

Electronic Voting with an Audit Trail

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Comments and suggestions for clarification are welcome. Please email comments to the author at bmeacham@bmeacham.com.

Revision History

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Introduction

Electronic voting (e-voting) machines are intended to streamline the voting process, making it easier for voters to register their votes and for vote counters to count the votes. In many cases they succeed in this goal admirably. However, there is a fundamental flaw in voting systems that are entirely electronic: the absence of an independently-verifiable audit trail. If there is a problem with an all-electronic system, there is no non-electronic way to count the votes accurately. If there is a dispute with the electronic system, there is no non-electronic way to resolve the dispute.

There are a number of things that can go wrong with electronic voting. Electronic components can fail, mechanical components can fail, the software controlling the system can have defects, and there is the possibility of electronic tampering with the software. Some problems might be evident to the naked eye. For instance, some e-voting systems have two or more storage media to record the votes. If one does not agree with another, it is clear that there is a problem. Some problems might not be evident to the naked eye. If the software that records the votes on the media or the software that reads the media and displays the results has a flaw, whether by mistake or by malice, the media will all agree but the votes recorded will not match those actually entered by voters. Without a non-

electronic independent audit trail, there is no way to resolve problems that are evident to the naked eye, and no way to detect problems that are not evident to the naked eye.

In a democracy, voters have a fundamental right to have their votes counted accurately and in such a way that disputes can be resolved objectively. The lack of an independently-verifiable audit trail in e-voting systems infringes that right.

The purpose of this paper is to describe how an e-voting system with a non-electronic, independently-verifiable audit trail would work. In software terms, this paper describes the functional requirements for such a system. This is not a description of how it does work, but how we would like it to work.

This paper does not elaborate on why this is a good idea. Please see the section titled [Additional Resources](#) on page 5 for further analysis of the need for such an audit trail.

Scenarios

The functional requirements for an e-voting audit trail can be described by the use of scenarios describing how a voter would interact with the e-voting system and what the system would do in response to the voter's actions. Technically, the set of scenarios is called a "use case." It describes how a voter would use the system, and in so doing it describes the what the system must do (its functional requirements) in order to accomplish the voter's goals.

Pre-conditions

These scenarios all start with the pre-condition that the e-voting machine is in an idle state, waiting for a voter to walk up and start recording votes. They also assume that each e-voting machine is equipped with a printer that can print a paper copy of the voter's ballot.

1. Normal Course

This scenario describes the normal course of events in which the voter encounters no problems.

1. The voter records his or her votes on the e-voting machine.
2. After verifying that the machine is displaying the votes correctly, the voter clicks or presses something that signifies the voter's wish to print the ballot.
3. The machine prints a paper copy of the voter's ballot which clearly shows the voter's votes.
4. The voter inspects the paper copy of the ballot and verifies that it correctly reflects his or her choices.

5. The voter clicks or presses something that signifies his or her assent to the paper copy and intent to cast the ballot. The e-voting system records the votes electronically and returns the machine to the idle state, waiting for a voter to start recording votes.
6. The voter deposits the paper copy of the ballot in a locked and secure receptacle (ballot box).

2. Voter Disagrees with Paper Ballot

This scenario describes an alternative course of events in which the voter decides that the paper ballot does not correctly reflect his or her choices. This could be because the voter made a mistake in registering the votes, or it could be because the voter changes his or her mind upon reading the paper ballot,

1. The voter records his or her votes on the e-voting machine.
2. After verifying that the machine is displaying the votes correctly, the voter clicks or presses something that signifies the voter's wish to print the ballot.
3. The machine prints a paper copy of the voter's ballot which clearly shows the voter's votes.
4. The voter inspects the paper copy of the ballot and sees that it does not correctly reflect his or her choices.
5. The voter calls an election official who, in the presence of the voter and with the voter's approval, marks the paper ballot void and deposits it in a secure container other than the ballot box.
6. The voter returns to the e-voting machine and continues to record his or her votes.

3. Voter Fails to Finish the Transaction – Ballot Printed

This scenario describes an alternative course of events in which the voter walks away without finishing the transaction.

1. The voter records his or her votes on the e-voting machine.
2. After verifying that the machine is displaying the votes correctly, the voter clicks or presses something that signifies the voter's intent to cast the ballot.
3. The machine prints a paper copy of the voter's ballot which clearly shows the voter's votes.

4. The voter leaves the voting machine and fails to click or press something that signifies his or her assent to the paper copy.
5. If an election official notices that the voter has failed to finish the transaction before the voter leaves the polling place, the election official asks the voter to return to the e-voting machine and complete the transaction.
6. If the voter leaves the polling place before an election official notices that he or she has failed to finish the transaction, the election official does the following:
 - 6.1. The election official cancels the transaction on the e-voting machine. The votes are not recorded electronically. The machine returns to the idle state, waiting for a voter to start recording votes.
 - 6.2. If the paper ballot is found, the election official marks the paper ballot void and deposits it in a secure container other than the ballot box.
7. If no election official notices that the voter has abandoned the e-voting machine without finishing, after a pre-determined period of time the e-voting machine resets itself to an idle state without recording any votes.

4. Voter Fails to Finish the Transaction – No Ballot Printed

This scenario describes an alternative course of events in which the voter walks away without finishing the transaction.

1. The voter begins to record his or her votes on the e-voting machine.
2. The voter leaves the machine without requesting a paper copy of the ballot.
3. If an election official notices that the voter has failed to finish the transaction before the voter leaves the polling place, the election official asks the voter to return to the e-voting machine and complete the transaction.
4. If the voter leaves the polling place before an election official notices that he or she has failed to finish the transaction, the election official cancels the transaction on the e-voting machine. The votes are not recorded electronically. The machine returns to the idle state, waiting for a voter to start recording votes.
5. If no election official notices that the voter has abandoned the e-voting machine without finishing, after a pre-determined period of time the e-voting machine resets itself to an idle state without recording any votes.

After the Polling Place Closes

After the polling place closes, the electronic votes are counted according to the standard procedure for the e-voting system. The ballot boxes are transported under guard to a secure location where they are stored just as paper ballots are stored in a non-electronic voting system. They are available for inspection or counting in the event that a dispute or question arises concerning the electronic results.

Additional Resources

This section lists places where you can find additional information regarding electronic voting and the problem of lack of an independent audit trail.

- David Dill's website, <http://verifiedvoting.org>. Dill is organizing opposition to paperless electronic voting machines by technologists, especially computer science researchers. This site contains background information, including an excellent Questions and Answers section, a resolution opposing paperless voting machines, and a good overview of the issues.
- “Voting Machines: Vote Tampering in the 21st Century” – http://www.whoseflorida.com/voting_machines.htm. Contains several interesting articles, among them the following:
 - 22,000 Georgia voting machines had their programming modified shortly before the November, 2002, election with no oversight by electoral officials.
 - A voting machine test engineer has filed a lawsuit against his former employer charging wrongful and retaliatory termination. He contends he was removed so that he could not blow the whistle to certification labs and pass critical information to the US General Accounting Office. He says he has evidence which shows voting systems are certified despite known flaws, demonstrating a weakness in accepted systems for certifying them.
 - An analysis alleging that all-electronic voting systems violate the Constitution of the United States.
- Rebecca Mercuri, a noted computer science professor examines the issues at <http://www.notablesoftware.com/evote.html>.
- Black-Box Voting – <http://www.blackboxvoting.org/>. News and opinion about possible electronic vote tampering.
- “If You Want To Win An Election, Just Control The Voting Machines,” by Thom Hartmann – http://www.truthout.org/docs_02/020203G.voting_mach.htm. Describes two cases of electoral victories tainted by doubts about the accuracy of e-voting systems. One of the victors had a stake in the company that built the e-voting machines. Somewhat polemical in tone.

- “Scientists question electronic voting” – <http://www.sfgate.com/cgi-bin/article.cgi?file=/chronicle/archive/2003/03/03/BU122767.DTL&type=tech>. A newspaper article describing computer scientists’ opposition to e-voting in Santa Clara County, California.
- Electronic Voting in Travis County, Texas – http://www.co.travis.tx.us/county_clerk/election/eSlate/history.asp. This official county description of an e-voting system fails to mention the lack of an independently-verifiable audit trail.
- Join a discussion group on electronic voting in Central Texas – <http://groups.yahoo.com/group/centex-evote/>.