

A Practical Election System with Integrity

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Marc Baber is a Computer Scientist of over twenty years who's worked for world-class companies such as Cray Research and Intel and has published and patented a number of his innovations over the years. He's also a supporter of VerifiedVoting.org and a member of TruthInVoting.org. After the 2004 election, he became aware of serious flaws in current election systems and began considering how to repair our democracy. This paper explains his recommended solutions and the rationale behind them.

Abstract

Wise use of appropriate technology for elections would be more reliable, economical and trustworthy than today's systems. All voting machines fail sometimes and such failures can be manipulated to disenfranchise voters in targeted areas. Voting machines are more expensive than paper ballots. Computer-based voting machines can be "cracked" and are usually obsolete in 2-4 years, so any efficiency they may provide over other systems is outweighed by the fact that they're only in service to voters about 72 hours before they must be replaced or overhauled. Paper ballots mailed to voters at their address of record both confirm the voters' addresses and give voters the opportunity to mark their ballots at their convenience in the privacy of their homes. Hand-delivery of ballots to polling places by the voters themselves on Election Holiday supports an unbroken chain of ballot custody, permits exit polls to be conducted and offers a venue where illegitimate voters can be challenged. Blind voters are just as easily accommodated with simple ballot marking devices as with current voting machines. Absentee ballots are still provided for those who can't get to their polling place for any reason. Cheap, mass-produced, unprogrammable optical scanners operating as peripherals to standard PCs and used at the county level, provide a way for interested parties to audit or recount the ballots. Web sites provide individual voters a way to confirm their votes are recorded as intended without compromising privacy. Special ballot printing techniques provide voter "receipts" and ways to detect ballot tampering.

Introduction

Election anomalies in the U.S. since 2000 have shown our current systems for vote recording and counting are not trustworthy. For reasonable people willing to examine the available facts, the outcomes raise serious doubts about the continued survival of democracy, both in the U.S. and abroad as questionable technologies spread to other countries.

Others have documented the unexplained discrepancies between exit polls and official results in many races and the vulnerability of electronic voting systems to cracking, tampering and manipulation.

The purpose of this paper is not to prove or disprove any alleged cases of election fraud. It's not important for us to know with certainty that election fraud has occurred before we can realize that a different solution is needed. A democracy cannot function properly unless the vote-counting system is verifiable, auditable and deemed trustworthy by all participating parties beyond any reasonable doubt. Today's systems simply don't meet these requirements for a functional democracy for many reasons, not the least of which is the fact that recounts in the era of electronic vote recording are impossible.

This paper is for readers who've already grasped the need for new election systems and are interested in moving forward to answer the question, "What would a good election system look like?"

Why Today's Systems are Inappropriate for Elections

I'm no Luddite when it comes to technology. I currently have eight computers at home, broadband internet, and use many internet resources for everyday life. During my career, I've worked with supercomputers composed of 512 single-board computers, clustered together into refrigerator-sized cabinets (Intel's Touchstone Delta), liquid-CFC-cooled multiprocessor systems (the Cray-2) and other somewhat exotic systems. I have trusted my health to scuba diving computers. In fact, I've relied on and trusted computers for much more than I probably even know. So, it should not be taken lightly when I say that programmable computers have no legitimate role in the ballot booth⁶.

There are many who would argue that, in spite of the poor-to-nonexistent security implemented on current voting systems, there's no reason electronic systems with appropriate security and strong encryption couldn't ensure verifiable elections.

That may be true. Knowledgeable people can discuss the merits of encryption standards from DES to RSA, from 40-bit, to 128-bit to 4096-bit encryption and beyond. However, there is a simple, fundamental reason why computer security cannot adequately resolve the problem of unverifiable elections.

It's this: Only a small percentage of our population will ever understand encryption technology. It's unrealistic and unfair to expect people to trust technologies they don't understand. Average people can understand paper ballots deposited in locked boxes that never leave the sight of observers from competing parties until the counting is completed. Average people cannot understand public key encryption to the degree necessary to trust one's way of life to it. We can listen to mathematical explanations as long as we want to, but, for most of us the explanations will mean little and ultimately we'll either decide we

trust the people offering explanations enough to risk our democracy on their claims of infallibility... or not.

But there's an even simpler reason why most electronic voting systems should not be used. They're just not economical. As with many insights, the key is to ask the right question, to wit: Who in their right mind would buy a piece of computing equipment they only plan to use about once every year and that will, like all computing equipment, be obsolete in about three years?

If I tried to sell you a personal computer that could only be used for, say, your individual income tax return and nothing else, would you buy it? Would you pay to keep it in a heated, secure place the other 364 days of each year? Would you buy a maintenance contract, knowing that if it failed on April 15th, even if it were fixed within a day, it would be too late for your purposes? I think most of us would rightly find such a proposition completely out of the question. So, why do our election officials rush to spend so much money on electronic voting machines?

Unfortunately, most people in the election technology debate have lost sight of the common-sense concept of "appropriate technology". The term "appropriate technology" came into vogue in the 1970's¹ when many International Development NGOs realized that advanced technologies were often inappropriate for societies without the skilled labor or access to capital needed to maintain them. They saw that the limited benefits achieved generally didn't justify the debt incurred. Put simply, a technology that serves people well in one country might be a dis-service in another country and, more to the point, a technology that delivers economies of scale when used on a daily basis might provide no advantage at all when only used annually. Similarly, it can also be determined that most electronic devices used in elections don't hold up to the scrutiny of simple cost-benefit analysis.

Most people agree that a Voter-Verified Paper Audit Trail (VVPAT) is essential to running auditable, verifiable elections with meaningful recount procedures. Because recounts tend to be rare, I maintain that the primary vote-counting process and the recount process should be one and the same so that elections officials always have the training and technology to perform a recount. Recount processes that are cumbersome are expensive and election officials tend to raise barriers to recounts when they're expensive, such as draconian fees. Therefore, I would add a requirement that paper ballots (or the paper audit trail) must be machine readable for ease of recounts. Optical scanners are a typical technology for achieving machine readability. The problem is that once you've accepted the necessity of machine-readable VVPAT with primary counting and recounting being one and the same process, then any voting machines used to create the paper records are reduced to the role of digital carbon paper and digital carbon paper will never be as cheap or reliable as actual carbon paper.

"The National Federation of the Blind has complete confidence in the proliferation and capacity of electronic voting systems and in Diebold Election Systems, in particular, to operate at an optimal level of security, accuracy and accessibility that protects the integrity of elections."

Dr. Marc Mauer, 9/11/2003
President, National Federation of the Blind
<http://www.diebold.com/nfb.htm>

At some point in the electronic voting debate, someone usually raises the issue of handicapped/disabled/alter-abled voters as a justification for electronic voting systems. It would be interesting to know more about the funding ties between electronic voting equipment companies and the advocacy organizations² who've stepped forward to champion the cause of electronic voting. Whether or not these organizations have been unduly influenced by funding from voting system manufacturers, there is certainly better technology available that satisfies both requirements of accessibility and auditability³. The best alternatives to paperless electronic voting systems are electronic paper ballot-marking systems.

Finally, aside from being uneconomical, most electronic voting technology in use today isn't auditable and, therefore, simply doesn't do the job it is supposed to do even when it's working as designed. Unlike paper balloting systems, however, electronic systems often don't work as designed—they fail (especially systems brought out of storage only once or twice a year), and thus they provide a plausible excuse for corrupt elections officials. There is no practical way to prevent corrupt elections officials from sabotaging electronic voting machines in certain precincts and blaming it on the technology. The more complex the technology, the easier it is to make such occurrences look unintentional. I am not suggesting that a large number of elections officials are corrupt, but that in a system of checks and balances, corrupt officials should at least be detectable and simpler systems provide fewer places for corruption to hide.

Characteristics of Election Systems with Integrity

We know what qualities a balloting system of integrity should have. Our guiding principles should be familiar to those who have been schooled in the prerequisites for democracy:

1. Elections (and ballots) must be auditable.
2. Eligible voters must be allowed to vote conveniently without unreasonable hardship.
3. Ineligible (and non-existent) voters must not be allowed to vote.
4. The ballot counting process must be transparent and open to public scrutiny.

5. Ballots must be cast, counted, transported and stored as part of an unbroken, multi-party chain of custody so that no party has any opportunity to tamper with ballots before, during or after an election.
6. Balloting technology must be trustable by the electorate.
7. Voter anonymity must not be compromised.

Additionally, it would be preferable if the vote-counting system:

8. Accommodates voters with disabilities
9. Is economical.

The Baber⁴ Plan for Verifiable Balloting

Voter registration:

1. State and/or local elections divisions maintain web sites (and office staff) allowing voters to confirm the status of their registration instantly on-line (or by phone).
2. No voter registration purges of any kind can occur in the 90 days prior to an election. All plans for registration purges are subject to public review.
3. Voters can register by mail up to 30 days before an election and receive their voter cards by mail within one week.
4. Voters can register up to, and including, Election Day at the Election Division offices. Offices must have evening and weekend hours in the 30 days leading up to any election to accommodate voters working hours that conflict with the Election Division's normal business hours.
5. Political parties may have access to digital voter registration databases, both on-line and downloadable for purposes of identifying and challenging any fraudulent registrations, both before and after the election.
6. Paper ballots are printed like many printed commercial forms, with unique serial numbers, both on the ballots themselves and on their attached "carbon" copies. The ballot sheets tear off from the form so the voter can keep a carbon copy with the top half-inch of the actual ballot sheet still attached. The paper in the ballots is made with embedded threads randomly interspersed into the paper and, possibly, other mechanisms to make it impossible for ballots to be substituted with forgeries without detection.
7. The paper ballots are mailed out to the voters at their registered addresses two weeks prior to an election in order to give voters plenty of time to fill in their ballots. (All voting systems in a real democracy must have a voter-verified paper audit trail and simple, paper ballots are the most economical solution). Black ink pens are used to mark the ballots (not pencil). Mailed out ballots also provide the best way to ensure that each voter gets a ballot appropriate to his or her precinct/districts and party affiliation.
8. The ballots are mailed with a voter's pamphlet if the voter opts to receive a paper copy of the voter's pamphlet (a check box on their voter registration) to save postage. Ideally, congress extends "franking" privileges to all elections divisions so no postage expense is necessary.

9. There is also an on-line web version of the voters' pamphlet if the voter wishes to help save paper and taxes by opting to use the online version (or share a friend's paper copy).
10. All of the following are crimes subject to fine and/or imprisonment:
 - a. Voter registration volunteers altering, destroying or failing to turn in voter registration cards
 - b. Disseminating by phone, mail, word-of-mouth, leaflets or any other means, false information about the locations and/or hours of polling places.
 - c. Likewise disseminating false info about harm that may come to voters if they vote (arrested for outstanding parking tickets, child support violations, etc.)
 - d. Theft or destruction of mailed-out ballots.
 - e. Coercion of voters to vote a particular way or to show their completed ballots (before they're returned to elections officials)

Election Day:

11. Election days are national holidays. Employers are required to give employees at least 4 hrs paid leave to cast their ballots at their precinct polling place. Employers who don't comply are penalized. Rewards are given to whistleblowers.
12. On Election Day, voters cast their ballots at their local precincts in person so that (a) local election volunteers can confirm they are living human voters, (b) exit polls are still possible to validate election results (c) ballots are automatically sorted to their correct precincts and (d) an unbroken chain of ballot custody can be confirmed. Casting a ballot is not a drive-thru, drop-off process, but involves signing the precinct book and personally placing one's ballot in the ballot box, keeping the carbon copy as a receipt. Voters have the opportunity to correct their ballots or trade in for a new ballot and re-vote if their original ballot was incorrectly marked or even if they just change their minds at the last minute.
13. If an observer has reasonable cause to suspect a registration is fraudulent (subject to a local, multi-partisan review board) the voter can be challenged when they turn in their ballot.
14. Lost or confused voters may turn in their ballots at a different precinct polling location, if they wish, as long as it's in the same county. Special multi-partisan teams make sure these ballots, as well as mailed-in ballots, get into the stacks for their proper precincts immediately after the polls close and ballots are delivered to

- central county facilities. Facilities are open to the public (for observation) and to independent parties who wish to count ballots with their own scanners.
15. Alter-abled voters and bona fide absentee (travelling) voters may mail in their ballots, as long as they're postmarked on or before Election Day and sent by certified, return-receipt mail. Elections officials must provide mail-in envelopes with pre-printed certificates of receipt. No postage is necessary because the USPS delivers all ballots and voter pamphlets to (and from, when necessary) voters for free, similar to "franking" privileges enjoyed by members of Congress. If the postal service complains about the cost, let them hike the rates for junk mail to cover the difference.
 16. Special polling places with ballot marking devices for alter-abled voters are provided as may be necessary, often located near city bus terminals.

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      B108,
      C27, C62,
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      AA19, AA103, AA108,
      AV1, AV50, AV100, AV108
    </filled_ovals>
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  </ballot>
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</ballot_stack>

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Fig. 1: One of many possible XML formats for ballot recording. Note that 48-by-108 is one industry standard scan grid size, thus A1 is the upper left corner and AV108 is the lower right corner of a ballot

17. Ballot counting is done at the county level, precinct by precinct, stack by stack, using ultra-simple optical scanners similar to the Scantron⁵ company's test scoring scanners used in schools for over three decades. Though ballots are printed differently for each district and party affiliation (for primaries), the scanners are never re-programmed between elections, so there is no opportunity for program tampering. The scanners themselves have a single program that doesn't change from election to election—they simply record coordinates of filled-in ovals like a battleship game: A-7, G-3, W-6, Z-15, etc. It is essential that scanners have no internal understanding of the significance of any filled oval's position on the ballot or even which district they're reading. Scanners are intended to be cheap so that each political party can field a scanner in each county on election night and compile their own data files from the precinct stacks. County officials are required to allow any independent party to scan any precinct stack on election night and up to four years after the election. Scanners have no internal clocks, no wireless interfaces, and no internet connections. Official county scanners must record directly to a write-once-read-many (times) (WORM) medium such as compact disk (CD) or punched paper tape, signed by county officials. Independent party scanners may record a stack of ballots as an XML file on a floppy-disk, or a CD or a flash-card, or punched paper-tape or to PC's hard disk connected by USB wire (essentially any medium). All ballots have pre-printed scanner-readable codes for precinct number and ballot numbers which are sequential and unique.
18. Election officials may require independent parties to successfully scan a stack of test ballots before scanning the actual ballots. In addition, independent parties may be required to register a scanning device, if there is reasonable doubt about the ability of scanners to operate without spoiling ballots.
19. Election officials scan the ballot stacks first and then independent parties are allowed to scan stacks under supervision one stack per independent party at a time. No preference can be given to one party over another. Officials record which parties scan which stacks and when. Video may be used to record these proceedings.
20. As election night proceeds, Election officials and all independent parties post their XML data files to the web on web servers controlled by each party and make them publicly accessible (read-only of course).
21. The Election Divisions, additionally make XML data files available for each precinct-district defining the significance of each filled-oval position.
22. Election officials, news agencies, political parties and even independent citizens can then
 1. Download ballot-definition XML files

2. Download precinct results XML files from both officials and independent parties
 3. Run programs on their own PC's to calculate totals for each candidate and issue
 4. Compare result files from different sources (to make sure they're the same)
 5. Compare ballot definition files with their receipts to make sure the definitions match the printed ballots.
23. Voters can look up their ballot numbers online and confirm their votes were recorded properly in the official data sets for their precinct.
24. Everyone can download the datasets of any precincts they're interested in from one or more sources (official and/or independent), verify the total counts and confirm individual ballots from the numbers on the paper receipts they've kept. They can also scan for duplicate ballot numbers (counted twice), check sum errors and calculate totals for themselves using open source ballot file analysis software.
25. Representatives of any party can bring their own approved scanner (approved to be non-destructive of ballots, transparent cases, ballots always visible) and scan the ballots of any precinct they wish to check immediately after the official count and/or later at a state-wide centralized ballot retention facility.
26. In addition to certified, paper off-line election results, vote counts are also reported publicly online nationwide (well, worldwide actually) so any concerned citizen or reporter can download, analyze and study the results.

Post-Election:

27. Ballots are sealed by precinct and locked in a vault and kept for at least four years.

Conclusion

The Baber Plan provides an alternative Vote-Counting Process that:

- Keeps the best features of mailed in ballots—voter address confirmation and freedom to mark ballots at leisure in the privacy of one's own home.
- Preserves the ability to conduct exit polls. Provides for face-to-face review of voter eligibility when there is doubt.
- Supports accessibility for voters with disabilities.

- Is economical.
- Preserves a paper record of the voter's ballot for both officials and the voter without possibility of tampering by intermediate electronic devices.
- Provides very high transparency for the vote counting process and open verifiability for any independent parties that wish to count the votes themselves.
- Enables voters to confirm their ballots were correctly recorded over the web
- Preserves the anonymity of voters.
- Makes wise use of simple and standard digital equipment and protocols.

Appendix A: A Comparison Grid for Elections Systems

The following table will serve to compare the Baber Plan with other serious balloting plans as dialog continues and other proposals are put forward.

			Option 4	
			Option 3	
	Oregon Vote-by-Mail Plan			
	Baber Plan			
Elections (and ballots) must be auditable.	Yes	Yes		
Exit polls should be possible as a time-honored method of verifying the integrity of official ballot counts.	Yes	No		
Eligible voters must be allowed to vote conveniently without unreasonable hardship.	Yes	Yes		
No possibility of Electronic or Mechanical failures leading to long lines and disenfranchisement	Yes	Yes		
Ineligible (and non-existent) voters must not be allowed to vote.	Yes	Maybe		
The ballot counting process must be transparent and open to public scrutiny.	Yes	No		
Ballots must be cast, counted, transported and stored as part of an unbroken, multi-party chain of custody so that no party has any opportunity to tamper with ballots before, during or after an election.	Yes	No		
Balloting technology must be trustable by the electorate.	Yes	Maybe		
Voter anonymity must not be compromised.	Yes	Maybe		
Accommodates sight-impaired voters	Yes	Yes ⁷		
Is economical.	Yes	Yes		
Eliminates possibility of voting machine failure and attendant disenfranchisement	Yes	Yes		

The Oregon Mail-In Ballot System

Although the Oregon system is much better than what's used in other states (I happen to be an Oregonian, so I'm familiar with the system), it has several serious flaws:

Vote-by-mail prevents the possibility of checking official vote counts against the accurate and time-honored standard of exit polls. Note that it is exit polls that tip us all off to election fraud in other countries (such as the Ukraine) even though exit polls have been falsely maligned in the U.S. since the 2004 presidential election.

Though US Postal carriers may be among the most honest in the world, we probably wouldn't trust the government postal employees in Panama under Noriega or mail

carriers in Iraq under Saddam or in any number of other countries where there's a distinct possibility that one's mail-sorting job could depend on losing large numbers of the opposition's ballots while "finding" large numbers of the current regime's ballots. The U.S. should be an example of democracy for the rest of the world to follow. We must maintain an unbroken chain of custody of ballots and, therefore, we must require voters (except for absentees or disabled) to preserve the integrity of elections by personally delivering their ballots to polling places where they will be received and monitored by representatives of multiple parties before, during and after official counting. Vote-by-mail doesn't meet this important criterion.

I have spoken with at least one mail carrier who noted that his job was only to deliver ballots, not to question whether the addressee was legitimate. Thus, he delivered many ballots to names he'd never seen other pieces of mail for at the delivery address. Requiring voters to personally deliver ballots provides a face-to-face point of contact that tends to reduce voter fraud. It is one thing to fraudulently mark a ballot in the privacy of your home (or a friend's home) and mail it in and quite another thing to risk getting caught when personally delivering a fraudulent vote to the polling place.

One benefit of the Oregon Vote-by-Mail system that is often touted is high turn-out (about 85% in the 2004 General Election), however the turnout in the 2006 primary was the lowest in 46 years. One wonders, if large numbers of ballots went missing, how would we know? How can we ever be certain that turnout wasn't actually closer to normal? In any other country but the U.S., these questions would be taken seriously.

Although Oregon uses mostly optical scan systems for counting ballots, these scanners are re-programmed between elections and contain logic that has knowledge of the individual ballot measures and candidates on each ballot (unlike the scanners in the Baber plan) and, therefore, could potentially be manipulated to undercount one candidate and overcount another. It is not easy to observe the process in any meaningful way and because the scanners tend to be quite expensive, it is unheard of for an independent party to conduct a recount using their own equipment (as is supported by the Baber Plan).

For these reasons, the author argues that the Baber Plan is superior to the Oregon Vote-by-Mail system and that it will be better to advocate for widespread adoption of election systems that follow the Baber Plan model instead of the Oregon Vote-by-Mail model.

FOOTNOTES:

1. Actually, the core idea of appropriate technology goes much further back. Henry David Thoreau, in "Walden", observed that although train travel is superficially much faster than walking, it required, for an average worker in his society, more time laboring to earn the money to purchase a train ticket to Fitchburg than it took to walk the distance and, thus, he concluded trains were the slower mode of travel.
2. "Diebold and the Disabled" by Kim Zetter, October 14, 2004, <http://www.wired.com/news/evote/0,2645,65292,00.html> Excerpt: "In November 2000, Diebold, a maker of automated teller machines, agreed to pay the National Federation of the Blind \$1 million over five years to help build a new research and training institute. The money was offered in exchange for the NFB agreeing to drop a lawsuit it filed against Diebold for installing ATMs inaccessible to blind customers, when technology for making the machines accessible was available. The NFB also [formed a partnership](#) with Diebold to help the company develop and market accessible ATM machines -- an agreement that later extended to the company's touch-screen voting systems.

The NFB, which calls itself "the voice of the nation's blind," then used the Americans with Disabilities Act to file lawsuits against banks not using accessible ATMs. It later sued two states to force them to upgrade or obtain e-voting machines -- while a debate about the security and reliability of such systems was growing nationwide."

3. "Accessibility and Auditability in Electronic Voting", EFF White Paper, May 17, 2004, Electronic Freedom Foundation, http://www.eff.org/Activism/E-voting/e-vote_white_paper_20040517.pdf
4. I've immodestly named the plan after my family's surname because (a) The plan will need a short name so it can easily be discussed in comparison with other plans as the voting technology dialog continues, and (b) I've spent too much of my life explaining to people how to spell and pronounce my name (it's BAY-ber) and couldn't pass up this long shot at sparing my sons some of the same inconvenience.
5. The Scantron company's website is at www.scantron.com. Author has no affiliation with the company and does not specifically recommend their products. They are cited only as an example of "similar" technology.
6. Except, of course, when computer-based ballot-marking devices are used by sight-impaired voters. Nonetheless, I prefer the main text above to keep the more strongly worded absolute statement than to mince words at this time.
7. The Oregon vote-by-mail plan includes "special machines and other options available for the disabled who might find filling out the paper ballot a burden" (5/22/2006 e-mail from Progressive States Network, Stateside Dispatch, apparently passing along reports from Oregon's Secretary of State Bill Bradbury. I'm not yet familiar with Oregon's "special machines", but they are in theory very similar to the ballot-marking machines included in the Baber Plan.

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