

Comparing Tabulation of Paper Ballots using Optical Scanning Electronic and Tabulation of Direct Recording Electronic with Voter Verified Paper Ballots

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State of Our Election Counting Systems

Unlike issues such as healthcare and national security that have significant impacts on our daily lives, the lack of election integrity do not have immediate or easily measurable effects. Almost everyone acknowledges that accurate and trustworthy election is paramount to our democracy. Few in the government and the public understand how to ensure an error-free balloting process along with accurate and secure counting of the ballots.

Although much has been done to improve balloting and ballot counting systems since year 2000 Florida election, much work remains. The current congressional solution exists in the form of the "Help America Vote Act of 2002 (HAVA)" has been implemented with a mixed bag of success over the last four years^{1 2 3}. While we believe there has been substantial progress made by the implementation of HAVA and the oversight efforts by voter activists groups. Like any congressional act, HAVA missed some components that led to many unforeseen issues. We believe most of these shortcomings can be readily fixed with amendments, provided we have the foresight and political courage. The needed improvements have come to the forefront through congressional agendas with notable efforts by Congressman Holt⁴ and Senator Feinstein⁵.

On the positive side, accessibility provisions to voters with disabilities have been dramatically improved. Provisional ballots are implemented to ensure voters will not be disenfranchised on the day of election. On the negative side, in addition to the total lack of independent verification of the earlier generation of direct recording electronic (DRE) voting systems, they also have inadequate engineering and technical design for reliability and system security. The engineering and technical flaws⁶ have caused dramatic failures in multiple elections. These failures may or may not have contributed to the errors in reflecting the voters intents but have certainly induced many emotional responses. It is clear that the critical loopholes must be closed and unforeseen issues must be addressed. These improvements are urgently needed with most of the voting systems deployed so far.

Even though DREs with tangible media, such as voter verified paper ballots or audit trail (VVPB or VVPAT), were developed and demonstrated as early as March 2001 by AVANTE, the road to acceptance has been hard fought and torturous. It took 4 years of persistent and heroic efforts by many groups across the country to convince 27 of the 50 states to require DRE to have VVPB or other form of paper audit trails. Groups that deserve most credits include "Verified Voting Foundation", under the leadership of Professor David Dill⁷ endorsed or acknowledged by more than 85% of the computer scientists nationally asking for DREs to be equipped with voter verified paper audit trail (VVPAT), "Black Box Voting" under the leadership of Bev Harris⁸, and literally thousands of concerned citizens and hundreds of groups across the nation.

¹ "RATIONAL AND PLURALISTIC MODELS OF HAVA IMPLEMENTATION", R. Michael Alvarez, Caltech; Thad E. Hall, University of Utah, VTP WORKING PAPER #22, July 2005; http://www.vote.caltech.edu/media/documents/wps/vtp_wp22.pdf

² "Election Preview 2006: What's Changed, What Hasn't, and Why"; <http://www.electionline.org/Portals/1/Publications/Annual.Report.Preview.2006.Final.pdf>

³ "Balancing Access and Integrity"; The Century Foundation; <http://www.tcf.org/Publications/ElectionReform/baicomplete.pdf>

⁴ Rush Holt's (D-NJ) [Voter Confidence and Increased Accessibility Act of 2007](#) (HR 811).

⁵ U.S. Senate Rules Committee Hearings on The Hazards of Electronic <http://www.verifiedvotingfoundation.com/article.php?id=6431>

⁶ "THE MACHINERY OF DEMOCRACY: VOTING SYSTEM SECURITY, ACCESSIBILITY, USABILITY, AND COST"; THE BRENNAN CENTER FOR JUSTICE; http://www.brennancenter.org/dynamic/subpages/download_file_38150.pdf

⁷ <http://www.verifiedvoting.org/article.php?list=type&type=50>

⁸ <http://www.blackboxvoting.org/>

Unfortunately, most DRE systems implemented with VVPB or VVPAT were done by vendors that have been fighting against them. They failed spectacularly because of improper technical design and inadequate engineering. The glaring and disturbing failures of DREs with VVPAT in Ohio in 2006⁹ and DREs without VVPAT in Florida^{10 11} (Sarasota County) has now seemingly put the last “nail in the coffin” of direct recording electronic voting with or without VVPB.

Is direct recording electronic voting even with voter verified paper ballots really the wrong solution? Or, is it the poor design and engineering used in DRE with VVPB the real problem?

AVANTE has proven that properly engineered DRE with VVPB can work flawlessly in elections since 2002.¹² These successful implementations have been limited to relatively small jurisdictions or pilot deployments. They are mostly not noted by the general public and certainly did not contribute much in counting the nation's ballot. It is none-the-less evidence that a properly engineered and designed DRE with VVPB can be made to work perfectly to provide accessibility and 0% residual votes. This may be the only method that can help to guide the voters to make 0% mistakes while ensuring the highest security among all kinds of voting methods. Most, but not all, of the engineering errors have been pointed out and are required compliance in the federal Election Assistance Commission (EAC) 2005 Voluntary Voting System Guidelines (VMSG). As a community of vendors, we have yet to face up to the responsibility of providing the best-known and proven solutions.

Some of the activists groups along with some computer scientists are now calling for the use of paper ballots counted with optical scanning technology as the “right” solution. The advancing argument is that with voter marked paper ballots, one can always trace back to the original votes as cast. Of course, that implies that we actually manually examine these paper ballots and that they can be protected to stay the same. The historic paper ballot tampering over the last hundred years seems to be totally forgotten along with the fact that “precinct-based optical scan” is also read and counted by electronics.

In a way, the downsides are known in DRE systems with or without VVPB or VVPAT. Can we say the same for paper ballots that are electronically read and tabulated by using optical scanning electronics and computers?

One cannot stop wondering what additional security, accuracy, and reliability problems will we discover if we put the same amount of effort and intensity that we used on DREs, to carefully examine the optical scanning electronic voting systems. After all, if we cannot trust electronics that record votes that have been verified by voters on the voting machine screen and on its corresponding paper records, how can we really trust electronic systems that scan and tabulate paper ballots without telling the voters how the paper ballots are being deciphered beyond whether there may be over-votes or under-votes?

As the company that pioneered the voter verified paper ballot for direct recording electronic and optical scanning electronic voting solutions that can be authenticated, AVANTE has an “insider” view of the problems and difficulties in improving our nation's election counting systems. This white paper relates our experience and our interpretation of not only the problems but also the best feasible technical solutions from a manufacturer and solution provider's perspective.

⁹ DRE Analysis for May 2006 Primary Cuyahoga County, Ohio http://bocc.cuyahogacounty.us/GSC/pdf/esi_cuyahoga_final.pdf

¹⁰ Sarasota Officials Freeze Election Data, as Jennings Battle Wages On; http://www.nytimes.com/cq/2007/02/02/cq_2229.html

¹¹ “Factors Associated with the Excessive CD-13 Undervote in the 2006 General Election in Sarasota County, Florida”; Walter R. Mebane, Jr. David L. Dill http://www.votetrustusa.org/pdfs/Florida_Folder/smachines1.pdf

¹² “A Manufacturer's View Point On the Voter Verifiable Paper Record and Audit Trail”; <http://www.vote-trakker.com/White%20Papers/A%20Manufacturer%27s%20View%20Point%20On%20the%20voter%20verifiable%20paper%20record%20FINAL.pdf>

Paper Ballots and the Direct Recording Optical Scanning Electronic (DROSE) Systems

Are there any accuracy, security and reliability issues in precinct-based optical scanning voting? Possibly the first thing we should do is to properly name the voting system used to count paper ballots. Most people tend to forget that an optical scan system is also an electronic system. The term “optical scan voting system” seems to ignore that electronics actually drive the more critical resolving and counting function of the system. Instead of calling it a “Precinct-Based Optical Scan (PBOS)” system, a more descriptive name will be “Precinct-Based **Direct Recording Optical Scanning Electronic (DROSE) System**”. The name is more proper because it records the votes to provide the final tallies as deciphered from the paper ballots being scanned. Figure 1 below represents today’s precinct-based DROSE system with the well-known vulnerabilities¹³¹⁴ that are inherent with such systems.

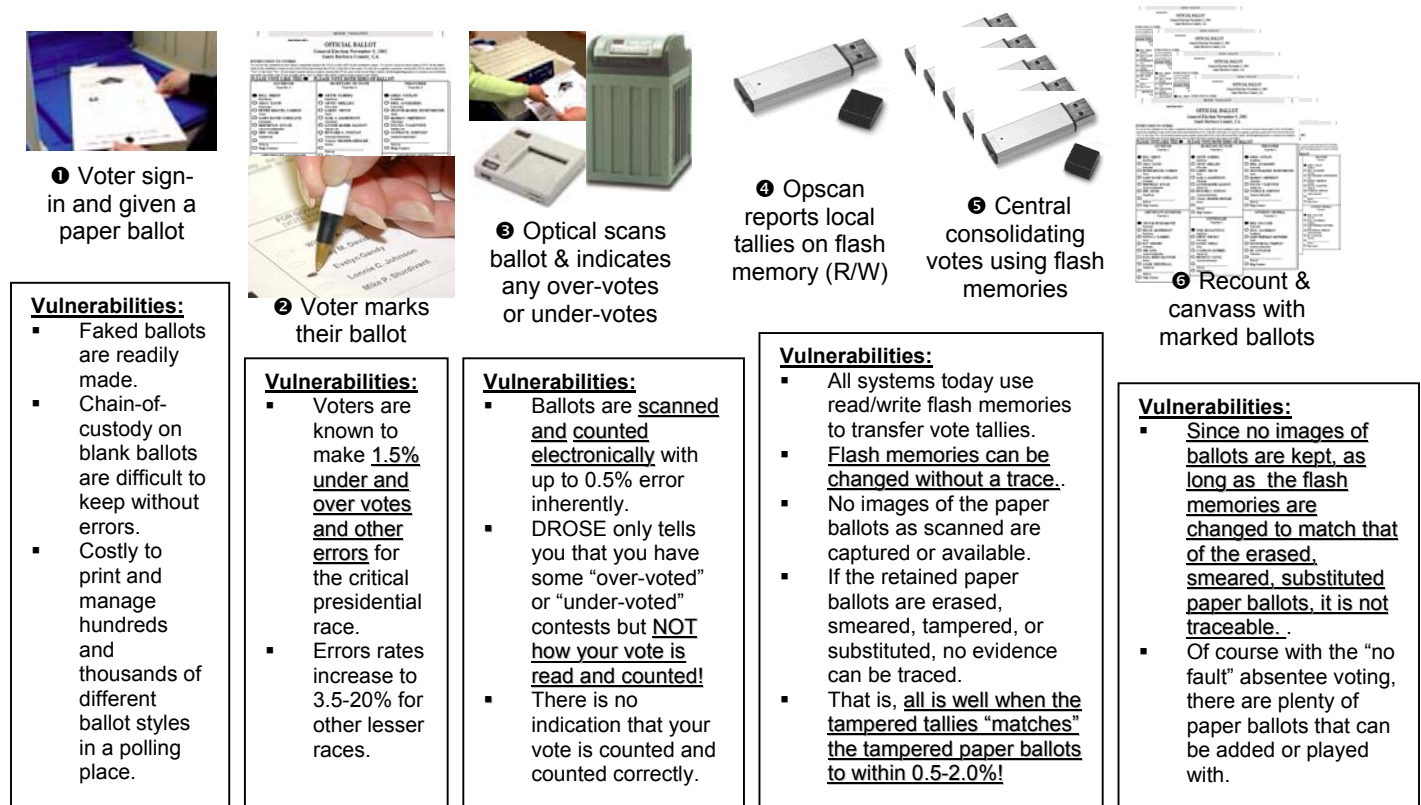


Figure 1: Direct recording optical scanning electronic paper ballot system and inherent vulnerabilities.

The best starting point for anyone with the desire to understand the optical scanning electronic voting solutions is to review the paper by Professor Doug Jones¹⁵. The precinct-based DROSE voting systems certified to use by most states uses older technology developed almost 20 years ago. The same inherent types of computer-related security vulnerabilities like those associated with DREs are the nature of these systems and may be even more critical.

It has been documented that they read and/or record the ballot incorrectly because of imperfect software and hardware. The data transfer media uses flash memories that lack adequate security and can be changed without leaving a trace. Some of these problems demonstrated in 2006 elections are summarized in Table 1 below.

¹³ Election Administration in the United States. Brookings; Joseph Harris. 1934; <http://vote.nist.gov/electiadmin.htm>

¹⁴ “Accuracy, Integrity, and Security in Computerized Vote-Tallying”, Saltman, Roy G. 1988; <http://www.itl.nist.gov/lab/specpubs/500-158.htm>

¹⁵ “Counting Mark-Sense Ballots: Relating Technology, the Law and Common Sense”, <http://www.cs.uiowa.edu/~jones/voting/optical/>

TABLE 1: ERRORS ATTRIBUTABLE TO PAPER BALLOT SYSTEMS¹⁶

Errors/Problems	Representative Examples	"Cause"	Human & System Solution
1. Chain-of-Custody Conflicts	Carroll County, Arkansas absentee ballots were open without independent observers.	Difficult to ensure full and complete chain-of-custody management.	"Solution" by Election Officials - Detailed documentation and workflow. System Design Perspective - Mechanism engineered for human-independent paper ballots authentication.
2. <i>Ballot stuffing and ballot tampering (modification, switching, etc.)</i>	- Unknown. Non can be proven or disproved. - Historical problems that can only be controlled with trustworthy chain-of-custody.	<i>Inherent in paper ballots without provision for ballot authentication</i>	"Solution" by Election Officials - Nothing can be done. System Design Perspective - Need ballots and system that can automatically authenticate faked ballots.
3. Not Enough Ballots	- MA causes voters to wait for hours with many walking away without voting in Boston. - Many across the nation. - Many jurisdictions in MI. - Bernalillo County, New Mexico	Too expensive to print adequate quantity?	"Solution" by Election Officials - Budgets more money. System Design Perspective - Use systems that have lower costs ballots.
4. <i>Double Counting</i>	- Osceola County, Michigan ran some ballots through tabulating machines twice. - Are there others that are not discovered?	- Human error. - What if the error or difference in vote counts are small enough that they are not noticed?	"Solution" by Election Officials - Training of poll-workers. System Design Perspective <i>Ballot identifier should prevent the acceptance of ballots that have been previously counted.</i>
5. Cannot Count	- Rockwell City & Sherman, Iowa. - Butler County in Iowa. - MI, high moisture expanding ballots jammed machine. - South Dakota: paper folding	- Programming error. - Intrinsic problem of most optical scan paper ballot.	"Solution" by Election Officials - L&A testing for program and ballots. System Design Perspective - More robust software. - More capable software and technology.
6. Counting Errors	- Johnson County Iowa. - Kentucky and Many others - What is the error or difference in vote counts that are small enough that they are not noticed?	Intrinsic paper ballot problem of error up to 0.5%.	"Solution" by Election Officials - Nothing can be done. System Design Perspective - Need better technology.
7. Inadequate accessible voting	- MA only provides 1/3 of what is required by HAVA. - Voters are discouraged to use the "ballot marking device" in Idaho and CT.	Reason? Money is provided by HAVA.	"Solution" by Election Officials - Better choice of system. System Design Perspective - Unified system all ballot marking device DRE with VVPB.
8. Paper jam in ballot marking accessible voting unit	San Francisco: 50 incidents a 3% increase over previous primary election.	Inherent in manual feeding of paper ballots.	"Solution" by Election Officials - Nothing can be done. System Design Perspective - Need more robust system.
9. Paper jam and other problems in optical scan voting	San Francisco: 356 total incidents. 185 optical-scan out of 561 polling places. An increase over previous election.	Inherent in manual feeding of paper ballots.	"Solution" by Election Officials - Nothing can be done. System Design Perspective - Need more robust system.
10. <i>Under-voting and Over-voting</i>	- Unpredictable. 0.5 to 5% is common even for the Presidential or gubernatorial races.	- Voter errors. - System cannot or discourages corrections.	"Solution" by Election Officials - Buy DRE with VVPB. System Design Perspective <i>Only properly engineered DRE can prevent over-vote and guide to prevent unintentional under-voting.</i>

With the use of paper ballot, the inherent vulnerability to counterfeiting, tampering via smearing, changing, substituting, adding and removing of paper ballots are well documented over the last 50 years and more.^{17 18 19} None of the vulnerabilities of paper ballot have been addressed by the DROSE systems deployed today. Yet, these vulnerabilities seem to have been totally forgotten by almost all of the voting integrity citizen groups and some of the academic experts with intimate knowledge of computer security.

¹⁶ The 2006 Election, <http://www.electionline.org/Portals/1/Publications/EB15.briefing.pdf>

¹⁷ "ANNALS OF DEMOCRACY COUNTING VOTES" By Ronnie Dugger; The New Yorker, November 7, 1988

¹⁸ "Computerized Voting. Evaluating the Threat..."; Proc. Third ACM Conf. on Computers, Freedom & Privacy. San Francisco, CA (Mar. 1993); Shamos, Michael, <http://www.cpsr.org/conferences/cfp93/shamos.html>

¹⁹ "Computerized Systems for Voting Seen as Vulnerable to Tampering"; By DAVID BURNHAM; The New York Times; July 29, 1985 <http://www.newsgarden.org/columns/burnham1.shtml>

An Auditable New Generation of Direct Recording Optical Scanning Electronic (DROSE)

All of the currently available precinct-based DROSE systems have high incidences of voter errors and the potential of insider hacking and tampering. Technical solutions exist to solve some of these problems. Bev Harris and associates with “Black Box Voting” have demonstrated the vulnerabilities of the DROSE and have proposed two solutions that AVANTE believes to be technically correct:

1. Hand counting of ballots under public supervision at the precinct after the poll is closed²⁰. While this method cannot resolve voter errors of under and over votes, it offers the security of audited tallies. It defeats any attempts to tamper with the counted ballots and adding new ballots. There are still other technical problems that need addressing:
 - Marginal markings on ballots will make finishing counting difficult in close elections.
 - It is difficult for humans to distinguish well-printed fake ballots if they are injected.
 - Most US elections have 10-50 contests with tens to hundreds of candidates. Unless we limit the number of contests, hand counting could take hours if not days to finish.
2. Use a DROSE that captures the ballot images as cast and posts/publishes the ballot images for the public to verify the tabulated results²¹. It will be obvious that this solution is more useful when the ballot images are captured in real-time at the precinct. The same apply for the central office when processing absentee ballots. It will be even better if the paper ballots can be authenticated individually without causing privacy concerns.

Figure 2 below represents a solution²² available from AVANTE that addresses most of the inherent vulnerabilities when using paper ballots and the precinct-based DROSE system.

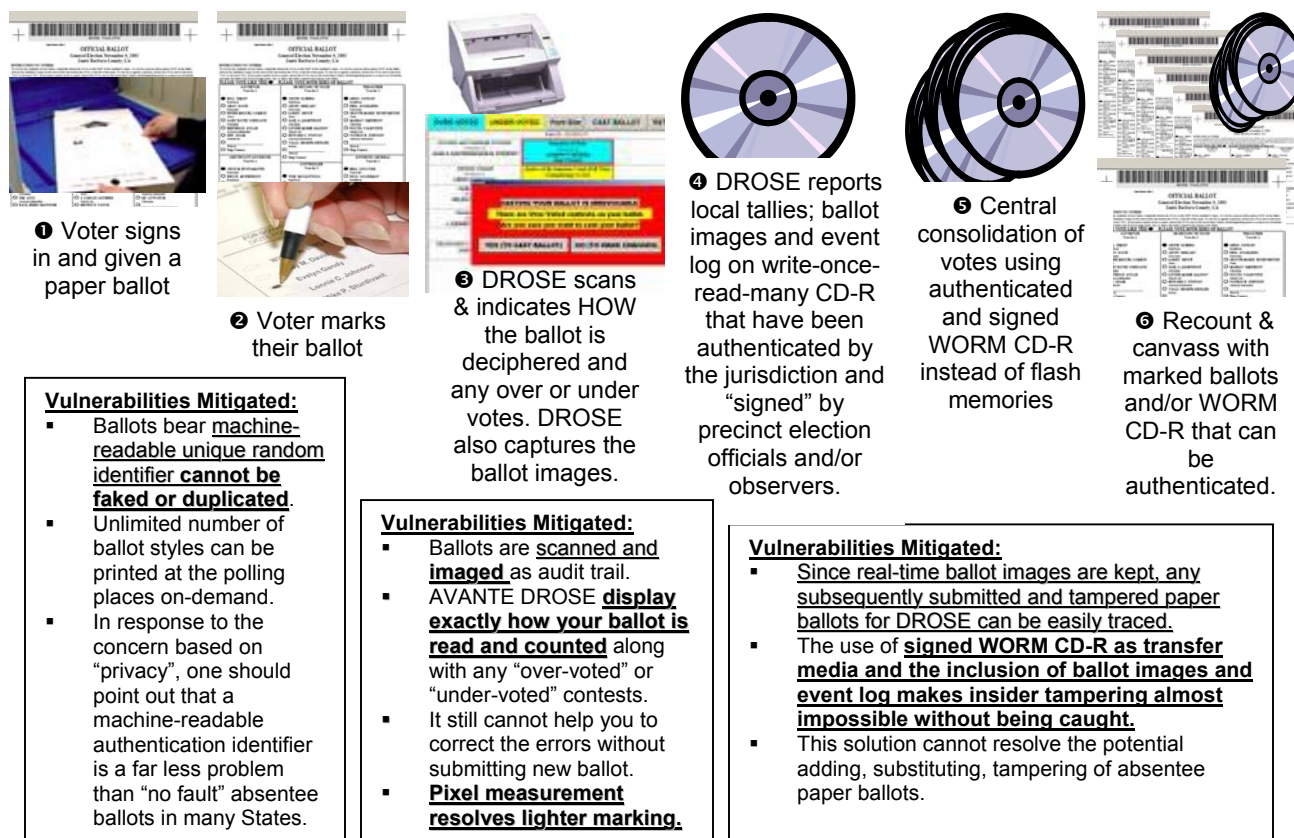


Figure 2: Direct Recording optical scanning electronic system with imaging capabilities to provide electronic audit.

²⁰<http://www.bbvforums.org/forums/messages/1954/40411.html?1159836941> http://www.bbvforums.org/forums/messages/157/were_counting_the_votes_2006_09_02-40394.pdf

²¹ Harri Hursti's invention, <http://www.bbvforums.org/forums/messages/1954/10268.html>

What are the real problems of the commonly used DRE with Voter Verified Paper Ballot?

Even though using VVPB is such an obvious solution to ensure proper functioning of DRE and to enhance the security of the system, many have spent much time and effort in defeating them. EAC with the recommendation of NIST have recently required that all DREs must provide independent audit capability. When coupled with the HAVA requirement for all non paper-based systems to produce paper records, DRE to include VVPB is all but guaranteed.

Widely promulgated mis-information by those that oppose the use of VVPB in DRE is that voters will ignore or will not verify the VVPB. A recent pilot and data collected during the 2006 Georgia Election debunked this myth forever. Instead of not noting the VVPB, **99.3% of the voters noticed and verified their VVPB**. They also find VVPB enhanced their confidence with the use of a DRE system that they have used for the last four years.²³

Figure 3 below is an illustration of some problems attributed to improper design and inadequate engineering in the earlier generation of DRE systems with VVPB or VVPAT.

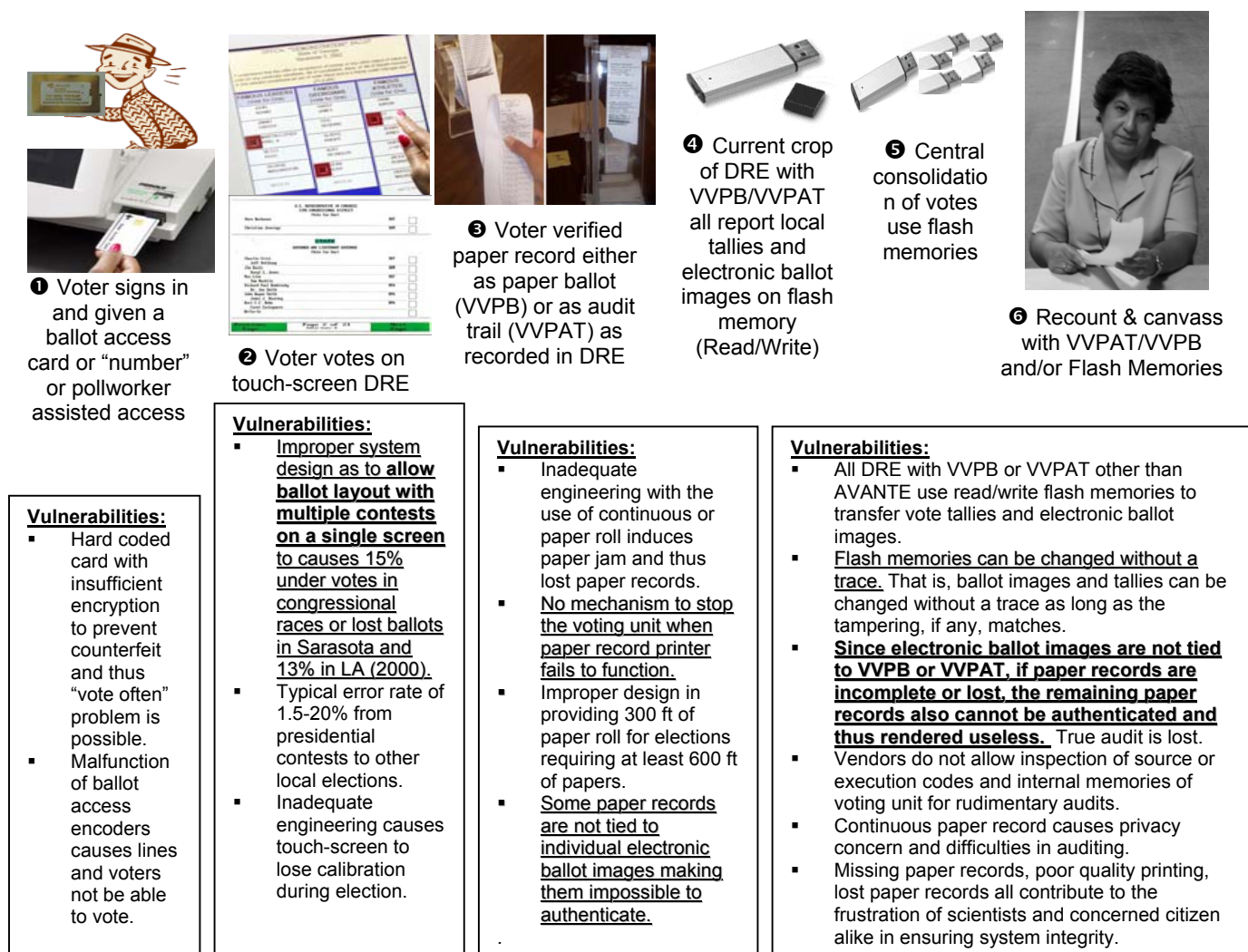


Figure 3: Engineering and design problems causes frustration in commonly used DRE with VVPAT.

²² OPTICAL VOTE-TRAKKER™: A “Mark-Sense” Absentee & Precinct Based Voting System that Minimizes Both Voter and System Errors <http://www.vote-trakker.com/OpticalVote-Trakker.pdf>

²³ November 2006 General Election Paper Voting Trail Exit Poll Study http://electionupdates.caltech.edu/UGA_Study_VVPAT_Nov_2006.pdf

Errors and problems seemed endless with the earlier generation DREs with VVPAT and VVPB. Almost all of these problems can be easily fixed or retrofitted provided the community of vendors does not fight these improvements that are almost self-evident.

Table 2 summarizes under-voting errors in Sarasota County, Florida that became the lightning rod for DRE problems. The problem is relatively simple to solve with proper software human interface engineering and the use of VVPB:

- As recognized by Steve Ansolabehere of MIT, each contest should be on a separate ballot page in a paging DRE voting system.
- A properly engineered VVPB with each of the paper records traceable to each of the electronic ballots will help to verify and avoid conflicts and loss of voter confidence.

TABLE 2: UNDER-VOTING WITH DRE			
Error/Problem	Example	“Cause”	Human “Solution” and System Solution
1. Explainable Extraordinary Unintentional Under-vote	▪ Sarasota County, FL 16+% under-votes on their paging DRE without real-time paper record for voter verification. In comparison to 3% on paper ballots.^{24 25}	○ Ballot designed with inconsistent use of color highlighting for some contest title.²⁶ ○ Several contests on a single paging screen.²⁷	“Solution” by Election Officials ▪ Election administration should not use color highlighting of contest title. ▪ Election administration should not put more than one contest per paging screen. System Design Perspective ▪ Software designed such that one contest per paging screen is the rule rather than a choice. ▪ Software design automatically makes all contests FONT SIZE and COLOR or other PRESENTATION the same.²⁸ Could Voter Verified Paper Ballot (VVPB) Help? ▪ Most think it is not clear that it will help since the review screen showed no choice made by the voter already. ▪ However, a proper presentation of paper record is linear on a paper rather than 20-30 contests spread out on a video screen. It is much easier to see and discover. ▪ At the minimum, the VVPB should eliminate the lingering doubt if the ballots were recorded correctly in the electronic memories.
2. Unexplainable Extraordinary Unintentional Under-vote	▪ Ocean County, NJ with 10+% under-votes on the older style Full-Face touch-button without paper record for voter verification. In comparison to 3+/-% on Counties with the same system.²⁹	○ Full-face presentations are the same for all systems. ○ The only possible explanations are: • The system records incorrectly. • Those voters are so different from the rest.	“Solution” by Election Officials ▪ Very little room for variation possible by the election officials. System Design Perspective ▪ Software designed such that voters are reminded of any under-vote. This is not possible for the over-lay based touch-button DRE. ▪ AVANTE touch-screen with full-face presentation and reminder for any under-vote recorded 2.38% “intentional under-vote”. Could Voter Verified Paper Ballot Help? ▪ A proper presentation of paper record is linear on a paper rather than 20-30 contests spread out on a video screen, is much easier to see and discover. ▪ At the minimum, the VVPB should eliminate the lingering doubt if the ballots were recorded correctly in the electronic memories.

The tragic facts are that many scientists and concerned citizens are frustrated by the vendors that fought against the obvious and needed improvements. Some of them are blinded with despairs and have lost sight of the true benefits and the potential of a properly designed and engineered DRE with voter verified paper ballots.

²⁴ <http://www.heraldtribune.com/apps/pbcs.dll/article?Date=20061205&Category=NEWS&ArtNo=612050604&SectionCat=&Template=printart> Analysis points to bad ballot design; By MATTHEW DOIG and MAURICE TAMMAN; matthew.doig@heraldtribune.com maurice.tamman@heraldtribune.com

²⁵ The same results have been previously documented in year 2002 General Election California Los Angeles with 12.3% not voting for US Senate.

²⁶ Florida's 'national model' for fair elections now under scrutiny

<http://www.miami.com/mld/miamiherald/news/state/16103229.htm?template=contentModules/printstory.jsp>

²⁷ Analysis suggests undervote caused by ballot design; <http://www.heraldtribune.com/apps/pbcs.dll/article?AID=/20061115/NEWS/611150751>

²⁸ This is part of the requirement of the EAC 2002 VSS.

²⁹ http://www.eac.gov/VVSG%20Volume_1.pdf

Table 3 is a summary of all other problems encountered by DRE systems that have demonstrated failures that may be attributable to inadequate design and engineering. All of the proposed solutions are available and proven. It is the responsibility of voting machine vendors to help their customer-jurisdictions to deploy the solutions properly.

TABLE 3: ERRORS OTHER THAN UNDER-VOTE WITH DRE³⁰			
Errors/Problems	Examples	“Cause”	Human “Solution” and System Solution
1. Unable to Display Candidate Name Completely	Virginia with Jim Webb’s name being cut off by an e-voting system	Limiting display field length because of system design	“Solution” by Election Officials - Buy better system. System Design Perspective - Almost all other DRE system can accommodate any length of name or at least with reasonable abbreviation. Could Voter Verified Paper Ballot Help? - No. The error is in system display design.
2. Did not display candidates or wrong ballot	Medina, TX with US senate race	No or improper testing of ballot loaded on the voting unit.	“Solution” by Election Officials - Enforce proper Logic and Accuracy testing on 100% units. System Design Perspective - Automation on L&A testing of all voting system. Could Voter Verified Paper Ballot Help? - Error is committed pre-election. Paper records will only confirm the error again.
3. Unable or card encoding problem or too few card encoders	- Utah - Maryland - Several other location	Electronic and programming error	“Solution” by Election Officials - Proper pre-testing of all components used for election. - Have a backup plan for any single point of failure. System Design Perspective - More robust design and reliability design. Could Voter Verified Paper Ballot Help? - No. Error is “mechanical” and disabling election.
4. “Flipping vote”: with wrong selection display after touching a selection	Many reported.	- Calibration problem. - Programming error.	“Solution” by Election Officials - Enforce proper Logic and Accuracy testing on 100% units. - Testing should include some manual testing component. System Design Perspective - More robust engineering so that touch-screen calibration is seldom necessary. Could Voter Verified Paper Ballot Help? - YES. It will ensure voters discover the errors.
5. Did not and cannot open poll on time	- East Cleveland, OH - Many others documented elsewhere	- Improper and/or inadequate training - System not user friendly	“Solution” by Election Officials - Buy more robust and user-friendly system. - Ensure proper staffing and training. System Design Perspective - Robustness in terms of reliability. Could Voter Verified Paper Ballot Help? - NO. Error is made before poll open.
6. “Double counting” from tallies and ballot image transfer media	Ocean County, NJ with touch-button older style full-face voting system	Improper software design that is not in compliance with EAC 2002 VSS	“Solution” by Election Officials - Buy better system that prevents such human potential error. - Ensure proper logistics and workflow. System Design Perspective - Proper software engineering and design to eliminate such error. Could Voter Verified Paper Ballot Help? - No. Error is in transferring and consolidating electronic votes.
7. System “freeze” up	Fayette County, Iowa with a touch-screen voting system	Ballot-activator triggers system failure	“Solution” by Election Officials - Buy more robust system. - Ensure proper staffing and training. System Design Perspective - Proper software engineering to eliminate such error. Could Voter Verified Paper Ballot Help? - No. Error is not in counting vote.
8. <i>Unable to perform proper recount in close races</i>	Virginia senate race is a typical example	No voter verified paper records	“Solution” by Election Officials - Buy system with voter verified paper records. System Design Perspective - No DRE should be without voter verified paper records. Could Voter Verified Paper Ballot Help? YES. All systems should be required to have VVPB.

³⁰ The 2006 Election, <http://www.electionline.org/Portals/1/Publications/EB15.briefing.pdf>

What is a properly designed DRE with voter verified paper ballot?

Even though paper balloting with precinct-based optical scanning electronic systems can be dramatically improved, as illustrated in Figure 2 described earlier, there are several inherent problems that cannot be addressed even with the best of technologies:

- The system can only remind the voters of mistakes that are made by them but cannot help the voters to correct the errors directly. It has been proven that 75% of these voters who are give the chance to make corrections will not be bothered with the trouble of having to get a new ballot and do the paper ballot over. Properly engineered DRE with VVPB “guides” the voters in avoiding all errors for a true 100% accurate reflection of voter intent³¹.
- Paper ballot systems are incapable of providing accessibility to some voters with visual or dexterity disabilities. Separate accessible solutions must be provided.
- Only DRE with VVPB that can be authenticated allows all voters to vote on the same system. It is equitable and democratic.

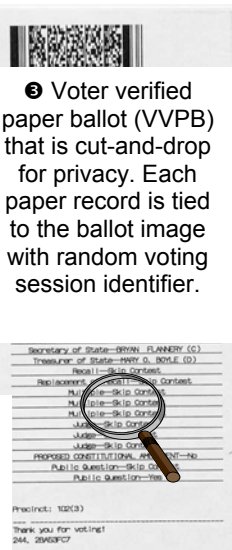
Figure 4 below is an illustration of a properly designed DRE with VVPB that solves all of the known problems of the earlier generation solutions provided by more established vendors. These solutions are not only possible but built and proven by AVANTE.



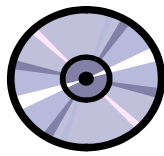
1 Voters signs in and given a ballot access cards that are secured against counterfeiting. Alternatively, pollworkers control access.



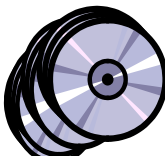
2 Voter is “guided” through one-contest at a time for paging screen or pro-active warning and requiring positive acknowledgement of under votes on full-face ballot.



3 Voter verified paper ballot (VVPB) that is cut-and-drop for privacy. Each paper record is tied to the ballot image with random voting session identifier.



4 All DRE with VVPB should use write-once-read-many CD-R that is authenticated by the jurisdiction and signed by pollworkers as transfer media to prevent tampering.



5 Central consolidation of votes uses WORM CD-R to ensure end-to-end system integrity.



6 Recount & canvass with VVPB and/or authenticated CD-R

Vulnerabilities Mitigated:

- Use of unique random identifier eliminates counterfeiting.
- Use orientation independent ballot access card to ease system failure and extra accessibility for the voters with disabilities.

Vulnerabilities Mitigated:

- 0% over vote.
- **One contest per screen for paging DRE with VVPB and innovative use of “Skip Contest” to eliminate all unintentional under votes.**
- Proper engineering of touch-screen to ensure lifetime calibration stability for the paging DRE with VVPB.
- Use of SAW touch-screen to ensure accuracy and stability of calibration for the larger full-face touch-screen DRE with VVPB.

Vulnerabilities Mitigated:

- Cut-and-drop VVPB paper record to ensure privacy.
- Use at least 800-ft of paper or at least double the normal usage to ensure system availability.
- **Automatic system shut-down whenever VVPB printer is not functioning.**
- Use archive grade thermal paper to ensure stability.
- VVPB is tied to individual electronic ballot image protecting system against insider tampering.

Vulnerabilities Mitigated:

- **WORM CD-R authenticated by the jurisdiction and signed by the pollworker eliminates any insider and outsider tampering.**
- CD-R has adequate capacity to includes all ballot images, event log, and local tallies.
- **Linking each VVPB with electronic ballot images with random voting session identifier enables end-to-end auditing.**
- 100% availability of high quality and individual VVPB enable verification of system integrity.
- **A properly designed/engineered DRE with VVPB is the only method to provide both accessibility and elimination of all voter errors.**

Figure 4: Examples and illustration of DRE with VVPB that have been proven to be reliable and secure.

³¹ SUMMARY OF EXPERIENCE: AVANTE ELECTRONIC VOTING MACHINES <http://www.vote-trakker.com/White%20Papers/accolade-%20Summary%20of%20experience%20Nov.%203.%202003%20election.pdf>

Some recommendations to mitigate the inadequate design and engineering of DREs

The industry is still in the process of resolving various problems produced by inadequately engineered earlier generation DREs with and without VVPB. The system failure in 2006 in Ohio is still in its initial phase of retribution. The Secretary of State in charge is in disgrace. The election directors of the state's biggest county resigned in disgrace and are facing potential legal problems along with some of the board members. The election in Sarasota County Florida is still in dispute and may never be resolved to anyone's satisfaction.

One can anticipate dramatic actions involving election systems and laws from the Congress and many of the States. HAVA will likely be rewritten.

In the midst of updating our election laws in Congress, the following points deserve careful consideration by both more established vendors, and their supporters. Irrational fights over previously mentioned self-evident solutions are not only counter-productive but also contribute negatively to the national interest.

1. NIST was wise in promoting the use of write-once-read-many electronic transfer media such as CD-Rs when drafting the 2005 VVSG but was voted down by those claiming hardship to current more established vendors. There is no encryption technique that can mitigate the potential for insider tampering when read/write flash memories are used. Any error, failure, and indication of possible problem will erode public confidence.
2. Voter verified paper ballots that are not linked to the respective electronic ballot images are meaningless in end-to-end auditing. This is critical in close races.
 - Original VVPB can be easily substituted with faked paper records.
 - A simple lost or incomplete paper record by 1% renders the rest of the 99% of paper records useless when the election is within 1%. There is no way to prove or disprove whether the rest of the 99% is accurate or not.
 - When coupled with easily changed ballot images and tallies on flash memories, tampering is possible and easy. It will unavoidably create confidence problems in the use of such DREs with or without VVPB.
 - The "potential loss of privacy concern" as arguing against the use of a random voting session identifier (machine and/or human readable) on the VVPB as required in 2005 VVSG (and asking NIST to reverse such security feature in 2007 VVSG) is not only contrived, it is against the national interest. Are we really worrying about someone being able to read the barcode identifier or use a 24-digit code to prove to someone they have voted in certain way? Wouldn't most people that are interested in buying or coercing someone's vote be more convinced with a physical picture using cell phone of the paper ballot hanging inside the DRE when the voter is ready to cast their vote rather than being given a 24 digit number that they cannot ever verify?
3. The wide use of "no fault" absentee paper ballots and "all mail paper balloting" dissolved all arguments of "privacy" towards potential coercion and vote-buying protection. Anyone can sell their votes or be coerced to vote in certain ways when using absentee ballots in the privacy and comfort of their homes.
4. Any wider use of paper balloting systems without using a means to authenticate the paper ballots is placing much too much faith in our election and polling officials. Such "ease in tampering" is just too attractive and will lead to diminished voting integrity. It should be mandatory that paper ballots from optical scanning electronic voting solutions, like voter verified paper ballots, should incorporate unique random ballot identifiers for authentication. They can be made to be machine-readable only. Even third world countries such as Philippines and Nigeria are asking for better security features like randomized ballot identifiers when paper ballots are used.

5. All paging DREs with VVPB should present contests to voters one at a time. If choosing to not vote on any individual contest or question, the option to vote "skip contest" should be given to the voter to avoid any confusion of the voter's intent. Such simple software guidance costs nothing and dramatically improves system accuracy to the level of 0% residual votes versus the average of 1.8% including presidential races.
6. All full-face DREs with VVPB should provide means asking voters to positively acknowledge their wishes to skip any contests. This is a proven tested feature of the AVANTE system. Such low cost solutions eliminate all unintentional under votes.

We all understand the need for time to implement improvements as those outlined above. It is disheartening to hear the argument that it costs too much. Taxpayers continue to pay for solutions that have been minimal at best and actually useless at worst in implementing DRE with VVPB that cannot be audited. Case in point is the wide adoption of the earlier generations of DREs without VVPB. When the 25 of the 27 states enacted election codes to adopt the use of VVPB, they again bowed to the influences of interests to adopt VVPB systems without link to the electronic ballots making them useless and not auditable. They simply ignore the recommendation of EAC 2005 VVSG and more proven solutions.

The current HAVA law also facilitates the counter-productive influence from the groups with special interests. As previously mentioned, the inability of NIST to convince the VVSG board to implement or carry out recommended improvements of the voting system such as the use of write-once-read-many transfer media based on solid technical considerations is regrettable. Being "convinced" to retract what is a correct requirement in 2005 VVSG, to eliminate the possibility for end-to-end auditing in VVPB for the future 2007 VVSG, is another travesty.

Dangers of knee-jerk reactions to the poor design and inadequate engineering of DREs

The knee-jerk reaction to the current problems of DRE with VVPB is not only unwise. The wholesale return to paper balloting systems without proper security provisions is not only dangerous but also costly. The following are some predictions if such "knee-jerk reactions" are not curbed.

- **"Florida":**
 - 1) The proposal of the well-intentioned Governor Crist in Florida changing to all paper ballots because of the failures of the poorly designed DRE without VVPB in Sarasota County in this 2006 election.
 - 2) All the jurisdictions are "forced" to buy more of the insecure optical scanning electronic from the same vendors that failed them on DRE because of the timeline in implementation. Yet these precinct-based DROSE are more than 20 years old and cannot provide any security features discussed for the paper balloting systems. They also can never be upgraded in the future.
 - 3) One day another election is too close to call. More paper ballots are found than those that are actually cast. Some ballots are found to have evidence of tampering. Electronic tallies do not match the manual recounts but are well within the accuracy of the system of 0.5-2.0% for the presidential race and 3-20% for the other races. Voter confidence and the election results are thrown into turmoil.
 - 4) The voters and legislature become more educated and call for systems that can authenticate the ballots and capture the ballot images during ballot scanning as proposed by many experts and are also available from other vendors other than the current vendors.
 - 5) All of the DROSE systems were newly purchased for more than \$50 million from the same vendor that just scrapped the DREs purchased a few years ago because the equipment could not comply with current requirements. To authenticate the ballots and capture the ballot images, all new systems must once again be purchased.

6) Another joke played on Florida voters?

▪ “Maryland”:

- 1) The legislature votes to upgrade the current DREs without VVPB to DREs with VVPB that meet the 2005 VVSG.
- 2) The current systems cannot be upgraded without almost total replacement. New systems are purchased under the guise of upgrading, and old systems are traded-in for \$50 millions.
- 3) The vendor provides a newly designed system that meets the proposed 2007 VVSG rather than meeting the 2005 VVSG with VVPB that does not require a unique voting session identifier for end-to-end auditing.
- 4) A close election for the governor occurs similar to Virginia’s in 2006. There are discrepancies of paper records not matching the electronic tallies during recounts. The discrepancy is greater than the difference separating the candidates but within the difference of lost paper records due to failure to print and jamming. An end-to-end audit of accuracy is not possible because of the lack of links between the electronic ballot images and the VVPB paper records.
- 5) Everyone is upset and many careers are ruined.
- 6) Should we buy a new paper ballot system that may yet failed in similar ways as outlined in the example of Florida?
- 7) Another joke played on Maryland voters?

▪ “New Jersey”:

- 1) The Court orders the “touch-button” DRE machines based on Z80 processors to upgrade to include a paper audit trail by January of 2008. The court further finds the certification of such models in the 18 counties in NJ not proper, highlighting the ease of tampering with the system in the pending lawsuit.
- 2) The company upgrades the systems with the paper trail immediately, to comply with the State’s paper audit trail requirement beginning January 1, 2008 costing the State in excess of \$30 million.
- 3) A close election for the US Senate occurs much the same way as in Virginia in 2006. There are discrepancies of paper records not matching the electronic tallies during recounts. The discrepancy is greater than the difference separating the candidates but within the difference of lost paper records due to failure to print and jamming.
- 4) There is no end-to-end one-to-one link between the paper records and the electronic ballot images. No real assessment can be made as to the systems’ accuracy.
- 5) Everyone is upset and many careers are ruined.
- 6) EAC finally takes charge of certifying voting systems based on EAC 2005 VVSG and de-certifies all other systems that cannot meet this standard.
- 7) Like most states, New Jersey’s machines with the older Z80 processor are not capable of meeting the linking requirement. The State and counties have to buy a new set of voting machines for another \$100 million dollars.
- 8) Should we buy a new paper ballot system that may yet failed in similar ways as outlined in the example of Florida?
- 9) Another joke played on New Jersey voters?

There are plenty of similar circumstances that are unfolding. The name of states cited above as examples can be easily replaced with some other states names in similar situations.

A recent scientific and unbiased study sponsored by New York State debunked another myth among the election activist communities. This report made by American Institutes for Research investigates the common voters’ perception on “trustworthiness” and “ease of use” between

three full-face DRE with VVPB and three optical scanning electronic voting systems. ***All three DREs with VVPB were judged to be 10-20 points more positive and 100% less negative than all three precinct-based DROSE systems in both “trustworthiness” and “ease of use”.***³²

Where are the voters with disabilities?

With the drumbeat and call for abandoning DREs with VVPB and the adoption of all paper ballot systems, most notable is the total silence of the usually vocal disability community. They have been part of the reason for preventing or prolonging the adoption of DREs with VVPB because they cannot “see” the VVPB, even though they can hear the reading back of the VVPB, the same way that they are guided by voice-assistance to make a selection.

Now that DREs with VVPB have been trumped with the “ballot-marking device”. It is obvious that the use of “ballot marking devices” for voters with visual disabilities and limited dexterity is not easy without some assistance. This “negative return” to those of visually impaired groups that oppose the use of DREs with VVPB must be unsettling. Yet, there has been total silence among the groups representing the voters with visual disabilities.

Still, the influence from those claiming to represent the interests of voters with visual disabilities on the voting systems is dramatic. Some are asking for a separate and costly solution to add interpretative programs to read the VVPB or the paper ballots that are marked by ballot marking devices using text-to-voice conversion rather than reading from the data stream of the electronic voting system.

This “fairness” sounding proposal is not only unwise and costly it is also technically unreasonable. If one is worried about the visually impaired voter (who can’t read the VVPB or paper ballot after they are guided through the selection process) not being able to trust the reading of the data stream from the electronic voting system, then how is one to trust the reading back using another “independent” means that is provided by the same vendor? No one else can read it for them because of the privacy requirement!

In all fairness, we have not heard the visually impaired voters or groups actually asking for such special “fairness” treatment on verifying their paper records. There is only one vocal leader of a group that merely opposed the use of VVPB along with more established vendors that do not wish to implement them. Almost all groups that we have been demonstrating DREs with VVPB and voters that have used them are more than happy to have the chance to verify their ballots with read back of the paper records. This “make believe” wish is actually promulgated by those that claim to represent these visually impaired voters that also oppose anyone using DREs with VVPB by making its use cumbersome and costly.

This may be one of the remnants of the roadblocks placed by those trying to slow the adoption of DREs with VVPB. It is time for the visually impaired voters to help remove this roadblock.

Comparative vulnerabilities in election management processes using DRE with VVPB and paper ballot system with optical scanning electronic system:

Figure 1 in the previous section described in detail the various vulnerabilities and issues related to the use of paper balloting and optical scanning electronic systems. Figure 2 depicted the

³² “New York State Voter System User Rate Assessment Study Research Report”, December 11, 2006; American Institutes for Research <http://www.elections.state.ny.us/NYSBOE/hava/DRAFTAIRSTUDY.pdf>

best-of-breed solution that resolves most of the issues that can be addressed using state-of-the-arts technologies. Figure 3-4 summarized the same for the DRE system with VVPB or VVPAT. Figure 5 represents two workflows representing the basic election processes and potential errors (human or intentional). Properly designed and engineered DREs with VVPB in accord with EAC 2005 VVSG mitigate all potential tampering and voter errors.

The inherent weakness of paper ballots using optical scanning electronic systems have not been addressed by the 2005 VVSG or proposed 2007 VVSG. It may take another 6 years for all of us to “rediscover” the vulnerabilities that have been well documented in the 1934 milestone book by Joseph Harris (Ref. #13). *In fact, those ballot tampering problems were what led to the adoption of direct recording mechanical lever systems used in New York and other States.*

If we are serious in incorporating the paper balloting and counting system, we must require the optical scanning electronic systems to meet the same level of security requirements of DRE with VVPB. There are serious loopholes in the current HAVA dealing with direct recording electronic systems and optical scanning electronic systems. EAC 2005 VVSG addressed the DRE with VVPB admirably but is woefully inadequate in dealing with optical scanning electronic systems.

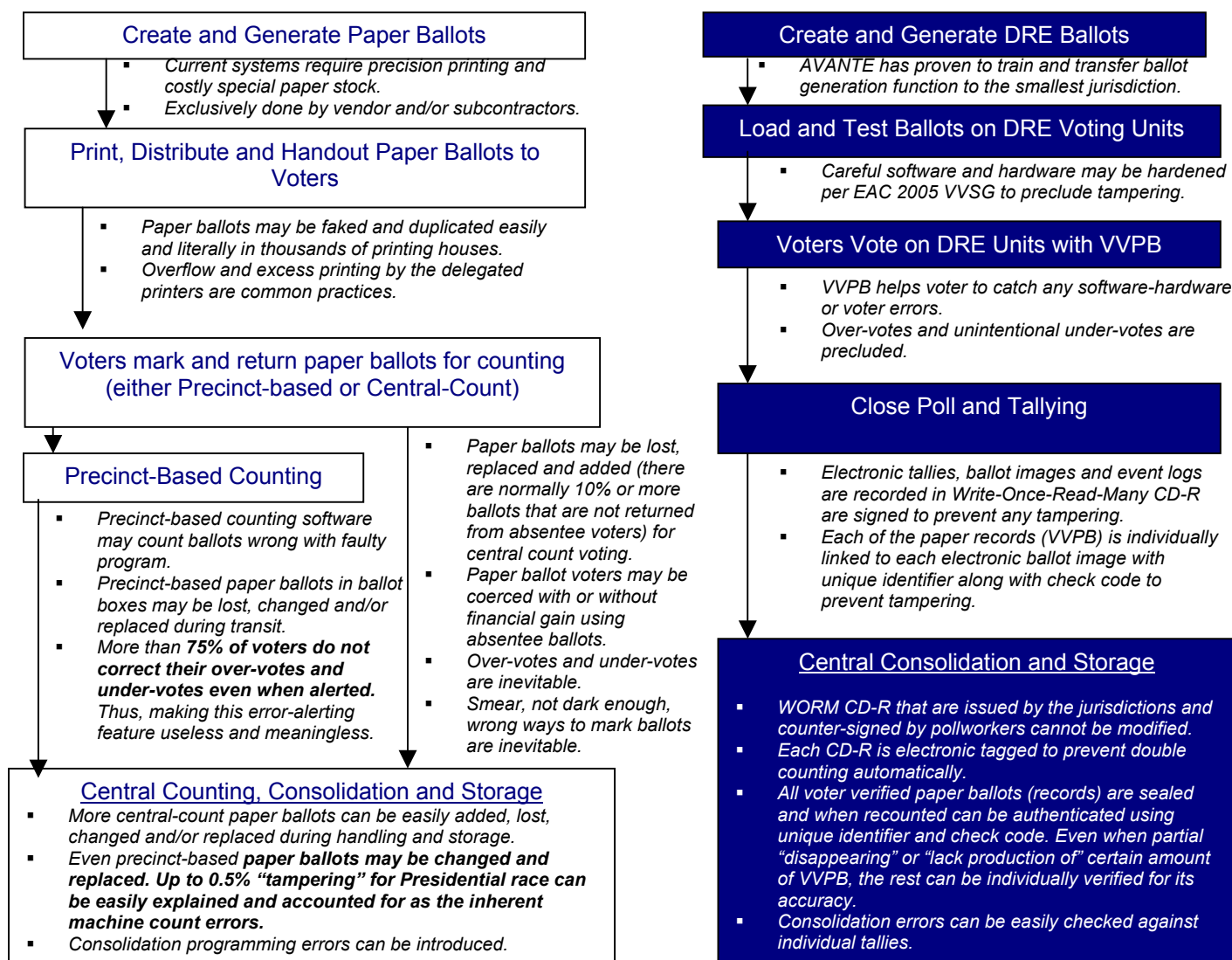


Figure 5: Inherent vulnerabilities of voting systems based on paper ballots deciphered and tabulated with optical scanning electronic systems and electronic ballots and tabulation with voter verified paper ballots.

Conclusions and Suggestions:

The following are key conclusions of this study and analysis on how we can secure paper and electronic balloting.

1. **All voting systems without paper records as required in HAVA and in particular DRE without real-time paper records must be immediately retrofitted with VVPB that meets EAC 2005 VVSG.** NIST scientists chartered to provide advice to the Federal Election Assistance Commission (EAC) have suggested phasing out all DREs without VVPB³³. With the objections of some members of the advisory committee, this rational decision is only a recommendation for buying new systems, but will not requiring retrofitting of the existing systems³⁴. As a nation this is not beneficial in helping the voters to buy in and honor the results of an election. It certainly will cost some money to retrofit or replace the earlier generations of DRE voting systems, not fixing them will definitely damage voters confidence in future elections.
2. **Each and every voter verified paper ballots must have one-to-one correspondance to the electronic votes to provide end-to-end auditing as described in the EAC 2005 VVSG.** It is critical to point out to the Federal and state legislators that almost 25 of the 27 states that asked for DREs with VVPB or VVPAT have been misguided to ask for inferior solutions. Only New York and Illinois State Election Codes asked for the right solution of VVPB for DRE voting systems. This missing critical element to ensure end-to-end auditing in the 25 States election codes must be immediately corrected and added to the pending HAVA amendments. In the case of DRE with VVPB used in Ohio that “misprinting” or “fouled up” of close to 10% of the VVPB, the damage to voter confidence would have been less severe if there was a one-to-one tracking between the electronic ballot images and VVPBs. Any one of the paper records can be authenticated with the corresponding electronic ballot image to project the accuracy of the rest of 10% of the VVPB. Assuming the lost ballots are random, this cross check is equivalent to a 90% audit that will statistically discover almost any tampering if present.
3. **The wholesale replacement of the inadequately engineered DREs with VVPB with the current crop of precinct-based optical scanning electronic systems is just a replacement of one error-laden electronic voting solution with another.** It is irrational to cast away DRE with integrated or properly retrofitted VVPB voting systems just because some systems have lesser performance than others. The many errors and problems encountered in using the earlier generation DREs with voter verified paper ballots can all be attributed to inadequate engineering and weak design. When properly designed and engineered, AVANTE has proven and demonstrated that DRE with VVPB can be made to work almost flawlessly since 2002. As newly elected California SOS Debra Bowen noted, while it is abundantly clear that DREs with VVPB need further improvements, it is also equally abundantly clear they have provided proven accessibility to voters with disabilities.³⁵
4. **If paper balloting is to be used more extensively other than for limited absentee voting only, we should require the paper balloting system to have the same level of security and anti-counterfeiting as that of the best designed and engineered DRE with**

³³ Requiring Software Independence in VVSG 2007: STS Recommendations for the TGDC <http://vote.nist.gov/DraftWhitePaperOnSlinVVSG2007-20061120.pdf>
On the he no notion on of “so software independence” in voting systems; <http://vote.nist.gov/Sl-in-voting.pdf>

³⁴ “Panel Backs Guideline Favoring Voting-Machine Verification” By Cameron W. Barr; Washington Post Staff Writer Wednesday, December 6, 2006; A09
http://www.washingtonpost.com/wp-dyn/content/article/2006/12/05/AR2006120501355_pf.html

³⁵ “Daniel Weintraub: Debra Bowen won't push for return to paper ballots”; “Bowen, however, said she does not believe that electronic voting can be scrapped because it has brought important advances that need to be preserved. Among them: access for the disabled, for whom touch-screen voting is usually far easier, and early voting in public places, which in most counties is not viable without touch-screen voting because there are so many different versions of the local ballot, depending on a voter's exact address and precinct.” <http://www.sacbee.com/110/v-print/story/87474.html>

VVPB. All of the existing precinct-based direct-recording optical scanning electronic voting systems have worse security problems and inherent errors.

- No technology can help 1.5-15% or more voters to NOT make mistakes in marking their paper ballots for the President and other elected offices.
- The fact that paper ballots are easy prey to vote tampering by “ballot stuffing”, “ballot switching”, “ballot loss” and “ballot modification”^{36 37} cannot be reasonably addressed by all of the currently used optical systems. ABSOLUTE control of chain-of-custody may help but has hardly proved to be possible when politics are involved. There are technical solutions to the securing of the paper ballots. Fake and duplicate ballots can be recognized and rejected with incorporation of a randomly generated ballot identifier that can be either machine readable or human readable or both. AVANTE has also pioneered optical ballot solutions³⁸ that can automatically authenticate paper ballots with randomized ballot identifiers.
- Substitution, removal, and addition of ballots post election, can be prevented with the real-time capturing of ballot images, while the voters submit their ballots during precinct-based optical scanning voting. Requiring that all optical scanning electronic voting systems capture the image of the paper ballot as part of the audit trail. The need to have absolute chain-of-custody management in DROSE can be minimized.
- The error rate of reading and deciphering ballots by the DROSE can be minimized by quantitatively counting the pixels on the marked positions. This method allows the evaluation of light marking and smearing for possible misinterpreting of voters’ intents.
- AVANTE is happy to provide licensing and know-how to all other manufacturers to help ensuring that all DROSE voting systems can provide indisputable verification.

5. **Demand all transfer media for election data (tallies, ballot images, and event log) to be write-once-read-many media such as CD-R with procedure of having the pollworkers to countersign the CD-R from each voting unit of DRE with VVPB and DROSE.** They are low cost and secure. A signed WORM CD-R formatted and placed into the voting unit by the jurisdiction and countersigned by the poll workers at the end of the election that contain the ballot images, tallies, and event log is the best mean to mitigate chain-of-custody security concerns. If acceptable, posting and publishing all of the ballot images from the DROSE provide the transparency that most voting integrity groups are looking for. Voting systems using such media are available today for both DRE with VVPB and DROSE.
6. **Our complex society will likely require the use of both DREs with VVPB and optical ballot solutions to provide 100% accessibility to all voters for the foreseeable future. The nation will be best served for all of us to focus on all aspects of improvements for both systems.** AVANTE had proven that properly designed and engineered DRE with VVPB that is secure and reliable. They can help to guide the voters to avoid all unintentional under-votes besides the prevention of over-votes. They may be the only election solution that can be made to be error free in balloting by the voters of different physical, mental and language abilities and disabilities. Paper ballots, even with the best authentication and deciphering technologies that have been proven to work by AVANTE, still cannot help to eliminate or minimize the 1.5-15% or more errors that are made by voters. However, most but not all absentee voting with paper ballots can be replaced with the use of early voting using properly designed DREs with VVPB based on EAC 2005 VVSG.

Note: Picture credits are due to many State websites on voting and electionline.org

Rev. C March 2, 2007

³⁶ Paper v. Electronic Voting Records – An Assessment Michael Ian Shamos; <http://euro.ecom.cmu.edu/people/faculty/mshamos/paper.htm>

³⁷ The Election Integrity Audit; Kathy Dopp and Frank Stenger; <http://electionarchive.org/ucvAnalysis/US/paper-audits/ElectionIntegrityAudit.pdf>

³⁸ <http://www.vote-trakker.com/White%20Papers/OPTICAL%20VOTE-TRAKKER%20MINIMIZING%20VOTERS%20AND%20SYSTEM%20ERRORS.pdf>

Post AVANTE White Paper Comments and Discussions #1:

Accessibilities of “voter verified paper ballot” to visually impaired voters

(Rev A March 1, 2007)

The following is a discussion based on some information and discussions on a report by “Voter Action” in Washington in conjunction with “Demos” in New York by Mr. Noel Runyan.³⁹ AVANTE has tremendous respect for Mr. Noel Runyan and his careful and diligent work in improving the accessibility of our nation’s voting systems. The following comments are offered in the spirit of clarification and perspective from a manufacturer who has given different options careful consideration.

The technical objection to the reading back of the VVPB from the data stream that is used for the printing of VVPB, using the original voting system, placing too much trust on the manufacturers of the voting systems. Some even oppose it, when this specific portion of the source code is made public, as required by some State election codes.

Technically, a truly and totally independent and private verification of paper ballots for the visually impaired voters is having a third party equivalent of “machine-person” to read back the votes as recorded on the voter verified paper ballot. Such facility should be independent of the voting system manufacturer. The best mode of operation will require a system (hardware-firmware-software) that is commercial-off-the-shelf (COTS) and preferably based on open standards. Even a third party developed system that is open-source may not be independent enough if they are not truly COTS. After all, it is dependent and controlled by yet another manufacturer.

Most people forgot that all of the current ballot-marking devices (BMD) use templates to print or mark on pre-printed ballots, or print and mark the ballot. When such printed/marked ballots are fed back for the reading back, they do not use third party OCR or a barcode reader as an independent mechanism. Instead, they retrieve and use the same template to compare on the marked area and use the table to read back to the voters. They are one and the same in terms of independence whether reading from the data stream for printing or reading back by using the template after scanning.

The only commercial-off-the-shelf (COTS) means of reading a paper ballot is the use of optical character recognition (OCR, that still lacks common industrial standards), or reading a condensed representation such as 2-D barcode (e.g. PDF-417) that has public standards.

In the case of the BMD system, the use of OCR coupled with a text-to-speech engine represents the most direct method that may be able to use third party or open source software. The accuracy is still not yet adequate to provide 100% accuracy and thus may cause confusion.

Even if accuracy is not a problem, it still has many practical issues:

- OCR engine coupling with text-to-speech engines that are COTS must read a complete ballot including those not selected. Unless of course, one incorporates special software. It will be equivalent to doubling the time of normal 20-30 minutes of voting that even the visually impaired voters may object to.
- Even then, it still needs special programming to interpret and “read” only the voter’s filled ovals as a selection and read back interpretive words like “filled oval” and “unfilled oval”. By itself, COTS OCR will not know what a filled or unfilled oval means. And sometimes, the system may be required to be pre-programmed to “read” the signature of the County

³⁹ “Improving Access to Voting-A Report on the Technology for Accessible Voting Systems”, By Noel Runyan; February 14, 2007
(http://demos.org/pubs/improving_access.doc)

Clerk of the jurisdiction, or must be programmed to disregard such markings along with all other timing and other marks. Again one has to inject non-COTS software.

- If only those candidates that have been selected are read, the use of the original software and database will be a pre-requisite. There is no technical difference with the method of reading from the same data stream that is used to print the voter verified paper ballot. This is exactly what some of the blind voters and their supporters object to.
- Another potential issue is the use of the “computer voice” that some visually impaired voters object to. If a recorded voice is to be used, it will need yet separate programming on top of the otherwise open-source or public domain software.
- That is, OCR is not a real solution for total independent verification for the visually impaired voters.

We agree with Mr. Runyan that the alternative approach of using barcode representation is a more feasible solution.

To use a commonly available and open standard third party hardware and software system to decipher a condensed representation of the selections made and printed on the VVPB may be technically the only feasible and practical solution. The most commonly used machine-readable representations are 1-D and 2-D barcodes. Using the low data density of 1-D barcode will be inevitably cumbersome when there are multiple contests that are typical in US election. It may need as many lines of barcodes as the number of contests.

2-D barcodes such as PDF-417 have relatively high data capacity to accommodate the requirements of reading as much as 500-1000 bytes of characters of 20-50 contests. PDF-417 is based on open standards that allow independent verification by anyone. Even with the data capacity of 2-D barcodes, sometimes multiple barcodes may be required but they are still manageable. However, there are other technical difficulties inherent with this approach that may not be easily overcome:

- Typical barcode reading using a handheld device is not adequately accurate for a close to 100% read rate required for the election application. A detailed and controlled scanner such as a standard fax machine or document imaging system may be currently the only means that can provide such accuracy. As Mr. Runyan noted, it may present difficulty for some visually impaired voters to manage and in some cases may be just physically not possible.
- AVANTE believes it is possible to engineer a solution that the VVPB from the DRE or BMD with a printed 2-D barcode is fed into an imaging device without manual handling. Hardware adaptation of such COTS imaging system must be developed by a third party or by the original manufacturer. This third party will also have to be responsible to develop software to automatically read the barcode and ignore the rest. It may not be as independent and certainly not COTS with an open standard anymore.
- To be totally independent of the original voting system, the only possible read back voice is again, a synthesized voice. Some visually impaired voters may find it objectionable again.

In short, we have two options but none are perfect or totally independent of either a third party solution provider that may or may not be the original voting system provider. Like Mr. Runyan, we believe something has to be compromised.

Unfortunately, this is the state of our technological know-how. By the very nature that we have to use technology to provide voice assistance, it is almost inevitable that specific hardware and software must be used. Someone other than the visually impaired voters may have to ensure its correctness of such system in advance. Procedures and processes must be in place to prevent

any tampering. We are sure we will be able to continuously improve on it over time when new technological breakthrough becomes available. In the meantime, the following may be the only choices that each bears their respective limitations and costs:

1. Use a text-to-speech synthesized voice (may incorporate recorded voice of candidates) to read back what was printed from the **data stream** that is sent to the printer of VVPB. To make this option more independent and acceptable, we should include the following provisions:
 - At least the portion of such read back software should be open source to allow independent verification.
 - Incorporate a third party developed software module that is open source (and better yet a public domain developed with sponsorship from EAC) to read the data stream using the database table provided by the manufacturer of the voting systems.
 - All visually impaired voters must accept the synthesized voice.
 - This approach costs almost nothing. They are available today from all manufacturers that are providing VVPB solution.

2. Use a text-to-speech synthesized voice to read the **2D barcode** representations of the selections and other relevant ballot identifiers. The caveats are listed below:
 - Only limited ballot-marking devices have the capability to print 2-D barcode.
 - All visually impaired voters must accept the synthesized voice.
 - This approach must still incorporate a third party developed software module to extract the barcode data image and ignore the rest of the printed data images.
 - This third party developer may be sponsored by EAC to provide a public domain software module but must also work with the original voting system manufacturer to ensure proper adaptation to accept the VVPB in whatever form-factor.
 - Its cost may be as high as \$2,000 for physical hardware adaptation and incorporation of another computer independent of the original voting system. If such ballot- reading module is to be loaded into the original voting system, some form of “handshake” must be worked out. For lesser independence, the cost may be reduced to the range of \$1000 each.

We hope it is clear to all that it is not the intent of AVANTE to discourage and/or encourage specific approaches. We only wish to point out the reality and facts of the current available technologies and those that have been incorporated in our nation’s voting systems today.

Post AVANTE White Paper Comments and Discussions #2:

On the issue of source code escrow and/or disclosure

(Rev A March 1, 2007)

Source code disclosure and escrow is becoming critical in part due to the proposed HR 811 bill by Congressman Holt. Unlike VVPB that is self-evident, this is one of the murkiest aspects in the pursuit of improvement in the integrity of our nation's voting systems. AVANTE does not think it has an ingenious idea to offer beyond what has been superbly discoursed in several Internet blogs⁴⁰ and websites⁴¹. We offer our comments below from the perspectives of a manufacturer that may offer slightly different insights.

AVANTE agrees with the approach taken in the EAC 2005 VVSG in terms of reviewing and escrowing of source codes. The following is a summary of the key points:

- Voting system manufacturers must submit all of the source codes that they developed to authorized independent testing agencies for source code review and certification.
- Final certified source codes are compiled to produce the "witness build" that serves as the "gold" standard of the voting system.
- All source codes and execution codes that are certified are escrowed in NIST (almost all vendors comply with this voluntary requirement).
- All source codes and execution codes incorporate "hash" codes to ensure authenticity that can be independently verified.
- Most States require additional escrowing of the source codes and execution codes for the voting systems that may or may not have variations that are certified by the States.
- The EAC 2005 VVSG specifically exempt reviewing or certifying commercial-off-the-shelf (COTS) third party source codes such as operating systems, database, firmware embedded in ancillary devices.
- Most States require the submission of at least a set of certified hardware and software used in their States as hard evidence and reference.

AVANTE believes the current approach used by EAC with the assistance of NIST on source code is wise and practical. Maybe the following aspects can be made more specific.

- Require that COTS software and firmware be defined as those that have established commercial applications besides the voting system.
- Require that no modifications on such firmware and software can be made to meet the specific needs of the voting systems incorporating them.
- If any modifications of such firmware and software is done to meet the voting system applications, such firmware and software should be certified and source code placed into escrow in NIST, and other State agencies that requiring escrowing of the specific source codes.
- Incorporate election codes (Federal or State or EAC requirements) that all source code in the escrow can be reviewed by court appointed experts. Expert opinions can be rendered on any aspects of the source codes as long as the actual source codes are not disclosed.

AVANTE agrees with the team of computer and election experts associated with "ACCURATE" in their position on restrictive and controlled disclosure⁴² of the source codes developed by the

⁴⁰ <http://avi-rubin.blogspot.com/2007/02/hr-811-new-holt-bill.html>; http://www.votetrustusa.org/index.php?option=com_content&task=view&id=2276&Itemid=26;

⁴¹ <http://www.bbvforums.org/forums/messages/46591/46677.html?1171306118>

⁴² <http://accurate-voting.org/wp-content/uploads/2007/02/AR.2007.pdf>

voting system manufacturers. Our rationale has been stated earlier⁴³. The following outline some additional clarifications:

- Very light penalties are ever imposed on the offenders that changed the source codes for elections without prior State approval. The legal precedence provides very little deterrent to those that are willing to commit such offenses. With the availability of source codes without any chain-of-custody control, it just make it that much easier and more tempting. Tracing to a responsible party is made that much more difficult.
- Voting systems are managed independently by more than 100,000 independent jurisdictions each with different State election codes and traditions. They also use different approaches for election security protections. It is unwise to have total open source to the public.
- Currently, experts appointed by the State (in some but not all States) can review and examine the source codes used in the voting systems.
- AVANTE agrees that source codes should be available for qualified independent public reviews.
- AVANTE appreciates the desire of the voting integrity community to have a more transparent voting process. We propose that such a review process be opened up more, to allow qualified public expert to review the source codes with the following conditions:
 - The experts must be US citizens so they are subject to US jurisdiction.
 - Preferably, these experts are endorsed by publicly registered citizen groups (e.g. 501C, etc.), Universities, and other public institutions as stipulated by a court of proper jurisdiction.
 - Review and examination must be done in an environment that is controlled by the Court with video monitoring as to prevent any form of copying.
 - All such experts must sign an agreement of non-disclosure of the actual source codes but are allowed to make comments to the manufacturers. Such comments must not be made available to the public unless sanctioned and allowed by the Court of proper jurisdiction.
 - All such experts having the desire to perform such source code review services on behalf of the public, must sign an agreement that they will be barred from working on products or consulting for any voting systems manufacturers, including that of not-for-profit institutions, for the next 10 years.

AVANTE believes there is an implicit public responsibility of all voting system manufacturers in such a public endeavor as election and the nation's democracy. Such implicit public responsibility should include proper and adequate transparency. However, the public's right-to-know must not damage the business interests of the entities that provide such commercial systems and services.

AVANTE offers the above ideas for discussion and modification and hopes some of its merits be adopted to satisfy the interests of all concerned.

⁴³ <http://www.vote-trakker.com/IS%20OPEN%20SOURCE%20OR%20SOFTWARE%20ELECTRONIC%20VERIFICATION%20A%20SOLUTION%20FOR%20SECURED%20E-VOTING.pdf>