BRENNAN CENTER FOR JUSTICE

AMERICA'S VOTING MACHINES AT RISK

Lawrence Norden and Christopher Famighetti

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Interviews

The Brennan Center interviewed more than 30 state and 80 local election officials in the process of writing this report. When possible, we spoke with election officials over the phone. In some cases, election officials provided written responses to our questions by email. We conducted interviews in the first half of 2015 and the information cited from these interviews is current as of July 2015.

The Brennan Center also interviewed dozens of experts in election technology, administration, and security. We spoke to computer scientists, policy analysts, usability experts, election security experts, voting equipment vendors, and various innovators in the field of election technology. Interviews with experts provided critical perspectives on the limitations of our current voting equipment and the potential for innovation in future election technology. The information cited from these interviews is also current as of July 2015.

Finally, the Brennan Center reviewed scores of news reports, press releases, legislation, meeting minutes, and other publicy available materials to identify local election officials with plans or intensions to purchase new voting equipment. We also consulted academic articles, government reports, and policy literature specific to the field of voting technology to inform and support the analysis provided in this report.

Use of Verified Voting Data

The Brennan Center consulted publicly available information on Verified Voting's website to identify the model and manufacturer of the machines used by jurisdictions. Information from Verified Voting's data underlie our analysis of: (1) states using voting machines that are no longer manufactured, (2) states using DREs as the primary polling place voting equipment, and (3) states where machines will be at least 10 years old in 2016. In the case of the last point, Verified Voting provided the Brennan Center with data showing the voting machines used by jurisdictions in 2006. The Brennan Center compared this information to Verified Voting's most recent data from 2015 to estimate the age of machines used across the country. In cases where we note that states use machines more than 15 or 20 years old, the information was gathered from our interview process, not Verified Voting.

GLOSSARY OF TERMS

Commercial Off The Shelf (COTS): In this report, COTS specifically refers to hardware that can be purchased commercially, such as an iPad or Android, and used as part of a voting system.

Direct Recording Electronic (DRE): A voting machine, that electronically stores votes, and on which voters use interfaces (pushbutton, touchscreen, or dial) to record their votes. The votes are stored in a memory cartridge, diskette, or smart card and added to the votes of all other voters. DREs are used in polling places in jurisdictions in 30 states. [1]

Election Assistance Commission (EAC): A federal commission that was established by the Help America Vote Act of 2002 (HAVA). EAC is an independent, bipartisan commission charged with developing guidance to meet HAVA requirements, adopting voting system standards, and serving as a national clearinghouse of information on election administration. EAC also accredits testing laboratories and certifies voting systems.

Help America Vote Act (HAVA): An act passed by the United States Congress in 2002 to reform the nation's voting processes and procedures. HAVA required improvements to voting systems and voter access following the 2000 election. HAVA mandated that states create statewide voter registration databases, allow for provisional voting, and upgrade voting equipment, among other requirements.

Optical Scan: A voting system in which voters mark paper ballots that are counted by scanner devices. Voters generally indicate their selections by filling in an oval, completing an arrow, or filling in a box. [2]

PCOS (Precinct Count Optical Scan): PCOS units are optical scan voting machines that are specifically designed and used for precinct-based vote tabulation. PCOS units are used in polling places in jurisdictions in 40 states. [3]

Personal Computer Memory Card International Association (PCMCIA) card: A computer memory expansion and storage device — a precursor to USB memory storage devices, such as "thumb drives."

Presidential Commission on Election Administration (PCEA): A bipartisan commission established by President Obama in March 2013. The PCEA's mission was to identify best practices to promote efficient election administration and to make recommendations to improve the voting experience. In January 2014, the PCEA submitted its report calling for expansion of online voter registration, expansion of early voting, modernization of polling place management, and reformation of the certification process for voting technology, among other recommendations.

Risk-limiting audits: A risk-limiting audit is a type of post-election audit, during which a random sample of ballots is selected and the selections on the ballots are compared to the electronic "cast vote record" inside a voting machine. In a decisive contest, a small sample of ballots can be audited, while a close race will require a comparatively larger sample.

Technical Guidelines Development Committee (TGDC): A committee of election officials, computer scientists, and other experts that assists the EAC in developing the Voluntary Voting System Guidelines (VVSG). The chairperson of the TGDC is the director of the National Institute of Standards and Technology (NIST).

Voluntary Voting System Guidelines (VVSG): A set of requirements and specifications that are used to test and evaluate the quality of voting systems. Machines are tested to meet the VVSG as a quality assurance measure. The VVSG tests machines to make sure they meet requirements in a number of categories, including but not limited to functionality, accessibility, and security. HAVA requires that the EAC periodically update the VVSG.

EXECUTIVE SUMMARY

In January 2014, the bipartisan Presidential Commission on Election Administration (PCEA) issued a stern warning that should be of grave concern to all Americans: There is an "impending crisis … from the widespread wearing out of voting machines purchased a decade ago. … Jurisdictions do not have the money to purchase new machines, and legal and market constraints prevent the development of machines they would want even if they had funds."[4]

This report, nearly two years later, documents in detail the extent of the problem and the steps we must take in the coming years to address it. Over the past 10 months, the Brennan Center surveyed more than 100 specialists familiar with voting technology, including voting machine vendors, independent technology experts, and election officials in all 50 states. In addition, we reviewed scores of public documents to quantify in greater detail the extent of the crisis. We explore the current challenge in three parts: (1) the danger, looking at the age of machines around the country relative to their expected lifespans and the problems that we can expect; (2) the new technologies that can help solve the problem going forward; and (3) recommended solutions to the impending crisis.

Among our key findings:

- Unlike voting machines used in past eras, today's systems were not designed to last for decades. In part this is due to the pace of technological change. No one expects a laptop to last for 10 years. And although today's machines debuted at the beginning of this century, many were designed and engineered in the 1990s.

- While it is impossible to say how long any particular machine will last, experts agree that for those purchased since 2000, the expected lifespan for the core components of electronic voting machines is between 10 and 20 years, and for most systems it is probably closer to 10 than 20.

  › The majority of machines in use today are either perilously close to or exceed these estimates. Forty-three states are using some machines that will be at least 10 years old in 2016. In most of these states, the majority of election districts are using machines that are at least 10 years old.

  › In 14 states, machines will be 15 or more years old.[5]

  › Nearly every state is using some machines that are no longer manufactured and many election officials struggle to find replacement parts.

- The longer we delay purchasing new equipment, the more problems we risk.

  › The biggest risk is increased failures and crashes, which can lead to long lines and lost votes.

> › Older machines can also have serious security and reliability flaws that are unacceptable today. For example, Virginia recently decertified a voting system used in 24 percent of precincts after finding that an external party could access the machine's wireless features to "record voting data or inject malicious data[.]"[6]

> › Smaller problems can also shake public confidence. Several election officials mentioned "flipped votes" on touch screen machines, where a voter touches the name of one candidate, but the machine registers it as a selection for another.

- Election officials who believe they need to buy new machines do not have sufficient resources.

  > › Election jurisdictions in at least 31 states want to purchase new voting machines in the next five years. Officials from 22 of these states said they did not know where they would get the money to pay for them.

  > › Based upon recent contracts and assessments provided by election officials, the Brennan Center estimates the initial national cost of replacing equipment over the next few years could exceed $1 billion, though that could be partially offset by lower operating costs and better contracts than are currently used in many jurisdictions.

  > › As election jurisdictions diverge in how they respond to the crisis, we see an increasing divide among, and even within, states in the ability to ensure elections can be conducted without system failures and disruption.

  > › A preliminary analysis by the Brennan Center lends support to the concern expressed by some officials that without federal or state funding, wealthier counties will replace aging machines, while poorer counties will be forced to use them far longer than they should.

These are troubling findings, but our study also provides hope for the future. Technology has changed dramatically in the last decade, offering the possibility of machines that are more reliable, more usable, and less expensive. Several recent innovations — often driven by election officials who have worked with vendors, academics, and voters — could point the way to more affordable and flexible 21st century machines.

While such advances may help us in future years, they will not resolve today's crisis. There is no escaping the immediate need to plan and set aside sufficient funds to buy new machines.

INTRODUCTION

Fifteen years after a national election trauma that was caused in significant measure by obsolete voting equipment, the country is faced again with outdated machines that, as a report by Maryland's Department of Legislative Services put it, are "rapidly approaching the end of their lifespan."[7] Louisiana Secretary of State Tom Schedler put it more plainly when speaking before the Louisiana House and Government Affairs Committee: "It's getting a little scary out there."[8]

In interviews with dozens of election officials and independent technology experts, the word "crisis" came up repeatedly. Election Assistance Commissioner Tom Hicks's view was representative: "Our voting equipment is old and past its usefulness. We're getting by with Band-Aids, but I worry about a crisis with some of the older machines."[9]

No one we talked to predicted there will be a vast meltdown of all, or even most, of the nation's voting equipment in 2016. Aging machines do not all fail at once on a single day. But many argued that unless and until equipment is replaced, we will increasingly see problems from aging equipment that have already been occurring more frequently than they should — flipped votes, freezes, shut downs, long lines, and, in the worst case scenarios, lost votes and erroneous tallies.[10] Beth White, the former clerk in Marion County, Indiana, pointed out that even a partial system failure could result in huge problems. "If we even have a 10 percent failure rate on election morning, or 5 percent, that is significant," White told a local TV affiliate. "That is a dramatic administrative challenge for us, and these are the things we're approaching."[11]

It is worth remembering that the machine problems in Florida in 2000 could have gone unnoticed by most Americans had they not happened in an exceptionally close election. In fact, the machine-related flaws revealed on that Election Day (hanging chads, high voter error rates, lost votes) had been problems for years, and were accompanied by warnings from experts and election officials that it was only a matter of time before they caused a catastrophe.[12]

We face an eerily similar situation today. Experts and election officials have again sounded the alarm.

As this report documents, officials in at least 31 states are hoping to purchase and deploy new voting machines in the next five years.[13] *But officials from 22 of those states do not yet know where or whether they will get the money to pay for new machines.*[14]

The jurisdictions looking to deploy new equipment represent approximately 40 million registered voters and their states total 387 of the 538 electoral votes.[15]

In fact, these figures probably underestimate the need for new equipment and overstate the percentage of jurisdictions that have lined up the necessary funding. Many election officials may not be willing to discuss their desire for new machines publicly, for fear of undermining voter confidence. When asked how many jurisdictions would like to purchase new machines, Merle King, executive director for the Center for Election Systems at Kennesaw State University in Georgia, replied simply, "they all would."[16]

It is unclear where the money will come from. As Tammy Patrick, a senior advisor of the Democracy Project with the Bipartisan Policy Center, and former federal compliance officer for the Maricopa County Elections Department in Arizona, put it, "some jurisdictions seem to be saying we're just going to wait until another catastrophe and then maybe Congress will pay for it. This is not a good plan."[17]

The need for new machines presents a rare opportunity to dramatically improve voting. As the National Institute of Standards and Technology (NIST) and the Center for Civic Design noted in their *Roadmap for Usability and Accessibility of Next Generation Elections,*[18] "[R]ecent years have brought changes to the state of the art and technology for voting systems as well as public expectations about how voters will participate in elections." New machines could result in smoother elections and increased confidence in the results. They could make early voting and other innovations easier to implement. And they could result in substantial savings for many jurisdictions that are now tied to expensive service and software licensing contracts.[19]

There is reason to be hopeful about the future of voting technology, but also reason to be extremely concerned that, as has too often been the case in recent decades, we will fail to invest adequately in the nation's democratic infrastructure.

This report will explore that challenge in three parts. First, the danger: We look at the funding crunch for the many election officials who believe they need new equipment, provide a detailed look at the age of equipment, and examine the problems that occur when equipment is not replaced or adequately maintained. Second, the promise: how recent technological breakthroughs could make elections more accessible, secure, and accurate. And third, the solutions: steps policymakers can take to ensure jurisdictions can purchase better systems for less money, and for those who cannot secure funding for new systems as quickly as they would like, how to minimize the risk and impact of failures that disenfranchise voters and shake public confidence on Election Day.

Important Developments at the Election Assistance Commission

While there is no clear path to resolve the election technology crisis, there have been some encouraging developments. Perhaps most importantly, in December 2014 the U.S. Senate finally confirmed three new commissioners to the Election Assistance Commission (EAC), the federal agency charged with establishing testing regimes for new voting systems. Between 2010 and 2014, the EAC did not have a quorum of commissioners to approve new certification guidelines. This made it difficult for some jurisdictions to buy new machines. Within a few months, the EAC approved new voting system certification guidelines, a new program manual for certification and testing, and established a new web-based clearinghouse of sample Request for Proposals for voting equipment.

While the flurry of recent EAC activity is encouraging, serious challenges remain, and the agency should play a critical role in supporting state and local election agencies. In the years to come, the EAC can provide vital support by: (1) helping localities develop plans for buying new voting equipment, (2) providing critical information about problems with existing systems and best practices for maintaining aging equipment, and (3) guiding the direction and quality of the next generation of voting systems.

I. THE DANGER: WHAT CAN HAPPEN IF ANTIQUATED MACHINES ARE NOT MAINTAINED OR REPLACED

To understand how to address the problem of aging voting equipment, it is necessary to understand how we got to the point that so many systems need to be replaced or upgraded at the same time.

On October 29, 2002, President George W. Bush signed the Help America Vote Act (HAVA). HAVA made sweeping changes to the nation's voting process, and was seen as a response to revelations in the 2000 election of serious flaws in the nation's voting systems, voter access, and election administration.[23]

Of course, not least among these flaws were the voting system failures in Florida. HAVA provided states with more than $2 billion to replace obsolete voting equipment, and created new standards for certification.[24] It also established the Election Assistance Commission as an independent agency and charged it with the task of creating a testing program for new voting systems, as well as functioning as a clearinghouse for election administration, among other things. By 2006, "the vast majority of election jurisdictions in the United States purchased and deployed new voting systems."[25]

For better and worse, by providing a huge infusion of money to replace voting equipment in 2002, Congress fundamentally changed the voting machine market, and it did so before new voting system standards or testing programs were in place. Even so, HAVA-era machines are in several ways more accurate and more accessible than the lever and punch card machines that preceded them.[26] At the same time, voting systems have become more complicated, less static, and less durable.[27] The federal government is unlikely to provide another infusion of billions of dollars, but the need to maintain and replace equipment grows.

A. The Lifespan of Current Machines

How old is too old? Is there a particular age when a machine simply becomes too risky to use? There are no simple answers to these questions. There are literally dozens of models of machines in use today,[28] and lifespan is dependent on a number of factors, including the make of the machine, frequency of its use, how often parts are replaced, and the conditions under which the machine is stored and maintained.[29]

Nevertheless, it is possible to make some useful generalizations. Merle King, the executive director for the Center for Election Systems, noted, "Most people think that a voting system — the core voting components — should last between 10 and 20 years."[30] Others, including professor Doug Jones of the University of Iowa, former chair of the Iowa Board for Voting Machines and Electronic Voting Systems, agree this is a reasonable estimate for older systems, but they note that for most systems manufactured and purchased since 2000, the proper lifespan is probably closer to 10 years.[31] "By the late 1990s voting machines started using more laptop computer technology and other commodity hardware that we expect to have a shorter life cycle," Jones said.[32]

These lifespan estimates are consistent with what the Brennan Center heard from vendors about projected lifespans.[33] Where we have been able to find such projections in government documents, they generally do not exceed 10 or 15 years.[34] This of course does not mean that machines do not or cannot last longer with proper maintenance, but these estimates provide a good benchmark for gauging the state of current equipment.

What they tell us is that the majority of systems in use today are either perilously close to or past their expected lifespans. Based on data from Verified Voting and interviews with elections officials in all 50 states, the Brennan Center estimates that in 2016, 43 states will be using machines that were purchased 10 or more years ago.[35] Fourteen states (Alaska, Arizona, Delaware, Florida, Kentucky, Louisiana, Massachusetts, New Hampshire, New Jersey, Rhode Island, Texas, Vermont, Virginia, and Washington) will be using some machines that were purchased more than 15 years ago.[36] The map below assumes that equipment currently used will not be replaced before 2016.

Machines At Least 10 Years Old in 2016

All Machines Purchased Since 2006

Minority of Election Jurisdictions Purchased Machines in 2006 or Earlier

Majority of Election Jurisdictions Purchased Machines in 2006 or Earlier

All Election Jurisdictions Purchased Machines in 2006 or Earlier
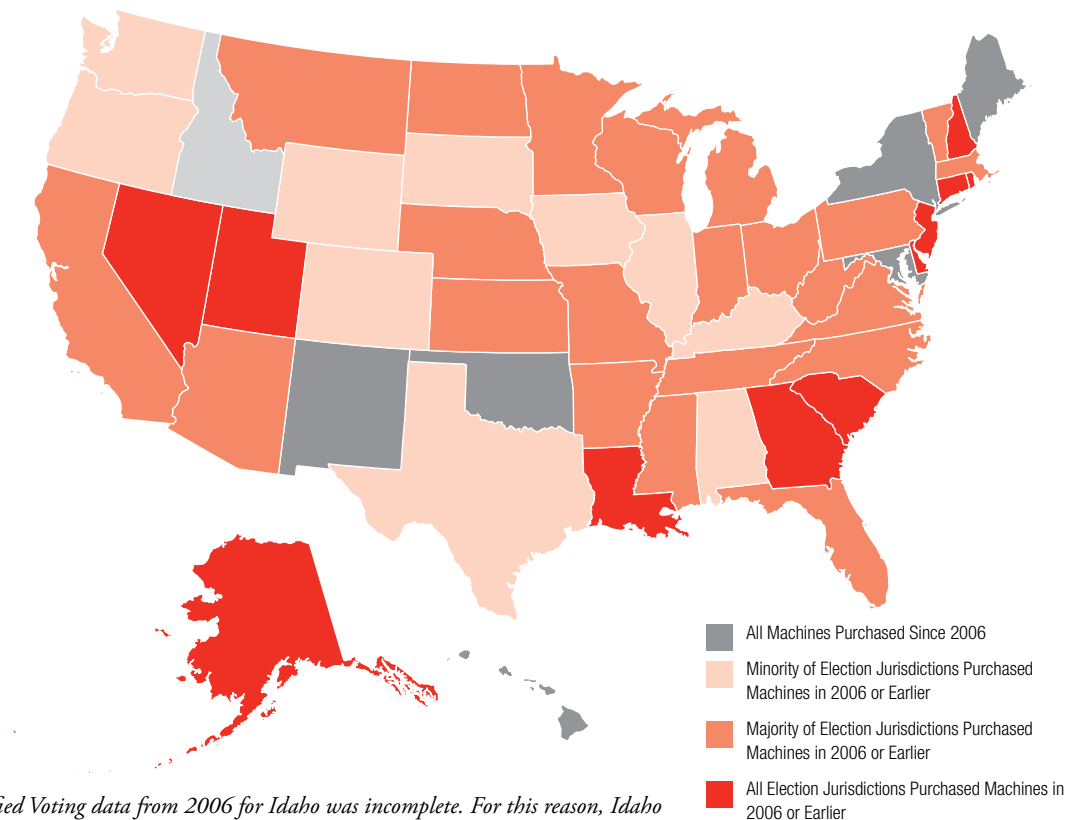
Verified Voting data from 2006 for Idaho was incomplete. For this reason, Idaho is not included in this analysis. In Colorado, Oregon, and Washington, this analysis applies to central count machines for processing mail ballots. Otherwise the analysis applies to polling place equipment.

The director of elections for Pickens County, South Carolina, Rodney Allen, spoke for many election officials when discussing his 10-year-old machines with the *Seneca Daily Journal.* "Can you imagine using a personal computer for [this long]? We properly maintain our equipment for service, and that extends the life, but we're on the final run of the need for new voting machines."[37]

A 2010 report commissioned by the Maryland Department of Legislative Services highlighted the risks of using Maryland's aging machines in future elections and probably helped persuade the legislature to lease new machines for the 2016 election. "Continuing to use the system beyond 2012 comes with increased risk of equipment malfunctioning," the report stated. "The nature and frequency of equipment failure beyond the manufacturer's life expectancy cannot be predicted."[38]

Internet Voting

As election officials face pressure to replace aging technology and make voting easier, many point to online voting as an obvious solution. It would seem to address several problems: eliminating or greatly reducing the cost of purchasing and maintaining polling place machines, making it less burdensome for military and overseas voters to cast ballots, giving many more disabled voters the opportunity to vote privately and independently, and generally making it far easier for nearly anyone with Internet access to vote from home.

And yet, the vast majority of security experts express alarm at the idea.[39] They argue that we have not yet developed the tools to ensure voting over the Internet can be done both privately and securely. David Jefferson, a computer scientist at Lawrence Livermore National Laboratories and chairman of Verified Voting told *Computerworld* that "from a security point of view, [Internet voting] is an insane thing to do."[40] The National Institute of Standards and Technology (the federal body charged with researching Internet voting) published at least two reports that detail the ways votes sent over the Internet can be manipulated without detection, and concluded secure Internet voting is not yet achievable.[41] A senior Department of Homeland Security official recently warned election officials that online voting is premature.[42]

MIT professor Ron Rivest, one of the nation's leading experts in cryptology and voting system security, told *The Hartford Courant* that Internet voting is not secure enough to protect the integrity of elections. "The biggest concern I have about Internet voting is that we don't know how to do it securely," said Rivest, "It sounds wonderful but it's an oxymoron. We don't have the Internet experts who know how to secure big pieces of the Internet from attack."[43]

This deep skepticism, echoed by numerous independent experts who have studied the question, baffles much of the public, including many election officials.[44] Given how many of our daily tasks are done on the Internet, how can this be so hard? If we can bank and buy shoes online, the question goes, why can we not vote online?

In fact, we need only look at the newspaper to understand why Internet voting is not yet prudent. A recent article in *The Washington Post* explained that the original architecture of the Internet, developed in the 1970s, leaves it vulnerable to security breaches.[45] As a result of this vulnerability, nearly every week we learn of federal agencies (including the FBI and CIA), banks, insurance companies, news organizations, and other private businesses that have had their websites and e-mails hacked, sometimes by foreign governments.[46] These institutions spend billions of dollars on cybersecurity[47] — far more than we are likely ever to spend on elections — and they still cannot fully protect themselves from successful attacks from bad actors.

Just recently, Russian hackers accessed President Obama's unclassified e-mails.[48] In the case of national elections, it does not take a great leap of imagination to suppose there are similarly powerful actors who have the motivation to disrupt an Election Day conducted over the Internet, spy on voters, or even attempt to change results. Barbara Simons, voting technology expert and past president of

the Association for Computing Machinery, noted dryly that "the idea that any election official can provide more security for email ballots than is provided for the president is, well, hard to fathom."[49]

Despite these risks, more than 30 states allow some kind of voting by the Internet, primarily for military and overseas voters.[50] Alaska goes even further, allowing any citizen to vote by Internet without excuse, though the state does warn voters "when returning the ballot through the secure online voting solution, you are voluntarily waving [*sic*] your right to a secret ballot and are assuming the risk that a faulty transmission may occur."[51]

There is overwhelming evidence that Internet voting in a national election is currently inadvisable. Nevertheless, election officials report that voters increasingly ask for and expect to vote by the Internet.[52] As these officials continue to be squeezed by the cost of replacing aging voting technology, the battle over Internet voting between vendors and advocates in favor of such systems on the one hand, and election integrity groups and security experts on the other, will likely intensify.

B. The Challenges of Aging Machines

Election officials are often reluctant to talk about problems with voting systems. Publicly complaining about such problems risks undermining voter confidence and depressing turnout. As Tammy Patrick of the Bipartisan Policy Center put it, "Election officials are in a difficult position ... they don't want to cause a panic. Voters need to have confidence in the system throughout."[53] Lori Edwards, supervisor of elections in Polk County, Florida, echoed this sentiment when speaking with *USA Today*. "If I thought people's attention would help the problem, I might be making more of a stir down that avenue," she said. "Just by instinct, election officials know it's a big part of their job to maintain confidence."[54] Despite this fear, we have found many election officials are speaking publicly and forcefully about the problems of aging machines, and their concerns about what might happen if machines are not replaced soon. "We need to be honest with policymakers," said Edgardo Cortes, commissioner of elections in Virginia. "There is a tradeoff. They need to know if you don't replace equipment there will be repercussions."[55]

Just last year, Florida Secretary of State Ken Detzner, estimated that 30 of Florida's 67 counties should replace voting equipment before the 2016 election. When speaking with the *Sun-Sentinel*, Detzner said, "It's kind of one of those things that you don't think about until something happens […] We know we need to do something […] Some of the equipment is old, some as old as 10 years old. And we'll be evaluating that, working with the supervisors and their local county commission to make sure they get funded in preparation for 2016."[56] In the course of writing this report, the Brennan Center spoke with election officials who identified 12 Florida counties that have plans to replace machines before the 2016 election.[57] The Florida Department of State did not respond to requests for a complete list of counties that will have new machines for the 2016 election.

The top election official in Ohio, Secretary of State Jon Husted, echoed these concerns in testimony before the PCEA, stating that 10 years after HAVA, "…machines are aging, they need maintenance and, at some point, will need to be replaced. The next time we go to the polls to elect a president, these machines will be 12 years old. That's a lifetime when it comes to technology." [58]

Lori Edwards — the supervisor of elections in Polk County, Florida — expressed similar concerns. "It's something I'm kind of facing every day," she told *USA Today*. "The equipment is going to start breaking down I feel like I'm driving around in a 10-year-old Ford Taurus and it's fine and it's getting the job done, but one of these days it's not going to wake up."[59]

Ultimately, the election official's greatest fear is that equipment failures undermine confidence in election results. As Bob Nichols, an election director for Jackson County, Missouri, put it to *The Kansas City Star*, "We're just really concerned […] Going into a presidential election year with old equipment — we don't want to be another Florida."[60]

But the challenges of using antiquated equipment are more complicated than simply having a machine that might not work on Election Day. Below we detail three of the most common concerns election officials told us they had with continuing to use old machines: (1) the failure of equipment to work as intended, (2) an inability to connect voting machines to current computers because the software is unsupported and outdated, and (3) difficulty finding replacement parts for machines that are no longer manufactured.

1. *Recent Failures and Vulnerabilities Related to Age*

We already know in some detail what kinds of problems are associated with continuing to use antiquated voting systems. As Barbara Simons, an expert on electronic voting and past president of the Association for Computing Machinery noted, "We know that a lot of machines were breaking in the 2012 election. It's not that it's an impending crisis. The crisis is already here."[61]

After years of wear and tear, machine parts like motherboards, memory cards, and touch screens can fail. When this happens on Election Day, voters can be forced to wait in line while repairs are made or machines replaced.[62]

The most recent high-profile example of the increased vulnerabilities of older machines occurred in Virginia. Following reports of machines crashing during the 2014 election, the Virginia State Board of Elections enlisted experts to conduct a post-election review. Investigators found that the WinVote, a Wi-Fi enabled machine that was not EAC certified, had serious security vulnerabilities.[63]

In particular, investigators found that wireless cards on the voting systems could allow "an external party to access the [machine] and modify the data [on the machine] without notice from a nearby location." They added that "an attacker could join the wireless ad-hoc network, record voting data or inject malicious [data.]"[64] The WinVote dates back to the early 2000s, when Wi-Fi encryption standards were significantly weaker.[65] EAC Commissioner Matt Masterson said the WinVote system was never certified by the EAC's

testing program. "Virginia found out they have issues with the WinVote system. What would that system have looked like if the EAC had tested the WinVote? It would have never passed federal certification today."[66] The findings startled Virginia election officials and led the State Board to decertify the WinVote.[67] As a result of the Board's action, 30 Virginia localities must purchase and deploy new machines.[68]

The Virginia Board also investigated problems with a different touch screen machine, the AccuVote TSX, which is used in some form in 20 other states.[69] In 2014, voters in Virginia Beach observed that when they selected one candidate, the machine would register their selection for a different candidate. This issue, the result of an "alignment problem," affected 26 Virginia Beach machines.[70] Jack Cobb, the laboratory director at Pro V&V — a federally accredited voting test system laboratory — told us that a coating on the edge of the touch screen "slowly degrades" the glue that holds the screen in place.[71] As a result, the touch screen can slip out of place, and register votes incorrectly. "It just so happens that there were thousands of AccuVote TSXs produced, and some portion of these machines has this problem," Cobb told us.[72]

Virginia is not alone. Election officials told us they struggle to keep aging voting machines operable. In Oakland County, Michigan, Director of Elections Joe Rozell told the Brennan Center his optical scan units are having increasing problems as they age. "We have had motherboards go down — in essence the voting machine just stops working on Election Day because the motherboard is dead. The memory cards are going bad […] this delays tabulation and makes second chance voting impossible."[73]

Other elections officials must improvise to keep old machines running. Neal Kelley, registrar in Orange County, California, took unusual measures to maintain his decade-old voting machines. When the wiring in his direct-recording electronic (DRE) machines started to fail, Kelley replaced "cable connections" in 11,000 machines with military grade hardware. When speaking with *USA Today* in 2014, Kelley stated, "If we did nothing to continue ongoing maintenance with the system, realistically, we shouldn't be fielding it in the 2016 cycle." The *USA Today* article also noted that the county was purchasing voting machines to "cannibalize for extra parts," which Kelley remarked "can probably extend our life cycle to 2018."[74]

For computerized DRE machines that do not require a voter to use a paper ballot, touch screen and other failures can be especially problematic. Jeremy Epstein, a voting systems expert and computer scientist at SRI International, notes jurisdictions using these systems need to take extra precautions in case of a machine shutdown. Unlike jurisdictions that use paper ballots that are later scanned (either in the polling place or at a central location), voters in jurisdictions that use a DRE as their primary machine will not be able to vote until the machines are replaced or voters are provided with emergency paper ballots.[75]

Touch screen machines are vulnerable to "calibration" problems, sometimes referred to as "vote flipping." Similar to alignment errors, calibration errors can cause machines to register voters' choices for the wrong candidate. In recent elections, voters uploaded videos of this vote flipping to the Internet and they went viral.[76] EAC Commissioner Matt Masterson stated that calibration errors become more frequent as machines age. "Most of the time the problem with touch screen units is a calibration issue. A touchscreen is three pieces of plastic layered over each other, the casing that holds those will loosen and that leads to calibration problems — that is going to happen with aging units."[77] Masterson also noted that election

officials have become familiar with this issue and have learned to pull machines out of service and recalibrate them when it happens.[78] In the past two federal elections, news outlets documented calibration errors in Colorado, Illinois, Maryland, Nevada, North Carolina, Ohio, Pennsylvania, Texas, and Virginia.[79]

Memory cards, used to transfer critical election data, including results, are susceptible to more errors as they age, regardless of type of voting system. Maggie Toulouse Oliver, the county clerk in Bernalillo County, New Mexico, told us how scanners her county purchased in 2006 saw increasing problems as they reached the seven-year mark. "As the machines got older, they had more and more functionality issues. In particular there was a high failure rate for memory cards. It got so bad that we had to replace one-third of machines in every election."[80] Of course, taking one in three machines out of service in an election can create many problems, including long lines, and a loss of public confidence in the technology. Because of issues such as these, New Mexico spent $12 million in 2014 on new machines for the entire state.[81]

To avoid catastrophe on Election Day, elections officials must replace memory cards on a regular basis. Ken Terry, director of the Allen County, Ohio Board of Elections, said that his voting machines use memory cards that are both antiquated and expensive. "[Our machines] use PCMCIA cards — these cards […] cost $100 each to replace and they can only store 512 kilobytes."[82] Other officials told us that they have had trouble finding PCMCIA cards for their machines.[83] The $100 price of PCMCIA cards is exorbitant by today's standards. Today's memory storage devices are drastically cheaper: A 16 gigabyte USB drive costs $7 or $8 and provides roughly 30,000 times the memory as a 512 kilobyte PCMCIA card.

As systems age, the commercially produced parts that support them, like memory storage devices, printer ribbons, and modems for transmitting election results, go out of production. Several election officials told us they have used eBay to find these parts.[84] Mark Earley, voting systems manager in Leon County, Florida, told us his old voting system used an analog modem that he could only find on eBay. "The biggest problem was finding modems for our old machines. I had to buy a modem model called the Zoom Pocket Modem on eBay because they weren't available elsewhere."[85] Earley told us that the Zoom Pocket Modem can transmit data at just kilobytes per second, making it utterly obsolete by today's standards.[86]

Ken Terry, from Allen County, Ohio, told us that he feels like he is living in a technological time warp. When he ordered "Zip Disks" for his central tabulator, the package included literature that was more than a decade old. "When we purchased new Zip Disks in 2012, they had a coupon in the package that expired in 1999."[87]

"The equipment is going to start breaking down. I feel like I'm driving around in a 10-year-old Ford Taurus and it's fine and it's getting the job done, but one of these days it's not going to wake up."
— Lori Edwards, Polk County (Florida) Supervisor of Elections

2. Running Systems on Outdated Software

Election officials in California, Georgia, Michigan, Minnesota, Ohio, and Washington told us they use voting systems that rely on outdated software.[88] As time passes, software that is out of date today will only get older, and the hardware designed to work with it scarcer. Jeremy Epstein of SRI International notes that this can be a huge problem, as jurisdictions cannot replace critical hardware that is failing because their software will not run on it. Moreover, "from a security perspective, old software is riskier, because new methods of attack are constantly being developed, and older software is likely to be vulnerable."[89]

Ryan Macias, voting system analyst at the California Secretary of State's Office, said voting systems using outdated software are common in his state. "Almost all California jurisdictions are using Windows XP or earlier. We even have jurisdictions that are still on Windows 2000 — being able to purchase a server or getting licenses for commercial-off-the-shelf (COTS) hardware that works in conjunction with those operating systems is difficult or impossible, and the supplies are running thin."[90]

Sherry Poland, director of elections in Hamilton County, Ohio, built a war chest of obsolete hardware to keep her system running. "There is a point where you cannot purchase computers that will run on the outdated operating system […] We have stockpiled older PCs that will run on Windows XP. We need backups so we can maintain the current system through 2018."[91]

Georgia developed a long-term strategy to maintain its system, which depends on Windows 2000. Merle King, the director of the Center for Election Systems, told us Georgia hired a contractor to custom design hardware that will work with Windows 2000. "In Georgia, we looked at the issues running Windows 2000 Service Pack 4 and we contracted with a company to custom build a server for us — we have about 170 of these servers. We would order them in blocks of 40 or 80 units so that we could continue to run the Windows 2000 operating systems that we use to run our election management system."[92]

3. Difficulty Finding Replacement Parts When Machine Models Have Been Discontinued

The problem of maintaining machines is particularly challenging (and worrying) in the many jurisdictions that use machine models that are no longer produced. Using data provided by Verified Voting and information gathered from interviews with voting machine vendors, the Brennan Center estimates that 43 states and the District of Columbia are using voting machines that are no longer manufactured.[93] While some states like Georgia and South Carolina

use one discontinued model for the entire state, others states, such as Virginia and North Carolina, are home to jurisdictions using several different models.[94] Multiple election officials using such machines told us of difficulties they have finding replacement parts. Others expressed fears about how much longer they will be able to find parts and technicians.[95] As Virginia Elections Commissioner Edgardo Cortes put it, "finding replacement parts for some of the old machines is not even possible."[96]

States Using Primary Polling Place Machines That Are No Longer Manufactured

■ Machines Currently Manufactured

■ Entire State Using One Model No Longer Manufactured

■ Jurisdictions Using One or More Models No Longer Manufactured
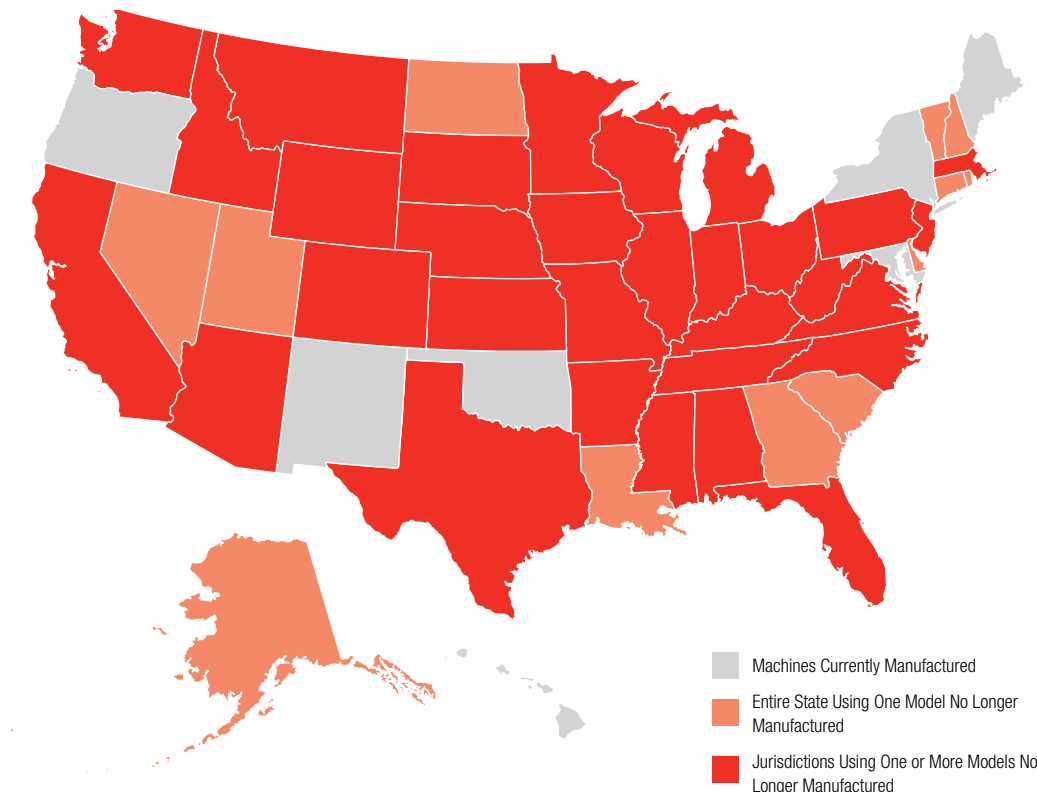
Local elections officials echoed Cortes. Brad Nelson, the head of elections in Pima County, Arizona, told us he replaced his machines because parts became difficult to find. "The equipment was becoming undependable on a level of maintenance. We had a system that was beginning to fail, but there were no parts to keep it running."[97]

Local election officials using discontinued machines are uncertain how long they can keep their systems running. Marion County, Indiana, purchased its optical scan machines in 2002. Brienne Delaney, the director of elections, worries spare parts for her scanners will be unavailable. "Our concern is that in the future we won't be able to maintain [the machines] at all, that the replacement parts will become obsolete."[98]

Officials in Rhode Island also stated that finding parts for aging machines is difficult. When testifying

before the Rhode Island House, Robert Kando, executive director of the Rhode Island Board of Elections, said parts for his nearly 20-year-old precinct-count optical scan units (PCOS) were hard to find. Kando told the Rhode Island House Committee on Oversight the machine parts were becoming difficult to find and the machines were experiencing more problems, like paper jams, when scanning longer ballots.[99]

How can election officials make sure they will have enough parts to keep their machines running? Some officials told us they are hoarding scarce parts so they do not run out of supplies. Neal Kelley, the registrar of voters in Orange County, California, said there is a finite supply of available machine parts for his voting system. "What I have been doing is gobble up as many parts as I can. […] There are all kinds of moving parts in the printer that are not being supported anymore. Right now we are relying on the back stock of inventory."[100]

But the inventory of parts cannot last forever. Howard Cramer, executive vice president for government affairs at Dominion Voting, said for some machines the only parts available are those in other machines. "In many cases, the only way to get parts for some products is by parting out other similar products. For instance, a county will upgrade to a new system and sell the old machines — a vendor might buy that inventory, take the devices apart, inventory those used parts, and use them in a support role."[101]

C. Lack of Funding for New Equipment

As already discussed, with billions of dollars in federal funding from HAVA, Congress fundamentally changed the market for voting machines. It did so without much thought as to who would make future payments. The next bill is now coming due. The Brennan Center estimates it could cost well over $1 billion to replace all of the voting machines that should be replaced in the next few years.[102] In fact, as Merle King noted, this is probably a conservative estimate. "Because of the interconnectivity between the voting [machine] and other election systems, replacing a voting [machine] will require replacement of incompatible […] systems." As an example, he noted that replacing a DRE system that uses ePollBooks to activate voter access cards "will require the replacement of the ePollBook system, which may in turn require modification of the voter registration system."[103]

While some jurisdictions will have remaining HAVA money to purchase new machines, most will not have nearly enough. As of September 2013, 34 states had less than 20 percent of their HAVA disbursements remaining, and 24 states had less than 10 percent.[104] Even in some states that have more HAVA funds, those funds are often already earmarked for ongoing maintenance and operating costs.[105]

Meanwhile, many state legislators and county bodies responsible for funding new equipment do not appear to see the looming crisis as a matter of great urgency, and have rejected the idea that they should be responsible for the increased costs associated with greater maintenance and new purchases. In fact, while nearly every state and county election office looking to purchase machines will need an infusion of cash, many state agencies have instead seen their budgets cut or raised concerns about future funding.[106]

On the EAC blog, Commissioner Matt Masterson wrote that too many local election officials cannot

convince their elected officials to appropriate the funds for new machines. "At a recent Election Center conference, a Florida election official asked [...] 'How can you help us train our funders?'" Masterson wrote. "She pointed out that one funder suggested that the only way they could draw attention to the voting equipment issue in order to get funding was to have something go wrong during an election."[107]

William Anthony, director of elections in Franklin County, Ohio, characterized the problem succinctly: "The problem is money. Until we figure out how to pay for new machines, the problem will always be money."[108] As of September 2013, Ohio had $3.6 million in HAVA funds remaining, just 2.5 percent of the $143 million it received.[109] EAC Chair Christy McCormick echoed this: "The funding is a problem — there is no question about that."[110]

Over the past few years many states slashed election budgets. These cuts leave election agencies on their own to pay for new voting systems. Election officials from 22 states told us they do not know how they will pay for new machines.[111] Since 2011, the Ohio Secretary of State's Office saw its staff reduced by more than 20 percent.[112] Lawmakers in Virginia made drastic cuts to the State Department of Election's budget, leading to a 10 percent reduction in staff during the last fiscal year.[113] Counties have also faced budget cuts. Ken Terry, Director of the Allen County, Ohio Board of Elections told us that cuts to the state budget have trickled down to his office. "In Ohio, in addition to all the budget problems that everyone is having at the local level, the state government cut local government budgets, which has made the problem even worse."[114]

States with Jurisdictions That Report Looking for New Machines

Unfortunately, many state and local policymakers — who never before had to provide significant

Legend:
- No Jurisdiction Reported Looking For New Machines
- At Least One Jurisdiction Replacing Machines, Less Than 100,000 Registered Voters
- At Least One Jurisdiction Replacing Machines, 100,000 or More Registered Voters
- Statewide Law or Initiative to Replace Machines
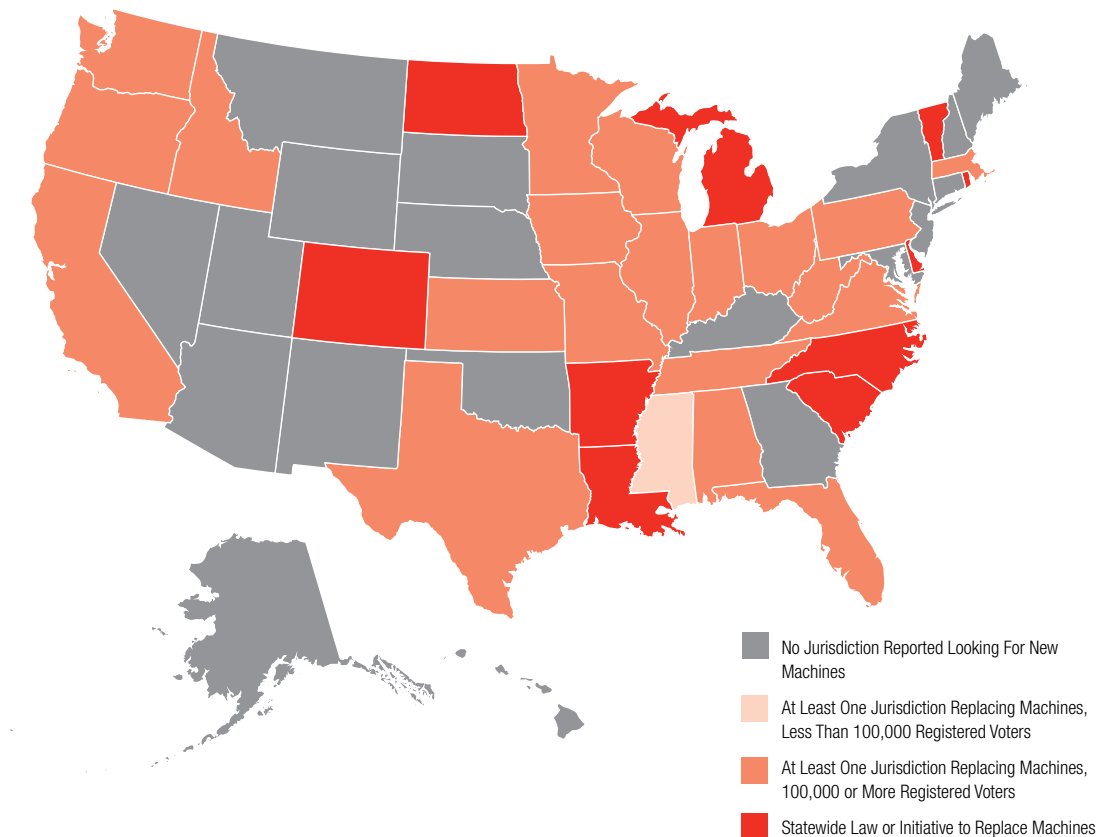
funding for voting machines, and who have other competing needs to address — have not accepted the new reality. Edgardo Cortes of Virginia noted that many legislators treat elections differently than they would nearly any other government function: "We don't ask the fire department to wait until the truck breaks down before they can ask for a new vehicle. We need to think about a replacement cycle for machines."[115]

Virginia provides a recent example of how difficult it can be to convince policymakers they need to invest in new equipment. In December 2014, Gov. Terry McAuliffe proposed that Virginia spend $28 million to replace aging voting machines. When McAuliffe, a Democrat, announced the proposal, GOP Rep. Scott Rigell was by his side.[116] Despite the bipartisan announcement, Virginia lawmakers stripped the funding for new machines from the budget.[117] The spokesperson for Speaker William J. Howell told the *Daily Press* that paying for new machines was a "local prerogative."[118]

As states adopt different policies, there will be a division between those states that fund new systems and those that continue to use aging machines. Furthermore, within the states that will not provide money for new machines, only some counties will have the funds to purchase them. As Cortes said, "In Virginia, you can already see what will happen if the state doesn't provide money for new machines. Loudon and Fairfax counties — two of the largest and wealthiest in the state — have bought new equipment. Smaller, poorer, and more rural counties around the state are going to have a tough time."[119]

A preliminary analysis by the Brennan Center supports Cortes's contention. In Virginia, prior to the decertification of the WinVote machine in April 2015 (which forced many counties — rich and poor — to purchase or lease new equipment), the median income of the 16 election jurisdictions that had recently replaced aging equipment was $69,800. By contrast, the median income of the remaining election jurisdictions that had not made purchases was $50,100.[120] Using data provided by Verified Voting and other sources, we found a similar pattern in other states.[121]

Voting machines are just one of many infrastructure needs for cash-strapped municipalities. "For some counties, they are concerned about the expense of buying new machines, especially counties with fewer resources that have other priorities on their list," Michael Belarmino, associate legislative director at the National Association of Counties (NACO) told us. "There are competing interests when it comes to who or what priorities get funding. I think that the revenue side is also adding some of the pressure, from the county perspective, really there are some that are still trying to dig back out after the recession."[122]

Voting Machines and the Future of Accessibility

One of the promises of HAVA when it was passed was that voting machines throughout the country would be "accessible for individuals with disabilities, including nonvisual accessibility for the blind and visually impaired, in a manner that provides the same opportunity for access and participation (including privacy and independence) as for other voters" as required by the new law.[123] While there is no question the new requirements made it easier for many voters with disabilities to vote privately and independently for the first time, in many respects the new equipment failed to live up to expectations. Diane Golden, an expert on assistive technology, wrote that there is substantial evidence that "voters with disabilities have significant difficulty using [these] accessible voting systems."[124]

Part of the reason HAVA-era systems are not as simple to use as many had hoped is accessible features were "an afterthought" for previously designed systems, according to Whitney Quesenbery, one of the authors of the *Roadmap for Usability and Accessibility of Next Generation Elections* (the "*Roadmap*") and co-director of the Center for Civic Design.[125]

States and counties looking to purchase new equipment have an opportunity to correct for this, and to take advantage of the dramatic improvements in assistive technology,[126] by purchasing machines that have been designed from the start with accessibility as a consideration. As the authors of the *Roadmap* note, "voting systems that are designed with accessibility and usability practices in mind have the potential to greatly benefit voters with and without disabilities." In particular, the authors stress, "creating a single system to be used by all voters ensures that accessibility options are available to all who may need them, even if they do not identify as having a disability."[127]

II. THE PROMISE: WHAT COULD BE

Technology has changed dramatically in the last decade. EAC commissioner Matt Masterson noted that most voting machines in use today predate the first iPhone by three years.[128] More to the point, as noted by Dana Chisnell, director of the Center for Civic Design and a visiting scientist at MIT, the technology in voting machines is even older than their age would suggest. While jurisdictions "*bought* these systems 10, 12, or 15 years ago […] they were designed and engineered in the 1990s."[129]

Old technology is not only dangerous because it can fail. Older machines will often contain security and accessibility flaws that are no longer acceptable. Just as importantly, because this older technology does not reflect voters' experience with technology in daily life, it can lead to an erosion of confidence in the system. Chisnell noted, "effectively, [the machines in use today] are PCs built with components, including storage and memory, that were designed for a very different world that had fewer security concerns and weaker engineering, in general. In addition, user interfaces were designed without the benefit of everything we knew in the private sector by 2000 about how people interact with computers."[130]

Ask election officials what they would like in new machines, and you do not get a single answer. But important themes emerge.

Many officials would like to use systems that employ commercial-off-the-shelf (COTS) hardware — such as an iPad or Android tablet — as a "digital ballot-marking device."[131] Voters could combine these touch screen products with COTS printers that produce a paper ballot for the voter to review. The voter could then submit this "paper ballot" into a scanner, which both tabulates ballots and stores an image of the ballot.

Such a system would have many advantages. First, commercial tablets and printers are far cheaper than current voting machines.[132] Mass-produced commercial products can be easily and cheaply replaced. Election officials and voters would have the added benefit of paper records to verify vote totals, without the expense of specially printed paper.

This type of voting system could offer increased flexibility to election officials. Voting on a tablet would make it easier to implement changes to election law at minimal cost. Tablets could easily provide the multiple ballot styles required by vote centers, and could accommodate early voting and ranked choice voting.

Election officials, technologists, and vendors have floated the idea of "pre-voting," where a voter could download an application on their phone and pre-mark a ballot.[133] The voter would then bring their phone to the polling place and transfer the pre-marked ballot to the voting tablet. Conceivably, voters could transfer pre-marked ballots by scanning a quick response (QR) code, much like an airline e-ticket. Security experts caution that before implementing such technology, election officials must make sure proper security measures are in place.[134]

New technologies can also make post-election auditing easier, cheaper, and more reliable. New approaches to auditing, such as "risk-limiting audits," can confirm election results at a high probability by sampling just a few ballots.[135] Risk-limiting audits require systems to provide a link between paper ballots and electronic ballot data, so that officials can compare a physical paper trail with the electronic count, all while protecting voter anonymity. Counties in Colorado and California are already piloting risk-limiting audits. Several vendors are offering systems that should make it much easier to compare physical ballots to a cast vote record.[136]

While mainstream voting machine vendors are doing much to improve new offerings, officials, working with vendors, academics, and their voters, have driven some of the most promising innovation. Their work offers some promise for American elections: the hope that better and less expensive voting machines are in our future. Below we detail this work in several case studies.

A. Case Study: Los Angeles County, California

Los Angeles County is the largest jurisdiction in the country. It is home to roughly 5 million registered voters that speak 12 languages. Elections in Los Angeles County require a Herculean effort. Each election, the county distributes its ballots and vote casting system to more than 4,800 polling places in an area twice the size of Rhode Island. In 2012, the county centrally counted 2.8 million ballots.[137] Amazingly enough, the system that tabulates all these ballots dates back to the late 1960s (though it was retrofitted in 2003) and is approaching the end of its lifespan.[138]

Unlike most jurisdictions, the county has a significant balance of allocated HAVA dollars (and some other state funds) to purchase new voting machines, because it never purchased a new system after HAVA was passed. The county's HAVA funds, combined with state bond funding allocated to replace touch screen voting systems, totals nearly $70 million. When Dean Logan, head of elections in Los Angeles County, looked at the voting systems on the market, he did not see a product that was a good fit for his county. The machines on the market were not much different than those available a decade ago. Instead of buying a vendor's product, the county decided to develop its own system specifications and design. Logan said, "We wanted to design a system around the voter's experience, not around the limitations of the market and the current regulatory environment."[139]

Logan uses the term "human-centered" to describe the county's approach to modernized system development and acquisition. Logan and his staff spent two years asking voters what they wanted to see in a future voting system. Officials used this information to develop 14 guiding principles of a future system, which will inform its design. The proposed design combines touch screen technology with a human-readable and auditable paper ballot of record: Voters would use a touch screen ballotmarking device to fill out a ballot, print it out, and then place it in a ballot box. The county intends to own the new system, which will free it from the expensive maintenance contracts that vendors often bundle with traditional voting systems.[140]

"To a certain extent, we are designing for a voting experience that is not fully defined in the regulatory environment or elections code," Logan said. Officials in Los Angeles are considering new services,

like an interactive sample ballot that voters can scan into a machine and start the voting process with their choices already pre-selected to expedite the voting experience, if desired. Logan told us that the new system will also make it easier to conduct risk-limiting audits, a type of post-election audit that is more accurate and efficient than those that are currently conducted in most of the country. Most importantly, county officials hope to design a system that is flexible, so it can adapt easily to changes in election laws or procedures.[141]

Before Logan could go ahead with his project, he needed to change state law. When Los Angeles originally conceived the project, California law required that voting systems be federally certified before they could be purchased using HAVA and state bond funding — and there were no available funds for research and development.[142] This meant it was impossible for the county to invest in creating a new system that, by definition, could not be certified because it didn't yet exist. But in 2013, California Gov. Jerry Brown signed a law separating California from the federal certification process. This gave Logan and Los Angeles County the authority needed to leverage funding for research and development — and the possibility of piloting components of a new voting system.[143]

Currently, Logan is working with the design consulting firm IDEO to develop the specifications for an electronic ballot marking device and associated components of a comprehensive, modernized voting system. Next, the county will move forward with a contract to manufacture the device. On the software side, Logan envisions the system relying on open-source software, which will be maintained in-house at the registrar's office. Fortunately, Logan's office has a robust IT department that maintains the county's existing vote tabulation system, and will maintain the county's next system.[144]

Logan believes the project has the potential to change the voting equipment marketplace for the better. "The design approach we are taking should result in lower cost voting systems and market expansion. I think it has the ability to move the regulatory environment and the market to a more competitive landscape that could allow jurisdictions to replace systems at a lower cost than in the past."[145]

Logan plans to begin implementing the system in 2017, and achieve a complete turnover of equipment by the 2020 election cycle. Across the country, election officials told us they are watching this project closely, and are excited to see what Logan and his team develop. "Our goal is not to just meet the needs of Los Angeles County, but to offer our data and research as a set of information that can be used by any jurisdiction that is looking at modernizing their voting system," Logan said.[146]

B. Case Study: Travis County, Texas

Dana DeBeauvoir, the clerk for Travis County, Texas, knew her voting machines were approaching the end of their life. Travis County purchased machines 16 years ago.[147] In 2009, DeBeauvoir assembled a group of local political leaders, elections experts, cryptographers, and computer scientists to talk about replacing the machines. The 45-member advisory group, called the Elections Study Group (ESG), recommended that Travis County replace its system after the 2012 presidential election. The ESG also recommended the system produce a paper trail.[148]

DeBeauvoir looked at the systems on the market and was not impressed by their security capabilities. Instead of purchasing a vendor's system, DeBeauvoir enlisted a group of experts to design the county's own system. What they developed is called "STAR-Vote" — Secure, Transparent, Auditable, and Reliable. "My main concern is that we build a system that has security built into it from the bottom floor, not something that was added on to a completed system, which is how the current systems are designed," DeBeauvour said.[149]

A voter using the STAR-Vote system will fill out an electronic ballot on a commercial-off-the-shelf (COTS) tablet device running open-source software, confirm their selections on a printed paper receipt, and then feed the ballot into a scanner. The system will provide the voter with a tangible receipt to confirm the machine recorded their choices correctly. Once home, voters use their receipt to log into a website and confirm their ballot was cast and counted — a testament to the system's transparency and auditability.[150] DeBeauvoir also wants the system to perform risk-limiting audits.[151]

DeBeauvoir now has $2 million in her budget to fund STAR-Vote. Travis County estimates the STAR-Vote system will cost about $8 million, about $6 million less than a vendor-designed system. Software development will account for most of the cost, approximately $5.5 million. Hardware and implementation will account for the rest. The COTS hardware will be considerably less expensive than the proprietary hardware sold by vendors. And since STAR-Vote will be publicly owned, DeBeauvoir believes she will be in a better position to negotiate with vendors for ongoing maintenance. If the county owns the hardware, it will be able to pick and choose the right vendor through a competitive bidding process.[152]

DeBeauvoir recently started the procurement process. "We made a strategic decision to release the document as an RFI (Request for Information), instead of an RFP (Request for Proposal), because it needs a little more time for discussion and development." RFIs are generally issued by a jurisdiction that has an idea of what they want, but wants to canvass the marketplace to see what is available. Travis County officials will use the information gathered through the RFI process to design a more specific RFP. DeBeauvoir hopes the project will change the expectations for vendor-client relationships. "I'm hoping that what the marketplace gives us will involve a new collaboration. I don't want the vendors in the market to come up with a solution. I am hoping that it will be a collaboration such that we have never seen before, it may involve vendors, it may not."[153]

As the owner of the system, Travis County could share it with other jurisdictions — an exciting prospect that could redefine possibilities for local governments. Officials in Travis County are considering models

for sharing the system. TechShare, a program run by the Texas Conference of Urban Counties, facilitates technology sharing between the Texas county courts. A similar project could be undertaken for STAR-Vote. Michael Winn, Travis County director of elections, said: "I think a professional organization could act as a clearinghouse and help streamline the process. This way you have buy-in from other election officials and other professional organizations."[154]

If all goes according to plan, DeBeauvoir and her staff will have the system in place for the 2018 general election, although it may not be ready until 2020. Regardless of the timeline, quality is the first priority. "The most important thing for us is to have something that is well thought out and is good for the future of the field," Winn said. "I think we have only scratched the surface. We are new to this game. Other counties in other states can put their heads together and come up with better systems that can benefit all jurisdictions."[155]

C. Case Study: Denver, Colorado

About four years ago, Denver decided to design and implement a new voting system. Denver officials, likes those in Los Angeles and Travis County, did not see the right product on the market. Instead of developing their own voting system, Denver teamed up with their vendor — Dominion — to tailor a new system to meet the needs of voters, a new voting model, and administrators.[156]

Denver, like Los Angeles, wanted the system to be designed around the voter. Amber McReynolds, Denver's director of elections stated: "Our approach has always considered the voter's experience first. We believe that designing a solution that puts the voter first will inherently bring operational efficiencies, cost savings, transparency, and accountability. This approach has proven to be effective with other innovative solutions that we have implemented in Denver."[157]

In Denver, about 95 percent of voters cast ballots by mail. Any system the city purchased would need to count hundreds of thousands of paper ballots. Denver's new system uses a high-speed COTS scanner to centrally count all ballots, including those cast on Election Day. For the 5 percent of voters that choose to cast an in-person ballot, the city provides voter service and polling centers. In-person voters make selections on a tablet device and then print their selections on a COTS printer. The system also allows disabled voters to bring their personalized accessibility devices to a voter service and polling center, which can be connected to a tablet using a Bluetooth connection.[158]

The hardware used in the new system is cheaper than other systems because all the parts are COTS. The scanners, which are produced by Canon, cost just a quarter of proprietary units. If a tablet breaks, it will cost the city only about $400 to $500 to replace. This is significantly cheaper than replacing a $1,000 screen on a direct-recording electronic (DRE) unit or the entire DRE unit, which could cost as much as $5,000. COTS devices offer other advantages, including more accessible support, cost-effective maintenance, and user-friendly interfaces.[159]

The system offers new features for auditing election results and confirming voter intent. The Canon scanners have the ability to print a unique number on each ballot, which cannot be tied to the voter.

This makes performing a risk-limiting audit easy, since each paper ballot can be compared to both a cast vote record and a digital ballot image. Denver officials also use the digital ballot images to confirm voter intent. If a voter marks a ballot incorrectly, the ballot image is digitally transferred to a bipartisan adjudication panel that makes a decision as to the voter's intent.[160]

Denver tested the new system during the spring municipal election, and will continue to test it in the November 2015 coordinated election in preparation for the 2016 presidential race. While the central Dominion system has been federally certified, the tablet portion is in testing now.[161]

D. Case Study: Evidence-Based Elections and Risk-Limiting Audits

Philip Stark, a professor of statistics at the University of California at Berkeley, is interested in the accuracy and security of elections. Stark has a central idea: Local election officials should be able to give affirmative evidence that the reported election result is correct. How can election officials collect the evidence needed to prove that election results are accurate? Stark said it is simple. "You need an audit trail and right now that means paper. You also need evidence that the audit trail was curated well, until the time someone could review it. And then you need to audit enough of it to ensure that the announced outcomes are correct."[162]

In 2012, Stark and a Berkeley colleague and computer scientist, David Wagner, wrote a paper outlining the concept, *Evidence-Based Elections.*[163] For an election to be evidence-based, the voting system must be software-independent. For a system to be software-independent, an undetected change or error in the system's software cannot lead to an undetected change or error in election results.[164] One common way to meet this requirement is to have voters mark a paper ballot or have machines produce a voter-verified paper record.

Evidence-based elections also require that election workers follow security procedures and document their compliance. Election workers must document that election machines and paper records are properly secured from start to finish on Election Day. Stark stated: "You can't retroactively go back and check chain of custody logs if there were none. […] That kind of physical chain of custody and security, it doesn't require a capital expense, it only requires the implementation of procedures."[165]

The next step is using the secure paper records to audit the election results. Stark developed an efficient and accurate technique for auditing election results that he calls a risk-limiting audit. Risk-limiting audits confirm election results at a high probability by drawing a random sample of ballots from the

"My main concern is that we build a system that has security built into it from the bottom floor, not something that was added on to a completed system, which is how the current systems are designed."
— Dana DeBeauvoir, Travis County, Texas, Clerk

pool of cast votes. In the case of a decisive contest, election workers can audit a small sample of ballots, while a close race will require auditing a comparatively larger sample to confirm the winner.[166]

But to make a risk-limiting audit possible, there must be a tangible record for each ballot. And to make a risk-limiting audit efficient, there must be a way to compare the physical ballot with the machine's cast vote record — essentially a spreadsheet exported from the voting system that shows the system's interpretation of the voters' choices on each physical ballot. By manually comparing a selection of paper ballots with the cast vote record, election workers can confirm that machines are recording and tabulating votes accurately. Election officials performing risk-limiting audits must accomplish all of this while maintaining voter anonymity.[167]

Stark has worked with more than 20 California counties to conduct risk-limiting audits. He created an online tool to make it easier for counties to conduct risk-limiting audits on their own. "I built tools to try and make auditing easier for election officials, so they don't have to do any of the arithmetic. If you are trying to select ballots to audit at random, the tool helps you select them, and then, based on what the audit shows, it tells you whether you looked at enough ballots to confirm the results."[168]

Stark's work gained the support of state and federal governments. In 2009, Colorado passed a law requiring risk-limiting audits beginning in 2014, though implementation was subsequently postponed to 2017.[169] In 2010, California passed a measure[170] establishing a pilot program for counties to conduct risk-limiting audits, and in 2013 it passed another[171] requiring risk-limiting audits as a condition for use of some voting systems. In 2011, the EAC granted California and Colorado $230,000 each to fund pilots of risk-limiting audits.[172]

Evidence-based systems could also reduce the need for some of the expensive and time consuming parts of certification testing, like source-code review. This change could help machines make it onto the market faster. "I think [evidence-based elections] would greatly reduce the time and expense required for certification. For one, I don't think you need the source code review for the purpose of ensuring tabulation accuracy," Stark said.[173]

Evidence-based elections, and risk-limiting audits, are growing in popularity. Stark said election officials like risk-limiting audits because they are efficient and accurate. "There are lots of election officials who like the idea of a risk-limiting audit, because it gives them more scientific information as to whether they are getting it right, and it may be cheaper than audits currently required by state law."[174]

The idea appears to be spreading. Officials in Arapahoe (with the help of Stark, Harri Hursti, a computer programmer and security expert, and Maggie MacAlpine, an advisor on post-election audits) and Boulder counties in Colorado and Cuyahoga County, Ohio, conducted their own risk-limiting audits.[175] Forward-thinking election officials, like those in Travis County, Los Angeles, and Denver, are designing systems to allow for evidence-based review of counting accuracy.[176]

III. RECOMMENDATIONS

The key challenge facing American elections as voting machines reach the end of their lifespans is that, in too many instances, no level of government believes it should be responsible for maintaining or replacing them. The Brennan Center estimates the cost of replacing aging equipment could easily exceed $1 billion. Someone must come up with the money.

As already discussed, in many ways, Congress is responsible for this problem. By mandating new equipment and providing hundreds of millions of dollars to upgrade American voting technology through the Help America Vote Act in 2002, Congress committed the United States to a more sophisticated infrastructure that has many benefits for voters, but that also brings with it an ongoing financial commitment that did not exist in the days of lever machines and punch card ballots. Congress made the down payment, but has shown no inclination to provide additional support more than a decade later, and few expect this to change anytime soon.

Meanwhile, many state and local governments have refused to accept this new financial responsibility. There are steps that federal, state, and local officials can take to lower costs or shift them. But ultimately, there is no avoiding the fact that running elections is a necessary government expense. We must find a way to pay for them.

Finding money is not the only step that policymakers should consider, however. Below, we detail several recommendations that result from our study of voting technology and the market for voting machines. First, for those jurisdictions that need new equipment but will not get the funding to buy it as soon as they would like (a disturbingly high number, if our interviews are any indication of what the future holds), what steps can be taken to minimize the potential damage? Second, as jurisdictions do buy new machines, what can be done to lower expenses in the next few years, and ensure the long-term needs of voters are met?

A. Precautionary Steps for Jurisdictions That Cannot Purchase New Machines

It is clear that some jurisdictions in need of new machines will not be able to purchase them in the next few years. For many that would have liked to have purchased new machines before 2016, it is now probably too late to do so.

For these localities, proper storage, preventative maintenance, and pre-and post-election testing will be critical. Making sure election officials are immediately notified of any potential problems with these systems is essential as well. The newly reconstituted EAC, in particular, has a critical role to play in ensuring that jurisdictions with antiquated equipment use it in a way that minimizes the chances of problems in the 2016 election and beyond.

Ultimately, if a jurisdiction needs new machines, these precautionary recommendations can only serve as a stopgap, and are certainly no guarantee that problems will be avoided. But if extra precautions are not taken, what is already an extremely worrying situation may be far worse.

1. Proper Storage, Preventative Maintenance, and Testing

We are hopeful the EAC will work with voting machine vendors as well as state and local election officials (and their constituent organizations) to continually update and share detailed best practices for extending the life of voting machines and ensure that jurisdictions catch and plan for the biggest problems. The EAC just covered this subject in its publication, "10 Things to Know About Managing Aging Voting Systems." This was the first public guidance from the agency on the topic in 10 years. The new publication provides a much needed update, but many jurisdictions will benefit from more detailed guidance from the agency and its staff in the coming months and years.[177] Below are some critical steps all jurisdictions, but particularly those with antiquated equipment, should ensure they adopt.

- **Store and transport machines correctly.** Several technology experts noted that the proper storage of machines goes a long way toward ensuring reliability. Moist storage conditions can cause machine parts to corrode.[178] Warehouse floods and fires damaged, or destroyed, machines in several jurisdictions.[179] The right storage conditions can extend the life of a voting machine. Counties and states should explore whether they are storing machines in facilities that will maximize their lifespan and, particularly for those that are unable or unwilling to purchase new equipment, make the necessary investment to ensure machines are stored correctly. We are encouraged to see guidance for the storage of voting equipment in the EAC's recent publication, "10 Things to Know About Managing Voting Systems." Election officials will benefit from more publications like this, with greater detail on the best practices for storing and transporting voting equipment.[180]

- **Adopt best practices for machine maintenance.** Preventative maintenance, where technicians inspect machines and replace aging parts, reduces the likelihood of a machine failure. If local election officials do not perform adequate maintenance between election cycles, machines are more likely to break down. Some states, like Ohio, issue memorandums and directives for machine maintenance, but many do not.[181] More detailed guidance from the EAC could go a long way toward avoiding failures on Election Day.[182]

- **Ensure better pre-election machine testing.** EAC Commissioner Matt Masterson noted that those election officials who are struggling with older equipment need to identify and see performance issues.[183] That means, among other things, conducting pre-election testing on every voting machine just before Election Day to catch problems ahead of time. The EAC's most recent direction on pre-election testing can be found in a document that was created in 2010, and it provides little guidance for how best to conduct such tests.[184] During these tests, election officials vote different combinations of ballots on the machine to see whether the machine is operating and recording votes correctly.

  John Washburn, a software testing expert who has testified before the EAC and Congress on pre-election testing, among other subjects, has provided trainings to election officials for how they should conduct tests. Washburn said all too often, election officials see this testing as something to "get through" rather than to identify any defects.[185] His "Five

Simple Rules for Testing Your Voting Machinery" should be required reading for election officials using electronic voting machines.[186] Among other things, Washburn noted, election officials should make sure they are: testing their machines in "election mode" (as opposed to "test mode" which some machines offer); testing in a way that looks for programming defects, as opposed to what a "normal" vote might look like; actually running the tests on all machines before using them; and ignoring the pressure to simply add an illegal software patch when a problem is found, as opposed to immediately reporting the problem to the secretary of state, EAC, and vendor, and working to uncover the source of the problem.[187]

- **Create contingency plans and update poll worker training for system failures and other emergencies.** While preventative maintenance and pre-election testing are critical, more failures as machines age — ranging from paper jams and flipped votes to freezes and shut downs — are inevitable. Preparation for these failures is critical. As Pam Smith, president of Verified Voting noted, "Well implemented emergency procedures can make the difference between a jurisdiction that's all over the news as an epic fail, or a jurisdiction that had a few issues that were resolved, and everyone got to vote."[188] The EAC recently issued "6 Tips for Contingency and Disaster Planning," which should be of value to election officials as they consider how to prepare for technological failures and other emergencies.[189]

Election officials with older systems, in particular, should identify past voting system failures and assume they may see more of these in 2016. Poll worker training will be crucial in ensuring problems are dealt with appropriately. A recent National Science Foundation-funded report authored by the Center for Civic Design suggests creating useful checklists for the most important tasks, and emphasizing their importance during training, can help ensure key procedures are correctly followed.[190]

Machine failures are particularly problematic in the 22 states that have jurisdictions that use DREs (as opposed to paper ballots and optical scanners) as the standard polling place equipment.[191] As a 2012 report by Common Cause, Verified Voting, and Rutgers School of Law's Constitutional Litigation Clinic noted, "if these machines break, or fail to start up, voters may have to wait in long lines while election workers scramble to repair them."[192] This is in contrast to polling places that use optical scan machines, where voters can fill out paper ballots even if machines are not functioning, and the ballots can be read after the scanners are replaced or fixed.

States Where DREs Are Used as Standard Polling Place Equipment
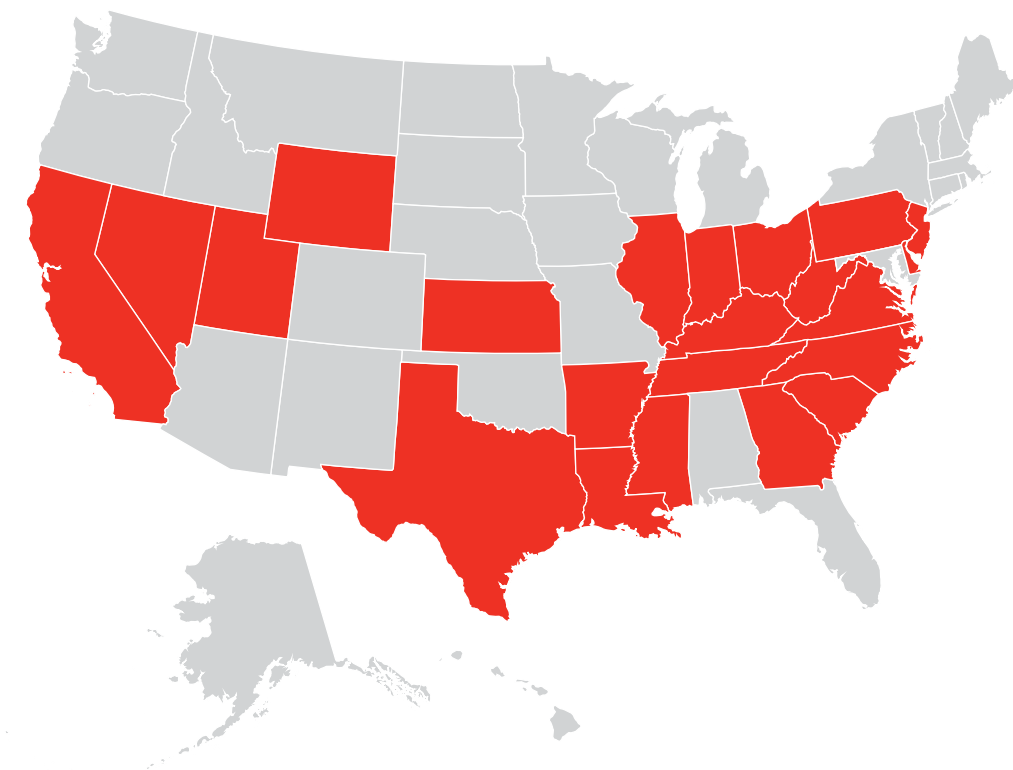
The 2012 report by Common Cause, Verified Voting, and Rutgers also makes four recommendations in the event of DRE failure: (1) have contingency plans in place for immediate repair or replacement in the event machines fail to start up or break down in the middle of the voting day; (2) have emergency paper ballots available at every voting place; (3) allow emergency paper ballots to be deployed when any machine malfunctions (to prevent long lines that may occur when less than the full number of machines are operating), or because there are not enough machines to support the number of voters in the polling place at a particular time; and (4) treat emergency ballots as regular ballots, not subject to additional scrutiny that could result in them not being counted.[193] The report concluded that only three states — California, Indiana, and Ohio — had state mandated requirements that satisfied all or most of these recommendations.[194]

- **Update procedures for post-election audits and ballot reconciliation, where possible.** While pre-election testing, proper storage, and preventative maintenance can avert machine problems, catching miscounts of votes after the fact and correcting them is better than missing these problems altogether. The 2012 report by Common Cause, Verified Voting, and Rutgers found 38 states had auditing procedures in place that were either "inadequate" or "[needed] improvement."[195] The same report found 16 states used voting systems that did not produce the paper records needed to audit election results.[196]

A lot has been learned about auditing in recent years. Even though the EAC published some guidance for post-election auditing, as recently as 2010, election officials could benefit from updating these lessons.[197]

New approaches to auditing have the potential to increase the public's confidence in the accuracy of election results. Risk-limiting audits allow election officials to confirm election results are correct at a high-probability, while utilizing resources efficiently.[198] This process requires a voter-verified receipt or paper ballot. Vendors should design machines so they include the features needed to perform risk-limiting audits. These features should make it easy for election officials to compare actual paper ballots to the machine's cast vote record.

2. *The EAC Should Do More to Notify Election Officials About Machine Problems*

In the last few years, the EAC has taken several steps to make information about voting system malfunctions publicly available, particularly for EAC-certified voting systems. But many of the systems that are reaching the end of their lifespans are not EAC certified.[199] While election officials we interviewed generally expressed appreciation for the efforts the EAC has taken to provide them with information when problems occur, we heard complaints that more can be done.

- First, several election officials we interviewed said they would like to see more reporting of problems with non-federally certified voting systems.[200] A database of machine problems should include reports of issues with uncertified systems, and election officials should be encouraged to provide such information. This data could be critical in preventing the same kind of problem from occurring in multiple jurisdictions. It could also assist election officials as they look to purchase new systems.

- Second, we heard complaints from election officials that there is too much of a time lag between a reported failure to the EAC and a report of that failure by the EAC to election officials.[201] We suggest that the EAC modify its procedures so it informs election officials of voting system malfunctions as soon as they are reported, making clear that the report is under investigation. This would allow the EAC itself to obtain more information on the systems it investigates, as reported problems may also be experienced by multiple jurisdictions (and those jurisdictions may have developed "workarounds" that manage the problem but ultimately create other issues). Election officials complain that the current procedure keeps administrators uninformed about potential problems with their voting equipment until an investigation is complete.[202]

B. Helping Jurisdictions Get the Best Products for Their Money

There is much that can be done at the federal, state, and local level to lower total costs to states and counties that must buy new voting machines. We discuss some ideas that repeatedly came up in our interviews with election officials, vendors, and technology experts.

1. Encourage Solutions That Are Driven By Election Officials and Their Voters

While most experts we spoke to agree there is little chance Congress will provide hundreds of millions (or potentially billions) of dollars for new machines, targeted investments by the federal government and state governments could have enormous benefits. Two or three more systems, designed directly around the needs of specific states and counties, and developed using open-source software, could have a transformative effect on the market.

Several election officials we spoke to are following the development of publicly owned systems in Los Angeles and Travis County. William Anthony, director of the Board of Elections in Franklin County, Ohio, stated, "I'm following LA, and I like what they are doing. I would like for us to do something similar, I am going to watch it real closely and I think that it is on the cutting edge."[203]

Dawn Williams, director of elections at the Iowa Secretary of State's Office, echoed Anthony: "I think that LA's project is really exciting. I expect that it is only large counties that can afford to develop their own equipment, but all counties are going to benefit from it. They are going to raise the bar with what they are doing. The fact that counties share among each other is fantastic. That is local government at its best."[204]

If other jurisdictions reproduce projects like those being pursued by Los Angeles, Denver, or Travis County, Texas, the market for voting equipment could be changed for the better. The EAC is well-suited to encourage more non-proprietary systems that are developed around the needs of specific jurisdictions. In 2010, the EAC announced a competitive grant program that provided $2 million to spur innovation in pre-election logic and accuracy testing.[205] A similar grant program could spur counties to develop more systems like those in Travis, Los Angeles, and Denver counties.

2. Streamline the Certification Process

Currently 47 of the 50 states rely on the EAC's certification program in some way[206] — underscoring how critical the EAC's role is in ensuring machines meet minimum quality standards. In the past, many vendors, election officials, and advocates have argued the testing regime for machines takes too long, is too expensive, and is a barrier to market entry. Certifying machines, this argument went, was an especially burdensome process that could take years and cost millions.[207]

The EAC has responded that many of the delays related to testing have been the fault of the manufacturers, who submitted systems that were not ready for testing.[208] They point out that entire systems have been certified in 6 to 8 months, and that recently the agency certified a *minimal* change to an existing voting system in just 12 days.[209] Despite these criticisms, the EAC is taking steps to avoid delay and expedite the certification process.

Even with these improvements, the EAC agrees more can be done to improve the testing process, encourage more entrants into the market, and make the system more fair and efficient.[210]

a. Completely Update the Federal Guidelines for Voting Machines

The EAC took an important step in adopting a new version of the federal voting machine standards — the Voluntary Voting System Guidelines (VVSG) 1.1. Now that the EAC has commissioners, and the Standards Board and Technical Guidelines Development Committee are coming back online, the EAC should begin a careful and deliberate overhaul of the VVSG. Vendors and voting technology experts told us the 2005 VVSG, while providing an important floor for the quality of voting equipment, made innovation more difficult than necessary.[211] Future versions of the VVSG must balance the need for quality assurance with the flexibility needed for technological innovation.

EAC Commissioner Matt Masterson thinks the next set of standards should allow for greater flexibility in machine design. "I think that the next set of standards cannot function at the design level that the previous set did, that is just not going to fly given where we are at with election technology," he said. "The next set of standards will have the flexibility you need for some of the innovation, but the part that we are concerned about is making sure the rigor of the process remains the same."[212]

b. Reduce the Cost and Time Associated with Certification

Certifying a voting system can cost millions and vendors bear the costs.[213] Doug Kellner, commissioner of the New York State Board of Elections, believes state and federal governments should pay for parts of the testing process.[214]

Other experts want vendors to take on more of the responsibility for testing. Brian Hancock, director of testing and certification at the EAC, believes vendors should perform some of the testing in-house. When testifying before the PCEA, Hancock suggested that vendors assure the EAC that a system meets certain specifications when it is submitted for certification. This assurance, called a "manufacturer's declaration of conformity," should be enforceable and come with penalties if it is not met.[215]

In 2000, the Federal Communications Commission (FCC) established a system that permitted manufacturers to "self-certify" certain types of communications equipment. Prior to implementing this program the FCC certification process could take between 60 and 100 days. Now, due to the FCC's Declaration of Conformity program, the testing process takes on average 35 days.[216]

c. Reduce Redundancies between State and Federal Certification Programs

Many states have their own certification requirements.[217] Once a machine is certified by the EAC, many states require additional testing, which keeps machines in the laboratory and off the market. The EAC is already working with several states (California, Indiana, and Ohio) to identify common state certification requirements and include these in the federal process. We hope the EAC will expand these efforts and include more states' testing requirements in the federal certification program. By

continuing to streamline the certification process in this way, voting equipment could make it to the market faster, because machines would not need to go back to the lab for state certification after completing the EAC process.

3. Long-Term Planning Is Critical to Negotiating Price and Effective Implementation

Merle King of the Center for Election Systems noted that "when you press election officials, often they don't know what their expectations [for life expectancy of their machines] are. The vendors have fielded systems that you don't know what to expect from as far as the serviceable life."[218] Today's crisis is partly the result of this poor planning. As professor Doug Jones noted, if jurisdictions wait until machines start failing to begin thinking about replacements (as some jurisdictions have), they will be in a weak negotiating position with vendors.[219]

Moreover, jurisdictions may be forced to field systems in a high-stakes election, before they have been vetted in low turnout elections, where election officials can discover and correct for potential problems. Professor Jones recommends a minimum of one year of competitive bidding, followed by an initial deployment of new machines during an off year (non-federal) election.[220] By deploying machines earlier, jurisdictions can have more than one year — and several smaller elections of experience — to test machines before higher turnout elections. Michael Belarmino, of the National Association of Counties, told us that jurisdictions should not rush to purchase machines shortly before an election. "A good practice is to plan ahead, get the process started early, and to be adequately prepared for elections."[221]

Dana Chisnell, director of the Center for Civic Design, noted that election officials may want a dramatic change in future voting equipment. "System design and development has changed fundamentally since the voting systems that are in use now were engineered," Chisnell stated. "In the 1990s, when the existing systems were designed, engineered, and manufactured, it was common to specify a thing to be delivered. The vendor sold the voting systems, the training to understand how to use it, and a maintenance contract […] Excellent technology just doesn't get made that way anymore. Most of the best-in-class development is done based on a method called 'agile' (and its many variations) in which there is continuous, iterated correction and improvement. This means that the system is never 'done.' This affects the way contracts are written, carried out, and managed."[222]

At a practical level, "agile" systems could mean a shift away from a single product that is delivered and will exist in its present form for a certain number of years. Instead, the design of voting systems would benefit from testing and development over the life of the contract. Information gathered in the field would allow for flaws and bugs to be fixed as they are discovered. Additionally, a feedback loop between the design and implementation of voting systems would allow jurisdictions to add features, enhancements, and innovations as legislation and technology change. As Chisnell noted, "In theory, under this kind of development, voting systems would never become obsolete […] because they would be continually tested and improved, with parts of the hardware being replaced when needed and software being constantly upgraded and tested."[223]

A new way of planning, that involves making iterative improvements to existing voting systems, could be better for both election administrators and voters. The ability to make piecemeal improvements to voting systems could lead to a massive change in election administration, specifically with regard to budgeting, contract negotiation, and management of voting systems contracts. It would effectively put election officials at all levels in the technology development business.

4. *Help Jurisdictions Negotiate Better Contracts for New Machines*

As this report illustrates, many jurisdictions cannot wait for new federal standards, or the development of new systems in counties like Los Angeles. Some jurisdictions have plans to purchase in the short window before the 2016 election. Others will need new systems soon after. The initial price of a voting system can be just a fraction of the cost of using a voting system over time.[224] Sometimes jurisdictions enter into expensive repair and maintenance agreements with vendors,[225] which are embedded in contracts that election administrators may not fully understand.

Rokey Suleman, who has run election departments in Ohio, Virginia, and Washington, D.C., called the challenge of negotiating new contracts "huge." He added: "Some localities just turn to the vendor to develop the contract. Small jurisdictions with little procurement experience rely on vendor 'benevolence.' This will be a growing issue as localities negotiate for new equipment."[226]

There is much the EAC, state governments, and others can do to assist jurisdictions in reducing long-term costs.

a. Define Best Practices for RFPs

When states and counties decide to purchase new machines, they typically issue a Request for Proposal (RFP) to solicit bids. When drafting the RFP, a jurisdiction outlines the specific elements it requires. The RFP provides an opportunity for jurisdictions to communicate exactly what they want from a vendor and it determines the structure of contracts between vendors and jurisdictions.

EAC Commissioner Matt Masterson highlighted that the contract determines the quality of a voting system. Masterson said in some ways, contract terms are more powerful than certification — a jurisdiction can contractually guarantee certain kinds of performance and legally enforce that vendors meet contract terms.[227]

The EAC is collecting RFPs in a section of its website that serves as a repository of RFPs for voting systems.[228] The RFP repository will provide important guidance to election officials procuring new machines.

The EAC should also work with election officials that have developed high quality RFPs, highlighting the key terms and explaining their benefits to the quality of a voting system. RFPs are often dense documents, and the reason for various terms in them will not always be clear. By explaining the benefit of certain RFP terms, the EAC could provide election officials with a clearer sense of what kinds of contracts will benefit their jurisdictions and voters.

Election officials provided the Brennan Center with some clauses they believe were critically important to their RFPs. We discuss some below:

- Local elections agencies should be on equal footing with vendors, so they can negotiate financially sustainable contract terms. For this reason, RFPs should limit the elements of a voting system that are proprietary.

  › RFPs should provide jurisdictions with the right to maintain voting software. When New York State issued an RFP for new voting machines, it requested that the vendors permit the state to keep the system's source code in escrow. The state insisted on terms that would allow them to procure services from other vendors if the original vendor went out of business or was unresponsive to the needs of an election agency.

  › RFPs should include terms that permit state and local governments to share voting system documentation, and the eventual contract, with the public. Local election officials will have more power to negotiate with vendors if the process is transparent and subject to public accountability.

  › RFPs should ensure data created by voting machines are the property of election agencies. When a voting machine malfunctions, it creates an internal log, defining what kind of error occurred. These event logs help election officials evaluate machine performance and understand the cause of a machine malfunction. If these logs are not available to election officials, they cannot address machine problems on their own. Maggie Toulouse Oliver, clerk of Bernalillo County, New Mexico, stated: "If vendors are not forced to share information, it makes it hard for counties to do their own maintenance. Even though New Mexico has a law requiring that counties perform preventative maintenance, vendors would not share information, so the only way to service machines was through the vendor."[229]

  › RFPs should guarantee part availability for the new machines for their lifespan. Professor Douglas Jones notes that without such a guarantee, in a few years jurisdictions could again find themselves wondering how they will support a voting system that their vendor discontinued.[230]

- RFPs should break down contracts into as many elements as possible. In the past, many jurisdictions signed contracts that bundled expensive maintenance contracts with equipment purchases, to the financial detriment of local governments. Contracts stifled competition by locking jurisdictions into long-term maintenance contracts with the same vendor from which they purchased their equipment.

  › RFPs should allow states and localities to shop around for the best and most affordable service contracts for software and hardware maintenance. Election agencies should not be dependent on just one vendor to help them adapt to changes in election law, such as early voting, vote centers, instant runoff voting, or a paper trail requirement.

- RFPs should require voting systems to export election data in a standardized format. The National Institute for Science and Technology and the Institute of Electrical and Electronics Engineers are working on a "common data format" for election data,[231] which could lead to machines producing results identically across model types, precincts, and counties. This would make election night reporting easier, since machines would essentially produce spreadsheets of vote totals in the same format, and results could be more easily compiled.

b. Central Purchasing and Cross-Jurisdictional Resource Pooling

States and jurisdictions may benefit from pooling their resources to save funds. Since states have more purchasing power, they can get better deals for voting equipment. Some states, such as Georgia, Michigan, and South Carolina, use state funds to purchase machines.[232] Other states, like West Virginia, allow jurisdictions to buy from a pre-negotiated statewide contract.[233] States, or even large jurisdictions, that purchase hundreds or even thousands of machines are frequently able to procure machines at a lower price.[234]

Wendy Noren, director of elections in Boone County, Missouri, stated that as a county election official she is interested in how she can increase her purchasing power. "Having the coordinated buying power is really important," she said. "It would be great if the state required vendors to submit and buy as part of a centralized state procurement process." Noren also suggested that an organization, such as the National Association of Counties, could collaborate with the EAC to help localities pool their resources to get better contract terms and pricing.[235]

THE PROMISE OF COMMERCIAL-OFF-THE-SHELF (COTS) CONSUMER ELECTRONICS IN VOTING SYSTEMS

In most counties, voting machines do not look like the computers, tablets, and smartphone devices that many Americans use on a daily basis. Most of the voting machines used in the United States are composed of a set of interconnected commercial components, like touch screens, CPU processors, and motherboards.[236] As discussed earlier, the electronics inside machines can be more than a decade old and the machines themselves can be expensive, costing between $3,000 and $6,000 each. When a state or county buys hundreds or thousands of these machines, the cumulative price can total tens of millions of dollars.

The PCEA recommended that vendors leverage newer COTS devices — like tablet computers — for use in voting systems. Integration of consumer electronics into voting systems would make them more accessible to disabled voters (because of features that are built into the operating systems) and more flexible to adapt to changes in state laws, according to the PCEA.[237] Mass produced consumer electronics are cheaper than current voting machines, which are manufactured in comparably smaller batches. An iPad Air 2 costs $500 — as little as 10 percent of the cost of a proprietary voting machine.[238]

What stands in the way of using more affordable, consumer electronics in voting systems? According to the PCEA, the 2005 voting machine standards, "were primarily designed for end-to-end products rather than components that can be interchangeable with other products to increase customization, updating technologies, and usability."[239] If jurisdictions need to replace just one part of a much larger voting system — like a touch screen or printer — they must use the exact hardware that was originally certified for use in the system. Newer hardware cannot be used in a certified system, unless the vendor chooses to submit the change to the system for EAC approval. If the vendor does not certify the small change — elections officials will be stuck using old parts that can be difficult, if not impossible, to find.

New voting machine standards could establish a certification process for testing the individual components of a system. "Component certification" would allow election administrators to replace one COTS device with another similar model — as long as both devices were certified.[240] In practice this could mean replacing an aging iPad with a newer Android or Microsoft tablet, or a Canon printer with a similar Hewlett-Packard model.

But it is far from clear that all jurisdictions, particularly smaller jurisdictions, could fully benefit from such a change. As EAC Commissioner Matt Masterson noted, this kind of system would shift the roles and responsibilities of election officials across the country and require significant IT resources at the local level. "This kind of certification will require local election officials to be much savvier with their testing," Masterson said. "In essence they will be system integrators and that is a role that they have not served before. […] An election office will need a strong IT staff to be able to do this."[241]

In addition, security experts caution that the use of consumer electronics cannot come at the expense of election security. Voting systems that include tablets or other COTS devices, they note, can have built-in features that have the potential to compromise election security. Among their warnings is that tablets should not have the ability to connect to the Internet.[242] If systems are not secured properly, voter privacy could be compromised or ballots could be manipulated.

Ultimately, a greater reliance on consumer electronics could mean a fundamental change in the way many jurisdictions budget and plan for the future of elections. As Jeremy Epstein of SRI International pointed out, shifting to commercial tablets, scanners, and printers could mean dramatically lower initial costs and more flexibility when purchasing systems. At the same time, the lifespan for these commercial products is even shorter than many voting system components in use today, and election officials would need to grapple with a voting system that evolves over time (with changes to critical component parts as technology changes), rather than one that is essentially static over its lifespan, as systems exist today. [243]

CONCLUSION

As this report demonstrates, the problem of aging and outdated voting equipment is national and widespread. We ignore it at our collective peril.

A majority of jurisdictions in 2016 will be using machines at or near the end of their projected lifespans. This is a short-term problem that must be addressed at two levels. First, these jurisdictions must put proper contingency plans in place to deal with machine failures in upcoming elections. Among other things, this means: implementing good poll worker training focused on the most common problems associated with aging machines, executing effective pre-election software testing and post-election audits, and ensuring the availability and proper use of emergency paper ballots where applicable.

Second, we must find money to pay for these emergency measures and, perhaps even more importantly, replace aging machines. Purchasing and deploying new voting systems takes time. It should be done methodically, with proper planning, including strategies to support new systems during their lifetimes. As long as election officials are unsure whether they can afford to buy new systems and support them over the long haul, that process is delayed, and the risk of Election Day failures increases.

We estimate that the cost of replacing new voting equipment could easily exceed $1 billion. Many experts we spoke to doubted that Congress would supply those funds. Given how urgent the problem is, and how soon new money must be found, that probably means the burden of funding new equipment will fall in significant measure on states and counties. Between them, they must find a way to pay for new equipment so that all voters, and not only those who live in counties that can afford new machines, are able to vote on equipment that works.

In the long term, we as a country need to adopt a new reality, where voting systems will be more flexible but less durable than in the past. There is much that can be done to reduce the costs associated with that future. While we strongly discourage the deployment of Internet voting until far better security is developed, there are other important steps that can be taken. For larger jurisdictions that can handle the transition to systems that use more COTS devices — like tablet computers — there is the prospect of significantly lower purchase and maintenance costs. With the benefit of past experience and greater resources, state and local election officials should be able to negotiate better contracts than they have in the past, lowering both immediate and long term expenses.

Even if Congress does not supply states and localities with large amounts of money to buy new equipment in the short term, they have a very important role to play in reducing costs in the long term. In particular, Congress can use the EAC to make grants to election officials and vendors to encourage more innovative voting system solutions. As highlighted in this report, such efforts are already underway in places like Los Angeles, California and Travis County, Texas. For a very small price, more efforts like these could produce far better (and less expensive) machines for states and counties around the country. Similarly, proper oversight of the EAC — to ensure that it updates the voting system guidelines, reduces the cost and time associated with certification, provides guidance to smaller jurisdictions as they negotiate new contracts, and helps local election jurisdictions share and

pool resources and information — can help drive down the long-term costs associated with the fact that for the foreseeable future, we will be using more complicated, less durable voting equipment.

Ultimately, if we are to avoid a new technology crisis every decade, all levels of government — federal, state, and local — must work to ensure that we develop long-term plans and sources of funding to support and regularly update our voting infrastructure, just as we budget and plan to maintain (and periodically replace) other critical infrastructure, from roads and bridges to fire trucks and police cars. The good news is, unlike in 2000, there is a deep understanding of the challenge, and an infrastructure in place that should allow state and local officials to develop plans to deal with this problem in the short and long run.

ENDNOTES

1   *See The Verifier – Polling Place Equipment*, Verified Voting, https://www.verifiedvoting.org/verifier2014/ (last visited June 29, 2015).

2   *See Voting Equipment in the United States*, Verified Voting, https://www.verifiedvoting.org/resources/voting-equipment/ (last visited June 26, 2015).

3   *See* Verified Voting, *supra* note 1.

4   The Presidential Comm'n on Election Admin., The American Voting Experience: Report and Recommendations of the Presidential Commission on Election Administration 62 (2014), *available at* https://www.supportthevoter.gov/files/2014/01/Amer-Voting-Exper-final-draft-01-09-14-508.pdf.

5   *See* Telephone Interview with Gail Fenumai, Dir. of Elections, Alaska (Apr. 2, 2015); Telephone Interview with Judy Dickerson, Election Dir., Graham Cnty., Ariz. (Aug. 31, 2015); Telephone Interview with Elaine Manlove, Election Comm'r, Del. (Mar. 19, 2015); Telephone Interview with Lori Edwards, Supervisor of Elections, Polk Cnty., Fla. (Feb. 20, 2015); Gregory D. Stumbo, Attorney General, Ky., Ensuring Your Vote Counts: Kentucky's Electronic Voting Systems 78 (2007), *available at* http://www.eac.gov/assets/1/Page/Kentuckys%20Election%20Voting%20Systems%20and%20Certification%20Process%20Report.pdf; E-mail from Angie Rogers, Comm'r of Elections, La., to Christopher Famighetti, Voting Rights Researcher, Brennan Ctr. for Justice (Mar. 13, 2015, 12:30 EST) (on file with author); Telephone Interview with Gladys Oyola, Comm'r / Deputy City Clerk, Springfield, Mass (Mar. 23, 2015); E-mail from David Scanlan, Deputy Sec'y of State, N.H., to Christopher Famighetti, Voting Rights Researcher, Brennan Ctr. for Justice (Mar. 17, 2015, 10:13 EST) (on file with author); Telephone Interview with Patti DiCostanzo, Superintendent of Elections, Bergen Cnty., N.J. (Apr. 10, 2015); R.I. House Comm. On Oversight, Review of the 2012 Elections 12 (2013); Telephone Interview with Dana DeBeauvoir, Cnty. Clerk, Travis Cnty., Tex., and Michael Winn, Director of Elections, Travis Cnty., Tex. (Apr. 2, 2015); Telephone Interview with Gene Bergman, Senior Assistant City Attorney, City of Burlington, Vt. (Apr. 20, 2015); Telephone Interview with Edgardo Cortes, Elections Director, Va. Board of Elections (Mar. 20, 2015); Telephone Interview with Garth Fell, Elections and Recording Manager, Snohomish Cnty., Wash. (Apr. 30, 2015).

6   Va. Info. Tech. Agency, Security Assessment of WinVote Voting Equipment for Department of Elections 3 (2015), *available at* http://elections.virginia.gov/WebDocs/VotingEquipReport/WINVote-final.pdf; *see Localities Using WinVotes*, Va. Dep't of Elections, *available at* http://elections.virginia.gov/webdocs/VotingEquipReport/5.pdf; Commonwealth of Va. State Board of Elections, Registrant Counts by Locality Voters Registered as of 2/1/2014, (Feb. 2, 2014), *available at* http://elections.virginia.gov/Files/Registration-Statistics/2014/01/Registrant_Count_By_Locality.pdf.

7   Research Triangle Inst. Int'l, Maryland Voting Systems Study 3-40 (2010) [hereinafter Research Triangle Inst. Int'l], *available at* http://mgaleg.maryland.gov/pubs/legislegal/2010-voting-systems-study-report.pdf. Since this report was published, Maryland has signed a new contract to replace the state's voting system. This occurred in January of 2015. See Telephone Interview with Paul Aumayr, Voting Sys. Dir. (Feb. 26, 2015).

8   Sue Lincoln, *Sending out an S-O-S for Voting Machines*, 89.3 WRKF (Mar. 5, 2015), http://wrkf.org/post/sending-out-s-o-s-voting-machines.

9   Telephone Interview with Thomas Hicks, Comm'r, U.S. Election Assistance Comm'n (Feb. 17, 2015).

10   *See generally* Lawrence Norden, Brennan Ctr. for Justice, Voting System Failures: A Database Solution (2010), *available at* www.brennancenter.org/sites/default/files/legacy/Democracy/Voting_Machine_Failures_Online.pdf.

11   Ann Keil, *Aging Voting Machines in Marion County Creating Concerns*, FOX59 (Dec. 24, 2013, 4:48PM), http://fox59.com/2013/12/24/aging-voting-machines-in-marion-county-creating-concerns/.

12   The warnings of the Commission and the relative lack of attention they have received represent an eerie repetition of the silence that greeted a 1988 National Bureau of Standards report written by Roy Saltman, who argued that punch card voting systems of the kind used in Ft Lauderdale, Florida needed to be upgraded or replaced, or serious consequences would follow. *See* Roy G. Saltman, Nat'l Bureau of Standards, Accuracy, Integrity and Security in Computerized Vote-Tallying (1988), *available at* http://www.itl.nist.gov/lab/specpubs/500-158.htm. In addition, election officials in

Massachusetts and New Hampshire banned the use of punch card voting machines before 2000. Lucy Morgan, *Punch Cards Fraught with Errors*, Sᴛ. Pᴇᴛᴇʀsʙᴜʀɢ Tɪᴍᴇs, Nov. 14, 2000, *available at* http://www.sptimes.com/News/111400/ Election2000/Punch_cards_fraught_w.shtml; Richard Lacayo, *Is This Any Way to Vote?*, TIME, Nov. 27, 2000, *available at* http://content.time.com/time/world/article/0,8599,2047399,00.html; John Minz, *Most States Don't Count Dimples*, Wᴀsʜ. Pᴏsᴛ, Nov. 24, 2000, *available at* http://www.washingtonpost.com/archive/politics/2000/11/24/most-states-dont-count-dimples/d2c0741a-4a2d-474d-8321-643ea930a375/.

13   Alabama, Arkansas, California, Colorado, Delaware, Florida, Idaho, Illinois, Indiana, Iowa, Kansas, Louisiana, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, North Carolina, North Dakota, Ohio, Oregon, Pennsylvania, Rhode Island, South Carolina, Tennessee, Texas, Vermont, Virginia, West Virginia, Washington and Wisconsin. In Arkansas, Louisiana, Michigan, and Rhode Island statewide plans are contingent on funding, and in the case of Virginia, a funding request by the Governor has been rejected by the state legislature. In North Carolina and Vermont, we refer to relevant state statutes. Finally, we found evidence – through interviews or in publicly available documents – that election officials in Arkansas, Colorado, Florida, Idaho, Indiana, Massachusetts, Michigan, Minnesota, Mississippi, Oregon and Wisconsin planned or intended to replace machines before the 2016 election. *See* Telephone Interview with Daniel Baxter, Dir. of Elections, Montgomery Cnty., Ala. (Apr. 30, 2015); Associated Press, Arkansas Scales Back Voting Machine Plan to 4 Counties, THV11 (June 17, 2015, 6:52PM), http://www.thv11.com/story/ news/2015/06/17/arkansas-scales-back-voting-machine-plan-to-4-counties/28896107/ (noting Arkansas Secretary of State program for replacing voting equipment has been limited to Boone, Columbia, Garland and Sebastian counties with the hope of expanding state-wide for the 2016 general election); Telephone Interview with Dean Logan, Cnty. Clerk, L.A. Cnty., Cal. (Mar. 30, 2015); Telephone Interview with Neal Kelley, Registrar of Voting, Orange Cnty., Cal. (Feb. 2, 2015); Press Release, Colo. Dep't of State, The Path Forward to a Uniform Voting System, (2015), *available at* http://www.sos.state.co.us/pubs/elections/VotingSystems/files/2015/UVSOverview.pdf (outlining an implementation plan for a state-wide uniform voting system); Telephone Interview with Elaine Manlove, Election Comm'r, Del. (Mar. 19, 2015); Telephone Interview with Lori Edwards, Supervisor of Elections, Polk Cnty., Fla. (Feb. 20, 2015); Telephone Interview with Paul Lux, Supervisor of Elections, Okaloosa Cnty., Fla. (Mar. 23, 2015); Telephone Interview with Sylvia Stephens, Supervisor of Elections, Jackson Cnty., Fla. (Feb. 23, 2015); Telephone Interview with Janice Shiner, Deputy Clerk, Shoshone Cnty., Idaho (Apr. 30, 2015); E-mail from Jared Hays, Ada Cnty. Elections, Idaho, to Katherine Valde, Research and Program Associate, Brennan Ctr. for Justice (Apr. 15, 2015) (on file with author); Telephone Interview with Jim Allen, Spokesman, Chi. Board of Election, Chi., Ill. (Apr. 13, 2015); Telephone Interview with Brienne Delaney, Director of Elections, Marion Cnty., Ind., and Jenny Troutman, Deputy Election Administrator, Marion Cnty., Ind. (Feb. 24, 2015); Telephone Interview with Debra Walker, Clerk, Board of Elections, Henry Cnty., Ind. (Feb. 9, 2015); Telephone Interview with Jennifer Bentley, Cnty. Clerk, Montgomery Cnty. Ind. (Feb. 20, 2015); Telephone Interview with Richard Bauer, Elections Supervisor, Scott Cnty., Iowa (May 4, 2015); Telephone Interview with Rick Piepho, Cnty. Clerk, Harvey Cnty., Kan. (Apr. 6, 2015); Telephone Interview with Brian Newby, Election Comm'r, Johnson Cnty., Kan. (Mar. 27, 2015); Tᴏᴍ Sᴄʜᴇᴅʟᴇʀ, Lᴀ. Sᴇᴄ'ʏ ᴏғ Sᴛᴀᴛᴇ, Rᴇᴘᴏʀᴛ ᴏғ ᴛʜᴇ Sᴘᴇᴄɪᴀʟ Cᴏᴍᴍɪᴛᴛᴇᴇ Dᴇsɪɢɴᴀᴛᴇᴅ ʙʏ HRC 147 (2014) ᴛᴏ Sᴛᴜᴅʏ Nᴇᴡ Vᴏᴛɪɴɢ Tᴇᴄʜɴᴏʟᴏɢʏ 6-7 (Mar. 1, 2015) (on file with author); Telephone Interview with Elizabeth Camara, Chairperson of Board of Election Comm'rs, Fall River City, Mass. (Mar. 25, 2015); Telephone Interview with Joseph P. Shea, Board of Registrars of Voters, Quincy City, Mass. (Apr. 16, 2015); Telephone Interview with Mary Ellen Lannon, Town Clerk, Winchester, Mass. (Feb. 12, 2015); Telephone Interview with David Rushford, City Clerk, Worcester, Mass. (Mar. 20, 2015); Telephone Interview with Gladys Oyola, Comm'r / Deputy City Clerk, Springfield, Mass (Mar. 23, 2015); Telephone Interview with Chris Thomas, Dir. of Elections, Mich. (Mar. 20, 2015); Telephone Interview with Joseph Mansky, Elections Manager, Ramsey Cnty., Minn. (Apr. 30, 2015); Telephone Interview with Lisa Shadick, Elections Coordinator, Scott Cnty., Minn. (Feb. 9, 2015); Telephone Interview with Dave Walz, Dir. Of Elections, Stearns Cnty., Minn. (July 23, 2015); Telephone Interview with Danny Klein, Dir., Board of Elections, DeSoto Cnty., Miss. (Feb. 26, 2015); Telephone Interview with Wendy Noren, Dir. of Elections, Boone Cnty., Mo. (Mar. 13, 2015). Telephone Interview with Diane Norcross Thompson, Cnty. Clerk, Johnson Cnty., Mo. (Mar. 27, 2015); Telephone Interview with Eric Fey, Dir., Board of Elections, St. Louis Cnty., Mo. (Apr. 15, 2015); H.B 589, Gen. Assemb., Sess. 2013 (N.C. 2013) (requiring the use of paper ballots and thus new machines in more than thirty counties); Telephone Interview with Jim Silrum, Deputy Sec'y of State, N.D. (Mar. 20, 2015); Telephone Interview with Sherry Poland, Dir. of Elections, Hamilton Cnty., Ohio (Feb. 18, 2015); Telephone Interview with Ken Terry, Dir. of Board of Elections, Allen Cnty., Ohio (Feb. 11, 2015); Telephone Interview with Jocelyn Bucaro, Deputy Dir. of Elections, Butler Cnty., Ohio (Feb. 2, 2015); Telephone Interview with William Anthony, Dir., Board of Elections, Franklin Cnty., Ohio (Mar. 12, 2015); E-mail from Steve Kindred, Elections Manager, Clackamas Cnty., Or., to Christopher Famighetti, Voting Rights Researcher, Brennan Ctr. for Justice (Mar. 7, 2015, 12:24 EST) (on file with author); Telephone Interview with Tim Scott, Dir. of Elections, Multnomah Cnty. Or. (Apr. 13, 2015); Telephone Interview with Marisa Crispell, Dir.

of Elections, Luzerne Cnty. Pa. (Mar. 3, 2015); Telephone Interview with Tim Dowling, Supervisor of Elections, Phila., Pa. (Feb. 2, 2015); Telephone Interview with Rob Rock, Dir. of Elections, R.I. (July 21, 2015); Telephone Interview with Chris Whitmire, Public Information Officer, Election Comm'n, S.C., (Apr. 16, 2015); Telephone Interview with Charles Holiway, Adm'r, Election Comm'n, Roane Cnty., Tenn. (Feb. 25, 2015); Telephone Interview with Philip Warren, Adm'r of Elections, Wilson Cnty., Tenn. (Feb. 19, 2015); Telephone Interview with Richard Holden, Adm'r of Elections, Shelby Cnty., Tenn. (Feb. 11, 2015); Telephone Interview with Dana DeBeauvoir, Cnty. Clerk, Travis Cnty., Tex., and Michael Winn, Director of Elections, Travis Cnty., Tex. (Apr. 2, 2015); E-mail from Jean Paul Isabelle, Elections Adm'r, Vt. Office of the Sec'y of State, to Christopher Famighetti, Voting Rights Researcher, Brennan Ctr. for Justice (Apr. 1, 2015, 16:16 EST) (on file with author) (noting that due to 17 V.S.A. § 2491 "all towns with 1,000 voters or more will be required to have a vote tabulator by the 2016 election"); Telephone Interview with Edgardo Cortes, Elections Director, Va. Board of Elections (Mar. 20, 2015) (noting that the governor's request for $28 million for state-wide voting machine replacement was rejected by the legislature); Telephone Interview with Vera McCormick, Cnty. Clerk, Kanawha Cnty., W. Va. (Feb. 4, 2015); Telephone Interview with Garth Fell, Elections and Recording Manager, Snohomish Cnty., Wash. (Apr. 30, 2015); Telephone Interview with Kathleen Novack, Cnty. Clerk, Waukesha Cnty., Wis. (Feb. 5, 2015).

14   Alabama, Arkansas, California, Delaware, Florida, Illinois, Indiana, Kansas, Louisiana, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, North Carolina, Ohio, Pennsylvania, Rhode Island, Tennessee, Texas, Virginia and West Virginia. Telephone Interview with Kim Tillman, Election Div. Coordinator, Mobile Cnty., Ala.; (Jul. 27, 2015); Telephone Interview with Pam Walker, Voting Equipment Specialist, Election Comm'n, Pulaski County, Ark. (Apr. 14, 2015); Telephone Interview with Neal Kelley, Registrar of Voting, Orange Cnty., Cal. (Feb. 27, 2015); Telephone Interview with Elaine Manlove, Election Comm'r, Del. (Mar. 19, 2015); Telephone Interview with Lori Edwards, Supervisor of Elections, Polk Cnty., Fla. (Feb. 20, 2015); Telephone Interview with Jim Allen, Spokesman, Chi. Board of Election, Chi., Ill. (Apr. 13, 2015); E-mail from Jim Allen, Spokesman, Chi. Board of Election, Chi., Ill., to Carson Whitelemons, Senior Research Assoc., Brennan Ctr. for Justice (June 24, 2015, 13:23 EST) (on file with author); Telephone Interview with Debra Walker, Clerk, Board of Elections, Henry Cnty., Ind. (Feb. 9, 2015); Telephone Interview with Jennifer Bentley, Cnty. Clerk, Montgomery Cnty. Ind. (Feb. 20, 2015); Telephone Interview with Rick Piepho, Cnty. Clerk, Harvey Cnty., Kan. (Apr. 6, 2015); Telephone Interview with Brian Newby, Election Comm'r, Johnson Cnty., Kan. (Mar. 27, 2015); E-mail from Angie Rogers, Comm'r of Elections, La., to Carson Whitelemons, Senior Research Assoc., Brennan Ctr. for Justice (June 23, 2015, 16:18 EST) (on file with author); Telephone Interview with Elizabeth Camara, Chairperson of Board of Election Comm'rs, Fall River City, Mass. (Mar. 25, 2015); Telephone Interview with Madeline Scully, Town Clerk, Windsor, Mass. (Apr. 3, 2015); Telephone Interview with Chris Thomas, Dir. of Elections, Mich. (Mar. 20, 2015); Telephone Interview with Dave Walz, Dir. of Elections, Stearns Cnty., Minn. (July 23, 2015); Telephone Interview with Danny Klein, Dir., Board of Elections, DeSoto Cnty., Miss. (Feb. 26, 2015); Telephone Interview with Diane Norcross Thompson, Cnty. Clerk, Johnson Cnty., Mo. (Mar. 27, 2015); Telephone Interview with Eric Fey, St. Louis Cnty., Mo. (Apr. 15, 2015); Telephone Interview with Steve Hines, Dir., Board of Elections, Forsyth Cnty., N.C. (Apr. 6, 2015); Telephone Interview with Ashely Tew, Dir., Board of Elections, Sampson Cnty., N.C. (Feb. 18, 2015); Telephone Interview with Jocelyn Bucaro, Deputy Dir. of Elections, Butler Cnty., Ohio (Feb. 2, 2015); Telephone Interview with William Anthony, Dir., Board of Elections, Franklin Cnty., Ohio (Mar. 12, 2015); Telephone Interview with Sherry Poland, Dir. of Elections, Hamilton Cnty. Ohio (Feb. 18, 2015); E-mail from Tim Dowling, Supervisor of Elections, Phila., Pa., to Carson Whitelemons, Senior Research Assoc., Brennan Ctr. for Justice (June 24, 2015, 10:21 EST) (on file with author); Telephone Interview with Marisa Crispell, Dir. of Elections, Luzerne Cnty. Pa. (Mar. 3, 2015); Telephone Interview with Rob Rock, Dir. of Elections, R.I. (July 21, 2015); Telephone Interview with Charles Holiway, Adm'r, Election Commission, Roane Cnty., Tenn. (Feb. 25, 2015); Telephone Interview with Philip Warren, Adm'r of Elections, Wilson Cnty., Tenn. (Feb. 19, 2015); Telephone Interview with Dana DeBeauvoir, Cnty. Clerk, Travis Cnty., Tex., and Michael Winn, Director of Elections, Travis Cnty., Tex. (Apr. 2, 2015); Telephone Interview with Edgardo Cortes, Elections Director, Va. Board of Elections (Mar. 20, 2015); Telephone Interview with Vera McCormick, Cnty. Clerk, Kanawha Cnty., W. Va. (Feb. 4, 2015).

15   Based on publicly available registration data from the following jurisdictions cited in Footnote 13: Alabama (Montgomery Cnty.); Arkansas, California (L.A. Cnty., Orange Cnty.); Colorado; Delaware; Florida (Okaloosa Cnty., Polk Cnty., Jackson Cnty.); Idaho (Shoshone Cnty., Ada Cnty.); Illinois (Chicago City); Indiana (Marion Cnty., Henry Cnty., Montgomery Cnty.); Iowa (Scott Cnty.); Kansas (Harvey Cnty, Johnson Cnty.); Louisiana; Massachusetts (Fall River, Quincy, Winchester, Worcester, Springfield); Michigan; Minnesota (Ramsey Cnty., Scott Cnty.); Mississippi (DeSoto Cnty.); Missouri (Boone Cnty., Johnson Cnty., St. Louis Cnty.); North Carolina (Selected counties using DREs as primary policy place equipment); North Dakota; Ohio (Erie Cnty, Hamilton Cnty., Allen Cnty., Butler Cnty., Franklin Cnty.); Oregon (Clackamas Cnty., Multnomah Cnty.); Pennsylvania (Luzerne Cnty., Philadelphia); Rhode Island; South

Carolina; Tennessee (Roane Cnty., Wilson Cnty., Shelby Cnty.); Texas (Travis Cnty.); Virginia (selected counties); West Virginia (Kanawha Cnty.); Washington (Snohomish Cnty.); Wisconsin (Waukesha Cnty.).

16   Telephone Interview with Merle King, Exec. Dir., Ctr. for Election Sys., Kennesaw State Univ. (Feb. 5, 2015).

17   Telephone Interview with Tammy Patrick, Senior Advisor, Bipartisan Policy Ctr., (Mar. 20, 2015).

18   Sharon Laskowski et al., National Institute of Standards and Technology, A Roadmap for Usability and Accessibility Guidance 3 (Feb. 9, 2015) (preliminary report), *available at* http://civicdesign.org/wp-content/uploads/Roadmap-V1-FINAL-15-0205a.pdf.

19   *See* Norden, *supra* note 10, at 25.

20   Martha T. Moore, *Lengthy Vacancy Ends for Election Commissioners*, USA TODAY On Politics (Dec. 17, 2014, 17:22PM), http://onpolitics.usatoday.com/2014/12/17/elections-assistance-commission-senate/.

21   *See id.*

22   Telephone Interview with Matthew Masterson, Comm'r, U.S. Election Assistance Comm'n (Apr. 2, 2015).

23   *See* Help America Vote Act, 52 U.S.C.A. §§ 20901-21145 (2015).

24   E-mail from Monica Evans, Grants Manager, U.S. Election Assistance Comm'n, to Christopher Famighetti, Voting Rights Researcher, Brennan Ctr. for Justice (Feb. 25, 2012) (on file with author).

25   U.S. Election Assistance Comm'n, Voting System Lifecycle/Sustainability Roundtable 2 (2011), *available at* http://www.eac.gov/assets/1/Events/Lifecycle_Sustainability_Roundtable_Verbatim-05.05.11.pdf.

26   Stephen Ansolabehere and Charles Stewart found that the residual vote rate for DRE machines and Optical Scan units was lower than for punch card and lever machines. *See* Stephen Ansolabehere & Charles Stewart III, *Residual Votes Attributable to Technology*, 67 J. Pol. 365, 365 (2005), *available at* http://vote.caltech.edu/sites/default/files/residual_votes_attributable_to_tech.pdf. HAVA set new requirements for voting machine accessibility. *See* Lawrence Norden, Brennan Ctr. for Justice, The Machinery of Democracy: Voting System Security, Accessibility, Usability, and Cost 46 (2006), *available at* https://www.brennancenter.org/sites/default/files/publications/Machinery_Democracy.pdf.

27   Telephone Interview with Merle King, Exec. Dir., Ctr. for Election Sys., Kennesaw State Univ. (Feb. 5, 2015).

28   According to Verified Voting, there are more than 30 pieces of voting equipment in use today, including accessibility devices, central count tabulators and polling place machines. Verified Voting lists 25 different models of DREs and Optical Scan units specific to polling place voting. *See Voting Equipment in the United States*, VerifiedVoting, https://www.verifiedvoting.org/resources/voting-equipment/ (last visited June 15, 2015).

29   Telephone Interview with Merle King, Exec. Dir., Ctr. for Election Sys., Kennesaw State Univ. (Feb. 5, 2015).

30   *Id.*

31   *See* Telephone Interview with Doug Jones, Professor, Univ. of Iowa (May 21, 2015); Telephone Interview with Daniel Lopresti, Professor of Computer Sci., Lehigh Univ. (May 26, 2015); E-mail from Rokey Suleman, former Exec. Dir. of the D.C. Board of Elections and Ethics to Lawrence Norden, Deputy Dir., Democracy Program, Brennan Ctr. for Justice (June 1, 2015, 11:50PM) (on file with author).

32   Telephone Interview with Doug Jones, Professor, Univ. of Iowa (May 21, 2015).

33   *See* Telephone Interview with Howard Cramer, Exec. Vice President of Gov't Relations, Dominion Voting (Mar. 12, 2015) ("The product might last for 10-15 years. Are we talking about the components? The functional usefulness? […] There are so many variables that the true answer is that it is hard to predict."); Telephone Interview with Kathy Rogers and Ken Carbullido, ES&S (Apr. 3, 2015) ("Jurisdictions that have made investments, or are thinking about investments, are expecting systems to last 12-15 years.").

34   *See* Legislative Audit Council, S.C. Gen. Assembly, A Review of Voting Machines in South Carolina 45 (2013), *available at* http://lac.sc.gov/LAC_Reports/2013/Documents/SEC.pdf; Research Triangle Inst. Int'l, *supra* note 7, at 3-40.

35   The Brennan Center used data provided by Verified Voting to perform the analysis underlying the map titled, "Machines At Least 10 Years Old in 2016." Verified Voting provided information from the "Verifier" from 2006 – an online tool showing the type and model of machines used in jurisdictions across the country. See *The Verifier – Polling Place Equipment*, VerifiedVoting, https://www.verifiedvoting.org/verifier2014/ (last visited June 15, 2015). We compared the 2006 data to the 2015 data currently on Verified Voting's website. Based on a jurisdiction by jurisdiction comparison of these two data sets, the Brennan Center estimates that jurisdictions in 43 states are using equipment from 2006 or earlier. For Massachusetts, New Hampshire, Vermont, and Wisconsin, this analysis was only possible using county level data. In addition, we supplemented this analysis with a review of press reports, public documents, and interviews with election officials. Although they have not yet signed contracts, as of July 2015, the following states intend or plan to deploy new machines in 2016: Colorado, Michigan and Arkansas. In addition, we include jurisdictions in Florida, Idaho, Massachusetts, Minnesota, Mississippi, Oregon and Wisconsin that intend to deploy new equipment in 2016, and in some cases in the second half of 2015. This map assumes that equipment currently used will not be replaced before 2016.

36   *See* Telephone Interview with Gail Fenumai, Dir. of Elections, Alaska (Apr. 2, 2015); Telephone Interview with Judy Dickerson, Election Dir., Graham Cnty., Ariz. (Aug. 31, 2015); Telephone Interview with Elaine Manlove, Election Comm'r, Del. (Mar. 19, 2015); Telephone Interview with Lori Edwards, Supervisor of Elections, Polk Cnty., Fla. (Feb. 20, 2015); Gregory D. Stumbo, Attorney General, Ky., Ensuring Your Vote Counts: Kentucky's Electronic Voting Systems 78 (2007), *available at* http://www.eac.gov/assets/1/Page/Kentuckys%20Election%20Voting%20Systems%20 and%20Certification%20Process%20Report.pdf; E-mail from Angie Rogers, Comm'r of Elections, La., to Christopher Famighetti, Voting Rights Researcher, Brennan Ctr. for Justice (Mar. 13, 2015, 12:30 EST) (on file with author); Telephone Interview with Gladys Oyola, Comm'r / Deputy City Clerk, Springfield, Mass (Mar. 23, 2015); E-mail from David Scanlan, Deputy Sec'y of State, N.H., to Christopher Famighetti, Voting Rights Researcher, Brennan Ctr. for Justice (Mar. 17, 2015, 10:13 EST) (on file with author); Telephone Interview with Patti DiCostanzo, Superintendent of Elections, Bergen Cnty., N.J. (Apr. 10, 2015); R.I. House Comm. On Oversight, Review of the 2012 Elections 12 (2013); Telephone Interview with Dana DeBeauvoir, Cnty. Clerk, Travis Cnty., Tex., and Michael Winn, Director of Elections, Travis Cnty., Tex. (Apr. 2, 2015); Telephone Interview with Gene Bergman, Senior Assistant City Attorney, City of Burlington, Vt. (Apr. 20, 2015); Telephone Interview with Edgardo Cortes, Elections Director, Va. Board of Elections (Mar. 20, 2015); Telephone Interview with Garth Fell, Elections and Recording Manager, Snohomish Cnty., Wash. (Apr. 30, 2015).

37   Greg Oliver, *Pickens Elections Director Says Office Understaffed*, Daily Journal-Messenger, July 8, 2014 at A6.

38   Research Triangle Inst. Int'l, *supra* note 7, at 3-40.

39   *See* David Jefferson et al., *Analyzing Internet Voting Security*, 47 Commc'ns of the ACM 59 (2004), *available at* http://www.cs.berkeley.edu/~daw/papers/cacm-serve.pdf; Avi Rubin, Security Considerations for Remote Electronic Voting over the Internet (2001), *available at* http://avirubin.com/e-voting.security.pdf; Scott Wolchok et al., Attacking the Washington, D.C. Internet Voting System (2012), *available at* https://ericw.us/trow/dc-internet-voting-fc.pdf; David Jefferson, If I Can Shop and Bank Online, Why Can't I Vote Online? (2011), *available at* https://electionlawblog.org/wp-content/uploads/jefferson-onlinevoting.pdf; *Internet Voting—Not Ready for Prime Time?,* The Canvass States and Election Reform (Nat'l Conf. of State Legs. Legislatures, D.C.), Feb. 2013, *available at* http://www.ncsl.org/Documents/legismgt/elect/Canvass_Feb_2013_no_37.pdf; David Talbot, *Why You Can't Vote Online,* MIT Technology Review (Nov. 5, 2012), http://www.technologyreview.com/news/506741/why-you-cant-vote-online/.

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[93] The Brennan Center confirmed with two major vendors - ES&S and Dominion - that the following models are no longer manufactured: iVotronic and M100 (ES&S); AccuVote OS, AccuVote OSX, AccuVote TS, AccuVote TSX, AVC Edge, AVC Advantage, Optech IIIP-Eagle and Optech Insight (Dominion). In addition, the Danaher 1242 – used statewide in Delaware – is no longer in production. There may be additional models that were produced by other vendors that are no longer manufactured. This map assumes that equipment currently used will not be replaced before 2016. Washington, Oregon, and Colorado are primarily vote-by-mail states. According to Verified Voting and vendors we spoke with, Washington and Colorado use models that are no longer manufactured for tabulating absentee ballots. For Massachusetts, New Hampshire, Vermont, and Wisconsin, this analysis was only possible using county level data. *See* E-mail from Howard Cramer, Executive Vice President of Governmental Relations, Dominion Voting Systems, to Christopher Famighetti, Voting Rights Researcher, Brennan Ctr. for Justice (June 11, 2015, 12:41 EST) (on file with author); Telephone Interview with Kathy Rogers and Ken Carbullido, ES&S (Apr. 3, 2015); Telephone Interview with Tom Ferguson, Nat'l Dir. of Sales, ELECTEC Election Servs., Inc. (Aug. 11, 2015).

[94] *See The Verifier – Polling Place Equipment*, Verified Voting, https://www.verifiedvoting.org/verifier2014/ (last visited June 29, 2015).

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[96] Telephone Interview with Edgardo Cortes, Elections Director, Va. Board of Elections (Mar. 20, 2015).

[97] Telephone Interview with Brad Nelson, Elections Director, Pima Cnty., Ariz. (Feb. 27, 2015).

[98] Telephone Interview with Brienne Delaney, Director of Elections, Marion Cnty., Ind., and Jenny Troutman, Deputy Election Administrator, Marion Cnty., Ind. (Feb. 24, 2015).

[99] R.I. House Comm. On Oversight, Review of the 2012 Elections 12 (2013).

[100] Telephone Interview with Neal Kelley, Registrar of Voting, Orange Cnty., Cal. (Feb. 2, 2015).

[101] Telephone Interview with Howard Cramer, Exec. Vice President of Gov't Relations, Dominion Voting (Mar. 12, 2015).

[102] The average cost of a voting machine is $4500. *See Voting Technology: Current and Future Choices,* The Canvass: States and Election Reform 3 (Nat'l Conf. of State Legs., D.C.), June 2012, *available at* http://www.ncsl.org/documents/legismgt/elect/Canvass_June_2012_No_31.pdf. Assuming one DRE for every 250 registered voters in the nation, it would cost approximately $3.5 billion to replace machines across the country. Assuming one PCOS unit for every 1500 registered voters in the country, it would cost approximately $580 million to replace machines across the country. Based on these assumptions, we estimate that replacing machines would fall somewhere between $580 million and $3.5 billion.

[103] E-mail from Merle King, Exec. Dir., Ctr. for Election Sys. Kennesaw St. Univ., to Christopher Famighetti, Voting Rights Researcher, Brennan Ctr. for Justice (June 14, 2015, 18:49 EST) (on file with author).

[104] U.S. Election Assistance Comm'n, Fiscal Year 2013 Interim Annual Grant Expenditure Report 12 (2015), *available at* http://www.eac.gov/assets/1/Documents/FY%202013%20Grants%20Report%20Jan%2029%202015%20FINAL.pdf.

[105] *See* Telephone Interview with Ryan Macias, Voting Sys. Analyst, Cal. (Mar. 13, 2015); Telephone Interview with Matt Kitzman, Electronic Voting Sys. Election Specialist, Wis. (Apr. 1, 2015).

[106] *See* Telephone Interview with Ed Packard, Dir. of Elections, Ala. (Mar. 3, 2015); Telephone Interview with Ryan Macias, Voting Sys. Analyst, Cal. (Mar. 13, 2015); Telephone Interview with Peggy Reeves, Dir. of Elections, Conn. (Mar.

19, 2015); Telephone Interview with Kyle Thomas, Dir. of Voting and Registration Sys., Ill., and Kevin Turner, IT Dir, Ill. (Mar. 17, 2015); Maryellen Allen, Exec. Dir., Board of Elections, Ky. (Apr. 15, 2015); E-mail from Angie Rogers, Comm'r of Elections, La., to Christopher Famighetti, Voting Rights Researcher, Brennan Ctr. for Justice (Mar. 13, 2015, 12:30 EST) (on file with author); Telephone Interview with Paul Aumayr, Voting Sys. Dir., Md. (Feb. 26, 2015); Michelle Tassinari, Dir. of Elections, Mass. (Mar. 19, 2015); E-mail from Lisa Kimmet, Deputy, Elections and Gov't Division, Mont., to Christopher Famighetti, Voting Rights Researcher, Brennan Ctr. for Justice (Mar. 16, 2015, 10:50 EST) (on file with author); Telephone Interview with Matt Damschroder, Sec'y of State, Ohio (Feb. 23, 2015); Telephone Interview with Mark Thomas, Dir. of Elections, Utah (Mar. 24, 2015); Telephone Interview with Edgardo Cortes, Elections Dir., Va. (Mar. 20, 2015); Telephone Interview with Layna Brown, Elections Dir., W. Va. (Mar. 20, 2015); Lori Augina, Dir. of Elections, Wash. (Apr. 1, 2015); Telephone Interview with Matt Kitzman, Electronic Voting Sys. Election Specialist, Wis. (Apr. 1, 2015).

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[108]   Telephone Interview with William Anthony, Dir., Board of Elections, Franklin Cnty., Ohio (Mar. 12, 2015).

[109]   U.S. Election Assistance Comm'n, Fiscal Year 2013 Interim Annual Grant Expenditure Report 12 (2015), *available at* http://www.eac.gov/assets/1/Documents/FY%202013%20Grants%20Report%20Jan%2029%202015%20 FINAL.pdf.

[110]   Interview with Christy McCormick, Comm'r, U.S. Election Assistance Comm'n (Apr. 21, 2015).

[111]   Alabama, Arkansas, California, Delaware, Florida, Illinois, Indiana, Kansas, Louisiana, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, North Carolina, Ohio, Pennsylvania, Rhode Island, Tennessee, Texas, Virginia and West Virginia. Telephone Interview with Kim Tillman, Election Div. Coordinator, Mobile Cnty., Ala.; (Jul. 27, 2015); Telephone Interview with Pam Walker, Voting Equipment Specialist, Election Comm'n, Pulaski County, Ark. (Apr. 14, 2015); Telephone Interview with Neal Kelley, Registrar of Voting, Orange Cnty., Cal. (Feb. 27, 2015); Telephone Interview with Elaine Manlove, Election Comm'r, Del. (Mar. 19, 2015); Telephone Interview with Lori Edwards, Supervisor of Elections, Polk Cnty., Fla. (Feb. 20, 2015); Telephone Interview with Jim Allen, Spokesman, Chi. Board of Election, Chi., Ill. (Apr. 13, 2015); E-mail from Jim Allen, Spokesman, Chi. Board of Election, Chi., Ill., to Carson Whitelemons, Senior Research Assoc., Brennan Ctr. for Justice (June 24, 2015, 13:23 EST) (on file with author); Telephone Interview with Debra Walker, Clerk, Board of Elections, Henry Cnty., Ind. (Feb. 9, 2015); Telephone Interview with Jennifer Bentley, Cnty. Clerk, Montgomery Cnty. Ind. (Feb. 20, 2015); Telephone Interview with Rick Piepho, Cnty. Clerk, Harvey Cnty., Kan. (Apr. 6, 2015); Telephone Interview with Brian Newby, Election Comm'r, Johnson Cnty., Kan. (Mar. 27, 2015); E-mail from Angie Rogers, Comm'r of Elections, La., to Carson Whitelemons, Senior Research Assoc., Brennan Ctr. for Justice (June 23, 2015, 16:18 EST) (on file with author); Telephone Interview with Elizabeth Camara, Chairperson of Board of Election Comm'rs, Fall River City, Mass. (Mar. 25, 2015); Telephone Interview with Madeline Scully, Town Clerk, Windsor, Mass. (Apr. 3, 2015); Telephone Interview with Chris Thomas, Dir. of Elections, Mich. (Mar. 20, 2015); Telephone Interview with Dave Walz, Dir. of Elections, Stearns Cnty., Minn. (July 23, 2015); Telephone Interview with Danny Klein, Dir., Board of Elections, DeSoto Cnty., Miss. (Feb. 26, 2015); Telephone Interview with Diane Norcross Thompson, Cnty. Clerk, Johnson Cnty., Mo. (Mar. 27, 2015); Telephone Interview with Eric Fey, St. Louis Cnty., Mo. (Apr. 15, 2015); Telephone Interview with Steve Hines, Dir., Board of Elections, Forsyth Cnty., N.C. (Apr. 6, 2015); Telephone Interview with Ashely Tew, Dir., Board of Elections, Sampson Cnty., N.C. (Feb. 18, 2015); Telephone Interview with Jocelyn Bucaro, Deputy Dir. of Elections, Butler Cnty., Ohio (Feb. 2, 2015); Telephone Interview with William Anthony, Dir., Board of Elections, Franklin Cnty., Ohio (Mar. 12, 2015); Telephone Interview with Sherry Poland, Dir. of Elections, Hamilton Cnty. Ohio (Feb. 18, 2015); E-mail from Tim Dowling, Supervisor of Elections, Phila., Pa., to Carson Whitelemons, Senior Research Assoc., Brennan Ctr. for Justice (June 24, 2015, 10:21 EST) (on file with author); Telephone Interview with Marisa Crispell, Dir. of Elections, Luzerne Cnty. Pa. (Mar. 3, 2015); Telephone Interview with Rob Rock, Dir. of Elections, R.I. (July 21, 2015); Telephone Interview with Charles Holiway, Adm'r, Election Commission, Roane Cnty., Tenn. (Feb. 25, 2015); Telephone Interview with Philip Warren, Adm'r of Elections, Wilson Cnty., Tenn. (Feb. 19, 2015); Telephone Interview with Dana DeBeauvoir, Cnty. Clerk, Travis Cnty., Tex., and Michael Winn, Director of Elections, Travis Cnty., Tex. (Apr. 2, 2015); Telephone Interview with Edgardo Cortes, Elections Director, Va. Board of Elections (Mar. 20, 2015); Telephone Interview with Vera McCormick, Cnty. Clerk, Kanawha Cnty., W. Va. (Feb. 4, 2015).

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113   Telephone Interview with Edgardo Cortes, Elections Director, Va. Board of Elections (Mar. 20, 2015).

114   Telephone Interview with Ken Terry, Dir. of Board of Elections, Allen Cnty., Ohio (Feb. 11, 2015).

115   Telephone Interview with Edgardo Cortes, Elections Director, Va. Board of Elections (Mar. 20, 2015).

116   *See* Elisabeth Hulette, *Virginia Governor Announces New Voting Machines*, Gov't Tech. (Dec. 16, 2014), http://www.govtech.com/products/Virginia-Governor-Announces-New-Voting-Machines.html.

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120   For this analysis, the Brennan Center used data provided by the U.S. Census Bureau. Our measure of median income in Virginia jurisdictions is based on the following data set: Median Household Income in the Past 12 Months, 2009-2013 American Community Survey 5-Year Estimates. In addition, the Brennan Center confirmed that the following 16 jurisdictions purchased new machines, or had plans to purchase new machines, before the Virginia Department of Elections decertified the WinVote: City of Bristol, Caroline County, Chesterfield County, Fairfax County, Goochland County, Halifax County, Henrico County, King George County, Loudoun County, City of Mannasas Park, Montgomery County, Orange County, Pittsylvania County, Prince William County, City of Virginia Beach, and York County. We found that the average median income for these jurisdictions was approximately $69,800. Comparably, the average median income for all other Virginia jurisdictions was approximately $50,100. Telephone Interview with Rokey Suleman, Consultant, Va. Dep't of Elections (Aug. 14, 2015).

121   The Brennan Center performed the same analysis for jurisdictions in Arizona and Minnesota. In Minnesota, the Brennan Center found that the six jurisdictions that purchased new machines, or that initiated the procurement process for new machines, had a higher average household median income ($71,735) than the remaining jurisdictions ($50,890). The Brennan Center found evidence that the following Minnesota jurisdictions purchased new machines or were in the process of procuring new machines: Anoka County, Dakota County, Hennepin County, Ramsey County, Scott County and Washington County. Email from Julie Strother, Dir. of Gov't Relations, Office of Minn. Sec'y of State, to Christopher Famighetti, Voting Rights Researcher, Brennan Ctr. for Justice (Aug. 28, 2015, 11:29 EST) (on file with author). Similarly, in Arizona, the Brennan Center found that counties that purchased machines had a higher average household median income ($44,800) than remaining counties ($42,200). The Brennan Center found that five Arizona counties had purchased, or had plans to purchase, machines: Cochise, Mohave, Pima, Pinal, and Yavapai counties.

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[130]   *Id.*

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