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DEPARTMENT OF THE PUBLIC ADVOCATE
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JON S. CORZINE
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September 13, 2007

Honorable Linda R. Feinberg, A.J.S.C.
Superior Court of New Jersey
Law Division, Mercer County
209 South Broad Street, 3rd Floor
P.O. Box 8068
Trenton, New Jersey 08650

Re: Gusciora v. McGreevey, No. MER-L-2691-04

Dear Judge Feinberg:

Please accept this letter-brief in lieu of a more formal brief, on behalf of *amicus curiae* Public Advocate of the State of New Jersey (the "Public Advocate").¹

At the hearing in this case on September 5, 2007, the Court directed the State to submit plans for conducting elections in and after January 2008. This plan was to include alternatives to the current proposed complement of voting systems (i.e., the Sequoia Advantage D-10, firmware version 10.3.11, with Seiko CAP9347A-S640-E printer; the Sequoia Edge, firmware version 5.0.31, with APS CP305

¹ The Public Advocate filed a motion for leave to participate in this action as *amicus curiae*, and a brief in support of that motion, contemporaneously with this brief.

printer; and the Avante Vote-Trakker EVC308-FF, hardware version 1.4.0 and firmware version 1.2.1A, with Seiko KPU S347 printer).²

After learning of the Court's Order, the Public Advocate determined it was in the public interest to seek the Court's leave to participate in this action as *amicus curiae*. The Public Advocate urges the court to ensure that any voting system put in place for use after January 1, 2008 – whether on an interim or more lasting basis – meet the state statutory standards requiring *inter alia* thorough testing, prevention of over-votes, reliability, secrecy, and accuracy. N.J. Stat. Ann. § 19:48-1. The Public Advocate has had serious concerns about the testing standards and protocols the State has so far employed in the voting system certification process. The inadequacies of these standards and protocols leave the voting systems presently under consideration vulnerable to challenge in an appropriate proceeding should the Attorney General ultimately decide to certify them. Because such a challenge could delay or even prevent the final adoption of these systems, New Jersey citizens could find themselves voting on an “interim” or “stop-gap” system in more elections over a longer period than might be anticipated. It is therefore critical that any such interim system itself conform to all relevant statutory requirements.

I

The Public Advocate's motion to appear in this case follows months of consistent and vigorous dialogue with the Attorney General, dating from December 2006, on the need to (1) establish clear and rigorous standards to verify that all proposed voting systems meet the requirements of State law; and (2) verify compliance with State law through testing performed in accordance with scientifically accepted principles.

Initially, we highlight for the Court's benefit some of the prior statements made by the Public Advocate on the issue of voting machines.

In our comments of April 16, 2007, about the State's nonregulatory criteria for testing voting machines, we stated that these criteria:

- (1) failed to set forth any maximum acceptable failure rate for the voting machines or their printers, leaving it unknown what kinds or number of failures would result in the machines' receiving either a “passing” grade or a “failing” grade;

² As of this date, *amicus* understands that neither the New Jersey Institute of Technology nor the Voting Machine Examination Committee has completed its examination of the voting system proposed for use in Sussex County, the ES&S iVotronic.

- (2) failed to prescribe the minimum amount of testing of the machines to be performed by the State's independent testers, to verify that the machines would actually work on election day; and
- (3) failed to require testing of the voting systems' source code.³

During hearings by the Voting Machine Examination Committee ("VMEC") on July 24-26, 2007, and in connection with the Attorney General's subsequent review of the VMEC's recommendations, the Public Advocate offered extensive oral testimony and documentary evidence, and provided three expert reports.⁴ Collectively, this evidence shows that the testing performed by the New Jersey Institute of Technology ("NJIT") and others is insufficient to prove that the proposed voting systems meet the relevant statutory standards.

Although we have consistently supported the State's decision to engage independent testers such as NJIT, the Public Advocate remains concerned about the implementation of this decision. Specifically, where – as here – those testers do not even vouch that the tests they performed are a "valid means for testing the voting machines,"⁵ the public interest requires a more searching inquiry to find a solution to the parties' and the Court's common goal of a legally compliant, fiscally viable, and long-term solution for the State's voting technology.

³ See Public Advocate's Memo on Voter-Verified Paper Trails attached hereto as Exhibit A, also available at <http://www.state.nj.us/publicadvocate/home/reports/pdfs/PaperTrailMemo.pdf>. These comments were Exhibit 14 in the Public Advocate's submission of documents to the Voting Machine Examination Committee in its recent hearings. This brief will refer to such exhibits, which are of the public record, with the notation "VMEC Exhibit DPA-##."

⁴ The oral testimony can be found in the transcripts of the Voting Machine Examination Committee (VMEC) of July 24, 25, and 26, 2007, which the State previously lodged with the Court. The expert reports on behalf of the Public Advocate, described in more detail *infra*, are appended hereto.

⁵ Transcript of Record at 169:9-17, *State of New Jersey Office of Attorney General Division of Elections Public Hearing, In Re: New Jersey State Voting Machine Examination Committee* (July 25, 2007) (available at <http://www.nj.gov/oag/elections/Hearing-Reports-7.07/July-25-2007-Transcript.pdf>). This brief will refer to such transcripts with the notation "VMEC transcript of July ##, 2007."

II

A

By way of background, in July 2005, the Legislature amended state law to ensure that every New Jersey voter would, effective January 1, 2008, have the right to cast a ballot on a voting machine that:

- was “thoroughly tested”;
- was “reliable”;
- would guarantee “secrecy” to every voter;
- would “correctly register or record and accurately count all votes cast”; and
- included a voter-verified paper audit trail that also met all of the foregoing mandates, so that voters could verify the accuracy of their votes.

P.L. 2005, c. 137 (codified at N.J. Stat. Ann. § 19:48-1). The law also requires the Attorney General to conduct a review of the machine as a whole, rather than just its added or upgraded components, where additions to the voting systems “impair” the “efficiency” of the voting machine.⁶

In an effort to determine compliance with these provisions, the Attorney General, in May 2007, engaged the New Jersey Institute of Technology to perform testing on these machines. The State’s agreement with NJIT required a physical examination of the machines, and then (1) a computer-generated “stress” test consisting of 1,200 votes and (2) a test involving human beings who would cast 400-600 votes on each system in a single “test” day of 14 hours.⁷

⁶ N.J. Stat. Ann. § 19:48-2. As the Public Advocate argued before the VMEC, the printers that have been added to the voting machines under consideration will extend the time each voter needs to cast his or her ballot. As “efficiency” is defined as the “time taken to vote,” and an adverse impact on “efficiency” means something that “slow[s] down the process,” the addition of the printers is an “impairment to efficiency” that requires re-evaluation of the voting system as a whole. *See generally* Exhibit A hereto at 2 and n.1 (citations omitted). In deciding against a re-examination of the entire system, the VMEC misstated the statutory standard, suggesting that the printers did not “impair[]” the “operation” of the voting system. *See, e.g.*, Title 19 Committee Report, Re: Sequoia Advantage VVPRS, at 6 (August 21, 2007) (available at <http://www.nj.gov/oag/elections/committee-rpt-sequoia-ad-8.21.07.pdf>) (copies previously filed with court). However, that is not the legal standard, and the evidence of “impair[ment]” of the “efficiency” of the voting system was unrebutted. VMEC transcript of July 24, 2007 at 161:6-18 (<http://www.nj.gov/oag/elections/Hearing-Reports-7.07/July-24-2007-Transcript.pdf>).

⁷ *See* NJIT Project Outline for Testing Voter Verified Paper Record System, attached hereto as Exhibit E and previously submitted as VMEC Exhibit DPA-1-B. The agreement also provided for NJIT to perform a test of 52 votes on two of the systems to determine whether those machines could satisfactorily handle longer than normal ballots. The results of the 52-vote tests are not at issue.

The State thus elected to rely on tests involving only two machines per system, with each system recording no more than 1,800 votes, as a basis for determining whether the systems would function in a real-world election. To set this decision in context, a real election in New Jersey calls for approximately 10,000 machines (in the case of the Sequoia Advantage) which receive more than 3 million votes in a presidential race.

The undisputed evidence presented to the Voting Machine Examination Committee and the Attorney General led to the conclusion that the testing performed by NJIT, either alone or in combination with testing performed by federal laboratories, was insufficient to determine whether the machines met the statutory mandates:

- The NJIT testers admitted in testimony before the VMEC that they were unable to conclude that their tests, which examined compliance with the State's nonregulatory voting machine criteria, "represent[ed] to a reasonable degree of scientific certainty a valid means for testing the voting machines."⁸
- The VMEC also expressly disclaimed that it was "taking any position" one way or the other about whether the State's nonregulatory "criteria" represented "a reasonable and scientifically valid framework for determining the reliability and the usability and the security of the machines that they evaluated."⁹

⁸ MR. KOMUVES: . . . The question is whether NJIT takes any position about whether the criteria that you were given by the State represents to a reasonable degree of scientific certainty a valid means for testing the voting machines?

MR. DARER: No. We have no position. That was not within the scope of our project or what we were engaged to do.

VMEC transcript of July 25, 2007 at 169:9-17 (available at <http://www.nj.gov/oag/elections/Hearing-Reports-7.07/July-25-2007-Transcript.pdf>).

⁹ MR. KOMUVES: . . . [Has] NJIT [taken] any position one way or the other about whether the State's criteria, as given to them, represent a . . . reasonable and scientifically valid framework for determining the reliability and the usability and the security of the machines that they evaluated?

MR. WOODBRIDGE: . . . I should remind the public that the Committee itself is not taking any position on that . . .

- In expert testimony submitted to the VMEC, J. Alex Halderman and Harlan Yu, graduate students in computer science at Princeton University whose work has included testing voting machines in California, opined that, because NJIT did not perform a security audit of the machines' programming, "it is impossible to say whether these machines can reliably deliver an accurate count . . . It would be difficult for anyone to claim that these voting systems comply with" even the State's "[C]riteria."¹⁰
- Messrs. Halderman and Yu, after explaining a variety of security vulnerabilities found in Direct-Record Electronic ("DRE") voting machines generally, determined that "[t]he only way to reasonably address these risks is to conduct a comprehensive source code security review, accompanied by 'red team' testing that simulates the role of a malicious attacker."¹¹ In their review of the relevant literature, Messrs. Halderman and Yu found that no such testing has been performed with respect to the Sequoia Advantage or the Avante Vote-Trakker. The Sequoia EDGE, the one machine that was tested in this manner -- by the California authorities -- failed.
- Messrs. Halderman and Yu also found insufficient testing to determine whether the systems at issue would compromise "voter privacy and the integrity and reliability of elections."¹²
- Professor Kevin Wayne, also of Princeton University, testified that the machines were not tested for a sufficient number of hours or votes to yield scientifically supportable conclusions. Only 1,794 or fewer ballots were tested in each of the systems under review, leading Professor Wayne to conclude that "the NJIT tests were insufficient to determine whether the systems satisf[ied]" any accepted standard for assessing voting machine reliability.¹³
- Professor Wayne explained that the Sequoia Advantage, with

¹⁰ Written Testimony of J. Alex Halderman and Harlan Yu, July 27, 2007, attached hereto as Exhibit B.

¹¹ *Id.*

¹² *Id.*

¹³ Written Testimony of Kevin Wayne dated August 22, 2007, attached hereto as Exhibit C.

1 failure in 1,794 ballots[,] falls well short of the 1 in 10,000 NIST standard.¹⁴ In fact, 83.5% of the time a machine that achieves a 1 in 10,000 (or better) will have 0 errors in 1,794 ballots. . . . Obviously, 0 failures in 1,794 ballots is [the] best possible result for a system, but what can we conclude statistically when this happens? Unfortunately, not much. For example, a machine that fails at the rate of 2 times in 10,000 (twice the NIST standard) would have no failures in 1,794 ballots 70% of the time. In other words, if no mechanical failures are observed, the NJIT test does not have sufficient *power* to identify whether a machine that [sic] meets the NIST standard.¹⁵

- Similarly, computer engineer Howard Stanislevic stated in his testimony, “New Jersey’s testing protocol fell far short of what would be needed for a ‘thorough test’ to determine voting system reliability. The tests performed in New Jersey were not adequate to uncover serious reliability problems with DRE hardware, software, or printers.”¹⁶

Moreover, even if NJIT had performed the kind of “thorough” testing contemplated by the statute, one of the systems examined – the Sequoia Advantage – failed. The printer on that system, proposed for use in 18 counties in New Jersey, jammed once during NJIT’s test of 1,794 ballots, resulting in the loss of 56 paper ballots. While there is some evidence that the ballot losses might not have occurred in a real-world election (as distinct from a laboratory test), there is no reason to believe the jam would not have occurred in a real-world setting.¹⁷

¹⁴ Professor Wayne refers here to a draft proposal of the National Institute of Standards and Technology (“NIST”) that voting systems should be approved for use only if they fail no more than once in 10,000 ballots. Since Professor Wayne presented his testimony, NIST researchers adopted a more stringent and detailed standard for measuring voting system failures. This new proposal was presented to the United States Election Assistance Commission on August 31, 2007. See *Voluntary Voting System Guidelines Recommendations to Election Assistance Commission*, Aug. 31, 2007, at 186 (available at <http://www.eac.gov/files/vvsg/Final-TGDC-VVSG-08312007.pdf>).

¹⁵ Written Testimony of Kevin Wayne dated August 22, 2007, attached hereto as Exhibit C.

¹⁶ Testimony of Howard Stanislevic Regarding New Jersey’s VVPRSA Testing, dated August 23, 2007, attached hereto as Exhibit D.

¹⁷ See NJIT’s Report to the Office of the Attorney General, Sequoia AVC Advantage Voter-verified Paper Record System Assessment (July 2007) (copies previously filed with court); NJIT’s Addendum to Sequoia AVC Advantage Voter-verified Paper Record System Assessment (July 19, 2007) (copies previously filed with court).

Finally, there was evidence that the Sequoia EDGE system would compromise voter privacy. The continuous spool paper record on the Sequoia EDGE, together with the paper election records used under New Jersey law (i.e., voting authority slips) and the presence of challengers, undermines the secrecy of the ballot by allowing votes recorded on the paper trail to be matched with documents showing the order in which people voted.¹⁸

While the State's engagement of independent testers was commendable, the testing NJIT performed was not adequate to determine whether the systems comply with the governing statutory standards. Unlike other jurisdictions such as California, which conducted a "top-to-bottom" review of voting systems, the tests New Jersey commissioned from NJIT did not examine the details of the machines' programming, nor did they cast enough test ballots to demonstrate that the systems will be reliable, will ensure a secret ballot, and will correctly register and count votes. We cannot know from these tests how vulnerable the systems are to machine malfunctions, printer jams, or hackers who may seek to alter election results. And the State has indicated that NJIT's retesting will follow effectively the same inadequate protocol as before.

B

Although the State, before this current round of voting machine testing, had relied on certifications of voting systems by federally certified independent testing authorities ("ITAs"), funded by the manufacturers of voting systems, the State has rightly concluded that ITA certification of a particular system, standing alone, is not sufficient to demonstrate that the system satisfies State law. As the Attorney General remarked during the recent VMEC hearings, the State decided to "not only follow [one national voting system standard], but actually go beyond it in a number of areas. The State Division of Elections felt we could and should do more to protect the right to vote."¹⁹

The decision not to rely on ITA testing alone for certification makes eminent sense given the historical record. The evidence before the VMEC showed that "federally certified" machines have experienced massive failures in both real-world elections and in other laboratories. Specifically:

¹⁸ VMEC transcript of July 25, 2007 at 182:8 to 191:25 (available at <http://www.nj.gov/oag/elections/Hearing-Reports-7.07/July-25-2007-Transcript.pdf>).

¹⁹ VMEC transcript of July 24, 2007 at 7:2-7 (available at <http://www.nj.gov/oag/elections/Hearing-Reports-7.07/July-24-2007-Transcript.pdf>).

- Although the Sequoia Advantage machine passed federal certification, reportedly with no hardware failures in 163 hours of operation, this system nevertheless failed NJIT's test, with a printer jam occurring during approximately 21 hours of testing.²⁰
- During the August 2007 California "top-to-bottom" test described above, the software reviewers found that the WinEDS software, which is used in New Jersey's EDGE and Advantage voting systems, had "numerous programming, logic, and architectural errors" that have "serious security implications." Again, this was despite these systems' federal certification.²¹
- In the 2007 general election in Riverside County, California, using the EDGE – a federally certified system under consideration for use in New Jersey – observers noted equipment problems in 21 of the 24 precincts under study (88%), including multiple printer jams and stuck activator cards.²²
- In the 2006 general election in Guilford County, North Carolina, 9 percent of the federally certified machines experienced printer jams or other problems that "made the paper record[s] . . . unusable for purposes of a state-mandated audit."²³
- In the 2006 primary election in Cuyahoga County, Ohio, a federally certified machine resulted in "10 percent of the paper ballots [being] either smeared,

²⁰ NJIT's Report to the Office of the Attorney General, Sequoia AVC Advantage Voter-verified Paper Record System Assessment (July 2007), at 7. The State has previously lodged this Report with the Court.

²¹ The scientists testing the voting systems in California found the 2002 Voting System Standards (VSS) – the federal standards to which all current DREs have been tested – to be "inadequate." See, e.g., California Secretary of State, *Withdrawal of Approval of Hart Intercivic System 6.2.1 DRE & Optical Scan Voting System and Conditional Re-approval of Use of Hart Intercivic System 6.2.1 DRE & Optical Scan Voting System*, at 1 (August 3, 2007) (available at http://www.sos.ca.gov/elections/voting_systems/ttbr/hart.pdf).

²² Report to the Riverside County Board of Supervisors (Save R Vote, December 5, 2006) (available at http://www.bradblog.com/Docs/SAVERVOTE_RiversideCounty_2006ElectionReport_120506.pdf). This document was previously submitted as VMEC Exhibit DPA-61.

²³ See Mark Binker, *Printers Failed on Voting Machines*, News & Record (Greensboro, NC), December 15, 2006, attached hereto as Exhibit F and previously submitted as VMEC Exhibit DPA-58.

torn, crumpled, or blank. In some precincts, the paper record count and the machine count were off by considerable amounts.”²⁴

Again, the Public Advocate is not asking this Court to rule on the sufficiency of the testing of New Jersey’s machines. We point to flaws in the testing standards and protocols only to suggest that, should the State ultimately certify these or other systems based on such inadequate review, the certification decision would be subject to potentially successful challenge in the appropriate tribunal. *See* N.J. Stat. Ann. § 19:48-2. Such a challenge could delay or stymie the final adoption of these systems. In considering potential interim solutions, therefore, this Court should take account of the possibility that they may be in use for many elections.

III

We now turn to the question of what alternatives would be legally compliant, fiscally viable, and part of a long-term solution to the State’s voting technology problem. We will address in turn the requirements and viability of paper-based systems and then DREs.

A. Paper-based systems

If the State and the several counties elected an interim solution based on paper ballots, there are four general options. In each case, voters would mark a paper ballot, using a pen or pencil. The ballots would then be counted in one of several ways, described below.

Paper ballots have the advantage of being directly marked by voters, without mediating technology. Any errors on the ballot are the product of the voter’s mistakes, not of machine failure or tampering. And these paper ballots are the official election records, available for recounts as necessary. *See* N.J. Stat. Ann. § 19:48-1.

The options include:

- Hand-counted paper ballots – poll workers at each polling place could hand-count paper ballots immediately after the close of the polls. *See* N.J. Stat. Ann. § 19:16-2 to -10.²⁵

²⁴ *See* Stephen Manning, *Paper Jams Hamper Electronic Voting*, Washington Post (Wash., D.C.) December 21, 2006, attached hereto as Exhibit G and previously submitted as VMEC Exhibit DPA-59.

²⁵ Historical figures on voter turnout in New Jersey primary elections suggest that this would not be an undue burden on poll workers in a presidential primary election. In the past six years, voter

- Vote-by-mail – Cf. N.J. Stat. Ann. § 19:62-1 to -13 (providing the framework by which municipalities of 500 or fewer persons may conduct mail-based elections) – mailed-in ballots could be counted either by hand or by use of optical-scanning machines. Many counties already own machinery that scans and counts absentee ballots.²⁶
- Central-count optical scanning machines – voters could fill out complete ballots at their local precincts, which would then be collected and read by optical scanning machines at some other, central location.
- Precinct-count optical scanning machines (PCOS) – voters could complete ballots at their precincts and then immediately feed them into a machine that scans and tallies them.

Each of these options will require the State to acquire and use products to accommodate voters with visual or dexterity impairments. These accommodative devices would have to preserve the privacy and independence required by law.²⁷ These alternatives could include the following:

- Purchase or lease of a ballot marking device. A ballot marking device is a machine that, upon receiving the appropriate commands from a voter privately using an audio device, sip-puff device, or otherwise, marks the ballot and places it into a privacy sleeve. The voter or an assistant then feeds the marked ballot from the privacy sleeve directly into the ballot receptacle; or
- The State might keep one DRE per precinct for accessibility purposes.

turnout in primary elections peaked at 600,000 (in 2001), which computes to less than 100 ballots per polling place. While turnout may be higher in the February 2007 presidential primary, the ballot will also be simpler than in other primaries, with one Democratic and one Republican race.

However, a hand-count system would not likely be feasible in other elections, especially general elections. In those races, the ballot is much more complex, involving several races and, often, public questions. Moreover, turnout in general elections is far higher than in primary elections; in the 2004 presidential election, some 3.6 million people cast ballots.

²⁶ See generally New Jersey Division of Elections Voting Equipment Inventory (available at <http://www.nj.gov/oag/elections/voting-equipment/Voting%20Machine-software%20inventory-3.6.07.pdf>).

²⁷ See generally 42 U.S.C. § 15481(a)(1)(A) (requiring certain voting systems to provide for privacy and independence in voting); N.J. Stat. Ann. § 19:4-11 (providing that at least one voting system per district must permit “individuals with disabilities to vote”); N.J. Stat. Ann. § 10:5-4 (forbidding discrimination against persons on account of disability).

Any paper-ballot system that includes machine tallying must meet the requirements of N.J. Stat. Ann. § 19:53A-3. Among other things, the machine would have to provide for “secrecy,” be capable of being “used safely, efficiently and accurately,” and “record correctly and count accurately every vote cast.”²⁸

Unlike other tallying machines, a PCOS has the major advantage of immediately alerting voters when they vote for more than one candidate for a single office (over-vote) or inadvertently skip a race (under-vote), providing them an opportunity to correct such errors. Other paper-based systems, in which ballots are not scanned or counted in the voter’s presence, do not alert voters to their errors. Because of this added functionality in PCOS systems, studies have found that they generally produce the lowest rate of over- and under-votes of any voting technology, and that the reduction in error is especially pronounced in jurisdictions with a high number of ethnic or racial minority voters.²⁹ Moreover, a PCOS can serve multiple election districts sharing a single polling place; consequently, the State could purchase fewer pieces of equipment.

B. Alternate DRE system

Another option for consideration is switching to a DRE system that has been subject to rigorous testing.

The Secretary of State of California recently granted a conditional approval of the “eSlate” Hart Intercivic System 6.2.1 DRE.³⁰ This system was subject to several tests conducted by experts at the Berkeley and Davis campuses of the University of California to determine if the voting system was “defective, obsolete, or otherwise unacceptable for use.”³¹ The experts had found the voluntary federal

²⁸ The requirements of N.J. Stat. Ann. § 19:53A-3, which would cover tallying machines such as optical scans, are similar, but not identical, to those of N.J. Stat. Ann. § 19:48-1, which covers DREs.

²⁹ See Brennan Center for Justice, *The Machinery of Democracy: Voting System Security, Accessibility, Usability, and Cost*, at 99-101 (2006) (available at http://www.brennancenter.org/dynamic/subpages/download_file_38150.pdf). This document was previously submitted as VMEC Exhibit DPA-29.

³⁰ See California Secretary of State, *Withdrawal of Approval of Hart Intercivic System 6.2.1 DRE & Optical Scan Voting System and Conditional Re-approval of Use of Hart Intercivic System 6.2.1 DRE & Optical Scan Voting System*, at 1 (August 3, 2007) (available at http://www.sos.ca.gov/elections/voting_systems/ttbr/hart.pdf).

³¹ *Id.*

2002 Voting System Standards inadequate.³² In light of this, the State of California created its own criteria and conducted a thorough evaluation including source code review, volume testing, and “red team” attacks.³³

The Source Code Review Team and the Red Team found some vulnerabilities in the Hart Intercivic System.³⁴ However, the Secretary of State believes that this system will be safe to use in California if election officials institute protocols such as chain of custody controls, software security measures, and adequate poll worker training.³⁵ The Hart Intercivic was the only DRE that the Secretary of State of California deemed fit for general use after rigorous testing.³⁶

While the Public Advocate does not endorse either the Hart Intercivic or any other technology, we include this as an example of a DRE that has received the kind of thorough testing that New Jersey law requires. To the extent that the Attorney General would require additional testing, beyond that conducted for the California authorities, the Public Advocate welcomes such additional testing. However, the California testing provides a good example of the kind of review that would satisfy New Jersey’s statutory requirement of “thorough” testing.

C. The role of audits

Finally, whichever system is ultimately chosen, the State should provide for routine post-election auditing of the results. At present, there is legislation pending to provide for such audits, but there is no guarantee that such legislation will pass in time for the February 2008 presidential primary. In at least one previous case management conference before the Court (on April 23, 2007), the Attorney General’s

³² *Id.* at 1-2.

³³ Red team tests determine whether tampering or error can compromise a system, resulting in incorrect recording, tabulation, tallying or reporting of votes or alteration of critical election data such as election definition or system audit data.

³⁴ *See id.* at 2-3.

³⁵ *Id.* at 4-11.

³⁶ In contrast, the California Secretary of State limited use of the Sequoia EDGE to one machine per precinct, for accessibility purposes, and required a 100% hand-count of all EDGE ballots. *See* California Secretary of State, *Withdrawal of Approval of Sequoia Voting Systems, Inc., WINEDS V 3.1.0121 AVC EDGE/Insight/Optech 400-C DRE & Optical Scan Voting System and Conditional Re-approval of use of SEQUOIA VOTING SYSTEMS, INC., WINEDS V 3.1.012 AVC EDGE/Insight/Optech 400-C DRE & Optical Scan Voting System* at 5, 6 (August 3, 2007) (available at http://www.sos.ca.gov/elections/voting_systems/ttbr/sequoia.pdf).

Office had indicated that it might consider mandating audits; however, no such plan has been proposed for review by the public or the Court at this time.

As noted in a recent report by the Brennan Center for Justice, a fair-elections think-tank based at the New York University School of Law, "[p]ost-election audits of voter-verifiable paper records are a critical tool for detecting ballot-counting errors, discouraging fraud, and improving the security and reliability of electronic voting machines in future elections."³⁷

While the Public Advocate cannot comment on hypothetical audit proposals, we urge the Court to raise with the parties the feasibility of a post-election audit, with sufficient statistical power to detect anomalies in voting returns, as part of any solution to the State's voting technology problems. This recommendation applies to all methods of voting that the State and the several counties may adopt, including optical scanners, other paper ballot systems, or DREs with VVPATs.

Conclusion

We appreciate the Court's consideration of the importance of ensuring that any voting system used in New Jersey – whether on an interim or more permanent basis – complies with all relevant state and federal laws, so that citizens may have justifiable confidence in the integrity of the franchise.

Respectfully submitted,



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³⁷ Lawrence Norden et al., Post-Election Audits: Restoring Trust in Elections 3 (Brennan Center for Justice, 2007) (available at http://www.brennancenter.org/dynamic/subpages/download_file_50227.pdf).

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April 16, 2007

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Re: April 2, 2007 Draft Criteria for Voter-Verified Paper Records

Dear Ms. Kelly:

The Department of the Public Advocate has conducted a review of the State's revised draft criteria for the operation of a voting system including a voter-verified paper record (VVPR) dated April 2, 2007 (the "Draft Criteria"). Pursuant to the invitation for comments on the Draft Criteria, we now provide this response.

While the Draft Criteria present some progress toward a functional and accurate voting system, we believe revisions are needed to meet legal requirements and ensure best practices sufficient to give the voting public justifiable confidence in the electoral system.

The Draft Criteria do not appear to be rigorous enough to ascertain adequately whether a given Direct-Recording Electronic (DRE) voting system with VVPR is fit for use in New Jersey. Many of the standards require greater detail, and only some contemplate further refinements (while leaving unstated what those refinements will be). More importantly, the Draft Criteria do not detail the protocols that will be used to conduct volume testing of the printer component of the voting system, or the system as a whole.

The Department recommends some revisions to the VVPR criteria, more fully described below. We begin with some general comments about the process of establishing standards for New Jersey voting machines. We then turn to recommended improvements in the printer certification criteria (including mean-time-between-failure testing and volume testing). Finally, we review some of the other questions and suggestions we have about the balance of the Draft Criteria and suggest revisions.

I. GENERAL COMMENTS

Initially, it appears that LPS contemplates issuing the Draft Criteria as only a guidance or policy document, and not as binding, codified regulations (with the procedural protections attendant to formal rulemaking). The comment on page 12 of the Draft Criteria indicates that LPS may in its sole discretion, "revise, amend, or otherwise modify any of the criteria," and there is no indication whether LPS contemplates providing notice of such changes or an opportunity for public comment.

We believe, in accordance with the standards set forth in *Metromedia, Inc. v. Director, Div. of Taxation*, 97 N.J. 313 (1984), and its progeny, that any VVPR criteria can only be implemented by formal rulemaking. Such an approach will promote transparency and clarity among stakeholders in the voting system, most especially voters. Potential sellers of voting technology would understand that changes to the criteria would need to be based on reasoned judgment guided by law.

These comments should not be construed as an expression of our position on whether New Jersey's current voting machines are lawfully in use. We also maintain our position that since a VVPRS printer will extend the time each voter needs to cast his or her ballot, its addition constitutes an "impairment to efficiency."¹ For this reason, it is our view that its addition will require a complete re-examination of the entire voting system by the statutory voting machine committee,² using detailed and judicially reviewable standards. We look forward to seeing and commenting on those standards when they are proposed.

¹ See United States Elections Assistance Cmsn., 2005 Voluntary Voting System Guidelines, Vol. I at 47 (available at [http://www.eac.gov/VVSG%20Volume I.pdf](http://www.eac.gov/VVSG%20Volume%20I.pdf)) (hereinafter "2005 VVSG") (defining "efficiency" as the "time taken to vote" and an adverse impact on "efficiency" as "slow[s] down the process").

² N.J. Stat. Ann. § 19:48-2.

Further, we note that nothing in the Draft Criteria sets forth the standards that would apply to a precinct-count optical scan (PCOS) system. While the Draft Criteria, with our suggested amendments, could be adapted to a PCOS system without a great deal of difficulty, this entire category of voting technology is omitted from the Draft Criteria, which could suggest that the State is foreclosing the adoption of this alternative type of voting system. Since this should not be the case, we recommend that the State (1) affirmatively state that PCOS systems are not precluded from certification in New Jersey; and (2) set forth the deadline by which it intends to issue standards for testing PCOS systems and other optical-scan systems already in use throughout the State for counting absentee ballots.

Finally, we understand that the State will be proposing regulations and/or guidance regarding testing of the voting system as a whole at a later date. We expect to provide comments on those draft regulations and/or guidance when it is published.

II. COMMENTS ON PROPOSED CERTIFICATION STANDARDS

Section VI(A) of the Draft Criteria requires manufacturers of Voter-Verified Paper Record Systems (VVPRS) to submit all reports issued by an Independent Testing Authority (ITA) "concerning" the VVPRS. We interpret this to include all ITA reports, whether they are reports of passes, failures, or otherwise, and if this interpretation is incorrect, we urge that it be clarified. Moreover, it should also state that required ITA report(s) are those that examined the precise unit being offered for use in the State, along with all software or firmware actually in use on the unit. The State should not accept a test from earlier, later, different, or incomplete versions of the DRE with VVPR. Furthermore, the regulations should specify that the State will only accept reports by an ITA that was duly accredited at the time of its report, which indicates full compliance with the then-applicable federal standards. Next, a manufacturer offering a machine for testing should also provide to the State all reports for that voting system which were delivered to the National Association of State Elections Directors (NASD) Technical Subcommittee or to the Director of the Elections Assistance Commission (EAC) Testing and Certification Program. Finally, the regulations should regard all ITA results and any documents submitted to NASD or EAC as government records subject to disclosure under the Open Public Records Act (OPRA).

Section VI(B) should provide for enhanced transparency by stating that the Examination Committee and any technical advisors must publish the minimum review standards before the examination commences. This will prevent the possibility of molding the standards to fit the evidence, rather than testing to a

defined standard. Furthermore, to the extent practicable, the examination should be public. The examiners should publish all results of their testing, and the backup documentation generated in the testing should be designated as a government record disclosable under OPRA.

Mean Time Between Failure Criteria

Section VI(G) requires documentation of the Mean Time Between Failure (MTBF), but does not specify what MTBF threshold would be permissible. The MTBF published in the EAC's 2005 Voluntary Voting System Guidelines (VVSG) is 1 per 163 hours³, which we view as inadequate. If this were the standard, it would mean there would be 969 incidents of voting machine failure in New Jersey at some point during a 14-hour election day. Of course, it is unreasonable to think that voting machine failures would be randomly distributed among all 11,278 voting machines in use in the state. Thus, it is likely that those failure would include many machines that fail multiple times, thereby causing an unusual hardship on the voters assigned to vote on that particular machine.

To put it in even more stark relief, under the above-cited federal standard, a voting machine would, on average, fail somewhere in the State every 52 seconds at some point during Election Day. This would be an unacceptable failure rate.

This standard already has been recognized as inadequate by the drafters of the *2007 Draft VVSG Recommendations to the EAC* (the "2007 VVSG Draft").⁴ Prompted by various advocates, the present working draft prepared by the Technical Guidelines Development Committee of the National Institute on Standards and Technology has rejected an hourly measure of failures, in favor of one based on the number of voters.

The 2007 VVSG Draft recommends that certification be denied upon a failure rate higher than 1-in-10,000 for each voting device (meaning a component of the voting system). The relevant parts of the 2007 VVSG Draft provide as follows:

[definition of] failure: (Voting system reliability) Event that results in (a) loss of one or more functions, (b) degradation of performance such that the device is unable to perform its intended function for longer than 10 seconds, (c) automatic reset, restart or reboot of the voting

³ See 2005 VVSG, Vol. I at 85.

⁴ <http://vote.nist.gov/meeting-03222007/VVSG-SETdraft-20070306v5.pdf> (March 2007 Draft).

system, operating system or application software, (d) a requirement for an unanticipated intervention by a person in the role of poll worker or technician before the test can continue, or (e) error messages and/or audit log entries indicating that a failure has occurred. (Source: Expanded from [2] I.3.4.3.)

Note: In plain language, failures are equipment breakdowns, including software crashes, such that continued use without service or replacement is worrisome to impossible. Normal, routine occurrences like running out of paper are not considered failures.

[definition of] failure rate: Ratio of the number of failures that occur to the number of voters served.

[definition of] voting device: Device that is part of the voting system. Note: Components and materials that are vital to the function of the voting device within the voting system, such as smart cards and ballot printers, are considered parts of the device for the purpose of certification testing.

[Comment on core requirements:] The benchmark for reliability has been changed from Mean Time Between Failure to a failure rate based on volume. Note also revision of benchmark based on data collected.

11.3.1-B Failure rate benchmark

All devices shall achieve a failure rate of no more than 10^{-4} (1 / 10 000).

Applies to: Voting device

Test Reference: Volume V Section 5.3.2⁵

We believe that the standard of one failure per 10,000 voters for each voting device is an appropriate standard, and that any voting machine containing a component that fails to meet or exceed this standard, should be prohibited in New Jersey.

⁵ *Id.* at 1:2-4, 1:2-8, 1-3, 11:11.

Volume Testing Criteria

Section VI(C) promises "volume testing," but the Draft Criteria does not provide any detail as to what this volume testing will include.

We have reviewed California's 2006 "Volume Reliability Testing Protocol"⁶ as a possible framework for volume testing. While the tests we propose below are somewhat more intensive than those required by California, we think that its basic framework with our improvements makes sense given technological developments that have occurred since then. We would therefore propose that New Jersey's volume testing include the following protocols:

1. For volume testing to be meaningful, it must be performed on a sufficiently large test pool of machines, perhaps 50 machines or more. The machines should be randomly selected and the tests performed in a central location or at voting machine storage areas in selected counties.
2. The test should employ poll workers selected at random from the existing pool of poll workers in order to best replicate actual conditions on election day.
3. The test should also employ voters of average skill and ability. In addition to a public call for participants, the test might also use public employees not regularly involved in election administration.
4. The volume test should use the exact machines being proposed for use, i.e., the voting machine, audio kit, and VVPR system, with current versions of the software and firmware, and a verifiable written record of which machines were used should be maintained.
5. The volume testing should involve two days of voting to replicate the ballot as it appears in a general election and a primary election. On each of those days, each machine should receive not less than 310 votes.⁷ If 50 machines were used, the testers could cast 310 ballots per day on each machine, for a total of approximately 31,000 votes.

⁶ http://www.ss.ca.gov/elections/voting_systems/volume_test_protocol_final.pdf (Jan. 31, 2006).

⁷ The machine should be tested to its most intensive use, i.e., a presidential election. In the 2004 presidential election, 3,638,153 voters cast ballots in New Jersey. Roughly 96 percent of ballots are cast in machines. With a total of 11,278 voting machines in use in the State, this is an average of 310 voters per machine.

6. In addition, the volume testing should include a full review of the voting machine's VVPR records paper records against the totals shown on the voting machine. The machine should be deemed to have failed if the vote totals from the each machine do not match the count from that machine's VVPR records. The VVPR records should be counted both by hand and by the barcode contemplated in Section IV(A)(2) of the Draft Criteria, if one is used, and both should match in order to pass this test.

7. Applying the failure rate of 1 per 10,000 (and assuming approximately 31,000 votes are received in the volume test), the voting system would pass only if a component of the voting system "failed" three or fewer times and/or a machine did not miscount any votes. Multiple failures by any one machine would each be considered separate failures.

Of course, the specifics of the test can be changed or clarified as circumstances require. Satisfactory volume testing, however, must (1) have a meaningful number of machines and voters; (2) approximate the busiest election; (3) involve people of reasonable skill and ability; (4) use the failure definition from the 2007 VVSGs; and (5) require a complete match between the paper records and the machine records. The Draft Criteria do not describe any of those standards.

The Draft Criteria also do not include a recommendation of meaningful usability and accessibility testing of the proposed voting system. I am advised that researchers from the National Institute of Standards and Technology have piloted a protocol for such tests, and when this protocol is available, the entire voting system (including the VVPRS) should be tested under these standards before being deployed for use.

Section VI(D) is unclear as to whether a voting system must list all software or firmware in use within the system (with version number), or whether all software executables or the software source code itself must be available to the Attorney General for inspection. Once we receive an explanation of this point, we will offer our comments.

Section VI(E), regarding the escrowing of source code, is inadequate. Instead of escrow, the regulations should require the complete source code that operates on all components of the voting system, as a condition of certification.⁸ If the State lacks a copy of the source code that it can test, there is simply no way to verify that what was offered for certification is in fact in use on the machines, nor is there any

⁸ We note this is the standard in California. See California "Voting System Requirements" at ¶ 5 (Oct. 5, 2005) (available at http://www.ss.ca.gov/elections/voting_systems/requirements.pdf).

way to determine whether it is free of programming defects that impair security. The technical advisors to the voting machine examination committee could examine the source code and conduct a security evaluation of the system and the source code and if they are not provided with the source code, the Attorney General should be authorized to immediately obtain and security-test the source code.

III. OTHER ASPECTS OF THE DRAFT CRITERIA

We also have the following comments and observations on other aspects of the Draft Criteria.

Section I, Definition of Direct recording electronic voting machine (DRE).

The definition of DRE mentions nothing about redundancy for the recording of voting data and ballot images, stating instead that such information will be stored in "internal or external memory components." The definition should describe a DRE as being capable of recording such information separately in at least one internal and one external memory component. Moreover, the description of the DRE as a machine that produces tabulation information "stored in a removable memory component" is also deficient. A satisfactory DRE should be defined as one capable of storing tabulation information in both removable and fixed memory and have the capacity to print the information at the closing of the polls, as with the current Sequoia Advantages. Finally, the regulations should require poll workers to print out the tabulation information immediately after the close of the polls. Likewise, as a defense to software errors or malicious attacks on tally servers, or the inadvertent loss of voting machine printouts turned over to municipal and county clerks by the district board of elections, the senior member of the district board of elections should be required to retain personally one copy of the machine(s)' printed tabulation totals for checking against the tally server totals in addition to their statutory obligation to print multiple copies of the tabulation information and make the results viewable by people present during counting.

Section I, Definition of Voter-Verified Paper Record System VVPRS.

This definition should specify what else it includes beyond the printer and storage unit. It should also stipulate that the VVPRS includes the DRE itself, rather than just the printer that is used "in conjunction with" the DRE. This is repeated in Section II(A), where a "DRE with VVPR capability" consists of 4 components, none of which is the DRE itself.

Section II(B)(2) and IV(C)(5).

These sections allow the voter an opportunity to accept or reject the first or second VVPR that is printed. We recommend that the standards specify how accepted and non-accepted ballots must be distinguishable. For example, a non-accepted ballot could be marked "SPOILED" or an accepted one could be marked "ACCEPTED," or both.

Section II(B)(3)(b).

So long as New Jersey uses voting authority slips that identify a voter, and given that the majority of election districts use a single machine, we do not believe that any continuous-spool method can adequately protect a voter's identity or privacy. Even if these specific privacy issues could be addressed, a continuous-spool method can still compromise voter privacy where a poll worker observes the order in which individuals vote on a given machine. We recommend you delete this section (along with the reel-to-reel reference in Section VIII(F)), and clearly establish that continuous-spool methods are impermissible.

Section III(A)(1).

The description of a qualifying printer would appear to allow thermal or plain paper (in that it refers to "ink, toner, ribbon or like"). It is unclear whether there are benefits to having a more complex system that prints on regular, more durable paper, versus simpler printer technology with the relatively poorer quality of thermal paper. We have no evidence before us as to whether this issue has been adequately studied and whether giving a manufacturer an alternative of one paper over the other is the best practice. We would like to explore this point further.

Section III(A)(1) and (a).

The Draft Criteria are not clear on what machine capacity will be required before paper, ink and any other components must be replaced. It is unclear whether the machine must be capable of printing 750 VVPATs (including rejected VVPATs) before any replacement is required. The resulting capacity should be specified and it should exceed 150 percent of the average machine turnout in a presidential election in order to minimize paper changes during voting.

Section III(A)(2).

The threshold number for a low-paper indication should be specified, and should be high enough to accommodate a quick change of paper during the busiest voting hours. Perhaps 25-50 is an appropriate number.

Section III(A)(3).

The regulations should specify which persons possess the legal authority and ability to unlock seals, and the regulations should require a log of each such unlocking and re-locking.

Section III(B)(1).

The regulations should cross-reference the alternate verification requirements for voters using an audio kit set forth in the second paragraph bearing Section number II(B)(3), i.e., the one on page 3.⁹

Section III(C)(2).

The resulting regulations should direct custodians to store paper records in accordance with manufacturer specifications.

Section III(D).

The regulations should prescribe chain of custody information, and should include an administrative complaint procedure whereby individual voters and candidates may obtain remedies against election officials who fail to follow these regulations. These regulations should be adopted together with the VVPR regulations, not separately.

Section IV(B).

Any storage of electronic ballot images should be redundant, duplicated in both internal and external memory.

Section IV(C).

There is nothing in this section or the Draft Criteria that addresses poll worker training, beyond a requirement to distribute training materials to county

⁹ The Draft Criteria has two sections labeled II(B)(3).

boards. As of January 1, 2006, State law requires poll worker training information to be posted on the internet, pursuant to N.J. Stat. Ann. § 19:50-2(b). That information is not posted, and should be, as required by law. The regulations also should make provision for universal retraining of all poll workers on VVPR functionality, before deploying such a system.

Section IV(C)(1)(a).

We recommend that the request of material by LPS and the providing of materials by the vendor be transparent. County election officials, voter advocacy groups, election participants, experts on plain language and others should be able to review and comment on a transparent process of creating the requisite materials.

Section IV(C)(1)(c).

The number of demonstrations will vary by county, but the number of demonstrations should be stipulated in the regulations. Moreover, the regulations should make clear that, pursuant to N.J. Stat. Ann. § 19:50-2(a), these demonstrations need to continue for a period of 4 years.

Section IV(C)(2).

The standards should require that the VVPAT record be printed for all voters, including voters using the audio interface. The standards should require that all voters be able to inspect and approve or reject the VVPAT record, even if they are using the audio interface. We are advised that in one system on the market, if a voter uses the audio interface, the system reads back the summary and asks the voter to confirm it. If the voter proceeds, it then prints the VVPAT record and immediately scrolls it into the ballot box without giving the voter a chance to look at it (on the assumption that the voter is blind and can't see it). This automatic-acceptance functionality should be prohibited.

Section IV(C)(4).

We agree with this sentiment, but we understand IV(C)(3) to require *all* VVPRs in districts where an additional language is required by Federal or State law to contain such additional language(s). If IV(C)(3) is amended to clarify this point, the requirement of IV(C)(4) seems superfluous.

Section IV(C)(5)(a)(2).

It is unclear whether this warning is going to be printed on the second VVPAT, on the machine, or the third VVPAT. If it appears on the third VVPAT, it is not an effective warning, it is just informational.

Section V(A).

The standard should state that the printer may not contain any component that would allow for external communication. This would clearly prohibit the use of a printer that has an external-communication feature that can be turned off.

Section V(C).

The regulations should stipulate which election officials are authorized to access the paper path and at what times.

Section V(F).

The regulations should stipulate the obligation of poll workers to both keep a log of such "detections and notifications," and the obligation of poll workers to communicate this information to the Board of Elections and/or voting machine warehouse.

Section V(I).

It is unclear whether a verbal report by a voter that he or she saw a non-match would be conclusive evidence that the DRE must be withdrawn from service. If this would not be conclusive evidence, it is unclear what evidence would suffice. The regulations should specify what conditions must be satisfied to restore the DRE to service, such as a signed test log by a technician.

Section V(J).

This information, being "information helpful for voters," should also be posted on the Division of Elections website pursuant to N.J. Stat. Ann. § 19:12-10, and communicated to district boards of election.

Section V(M).

As with Section V(F), the regulations should require district boards to communicate a machine failure to the Board of Elections and/or voting machine warehouse. District boards' awareness of a failure, without a regulatory mandate that they notify higher-level authorities, will do little to remedy or document problems.

Section VIII(A).

We agree with this sentiment, but rather than the term "malfunctioned or became inoperable," we urge that it substitute the definition of "failure" as defined in the 2007 draft VVSG.

Section VIII(B).

We are gratified to see that LPS recognizes the need for an audit requirement and look forward to seeing a proposal for implementing it, and for the opportunity for public comment on such a requirement. Rather than "procedures," however, these requirements also should be adopted as regulations or by statute.

Section VIII(C).

This section is unclear as written, in that it refers to "votes cast on the paper records." This phrase could be taken to refer to the election results tape. The phrase should be rewritten to stipulate that it refers to the individual accepted VVPR of each voter.

Section VIII(D).

This provision refers to a "machine cartridge." While some voting systems in fact use a cartridge, we think this definition should be more generic, e.g., a device removable from the machine that stores ballot images in non-volatile memory. Moreover, in our view, the production of the ballot image audit log should be a part of every recount, not just those where the removable device fails. At a minimum, the regulations should specify that such records may be produced in the discretion of the judge presiding over the recount and/or contest. The regulation should further stipulate to whom the device will be produced, e.g., litigants, Attorney General representatives, etc.

Donna Kelly
Assistant Attorney General
April 16, 2007
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For the reasons enumerated above, we cannot support the Draft Criteria as currently written.

Thank you for the opportunity to comment on these matters. We are at your disposal to further discuss the important issues they raise.

Very truly yours,

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By: 

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Written Testimony of Harlan Yu and J. Alex Halderman

Graduate Student Researchers

Department of Computer Science and the Center for Information Technology Policy
Princeton University

New Jersey State Voting Machine Examination Committee
Public Hearing on Voter Verified Paper Record Systems
for the Sequoia and Avante Electronic Voting Systems

July 27, 2007

Harlan Yu and J. Alex Halderman, Ph.D. candidates in the Princeton University Department of Computer Science, have conducted extensive research on the security and reliability of electronic voting systems. Yu has studied applications of cryptography to the voting process. Halderman has published a security analysis of the Diebold AccuVote-TS electronic voting system. Both recently completed an analysis of electronic voting systems used in the State of California, as part of the "Top-to-Bottom" review commissioned by the California Secretary of State [1]. We thank the New Jersey Voting Machine Examination Committee for the opportunity to submit written testimony in this hearing.

The recently published New Jersey Institute of Technology (NJIT) reports [6] on electronic voting paper records appear to have applied the Criteria [7] set forth by the Attorney General's Office in a scientifically appropriate manner. However, the NJIT study does not constitute a comprehensive security review of the paper record systems on the three voting systems, and it is not sufficient to determine whether the machines comply with the Criteria. The procedures used in the study only tested the voting machines for natural failures under favorable conditions. But, how these machines perform under adverse conditions—conditions caused by an active attacker trying to induce unexpected machine failure—is the critical security question.

In particular,

- Is it possible for an attacker to install malicious software on the voting machine?
- If so, how difficult would it be for an attacker to do so, and how much damage could be done?
- Is it possible for malicious software to alter the paper record by, say, discreetly adding extra ballots or cancelling verified ballots after the voter leaves?
- Even with the paper record system, is it possible for malicious software to alter the election results undetectably?
- Is it possible for malicious software to cause a denial-of-service attack that would disrupt an election?
- Is it possible for malicious software to compromise the ballot privacy of individual voters?
- What digital signature scheme is used by the machines to ensure the authenticity of votes, and is it cryptographically secure?
- Are serial numbers contained in ballot barcodes and other records securely random, or can they violate voter privacy by exposing the order of voters?¹

Unfortunately, these questions have been left unanswered by the NJIT study and other published literature of which we are aware. Until they are addressed, it is impossible to say whether these machines can reliably deliver an accurate count.

¹A study of another voting system found that ballot serial numbers that appeared to be random were in fact generated using an insecure method that would allow an attacker to discover the order in which the ballots were cast [5].

If security vulnerabilities exist in the voting systems, the NJIT methodology is incapable of uncovering many of them. For example, the software could potentially include malicious code that is triggered only when a user gives the machine a "secret knock." This "secret knock" could be a ballot that has a special write-in candidate, a ballot with a particular set of candidate selections, or a particular sequence of button presses on the machine interface. If the attacker votes on the machine on election day and gives the "secret knock," the machine could begin to swap votes to the attacker's favored candidate. Depending on the design of the paper record system, the malicious code could even manipulate the paper record to match its electronic count.

The NJIT methodology would not detect these conditional attacks, such as the "secret knock" or "time-based" attacks that are triggered only on a particular date and time. Conditional attacks, if they exist in the voting machines, could affect voter privacy and the integrity and reliability of elections.

Moreover, if an attacker wants to throw an election, he would attempt to use the machine in an unexpected way. For example, he could attempt to take over the machine from the exposed interface by exploiting common computer programming errors such as buffer overflow or format string vulnerabilities. He could attempt to gain additional privileges, such as access to election supervisor machine functionality. He could attempt to subvert security seals to try to replace the machine's physical memory devices or upgrade the firmware.

If any of these attacks are possible, the machines' compliance with the Criteria would be affected, but the NJIT study is unable to rule out these risks. The study was restricted to simple functionality tests and volume tests that do not take adversarial situations into account. It was unable to address the underlying question—whether the machines are reliable, accurate, and privacy-preserving—mainly because the NJIT team lacked the tools or the mandate to study many of the most dangerous potential attack vectors.

The only way to reasonably address these risks is to conduct a comprehensive source code security review, accompanied by "red team" testing that simulates the role of a malicious attacker. A source code examination would provide valuable insight into potential implementation and design flaws that might need to be fixed. "Red team" testing would reveal potential failure modes of the machines and expose what other problems might need fixing. Any future upgrades to add or fix paper record systems on existing voting machinery would necessarily require significant changes to the machines' source code. These changes might create new security and reliability problems, so new versions of the software would also need to undergo the same scrutiny. Without this type of comprehensive review, it would be difficult for anyone to claim that these voting systems comply with the Criteria.

Where reviews like these have been performed in other electronic voting contexts, they have often found significant security failures. Studies of the Diebold AccuVote-OS optical scan machine, the Diebold AccuVote-TS and -TSX DREs, and the ES&S iVotronic have revealed ways that an attacker could alter the vote count [2][3][4][5][8], identify voters with the contents of their ballots [5], or even spread a voting machine virus from machine to machine [2].

The California Secretary of State recently conducted such a review of several electronic voting systems used in that state [1]. We assisted in the preparation of this "Top-to-Bottom" review, which included source code analysis and "red team" testing of voting systems manufactured by Diebold, Sequoia, and Hart InterCivic. The Sequoia AVC Edge, which is used in New Jersey, was examined in the California review. We expect the California Secretary of State to make the results of the review public as early as today. We anticipate that these findings will be relevant to New Jersey's decisions concerning its own electronic voting systems, and we recommend that the Committee postpone any decision until after it has had an opportunity to review the California reports.

We applaud the Attorney General for requiring voter-verifiable paper records for all electronic voting machines used in New Jersey. A properly implemented voter-verifiable paper record is a key component of any voting system. The question now is whether the paper record systems, and the machines as a whole, are properly implemented and secure for use.

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Written Testimony of Kevin Wayne

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Introduction. The recently published New Jersey Institute of Technology (NJIT) reports [1, 2, 3, 4] assess the accuracy and reliability of three voter-verified paper record systems (Sequoia AVC Advantage, Avante Vote-Trakker, Sequoia AVC Edge). For each of the three systems, NJIT performed two volume testing experiments. In the first test, several mock voters were recruited to simulate the behavior of a real election, casting 414-594 ballots in a 14-hour period. In the second test, a computer test mode of the machine (when available) was used to simulate 1,200 ballots.

The main question is how accurate and reliable are these systems. The NIST draft standard [5] recommends a failure rate of at most 1 in 10,000 ballots. The VVSG standard [6] recommends a mean time between failure (MTBF) of 163 hours. This raises several natural questions.

- Do the machines tested satisfy the NIST or VVSG standards? How much testing must be done to find out with a given level of confidence?
- What is the variability among machines within a system due to manufacturing imperfections? How many machines of each type should be tested?
- What is the variability of a single machine over time due to factors such as overheating and mechanical wear?

We conclude that the NJIT testing procedure was insufficient to determine the answers to any of these basic questions. Until they are addressed, it is impossible to conclude that these machines will experience mechanical failures at a rate conforming to the NIST or VVSG standards.

We emphasize that the NJIT testing assesses only natural mechanics failures (e.g. paper jam, software crash, electrical short-circuit), under favorable operating conditions. It does not attempt to address how the machine would perform under adverse conditions caused by an active attacker trying to induce unexpected machine failures.

Ballot-based criteria. We propose a simple test to determine whether a machine meets the NIST 1-in-10,000 standard. To simplify the analysis, we begin by assuming that all trials are independent and identically distributed. That is, the chance that a machine fails to handle a particular ballot does not depend on the machine or on the sequence of ballots processed before it.

We seek to test n ballots so that we have, say, a 95% likelihood, of being able to correctly identify whether a machine fails more frequently than 1 time in 10,000. The *binomial test* is a classic statistical test that applies to this model. To determine whether a machine meets the NIST standard (of less than 1 failure in 10,000 ballots), simulate $n = 100,000$ ballots. If there are 7 or more failures, reject the hypothesis (at the 95% confidence level) that the machine has a failure rate meeting the NIST standard. Note that this test will reject some machines that conform to the NIST standard. At the expense of more testing, we can do a better job of discriminating between conforming and non-conforming machines: if we simulate $n = 1$ million ballots, we should reject machines with 85 or more failures. The main lesson is that to certify a very rare thing from happening, we must perform a large number of tests.

Time-based criteria. Appendix C of the VVSG report [6] proposes a test to determine whether a machine meets their MTBF standard. They assume that the time between failures obeys an exponential distribution. Using this model, they derive a test for whether a machine has (at least a 90% chance of having) a MTBF of at most 45 hours.¹ They propose using Wald's Sequential Probability Ratio Test. This test is *adaptive*, which enables the experimenter to terminate the test as soon as a statistically valid decision can be reached. In particular, if the machine runs without a failure for 169 hours, then it passes the test; if the machine fails more than once in this period, then it fails the test; if the machine fails exactly once in this period, additional testing is required according to the table on page C-6.

Refinements. A more refined model would account for variational noise due to differences among machines due to manufacturing imperfections, or within a particular machine over time due to mechanical wear. Without knowing the variability among machines or of an individual machine over time, it is impossible to accurately say how many machines must be tested. The state of California tests 100 machines. We recommend testing at least this many machines to gain confidence in the assumptions made in each of the models. In any case, accounting for any of these refinements requires *more* testing, not less.

NJIT test. To analyze the results of the NJIT test, we aggregate the two volume tests together. For the Sequoia AVC Advantage, there was one mechanical failure (a paper jam) in 1,794 ballots (594 from mock voters, plus 1,200 from computer test mode); for the other two, there were no mechanical failures. What results can we conclude?

¹The details in the Appendix C refer to a MTBF of 45 hours, whereas Section 4.7.3 demands a MTBF of 163 hours.

Intuitively, for the Sequoia AVC Advantage machine, 1 failure in 1,794 ballots falls well short of the 1 in 10,000 NIST standard. In fact, 83.5% of the time a machine that achieves a 1 in 10,000 (or better) will have 0 errors in 1,794 ballots. Moreover, we can reject (at the 95% confidence level) the hypothesis that the machine fails less than 1 time in 10,000.

Obviously, 0 failures in 1,794 ballots is best possible result for a system, but what can we conclude statistically when this happens? Unfortunately, not much. For example, a machine that fails at the rate of 2 times in 10,000 (twice the NIST standard) would have no failures in 1,794 ballots 70% of the time. In other words, if no mechanical failures are observed, the NJIT test does not have sufficient *power* to identify whether a machine that meets the NIST standard.

Similarly, the NJIT test involved an insufficient amount of data to pass the VVSG standard because at least 169 hours of testing are required (even to pass the 45-hour test as opposed to the recommended 163-hour test), whereas NJIT only performed about 30 hours of testing per machine.

Conclusion. The NJIT tests were insufficient to determine whether the systems satisfy the NIST 1-in-10,000 standard for reliability. They were also insufficient to determine whether the systems satisfy the VVSG 163-hour standard. We recommend testing the machines using an adaptive test, such as the Wald's Sequential Probability Ratio Test used in [6].

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Testimony of Howard Stanislevic Regarding New Jersey's VVPRSA Testing

August 23, 2007

My name is Howard Stanislevic and I am a resident of Queens, NY. I have been a computer network engineer for over 25 years and since the passage of the Help America Vote Act (HAVA), I have devoted nearly all of my free time to election integrity advocacy. I have given particular attention to the electronic vote counting issue and ways to ensure the accuracy of election results. The New Jersey Department of the Public Advocate has requested that I provide my opinion of the Voter-verified Paper Record System Assessment (VVPRSA) conducted by the New Jersey Institute of Technology (NJIT) in July 2007 at the request of the Office of the Attorney General.

Over the past several years, I and other engineers, scientists, and advocates have studied the reliability of direct recording electronic (DRE) voting machines. This includes the benchmarks required by the federal Voting System Standards/Guidelines (VSS/G 2002) and Voluntary Voting System Guidelines (VVSG 2005). We have suggested improvements to the Institute of Electrical and Electronics Engineers (IEEE) voting system standards committee known as P1583,^{1,2} the Election Assistance Commission's Technical Guidelines Development Committee (TGDC),^{1,3} and the National Institute of Standards and Technology (NIST) who chairs the TGDC.⁴

After years of perseverance some significant improvements have been drafted for future voting systems,⁵ but by any reasonable measure, the reliability of today's systems remains quite low.

Data from the New York City Board of Elections, the State of California, and counties in Maryland show that thousands of voting machines, which have been in service for over four decades, are more reliable than many DREs.⁶ Therefore, we must look at New Jersey's VVPRSA in the context of reliability testing – not just functional testing.

The Center for Correct, Usable, Reliable, Auditable, and Transparent Elections (ACCURATE) is a multi-institution voting research center funded by the National Science Foundation (NSF) under their CyberTrust Program. The goals of the center include (a) to research ways in which technology can be used to improve voting systems and the voting process; and (b) to develop the science that will help inform the election community and the public about the tradeoffs among various voting technologies and procedures.

According to comments on the VVSG 2005 by the ACCURATE center, about voter-verified paper audit trails (VVPATs), one of the "requirement[s] related to the reliability of printers to be used is the system-wide requirement that there be 163 hours mean time [between] failures

¹ Stanley A. Klein, Public Comment on voting machine reliability, http://www.vote.nist.gov/ecposstatements/comment-memo-5_3_2.pdf

² Alfred DuPlessis, IEEE Reliability Draft, <http://grouper.ieee.org/groups/scc38/1583/emailtg2/doc00000.doc>

³ Rebecca Mercuri, Public Comment to the TGDC, http://guidelines.kennesaw.edu/vvsg/section_display.asp?type=section&id=1354

⁴ Howard Stanislevic, The Long Road to a Reliable Voting System, Letter to NIST, http://votetrustusa.org/index.php?option=com_content&task=view&id=1151&Itemid=26

⁵ VVSG 2007 Draft, Vol 3, May 2007, Pg. 16-332, <http://vote.nist.gov/meeting-05212007/VVSG-Draft-05242007.pdf>

⁶ Stanislevic, DRE Reliability: Failure by Design?, http://www.votetrustusa.org/pdfs/DRE_Reliability.pdf

[MTBF], which is inadequate.”⁷ Since this requirement is deficient, and is substantially unchanged from the VSS/G 2002 and the prior 1990 version, and will not be improved until the next iteration of the VVSG (2007), which will not go into effect until at least 2009, it is incumbent upon the States to ensure that DREs with VVPATs are as reliable as those without VVPATs. (The VVPAT is the only means by which the DRE vote tallies can be independently audited but its reliability is still dependent on that of the printer and the DRE hardware and software.)

Many observers and participants note that the 163-hour requirement is equivalent to a failure rate of 9.2% in any 15-hour period e.g., an election day.⁶ The addition of printers will have an unknown effect on this already unacceptable failure rate, but the failure rates are not likely to improve since the more complex a system becomes, the more likely it is to fail.

Whether software or hardware is the primary reason for poor DRE reliability is an open research question. Because there is evidence to support both sides of this debate, neither hardware nor software should be taken for granted or trusted.

The tests performed by NJIT did not persist long enough to accumulate sufficient machine-hours to know if even the inadequate federal reliability standards were met. The only NJIT test that examined normal voting operations appears to be only 14 hours in duration per system. NJIT also performed an additional test of 1,200 votes per system using program scripts, which took between 6 and 21 hours each to complete. However, this 1,200-vote test is not a meaningful one, as it does not test the interface between the individual voter and the machine, which is the only relevant consideration on Election Day; instead, it only examines a computer being tested by a computer.

In order to meet even the current, albeit inadequate, federal standard of 1 failure in 163 machine-hours, there would have to be a minimum of 163 hours of testing. If an election day scenario of 14 hours were to be used, then the volume tests should be done using at least 12 machines (time for opening and closing the polls should be included as well so 11 machines may suffice). If this testing showed more than one failure (including but not limited to paper jams, machines ‘freezing’ for more than 10 seconds, or the loss of paper ballots), the system should be regarded as failing to meet the federal standards. In any event, such a test, like all volume tests, should be conducted using normal voting operations, with actual people casting the test votes, instead of computerized program scripts.

Based on the foregoing, the amount of testing performed by NJIT (even if one credited the 1,200-vote test), fell far short of the minimum amount of testing required to determine whether the system is “reliable”, either under the federal standards, or much less under a scientific assessment of whether the system is “reliable.”

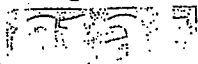
In contrast to NJIT’s testing protocol, I note that that the State of California conducts volume tests 100 DREs at a time, for approximately 600 machine-hours. California’s amount of volume testing, which used ballots actually cast by human testers – not program scripts – is an example of what a scientifically appropriate testing protocol would look like. Moreover, separate from the amount of testing performed in California, failures of 1 in 10,000 ballots or better are being

⁷ A Center for Correct, Usable, Reliable, Auditable and Transparent Elections (ACCURATE), Public Comment on the 2005 VVSG, http://accurate-voting.org/accurate/docs/2005_vvsg_comment.pdf

considered for future federal voting system standards.⁸ The NJIT testing, needless to say, is insufficient to determine whether New Jersey's machines meet that more rigorous standard.

New Jersey's testing protocol fell short of what would be needed for a "thorough test" to determine voting system reliability. The tests performed in New Jersey were not adequate to uncover serious reliability problems with DRE hardware, software, or printers. I hope the State will consider revisiting this in light of the above information.

⁸ John Gideon and Howard Stanislevic, Voting Systems Batch Test Results – Reliability, http://votetrustusa.org/index.php?option=com_content&task=view&id=1054&Itemid=26



**NJIT PROJECT OUTLINE FOR TESTING VOTER VERIFIED PAPER
RECORD SYSTEM**

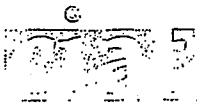
Voting System Vendor Provided Items

Documentation:

- For all Configurations or statements that relate to a function of a VVPRS, the voting system Vendor will provide a specific description of how the system meets the criteria described, and also the specific standards and test procedure(s) used. All use and technical specifications and documentation will be provided electronically and in hard copy.

Equipment:

- Any input and output equipment required for reviewing, exporting barcode reading of records.
- One machine that can be put into specific test states for items like "Ballot not created before voted accepts printed item";, along with a description of how this machine was modified to achieve those test states, and instructions for each test scenario or a qualified person designated to do the same.
- For each system type, three test voting machines each with a VVPRS.
- Equipment for creation of the test ballots and will either program the elections to the specifications of NJIT, or LPS will provide a person to perform the programming.
- Barcode readers and systems to read barcodes.
- Any hardware, software or other items needed for the export.
- Other equipment as required to program a stress test that will be run electronically, and will either program the script or the State will provide a person competent to program the script. The scripted program will be reviewed by NJIT and verified. The test is planned to cover approximately 1200 votes for each system on one machine for one voting period.
- Another system will be used for simulation of a 14 hour voting period with persons voting on ballots that contain National, State County, Municipal elections as well as propositions. These voting scenarios will include some audio and write in ballots.



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- All equipment required to run the 1200 voting simulation, and the 14 hour test. These machines will be certified by the vendor to the exact same type as will be provided to the State, including Source Code levels.

The vendor will provide the spare parts required for any tests (Printer, Ink Cartridges, etc.) where there would be a voting floor replacement, or where a current NJ specification calls for verification of a machine action.

Staff:





- Technical vendor staff must be available in person when the documentation and systems are delivered, and during most of the testing time. Specific dates and availability (e.g. in-person vs. email vs. phone) will be determined.

New Jersey Criteria for Verified Voter Paper Record for Direct Recording Electronic Voting Machines (the "Criteria")

Sections to be Tested:

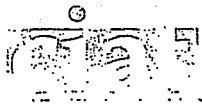
Testing will be done for machine types as requested by the Department of Law and Public Safety.

This following "legend" relates to the New Jersey Criteria for Verified Voter Paper Record for Direct Recording Electronic Voting Machines (the "Criteria"), marked up to indicate the extent of NJIT Testing for each machine:

-  are sections that will be covered in the Voting tests (Simulation of a Full 14 hour day of voting. And/or a volume test run by preprogrammed machine test against the same ballot. Voting test will cover Federal, State, Local, and Question contests. Only the voter simulation will be reviewed in detail. Stress test will simply summarize results.
-  Sections marked in Gray will be covered by inspection against the standards and tests described by the vendor, i.e., reviewed once or twice, but not volume test.
-  Sections marked in Green will be part of both inspection and volume testing.
-  or not marked at all will not be tested.

Project Timeline:

After signature of the contract, time will be required to conduct pre-testing activity, such as establishing the facility, procuring additional necessary equipment, and recruiting staff. This may take two weeks.



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At that point, NJIT will be ready to receive vendor information, documentation and equipment, and have it installed and explained to the team. About one to two weeks will be required to review the documentation, and establish specific test plans. Testing will then begin and take about three weeks. The Report will follow. Lapsed time will be about six to eight weeks. NJIT is aware that the State is seeking to complete this project as soon as possible and NJIT will use its best efforts to accelerate this project schedule.

Report Outline:

The Report will include sections covering:

- Testing (what will be tested and how),
- environment, including security arrangements,
- people involved/credentials,
- results vs. specific criteria, and
- a summary.

Project Charges:

The project charges will be \$37,500 per VVPRS type tested. Payment for this project is based on milestones, not time spent. We will issue three invoices, each for one-third of the total charges, as follows:

- after delivery of machines and documentation
- at the end of testing
- after Report is submitted

4 of 4 DOCUMENTS

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December 15, 2006 Friday
Greensboro Edition

SECTION: TRIAD; Pg. B1

LENGTH: 564 words

HEADLINE: Printers failed on voting machines

BYLINE: MARK BINKER

DATeline: GREENSBORO

BODY:

GREENSBORO - The system meant to produce a paper backup of votes cast on Guilford County's electronic voting machines failed in many cases during the election Nov. 7.

About 9 percent of the printers attached to the county's voting machines had a jam or other problem. In many cases, that problem made the paper record generated unusable for purposes of a state-mandated audit, according to county elections director George Gilbert. The electronic records were not affected and remained intact, he said.

Guilford County voters cast ballots on direct-record, or DRE, systems that have a computer touchscreen. During the past several years, some computer scientists and voting advocates have charged this type of system is susceptible to error and fraud.

So in 2005, state lawmakers required each such machine produce a paper record, typically produced on a small reel-to-reel printer. Those printers were what failed on some systems.

Gilbert, who has long been a critic of paper records, called the problems "predictable." He said the fact no one noticed the problem until post-election audits belied one of the supposed benefits of the paper backup: that it allows voters to verify their choices.

"The vast majority of voters I witnessed never looked at the paper," Gilbert said.

Printer problems were not restricted to Guilford County. Similar problems occurred in Alamance and Mecklenburg counties, according to Gilbert and state officials.

"We have contacted the vendor and we're going to be meeting with them after the first of the year," said Johnnie McLean, the deputy director of the State Board of Elections.

That vendor is ES&S, one of only a handful of companies in the United States that makes the machines and the only company allowed to sell voting equipment in North Carolina.

"Based on the information we have now, we're not in a position to determine if it was something with the way the machine was being used or operated or whether it was an issue with the equipment itself," said Ken Fields, a spokesman for the company.

Guilford County spent \$3.4 million on new voting equipment that was first used in 2006. Federal grants funded \$2.1 million of that amount. Before the 2008 elections, Gilbert said, the county will need to spend at least \$1.4 million for additional equipment, all of that from local tax dollars.

Printers failed on voting machines News & Record (Greensboro, NC) December 15, 2006 Friday

Local voting advocates urged the county to use a different type of system known as optical scan, in which a voter marks their choice on a piece of paper that is counted by a machine. The system is similar to those that score standardized test forms.

"He (Gilbert) knew that there would be problems," said Joyce McCloy, a voting advocate who has been critical of Gilbert on the paper record issue. "He asked his county to buy these machines when he himself testified to the state that there would be problems with the paper backups."

Where McCloy sees an argument for switching to optical scan systems, Gilbert says the problems with paper argue for a move to other backup technology, such as a system that uses sound to independently record a voter's choice.

In cases where the printers did work and their results were compared to those counted electronically, they matched exactly, Gilbert said.

Contact Mark Binker at (919) 832-5549 or mbinker@news-record.com

* About 9 percent of the county's printers attached to direct-record machines had jams or other problems.

LOAD-DATE: December 15, 2006

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Paper Jams Hamper Electronic Voting

Advertisement

By STEPHEN MANNING

The Associated Press

Thursday, December 21, 2006; 10:58 AM

GAITHERSBURG, Md. -- The paper ballots and hanging chads that marred the 2000 presidential election have almost vanished from polling places, replaced by electronic-voting machines that are supposed to eliminate recount chaos.

But now election directors have a new worry: printer jams.

The new machines spool out a small paper receipt of each vote cast to verify the machine correctly recorded the vote and to provide a hard copy during a re-count.

Some states like Maryland have been using paperless systems using touch-screen ATM-like computers that record and tabulate votes. But that has produced its own problems and legislation is likely to be filed in Maryland next year to switch from touch-screen to optical-scanning devices, leaving a paper trail.

In Cuyahoga County, Ohio, a manual count of the paper record during the May primary didn't match the voting results tallied by touch-screen machines.

Machines in some California, Missouri and Mississippi precincts jammed. In Guilford County, N.C., where the paper record would be used in a recount, an audit of a sample of machines showed 9 percent of printers that were supposed to record touch-screen votes either didn't work properly or had paper problems.

"How many votes were lost as a result of that, with the printer chewing it up?" asked George Gilbert, elections director for the county that includes Greensboro, N.C. "If you don't have a complete paper record, you can't use it for a recount."

Paper trails have other shortcomings. Blind voters can't read the paper to verify their votes were correctly recorded. And a paper printout from a touch-screen machine could be used to tell how a person voted, compromising privacy.

Even electronic voting critics who have long sought a paper record or other way to independently verify voting machines say the current paper trail systems are inadequate.

"This isn't what we had in mind when we called for paper," said Johns Hopkins University computer scientist Avi Rubin, who has studied the security of voting machines. "I have yet to see a paper trail system I like."

After the problem-plagued 2000 election, most states fled voting systems that use paper ballots, spending millions of dollars on new electronic voting systems that were paper free. These include the touch-screen devices.

But critics claimed those computerized systems could be easily hacked or malfunction, altering election

results without anyone knowing. They also fretted that some voting machine manufacturers don't provide access to the computer coding of the machines, making it difficult for outsiders to check for glitches.

In response, many states have gone back to adding paper to voting. Printers that spool out a thin paper tape similar to an ATM receipt were added to touch-screen machines. Other states bought optical-scan machines where voters fill out ballots by hand that are then read by a computer.

Twenty-seven states now require the use of paper records, while another 18 don't require them but use them either statewide or in local jurisdictions. More than half of all voters used machines with paper records during the 2006 elections. Five states — Maryland, Delaware, Georgia, Louisiana and South Carolina — use touch screens without paper trails.

In Congress, Sen. Dianne Feinstein, D-Calif., and Rep. Rush Holt, D-N.J., have said they plan bills next year to require paper trails.

Earlier this month, a report by staffers at the National Institute of Standards and Technology recently recommended that states not use voting machines that don't have a paper trail or other means of independent verification.

An advisory panel to the U.S. Election Assistance Commission recently called for states to change to independently verifiable voting devices, but advised against using the thermal printers now widely used by touch screens.

While many printers performed well during this year's elections, some had problems. Cuyahoga County, which includes Cleveland, is considering dropping its touch-screen machines after an audit of paper record samples from the May primary found 10 percent of paper ballots were either smeared, torn, crumpled or blank. In some precincts, the paper record count and the machine count were off by considerable amounts.

Diebold Election Systems, which makes touch-screen machines used by Cuyahoga and many other jurisdictions, said most of the errors were caused by election workers, not the printers. Company spokesman David Bear noted other states, such as Nevada and Utah, had few problems with the Diebold printers.

"The technology has proven itself in thousands of elections," Bear said.

New paperless systems that allow voter verification are under development. Some paper trail advocates say optical scan is the best option currently available, despite the fact it could be vulnerable to some of the old errors that voters made on paper ballots filled out by hand. About half of all voters used optical-scan machines this fall.

Maryland spent \$70 million on Diebold touch screen machines and some election officials question why it should be abandoned in favor of scanners. "If we wanted to have paper, we could have stayed with the old machines," said Barbara Fisher, elections director for Anne Arundel County, which includes Annapolis, the state capital.

Groups representing the blind have largely embraced electronic voting because of audio features that allow them to cast ballots without assistance.

"We must have a way to independently vote in private," said John Pare, a spokesman for the National Federation of the Blind in Baltimore, arguing that if there is to be a paper trail it must be done in a way to maintain privacy.

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