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# Risks of Computers: Voting Machines



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# Voting Systems and Computers

- There is a long history of problems (or perceived problems) with voting systems
- Technology has frequently been invoked to solve the problems
- Over the years, many different kinds of voting machines
- Elections are process-driven and often highly partisan

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## Paper Ballot Problems

- Too easy to stuff the ballot box
- ☞ During voting—slide two pieces of paper in
- ☞ Or—add ballots after voting, during counting
- (In 19th century America, *any* piece of paper was a valid ballot; candidates would hand out ballot flyers or tell people to clip a newspaper ad)
- Counting is slow and error-prone
- Many designs for voting machines in the late 19th century

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# Requirements

- Accuracy
- Voter privacy
- Resistant to fraud
- Resistant to error
- Resistant to information leakage
- Usable by voters
- Usable by handicapped voters
- Auditability and recountability
- More...

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## Process versus Technology

- Some precautions are enforced by mechanisms
- Others are done by process
- Example: limits on how many ballots can be printed
- What is the right tradeoff?

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# Participants

- Voters
- Election boards (usually county-run, but following state standards)
- Poll workers
- Poll watchers from political parties
- Courts (state and federal)
- News media

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## Processes (Simplified!)

- Voter registration
- Distribution of the eligible voter rolls
- Zeroing the counting mechanism
- Voter verification at the polls—and must handle challenges
- 👉 Voter must be given the right ballot
  - Casting a vote
  - “Closing the polls”
  - Quick count and reporting
  - Preservation of the ballots
  - The official count
  - Recounts

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## Responsibilities in the US

- Voting is decentralized, typically on a county basis
- Procurement and operation are done by local boards of election
- In some states, software and hardware are selected by the state; in other states, it's local option
- There are often state-wide portals to the registration system

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# Voter Registration

- How is registration data stored?
- Hard copy? (I once had problems voting because the cards were alphabetized incorrectly)
- Computers? What about software bugs? Backups?
- What about typographical errors in someone's name? Suffixes like "Jr." or "III"? Name collisions?

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## Hacking Registration Data

- Delete records
- Alter records—and perhaps add fake voters
- Steal the information, to aid in targeting people with propaganda

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# Checking Registration Status Online (Pennsylvania)

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## FIND VOTER REGISTRATION STATUS

You may search for your voter registration status with your Name or your PennDOT Driver's License or PennDOT ID. Your party affiliation and polling place address will be displayed once you have provided an exact match with the information on your voter registration record.

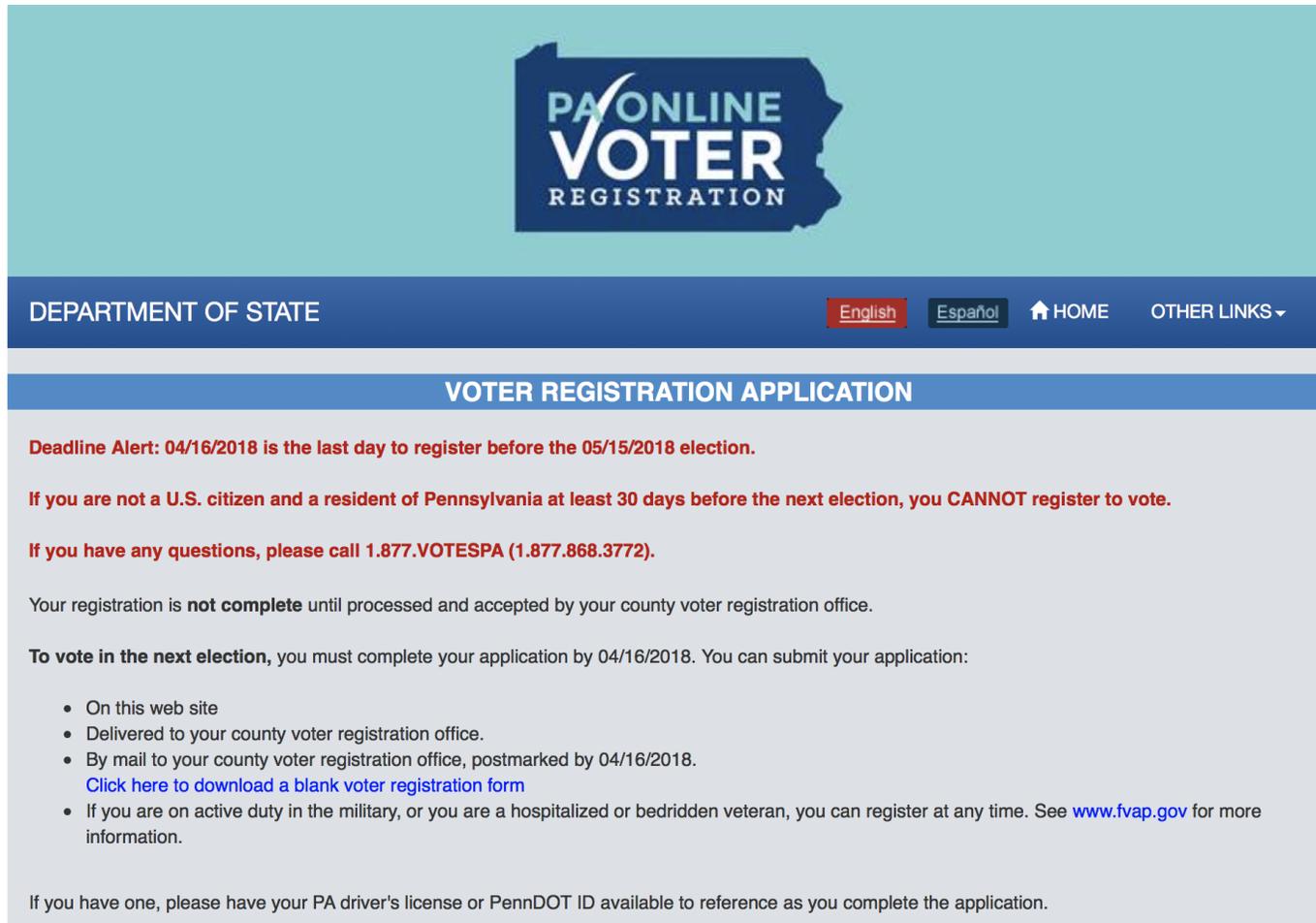
**Find your Voter Registration Status by Name**       **Find your Voter Registration Status by Driver's License Number or PennDOT ID**

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# Registering Online (Pennsylvania)



**PA ONLINE VOTER REGISTRATION**

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## VOTER REGISTRATION APPLICATION

**Deadline Alert: 04/16/2018 is the last day to register before the 05/15/2018 election.**

**If you are not a U.S. citizen and a resident of Pennsylvania at least 30 days before the next election, you CANNOT register to vote.**

**If you have any questions, please call 1.877.VOTESPA (1.877.868.3772).**

Your registration is **not complete** until processed and accepted by your county voter registration office.

**To vote in the next election**, you must complete your application by 04/16/2018. You can submit your application:

- On this web site
- Delivered to your county voter registration office.
- By mail to your county voter registration office, postmarked by 04/16/2018.  
[Click here to download a blank voter registration form](#)
- If you are on active duty in the military, or you are a hospitalized or bedridden veteran, you can register at any time. See [www.fvap.gov](http://www.fvap.gov) for more information.

If you have one, please have your PA driver's license or PennDOT ID available to reference as you complete the application.

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## Zeroing the Count



(Public domain photo, Wikipedia)

- Must show that no votes are recorded before the polls open
- Transparent or translucent ballot boxes; sometimes opened and showed to everyone
- Poll workers—and watchers—verify the counters on mechanical voting machines
- 👉 Print a “zero tape” on an electronic voting machine

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## Voter Verification

- How do you find a voter?
- Software?
- What if the software is buggy?
- What if the system crashes?
- What about network links in “vote anywhere” jurisdictions?
- What about exception processing?

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## Typical Work Flow

- A voter goes to the “proper” check-in table
- Sorted by precinct, alphabetically, etc.
- With *electronic poll books*, any table works
- Poll worker looks up the voter, notes that they’ve voted, gives them a “token” to allow them to vote
- The token may be a piece of paper with precinct, party, etc.
- Or, it’s a mag card with the proper ballot on it
- The voter goes the “proper” voting machine, turns over the token, and votes
- The token is retained for audits or reuse

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## Exception Processing

- There are strict—and complicated—processes for verifying and recording each voter
- Sometimes, there's an exception: someone who isn't listed but claims to be registered, or perhaps gets a court order allowing them to vote
- What is the process? Does the software support it?
- Example: some electronic polling books produce a magnetic card with the proper ballot for that voter. Can it handle an unlisted voter?
- Computers are inflexible!

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## Casting a Vote

- Paper—it's pretty easy, though people can get it wrong
- (There are strict legal requirements for valid ballots)
- Mechanical machines: move levers; move large lever to vote
- Punch cards—but watch out for hanging chads
- Electronic: many different ways. . .
  - Press physical buttons under ballot labels
  - Use a touch screen, repeatedly
  - Mark paper ballots and immediately feed to an optical scanner
- Internet voting?
- Many problems in this space—more shortly

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# Votomatic



Used in Florida in the 2000 presidential election—but sometimes, the hole wasn't punched through completely (“hanging chads”)

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# New Hampshire Instructions

**659:17 Marking the Ballot; Instructions to Voters.** – The secretary of state shall provide on the top of the general election ballot the following voting instructions. The secretary of state is authorized to replace the phrase "Make the appropriate mark" with an appropriate description and example of the mark to be made for the type of ballot in use, such as "Make a cross (X) in the box," "Completely fill in the oval," or "Complete the arrow":

1) To Vote

Make the appropriate mark to the right of your choice. For each office vote for not more than the number of candidates stated in the sentence: "Vote for not more than \_\_\_\_." If you vote for more than the stated number of candidates, your vote for that office will not be counted.

2) To Vote by Write-In

To vote for a person whose name is not printed on the ballot, write in the name of the person in the "write-in" space. Make the appropriate mark to the right of your choice.

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## West Virginia—Write-Ins

NATIONAL TICKET	NATIONAL TICKET
<p data-bbox="359 740 894 862">For U.S. House of Representatives Third Congressional District (Vote for One)</p> <p data-bbox="331 919 951 1008"><input checked="" type="checkbox"/> <del>JOHN DOE</del> <del>EMMA PEEL</del> Bluefield (Mercer Co.)</p>	<p data-bbox="1150 740 1686 862">For U.S. House of Representatives Third Congressional District (Vote for One)</p> <p data-bbox="1098 919 1577 1008"><input type="checkbox"/> JANE DOE Beckley (Raleigh Co.)</p>

Cross out the name!

## West Virginia—Stickers

NATIONAL TICKET	NATIONAL TICKET
<p>For U.S. House of Representatives Third Congressional District (Vote for One)</p> <div style="display: flex; align-items: center; margin-top: 20px;"> <input style="width: 30px; height: 30px; margin-right: 10px;" type="checkbox"/> <div style="border: 2px solid black; border-radius: 10px; padding: 5px; display: flex; align-items: center;"> <input checked="" style="width: 20px; height: 20px; margin-right: 5px;" type="checkbox"/> <div style="margin-left: 5px;"> <p><b>EMMA PEEL</b> U.S. House of Representatives-3rd District</p> </div> </div> </div>	<p>For U.S. House of Representatives Third Congressional District (Vote for One)</p> <div style="display: flex; align-items: center; margin-top: 20px;"> <input style="width: 30px; height: 30px; margin-right: 10px;" type="checkbox"/> <div style="margin-left: 5px;"> <p>JANE DOE Beckley (Raleigh Co.)</p> </div> </div>

You can use a sticker (containing all the necessary candidate information) to cover up another candidate's name on the ballot. The sticker may be placed in other areas, *as long as it is on the front of the ballot*. Stickers placed on the **back** of the ballot *will not be counted*.

Place a sticker anywhere!

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## Closing the Polls



(Photo by MONUSCO, a UN agency)

- Must show that no votes are recorded after the polls close
- Seal the ballot boxes in a verifiable way
- Lock the actuating mechanism on mechanical voting machines
- 👉 Run the software that prints the vote totals to paper tapes and disables further voting

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## Ballot Box Seals



(Australian Government Department of Foreign Affairs and Trade)



(Photo by MONUSCO, a UN agency)

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## Quick Count

- Reporters want the totals *immediately*
- Paper ballots take a long time to count
- (That's one reason Americans prefer voting machines; another is the length and complexity of the ballots)
- Precincts send the immediate results to the local election board: phone calls, faxes, dial-up modems, more

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## Errors in the Quick Count

- It's easy to misread the numbers
- Handwriting errors in manual processes
- Data entry errors
- Arithmetic errors
- Buggy tallying software

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## Showing That All Votes were Counted



Photo by Dave Kopel; used by permission. (<http://volokh.com/2008/03/22/taiwan-presidential-election-results-and-process/>)

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## Preserving the Ballots

- The official count takes longer, and is done with more care
- Goal: try to eliminate the errors in the quick count
- Also: handle absentee ballots and provisional ballots
- In some states, determine “voter intent”
- This is the count that really matters
- So: recount the paper ballots, reread the mechanical counters, and—for electronic voting machines—use the data recorded on the memory cards

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## Errors...

- The quick count printouts from some voting machines *should* be the same as what's on the memory cards.
- Not always. . .
- In 2008, Ed Felten found a precinct where the tapes showed 280 Democratic voters, and 95 votes for Obama
- The memory cards showed 279 and 94
- But the tapes should just be a printout of what's on the memory card!
- The discrepancy was never satisfactorily explained. There was no independent investigation.
- (The vendor attributed a previous discrepancy to operators pressing buttons they shouldn't have. There are other errors that can't be explained that way.)

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# Recounts

- With paper ballots, a recount makes lots of sense
- With mechanical machines, you can eliminate errors in reading the counters or transcribing the figures
- With electronic machines, you're just running the same software again—there's no independent check

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## Risk-Limiting Audits

- Recount a small, random subset of ballots
- The number recounted depends on the purported margin of victory and the jurisdiction's risk tolerance—the closer the election, or the more assurance desired, the more ballots are rechecked
- Currently required by law in Colorado; Rhode Island is about to require them
- It's not possible to do risk-limiting audits on DRE machines: you need something physical to recount

# Englewood Voting Machine Tape

Candidate	Candidate Totals	Total
***	REPUBLICAN	***
*	US President C11	(1)
D11	Rudw Giuliani	1
E11	Ron Paul	1
F11	Fred Thompson	0
G11	Mitt Romney	6
H11	Mike Huckabee	0
I11	John McCain	14
B11	Personal Choice	0
***	DEMOCRAT	***
*	US President- 19th Dist C18	(1)
D18	Barack Obama	33
E18	Joe Biden	0
F18	John Edwards	2
G18	Hillary Clinton	49
H18	Dennis Kucinich	0
I18	Bill Richardson	0
J18	Uncommitted	0
B18	Personal Choice	0
Write In Votes		
No Write In Votes In Memory		
Option Switch Totals		
1	UNUSED	0
2	UNUSED	0
3	UNUSED	0
4	UNUSED	0
5	UNUSED	0
6	REPUBLICAN	22
7	UNUSED	0
8	UNUSED	0
9	UNUSED	0
10	UNUSED	0
11	UNUSED	0
12	DEMOCRAT	83
Total		105

- The per-candidate totals show 84 Democratic votes and 22 Republican votes

- The ballot selection totals show 83 Democratic votes and 22 Republican votes

- Why the discrepancy?

- (From <https://freedom-to-tinker.com/blog/felten/nj-election-discrepancies-worse-previous>

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## What's the Problem?

- Software can be buggy
- Vendors consider their source code proprietary, and have often blocked investigations
- There is nothing else to check on a recount: the software is the software

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## Errors!

- There is a long history of errors with DRE voting systems
- The NJ election tapes
- “Fleeing voters”: voter who don’t press the “cast my vote” button (Eight Clay County, KY)
- Cuyahoga, OH: none of the vote-tallying counts agreed
- NC: a 12-bit counter overflowed in a large precinct
- Many more...

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## Counting Software is Also Buggy

- Bernalillo County, NM: in-person voters used DRE machines; absentee ballots used optical mark cards
- On Election Day in 2000, the absentee ballots appeared to go for Gore
- That was odd—in that jurisdiction, absentee ballots tend to skew Republican
- The problem: the counting program didn't handle the “straight ticket” option
- The elections supervisor: the software was buggy
- The vendor: he programmed it incorrectly

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## Why Use DRE Machines?

- They're cheaper and mechanically more reliable
- Blind voters can cast ballots without assistance
- Other handicaps are also more easily accommodated
- They report results very quickly

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## Blind Voters

- With paper ballots or level machines, blind voters need assistance to vote
- Loss of secrecy
- Loss of dignity
- DRE machines can provide audio output
- But—are the risks worth it?

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## Evaluations

- To my knowledge, *every* independent evaluation of DRE machines has found serious flaws
- Bad crypto, poor design, no voter privacy, buggy software, susceptibility to viruses, and more
- California even decertified many

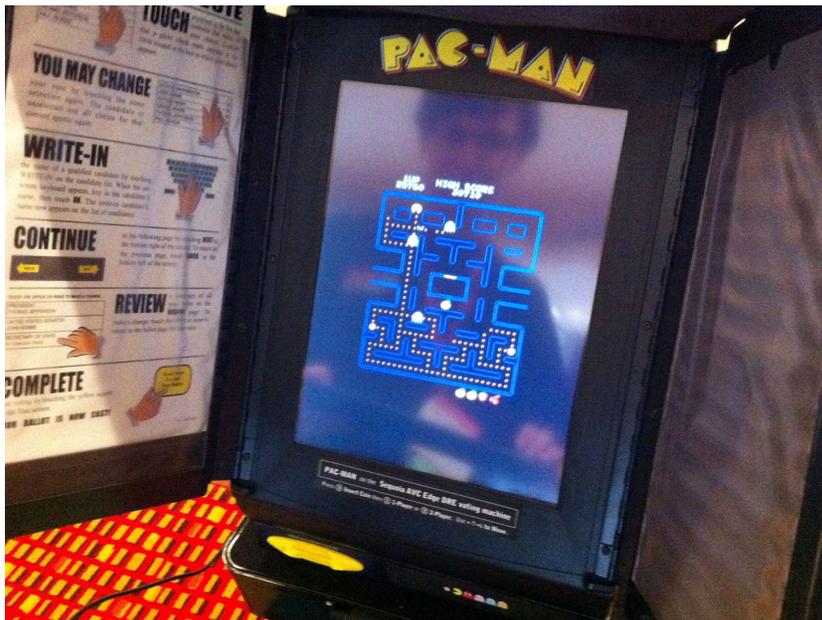
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## Physical Security

- If voting equipment isn't properly safeguarded, tampering can occur
- *Chain of custody must be maintained throughout the election process*
- Paper ballot boxes can be stuffed, before, during, or after voting
- Tamper with the gears and cams on mechanical machines
- Reprogram electronic voting machines
- There are supposed to be security seals, but they're easy to bypass
- 👉 It's much easier to introduce subtle, unauditible flaws

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# Pacman!



(Photo courtesy Alex Halderman)

- These machines are generally have their programming on a compact flash card
- There's supposed to be a security seal—but those are easy to bypass
- Alex Halderman and his students reprogrammed a voting machine to be a Pacman game
- <https://www.youtube.com/watch?v=TpMDCArDzWA>

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## Pre-Election Voting Machine Storage, Princeton, 2008



(Photos courtesy Ed Felten)

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## Current Standards

- Most places are moving to optical mark ballots that are scanned immediately
- Voters can verify that their ballots were read correctly, and there are pieces of paper for hand recounts
- But: do voters actually check the scan results? Not really. . .

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## Other Ideas

- Internet voting
- Cryptographically verified voting

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## Internet Voting

- It's software, with all that implies
- It's running on ordinary PCs with ordinary Web browsers
- (Washington, DC, ran a trial election that way, and challenged people to break it. Halderman and his students made it play the U. Michigan fight song when people cast ballots.)
- Imagine an electoral virus
- Imagine one written by a country that wanted to influence another country's elections
- What about authentication? Coercion? Usability?

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## Cryptographic Schemes

- Use fancy cryptography to cast and tally votes
- Anyone can look at the published (cryptographic) vote totals and verify that their vote was counted
- No one else can tell who voted for whom
- But—it's still all done with software

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## We Can Build ATMs; What's Different About Voting?

- ATMs have audit logs, cameras, etc.—but for voting, we need privacy
- Consumers get bank statements—but there's no receipt for your votes
- 👉 In some states, it's illegal to make a copy of your ballot
- Transactions can be checked and (if necessary) rolled back—but we rarely rerun elections
- Banks will spend more money than elections boards will. . .

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# No Proof of Voting—New Hampshire

## CHAPTER 659 ELECTION PROCEDURE

### Prohibited Acts

#### Section 659:35

##### **659:35 Showing or Specially Marking Ballot. –**

I. No voter shall allow his or her ballot to be seen by any person with the intention of letting it be known how he or she is about to vote or how he or she has voted except as provided in RSA 659:20. This prohibition shall include taking a digital image or photograph of his or her marked ballot and distributing or sharing the image via social media or by any other means.

II. No voter shall place a distinguishing mark upon his or her ballot nor write in any name as the candidate of his or her choice with the intention of thereby placing a distinguishing mark upon the ballot.

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## Virginia Decertifies AVS WinVote DRE Machines

- Runs Windows XP Embedded, but with no patches since 2004
- (The system was too old for some standard security tools!)
- Uses WiFi with WEP—and an unchangeable password of “abcde”, and you can’t disable WiFi without disabling the voting software
- Lots of ports open—including disk-sharing. It’s a WiFi file server!
- Administrator password hardwired to “admin”
- The database password is hardwired to “shoup”, the previous company name
- The USB ports are only marginally protected

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## Supply Chain Attacks

- Election boards don't write their own software, they buy it
- Don't go after the election boards' computers, go after their suppliers
- More bang for the buck for attackers—penetrate many counties with one attack

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## What are the Issues?

- Complex software, but low budgets
- Many different jurisdictions with many different sets of rules—and hence lots of code complexity and options to hand this.
- (Example: are straight party tickets supported? Straight tickets with exceptions? How does the election supervisor configure the machines?)
- Little or no opportunity to correct errors
- Typical software issues, only worse. . .

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## Conclusions

- With current technology, DRE machines are not nearly good enough
- We need a voter-verifiable audit trail
- We also need one that people will actually check
- The security and correctness of a voting system is a systems problem: you have to get them all right
- Very few security or software engineering people have any confidence in today's electronic voting systems

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## In Other Words...

- Computer security technology is not good enough
- Most—but not all—jurisdictions realize this and are moving away from computerized voting machines
- However, back-end systems are heavily computer-dependent—and will likely remain so, because it's a classic data processing problem
- Security is a *systems* problem