further study and action.

Appendix A provides references; Appendix B contains terms, Appendix C provides a requirements tracking table.

² Some voting systems provide voter verification via other methods such as via photographs of DRE displays or via cryptographic techniques, although various requirements discussed in this document may prove applicable to these other systems.

2. VVPAT: Definition and Existing Requirements Analysis

This section contains an overview of a VVPAT capability: its fundamental purpose, various associated benefits and drawbacks, and issues inherent in dealing with two distinct representations of voter's choices. With this discussion in mind, it contains summaries of enacted State legislation requiring VVPAT capability as well as the State of California's Accessible Voter Verified Paper Audit Trail Standards [1]. Lastly, this section contains a discussion of what enacted legislation and other analysis suggests as for the fundamental issues and requirements for VVPAT capability.

2.1 VVPAT Definition and Components

For the purposes of this document, a DRE voting system with VVPAT capability consists of a DRE, a means for printing a paper audit trail of the voter's choices, a means for the voter to verify the paper audit trail without handling it, and a ballot box used for storing the paper audit trails after they have been verified or spoiled. This will be referred to as a *DRE-VVPAT*.

A DRE-VVPAT creates two distinct representations of the voters' ballot choices: the electronic representation and the paper audit trail. These will be referred to as the *electronic record* and the *paper record*.

The overall aims or purpose of a VVPAT can be summarized as follows:

- To create a permanent record of voters' choices that is distinct from the electronic record maintained by the DRE-VVPAT and that can be used to audit the electronic record maintained by the DRE-VVPAT and for use in recounts,
- To permit the voter, at the time of voting, to verify that the DRE-VVPAT is recording the electronic ballot choices correctly and to resolve problems should they occur, and
- To overall increase the accuracy and trust in elections.

Generally, a voter uses the DRE-VVPAT to make ballot selections and then indicates that his or her selections are complete. At that point, the VVPAT-DRE prints a paper record summary of the voter's ballot choices so that the voter can inspect and verify that the paper record matches the displayed electronic record. During this verification, the voter can either accept or spoil, i.e., reject the choices represented on the paper record. After completing the verification process, the paper record copy is stored and retained in the DRE-VVPAT's ballot box.

Accessibility in the paper record verification procedure is assumed, but this may involve mechanisms in the DRE-VVPAT in addition to those already described. An example would be for sight-impaired voters, in which the verification step may involve the contents of the paper record being read back to the voter by an audio unit.

2.2 Benefits to Providing VVPAT

Handling paper ballots inserts more complexity into the voting process, but at the same time its presence can significantly increase the voter satisfaction and trust in the accuracy of electronic voting systems in elections. The paper records, once verified by the voter, can be used as an audit trail that is distinct from the electronic voting system and can be assumed, on an individual record by record basis, to be accurate. The following sections describe various benefits to providing VVPAT and electronic voting systems.

2.2.1 Permanency of Paper Records

Paper records are tangible and relatively permanent and thus they are directly verifiable by voters, whereas many other technologies will always have the property that the verification involves trusting computer software. Paper has the attribute of being directly verifiable by human senses and therefore can be used in manual recounts. There can be other methods for producing a tangible, verifiable audit trail such as via audio, but currently there are only research prototypes in existence.

2.2.2 Increased Trust

Various analyses and critiques of VVPAT capability come to common conclusions that VVPAT adds more trust to elections in the eyes of the voter because a paper record of voter's ballot choices is created and archived. Electronic voting systems are inherently complex and therefore difficult to ascertain whether they are implemented correctly. The issue of whether the DRE-VVPAT voting system has accurately recorded the voter's intent is less important because of the paper verification step and that paper is a tangible, permanent representation of voter choices that can be manually audited or recounted or used in case of problems with the electronic voting system.

2.2.3 Fraud Detection

A further advantage of providing VVPAT capability is that certain types of election fraud become easier to detect. Because the paper records are audited against the electronic records, ballot box stuffing or thefts and insertions of ballots becomes more obvious. The methods for subverting either the contents or the tallies of the paper records and the electronic records at the same time are quite different, requiring two set of skills and two sets of conspirators.

2.3 Major Issues in Providing VVPAT

Some analyses of VVPAT have asserted that States and jurisdictions have rushed to require VVPAT capability but have not adequately addressed various important associated issues. These issues add complexity and create various new requirements; therefore they must be properly identified and addressed carefully. These issues include:

- Handling and auditing physical paper records
- VVPAT printer reliability issues
- Time to vote and election space issues
- Near-term accessibility and usability issues

- Usability issues affecting the value of VVPAT
- Issues involved in handling multiple representations of votes
- Issues in resolving disputes

2.3.1 Issues Involved in Handling and Auditing Physical Paper Records

For voting officials, handling paper records is much like handling physical paper ballots. There is inherent difficulty in handling large amounts of paper records, and in maintaining a correspondence between the paper records and the electronic records. Large amounts of paper records can be cumbersome to handle and require large amounts of secure space to store. Currently, there are no commonly accepted requirements for the size or type of paper to be used for VVPAT.

Election fraud involving paper has been a long-term problem. Paper can be accidentally or deliberately marked or mangled in the process of handling it, rendering it useless as an audit trail. Security procedures involved in handling the paper are extremely important to ensure that the paper records remain valid and useful as an audit trail and for recounts.

There are many usability issues associated with paper, and large, complex ballots may lend themselves to be better viewed on electronic voting system screens rather than as paper ballots. The paper records need to be displayed such that they cannot be handled by voters or can be handled as little as possible, but at the same time be easily viewable and compared with their corresponding electronic records. This requires careful attention to usability aspects involved in the verification process.

Paper is inherently more difficult to handle as an audit record. The paper must be either manually or machine scanned and compared to the electronic record. There are many documented problems in auditing paper by hand, and these problems can be magnified if the paper records are not cleanly printed and subject to ambiguity in their markings. However, auditing can be made easier by making the paper records machine-readable. Barcoded and other encoded representations of information are used commonly in shipping labels and on product packaging; paper ballots could also contain encoded representations of their human-readable contents. This may actually reduce problems that are inherent in auditing paper ballots.

2.3.2 VVPAT Printer Reliability Issues

The smooth functioning of printing devices is critical to the use of VVPAT capability. In certain elections in which VVPAT capability was used, there have been reports of printer problems and delays as result of standard maintenance issues such as adding paper and changing printer ink devices, as well as printer malfunctions that required replacing the printer or, in some cases, taking the DRE-VVPAT out of service. There have also been reports of election management workers who did not have the requisite training and capability to administer and printer issues and problems. This has resulted in some cases in long delays at voting stations and use of hand-coded paper ballots.

Another problem associated with printing devices is that they can misprint or mangle paper records. This can result in inaccurate counts between the totals of electronic

and paper records, making the records more difficult to audit and requiring greater time to recounts and reconcile the records.

The solutions to these problems involve specifying printers that are highly reliable, and when they do break down or require maintenance, they are easily repaired or replaced without disrupting voting sessions except for the delay involved in disconnecting the faulty printer and reconnecting a different printer. Replacement printers and consumables will need to be readily available at all times. Lastly, procedures to anticipate printer problems will need to be specified and appropriately trained personnel will need to be on hand.

2.3.3 Time to Vote and Space Issues

A hidden consequence to adding a verification step to the DRE is that of increasing the time per voter required to cast votes. This may have the result of longer lines or the need for more voting equipment at each polling place. Readability and usability of the VVPAT capability directly affects these costs.

The additional verification-related equipment required for a DRE-VVPAT increases the size of the voting system overall, and may possibly make it heavier and more complicated to set up and break down. This has ramifications not only for voting officials who must manage the DRE-VVPAT but also for the physical space required for voting sites.

2.3.4 Near-term Accessibility and Usability Issues

Since VVPAT is relatively new, usability data associated with VVPAT capability is incomplete and more study must occur before there is common consensus on usability requirements for VVPAT. There are currently no commonly accepted requirements for the physical size of paper records, how they should be formatted, and how they should be displayed in accordance with the electronic records. However, some performance benchmarks are under development and it is possible to specify some generic design guidance.

The accessibility of DRE-VVPAT for voters with disabilities is also problematic. Current technology allows for paper records to be printed in multiple languages to accommodate non-English speaking voters, but VVPAT systems to accommodate voters with site impairments are not readily available. In the near-term, it may not be possible to accommodate site impaired voters for the 2006 election cycle, and these voters may be forced to use DRE systems without the paper record voter verification procedure.

It should be noted that storing paper records in non-English languages may present privacy problems for the respective voters. If there are relatively few voters using the accessible DRE-VVPAT, it may be easy to determine the identity of those voters. However, the privacy problems can be overcome somewhat by mandating that a certain minimum number of voters, such as five, shall use the accessible DRE-VVPAT.

2.3.5 Usability Issues Affecting the Value of Providing VVPAT

The usability of the paper record and of the DRE-VVPAT has been recognized as major issues of concern affecting the value of providing VVPAT capability. The usability of VVPAT affects two audiences: voters and the election officials who perform DRE-VVPAT management and auditing. If the usability is poor for either audience, the value of the voter verification and subsequent auditing can be greatly diminished.

For voters, the paper records must be easily viewed and compared with electronic records. If the usability of the verification procedure is poor, voters are less likely to perform the verification step [16] [17]. Consequently, one can conclude that the value of the verification procedure will be significantly affected by its usability, and if it is poor, the DRE-VVPAT essentially becomes a DRE with meaningless VVPAT.

If the management of the DRE-VVPAT is not well suited or is too difficult for the capabilities of typical election officials involved in DRE management, then proper procedures may not be followed in operating the DRE-VVPAT. This may result in the DRE-VVPAT becoming unreliable and perhaps unusable. If the usability of the auditing procedures is poor, then paper records may be handled incorrectly and the value of the auditing could be greatly diminished. If either procedures are not followed or paper records are not handled correctly, it may be impossible to assign any degree of correctness to the results of the auditing.

2.3.6 Issues Involved in Handling Multiple Representations of Votes

The electronic and paper records constitute two distinct representations of votes, each with different handling requirements. For the purposes of robust auditing, it is important that each type of record constitute a complete record of all votes cast on the DRE-VVPAT and that the paper records correspond exactly to the electronic records. Furthermore, it is important that spoiled paper records also have an electronic equivalent.

As stated in the discussion on printer reliability, printers may occasionally malfunction and mangle paper records -- or the paper records may become mangled by some other means. Paper records may be fraudulently inserted or stolen. This makes it more difficult to know whether the paper record tally is accurate and whether to trust that the DRE has accurately recorded votes -- which are primary reasons for performing VVPAT in the first place. Again, printer reliability and procedures to keep the paper records secure and in correspondence with the electronic records are critical.

Providing additional markings on paper records to assist in identifying the records and associating them with their corresponding electronic records can help simplify the auditing process. Paper records can contain an identification of the election, the voting precinct, and an identifier associated with the specific DRE-VVPAT, all without violating user privacy. If handled correctly, the paper record and its corresponding electronic record could both contain a unique identifier, which could then be used to perform a record by record audit. As a result, auditors could more easily detect

whether paper records have been lost or inserted, or vice versa, and then determine with more accuracy how to resolve discrepancies in the records.

While providing the unique identifier can add additional precision and simplification to auditing procedures, at the same time it may violate voter privacy if a voter is able to see and remember the unique identifier. Therefore, if used, the unique identifier would need to be hidden from the voter, as well as election officials, and might best be encoded such that it is not human readable.

2.3.7 Issues Involved in Resolving Disputes

A perplexing problem is: how does one handle disputes or discrepancies between paper and electronic records? The answer may not be clear in many cases as to which record should be trusted to be accurate.

For example, if the DRE-VVPAT system were to display different ballot contents than contained on the paper record, one could safely assume that the voting system is faulty and should be taken out of service. But, one then may not be able to trust that the previously recorded electronic or paper records are accurate, because they were printed and recorded by the same allegedly faulty system. In this particular case, one could assert that the paper record may be more reliable since there is the possibility that each voter verified the paper records, assuming that the usability of the verification procedure is such that a statistically significant number of voters have used the verification procedure.

In a situation where the total count of paper records does not match the total for the electronic records, it may not be possible to determine with certainty which of the records is accurate. In certain cases, such as when paper ballots have been garbled and can't be read, the electronic records may have to be trusted. However, if paper records appear to be missing, the answer as to whether the electronic records are to be trusted is more difficult to answer -- one may not be able to ascertain whether paper records are indeed missing or whether additional electronic records have been added. Ultimately, election officials may have to handle discrepancies between paper and electronic record counts individually. Thus, mandating that the paper record shall always be trusted over the electronic record (or vice versa) may not result in greater accuracy.

This suggests that the paper record and the electronic record should be treated as two separate but equal representations of voter's choices. The term, voter verified paper audit trail, indicates that paper be used to audit the accuracy of the electronic record, however it may not be meaningful to mandate that either the paper record or the electronic record always be used in recounts or when discrepancies occur. This, obviously, is something that cannot be addressed in voting standards and that must be handled in local election law.

2.4 Implications of Enacted State VVPAT-related Legislation

This section contains an overview analysis of enacted State legislation for States requiring DRE-VVPAT capability. The legislation here is current as of this document's date of publication.

The States that have enacted legislation containing requirements for VVPAT capability are as follows:

1. Alaska HB-459
2. California SB 1438
3. Illinois Public Act 093-573
4. Maine LD-1759
5. Ohio HB-262

The States of New Hampshire and Vermont have enacted legislation requiring use of paper ballots; however the legislation does not contain requirements relating to DRE-VVPAT capability. Also, some States such as Missouri, Nevada, and Oregon have issued mandates for use of DRE-VVPAT capability in elections, but again these mandates generally do not contain requirements useful for the analysis considered here. 23 other States have introduced VVPAT-related legislation, and five separate bills have been introduced for consideration by the U.S. Congress; it is unknown whether this legislation in its current forms will be enacted, thus it is not considered here for analysis.

Table 2-1 summarizes the enacted State VVPAT-related legislation. The State of California has issued a standard containing requirements for providing VVPAT capability [1]; this State's enacted legislation is considered in conjunction with its standard. The legislation and standards are summarized as to how they deal with the following issues as discussed in Section 2.3:

- Common definitions of VVPAT capability
- Usability requirements related to VVPAT procedure and paper record presentation
- Accessibility requirements
- The process for spoiling paper records
- Whether paper records are tracked against their electronic records
- Auditing requirements
- Machine readability of paper records
- Procedures for handling discrepancies in counts or content between paper and electronic records

Table 2-1: Enacted State VVPAT-related Legislation Summary

State Law Comparison	Alaska HB-459	California SB 1438/Standard	Illinois Public Act 093-573	Maine LD-1759	Ohio HB-262
Date for vendor compliance	Immediate	01/06	Unspecified	????	On & after 1st federal election after 01/06
Ballot of record	Electronic	Electronic	Electronic; paper for write-ins & if contested	Electronic	Electronic
Audit or recount	Paper	Paper	Paper	Paper	Paper
How are paper records spoiled	Paper reviewed, corrected by voter	Spoiled paper marked in voter's presence	Paper reviewed, corrected by voter	Spoiled paper counted; totals deducted from vote totals for that district	Paper is reviewed, corrected by voter at time vote is cast

State Law Comparison	Alaska HB-459	California SB 1438/Standard	Illinois Public Act 093-573	Maine LD-1759	Ohio HB-262
How are discrepancies between electronic and paper records handled	Unspecified	Paper record has precedence unless obvious errors	Unspecified; must be reported to canvassing board	Voter gets assistance of election officials; paper spoiled & preserved; voter fills out provisional ballot or uses other DRE; if 5 occur on a DRE, DRE impounded; paper hand recounted; used in tally	Unspecified
Audit frequency	Unspecified	Paper used for 1% manual recount and full recounts	1% of precincts after each election	Paper recount of up to 2% of voting places	Unspecified
Paper record machine-readable	????	Unspecified	Yes or manually transcribed	Unspecified	Yes
Electronic marked to correspond with paper record	Unspecified	Implied	Yes	Implied	Unspecified
Other markings on paper record	Unspecified	Security protections to prevent tampering	Must identify precinct & election	Must identify individual machine	Unspecified
Usability issues with paper or printer	Unspecified	Must meet federal, State readability requirements	Unspecified	DRE must produce legible, large-print ballot	VVPAT paper must be clean & sturdy.
Accessibility issues	Accessible without assistance	Accessible without assistance	Accessible method without assistance	Accessible method not required	Accessible method without assistance

Enacted State legislation is thus far not entirely consistent with regard to requirements for handling the major issues associated with VVPAT as discussed in Section 2.3. However, almost all of the major issues are dealt with by at least one of the States, although no one State specifies requirements for the complete set of issues.

2.5 Summary Implications Affecting Requirements VVPAT

It is clear that providing a VVPAT capability involves much more than simply attaching a printer to a DRE voting system. To achieve its aims, a VVPAT capability must include full recognition of its purpose as well as address its limitations and requirements as best possible. It requires adjustments to voting systems software and other hardware involved in viewing the paper record and handling the paper record for storage. It requires addressing the human factors of the voter verification process in the context of the DRE voter interface. It involves new procedures for voting system officials and workers to follow during elections and post elections. It involves the inherent drawbacks with handling paper ballots, as well as the potential malfunctions and breakdowns of printing equipment. It also involves new procedures required to handle potential discrepancies between the electronic record of votes and the equivalent paper record.

Drawing conclusions then, the following issues are critical to the proper functioning of VVPAT capability:

- The ease with which a voter can compare a paper record to the electronic record displayed by the DRE-VVPAT so that the verification procedure is used and is accurate
- The ease and accuracy with which election officials can handle the paper records, ensure their security, and audit them against the electronic records to determine whether votes are being captured correctly by the DRE-VVPAT
- Specification of procedures to handle discrepancies between the electronic and paper records
- The overall usability of the DRE-VVPAT equipment and its ability to be managed properly by election officials
- Anticipation of major issues and complexities associated with VVPAT and procedures to address them
- Proper training for election officials to handle all aspects of VVPAT capability and assist voters in using DRE-VVPAT systems

Based on the analysis in this chapter, Chapter 3 specifies core, fundamental requirements for providing VVPAT capability in DRE systems.

3. Core Requirements for Providing DRE-VVPAT Capability

This section describes core requirements that are fundamental for providing VVPAT capability in DRE systems. It contains a series of documented performance requirements that describe how the voting system with VVPAT capability should operate or what voting-related personnel must do, and design requirements that specify how the voting system with VVPAT capability must be structured or built such that it can satisfy the associated performance requirements. It can be viewed as a supplement to the requirements in the 2002 VSS.

Unless stated otherwise, other aspects to VVPAT capability not specifically dealt with in this discussion are assumed to be governed by requirements in the 2002 VSS. For example, the paper ballot records shall meet the 22 month retention requirements as stated in the VSS.

3.1 Physical Components Terminology for VVPAT Capability

For the purposes of the requirements discussion, a voting system that provides VVPAT capability consists of the following physical components:

- **DRE-VVPAT**: the DRE voting system containing VVPAT capability
- **electronic record**: the electronic ballot image created and maintained by the DRE-VVPAT consisting of a summary of the voter's ballot choices
- **paper record**: the paper ballot image or summary that is a copy of the electronic record and that is verified by a voter
- **DRE-display**: that part of the DRE-VVPAT that displays the electronic record, assumed to be accessible as required by State law
- **VVPAT-display**: a transparent covering over the paper record printed by the DRE-VVPAT; it permits a voter to inspect the paper record but prevents the voter from physically handling the paper record, assumed to be accessible as required by State law
- **VVPAT-printer**: the printing capability of the voting system, including the printer and any associated device involved in printing the paper records and transferring them to ballot boxes
- **VVPAT-ballot box**: the ballot box containing the paper records
- **election officials**: e.g., poll workers, those individuals who manage the operations of the DRE-VVPAT and who may perform such duties as assisting voters in using the DRE-VVPAT or managing the operations of the DRE-VVPAT or performing auditing of paper and electronic records

3.2 General Overview of DRE-VVPAT Operations and Usage

3.2.1 Voting Perspective

A voter uses the DRE-VVPAT to make ballot selections and then indicates that his or her selections are complete. At that point, the voter causes the DRE-VVPAT to create a paper record and make this viewable to the voter via the VVPAT-display. The voter is then able to verify that the paper record is an accurate representation of the voter's choices as displayed by the DRE-display.

During this verification step, the voter can either (a) finalize his or her voting choices or (b) spoil the electronic and paper records and return to the DRE-VVPAT to make different voting selections. When spoiling the paper record, the VVPAT-printer marks the paper record as spoiled and typically drops the spoiled paper record into the VVPAT-ballot box. When the voter is ready to finalize his or her voting choices, the VVPAT-printer marks the paper record as accepted. The voter or the VVPAT-printer then places the accepted paper record into the VVPAT-ballot box. If the voter spoils the paper record too many times, the election official generally provides a provisional paper ballot; the voter fills out the ballot by hand.

Voters with accessibility needs can use an accessible DRE-VVPAT. Voters with non-English language requirements can be accommodated by displaying and printing records in the voter's language. Sight-impaired voters, for the near-term, may not be able to verify the printed paper record, but may still use the indirect-verification of the electronic record as provided by current DRE technology.

3.2.2 Auditing Perspective

The DRE-VVPAT design contains specific capabilities for making the audit of its records more accurate and easier to accomplish. It marks the paper ballots with information concerning the election and voting precinct, and includes as well an identification of the specific DRE-VVPAT. It maintains a one-to-one correspondence between its paper records and electronic records by including a unique identifier for each record pair. It also prints the paper record such that it is machine-readable.

To support post-election analysis, the DRE-VVPAT can export its electronic records using a publicly documented format that can be processed on common computing platforms.

3.3 Core and Derived Requirements for VVPAT

The following sections contain a definition of core requirements considered to be fundamental to providing VVPAT capability, and then a series of performance and design requirements derived from the core requirements. A number of the requirements are traceable back to enacted State legislation, the IEEE's draft voting system standard, or the California State standard. Appendix C provides this traceability along with a mapping of the requirements to the following categories, based loosely on the IEEE draft's requirements categorization scheme:

- Paper and Electronic Records Handling

- Paper Record Properties
- VVPAT-Display
- VVPAT-Printer
- VVPAT-Ballot Box
- Auditing
- Procedures and Training

A summary of the core VVPAT requirements is as follows:

- R1. The DRE-VVPAT shall show the voter a paper record of the voter's electronic ballot choices which constitutes a distinct record of the voter's ballot choices.
- Requires that DRE-VVPAT create contemporaneous paper record of ballot choices.
 - Requires the paper record be a complete summary of the electronic display.
 - Makes explicit that electronic and paper records constitute distinct representations.
- R2. The DRE-VVPAT shall permit the voter to compare the paper and electronic records with maximum ease according to established accessibility and usability guidelines.
- Specifies accessibility and usability requirements for the appearance of the paper record.
 - Specifies usability requirements for how the paper record shall be displayed.
- R3. The method for voter verification shall be accessible to all voters.
- Specifies accessibility requirements for voters with disabilities.
 - Specifies accessibility requirements for voters with Limited English Proficiency (LEP).
 - Specifies requirements for voters with Native American and Alaska Native languages that are not written.
- R4. The DRE-VVPAT shall permit the voter to accept or reject the paper record and reenter ballot choices at the DRE-VVPAT.
- Requires procedures to handle verification-related problems.
 - Ensures correspondence between the electronic and paper records.
 - Specifies procedures for spoiling electronic and paper records.
 - Requires that spoiled electronic and paper records be tallied and compared to each other.
 - Requires procedures dealing with spoiling limits.
- R5. The voter's privacy and anonymity shall be preserved during the process of recording, verifying, and auditing ballot choices.

- R6. The DRE-VVPAT shall permit robust auditing, forensics analysis, and full recount capability of its electronic and paper records.
- Enables election officials to audit with greater precision.
 - Mandates that paper record be suitable for full recount.
 - Deals with problems in handling paper records.
 - Requires random auditing that can take place at surprise intervals.
 - Requires post election auditing.
- R7. The DRE-VVPAT equipment shall be secure and resistant to failures, and shall be usable in its administration.
- Specifies requirements for all aspects of VVPAT printing.
 - Includes requirements for high reliability, maintenance, and suitability.
- R8. Trained personnel, procedures, and consumables shall be in place during elections to handle all aspects of VVPAT capability.

The following subsections described each of the core requirements and their specific derived sub requirements.

3.3.1 Requirement 1: the DRE-VVPAT shall show the voter a paper record of the voter's electronic ballot choices which constitutes a distinct record of the voter's ballot choices.

Summary: This is the basic requirement for VVPAT capability. It requires that the paper record be created as a distinct representation of the voter's ballot choices as recorded by the DRE-VVPAT. It requires that the paper record contain the same information as displayed by the DRE-VVPAT, including warnings for undervotes and fields for write-in candidates.

- 3.3.1.1** The voter, upon completing his or her ballot choices at the DRE-VVPAT, shall be able to cause the DRE-VVPAT to print and display a paper record of the voter's ballot choices prior to making the ballot choices final.
- 3.3.1.1.1** The electronic and paper record shall, at a minimum, contain a summary of the voter's ballot choices.
- 3.3.1.2** The paper record shall contain all information and warnings displayed by the VVPAT-display.
- 3.3.1.2.1** The electronic and paper record shall contain warning messages indicating undervotes.
- 3.3.1.2.2** The paper record shall contain appropriate fields for write-in candidates.
- 3.3.1.3** The paper records shall constitute a complete record of ballot choices that is distinct from the electronic record and that can be used for a complete recount and auditing of the electronic record.

3.3.2 Requirement 2: The DRE-VVPAT shall permit the voter to compare the paper and electronic records with maximum ease according to established accessibility and usability guidelines.

Summary: It mandates that the paper record be formatted and displayed to promote voter verification. It requires that the paper record be displayed in conjunction with the DRE-display according to established usability guidelines, such that the voter is able to verify his or her votes with reasonable ease and satisfaction.

Generally, all accessibility and usability-related requirements should, in the generic-sense, refer back to the accessibility and usability supplements to the VSS that are under development by NIST, and the accessibility and usability requirements in this section should be here only if they are specific to VVPAT.

- 3.3.2.1** The paper record shall be of sufficient size to display a complete summary of the electronic record so that the voter may privately and independently review its contents.
- 3.3.2.2** The paper record shall be of sufficient size to contain an encoded representation of its contents, encoded markings on the ballot to support auditing, and other markings on the ballot as required by election jurisdictions such as identification of the election and the voting precinct
- 3.3.2.3** The ballot summary layout of the electronic and paper record shall be specified in the ballot design for the election and shall observe all usability requirements as specified for the ballot.
- 3.3.2.4** The paper record shall be formatted according to established accessibility and usability guidelines so that it is readable by voters and election officials.
 - 3.3.2.4.1** The fonts shall be of a certain size and density: simple serif or san serif, 3-4 mm height measuring the capital "X", see P1583 5.3.3.3 for details
 - 3.3.2.4.2** The ink shall be of a certain color and shade.
- 3.3.2.5** The voter shall be able to view the electronic record and the paper record from the same position and posture so as to maximize the ability to compare and verify the contents of the records.
 - 3.3.2.5.1** The DRE-display shall include a magnifying device to permit voters with more limited vision to inspect the paper record.
 - 3.3.2.5.2** The DRE-display shall be positioned so that it is well-lit and easily read without glare or reflections.
 - 3.3.2.5.3** If the paper record or electronic record are of such size so as to make it difficult to view in their entirety at one time, the voter shall have the opportunity to verify and compare the complete contents of the records before choosing to accept or spoil the records.
 - 3.3.2.5.4** The vendor shall provide clear, simple instructions for the verification process that shall be displayed to the voter.

- 3.3.2.5.5** Controls for scrolling the paper record on the DRE-display shall be clearly displayed.
- 3.3.2.5.6** The DRE-display and the display for the electronic record shall be as close in design and layout as possible to increase ease of comparison between the two records.
- 3.3.2.6** Physical requirements and control standards for the DRE shall also apply to the DRE-VVPAT where appropriate.
- 3.3.2.7** Usability requirements for the DRE-VVPAT shall be equivalent to that required for the DRE. Usability testing for the DRE-VVPAT shall include all aspects of the VVPAT capability.

3.3.3 Requirement 3: The method for voter verification shall be accessible to all voters.

Summary: It makes explicit that an accessible vote verification procedure for voters be provided at polling stations, including voters with disabilities, Limited English Proficiency (LEP), and voters with Native American and Alaska Native languages that are not written.

Generally, all accessibility and usability-related requirements should, in the generic-sense, refer back to the accessibility and usability supplements to the VSS that are under development by NIST, and the accessibility and usability requirements in this section should be here only if they are specific to VVPAT.

- 3.3.3.1** One or more DRE-VVPAT voting systems with accessibility features for voters with disabilities shall be made available at election sites according to State or local law.
- 3.3.3.2** The DRE-VVPAT shall permit voters with disabilities to privately and independently verify the electronic record.
 - 3.3.3.2.1** The DRE-VVPAT shall permit voter is to verify the electronic record from a seated posture.
- 3.3.3.3** The DRE-VVPAT shall print and store a paper record according to requirements for DRE-VVPAT voting systems without accessibility features.
- 3.3.3.4** The DRE-VVPAT shall display and print and store a paper record in any of the alternative languages chosen for making ballot selections on the DRE-VVPAT.
 - 3.3.3.4.1** Candidate names on the records shall be in English.
 - 3.3.3.4.2** Encoded portions of the paper ballot shall be in English.
- 3.3.3.5** The DRE-VVPAT shall include audio equipment by which the process of creating and verify the electronic record may be carried out without the use of vision.
 - 3.3.3.5.1** The DRE-VVPAT shall print and store a paper record according to requirements for DRE-VVPAT voting systems without audio equipment.
 - 3.3.3.5.2** The DRE-VVPAT shall provide audible indications of errors and malfunctions as those required for DRE-VVPAT voting systems without accessibility features.
 - 3.3.3.5.3** The DRE-VVPAT may include audio equipment by which the entire VVPAT capability and verification process may be carried out without the use of vision.
 - 3.3.3.5.4** If the DRE-VVPAT includes audio equipment by which the entire VVPAT capability and verification process can be carried out, the verification process shall obtain the data related to the audio device either directly from the data sent to the VVPAT-printer or directly from the paper record.

3.3.4 Requirement 4: The DRE-VVPAT shall permit the voter to accept or reject the paper record and reenter ballot choices at the DRE-VVPAT.

Summary: The DRE-VVPAT cannot create an electronic record without its corresponding paper record. It requires that the DRE-VVPAT mark the electronic record as accepted or spoiled in the voter's presence, and if spoiled, the corresponding electronic record be marked as spoiled and be preserved. It requires that the DRE-VVPAT display a warning message when a spoil limit is reached. It requires that spoiled paper records be compared with the corresponding electronic records, with procedures to address discrepancies.

- 3.3.4.1** If the voter accepts his or her ballot choices, the DRE-VVPAT and VVPAT-printer shall mark the electronic and corresponding paper record as accepted in the voter's presence.
- 3.3.4.2** If the voter rejects his or her ballot choices, the DRE-VVPAT and VVPAT-printer shall mark the electronic and corresponding spoiled paper record as spoiled in the voter's presence.
- 3.3.4.3** Prior to the maximum number of spoiled ballots occurring, the DRE-VVPAT shall display a warning message to the voter indicating that the voter may spoil only one more ballot.
- 3.3.4.4** If the maximum number of spoiled ballots occurs, procedures shall be in place to permit the voter to use other equipment or paper ballots.
- 3.3.4.5** At the close of the polls, the tally of spoiled paper records shall be compared with the tally of spoiled electronic records, and procedures shall be in place to address discrepancies in the tallies.
- 3.3.4.6** Errors involving the VVPAT-printer that prevent voter verification of the paper record or that prevent creation of the paper record shall not cause the electronic record to be marked as accepted nor shall the voter be able to cause the electronic record to be marked as accepted.
 - 3.3.4.6.1** If the paper record cannot be verified or created, the DRE-VVPAT shall discard the electronic record and erase it from its memory, and present a warning to the voter and to election officials.

3.3.5 Requirement 5: The voter's privacy and anonymity shall be preserved during the process of recording, verifying, and auditing ballot choices.

Summary: It requires that the voter's privacy be maintained during the verification step. It requires that the paper ballot contain no human or machine-readable markings that could identify the voter. It requires that the paper and electronic records be stored in ways that preserve the privacy and anonymity of the voter. It requires procedures to prevent the voter from leaving the polling station with the paper record.

- 3.3.5.1** The privacy and anonymity of the voter's verification of his or her ballot choices on the electronic and paper records shall be maintained.
- 3.3.5.2** The DRE-VVPAT shall protect the privacy and anonymity of the voter's ballot choices on electronic and paper records, including spoiled records.
 - 3.3.5.2.1** The electronic record shall be created and stored in a way that preserves the privacy and anonymity of the voter, such as by shuffling the order of the stored electronic records.
 - 3.3.5.2.2** Privacy and anonymity shall not be compromised when voters use alternative languages or other accessible features.
- 3.3.5.3** The voter shall not be able to leave the voting area with the paper record.
- 3.3.5.4** All markings on electronic or paper records used for purposes of auditing the paper records and the electronic records that may permit a voter to reveal his or her ballot choices or the ordering of the records shall be hidden from the voter.
 - 3.3.5.4.1** Unique identifiers for paper records may be hidden from the view of the voter on the VVPAT-display.
 - 3.3.5.4.2** Unique identifiers for paper records may be encoded so as not to be visible to the voter.
 - 3.3.5.4.3** Voters may not handle the paper records that contain such human readable markings.
- 3.3.5.5** Paper records shall be deposited in VVPAT-ballot boxes in a way that preserves the privacy and anonymity of the voter.
 - 3.3.5.5.1** Depositing the paper record in the VVPAT-ballot box by the VVPAT-printer or by the voter shall cause the order of the stored paper records to be sufficiently random so as not to preserve the order in which voters have used the DRE-VVPAT.
 - 3.3.5.5.2** Paper records shall be printed on individual sheets of paper to enable randomization to maintain voter anonymity.
 - 3.3.5.5.3** Paper records shall be able to lie flat without curling or folding.
 - 3.3.5.5.4** The ballot box shall be sealed and secured until the close of polls.

- 3.3.5.6** The privacy and anonymity of the voter shall be maintained during audits and other post-election procedures.
- 3.3.5.7** Paper records shall be stored post-election such that the identity of the voter or the order in which the voter used a DRE-VVPAT cannot be identified.

3.3.6 Requirement 6: The DRE-VVPAT shall permit robust auditing, forensics analysis, and full recount capability of its electronic and paper records.

Summary: It requires that electronic records and paper records contain election precinct information, information to link the paper record to its corresponding electronic record, and information identifying the DRE-VVPAT. It requires that the electronic records be maintained in a format that can be exported to a different computer, i.e., a personal computer, and that the format be well-documented to support analysis of the records. It requires that paper records be machine-readable to support machine-based auditing against the electronic records. It requires that DRE-VVPAT systems support auditing that can take place at surprise intervals (i.e., parallel auditing) during elections. It requires minimum percentages of DRE-VVPATs to be audited. It requires minimum percentages of the encoded representations on ballots to be audited.

- 3.3.6.1** The electronic records shall be able to be exported for auditing or analysis on common information technology computing platforms.
 - 3.3.6.1.1** The exported electronic records shall be in a format that is not proprietary to the vendor.
 - 3.3.6.1.2** The vendor shall provide documentation as to the structure of the exported records and how they shall be read and processed by software.
 - 3.3.6.1.3** The vendor shall provide a software program that will display the exported records and that may include other capabilities such as providing vote tallies and indications of undervotes.
 - 3.3.6.1.4** For purposes of integrity, the DRE-VVPAT shall export the records accompanied by a hashed value (i.e., *checksum*) of the records using the SHA-256 algorithm. The software module used for creating the hashed value shall have been reviewed by the U.S. Government's Crypto Module Validation Program (CMVP).
 - 3.3.6.1.5** The exported electronic records shall contain all markings and labels as specified for paper records, including the identification of the DRE-VVPAT, identification of the election in the precinct, and unique identifiers associated with each electronic record.
 - 3.3.6.1.6** For purposes of integrity and authenticity, the DRE-VVPAT may use a public-key associated with the DRE-VVPAT to digitally sign the records.
- 3.3.6.2** The electronic and paper record shall include information to identify the voting precinct and the name of the election.
- 3.3.6.3** The electronic and paper record shall include an identifier that is unique to the DRE-VVPAT and that can be used to identify the records as being created by that specific DRE-VVPAT.
 - 3.3.6.3.1** The identifier may consist of the DRE-VVPAT's serial number, provided the serial number is unique to the vendor.

- 3.3.6.9.1** If paper records include encoded representations of the human readable content on the record, at least 1% percent of the paper ballots per individual DRE-VVPAT under audit shall be manually audited to ensure that the human readable content is identical to the encoded representation. The manual auditing may use common industry-standard handheld scanning equipment to read and display the encoded information.
- 3.3.6.9.2** High-speed optical scanning equipment may be used to machine read paper records so as to reduce the time necessary to compare electronic records with their corresponding paper records.

3.3.7 Requirement 7: The DRE-VVPAT equipment shall be secure and resistant to failures, and shall be usable in its administration.

Summary: It specifies requirements for high reliability, maintenance, and security of the VVPAT-printer, VVPAT-display, and VVPAT-ballot box. It requires that adequate supplies be maintained. It requires that appropriate procedures and environmental controls be used to maintain supplies and paper records.

Generally, all accessibility and usability-related requirements should, in the generic-sense, refer back to the accessibility and usability supplements to the VSS that are under development by NIST, and the accessibility and usability requirements in this section should be here only if they are specific to VVPAT.

- 3.3.7.1** Voting systems shall communicate with printers over a standard, publicly documented port using a standard communication protocol.
- 3.3.7.2** An uninterruptible power supply (UPS) should be used to maintain power to both the printer and DRE-VVPAT control unit so no information is lost due to short power glitches, but is only necessary for the DRE-display if it is desirable to continue voting operations during power failures for some limited time. The size (and thus the cost) of the UPS will dictate the length of time operations can continue without power.
- 3.3.7.3** The VVPAT-display, VVPAT-printer, and VVPAT-ballot box 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 or printed or stored in the DRE-ballot box.
 - 3.3.7.3.1** If errors or malfunctions occur, the DRE-VVPAT shall suspend voting operations and shall present a clear indication to the voter and election workers of the malfunctions.
 - 3.3.7.3.2** If a printer malfunctions or otherwise does not complete the operation of printing or storing the paper record, the printer shall be able to be reset without loss of the ballot. If the printer cannot be reset, it shall be replaced.
 - 3.3.7.3.3** Vendor documentation shall include procedures for investigating and resolving malfunctions including but not limited to misreporting of votes, unreadable paper records, paper jams, low ink, miss feeds, and power failures.
 - 3.3.7.3.4** Vendor documentation shall include procedures for ensuring, in the case of malfunctions, that electronic and paper records are correctly recorded and stored.
 - 3.3.7.3.5** A sufficient number of replacement printers should be available at each polling location.
- 3.3.7.4** The VVPAT-printer, VVPAT-display and VVPAT-ballot box shall be physically secure from tampering, including intentional damage.

3.3.8 Requirement 8: Trained personnel, procedures, and consumables shall be in place to handle all aspects of VVPAT capability.

Summary: It requires that procedures be in place to handle all aspects of VVPAT and to ensure that poll workers in election officials are fully trained.

- 3.3.8.1** Voting officials shall have been trained to administer and maintain the DRE-VVPAT devices.
- 3.3.8.2** Voting officials shall have been trained in all procedures necessary to assist voters when using the DRE-VVPAT.
 - 3.3.8.2.1** Voting officials shall have had hands-on training on each type of DRE-VVPAT used in the election.
 - 3.3.8.2.2** Voting officials shall have had training on security procedures regarding use of the DRE-VVPAT by voters.
 - 3.3.8.2.3** Voting officials shall have had training on accommodating individuals with disabilities and individuals who are of limited English proficiency regarding use of an accessible DRE-VVPAT.
- 3.3.8.3** Procedures shall be in place to replace faulty equipment and to reload supplies without disruption to voting.
- 3.3.8.4** Procedures and frequencies for performing manual and automated audits of electronic and paper records at surprise intervals shall be documented.
- 3.3.8.5** Procedures and frequencies for performing manual and automated audits of electronic and paper records post election shall be documented.
- 3.3.8.6** Procedures and frequencies for performing audits of encoded information on paper records shall be documented.
- 3.3.8.7** Procedures by which election officials can be notified and prescribed actions can be taken to address discrepancies if a voter indicates that the paper audit record and the electronic records or counts do not match shall be documented.
- 3.3.8.8** Procedures for deciding whether an electronic or paper record is inaccurate, incomplete, or unreadable shall be documented.
- 3.3.8.9** Decisions shall be made pre-election as to whether the electronic or the paper record shall serve as the ballot of record if discrepancies between the records cannot be resolved.
- 3.3.8.10** There shall be a procedure for election officials to follow when voters leave the polling place without making their votes final.
 - 3.3.8.10.1** Vendor documentation shall include procedures for returning a DRE-VVPAT to correct operation after a voter has used it incompletely or in correctly.

3.3.8.10.2 This procedure will not cause discrepancies between the tallies of the paper records and the electronic records.

3.3.8.11 There shall be procedures to prevent the DRE-VVPAT from being a single point of failure within a precinct.

4. Recommendations for Further Action and Study

This chapter would have suggestions for States to do various things that would help their voting tie in better with the directions we taking in a longer-term standard. This would include things such as

- studying voter behavior based on the exportable records of votes
- usability and accessibility benchmarks
- working towards a common ballot format
- strong public key signature and integrity protection for ballots
- other voting technologies

Appendix A. References

Following is a list of documents and other material used in this document. This list is under development.

- [1] State of California Standards for Accessible Voter Verified Paper Audit Trail Systems in Direct Recording Electronic (DRE) Voting Systems, January 21, 2005.
- [2] 2002 Voting Systems Standard (VSS), Federal Elections Commission (FEC), <http://www.fec.gov/pages/vssfina/vss.html>, <http://www.fec.gov/pages/faqs/vss.htm>
- [3] IEEE P1583/D5.3.2 Draft Standard for the Evaluation of Voting Equipment, Copyright 2004 IEEE, all rights reserved. This is an unapproved IEEE Standards Draft, subject to change. December 6, 2004.
- [4] TGDC resolutions from the January 2005 meeting
- [5] Election Reform and Electronic Voting Systems (DREs): Analysis of Security Issues, November 4, 2003, Eric A. Fischer, Congressional Research Service
- [6] Verified Voting, <http://www.verifiedvoting.org>
- [7] Electionline.org, Election Reform Briefing: Securing the Vote, April 2004, http://www.electionline.org/site/docs/pdf/EB7_new.pdf
- [8] Links to text of federal and state paper trail legislation at Electionline.org, <http://www.electionline.org/index.jsp?page=Paper%20Trail%202005>
- [9] League of Women Voters, Questions and Answers on Direct Recording (DRE) Voting Systems and the Proposal to Require a Voter-Verified Paper Trail (VVPT), http://www.lwv.org/join/elections/HAVA_QAonDRE.pdf.
- [10] Brennan Center for Justice and the Leadership Conference on Civil Rights, Recommendations for Improving Reliability of Direct Recording Electronic Voting Systems, June 2004, http://www.brennancenter.org/programs/downloads/voting_systems_final_recommendations.pdf
- [11] CalTech-MIT Voting Technology Project, <http://www.vote.caltech.edu> CalTech-MIT Voting Technology Project, Voting: What Is; What Could Be, July 2001. <http://www.vote.caltech.edu/Reports/>.

- [12] IEEE Symposium on Security and Privacy 2004, Analysis of an Electronic Voting System, IEEE Computer Society Press, May 2004, <http://avirubin.com/vote.pdf>.
- [13] Science Applications International Corporation, Risk Assessment Report: Diebold AccuVote-TS Voting System and Processes, September 2003, <http://www.dbm.maryland.gov/SBE>.
- [14] RABA Technologies, LLC, Trusted Agent Report: Diebold AccuVote-TS Voting System, January 2004, http://www.raba.com/press/TA_Report_AccuVote.pdf.
- [15] Help America Vote Act of 2002, P.L. 107-252, available at http://fecweb1.fec.gov/hava/law_ext.txt Federal Election Commission HAVA Information, <http://fecweb1.fec.gov/hava/hava.htm>
- [16] http://www.technologyreview.com/articles/04/11/wo_selker111704.asp
- [17] http://www.vote.caltech.edu/media/documents/Caltech_MIT_Audit.pdf
- [18] Shamos, Michael, "[Paper v. Electronic Voting Records — An Assessment](#)." Proc. 14th ACM Conf. on Computers, Freedom & Privacy, Berkeley, CA (Apr. 1994).
- [19] Nevada procedures for voting systems, <http://www.leg.state.nv.us/NAC/NAC-293B.html>
- [20] Maine procedures for elections, Title 21-A, <http://janus.state.me.us/legis/statutes/21-A/title21-Ach9sec0.html>
- [21] David Jefferson, Aviel D. Rubin, Barbara Simons, David Wagner, *Analyzing Internet Voting Security*, Communications of the ACM (October, 2004).
- [22] Shamos, Michael, "Voting System Certification — An Examiner's View." Invited paper presented at the Election Center Conference, Reno, Nevada (Sep. 1989).
- [23] Florida Voting Systems Standards, <http://enight.dos.state.fl.us/laws/proposedrules/pdf/dsde101Form.pdf>
- [24] Ohio Electronic Voting Security, Management, and Technical Assessment, <http://www.sos.state.oh.us/sos/hava/security.htm>
- [25] "[Appendix 2C: Evaluation of Voting Machine, Peripherals and Software](#)", Richard Sinnott, Ted Selker, Bill Lewis, Brendan Whelan, James Williams and James McBride, in *Secrecy, Accuracy and Testing of the Chosen Electronic Voting System*.

Appendix B. Terminology

Following is a list of terms and definitions for those terms used in this document. These definitions should be consistent with the NIST voting systems glossary, which is under development.

audit trail: term use to describe information that can be used to perform audit operations on some primary information - often synonymous with the paper record produced by a DRE-VVPAT

checksum: a value calculated by a hashing algorithm that uniquely identifies another object, e.g., a file, such that any change in the file will result in the hashing algorithm calculating a different checksum

election officials: e.g., poll workers, those individuals who manage the operations of the DRE-VVPAT and who may perform such duties as assisting voters in using the DRE-VVPAT or managing the operations of the DRE-VVPAT or performing auditing of paper and electronic records

electronic record: the electronic ballot image created and maintained by the DRE-VVPAT consisting of a summary of the voters' ballot choices

DRE: Direct Recording Electronic, an electronic voting system that typically contains a mechanism for making ballot selections that are displayed to a voter the a the display unit and that records electronic records of the voters' ballot choices

DRE-display: that part of the DRE-VVPAT that displays the electronic record, assumed to be accessible as required by State law

DRE-VVPAT: the DRE voting system containing VVPAT capability

EAC: Election Assistance Commission

HAVA: Help America Vote Act of 2002

paper record: the paper ballot image or summary that is a copy of the electronic record and that is verified by a voter

SHA-256: the US Government's secure Hash algorithm

surprise auditing: unannounced audits of a voting system during Election Day voting, requiring the voting system to be temporarily taken out of voting mode and placed in an audit state

TGDC: Technical Guidelines Development Committee

VVPAT: Voter Verified Paper Audit Trail, term used to describe the capability for a DRE voting system to produce a paper record of the voter's ballot choices that can be verified by the voter to be accurate; the paper record is retained and becomes an audit trail for the electronic records

VVPAT-ballot box: the ballot box containing the paper records

VVPAT-display: a transparent covering over the paper record printed by the DRE-VVPAT; it permits a voter to inspect the paper record but prevents the voter from physically handling the paper record, assumed to be accessible as required by State law

VVPAT-printer: the printing capability of the voting system, including the printer and any associated device involved in printing the paper records and transferring them to ballot boxes

VSS: Voting Systems Standard of 2002

Appendix C. Requirements Tracking Table

The section contains requirements tracking information for the core and derived DRE-VVPAT requirements from Section 3.3. Many of the requirements are consistent with enacted State legislation (including the California State standard) and the IEEE's draft voting system standard. Table C-1 provides this consistency tracking and also provides a mapping of the requirements as they relate to the following categories:

- RH - Paper and Electronic Records Handling
- PP - Paper Record Properties
- V-D - VVPAT-Display
- V-P - VVPAT-Printer
- V-B - VVPAT-Ballot Box
- A - Auditing
- DPT - Documentation and Procedures and Training

Note: the intent here is to make it easier for readers to determine whether the NIST requirements are consistent with requirements that have already been legislated or that have been discussed by the IEEE in its draft voting systems standard. The IEEE draft has a useful characterization scheme that NIST did not use in Section 3.3, however it may still be useful to readers to provide some mapping to categories that are based loosely on the IEEE's draft. This table currently may not be entirely accurate.

Table C-1: VVPAT-DRE requirements tracking table

Requirement	State Law	IEEE Draft	RH	PP	V-D	V-P	V-B	A	DPT
3.3.1.1	X	X		X	X	X			
3.3.1.1.1	X	X		X					
3.3.1.2	X	X		X					
3.3.1.2.1	X	X		X					
3.3.1.2.2	X	X		X					
3.3.1.3	X	X	X					X	
3.3.2.1	X	X		X					
3.3.2.2	X			X				X	
3.3.2.3				X					
3.3.2.4		X		X					
3.3.2.4.1		X		X					
3.3.2.4.2		X		X					
3.3.2.5	X	X			X				

Requirement	State Law	IEEE Draft	RH	PP	V-D	V-P	V-B	A	DPT
3.3.2.5.1	X	X			X				
3.3.2.5.2		X			X				
3.3.2.5.3		X			X				
3.3.2.5.4					X				X
3.3.2.5.5					X				
3.3.2.5.6	X	X			X				
3.3.2.6		X			X				
3.3.2.7		X			X				
3.3.3.1	X	X			X				
3.3.3.2	X	X			X				
3.3.3.2.1		X			X				
3.3.3.3			X			X		X	
3.3.3.4			X			X		X	
3.3.3.4.1			X			X		X	
3.3.3.4.2			X			X		X	
3.3.3.5	X	X			X				
3.3.3.5.1	X	X			X			X	
3.3.3.5.2	X	X			X				
3.3.3.5.3	X	X			X				
3.3.3.5.4		X			X	X			
3.3.4.1			X	X		X			
3.3.4.2			X	X		X			
3.3.4.3	X	X			X				
3.3.4.4	X		X						X
3.3.4.5			X					X	
3.3.4.6			X					X	
3.3.4.6.1			X						
3.3.5.1	X	X	X	X	X				
3.3.5.2	X	X	X	X	X				
3.3.5.2.1		X	X			X	X		
3.3.5.2.2	X	X	X		X				
3.3.5.3	X	X	X						
3.3.5.4			X	X	X		X		
3.3.5.4.1			X	X	X		X		
3.3.5.4.2				X				X	
3.3.5.4.3			X						

Requirement	State Law	IEEE Draft	RH	PP	V-D	V-P	V-B	A	DPT
3.3.5.5	X	X					X		
3.3.5.5.1	X	X					X		
3.3.5.5.2				X		X			
3.3.5.5.3				X		X			
3.3.5.5.4							X		
3.3.5.6	X	X	X					X	
3.3.5.7	X	X	X						
3.3.6.1			X					X	
3.3.6.1.1			X					X	
3.3.6.2.2			X					X	
3.3.6.3.3			X					X	
3.3.6.4.4			X					X	
3.3.6.5.5			X					X	
3.3.6.2	X		X	X				X	
3.3.6.3	X		X	X				X	
3.3.6.3.1			X	X				X	
3.3.6.3.2			X	X				X	
3.3.6.4	X		X	X				X	
3.3.6.4.1			X	X				X	
3.3.6.4.2			X	X				X	
3.3.6.5	X			X				X	
3.3.6.5.1				X				X	
3.3.6.5.2				X				X	
3.3.6.6				X				X	
3.3.6.7				X					
3.3.6.8								X	
3.3.6.8.1								X	
3.3.6.8.2								X	
3.3.6.8.3								X	
3.3.6.8.4								X	X
3.3.6.9								X	
3.3.6.9.1								X	
3.3.6.9.2								X	
3.3.7.1				X					
3.3.7.2				X	X	X			
3.3.7.3				X	X	X			
3.3.7.3.1				X	X	X			

Requirement	State Law	IEEE Draft	RH	PP	V-D	V-P	V-B	A	DPT
3.3.7.3.2					X	X	X		
3.3.7.3.3					X	X	X		X
3.3.7.3.4					X	X	X		X
3.3.7.3.5					X				
3.3.7.4					X	X	X		
3.3.7.4.1					X	X	X		
3.3.7.4.2						X			
3.3.7.4.3						X			
3.3.7.4.4						X			
3.3.7.4.5						X			
3.3.7.5				X		X		X	
3.3.7.5.1				X		X		X	
3.3.7.5.2				X		X		X	
3.3.7.6						X			
3.3.7.6.1						X			
3.3.7.6.2						X			
3.3.7.6.3						X			
3.3.7.7					X				
3.3.8.1									X
3.3.8.2									X
3.3.8.2.1									X
3.3.8.2.2									X
3.3.8.2.3									X
3.3.8.3					X	X	X		X
3.3.8.4								X	X
3.3.8.5								X	X
3.3.8.6								X	X
3.3.8.7								X	X
3.3.8.8								X	X
3.3.8.9								X	X
3.3.8.10									X
3.3.8.10.1									X
3.3.8.10.2								X	X
3.3.8.11									X