

## VVPAT Update for the VMSG 2005

This white paper contains NIST's recommendations for updating the VMSG 2005 by broadening the scope of voting systems with a VVPAT (Voter Verifiable Paper Audit Trail) capability. It also contains an informative auditing section for VVPAT cast vote records that is recommended for consideration with EAC best practices for election officials. Attached is a white paper is a version of Section 7.9 of the VMSG 2005 VVPAT requirements, modified to support the broadened scope recommended in this paper.

Acronyms and terms used in this paper are defined in a glossary section, located as the last section of this paper.

This white paper is for consideration by the TGDC (Technical Guidelines Development Committee) at the March 29, 2006 Technical Colloquium.

## Broadened Scope of Systems Providing VVPAT Capability for the VMSG 2005

The VMSG 2005 defines the scope of VVPAT capability to DRE systems that utilize a printer to create the PAT (Paper Audit Trail) and a display mechanism to display the PAT to the voter such that the voter can compare the PAT to a summary screen on the DRE.

During the course of research, NIST has concluded that other types of voting systems besides DRE could provide VVPAT capability, and that it may be unnecessarily restrictive to States and voting system vendors of non-DRE systems to define VVPAT capability as being capable of being provided only by DRE systems.

Other potential arrangements of voting system equipment also could be considered as having a VVPAT capability as long as the following basic definition of VVPAT capability is satisfied:

- The voting system produces a PAT containing a record of each voter's choices.
- The PAT conforms to all requirements for potential use in counts or recounts, for post-election audits and analysis, and for archive.
- The paper audit trail is presented to the voter during the voting session so that the voter may inspect it (i.e., the PAT is potentially Voter Verifiable: a VV PAT).
- Upon the voter's request, the voting system, possibly in conjunction with election procedures, supports the voiding of any corresponding electronic cast vote record (or corresponding counts) and the paper audit trail.

## Use of EBM-PCOS to Provide VVPAT Capability

NIST recommends that the scope of the VVPAT requirements in the VVSG 2005 be broadened to include non-DRE voting systems that provide the overvote/undervote detection capability similar to DRE-based VVPAT voting systems, and that satisfy the basic definition of VVPAT.

This expanded scope includes voting system utilizing PCOS (Precinct Count Optical Scan) technology with EMPB (Electronically-Assisted Marked Paper Ballots) such as those produced by an EBM (Electronically-assisted Ballot Marker). An EBM-PCOS-based VVPAT voting system satisfies the basic definition of VVPAT capability by providing the following functions:

- A voter uses the EBM as part of the voting session to create a PAT. The EBM provides indications of overvotes/undervotes.
- The PAT is usable in post-election checks of the accuracy of the counts accumulated by the PCOS.
- The voter may examine the PAT and verify its accuracy.
- Election procedures can be used to void a scanned PAT if necessary.

*Note: A PCOS typically accumulates counts but does not store an electronic CVR (Cast Vote Record) for each scanned paper CVR, unlike a DRE. NIST recommends that storing an electronic CVR, while desirable, is not specifically required to achieve VVPAT capability for the VVSG 2005. NIST has not completed research to determine whether PCOS should be required in the VVSG 2007 to store electronic CVRs or scanned images of paper CVRs.*

## Resultant Changes to VVSG 2005

To broaden the scope of VVPAT capability in the VVSG 2005, the following overall changes to Section 7.9 are necessary:

1. An informative section indicating the broadened scope to be added to the beginning of section 7.9.
2. Requirements and/or discussions in requirements that would apply specifically to DRE voting systems would be preceded by the words, "For DRE voting systems,"
3. Some expanded text in Discussion fields may be advisable to clarify the scope of the requirements.

A modified version of Section 7.9 is included as an attachment, with changes indicated.

## Post-Election Audits for VVPAT

NIST has concluded that, because VVPAT capability is relatively new, there may be confusion as to how to use VVPAT cast vote records in post-election audits. In particular, the use of bar codes on paper audit trails and how they should be used in audits may need clarification. This section describes how auditing of cast vote records in voting systems with VVPAT capability is assumed to occur. NIST recommends that the information in this section be added to the EAC best practices for election officials.

### General Post-Election Audits of VVPAT Records

The VVPAT requirements in the VVSG 2005 are predicated on the existence of a mandatory post-election audit of the accuracy of the voting system's total counts and, potentially, its electronic CVRs. For this audit, a certain percentage of paper CVRs must be summed and then that sum compared to the machine totals and, potentially, any corresponding electronic CVRs. The need for this audit is in no way affected by the number of voters who perform verification on the paper CVRs during voting sessions.

The post-election audit must include a recount of paper CVRs on a certain number of VVPAT voting systems, that number to be determined by state law and affected by variables such as the number of votes cast, the closeness of the race, and other variables that may arise. The results of the recount must then be compared to the machine totals. If errors occur, the individual electronic CVRs can be compared to their corresponding paper CVRs to find the source of the error.

### Use of Bar Codes in Post-Election Audits

Some VVPAT voting systems print a bar code associated with each paper CVR; each bar code typically contains the human readable contents of the paper CVR and may also contain other information such as the unique identifier linking the electronic CVR to the corresponding paper CVR. The purpose of the bar code is to assist in optically scanning the paper CVRs.

It is important to note that the printed bar code is not verifiable by the voter, thus it is not a voter verifiable paper CVR record. Therefore, a post-election audit that compares only the bar code contents with electronic CVRs is not meaningful as an accuracy check on the electronic CVRs and machine totals. The post-election audit must utilize the human readable content of the paper CVR, with the exception of those bar code contents that may be present to assist auditing, such as if the bar code contains a unique identifier or other information about the election.

It is a policy question as to whether the bar code can be used in post-election counts or recounts of all ballots cast. The bar code is not the voter verifiable paper record, therefore if bar codes were to be used in counts or recounts, some audit process must occur to achieve a desired confidence factor that the bar codes correctly contain the human readable CVR contents. First, a certain number of randomly-chosen bar codes are compared for accuracy against their corresponding human readable contents (this number to be determined by state law and other variables as

per post-election audits). If the result of step one is that the comparisons are accurate, then the remaining bar codes can be scanned, stored in computer memory, and used for counts or recounts.

## Voter Verifiable Paper Audit Trail Requirements

This section contains the VVPAT requirements from Section 7.9 of the VMSG 2005 with modifications to support the expanded scope. All new text is in underlined red; deleted text is marked by ~~striketrough~~.

This section contains requirements for ~~DREs~~ voting systems with a Voter Verifiable Paper Audit Trail (VVPAT) component. VVPAT capability is not required for national certification. However, these requirements will be applied for certification testing of voting systems ~~DRE~~ systems that are intended for use in states that require ~~DREs to provide~~ this capability. The vendor'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.

### 7.9.1 Display and Print a Paper Record

- 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 (if a DRE) and be suitable for use in verifications of the voting machine's electronic records and/or accumulated counts.

- 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 and/or electronic counts, 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. For DRE voting systems, 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 voting equipment shall allow the voter to approve or void the paper record.

Discussion: For DRE voting systems, 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. For DRE voting systems, 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. For DRE voting systems, 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. 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 (for DRE voting systems) 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. For DRE voting systems, 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: The identifier serves the purpose of uniquely identifying and linking the records for cross-checking.

- d. For DRE voting systems, the voting machine should generate and store a digital signature for each electronic record.

e. For DRE voting systems, 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 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. **For DRE voting systems**, 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 a different audible alarm 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:

- For DRE voting systems, 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. For DRE voting systems, 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.



## **Glossary of Terms**

CVR - Cast Vote Record

DRE – Direct Recording Electronic

EBM - Electronically-assisted Ballot Marker

EMPB - Electronically-Assisted Marked Paper Ballots

PAT - Paper Audit Trail

PCOS - Precinct Count Optical Scan

TGDC - Technical Guidelines Development Committee

VV - Voter Verifiable

VVPAT - Voter Verifiable Paper Audit Trail

VVSG 2005 – Voluntary Voting Systems Guidelines of 2005