Position Statement on Electronic Voting

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December 2004 (modified 11/2006)

This statement is a response to several requests for my position on electronic voting systems. I share the concern of many of my colleagues about interactive electronic voting systems (e.g., touch-screen voting). Touch-screen systems generally record and tabulate votes electronically, so they are often called Direct Recording Electronic systems or DREs. The most serious concern is with paperless DRE voting systems, because they offer no means to verify the integrity of the final count, and the concept is fundamentally vulnerable to failures that could affect the outcome of an election.

I believe that my views reflect a consensus among computer scientists. Several organizations are actively promoting this consensus, including the Association for Computing Machinery (acm.org). I have endorsed the “Resolution on Electronic Voting” at verifiedvoting.org. This more detailed position statement is my own, and is based on 20 years of experience in computer systems research and advanced development. Many of my colleagues have studied this issue in more detail than I have, and are more qualified to comment on specific DRE systems and products and the various problems that have occurred with their use.

I emphasize that the concern is not with electronic or computerized voting systems per se. I take it as a given that voting and tabulation systems of the future will be largely electronic, and I believe that automation has potential to make voting more efficient, more responsive, and less error-prone. Rather, my concern is with the details of how automated voting systems are designed and deployed. That concern derives from my familiarity with the underlying technology and with the history of other mission-critical computer systems.

DREs and Optical-Scan Systems

DREs are currently deployed in about half of the counties here in North Carolina. The other half use optical-scan ballots: voters mark the ballots manually, and election workers feed them into a scanner for electronic tabulation. A Caltech/MIT study indicates that optical-scan systems have proven to be highly reliable across the country. Optical-scan counties in NC include Durham County, where I vote. I know from personal experience that optical-scan ballots are fast, convenient, and easy to use. I have never voted on a DRE.

The 2004 election cycle in North Carolina produced several serious problems. A few of these problems involved mistakes with optical-scan technology by election officials (e.g., ballots recorded twice). A high-profile failure of tabulation software in Guilford County affected votes recorded on DREs, but the failure was not specific to the way the votes were recorded, and could in principle have affected optical-scan votes as well. These kinds of errors are detected from irregularities in vote totals, and are rectified before vote counts are certified. However, a DRE failure in Carteret County led to an unrecoverable
loss of 4400 votes. These lost votes were within the margin of error for several races, creating a serious problem and illustrating the weaknesses of DREs.

The strongest argument in favor of touch-screen voting is that the software can warn voters of common errors such as undervotes or overvotes, and give the voter an opportunity to correct them. However, we can obtain this benefit of touch-screen voting without resorting to DREs, since the functions for interactive vote selection are independent of the actual recording of the vote. Consider an interactive voting kiosk that records the vote on an ordinary optical scan ballot. The kiosk can warn the voter of an incorrect ballot, the voter can verify the integrity of the final ballot, and failure of the kiosk is not catastrophic, since the ballots can be marked by hand. Note also that interactive voting is not essential to reduce or eliminate common errors: a programmable scanner could validate each scanned ballot and reject spoiled ballots immediately.

A DRE advocate might argue that DREs cost less to operate (e.g., because there is no need to purchase and manipulate paper ballots), but history suggests that the high cost and overhead to maintain and certify computerized voting kiosks will overwhelm any advantage with respect to total cost of ownership.

DREs Considered: Design Objectives

We can consider these alternative architectures with respect to three properties that we want for our voting systems. Indeed, these properties apply for any mission-critical computer system.

Objective 1: Robustness

People who work with computer systems know that computer systems fail. In particular, some voting kiosks will fail to start, and some will behave erratically or stop operating under various conditions. Rigorous (expensive) design and testing can reduce the rate of these failures, but it will not eliminate them. The incidence of failures will decline as these systems mature over the next few decades, but the failures will never disappear. DRE voting kiosks will never be as robust as ATM systems because their interfaces are more complex and they are customized for each election.

Redundancy is the key technique to improve robustness of systems. Even ATM systems fail frequently, but there are enough of them to meet demand even if some of them fail. A common technique in fault-tolerant computing is to maintain multiple implementations of each component (e.g., voting kiosks from two different vendors). For example, we can compare the behavior of the redundant components to verify that each is functioning correctly. Also, they will tend to have different failure modes, and there is a high probability that at least one of them will work. Unfortunately, redundancy is expensive and impractical in this setting.

The optical-scan alternative is also vulnerable to failure of the scanner. However, a scanner failure is less severe because the scanner is not in the “critical path” of voting. A DRE kiosk records votes, while a scanner only tabulates votes. A failed scanner does not prevent voters from recording their votes, and a replacement scanner can tabulate the votes after voting is complete. Thus the optical-scan alternative is more robust.
Objective 2: Scalability

A system is *scalable* if it can meet increasing demand with a constant marginal cost. In this case, voting systems must meet the demands of high-turnout elections. But turnout varies widely, and there is inadequate time to expand capacity for elections with unexpectedly high turnout, e.g., by deploying more kiosks. The choice of how many kiosks to deploy at each precinct location (*capacity planning*) is made in advance, and the cost of unexpectedly high turnout is passed on to voters in the form of higher wait times. High wait times may be considered a form of voter suppression—most memorably in the battleground state of Ohio in 2004.

DRE voting kiosks can serve voters at some maximum throughput. Throughput is difficult to predict because it depends on voter behavior. If the ballot interface confuses voters, then the average voter *service time* at the kiosk increases, and the maximum throughput drops.

The analytical techniques of queueing theory show that wait times grow very rapidly as demand increases, under a set of traffic assumptions that apply to voter arrival patterns. Specifically, wait time at a precinct location grows as the inverse of the *idle time*—the average percentage of the time that the average kiosk is idle. The idle time is determined by the average arrival rate for voters (which increases with turnout) and the average voter service time at each kiosk. For example, suppose a precinct plans capacity so that kiosks are idle about one-third of the time on average. If turnout increases by 45%, then queueing theory predicts that the average wait times increase by a factor of ten.

The election planners understand these principles. They apply to any voting system, and not just to DRE voting. However, DRE systems have a high cost per voter, which increases the incentive to plan capacity from optimistic assumptions about turnout and service times. The lower margin for error will inevitably lead to higher wait times when the unexpected occurs, as it often does. Moreover, kiosk failures (see Robustness above) further reduce capacity, leading to higher wait times.

The optical-scan alternative is more scalable for two reasons. First, the scan should not limit voting throughput, because the scan completes at machine speeds independent of voter behavior. Because service time at the scanner is small and fixed, a single scanner can serve many more voters than a kiosk. Moreover, it is not necessary for the voter to wait for the scan to complete, as discussed above. Second, it is cheap to deploy more optical-scan “kiosks” on demand: a kiosk for manually marked optical-scan balloting is little more than a table and a chair.

Objective 3: Accountability

A system is *accountable* if it provides participants with some means to verify that the system behaves correctly. Voting systems should be accountable as a matter of principle. It is unreasonable to expect that citizens will have blind faith in voting systems. History shows that the consent of the governed is a rare and precious commodity and is not to be trifled with.

Financial systems are designed to be accountable. Customers of financial institutions can track and verify transactions on their accounts independently; although many choose not to balance their accounts, they have confidence in the system because they know that they could do so and that others will do so. When independent verification is not possible, companies, financial institutions, and taxpayers are subject to audits and oversight. Waste, fraud, and abuse inevitably occur where checks and balances are weakest.
To be accountable, a voting system must produce a voter-verified, immutable, external record of the voter’s action. All previous voting systems produce a paper ballot: paper ballots are sufficient if the voter can verify its correctness and if it is not feasible for an attacker to modify or substitute the ballot after voting is complete. No system is perfect, but paper ballots—properly handled with an adequate system of checks, balances, and audits—are highly resistant to any systematic fraud. Since the vote is directly observable on the ballot without the assistance of a machine, the voter knows that any fraud or manipulation is highly likely to be detected in a count by a committee of observers with balanced interests in the outcome. Certainly such counts are rare in practice, but what is important is that the system is accountable: a complete audit is possible, and an attacker cannot know in advance if such an audit will occur.

A paperless DRE voting system is not accountable. To the voter, a DRE voting system is a “black box”: the voter cannot know exactly what it does or how it works. The voter has no means to verify that the machine recorded the vote correctly, because the machine reports only totals. This is a key difference from (say) an ATM system. No possibility of a valid audit exists because the recorded vote is not directly observable by the voter or by anyone else. Our only way to know the outcome is to believe what the machine tells us.

Moreover, we do not know how the machine actually determined the outcome. One way to gain confidence in the operation of the machine is to allow independent experts with balanced interests to examine the machine and its software. Partial inspection is possible, for example, if manufacturers of voting systems publish their software programs as “open source”. However, it is still necessary to verify that the certified software has full control of the machine on election day; in general, it is trivial to replace or modify software. Moreover, it is also necessary to validate the functioning of the computer hardware itself. In general, the only way to validate computer hardware is to run test software and validate the inputs and outputs. Confidence in black-box voting systems might be improved if they run open-source software on hardware built from standard, verifiable components (e.g., commodity computers). Even so, such a system still could not be considered truly accountable.

Naive audit procedures for black-box voting systems have little value. For example, it is not sufficient to validate the machine with voting tests before election day, because it is trivial to design software or hardware that behaves differently on election day. We can audit the tabulating system by resampling the counts on selected voting machines, but there is no way to verify that the count reported by any individual DRE kiosk accurately reflects the private actions of the voters using that machine. The likelihood of detection could be improved by assigning voters randomly to diverse voting systems and comparing the outcomes, but this approach cannot rule out simultaneous tampering or collusion unless a substantial subset of the voters use truly accountable voting systems.

In contrast, optical-scan systems are truly accountable because an optical-scan ballot can be considered a verifiable, immutable, external record of the voter’s intent, and the means exist to audit these ballots.

I emphasize that any views about who might tamper with voting systems, or why, or by what means, are irrelevant. It is not necessary to be a conspiracy theorist to believe that voting systems must be accountable as a matter of principle in a politically stable democracy. If they are not accountable, then some voters will refuse to accept the outcome of an election, whether or not any evidence of fraud or error exists. Concern about accountability is not a fringe view: according to the Pew Research Center, only 48% of the US electorate in 2004 has faith that votes are counted accurately nationwide. This is unacceptable.
Conclusion

I conclude that: (1) DRE voting systems offer no compelling advantages over optical-scan technology, and (2) paperless DRE voting systems are a threat to democracy.

This document has already considered and dismissed arguments for DREs in terms of usability and cost. An advocate for DREs might argue that paperless DREs offer better privacy precisely because no vote record exists, but this advantage is not compelling, and in any event a voter cannot verify that the machine does not record identity in some way (e.g., by taking a photograph as ATM systems do) and associate it with the vote.

Given the absence of any compelling technical case for DREs, it is little surprise that some citizens have apparently concluded that the pressure for DRE voting systems comes primarily from private corporations with a vested financial interest, and from their supporters among election officials, who have recently been seen to be partisan in key states. A quick Google search will turn up any number of websites claiming conspiracies related to DREs. I see these claims as symptomatic of a voting technology that is unaccountable and therefore fatally flawed, whether or not the specific claims have any validity.

The problems with electronic voting in the 2004 cycle in North Carolina were not unexpected, they are on the whole not unusual, and they are not surprising. In fact, it is surprising that there are not more problems, and the industry and election officials deserve some credit for the successful deployments of DRE systems. Nevertheless, many other states have experienced similar problems with DRE systems from various manufacturers. More importantly, the nature of these systems undermines confidence in elections across this country, and no amount of positive experience can overcome the reasonable fear of unaccountable voting systems. My colleague Dan Wallach has been quoted as saying: “The purpose of voting systems is not just to determine the winner, but to convince the losers that they have lost”.

In North Carolina, we should take the disturbing experience in Carteret County as a warning sign, slow the rush to deploy DRE voting systems, and reconsider the merits of these systems. I believe that North Carolina has an opportunity to lead in the deployment of sensible electronic voting systems, and that our state will be better for it.

In 2005, the State of North Carolina outlawed paperless DRE voting systems in Senate Bill 223.