IMPROVING ACCESS TO VOTING

A Report on the Technology for Accessible Voting Systems

By Noel H. Runyan

voter action

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A NETWORK FOR IDEAS & ACTION

About Voter Action

Voter Action is a not-for-profit organization that provides legal, research and organizing support to ensure election integrity in the United States.

Our present goal is protect as many states' upcoming elections as possible by blocking the federal Help America Vote Act (HAVA) funded purchases of electronic voting machines which have been shown to have the most severe security risks and records of inaccuracy and unreliability.

Voter Action can apply the experience and evidence gained in New Mexico to assist other states by providing legal expertise, expert witnesses, legal research and election data analysis. We are also in a position to broaden and deepen the national audience regarding this issue and help make accurate, transparent vote counting part of the national discussion of what it means to have clean elections.

Voter Action
PO Box 18122
Seattle, WA 98118-9998
Phone: 206-723-1941
Fax: 415-723-7141
info@voteraction.org
www.voteraction.org

About Dēmos

Dēmos: A Network for Ideas & Action is a non-partisan public policy research and advocacy organization committed to building an America that achieves its highest democratic ideals. We believe this requires a democracy that is robust and inclusive, with high levels of electoral participation and civic engagement; an economy where prosperity and opportunity are broadly shared and disparity is reduced; and a strong and effective public sector with the capacity to plan for the future and provide for the common good. Founded in 2000, Demos work combines research with advocacy—melding the commitment to ideas of a think tank with the organizing strategies of an advocacy group.

Dēmos: A Network for Ideas and Action
220 Fifth Ave., Fifth fl.
New York, NY 10001
Phone: 212-633-1405
Fax: 212-633-2015
info@demos.org
www.demos.org

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1. Author's Background and Qualifications

With his degree in electrical engineering and computer science, Noel Runyan has been working in human-factors engineering for more than 36 years, primarily developing access technologies for helping people with visual impairments use computers and other electronic devices.

During the five years he worked for IBM, he was involved in the design and testing of the security systems for both Bay Area Rapid Transit ticket machines and ATM credit card systems.

After starting his own company to supply access technologies, he designed and manufactured the Audapter speech synthesizer to enable computers to talk to users with visual impairments. He also authored the EasyScan, BuckScan and PicTac programs, which made it easier for users with visual impairments to read print books, identify dollar bills and convert print pictures into raised-line tactile drawings.

To help their customers with visual impairments access and make use of computer systems, the author and his wife, Deborah, have built more than 500 custom-integrated personal computers with speech, braille and/or large-print interfaces.

More recently, he has been involved in the development of talking Internet radios, talking pill bottles and other medical equipment for people who have difficulty reading print labels and displays.

For several years, the author has been studying and testing the accessibility features and usability of all the major voting systems used in this country. He has tested the systems actually delivered by the manufacturers, rather than the possible future systems promised by some of the manufacturers.

He has worked with the Santa Clara County (Calif.) Voter Access Advisory Committee, voting rights advocates and manufacturers to make voting systems more accessible for all voters with disabilities or special language needs. In addition to donating his time as a voting systems consultant, he has given testimony as an expert witness in six court cases. In each, he challenged the shoddy access features of many of the voting systems and pressed for meaningful rather than mere token accessibility.

The author has never received any form of financial compensation from any of the voting system vendors.

2. Acknowledgements

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The author wishes to gratefully acknowledge the tremendous contribution of Deborah Runyan as researcher, sounding board and main editor for this report, as well as input and feedback from Roger Petersen.

3. Executive Summary

3.1 The Need for Accessible Voting Systems

Basic demographic data reveal much about the need for better access to the voting process.

Studies have shown that 20% of the population of the U.S. has one or more disabilities and that approximately 10% of that number live with severe disabilities and that about 20% of U.S. adults with disabilities — more than 8 million potential voters — say they have been unable to vote in presidential or congressional elections due to barriers at or getting to the polls.

3.2 Current Law Requires Accessible Voting Systems

The Help America Vote Act (HAVA) requires that all polling places in elections for federal office anywhere in the United States have at least one voting system that shall "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

3.3 Most Currently Deployed Voting Systems Are Not Really Accessible

Most currently deployed voting systems, including direct-recording electronic (DRE) systems, do not meet current HAVA and ADA disability accommodation requirements, and they are far from compliance with the new Voluntary Voting System Guidelines. They are not accessible for significant numbers of individuals with disabilities for at least the following reasons:

1. The lack of a dual-switch input control interface for voters with severe manual dexterity disabilities who are unable to use touch screens or tactile key inputs.
2. The inadequacy of most of the systems' audio access features for voters who are blind or have low vision, cognitive impairments, severe motor impairments or dyslexia.
3. The lack of simultaneous and synchronized audio and visual outputs. These systems are inaccessible to many voters with visual impairments.
4. The lack of voter-adjustable magnification, contrast and display color settings that can improve the readability of text on the video displays.
5. The confusing menu selection systems that are difficult for people with cognitive disabilities to use effectively.
6. Almost all of the systems' blatant lack of adequate privacy curtains to prevent eavesdroppers from reading the voters' selections on their visual displays.

7. The systems' lack of capability to allow voters with disabilities to select for themselves different access modes or features without intervention from poll workers.

8. Lack of proper boosted audio output levels for voters with hearing impairments.

9. The inadequate tactile control keypads on most of the systems.

10. The requirement, on some electronic voting systems, for voters to manually handle paper ballots or voter ID cards, which may make it difficult or impossible for some voters with severe manual dexterity impairments to complete the voting process independently.

11. The verification of the voter-verifiable paper and audit trails (VVPAT) on the systems is inaccessible to many voters with visual or motor impairments and voters with special language needs.

In other words, a significant portion of citizens with disabilities or special language needs who attempt to cast their votes on these poorly designed voting machines will be unable to do so privately and independently.

3.4 Recommendations to Make Voting Systems Accessible

The following is a set of recommendations that should make the next generation of voting systems more accessible. A major redesign and simplification of all voting systems and their components will also make blends of voting systems more practical for election officials, poll workers and voters.

3.4.1 Use Blended Systems

There will never be a single perfect voting machine that meets everyone's accessible-voting needs. The best currently available solution to meet security and accessibility needs is a blended combination or mix that would include most of the following:

- Optical-scan ballots and precinct scanners.
- Ballot-on-demand printers.
- Bilingual paper ballots.
- Electronic ballot-marking devices (BMD) with accessible paper ballot scan/verification.
- Tactile ballots with verification wands (if properly designed and produced with good quality) for accessible absentee and deaf-blind voting.
- Simple digital electronic magnifier aids for the polling place.

3.4.2 Adopt Bilingual Ballot Systems

Bilingual paper ballot or bilingual VVPAT systems can facilitate preferred-language voting, prevent many security and privacy exposures and assure that the audit trail can be read in English. To support alternative language needs, precinct-count optical scanners and other voting machines should also include international icons or multilingual labels and displays.

3.4.3 Adopt Ballot-on-Demand Printing Systems

Ballot-on-demand printing with special ballot paper and standard printers will reduce the costs of paper ballots, assure a reliable and steady supply of multilingual ballots, and prevent waste of surplus ballots.

3.4.4 Do More to Create Privacy in the Polling Place

All paper ballot printing, scanning and verifying systems should support and be supplied with ballot privacy sleeves to help assure vote privacy.

Voting booths need much better privacy shields and curtains, and poll workers need to be more careful about how they set up and orient the screens and printers in the polling place.

3.4.5 Improve Accessibility Interfaces on Voting Systems

Despite the VVSG's more explicit standards for better accessibility features and functions, many vendors have not yet managed to deliver dual-switch input controls, simultaneous audio-video output, enhanced video display controls, and other essential and manageable improvements to their voting machine accessibility. Additionally, voting aids should be provided at the polling place, such as handheld lenses or electronic video magnifiers to assist voters with low vision. Tactile ballot marking systems can be used to accommodate voters who are deaf-blind. Ballot boxes and precinct optical scanners should have input slots with legroom below to accommodate voters in wheelchairs. PCOS scanners should also include international icons or multilingual labels and displays.

Electronic BMDs (including former DREs converted to BMDs with ballot printers) should include a voter-selectable control option to automatically deposit the printed ballot into a ballot box or drawer without requiring manual handling by the voter.

3.5 Conclusions

The technology for inexpensively providing good accessibility to voting systems has been commonly available for more than a decade, and it can and should be applied to all modern voting systems.

A completely new and redesigned generation of voting systems is needed. To accommodate a broad range of disability access needs, voting systems must be designed, from the beginning, with security, accessibility and good human factors in mind.

It is not likely that any single voting machine design can ever meet all the complex and sometimes contradictory needs and requirements of all voters.

Hybrid DRE-VVPAT designs and their accessibility Band-Aids should be phased out entirely. Adding VVPAT roll printers to currently fielded DREs will necessitate later having to tack on an awkward scanner-verifier capability to make verification of the printout even partly accessible.

If counties insist on making some use of their current DRE systems, they should not attempt to add tourniquets such as VVPAT roll-to-roll printers.

Converting DREs to BMDs by only adding cheap cut-sheet printers without verification scanner capabilities may become widespread but would result in unacceptable systems with major ballot-handling privacy exposures, as well as systems without reliably accessible paper ballot verification.

DRE systems already in the field should only be used if:

1. They incorporate an accessible and truly verifiable paper ballot printer/scanner/verifier that converts them into more reliable ballot marking devices.

2. Their accessibility is substantially improved to fully comply with all the new VVSG accessibility requirements.

Blended systems with optical-scan ballots, precinct scanners and accessible BMDs similar to the AutoMARK, such as now used in New Mexico, are the best and most likely solution for the foreseeable future.

4. Introduction

For many voters with disabilities, the passing of the Help America Vote Act held tremendous hope and promise for secure and reliable voting, a guarantee that every voter would have access to the voting process.

4.1 Why are Special Voting Systems With Access for Voters With Disabilities Needed?

Basic demographic data reveal much about the need for better access to the voting process.

Various studies, including those issued by the International Center for Disability Information and the National Institute on Disability and Rehabilitation Research, indicate that 20% of the population of the U.S. have one or more disabilities and that approximately 10% of that number live with severe disabilities.

A September 2004 poll by Harris Interactive for a study by the National Organization on Disability (NOD) found the following:

About 20% of U.S. adults with disabilities — more than 8 million potential voters — say they have been unable to vote in presidential or congressional elections due to barriers at or getting to the polls.

Of the roughly one-fifth of U.S. adults with disabilities who said they wanted to vote but were not able to:

- 29% said they could not get accessible transportation.
- 22% said their eligibility had been challenged.
- 21% reported that the polling place was not accessible.
- 21% reported that their mental or physical abilities were questioned.
- 19% said they could not understand the voting machine.
- 18% said they were made to feel embarrassed or uncomfortable.
- 12% reported that they needed alternative voting formats (large-print ballots, computer-assisted voting booths, paper ballots, etc.) that were not available.
- 12% said they needed assistance (such as a sign-language interpreter) that was not available.
- 8% said they were not allowed to have someone help them with the voting machine.

Additionally, 21% said they did not know how to register, in spite of legal requirements that those who provide services to people with disabilities also offer help in registering to vote.

Also, according to NOD, approximately 40 million Americans with disabilities are of voting age and 41% of voting-age citizens with disabilities voted in the 2000 elections.

4.2 The Legal Basis for Accessible Voting Systems

The Help America Vote Act of 2002 requires that all polling places in elections for federal office anywhere in the United States have at least one voting system that shall "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." [HAVA § 301(a)(3)(A)]

According to the federal Election Assistance Commission (EAC), established by HAVA, "[c]ompliance with Section 301(a)(3) requires that the voting system be accessible to persons with disabilities as defined by the Americans with Disabilities Act, including physical, visual, and cognitive disabilities, such that the disabled individual can privately and independently receive instruction, make selections, and cast a ballot." [EAC Advisory 2005-004, issued July 20, 2005.] This means, among other things, that states must acquire and make available voting systems that will accommodate the basic range of impairments, including cerebral palsy, aphasia, low vision, blindness, deaf-blindness and hearing impairment.

In addition to the Americans with Disabilities Act, HAVA and the EAC's Voluntary Voting System Guidelines (VVSG), most states have voting system standards that further extend the accessibility requirements.

5. Recent History of Voting Access for Voters With Disabilities

Originally, people with disabilities were not considered to be qualified to vote. Eventually, they were permitted to vote but were forced to allow election officials in the voting booth. For decades now, most states have allowed a personal choice of assistant to help in the voting booth.

With the passage of the Help America Vote Act, the goal of privacy and access for all voters with disabilities, as well as an end to hanging chad and over- and undervoting, seemed within reach.

Vendors began showing primitively modified prototype "accessible" voting systems. The computer interfaces on some of these new machine prototypes allowed some voters who were blind to vote successfully with audio output and tactile control keys. These new direct-recording electronic (DRE) voting systems seemed to hold a great deal of promise for reliable and accessible voting. This encouraged many to become vocal advocates of DRE voting systems. The National Federation of the Blind (NFB) and others strongly pushed for DREs in order to "hurry up and get accessible voting for the blind."

Today, the goal of private and independent voting has been achieved by some voters with disabilities. But many others have been disappointed and frustrated because they have not been able to vote privately and independently as they had hoped and as voting-system vendors had promised.

As this paper details, many of the DREs in use today do not fulfill the promise of accessibility for the majority of voters with disabilities.

5.1 Voting System Security and the Need for Paper Ballots

Because HAVA encouraged the purchase of DRE voting systems on the grounds that they were supposed to be accessible, they are now prevalent throughout the United States. As DRE security problems surfaced publicly, voter-verifiable paper audit trails (VVPATs) were proposed as the security "fix." Many disabilities advocates, thinking VVPATs would be just like paper ballots, worried that voters would be required but unable to handle the paper themselves, so VVPATs became a security versus access issue for many.

Many disability rights advocates feared that counties would use DRE security issues to justify delaying making their polls and voting accessible. Attacking DREs for bad security was considered by some disabilities advocates as an attack on the access movement. (Actually, most of the concerns about DRE security problems come from computer scientists and transparent-voting advocates, not from foot-dragging counties.)

It is now clear that voter verification of the paper record is necessary to guarantee reliability and security. The only voting systems that permit truly accessible verification of the paper record are the ballot marking devices (BMDs, which are mechanical or computerized devices that help the voter mark votes on standard optical-scan paper ballots).

Hursti II, the Princeton University hack/virus demo, and other high-profile DRE security vulnerability revelations have forced many advocates for accessible voting to accept the need for security through paper ballots.

Many disability voting rights advocates now accept the notion that access and security are both important and not incompatible, and this is resulting in a slow but steady movement toward support of paper-ballot-based voting systems.

5.2 The Promise of HAVA

Initially, with the passage of HAVA, many thought electronic voting systems would be great for reliability and accessibility.

Like many others, most of us in the disability community trusted that "federal testing" would assure security and accessibility, but we eventually found that we'd been misled. DREs did not turn out to be as secure, reliable or accessible as promised. And there turned out to be no actual "federal testing" by federal labs or "independent testing authorities" (ITAs). Instead, the "federal testing" was conducted by private labs that received payments from the voting machine vendors themselves, thereby creating an inherent conflict of interest.

Currently, there is no proper testing of the accessibility of voting machines, and there is no standard for comparison of results from accessibility, usability and accuracy testing.

Clearly, the ITA labs' testing of DREs and previous federal certification do not assure good disability accessibility compliance of a voting machine.

6. The Author's Experiences With Voting Systems

I have had experience with the Sequoia Edge II DRE in five real-world elections in addition to testing most of the available voting systems at conferences, accessible voting equipment fairs and the NFB Baltimore accessible voting systems lab.

Note that the frequent mention of the Sequoia Edge II DRE voting system in this report is not meant to indicate that it is any better or worse than any other voting system.

For a more complete description of each election, see Appendix B: Personal Experiences in Voting on the Sequoia Edge II DREs.

6.1 March 2004 Election

In my first attempt to vote on a DRE in a real election, the poll workers were never able to get any of the machines at our polling place to boot with the audio assist feature working. After 45 minutes of struggling with the systems, the poll workers gave up and I had to have someone do my voting for me.

6.2 November 2004 Election

From the time I signed in and got my voter smart card, it took eight minutes to reboot the machine as an audio voting machine, 30 minutes to make my choices, 23 minutes to review and verify, and another four minutes to make a correction and record my vote. So in all, it took me about 65 minutes to mark and record my ballot. An added complication was that the ballot races on the Sequoia voting machine were not in the same order as those printed in the previously released public sample ballot.

6.3 November 2005 Election

The poll workers were unable to get the Sequoia machine booted up in the audio mode. After my wife borrowed the poll workers' operator's manual and figured out the correct audio boot process, she finally managed to get the machine properly rebooted and talking.

After 18 very frustrating minutes trying to get through the reboot process, it took about six minutes to fill out the eight choices on the very short ballot, seven minutes to review my vote, and another minute to record my ballot and finish. My total time working on the voting machine was 32 minutes.

Clearly, if I hadn't been very tenacious and taken my own computer expert along when I went to vote, I wouldn't have been able to vote privately.

6.4 June 2006 Election

For 12 minutes, the poll workers struggled repeatedly to program the voter ID card properly so it would cause my voting machine to talk. After they gave up, I was able to convince them that they were not encoding my voter ID card properly. Luckily, at the previous Voter Access Advisory Committee meeting, a member of the registrar of voters staff told me the trick to properly encoding the voter ID card for audio access mode.

After that, it took 31 minutes for me to navigate through the ballot-marking procedure. It then took eight more minutes for it to play out the ballot review. At this point, I decided that I needed to change one of my votes to a write-in, and that complicated and tedious procedure took another seven minutes.

By the time the Sequoia Edge II system printed the non-accessible paper trail and then spit out my voter ID card, I had spent a total of 59.5 minutes trying to vote privately.

6.5 November 2006 Election

This time the poll workers knew how to properly set up the audio mode, so it only took about eight minutes to switch the Sequoia to audio. This makes only two out of five times that our poll workers have been able to successfully set up the audio voting mode by themselves.

The audio vote casting took a total of one hour and 17 minutes at the machine, not counting the time waiting in line to get in.

7. Lack of Accessibility of Voting Systems

Most of the voting-system manufacturers say they are working on making future improvements to the audio prompts and other capabilities of their DRE machines. This sounds good and should be encouraged. However, like the dual-switch input-control feature and other access options that have long been promised by several of these vendors, these features are still not available on most of our real voting systems in our real polling places today.

As my own experiences prove, it is certainly possible for some tenacious voters with disabilities to get through the voting process successfully on these voting systems. However, that experienced computer and access-technology users like myself have had such frustrating experiences trying to use the DRE voting systems clearly indicates that these systems have not been designed to provide appropriate access for the general population of voters with disabilities.

The problems that poll workers have had properly setting up the DRE voting systems for use by voters with disabilities show that the machines also are not designed properly for operation by the general population of poll workers. The problem is due to flaws in the human-factors design of the DREs and should not be blamed on either the poll workers' or the voters' lack of technical expertise or training. Clearly, most of these DREs were not designed correctly to be operated in the real world by normal poll workers and voters.

In general, the setup of these machines in audio access mode is still too complicated for the average poll worker, marking and reviewing the ballot is too complex and takes a very long time for the audio voter, the physical privacy shielding is much worse than it used to be with punch-card systems, and audio voters do not have any way of verifying the paper audit trail privately or otherwise.

7.1 A Summary of Accessibility Problems With DREs as Currently Deployed

Most of the available DRE voting systems do not meet current HAVA and ADA disability accommodation requirements and are far from being able to comply with the new Voluntary Voting System Guidelines. They are not accessible for significant numbers of individuals with disabilities for at least the following reasons:

1. The lack of a dual-switch input-control interface on systems such as Diebold AccuVote TSX and ES&S iVotronic. These systems are inaccessible to many voters with severe manual dexterity disabilities who are unable to use touch screens or tactile key inputs.

2. The inadequacy of most of the systems' audio access features for voters who are blind or have visual impairments, cognitive impairments, severe motor impairments or dyslexia. One of the results is that marking and reviewing the ballot takes an extremely long time for audio voters.

3. The lack of simultaneous and synchronized audio and visual outputs. These systems are inaccessible to many voters with visual impairments. For example, the failure of many of the DREs to accommodate elderly voters who have developed severe visual impairments with age but are unfamiliar with, and unable to cope with, audio-only access technology because they have had normal vision most of their lives.

4. The lack of voter-adjustable magnification, contrast and display color settings that can improve the readability of text on the video displays.

5. Confusing menu-selection systems that are difficult for people with cognitive disabilities to use effectively.

6. Almost all of the systems' blatant lack of adequate privacy curtains to prevent eavesdroppers from reading voters' selections on their visual displays. This violates, among other things, voters' constitutional rights to cast private and secret ballots.

7. The systems' lack of capability to allow voters with disabilities to select for themselves different access modes or features to provide accessibility without intervention from poll workers.

8. Lack of proper boosted audio output levels for voters with hearing impairments.

9. The inadequate tactile control keypads on most of the systems.

10. The requirement, on some electronic voting systems, of voters to manually handle paper ballots or voter ID cards, which may make it difficult or impossible for some voters with severe manual dexterity impairments to complete the voting process independently.

11. The verification of the VVPATs on the systems is inaccessible to many voters with visual or motor impairments and voters with special language needs so that these voters cannot personally verify the printout of VVPAT printers on the DRE systems.

In other words, a significant portion of citizens with disabilities or special language needs who attempt to cast their votes on these poorly designed voting machines will be unable to do so privately and independently.

See Appendix C: Detailed Lack of Accessibility on Voting Systems for more information.

7.2 Access Technologies That Have Been Available

The above failures and omissions could have been corrected using available adaptive or other technologies. Affordable disability-access technologies are readily available and have been so for more than a decade.

Many voters with visual impairments can now regularly use large-text, speech or braille interface systems on computers to do word processing, e-mail and Web browsing.

Unreasonable cost or unavailable technology cannot be argued as an excuse for the lack of accessible DRE designs.

See Appendix D: Available and Well-Established Access Technologies.

8. Description and Analysis of the Major Types of Voting Systems

Most mechanical voting machines such as lever machines and punch cards are rapidly being phased out and so will not be discussed in this report. There are a number of types of voting machines that are available for use. These include computer-based machines, of which DREs and BMDs are a subset; paper-based machines; tactile ballot-marking aids; vote by mail; and telephone-based systems.

8.1 Computer-Based Voting Machines

Computer-based voting terminals allow voters to use a computer to mark a paper ballot or create an electronic ballot. By touching a computer screen, pressing keys or using other technologies, the voter interacts with a computer to mark or create a ballot, as opposed to using a pencil to hand-mark a paper ballot. DRE voting machines and most BMDs use computer interfaces.

Computerized voting machines have been assumed by some to be better than low-tech voting systems, but this is not so in all cases. For example, closed-circuit TV magnifiers or electronic video magnifiers offer simple, language-independent, high-contrast magnification access for reading and marking paper ballots. It is likely that every polling place with paper ballots could benefit from having an electronic video magnifier aid.

It is important to note that touch screens are just a type of computer interface and that the term “touch screen” is technically not a proper alternate name for all the DRE voting machines.

Some DRE voting machines do not have a touch screen, and some voting systems that are not DREs have touch screens. For example, the full-face ballot system, or FFBS, is also a type of user interface for voting systems. FFBS machines have a single-sided ballot affixed over a large panel of lights and buttons. When the voter presses a choice on the ballot, the press is sensed by the switch behind the ballot and turns on the light, which shines through the paper at that point, indicating the selection. Some officials have the mistaken impression that having all races displayed on a single full-face ballot is the best way to make the voting process cognitively simple for the voters. On the contrary, it is clearly much simpler and easier on the voter to have a straight linear ballot showing only one race per page or screen.

In addition to differentiating among voting systems by the user interface they offer, it is helpful to differentiate by the vote-storage medium they use and whether the medium is for counting, auditing or just backup. DREs are computerized electronic voting systems that record votes in electronic memory or electronic ballots. With exceptions such as the eSlate DRE and the full-face ballot machines, most DRE systems have touch screens.

8.2 Electronic Ballot Systems (DREs With Voter-Verifiable Paper Audit Trails)

The term VVPAT has usually meant a roll-to-roll paper printer with a window that permits the voter to view a printed copy of his or her vote. This is meant to allow the voter to verify the printout to guarantee its accuracy for possible audits.

Some of the VVPAT systems have a continuous paper roll with the paper record under glass and not removable by the voter. A slightly different version of a VVPAT that attempts to remove the voter-sequence correlation privacy exposure uses separate cut sheets of paper that are displayed under glass, kept inside the machine and not voter-removable.

Many states have required such printers on their DRE voting systems. Currently, there is no way for most voters with visual impairments to accessibly verify the printed votes on DRE paper trails. Although the technology exists to scan and read back the paper record, it has not been deployed in conjunction with DREs.

Moreover, there are additional problems with the accessibility of DREs with VVPAT as currently configured and deployed:

- The VVPAT window may be physically inaccessible for viewing by many voters with motor impairments.
- The poor-quality print on VVPATs is usually hard to read because of the small font size and low contrast, due to use of cheap thermal printers.
- The VVPAT must be disconnected when the Diebold AccuVote TSX is used for curbside voting. In this case, the curbside voter will have no way to check the VVPAT printout.
- The ES&S iVotronic has no full-ballot paper verification. Instead, it prints and displays each selection you make, as you make it, in its small real-time audit-log window.
- The Sequoia Edge II does not pause the VVPAT printing to allow reading for voters using the audio feature. It flies through multi-window printouts without pausing, making the assumption that no one will be trying to read it for verifying. This prevents a sighted assistant or a sighted voter with a motor impairment from verifying the ballot.

Reviewing the electronic record in the DRE's memory with audio is not the same as verifying by reading the print on the VVPAT, despite the bogus claims to the contrary made by some of the DRE vendors. Unless the system employs a scanner to read back what actually was printed on the paper trail, such a system should not be considered a voter-verified paper audit trail that is truly accessible.

8.3 Paper-Ballot Voting Systems

Paper-based systems involve the voter marking a paper ballot with a pencil or with a ballot-marking device. The paper ballot is then optically scanned into a device that reads and counts the ballots.

Paper-ballot systems can be more flexible than computer-based systems in some cases, such as allowing absentee voting from home and even allowing voters who are profoundly deaf-blind to vote on paper ballots with tactile ballot-marking systems. For another example, optical-scan paper ballots can be used with electronic video magnifiers for absentee voting from home or at the polling place.

HAVA specifically calls for ballots cast in polling places to be checked for overvotes so the voter will have an opportunity to correct the ballot. If ballots are collected in precinct ballot boxes without checking and then tabulated by a central-count optical scanner (CCOS) at some other site, the voter will not have an opportunity to make corrections for overvotes. For this reason, the checking of and warnings about ballots should be done in the polling place by a precinct count optical scanner (when the voter turns in the ballot) or perhaps by an electronic BMD.

Many polling places are blending or combining precinct-count optical scanners (PCOS) for optical-scan paper ballots and BMDs for accommodating voters with disabilities. This is the approach used in New Mexico, where they threw out all of their DRE voting systems and switched to optical-scan ballots and AutoMARK BMDs.

8.4 Ballot-Marking Devices

BMDs record votes on paper ballots rather than electronic ballots or memory cards. The AutoMARK and Populex BMDs are examples of computerized electronic voting systems that have touch screens but record votes on paper ballots.

Many voters have wrongly assumed that the only way to get a broad spectrum of accessibility interfaces was with DRE voting systems because DREs are electronic and computerized. BMDs such as AutoMARK and Populex are also electronic and computerized and can give just as broad a spectrum of accessibility. In practice, the AutoMARK and Populex systems can provide better accessibility than most of the older DREs because both of these BMDs were designed from the start with access requirements and user interfaces in mind.

BMDs can also support multilingual ballots just as well as DRE systems can.

The main electronic voting systems that can support the security needs of a voter-verified paper ballot (VVPB) and allow voters with disabilities to accessibly verify the VVPB reliably, privately and independently are the AutoMARK and Populex BMDs. VVPBs are very different from the VVPAT systems because the paper ballot of a VVPB system is used for the main vote-tabulation record, not just for auditing.

Generally, the BMD class includes AutoMARK Populex InkaVote and Avante Vote-Tracker BMD devices, and tactile ballot-marking devices such as the Rhode Island tactile ballot, the Vote-PAD and the Equalivote.

8.4.1 When Is Independence Required for Privacy?

It is important to be aware of the difference between independence and privacy in voting procedures.

Independence is not essential to guaranteeing privacy before a voter starts marking their ballot. Independence is required to assure privacy during the process of marking the ballot but is not essential for guaranteeing privacy after the ballot has been deposited into, and protected by, a privacy sleeve.

Absolute independence is not required for the parts of the voting process that come before and after vote selection, ballot marking and deposition into a privacy sleeve.

Some advocates of DRE voting machines have suggested that print paper ballot-marking systems such as the AutoMARK might not accommodate independent handling of the privacy-sleeved print ballot by some voters with severe motor impairments. On the other hand, independent handling and insertion of voter ID cards in DRE voting machines can also represent a similar problem for some voters with severe motor impairments.

People who cannot manipulate a paper ballot independently may also not be able to handle and insert or remove a voter ID card independently. In some cases, for voters with limited manual dexterity for gripping ballots or smart cards, the larger paper ballot may be easier to manipulate than the smaller voter ID card. In other cases, the voters may be able to handle voter ID cards but not paper ballots.

Although the handling issues for cards and ballots are not necessarily the same, either one may prevent completely independent voting. In neither case do they have to compromise the voter's ballot privacy (assuming proper use of privacy sleeves).

If DRE advocates can argue that complete manipulation independence is not that important for voter ID card handling, they must concede that independent handling of privacy-sleeved paper ballots is also not essential. Having a poll worker help you handle your voter ID card or your privacy-sleeved paper ballot does not prevent you from keeping your ballot choices private.

Some voters with manual dexterity impairments may not be able to handle either voter ID cards or paper ballots independently.

I recently discussed this subject with a Stanford network engineering friend who has severe motor impairments. He said he felt that, for many voters with limited manual dexterity, printed paper ballots are easier to manipulate than small smart cards. He also said the important issue for independent voting should primarily be independently marking, reviewing and verifying the ballot to assure true secrecy and privacy of one's vote. He said independently handling the voter ID card or the privacy-sleeved printed ballot is relatively unimportant.

It is foolish to pretend that all voters with severe motor impairments can manage their voting activity in a polling place absolutely independently. For example, many cannot sign their name on the sign-in register, but that does not prevent them from having a private and reasonably independent vote.

When a friend with severe motor impairments tried to vote on the Sequoia Edge II, he found that he had to have a poll worker stand behind the touch-screen unit and hold up its back end to keep it from falling off his lap the whole time he was voting. Though it was private, this was not independent voting.

If completely independent handling of paper ballots and voter ID cards is decided to be absolutely necessary for complying with access requirements, then DRE and BMD voting system manufacturers will be forced to redesign their products to offer automated handling of ballots and cards for this special class of voters or redesign the systems to not use any physical ballots or ID cards. The impact of such changes on voting hardware costs and voting system security may be so high that it might be better to invest the same resources in improving other aspects of the accessibility of voting systems, including physical access to polling places.

Manufacturers should be encouraged to improve their voting machinery accessibility to minimize independent-handling issues for voter cards and paper ballots. For example, because of foot and legroom clearance issues, ballot boxes and precinct optical scanners should clearly be made more accessible by adding slot extension or side-load chutes to better accommodate paper-ballot voters in wheelchairs.

8.4.2 The AutoMARK Ballot-Marking Device

The AutoMARK looks something like other touch-screen electronic voting systems, with the addition of a built-in ballot scanner and printer.

Like the tactile ballot systems, the AutoMARK produces a marked paper ballot that can be accessibly verified by voters with disabilities.

The AutoMARK has the best access user interface of all the available voting systems. It has simultaneous audio-video; built-in rate and volume controls; cognitively simple tactile control keys; dual-switch input controls; and video controls for font size, color and contrast. Accessibility functions and user interfaces were included from the beginning of the AutoMARK's design, not tacked on later as modifications or Band-Aids.

Because the ballot printer-scanner is a mechanical system, ballot jams or failure-to-print problems can occur, especially if county elections officials have not learned how to design and produce the ballots properly. The AutoMARK manufacturer has said that the problems related to using perforated-edge ballots torn from pads of ballots, instead of clean-edged ballots, have been fixed, and the fix should be available in the next certified version of the AutoMARK software.

After vote selection and ballot marking, the print ballot can be removed from the AutoMARK. If the voter wants, the ballot can even be reinserted at a later time to re-scan and verify the ballot marking. The ballot can be automatically deposited into a privacy sleeve that is hooked to the ballot feed slot. The sleeve protects the voter's ballot privacy, shielding it from eavesdropping and assuring that no poll worker or other assistant can sneak a peek at the ballot while helping a voter move the privacy-sleeved ballot to a ballot box or precinct scanner. Many voting-access advocates appear unaware of the fact that the ballot can be automatically deposited into a privacy sleeve without requiring manual handling before it reaches the privacy sleeve. If the voter desires, a poll worker can help move the privacy-sleeved ballot to the ballot box or PCOS without a sacrifice of privacy.

It has been suggested that there is a potential threat to privacy when only one voter votes on an AutoMARK during an election day. If someone were to break into the ballot box or PCOS ballot storage, they might be able to identify which ballot was marked very neatly by the AutoMARK, and this might be correlated with the identity of the single voter who used the AutoMARK. The same kind of risk exists when there is only a single voter on a DRE voting system. On either DREs or BMDs, someone taking such a big risk to determine the vote of a single voter is considered very unlikely. The simple way to block this privacy threat is to make sure additional voters vote on the accessible DRE or BMD voting machine. This solution shows that the unique-marked-ballot is a bogus privacy concern.

AutoMARK voters maintain their essential independence and privacy when they make vote selections independently and have the AutoMARK mark their ballots for them. When moving the ballot to a ballot box or precinct scanner (with or without assistance), complete independence is not essential for maintaining the privacy of the voter's ballot.

8.4.3 The Populex Ballot-Marking Device

The Populex is an electronic BMD that is similar to the AutoMARK in many ways. Its major difference is that it prints a ballot slip that is not plain text and readable like a regular optical-scan ballot. Instead, it is tabulated by bar-code scanning. For voter verification, the ballot has printed numeric codes the voter can read by eye and then translate by looking up the number on a special chart. Because of this, the Populex paper ballot slip is not easy to visually read and verify. It is also more difficult for people with low vision or cognitive impairments to verify directly.

8.4.4 The InkaVote Ballot-Marking Device

The InkaVote (used in Los Angeles County) is a ballot-marking device that uses ballot cards about the size of the old punch-card ballots. Instead of punching holes in the card, voters use a manual marking device to ink mark their selections on the card. The InkaVote ballot card ends up with only marks and no printed text. For access by voters with disabilities, there is a computerized ballot-marking terminal with speech output and visual display that can be used to make selections and mark the ballot card for the voter. At the end of the marking process, the ballot card is automatically deposited into a privacy sleeve. This system is similar to other optical-scan paper ballot systems in that it uses a precinct optical scanner specially designed to scan and count paper ballot cards. Because the ballot cards do not contain any text, they, like the ballots from the Populex, are considered to be language-independent.

8.4.5 The Avante Ballot-Marking Device

Avante offers the Vote-Trakker DRE voting system with an external roll-to-roll VVPAT print-trail option, and it also offers a Vote-Trakker BMD version with a standard external cut-sheet printer for printing paper ballots.

The ballot-marking version of the Vote-Trakker prints a complete image of the voter's ballot on separate blank sheets of ballot paper, rather than printing on a continuous roll of paper. Although this ballot marking version is based on Avante's standard Vote-Trakker DRE terminal, the direct-recording electronic memory and vote-counting capability can be disabled when printing ballots in the BMD configuration.

Avante claims that this is an accessibly verifiable ballot system because an electronic representation of the graphical information printed on the ballot can be read back from the Vote-Trakker's memory with the Vote-Trakker's display screen or audio output feature. However, the Avante ballot printer is just a standard inexpensive off-the-shelf printer with no built-in image scanner capability that would allow a voter to authentically verify the ballot marking by reading back and reviewing the printing on the paper ballot. Because of this lack of scanning verification, voters with visual reading impairments would have no way to be sure that the paper ballot did not have an accidental or malicious misrepresentation of the ballot information they reviewed on the Vote-Trakker screen or audio output. Despite the manufacturer's claims to the contrary, this Avante BMD system does not truly provide accessible verification of the paper ballot printout.

Additionally, unlike some BMDs that can automatically deposit the finished ballot into private containment such as a privacy sleeve, the Avante Vote-Trakker BMD printer does not automatically deposit the finished paper ballot into a privacy sleeve, precinct scanner or ballot box. This represents a serious privacy risk for many voters, especially those who can not manually handle the bare ballot pages for themselves.

As implemented in New York state, the finished paper ballots of the Vote-Trakker BMD must be manually placed inside a privacy envelope, which is handed in and separately held for later counting, somewhat like provisional paper ballots. New York voters with visual impairments have expressed concerns that this means their votes might not really be counted.

Because non-scanning BMD printing systems such as this Avante BMD do not provide authentic accessible verification and do present major independent ballot-handling privacy risks, there are grave concerns that this might become a widespread but unacceptable model for cheap attempts to convert other DREs into supposedly "accessible" and "secure" BMDs.

8.5 Tactile Ballot-Marking Aids

Tactile ballot-marking devices (TBMDs) are technically BMDs and are basically mechanical aids for marking paper ballots.

Most TBMDs have a sleeve into which a paper ballot can be slipped and held in place. The sleeve has tactile indicators that are next to holes in the sleeve. These holes line up with the ballot mark positions, so the voter can insert a pen and mark the selection on the paper ballot.

On April 27, 2001, the National Organization on Disability presented the Elections Division of the Rhode Island secretary of state's office with an award for its pioneering work in introducing tactile ballots for voting systems.

The Vote-PAD and the Equalivote are newer tactile ballot-marking aids that include mark-sensing verification wands. Verification wands are small, handheld devices that vibrate when their tip is held over a marked position on a paper ballot. This allows the voter to review their ballot and check each ballot marking position for the presence or absence of a mark. Verification wands are a significant development for tactile ballot systems, as they even permit accessible verification of the paper ballot record.

In my testing of a tactile ballot with a verification wand, the wand was even successfully used to confirm the erasure of an unwanted pencil mark. That saved the ballot from having to be discarded and a new ballot completely re-marked.

Ballot navigation instructions can be in braille, audio or large print.

The finished ballot looks like anyone else's marked ballot.

A tactile ballot system with braille instructions is the only available method for voters who are profoundly deaf-blind to vote privately.

Tactile ballots can also be used by many voters with motor impairments, some even with mouth-stick pens. However, tactile ballot-marking systems are not accessible for voters with severe motor impairments that limit them to making selections with dual-switch input controls.

Because some voters who are blind cannot write with a pen or pencil, having only cut-out windows as write-in guides on tactile ballots may not be considered adequate. Some tactile ballot systems have a way to spell a write-in name by marking letters on a separate tactile grid page (although it is very tedious and awkward, as are other "accessible" write-in procedures on most electronic voting systems).

Tactile ballots can also be used to facilitate private and accessible absentee voting by many voters with disabilities. Since voters without disabilities can independently and privately vote absentee, why shouldn't voters with disabilities also have the right to do the same?

Would there be any real reason that private organizations or individuals could not volunteer to make up and supply tactile ballot sleeves and materials to help voters with disabilities to independently and privately mark their own absentee ballots? Such approaches might work well for absentee voting from home but should not relieve government officials from making their polling-place voting systems accessible.

Some resistance to tactile ballots comes from those who want accessible electronic voting systems and are worried that financially strained counties might force them to use tactile ballots instead of more complete access solutions.

A number of voters, myself included, who have had a chance to try out the Vote-PAD tactile ballot system have been disappointed by the poor quality of the audio and braille instruction materials, as well as by the write-in tactile grid pages. The quality of the Vote-PAD materials could and should be improved substantially. The audio instructions should be recorded by a human reader, rather than the synthetic speech used in an effort to cut costs.

Tactile ballot systems with verification wands are potentially a useful voting aid. However, major but simple-to-implement changes need to be made to the currently offered tactile ballot systems. Also, tactile ballot systems should be promoted and seen as a voting aid with unique capabilities, not as a replacement for broadly accessible voting systems.

8.6 Vote-by-Mail Systems

Voting by mail (VBM) requires support with aids such as tactile ballot aids.

VBM systems cannot accommodate private voting by many voters with disabilities, such as those with severe motor impairments, unless they have other tools such as access to a computer they can use with a printer to mark a paper absentee ballot — essentially their own home BMD.

VBM systems can be more accessible for some because they don't require transportation and access to public polling places.

There are serious security, privacy and voter-coercion concerns associated with vote-by-mail systems. Many voters' rights organizations are worried by the increasing use of vote-by-mail systems.

8.7 Telephone-Based Systems

Vote-By-Phone (VBP) systems function something like a voice mail system, with the voter entering their selections by pressing keys on the phone's keypad, while listening to computer-controlled audio messages.

Many folks with disabilities like the idea of voting by phone, because they think it means that they could vote from home and avoid hassles of transportation and physical access to polling places. It is one of only a few systems that could allow voters with certain disabilities to vote from home.

Regrettably, they may not realize that remote vote-by-phone is not currently being considered very seriously, as it has extremely challenging and serious security, privacy and voter-coercion problems.

In contrast to using remote telephones operated from home, some Vote-By-Phone (VBP) systems are designed to be used only from inside a polling place. The IVS Inspire and Avante IVR are examples of voting systems that use telephones for the voter terminal in the polling place.

Although the polling-place VBP systems have many of the significant security and privacy drawbacks of remote VBP, some of the problems are reduced by physical presence and identification of the voters in the polling place.

It is not surprising to hear some people with disabilities, especially those who are totally blind, say they like the idea of phone voting systems. Voters who are totally blind generally find telephone systems easy to operate. Unfortunately, meeting the access needs of just voters who are totally blind only solves part of the challenge of accessible voting systems.

Voters with severe manual dexterity impairments may need dual-switch-touch-tone input control converters or other special telephone interface modifications. Polling place telephones will need to support more of the wide variety of special telephone interface modifications that many folks with manual dexterity impairments are now using on their home phone systems. It won't work to just say, "Let them use a mouth stick." Some voters with severe motor impairments can use mouth sticks or helmet-mounted sticks on properly designed telephone keypads, but others can't. To relate to the challenge of voting with a head-controlled stick, the reader might try to imagine attempting to operate a telephone keypad with a small baseball bat held in their mouth.

Because of hearing and/or cognitive impairments, many voters (especially many of the elderly) cannot handle interface systems that only use voice output; they can't even deal with basic voice mail systems.

As demonstrated on DRE voting systems, many voters with disabilities cannot manage to use voting systems that aren't capable of simultaneously presenting audio and visual information. This is why the VVSG access guidelines call for simultaneous audio and visual output capability on voting systems.

Some voters who can't handle audio-only output might be helped by "cheat sheet" cards with large printed representations of the talking menu systems, to help them follow along visually as they listen to the audio output of the phone. Some of these voters would need these printed in white-on-black or with other high contrast colors. Even such large print aids will not be enough to allow certain voters with low vision to vote by phone. Voters with low vision who cannot use the vote-by-phone system might need closed-circuit TV or digital magnifiers to allow them to read, mark, and verify optical scan or other paper ballots.

Other voters have such severe hearing impairments that they cannot use the phone systems' audio output at all. Voters who cannot vote with audio output would need some other system such as hand marked optical scan ballots. Currently the only available voting systems that can accommodate voters who are profoundly deaf-blind are the optical scan tactile ballot marking systems with vibrating mark verification wands.

Polling-place voting systems using only telephone terminals for accessibility will not be HAVA-compliant. Their accessibility is too limited to accommodate the required wide spectrum of voters with disabilities. By themselves, VBP systems will not meet many of the access requirements of the new VVSG standards for dual-switch input controls, tactile keys that can be operated with a single hand, simultaneous audio-video display, or any large-print visual displays. However, it may be possible for VBP systems to be included as part of a carefully designed and blended system that, as a whole, could fully accommodate all voting system accessibility requirements.

Counties intent on using the currently offered phone voting systems will have to plan on blending VBP systems with other voting systems and adding a variety of other access options, support materials and procedures.

For privacy, security and reliability reasons, counties planning to use VBP systems will need to consider the costs and logistics of arranging for dedicated phone lines in each of their polling places. Obviously, the need for secure phone lines may limit the choice of sites for polling places. Counties should also carefully consider their VBP system's performance requirements, to avoid audio message "traffic jams" during periods of peak voting activity.

There are serious concerns about the privacy and integrity of the verifiable paper trail and the paper ballot systems now used or proposed for the VBP systems. In some cases, the paper trail is printed at the remote VBP support center. In others, the ballot is sent back from the support center as a fax, to be printed and cast in a ballot box in the phone voter's polling place. Faxing a copy of the support center printout back to the polling place does not offer voters who are blind any accessible method to verify their ballot. In some VBP systems, the paper record is printed in bar codes and in text at the remote support center. It is then scanned back into the computer by a bar code scanner, and this scanned bar code version of the ballot is read back to the voter to "verify" the plain text. Because the bar code version might not match the text or the computer might be speaking falsely to the voter, this is a very unreliable method of verifying the vote printed on the paper record.

In a VBP system recently proposed to officials of an East Coast state, workers at the remote support center were expected to manually transcribe the text version of the printout onto an optical scan marked sense ballot. Many members of the state's disabilities community objected to this method of marking optical scan ballots, as they felt it violated their privacy and did not include a method to verify the accuracy of the ballot transcription process. Generally, as is the case with DRE voting systems, polling place telephone voting systems configured as electronic ballot record systems can present serious problems for supporting reliably accessible paper trails.

Some advocates of VBP systems have said the systems are like a simple pencil, and are not at all like a computerized voting system. Telephones may seem simpler because most people are used to using them daily. However, as included in VBP systems such as the IVS Inspire or Avante IVR, the phones are just terminals on what amounts to a distributed data processing system, configured to record either electronic or paper ballots. Unlike pencils, VBP systems contain computers, software and other nontransparent "black box" components that voters must trust to operate correctly. Because of their computerized systems and other hidden components, these vote-by-phone systems should be tested carefully, managed with good security practices and open to responsible public monitoring, just like other computerized voting systems.

Disturbingly, some of the VBP manufacturers have not even bothered to apply for federal testing and certification, or they have not been able to pass the testing and certification. Clearly, there are nightmarish problems inherent in trying to responsibly test and certify each of the telephone networks that might be used to connect VBP support center computers to the voter phone terminals and ballot fax printers in the polling places.

Some of these serious drawbacks of polling place VBP systems are offset by attractive VBP features such as:

- General public familiarity with phone terminals.
- Simpler operation for poll workers.
- Lower cost for each voter terminal.
- Attractive one year lease contracts offered by at least one of the major VBP vendors.

8.8 DREs With Paper-Roll VVPAT Printers and Optical Scanners

Some DRE manufacturers have proposed using optical scanners with their DRE systems to permit accessible scanning and verification of the VVPAT paper trails. Some companies are working on designs for VVPAT systems with optical character recognition (OCR) scanners (for clear text paper trails), and some are working on optical bar-code recognition (OBR) scanners for VVPATs that print the paper trail as optical bar codes.

A security argument in favor of using optical scanning to make verification of the paper trail accessible is that DREs might be programmed to cheat more often on the VVPAT of voters who are using the accessibility options, assuming that these voters would not be as likely to detect the fraud, especially without some way to reliably read and verify the actual print on the paper trail.

OCR and OBR scanner systems may be designed to give access to "reading" the VVPAT paper trail with audio and/or large-character displays. A small, portable OCR scanner, the Kurzweil Portable Reader, was tested, at my suggestion, by Steve Booth, the voting access systems expert at the National Federation of the Blind Access Technology Lab in Baltimore. Mr. Booth concluded that, in its current form, the Kurzweil Portable Reader doesn't work well enough in this application to be useful for verification, but it might if it were reprogrammed and supported by a mechanical bracket on a VVPAT with a glare guard. Because the Portable Reader is a stand-alone unit, the voter would probably have to switch to using the reader's headphones and tactile controls to read the VVPAT. Although such a stand-alone scan-and-verify system might be made to work to some degree, it would be inherently awkward, confusing and hard for voters to learn.

To simplify the voter interface, it would be necessary to have the vote-selection function and the VVPAT scan and verification functions integrated into a single unit with a single voter interface. However, in order to obtain module isolation security, a DRE should not use the same or connected modules for marking and verification since they are using continuous-roll paper instead of separate voter-removable paper ballot sheets.

If the microprocessor in the DRE system is not powerful enough to give reasonable scan and verify response times, then the verification scanner-printer unit might need to have a more powerful microprocessor to handle the OCR and verification task itself.

If optical scanning is going to be used to verify the continuous paper-roll print trail for voters with disabilities, it is important that the VVPAT scanning and accessible verification function be done in a separate system, not the same vote-selection and printing unit that might have innocently or otherwise misrepresented the voter's choices on the printout. This is because it would be possible for perverse portions of a combined vote-selection, printing and scanning unit to make the same false or misleading representation of the ballot in the voter's pre-printing as well as post-printing verification reviews.

To support vote-verification integrity, the verification scanner unit and the vote selection/VVPAT unit would have to be completely modularized and isolated from each other, preventing any signals from the latter from corrupting the vote represented by the verification scanner unit. Housing both units in the same voting-station enclosure makes it difficult to assure the isolation and integrity of the two systems, especially if the VVPAT is implemented as the typical roll-to-roll printer system. However, isolating them as physically separate modules significantly complicates the accessible voter interfaces to these modules and makes it much more difficult for voters with disabilities to use.

If the VVPAT uses narrow thermal printer paper, its low contrast and small print size will make it difficult to get highly accurate OCR results for any verification scanner.

This basically means that it may not be possible to design a reasonably voter-friendly and easy-to-use VVPAT paper-roll scanner verification system that is also reasonably modularized for security.

Additionally, sequential voter correlation of continuous VVPAT paper rolls risks a privacy exposure, especially when only one DRE is used in a polling place. Many counties and states are beginning to avoid or even ban the use of roll-to-roll VVPAT systems because of the voter privacy exposures associated with correlation of observed order of voters using a machine and the sequential vote order on the VVPAT paper roll from the same machine.

8.9 DRE Conversion to BMD With Ballot Printer/Scanner/Verifier

Adding a cut-sheet printer to a DRE system in place of the roll-to-roll VVPAT could give it a more robust paper audit trail without the sequence-correlation privacy issues or even allow it to be converted to a ballot-marking system. When used as a BMD, the DRE's counting and electronic record storage functions would presumably be disabled.

Whether operating as a BMD or a similarly converted DRE, it will not have truly accessible verification of the paper printout unless it includes a scanner/verifier capability to read back what is actually printed on the paper.

When a DRE is converted to a BMD by the addition of a cut-sheet ballot printer, each voter's ballot information is printed on a separate paper slip, card or ballot sheet. The voter should then be free to remove the paper ballot record and put it in a separate ballot scanner and verification unit. This could effectively isolate the vote-selection and VVPAT system from the verification scanning system.

This separate scanner-verifier unit would also have to have its own voter interface with accessible input controls and output (including audio and visual output). However, as was the case for DREs with paper-roll VVPATs and separate scanner-verifiers, there would be serious human-factors complications. It would present the voter with more paper-handling challenges and require the voter to switch to and learn another accessible interface system for the scanner-verifier.

Alternatively, to simplify the paper handling and the user input control and output interfaces, it might be necessary to use voting machines that house the printer and the verification scanner in the same enclosure. In this more integrated system, the accessible user interface of the DRE would be used by voters to read back and verify the printed ballot information from the scanner-verifier portion of the printer-scanner-verifier unit. If the printer and scanner-verifier modules are integrated into a single enclosure, the system must be designed to allow voters the option of removing the printed ballot between the printer output and the input to the verification scanner. This would allow voters to have their ballot printouts verified on a different machine if they choose or maybe scanned back in and verified at a later time on the same machine they used to select votes and print the ballot.

This option for voter-removable printout to decouple the vote-selection and print-verification processes is necessary to help keep any mendacious software in a combined system from "knowing" that the ballot being scanned for verification was the same as the one that was just printed on its printer unit. However, although its verification-integrity security is much better than that of the DREs' scannerless roll-to-roll VVPATs or scannerless page printers, the combination of a DRE with VVPAT and scanner/verifier without voter-removable paper record does not guarantee perfect isolation or decoupling security.

To accommodate the needs of some voters whose motor impairments make it difficult or impossible for them to physically handle any form of paper ballot record independently, a combination system could be built to allow the VVPAT paper output to be optionally directed into the input of the verification scanner, and then finally directed into a secure paper ballot box, all without requiring manual handling of the printed paper record.

The hardware of a ballot-verification scanner-printer unit such as this could actually be about as simple as a standard fax scanner and printer. Unlike most current VVPAT systems, which use flimsy thermal role paper, these systems could print with clear, normal-size print on good-quality ballot paper.

Given the large number of DRE systems already in the field, adding a full-ballot printer-scanner-verifier system such as this — effectively converting DRE systems into ballot-marking devices — might be the only method of assuring accessibility and maintaining a good-quality voter-verifiable paper record on existing DRE systems. This kind of DRE conversion to BMD could end up having many of the design strengths inherent to the current electronic BMDs, but only if they can also be converted to be more reliable and meet VVSG accessibility standards.

Many of the DREs already in the field are so obsolete that they do not have the processing power, design flexibility or other resources to permit their conversion to support improved accessibility and/or reliable paper ballot printing/verification.

9. Ballot-on-Demand Printers in Each Polling Place

Ballot-on-demand (BOD) printing with blank ballot paper and reliable standard printers would reduce the costs of paper ballots, assure a reliable and steady supply of multilingual ballots, and prevent wasting surplus ballots. Counties would be able to buy and stockpile blank ballots pre-printed with the jurisdiction's own masthead, water marks and any other authentication options.

Ballot-on-demand printers could also be helpful in supporting requirements for the large number of ballot styles required in most early voting centers.

BOD printing could also be done at a county level for absentee ballots, facilitating even more inclusive alternative-language support.

10. Access to Voting in Alternative Languages

For many voters, successfully voting can be a confusing and daunting challenge even in their native language, so it is important to simplify the voting process in many ways, including by supplying all voters with materials in their preferred language. The numbers of voters needing access to voting systems with alternative languages is very large, even when compared to the number of voters with disability-related access needs. Accommodating access to voting systems in alternative languages has relatively clean and simple technical solutions and does not need to become a messy nationwide issue. It does need a major effort on the part of advocates and election officials to become well informed and press for available good solutions.

Some advocates for alternative-language voting access have the mistaken impression that DRE voting systems are the best and only way to handle alternative-language voting needs. This is simply wrong, for two main reasons. First, computerized BMDs can offer flexible alternative language interface options for voting systems just as well as those offered by DRE systems. Second, states, such as California, have already demonstrated that it is possible to provide many choices for alternative languages on optical-scan paper ballot systems.

Some of the following approaches can be easily implemented to make it even easier to support rich multilingual voting diversity on optical ballot systems.

10.1 Bilingual Ballot Systems

Bilingual pape r ballot or bilingual VVPAT systems can facilitate alternative-language voting, prevent many security and privacy exposures, and assure that the audit trail can be read in English.

To do this, bilingual optical-scan paper ballots could be given to all voters. Every voter could select which second language they want on their ballot. Voters who choose to vote in English would get a ballot with a randomly selected second language. All ballots would have each item printed in English and one other language. This bilingual ballot system prevents many security and privacy exposures. No one could look at a ballot and know the voter's language needs. This approach also assures that the audit can be read in English, while not crowding the ballot with copies of many different languages.

Bilingual ballots also seem to be the best way to address multiple language needs for absentee ballots. Such a bilingual ballot approach can work well with but does not require ballot-on-demand printer systems.

VVPAT systems could also use basically the same bilingual printout approach to accommodating multiple language needs of voters while still allowing paper-trail auditing in English.

A different approach for handling multiple-language paper-ballot voting needs incorporates multilingual marking-guide booklets with perforated templates for marking common English language paper ballots through holes in different language templates. The paper ballot would have only English printed on it, and each template page of the booklet would have the ballot text in a different language (and include holes for the marking positions). You could slip the English paper ballot underneath your chosen language template page (or inside, if pages are sleeves), and then you could mark the English paper ballot through the holes in the template.

11. Other Factors That Limit Access to Voting

The design of voting terminals is not the only thing that determines whether voters with disabilities will be able to vote successfully. Some other factors include:

- Access to sample ballots and other election information.
- Access to the voter registration process.
- Being homebound or institutionalized.
- Access to information identifying the location of the proper polling place.
- Transportation to the polling place.
- Physical access into and around the polling place.
- Lack of interpreters for sign or other languages.
- Requirement of poll-worker assistance to switch between visual and audio access modes on most DRE voting systems.
- Lack of the required technical expertise and special training for the poll workers.
- Ergonomic problems such as placement and adjustment of voting-system controls and displays.
- Requirements for photo IDs, driver's licenses or other IDs that may cause nondrivers or other potential voters to be disenfranchised.

12. Recommendations

12.1 The Notion That It Is Possible to Have One Ideal Voting Machine for All Should Be Seen as Impractical

There will never be a single perfect voting machine that has everything needed to meet everyone's accessible-voting needs. However, using one type of system for ballot recording media, ballot collection and ballot tabulation for the majority of voters and a different type of system for voters with disabilities or minority language needs is known as "ballot segregation". This does not include the devices and methods used to privately select votes and mark ballots. For obvious reasons, voting systems should not use ballot segregation.

12.2 Use Blended Systems

The best currently available solution to meet security and accessibility needs is a blend or mix that would include most of the following:

- Optical-scan ballots and precinct scanners.
- Ballot-on-demand printers.
- Bilingual paper ballots.
- Electronic ballot-marking devices with accessible paper ballot scan and verification.
- Tactile ballots with verification wands (if properly designed and produced with good quality) for accessible absentee and deaf-blind voting.
- Simple digital electronic magnifier aids for the polling place.

12.3 Require Redesign to Simplify All Voting Systems

A major redesign and simplification of all voting systems and their components would also make blends of voting systems more practical for election officials, poll workers and voters.

12.4 Adopt Bilingual Ballot Systems

Bilingual paper-ballot or bilingual VVPAT systems can facilitate preferred-language voting, prevent many security and privacy exposures, and assure that the audit trail can be read in English.

To support alternative-language needs, precinct scanners and other voting machines should also include international icons or multilingual labels and displays.

12.5 Adopt Ballot-on-Demand Printing Systems

Ballot-on-demand printing with special paper and standard printers would reduce the costs of paper ballots, assure a reliable and steady supply of multilingual ballots, and prevent waste of surplus ballots.

12.6 Do More to Limit Eavesdropping in the Polling Place

All paper-ballot printing, scanning and verifying systems should support and be supplied with ballot privacy sleeves to help assure vote privacy.

Eavesdropping in the polling place has become a much more significant threat to privacy due to compact digital cameras, cell phone cameras and the use of visual displays that can show one's ballot at a glance (especially the large, high-contrast text needed by some voters with low vision). Voting booths need much better privacy shields and curtains, and poll workers need to be more careful about how they set up and orient the screens and printers in the polling place. Additionally, polling places need to have tight controls on the use of cell phones, digital cameras, personal digital assistants and other electronic equipment that might be used for eavesdropping.

12.7 Improve Accessibility Interfaces on Voting Systems

Despite the VVSG's more explicit standards for better accessibility features and functions, many vendors have not yet managed to deliver dual-switch input controls, simultaneous audio-video output, enhanced video display controls, and other essential and manageable improvements to voting-machine accessibility.

Now that the HAVA-driven 2006 buying frenzy is mostly over, it's time to make all the voting systems truly accessible and secure and phase out any access-inflexible and obsolete voting systems. (See Appendix E: Some Suggestions for Improving Access on Current Systems.)

We should be demanding much better accessibility for virtually all voters with disabilities or special needs. We should not say, as some have, that because a voting machine may work for certain voters who are blind, it can be assumed to be good enough for everybody. As an example: A friend with low vision found the Sequoia Edge II audio access system so frustrating to use that she had to have her partner who is totally blind do her voting for her, using the Sequoia audio access. This was largely because she needs simultaneous audio and video display output, and the Sequoia Edge II system has not been able to supply that essential accommodation.

To begin accommodating voters who are profoundly deaf-blind, we should immediately push for well-designed tactile ballot-marking aids with mark-sensing verification wands. Tactile ballot-marking systems should be considered to be aids rather than replacements for all other accessible voting systems.

Institutionalized or homebound voters should not be excluded from voting privately and independently just because they may not be able to get to a polling place. We should have private absentee voting systems for voters with disabilities. These might use a blend of tactile ballots, remote telephone voting, vote-by-mail systems and mark-with-your-computer ballot systems.

Like handheld lenses, simplified digital electronic magnifier aids should be available in every polling place to help voters with low vision read voter information materials, as well as help some to mark paper ballots, including provisional paper ballots. Manufacturers of electronic video magnifiers should be encouraged to develop and supply simple, easy-to-use electronic video magnifier aids that are configured to simplify their operation for polling-place requirements.

Ballot boxes and precinct scanners should have input slots that have legroom below to accommodate voters in wheelchairs. Precinct scanners should also include international icons or multilingual labels and displays. They should also include private audible output to indicate scanning results such as "accepted", "undervoted" and "overvoted" in the same language as that in which the ballot was voted.

Electronic BMDs (including former DREs converted to BMDs with ballot printers) should include a voter-selectable control option to automatically deposit the printed ballot into a ballot box or drawer without requiring manual handling by the voter.

12.8 Verify Operation of Accessible Audio Output

To increase the integrity of voting systems using synthetic text -to speech (TTS) for their accessible audio output, any TTS pronouncing-exceptions dictionaries should be made accessibly available for public inspection. Additionally, for voting systems using either human or synthetic TTS audio access, polling-place procedures should include at least one sighted person check to make sure that votes on the paper records match the spoken choices of any audio access output. This print-audio correspondence check should be done at the start of the election day, as well as at random times during the day.

13. Conclusions

The technology for inexpensively providing good accessibility to voting systems has been commonly available for more than a decade, and it can and should be applied to all modern voting systems. A completely new and redesigned generation of voting systems is needed. To accommodate a broad range of disability access needs, voting systems must be designed, from the beginning, with security, accessibility, principles of universal interface design and good human factors in mind. It is not likely that any single voting-machine design can ever meet all the complex and sometimes contradictory needs and requirements of all voters.

Hybrid DRE-VVPAT designs and their accessibility Band-Aids will soon need to be phased out entirely. Adding VVPAT roll printers to currently fielded DREs will necessitate later having to tack on an awkward scanner-verifier capability to make verification of the printout even partly accessible.

If counties insist on making some use of their currently fielded DRE systems, they should not attempt to add tourniquets such as VVPAT roll-to-roll printers.

Converting DREs to BMDs only by adding cheap cut-sheet printers without verification scanner capabilities may become widespread but would result in unacceptable systems with major ballot-handling privacy exposure risks, as well as systems without reliably accessible paper ballot verification.

DRE systems already in the field should be used only if:

1. They incorporate an accessible and truly verifiable paper ballot printer-scanner-verifier that converts them into more reliable ballot-marking devices.
2. Their accessibility is substantially improved to fully comply with all the new VVSG accessibility requirements.

Generally, there is an obvious need to adopt a better forum and methodology for exploring the full voting-system architecture, creatively considering alternatives, weighing complex issues (such as security, practical economics, voter comfort and limits to absolute access for all), and building a more productive and consistent consensus.

Finally, the author believes that blended systems, with optical-scan ballots, precinct scanners and accessible BMDs similar to the AutoMARK, such as now used in New Mexico, are the best and most likely solution for the foreseeable future.

Appendix A: Abbreviations and Acronyms

ATL: Accredited testing laboratories

BMD: Ballot-marking device

CCOS: Central-count optical scan

COTS: Commercial off-the-shelf

DRE: Direct-recording electronic

EAC: Election Assistance Commission

EVS: Electronic voting system

FFBS: Full-face ballot system

HAVA: Help America Vote Act

ITA: Independent testing authority (private lab)

NASED: National Association of State Election Directors

NASS: National Association of Secretaries of State

NOD: National Organization on Disability

NVRA: National Voter Registration Act

Opscan: Optical scan

PCOS: Precinct-count optical scan

TBS: Tactile ballot system

TBMD: Tactile ballot-marking device

VBM: Vote -by mail

VRA: Voting Rights Act of 1965

VVPAT: Voter-verified paper audit trail

VVPR: Voter-verified paper record

VVSG: Voluntary Voting System Guidelines

Appendix B: Personal Experiences in Voting on the Sequoia Edge II DREs

I have attempted to vote on Sequoia Edge II DRE machines in five elections.

1. March 2004

The first time, in March 2004, the poll workers were never able to get any of the machines at our polling place rebooted with the audio-assist feature working. After 45 minutes of struggling with the systems, we gave up and I had to have someone else do my voting for me. Clearly, these Sequoia Edge DREs were not designed correctly to be operated by poll workers lacking high levels of technical sophistication.

2. November 2004

My experience voting on the Sequoia Edge II DRE with the audio-assist feature in the November 2004 election illustrates the problems faced by voters who are blind or have low vision when attempting to vote on Sequoia Edge II DREs.

2.1 Starting Up: Reboot; Finding a Chair; Intermittent Sound; Sample Ballot in Wrong Order

After signing in and getting my voter smart card, I had to wait eight minutes for officials to manage to reboot the audio voting machine. The polling officers had been using it for visual touch-screen voting, as there was a very long line and just five voting machines for our combined two-precinct polling place.

I had my notes in braille. Because there was no table surface for the notes, the poll workers had to find me a chair so I could read my notes with the braille on my lap.

The volume control on the front of the Sequoia Edge II keypad was not working well and resulted in scratchy and intermittent sound. By the time I got the volume set to where I could hear it, the introductory message had already finished the English instructions and was off into other languages. I was not sure what I should do, so I finally gave up and pressed the Select button several times. This eventually got me to the language menu, where I was able to select English and get started with my ballot.

Once I got started, the first major problem I had was that the ballot on the Sequoia Edge II voting machine was not in the same order as the printed sample ballot. When my wife pointed this out to the chief poll worker, the poll worker was surprised to see the difference and said maybe that would explain why it was taking most voters longer than expected to vote. Because my notes were done in the order of the sample ballot, I had to do a lot of hopping around in my notes and be very thorough and careful listening to the machine. In contrast to what we had been told, the list of candidate names was spoken in alphabetical order.

2.2 Reviewing: Can't Stop It; It Reads Everything

It took me 30 minutes to work my way through the ballot and make my selections. After that, I had quite a bit of trouble getting into the review mode to get a full list of my selections. When I did, it went on and on, for 23 minutes, like a long, uncontrolled drink from a fire hose.

The review function read each item, and then at the very end said what my selection was for that item. It even threw in the details of what the fiscal impact would be and took forever. This is completely backward. It should announce the name of the item, then state my selection, and then read the rest of the information for that item. Also, I should have the control to press the arrow key to move forward or backward through the items without having to listen to all the text about every item.

When I did find that I had made a mistake in my selections, I had to wait until the end of the whole review process to correct it, instead of being able to stop, make the change and then continue with the review where I left off. I did not want to abort the ballot-verification review to make a correction and then have to start the long, tedious review all over again from the beginning.

2.3 Time-Outs: Dumped Back to the Language Selection Menu

At one point, as I was nearing the end of the ballot, I was dumped back to the language selection menu. I found out later that this was because I hadn't hit a key in quite a while and the Sequoia Edge II has a time-out function. I hadn't hit a key for a while because it was taking a very long time to read out the ballot summary!

This is terrible human-factors design. If a system is trying to present a helpful prompt when it senses an overly long delayed response from the user, it should never bounce the user to a different place in the menu system. It might prompt the user, but it should then leave them at their previous position to minimize confusion. Furthermore, the time-out should not begin until the system has finished reading out its message — in this case, after the whole ballot review. For a scary minute, I was afraid I had just lost my ballot and would have to start all over. I re-selected "English"; pressed the Select key several times; and, fortunately, was returned to my previous location in the ballot.

2.3 Corrections: Have to Unselect First

When I later attempted to change one of my selections from "no" to "yes," the machine would not let me select "yes" until I had first gone to the unwanted choice and deselected it. This was very awkward and confusing. It is poor human factors design for anybody, but especially for those using the audio-assist feature. Many voters using the audio-assist feature would not be able to navigate this difficult review and correction procedure.

2.5 Sound Levels: Not Normalized

An additional frustration was that the volume on some of the messages was so much lower than the rest of the messages that I had to turn up the volume, repeat the message and then turn the volume back down before proceeding. The volume on all the messages should be normalized to make them the same.

2.6 Takes Too Long to Vote

From the time I signed in and got my voter smart card, it took eight minutes to reboot the machine as an audio voting machine, 30 minutes to make my choices, 23 minutes to review and verify, and another four minutes to make a correction and record my vote. Not counting the hour I had waited in line, it took me about 65 minutes to mark and record my ballot. It would have taken even longer if I had been willing to wait, as prompted, until the end of each message to push the Select button. The messages mislead some voters because they say something like "At the end of this message, you can press the...." This implies that you are supposed to wait until the speech message finishes.

I must emphasize that my ability to navigate this process at all was due to my familiarity with computers and computer technology. I doubt that many voters who are blind or have low vision would have been able to wade through all of that complex process.

2.7 No Way to Get Help

There were at least two times when I wanted to ask for help from the poll workers. One was during the confusion I encountered because of the difference between the printed sample ballot and the DRE ballot. The other time was near the end of my ballot marking, when I had a lot of trouble getting the review started and then was trying to find and change a mistake I found during the review. Because the poll workers would not be able to read anything on the blanked-out visual display on my system and didn't have any way to join me in listening to the audio output of the machine, I knew that I couldn't get much help from them (even though our head polling officer seemed very knowledgeable and helpful).

2.8 Incompetently Designed Audio Interface

As an expert in the design of audio access technology, it is my opinion that the Sequoia Edge II system was incompetently designed. The Sequoia Edge II audio review process is totally unacceptable and would cause most voters with disabilities to skip the review.

3. November 2005

In November 2005, I once again had a frustrating experience attempting to vote with the Sequoia Edge II machine.

3.1 Starting Up: Poll Workers Couldn't Reboot Into Audio Mode

The polling officers (who were very pleasant) thought they had booted the machine into audio mode first thing in the morning, but they had not. Once they realized it was not in audio mode, they could not figure out how to reboot the DRE into audio mode.

After my wife read their manual and figured out the correct audio boot-up process, she finally managed to get the machine properly rebooted and talking for them. This rebooting fiasco took 18 very frustrating minutes.

3.2 Eight-Choice Ballot Took 32 Minutes

After the Sequoia Edge II voting machine finally started talking, it took me about six minutes to fill out the ballot, seven minutes to review my vote, and another minute to record my ballot and finish. Total time in front of the machine was 32 minutes. Luckily, it was a short ballot, with just eight choices.

Clearly, if I hadn't been very tenacious and hadn't taken my own computer expert along when I went to vote, I wouldn't have been able to vote privately.

3.3 Bad Wording and Bad Recording

After I initially made all my ballot choices, the Sequoia Edge II machine prompted me with a message that said something like "You are finished voting" instead of "If you are finished voting . . .," which is likely to cause some voters to walk away before their votes have been properly recorded.

It should more obviously prompt with something like "If you are done making your choices, press Select to record your vote." Many of the factory built-in prompts of the Sequoia Edge II audio-assist feature are similarly poorly worded and misleading or confusing.

Additionally, understanding the locally recorded November 2005 ballot messages was very difficult because they had used a reader who had a very thick foreign accent.

3.4 Many Voters Would Not Be Able to Complete a Vote: Confusing Menus; Takes Too Long

I must emphasize that my ability to independently navigate the Sequoia Edge II voting processes at all was due to my familiarity with computers and computer technology. Many voters with visual or cognitive impairments would not be able to successfully navigate the Sequoia Edge II's confusing hierarchical menu systems.

Additionally, as one familiar with the technology, I was more likely than the typical voter using audio access to be able to figure out how Sequoia audio features worked and were structured, yet I encountered considerable difficulty that made the voting process slow, tedious and frustrating.

Many voters forced to use the audio-assist features might be embarrassed to tie up a voting machine for long periods or not have sufficient patience, and therefore decide not to vote the entire ballot or not to fully review their selections before casting their ballot.

4. June 2006

The June 6, 2006, primary election in Santa Clara County was my fourth opportunity to attempt to vote on the Sequoia Edge II electronic voting systems.

4.1 Starting Up: Card Has to Be Programmed Correctly; Still Have to Reboot to Get Audio Mode

For 12 minutes, the poll workers struggled with trying to get the system talking. By watching the screen for them, my wife was able to tell them it wasn't setting up correctly. The poll workers tried repeatedly to program the voter ID card properly so it would cause my voting machine to talk.

Fortunately, I remembered that at the last Voter Access Advisory Committee meeting, a member of the registrar of voters' staff told me that the Sequoia ID card encoder did not show a menu choice for the audio voting mode. Our poll workers did not know that just before the final step of encoding the ID card, they were supposed to issue a special menu command to bring up a hidden menu for selecting audio access mode.

After I explained this trick for properly using the card encoder, they were eventually persuaded to try it and were finally able to make me an ID card that actually worked and brought the machine up in the audio voting mode. What did happen, and what will happen in the general elections, to all the voters who were not told or did not remember enough to convincingly tell their poll workers how to properly encode their cards for audio access mode? They will not be able to vote using the Sequoia Edge II machines.

4.2 Almost an Hour to Vote: Reviewing Still Takes Too Long; Write-Ins Are Complicated and Tedious

After 12 minutes waiting for my Sequoia Edge II machine to be properly configured in audio mode, it took an additional 31 minutes for me to navigate my way through the ballot-marking procedure. It then took eight more minutes for it to play out the ballot review.

At this point, I decided that I needed to change one of my votes to a write-in, and that complicated and tedious procedure took another seven minutes.

By the time the Sequoia Edge II system printed the paper trail and then spit out my voter ID card, I had spent a total of 59.5 minutes trying to vote privately.

4.3 Other Problems: Card Slot Hard to Find; Distorted Recordings; Time-Outs

There were several other problems I encountered while trying to vote on this Sequoia Edge II voting system. The voter ID card slot was hard to find, as it was positioned so low on the front bottom of the machine and lacked a good tactile guide bezel around its opening. The locally recorded audio messages were distorted and of poor quality from the reader blowing on the microphone throughout the recording. At least three times while I was voting, the Sequoia Edge II timed out and put me back in the language selection menu, where it then required that I press the Select key twice to exit and return to my previous position in the ballot.

4.4 VVPAT Not Accessible: Doesn't Even Allow the Voter to Try to Verify

When the system printed my vote on the VVPAT roll-to-roll printer, I asked my wife to take a look at it to verify my vote for me. It turns out that if I am using the audio access feature, the printer prints the whole ballot in one shot and clears it out of the viewing window, without any break to stop and permit me to have a sighted friend read and verify the paper trail for me. When sighted voters are printing their ballot on the VVPAT, it prints only a single page at a time and then pauses for the user to press a button to make it print the next page, after the voter is ready.

Because the manufacturer of the Sequoia Edge II system thinks voters who are blind will not be able to read and verify the paper trail themselves, it incorrectly assumes that all audio voters want the whole ballot printed out without any pauses for viewing by anyone.

Voters with disabilities are more likely to have electronic voting systems misrepresent their vote, accidentally or maliciously, so they have even greater need than other voters to accessibly verify the paper record.

What I have heard from other voters, even sighted voters, is that they have often caught ballot-marking mistakes in the review or verification processes. It is clear from this and from my own experience that we really have to go through both the review and verification processes in order to make sure our ballots are accurate. The complicated and tedious review processes of most DRE voting systems are likely to cause most voters with disabilities to give up and skip the review.

4.5 Out of Service: What if the One Accessible Machine Breaks?

One of the Sequoia Edge II voting machines in our polling place was broken and taken out of service. Luckily for me, it was not the audio access voting machine.

5. November 2006

The November 2006 election was the fifth election in which I attempted to vote on a Sequoia Edge II.

5.1 Starting Up: Poll Workers Asked for Special Training; Rebooting Is Silent and Takes a Long Time

It took an hour and 17 minutes at the machine, not counting the time in line. This time, the poll workers actually knew how to set up the audio mode. They told me they asked for special training on the audio setup in their poll-worker training class because they "knew that a blind engineer" was going to be trying to vote there again. This makes only 2 out of 5 times that the poll workers have been able to successfully set up the audio voting mode for me by themselves.

It took about 8 minutes for the system to load the audio mode, all without any audible beeps or status indicators until it was up. I've heard its taken 15 minutes for some to load the audio.

There was no loud, publicly audible sound to alert the poll workers that the machine was reloading or finished booting up. For obvious security reasons, there ought to be loud public sounds at reboot and whenever a vote is cast. This is especially important now that it has been documented that voters can vote multiple times on Sequoia DRE systems by pressing the reset button on the back of the machine each time just after they have finished casting their vote.

5.2 New Keypad Not Much Better Than Old: No Up and Down; Multi-Modal keys; Hard to Hold

In this November 2006 election, Santa Clara County's Sequoia systems had the newer V5 keypad with rate and volume control buttons. I was disappointed to find that the navigation controls were just as bad as on the previous keypad. Unlike what some people had claimed, there were no up and down navigation control keys, just left and right arrow keys (for "previous" and "next").

Because of these missing key functions, the Select key must be used multi-modally, sometimes to select candidate choices and other times to navigate out of or into races. It isn't clear to the user exactly when the Select key is changing its mode.

I had to remove the Velcro strap on the back of the keypad to be able to hold the keypad in one hand.

5.3 Time-Outs and Bad Human Factors: Poor Wording of Messages; Poor Speech Quality; Speed Increase Distortion

The time-out bug that bounces back into the language selection dialog was still there, as well as all the cognitive complexity and problems I found in the primary election.

An example of the system's confusing and poor message wording:

"Press the round red Select button to exit this recording." The use of "exit this recording" is quite poor from a human-factors perspective, as users don't think in terms of exiting anything they didn't intentionally enter and are confused because they didn't think they were doing any recording from which they needed to exit.

The prompts still referred to the keys only by color and shape and did not reference them by position on the keypad.

The speech quality actually seemed to be worse than before. There seemed to be only three speed settings, and the fastest speed had chipmunk-like frequency distortion, rather than using VSC (variable speed control) compression to increase or decrease the speech rate. The speed-increase range was not enough to really speed up my vote-casting time.

I found that the audio messages seemed to be more distorted and noisier than the previous time I voted on the Sequoia Edge II. I even had my wife listen to the audio to confirm that the quality was poor.

5.4 Other Problems: No Simultaneous Audio and Video; No VVPAT Access; Voter ID Cards Time Out

The video screen was still blanked during audio mode and did not support simultaneous audio-video display.

There was a VVPAT with a privacy cover flap but no audio access for voters with visual impairments.

An additional problem with the voter ID cards was that they timed out on my wife and others who were waiting for a turn at the voting machines. The 10- or 15-minute time-out on the cards is much too short.

Appendix C: Detailed Lack of Accessibility on Voting Systems

1. The Systems Require Poll-Worker Intervention

Most DRE voting systems, such as the Diebold AccuVote TSX, Sequoia Edge II and ES&S iVotronic, do not permit voters with disabilities to select their audio and visual display modes by themselves. Instead, they must get a poll worker to select the access modes for them. This requires that the voter with disabilities is aware of, and knows how to ask for, the proper audio-visual mode, and it requires that the poll workers know how to properly select the mode for the voter.

The absence of this technology to allow immediate use and adaptation by people with disabilities without third-party intervention causes several problems for people with visual and other disabilities. One is the total lack of privacy, as the voter is required to inform election officials in front of other people of his or her disability and the need for assistance, denying that voter essential privacy in very personal matters. This problem is particularly acute for people who prefer to keep secret the fact that they have visual or reading impairments or other special needs, such as requirements for an alternative language.

Choosing to use access features should not require poll-worker intervention such as reprogramming the voter identification card (as is required by many DRE systems) or rebooting the system (as has been required by others, such as the older Sequoia Edge II systems).

1.1 Synchronized Audio-Visual Access Mode Should Be the Default

Synchronized audio-visual access mode should usually be the default access mode for all electronic voting systems. The selection of access options, such as larger or smaller text size, should be available at all times, for adjustment by the voters.

There is no good reason that voting systems could not have personal configuration abilities for selecting access input controls and output media settings.

1.2 Poll Workers Don't Know How to Set Up the Correct Mode

In practice, the lack of technical expertise and adequate training of poll workers has meant that many voters with visual impairments have not been aware of the audio-visual access mode or have been unable to get their poll workers to set up their electronic voting systems to use it.

In an article she sent to the American Council of the Blind Discussion List and other groups, Karyn Campbell described her first experience voting with a Diebold AccuVote TSX machine, in the March 2006 Illinois primary. She explained that she asked for an audio ballot and had to have poll workers reprogram her voter ID card, as it did not set up the Diebold AccuVote TSX properly the first time she tried it. When she put the reprogrammed card in the Diebold AccuVote TSX machine, it started working in audio mode but with the video output in the wrong mode. Not wanting to push her luck, she gave up and went ahead and voted with the Diebold AccuVote TSX machine, although it was not configured as she wanted.

In my first voting experience with the Sequoia Edge II, the poll workers were never able to get the DRE working in audio mode, even after 45 minutes of reading manuals and calling voter tech-support service centers. Out of the five times I've voted on Sequoia Edge II systems in elections, the poll workers have been able to get the systems into audio voting mode, by themselves, twice.

2 Learning How to Use the Systems, and Getting Help

The current state of adaptive technology allows for people with disabilities to do "discovery" and "personal adaptation" on well-designed computer systems without major intervention by an assistant (for example, going to a computer system and immediately beginning to privately adapt it for personal use). Just as voters can select a language on these systems by themselves, they should be able to select audio mode or video viewing enhancements by themselves, without the intervention of poll workers or other third parties. Voters should be able to figure out how to use the systems without previous training and without significant instruction by a poll worker.

Additionally, most of the voting systems need but do not have practice modes with a simplified example mini ballot, to give the voter who needs it a comfortable opportunity to independently figure out how to view, mark, review and correct their choices.

Most of the current voting systems should but do not have a "request help" key or other control to discretely summon assistance from a poll worker.

3. The Major DREs' Failure to Accommodate Severe Dexterity Disabilities

For a voting system to comport with federal accessibility requirements, a voting machine's adaptive technology must accommodate not only voters who are blind or have low vision but also people with physical disabilities, such as dexterity disabilities, as well as people with hearing impairments or cognitive disabilities.

3.1 No Interface With Dual-Switch Controls

Adaptive technologies for people with various manual keyboard impairments and/or complete inability to use hand controls currently exist, and these technologies are affordable and readily adaptable to voting machines. Such technologies include head switches, foot switches, giant jelly switches and sip-and-puff switches. The only practical way to connect these adaptive devices to a voting machine is through a standard 1/8-inch phone-plug dual-switch interface.

Voters with manual dexterity disabilities who need dual-switch adaptive devices cannot currently plug those devices into many DRE voting systems (such as the ES&S iVotronic) to gain control over the system. Voters with manual dexterity disabilities who are unable to use the voting systems' manual selection buttons or touch screen are thus prevented from privately casting their vote. These defects deny voters with severe manual dexterity disabilities the same opportunity for access and participation (including privacy and independence) enjoyed by other voters who use these voting systems.

As suggested in the Trace Center (University of Wisconsin at Madison) proposal for an ideal voting system, all voting systems should have a 1/8-inch phone jack (separate from the headphone jack) on the keypad for attaching a sip-and-puff or other standard switched input-control device.

3.2 Forcing Audio-Only Output

Another problem is that systems may force voters with severe motor impairments to vote as though they were also blind. For example, the sip-and-puff option proposed for the Sequoia Edge II works only with audio output, without any visual display.

The audio orientation instructions and prompts of the Sequoia Edge II are for using the tactile keypad and are totally inappropriate and unhelpful for users of dual-switch input controls. Because Sequoia's sip-and-puff switch controls only give voters the "forward" and "select" control input functions, they do not have access to the "help" functions, and voters are not able to reasonably back up to hear something again or to make corrections.

This ill-considered attempt to claim a sip-and-puff interface is bogus and not what the access industry would normally consider to be a dual-switch or sip-and-puff interface. Normally, a dual-switch control interface to a system with a visual display would permit users to select items on the visual display instead of forcing them to use an exclusively audio output system built for users who are blind. A system such as Sequoia's proposed token dual-switch interface represents a poorly considered, tacked-on approach to accessible voting-system design. It will not functionally meet the access needs of most voters with severe motor impairments.

3.3 Annoying Time-Outs

The no-key-pressed time-outs that are so annoying and confusing for voters with visual impairments on DRE systems such as the Sequoia II are likely to happen even more often to most voters with severe motor impairments who are forced to use audio-only "access" output systems and awkward keypads.

3.4 No Interface With Computerized Communicators

The major DRE voting machines do not support computerized communicators such as head-mounted laser pointers, eye gaze, eye blink and electronic lap-tray puck-selector systems because they do not support serial or other standard input-output interfaces. Therefore, voters whose dexterity disability requires them to use adaptive technologies are not afforded "the same opportunity for access and participation (including privacy and independence) as for other voters" on these voting systems. Nor can many voters with such a physical disability "privately and independently receive instruction, make selections, and cast a ballot."

3.5 Hard-to-Handle Voter ID Cards

The Diebold AccuVote TSX and Sequoia Edge II voting machines require voters to insert and remove the voter identification card, which is much smaller than the AutoMARK's paper ballot and for some people even more difficult than independently removing the ballot in its privacy sleeve.

4. Inadequate Keypads

4.1 Cannot be Operated With Only One Hand

As specified in the Section 508 Accessibility Guidelines of the Rehabilitation Act, "Controls and keys shall be operable with one hand and shall not require tight grasping, pinching, or twisting of the wrist." Many voters with motor impairments cannot hold tactile keypads such as the Diebold AccuVote TSX or Sequoia Edge II tethered keypads in one hand while attempting to press keys with the other.

Unlike smaller and more ergonomically designed single-hand-operated remote controls for television sets, the large size and form factor of the Sequoia Edge II and Diebold AccuVote TSX keypads do not facilitate their use as a keypad held in a single hand and operated by the thumb of the same hand.

The Sequoia Edge II tethered keypad is so bulky that many voters, not to mention those with dexterity impairments, find it awkward to hold and operate, even with both hands. Because the Sequoia Edge II has no built-in keypad cradle or place to park the keypad, a standing voter is forced to try to hold the keypad in one hand and operate it with the other.

The challenge faced by many voters with motor impairments who are trying to use the tactile keypad or touch-screen controls of electronic voting systems may be better appreciated if you imagine yourself trying to operate the touch screens, the keypad of the Sequoia Edge II or the telephone-style keypad of the Diebold AccuVote TSX with the heel of your hand, your elbow, a rod held in your armpit or a small baseball bat held in your mouth.

4.2 Confusing Keys

Proper accessible keypads should have a few large keys spaced far apart. Additionally, the keys should have high-contrast coloring, true braille and large print labels, and unique tactile shapes, all chosen to make them simple to discover, identify intuitively, remember easily and locate quickly.

Although Diebold's own literature represents the TSX's tethered keypad as a "tactile keypad," its telephone-style keypad with a bump on the 5 key is not what the access industry considers a tactile keypad. Its keys are much too small and close together for most people with major motor impairments to be able to use. There are too many keys, including keys that apparently have no obvious function.

The braille labels on the keys of many of the Sequoia Edge II keypads are difficult to read. They do not use standard braille dot spacing. They are also so close to the back edge of the keys that it is difficult for many braille readers to get their fingertips onto the dots to feel them.

4.3 Other Keypad Problems

There is no place to leave the Sequoia Edge II keypad when you are through voting. I have found Sequoia Edge II voting machines in polling places with the keypads and earphones left hanging over the edge by their cables and dragging on the floor.

Although it has reasonably separated keys on its front panel, the ES&S iVotronic also needs but does not have a detachable keypad that can be positioned on the lap, hand or other convenient place if required.

5. Inadequate Audio Interfaces for Voters Who are Blind or Have Low Vision (and Others Who are Forced to Vote as if They Were Blind)

The major DRE voting systems, from my direct experience, have no more than poorly functioning and ineffective audio interfaces.

5.1 Inadequate Speech Controls

5.1.1 Volume

Many DREs, such as the ES&S iVotronic, do not have a built-in volume control. The ES&S iVotronic DRE headsets are of poor quality, and the inline volume slide control makes the sound scratchy. There is also no tactile indication of where the volume control should be set for normal operation. Consequently, I missed the initial instruction message of the system before I figured out how to get the volume set properly.

Having the volume control built in is important for giving the system the ability to reset volume and rate at the beginning of a session for each voter. This helps to prevent painful volume blasting or missed overly quiet messages at the beginning of the audio voting session.

An additional frustration I and others have encountered with the speech on many of the DREs is that the volume on some of the messages is so much lower than the rest of the messages that we have to turn up the volume, try to make it repeat the message and then turn the volume back down before proceeding. There are simple methods available for making audio recordings with normalized volume levels.. This should be done for all messages.

In order to provide accessibility for people with modest hearing impairments, all these electronic voting systems should have a "boosted" high volume capability. The absence of such a high output capability on these electronic systems also means that the systems are inaccessible for some audio-using voters with significant hearing impairments.

5.1.2 Speech Rate Control

Many systems, such as the ES&S iVotronic DRE, lack any sort of voter-adjustable "speed" or speech rate control for the audio output. This is important for the elderly and people with learning disabilities, cognitive disabilities or other special needs who need to listen to the instructions and ballot selections at a slower rate than the default rate set by the system, while other voters cannot stand to listen to tediously slow speech.

Voice speed control is standard adaptive technology that has been around for many years. It can be easily implemented and commonly has been implemented in computer systems, even including some other electronic voting systems.

5.2 Awkward Keypads

If you are forced to stand while voting with systems such as the Diebold AccuVote TSX or Sequoia Edge II, you will need to hold the tactile control keypad in your hands while operating it. Many of us who are braille readers have found it extremely difficult to read the braille notes we bring to the polling place while trying to also hold and operate a keypad. When reading braille, it is important to be able to keep one's place by keeping one hand on the braille text. Having to switch back and forth between reading braille and holding the keypad is awkward, tedious and time-consuming, especially on long ballots. A lot of time is wasted each time we have to switch from holding the keypad to finding our place again in our braille notes.

The Sequoia Edge II has no cradle or other place to park its keypad for single-handed operation. This makes it very awkward and difficult to read braille notes while using these keypads.

Unlike the keys of the Diebold AccuVote TSX keypad, keys that are used to move forward or backward in an audio ballot should have shapes that indicate direction (for example, arrow-shaped keys that intuitively indicate their direction through the ballot choices).

5.3 Cognitively Difficult Menus

Many voters using the audio access feature of electronic voting systems such as the Diebold AccuVote TSX, Sequoia Edge II or ES&S iVotronic would not be able to navigate their cognitively difficult hierarchical menus and ballot-marking, review and correction systems.

For example, the iVotronic system uses a complicated and confusing process for navigating its hierarchical menu. Its poorly worded messages and complicated logic make it difficult to use, especially for the elderly and people with learning disabilities or cognitive impairments. A good example is that one button (the green, diamond-shaped button) is used on some screens to select a candidate but used elsewhere to move to the next race. A voting system with good human-factors design would not have more than one function per button, to avoid confusion and erroneous voting.

The iVotronic's navigation buttons also can cause confusion about what race you're on and whom you're voting for. For example the voter is initially placed in the top, or contest, level of the hierarchy and uses the yellow up and down arrow buttons to move from contest to contest and presses the green Select button to enter a race.

Once in a particular race, the voter is at the bottom, or candidate, level of the hierarchy and again uses the up and down buttons to move from candidate to candidate. The voter presses the Select button to choose the candidate of their choice in that race.

The problem is that if a voter moves past the last candidate in a race, the system immediately moves back up a level in the hierarchy to the contest level, positioned on the next race. If the voter realizes they have been automatically moved out of one race into another race, they would have to move back to the original race and again press the Select button to move back down into the candidate level.

If the voter doesn't comprehend what has happened in these situations (as is more likely with the elderly or people with learning disabilities, cognitive impairments, dyslexia or other special needs), the voter may be confused and think they are selecting a candidate for one race while the system has actually moved on to another race.

This confusing system of input controls and multilevel menu systems renders these DRE voting systems inaccessible to people with certain visual or cognitive impairments. These overwhelmingly complicated systems will also cause some people with disabilities to skip voting altogether, or to "short circuit" the process, such as by skipping the summary page. Incredibly, reading the summary page on the ES&S iVotronic is the only way for voters to confirm if they have undervoted (failed to vote for enough candidates for every race).

5.4 Slow and Tedious

Voting with audio output on the DRE voting systems is an excessively slow and tedious process. For example, in the case of the Diebold AccuVote TSX, this is due in large part to annoyingly long, pregnant pauses between phrases or messages. It also has overly verbose prompts that relentlessly keep repeating unnecessarily long messages throughout the ballot marking process. Moving back and forth between reviewing and making changes in the Diebold AccuVote TSX ballot can be a long, slow process because it usually requires many repeated pressings of the forward or backup keys.

The ballot review procedure on some systems, such as the Sequoia Edge II, is so poorly designed that most audio voters will not even attempt to review their ballots to check for accuracy. In my own experience with the Sequoia Edge II in an election, it took 23 minutes just to review my ballot! The system had no pause control, and if I interrupted its long-winded read-out process to note or make a change, I was forced to restart the review read-out from the beginning of the ballot.

5.5 Lack of Synchronized Audio and Video Outputs

When using audio output, the voter should always be able to turn off or on the visual display output and get audible acknowledgement of the display mode. This allows audio-only voters to have better privacy, if they want it, while allowing them to re-enable the visual display whenever they desire. For example, it might be helpful for the voter to enable the visual display when asking for assistance from a sighted poll worker.

Most of the DRE systems have no control to allow the voter to independently enable and disable the video display while using the audio voting feature.

Voting systems such as the Sequoia Edge II and ES&S iVotronic have not allowed voters to use simultaneous and synchronized audio and video outputs. In other words, if these systems are in audio mode, the visual displays are disabled, and if the systems are in visual mode, the audio mode is disabled.

5.5.1 Many Can't Cope With Audio Alone

The failure to allow simultaneous and synchronized audio and visual outputs makes the systems inaccessible for voters with visual impairments who require or prefer to have audio assistance when viewing the video display of ballot selections.

This problem is particularly acute for elderly voters who have developed severe visual impairments with age but are unfamiliar with, and unable to cope with, audio-only access technology. For these voters, neither a fully adjustable touch-screen display nor the audio access alternative is sufficient by itself. Rather, they require simultaneous output of both audio and video systems to vote independently and privately.

5.5.2 Must be Synchronous Audio and Speech

Proper operation of simultaneous audio-visual access does not mean just having the audio/keypad and video/touch-screen systems working at the same time, as separate systems. Rather, it means they must be integrated in a synchronous fashion. In a synchronous audio-visual output system, selecting an item on the touch screen highlights it visually and synchronously speaks it through the audio output. Similarly, selecting an item with the keypad or switch input control alternatives should cause the item to be both spoken and visually highlighted.

Empirical studies have confirmed that multi-sensory outputs are more accessible to voters with disabilities than single-sensory outputs. Indeed, these studies have shown that multi-sensory output systems reduce error rates for all voters. Adaptive technology that allows for such multi-sensory outputs has been around for a long time, is affordable and is easily implemented in computer systems. Synchronized, redundant input controls and output media allow voters to play to their own strengths by focusing on the combination of controls and output that best fits their abilities.

There is no good reason for electronic voting systems to lack such basic access technology.

5.6 Lack of Display Customization

Most of the DRE voting systems do not provide the combination of touch-screen display modification capabilities necessary to accommodate the full range of voter vision impairments. Some people with visual impairments prefer or need different colors or contrasts to read effectively. This adaptive technology has been around for 15 years or more, is affordable and is easily implemented in computer systems.

An adequate display modification system at least permits the user to change contrast, foreground and background colors, fonts, and font size, with options for multiple font sizes or zoom magnification. Systems such as the Sequoia Edge II and ES&S iVotronic are not accessible for many people with astigmatism, colorblindness or other visual impairments because they do not provide for contrast control or foreground-background color selection.

Contrast control allows for adjustment of the display's contrast sharpness, while color selection allows a person to change from the default black text on a white background to white text on a black background or some other color combination.

Here also, there is no good reason for these voting systems not to fully include this enhanced video presentation technology.

5.7 Lack of Accommodation for Voters Who are Deaf-Blind

The access functions of the currently available electronic voting systems are also not suitable for providing accessible voting to people who have both profound hearing impairments and visual impairments. The lack of a standard output interface port means that, for example, most voters who are deaf-blind cannot use standard braille display devices, connected through standard serial interfaces, to read the instruction materials and then mark, review and correct their ballots privately and independently. Because of the high cost of braille displays (typically $3,000 or higher) the only current cost-effective way to accommodate independent and private access for voters who are profoundly deaf and blind is with a tactile ballot that has braille instructions and a vibrating verification wand or mark sensor.

6. Protection From Eavesdropping

Because many voters with low vision would like to use large, clear text on the screen and may have difficulty detecting eavesdroppers, the lack of a privacy curtain enclosing the booth area (not just token side panels), appears to be a serious or even totally unacceptable privacy breach. The side privacy panels of voting systems such as the Diebold AccuVote TSX, Sequoia Edge II, and ES&S iVotronic systems are inadequate for assuring privacy for all voters. The lack of privacy in the booth has been made worse by the addition of VVPAT printers beside the DRE voting machines. This makes it harder or impossible for the voter to shield the screen and printer display window with their body.

The lack of a privacy curtain adequately enclosing the booth creates an unacceptable exposure, in violation of constitutional privacy requirements.

7. VVPAT Printouts Are Not Accessible to Many People with Disabilities

When attempting to read the output of the voter-verifiable paper audit trail (VVPAT) printers currently deployed on some DREs, voters with low vision can achieve useful magnification of the printout only through external lenses. For nonvisual readers and for voters whose impairments prevent them from positioning themselves close enough to the VVPAT printer view window to read the printout, verifying votes on the printout is not possible. Using the audio read-back feature of the DRE to confirm their electronic ballot marking in the DRE does not allow them to verify that their vote was recorded properly on the VVPAT printouts.

For example, the ES&S iVotronic voting system provides a VVPAT by means of a printer on each device that records on a rolling paper scroll the selections of voters, one selection at a time, in real time, as each of the selections is made. Voters are forced to verify their votes on the audit trail by viewing the printout on the paper scroll through a small "audit log window" on the printer.

The ES&S iVotronic VVPAT, however, is not adaptable for, nor usable by, many people with visual or motor impairments. Voters who are blind cannot read the printout at all, and other people with visual impairments might be able to read the paper only with the assistance of external lenses. Verification is also not possible for many voters with motor disabilities (those who use wheelchairs, for example) who cannot position themselves close enough to the printer's audit log window to read the printout.

Because these DRE systems lack a VVPAT that all voters with visual or motor impairments can use, they do not afford the same opportunity for access and participation (including privacy and independence) as for other voters on these voting systems. Instead, the electronic voting machines give voters without visual or motor impairments a verification feature not made accessible to all voters with visual or motor impairments.

In the case of systems such as the Diebold AccuVote TSX, verification of the printout is also not possible when the tablet portion of the machine is removed from the base, for example, to place it in a voter's lap or to take it outside for "curbside" voting in an automobile.

The VVPATs are really not accessible for most of the voters with disabilities or special needs. And voters with disabilities are more likely to have these DRE voting systems misrepresent their vote, accidentally or maliciously, so they have even greater need than others to verify the audit record.

When DRE representatives or advocates attempt to justify the lack of fully accessible VVPAT printouts by saying that it isn't important or doesn't matter because "other voting-system vendors don't have it," they are simply wrong. Adaptive technology to provide accessible VVPAT verification for voters with visual or motor impairments is available, and systems such as the AutoMARK and Populex electronic BMDs and tactile ballot aids such as Vote-PAD and Equalivote are able to provide accessible verification with standard paper ballots.

The failure of the DRE voting systems to include accessible voter-verifiable paper record technologies cannot be justified.

8. Conclusion

For the reasons discussed above, most DRE systems, such as the Diebold AccuVote TSX, Sequoia Edge II and ES&S iVotronic, fall far short of meeting HAVA compliance standards. As some of the voting systems' manufacturers have managed it, there appears to be no good reason that the manufacturers of these DRE voting machines could not have designed their voting systems with truly accessible technologies.

Appendix D: Available and Well-Established Access Technologies

1. Affordable Disability Access Technologies Are Readily Available

Omission of proper access capabilities from the current DRE voting systems cannot be attributed to impracticality of undue cost or unavailable technology. Adding the necessary switch-control inputs, alternative tactile-key controls, speech output and easy-to-read large-text display to electronic voting equipment does not have to entail major costs or great technology breakthroughs.

For more than 15 years, computer hardware and software have been successfully assisting people with a wide variety of disabilities to meaningfully communicate with and use computerized systems. Although not perfected and not implemented evenly across all possible applications, access technologies have made many computer systems reasonably accessible for many people with disabilities. This is especially true in the case of access to personal computers.

2. Blindness or Low Vision

Many voters who are visually impaired can now regularly use large-text, speech and/or braille interface systems on computers for word processing, e-mail and Web browsing.

For more than a decade, most personal computers have been able to speak to their users in a high-quality voice using only inexpensive software programs and standard built-in computer hardware.

Single-line braille displays (although costing several thousand dollars or more) have been used by many computer users who are blind for decades.

For more than 15 years, the standard built-in video hardware of personal computers has been powerful enough to allow screen magnifier programs to enlarge screen text and images, adjust contrast, and customize the colors used for text and background.

3. Motor Impairment

For at least a decade, people with motor impairments and some keyboarding capabilities have been typing on their personal computers with the aid of software programs that adjust keyboard timing to prevent unwanted key presses or stuttering repeats. This type of keyboard access software also offers “sticky key” options to allow single-finger or mouth-stick entry of keystrokes that would normally require typing with two hands or multiple fingers.

For decades, there have been alternative input-control systems that allow users with severe motor impairments to input text and control computers with just a couple of special switches (like sip-and-puff switches, large “jelly” switches, foot switches, head-movement switches and eye-blink switches). Sip-and-puff switches are devices that can attach to a voting machine and allow the voter to indicate his or her choices by sipping air from or puffing air into a tube. Jelly switches are large buttons that are easy for a person with limited hand strength and dexterity to press. Most of these switch input systems use the standard 1/8-inch phone plug for their common interface.

Today, many voters with motor impairments have sophisticated computerized wheelchairs with built-in accessible communications systems that allow their users to send text messages and control signals to other computer systems. Head-mounted laser pointers, eye-gaze input systems, lap-tray puck-sensor systems and voice-recognition systems are just a few of the many alternative input and control systems that have been in common use for decades.

4. Hearing Impairment

To aid users with hearing impairments, properly designed personal computer systems have, for many years, been able to route warning beeps through their sound systems and to redundantly indicate audible warning sounds, prompts and messages with visual flashes, captions or other visible cues.

This is not to say that all computer systems are completely accessible by all people with disabilities. Rather, it is to demonstrate that many good, inexpensive and mature access technologies have long been well known and readily available for computerized equipment designers to use in the design of equipment such as accessible electronic voting systems.

5. Voting Systems That Use the Available Technologies

Some voting systems incorporate many of the standard access technologies listed above, either singly or in combination. For example, the Hart InterCivic eSlate DRE and AutoMark BMD both allow alternative input controls with dual-switch devices, and the AutoMark and some of the tactile ballot systems produce printed paper ballots that can be accessibly verified privately by voters with disabilities.

Appendix E: Some Suggestions for Improving Access on Current Systems

Meeting the new VVSG accessibility requirements would go a long way toward improving the accessibility of all voting systems for a broader range of voters with various disabilities.

The following are some simple human-factors suggestions that, although they may also be in the VVSG, are listed here because they have been repeatedly neglected in the design of several of the current electronic voting systems.

1. The proper operation of the system by the voter should be highly discoverable. This means that a voter should be able to figure out how to use the system without previous training and without significant instruction by a poll worker.
2. Voting machines should have an audio key identification feature, such as holding the Help key down while pressing any other key to produce a message describing its function.
3. There should be a practice mode with a simplified example mini ballot to give voters a chance to figure out how to view, mark, review and correct their choices.
4. There should be a "request assistance" button or other control to discretely summon assistance from a poll worker.
5. If the accessible ballot-marking procedure were properly designed, there would be no need for the complexity of a separate accessible ballot review mode. It would be much easier to navigate the original ballot marking procedure again, listening to choice summary and status prompts without long-winded messages and awkward keystroke sequences.
6. Like the language-selection start-up menu on most of the systems, the choice of access output media and input controls should be available for private selection by the voter, rather than only by the poll workers.
7. A simple control should always be available to allow the voter to turn the visual display on or off (with appropriate spoken indication of its status). This is important for preventing eavesdropping and for allowing a chosen assistant to read the screen and provide help.
8. An option for synchronized simultaneous audio and video output is essential for many voters with visual impairments, dyslexia, special language requirements or other needs.
9. Zoom, font-size, contrast and color display controls should be available and voter-adjustable throughout the voting process, not just at the beginning.

10. The system should default by starting each voter's session at a normal volume and speech rate.

11. Audio volume and speech rate controls should be built in and available at all times for adjustment by the audio voter.

12. Normalization of the volume of all audio messages is very important, for both factory built-in messages and locally generated messages. This keeps the volume output reasonably constant so the voter does not miss quiet messages or have to keep adjusting the volume setting.

13. Speech rate should be controlled with Variable Speed Control (VSC) or other methods that do not result in "chipmunk" distortion. The current Sequoia Edge II has an improperly implemented speech rate control that causes chipmunk distortion and does not significantly increase the speed with which the voter can read through the ballot.

14. For audio voters with assistive hearing needs, support for both neck loop hearing aids and boosted volume levels should be available.

15. For audio access systems that use recorded human messages (in contrast to synthetic speech), it is important that messages be recorded by native speakers who are trained in proper recording techniques and using good-quality recording equipment.

16. When text-to-speech (TTS) software is used to generate spoken messages for audio access, the highest-quality TTS voices should be used. Many elderly voters find that it is difficult to understand and takes a long time (days to weeks, not just minutes) to adjust to some of the lower-quality TTS voices that some voting systems have been using. It is not wise to count on the judgment of younger voters who use computers with speech output every day when attempting to assess the acceptability of a TTS system for use by elderly voters.

17. Voting systems using synthetic text -to speech should include a pronunciation-exceptions dictionary or other method for elections officials to correct mispronunciations.

18. There should be controls to allow the audio voter to pause, continue and repeat audio messages.

19. Buttons that are used to move forward or backward in an audio ballot should have shapes that indicate direction (for example, arrow-shaped keys that intuitively indicate their direction for moving through the ballot choices). It is cognitively much easier to use tactile controls with up and down arrow keys to move within a contest and to have left and right arrows to move backward and forward through the races (as if they were simply pages of a book).

20. For cognitive simplification, each race should be displayed on a separate screen in a simple linear format without multiple columns (whenever possible).

21. Multilevel, hierarchical menus should be avoided, as they are unnecessarily challenging for voters who have cognitive impairments or use audio access. It is much better to use simpler linear menus or lists.
22. The touch screen systems should ignore jittery touches that last less than 0.75 seconds.
23. Any simultaneous secondary screen contact (such as by the palm or other fingers) should be ignored.
24. Having long fingernails should not prevent a user from reliably making selections on the touch screen.
25. Slide-in selection on a touch screen should be accepted without causing problems.
26. Blinking, pulsating or bright lights on a display should be avoided, as some voters with certain nervous conditions may tend to react negatively with sudden migraine headaches, seizures or other problems.

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