

**THE MACHINERY OF DEMOCRACY:
VOTING SYSTEM SECURITY,
ACCESSIBILITY, USABILITY, AND COST**

THE BRENNAN CENTER FOR JUSTICE

VOTING TECHNOLOGY ASSESSMENT PROJECT

LAWRENCE NORDEN, PROJECT DIRECTOR

**VOTING RIGHTS
& ELECTIONS SERIES**

**BRENNAN CENTER
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AT NYU SCHOOL OF LAW**

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This paper is the second in a series, which also includes:

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The Machinery of Democracy: Protecting Elections in an Electronic World by the Brennan Center Task Force on Voting System Security

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Response to the Report of the 2005 Commission on Federal Election Reform (2005) (co-authored with Professor Spencer Overton)

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ACCESSIBILITY

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INTRODUCTION

Traditionally, many voters with disabilities have been unable to cast their ballots without assistance from personal aides or poll workers. Those voters do not possess the range of visual, motor, and cognitive facilities typically required to operate common voting systems. For example, some are not be able to hold a pen or stylus to mark a ballot that they must see and read. Thus, the voting experience for citizens who cannot perform certain tasks – reading a ballot, holding a pointer or pencil – has not been equal to that of their peers without disabilities.

The Help America Vote Act of 2002 took a step forward in addressing this longstanding inequity. According to HAVA, new voting systems must allow voters with disabilities to complete and cast their ballots “in a manner that provides the same opportunity for access and participation (including privacy and independence) as for other voters.”¹ In other words, as jurisdictions purchase new technologies designed to facilitate voting in a range of areas, they must ensure that new systems provide people with disabilities with an experience that mirrors the experience of other voters.

This report is designed to help state and local jurisdictions improve the accessibility of their voting systems. We have not conducted any direct accessibility testing of existent technologies. Rather, we set forth a set of critical questions for election officials and voters to use when assessing available voting systems, indicate whether vendors have provided any standard or custom features designed to answer these accessibility concerns, and offer an evaluation of each architecture’s limitations in providing an accessible voting experience to all voters.

The report thus provides a foundation of knowledge from which election officials can begin to assess a voting system’s accessibility. The conclusions of this report are not presented as a substitute for the evaluation and testing of a specific manufacturer’s voting system to determine how accessible a system is in conjunction with a particular jurisdiction’s election procedures and system configuration. We urge election officials to include usability and accessibility testing in their product evaluation process.

THE NEED FOR ACCESSIBLE VOTING SYSTEMS

There are many reasons for election officials to be concerned about creating fully accessible voting systems. Not least of these is that such systems are long overdue: even today, millions of Americans cannot vote independently on secret ballots using the voting machines in their precincts.² For this reason, many of these citizens have found voting to be an “embarrassing, demeaning and time consuming” experience.³ It should surprise no one that the majority of such citizens do not vote.⁴

In addition to reasons of fundamental fairness, there are practical reasons for election officials to ensure that their systems are accessible. First, it is legally required. Second, disabled voters represent a very large and growing segment of the population. Put plainly, no matter where their jurisdictions are located, election officials are likely to find that a significant percentage of the citizens they serve are disabled, and the numbers of such citizens will continue to grow for the foreseeable future.

■ LEGAL ACCESSIBILITY REQUIREMENTS FOR VOTING SYSTEMS

Current accessibility standards reflect evolving standards in federal legislation and an essentially private certification regime formerly led by the National Association of State Election Directors (“NASED”) and now overseen by the Election Assistance Commission (“EAC”).⁵ This section summarizes those requirements and their role in state selection decisions.

■ ■ The Help America Vote Act

Congress has only recently passed an explicit law requiring a private and independent voting experience for people with disabilities. Under the federal Help America Vote Act (“HAVA”), at least one voting system “equipped for individuals with disabilities” must be used at each polling place for federal elections held on or after January 1, 2006.⁶ HAVA requires that such voting systems:

be accessible for individuals with disabilities, including non-visual 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.⁷

Specifically, every polling place shall have “at least one direct recording electronic voting system or other voting system equipped for individuals with disabilities.”⁸ In addition, all voting systems “purchased with funds made available under [HAVA] on or after January 1, 2007” must meet the statute’s standard for disability access.⁹ HAVA also requires that the voting system provide alternative language accessibility as already required by section 203 of the Voting Rights Act.¹⁰

■ ■ The Americans with Disabilities Act and the Rehabilitation Act

While HAVA is the first Congressional statute explicitly to require a private and independent voting experience for people with disabilities, earlier statutes cemented a strong foundation for equal access to the polls for voters with disabilities. The Americans with Disabilities Act of 1990 (“ADA”) and the Rehabilitation Act of 1973 prohibit exclusion of the disabled from government services, programs, or activities, including voting and elections. Title II of the ADA provides that “no qualified individual with a disability shall, by reason of such disability, be excluded from participation in or be denied the benefits of the services, programs, or activities of a public entity, or be subjected to discrimination by any such entity.”¹¹ Similarly, Section 504 of the Rehabilitation Act provides that “[n]o otherwise qualified individual with a disability ... shall, solely by reason of her or his disability, be excluded from the participation in, be denied the benefits of, or be subjected to discrimination under any program or activity receiving Federal financial assistance....”¹²

Under both the ADA and the Rehabilitation Act, Congress mandated promulgation of implementing regulations. Federal regulations provide:

- **Design and construction.** Each facility or part of a facility constructed by, on behalf of, or for the use of a public entity shall be designed and constructed in such manner that the facility or part of the facility is readily accessible to and usable by individuals with disabilities, if the construction was commenced after January 26, 1992.
- **Alteration.** Each facility or part of a facility altered by, on behalf of, or for the use of a public entity in a manner that affects or could affect the usability of the facility or part of the facility shall, to the maximum extent feasible, be altered in such manner that the altered portion of the facility is readily accessible to and usable by individuals with disabilities, if the alteration was commenced after January 26, 1992.¹³

Voting equipment has been found to fall within the expansive definition of “facility” contained in the regulations.¹⁴ Accordingly, election officials must employ means that make voting equipment “readily accessible to and usable by individuals with disabilities.”¹⁵ However, existing precedents do not require election officials to provide voting equipment “that would enable disabled persons to vote in a manner that is comparable in every way with the voting rights enjoyed by persons without disabilities.”¹⁶ The next few years will likely clarify the precise requirements of both HAVA and these earlier statutes with respect to the accessibility of voting systems, as courts hear challenges to the various choices made by elections officials across the country.

The Access Board is a federal agency committed to promulgating accessible design.

■ ■ The “Voluntary Guidelines”

In the meantime, federal agencies have issued two sets of voluntary guidelines for voting system design. In 2002, the Federal Elections Commission (“FEC”) in conjunction with the United States Access Board issued a set of technical standards and recommendations called the 2002 Voluntary System Standards (“VSS”).¹⁷ The “Accessibility” provisions (Section 2.2.7) of the VSS were divided into two categories: those that apply to all voting systems and those that apply only to direct recording electronic (“DRE”) voting systems. The “Common Standards” section (2.2.7.1) includes six requirements that address the appropriate height of the voting system, the maximum distance the voter should have to reach to be able to use the system, and the accessibility of the controls to the voter.¹⁸

The “DRE Standards” section (2.2.7.2¹⁹) includes requirements for accessible voting systems that can be summarized as follows:

- The voter shall not have to bring in his or her own assistive technology in order to vote privately and effectively using the DRE system.
- The system shall provide an audio output that accurately communicates the complete content of the ballot and instructions; supports write-in voting; enables the voter to edit, review, and confirm his or her selections; allows the voter to request repetition of information; supports the use of external headphones; and provides adjustable volume controls.
- When a system uses a telephone-style handset to provide audio information, it should provide a wireless coupling for assistive devices used by people who are hard of hearing.
- The system should avoid electromagnetic interference with assistive hearing devices.
- The system should allow for adjustments to be made to the display image, specifically the image’s contrast ratio, colors, and size of text.
- If the system uses a touch-screen, it should also provide an alternative tactile input option that will be easy to operate for individuals with limited motor skills (*i.e.*, lightweight, tactilely discernible, requiring little force and dexterity, operable with one hand).
- If the system requires a response from the voter within a set period of time, it must alert the voter before time is up and allow the voter to have additional time if necessary.
- If the system uses an audio cue to alert the voter of an error or confirmation, it must also provide a visual cue for voters to accommodate voters with hearing impairments.

- If the system's primary means of voter authentication uses biometric technology that requires the voter to have certain biological characteristics, a secondary means of voter authentication must be made available.

In December 2005, the EAC issued a new set of standards for voting systems, the 2005 Voluntary Voting System Guidelines ("VVSg"). These guidelines reaffirm criteria set forth in the 2002 VSS and push certain standards a step further by insisting that a standard "shall," rather than "should," be followed. In addition, the VVSg's requirements apply to all voting systems, not just DREs, and establish detailed parameters for each recommended accessibility feature. The most important new specifications can be summarized as follows:

- Machines shall be capable of displaying text in at least two font sizes, (a) 3-4 millimeters, and (b) 6.3-9.0 millimeters.²⁰ Sans-serif fonts are preferable to stylized fonts.²¹
- All machines must be capable of displaying information using a high-contrast display with a ratio of at least 6:1.²²
- Any buttons and controls on a voting system must be discernible by both shape and color.²³
- Machines must provide an audio-tactile interface that replicates a standard visual ballot and allows voters to access the full range of features and capabilities in a standard visual ballot. In addition, systems must allow a voter to pause and resume an audio presentation and to rewind the presentation to a previous contest.²⁴
- Default volume level for machines should be set between 40 and 50 dB. Voters should be able to adjust volume up to a maximum level of 100 dB in increments no greater than 10 dB.²⁵ In addition, machines must be programmed to allow voters to vary the speed of an audio presentation.²⁶
- Voters should be able to watch and listen to a ballot at the same time.²⁷
- For optical scan systems, "if voters normally feed their own optical scan ballots into a reader, blind voters should also be able to do so."²⁸

■ **DISABILITY DEMOGRAPHICS**

A large proportion of the voting-age population would benefit from a voting system accessible to people with disabilities. According to the 2000 Census, at least 44.5 million adult residents of the United States (ages 21 and above) have some form of disability.²⁹ Moreover, because many disabilities are associated with advanced age, a rapidly aging population stands to produce dramatic increases in the number of voters with disabilities.³⁰ The statistics in Table A1 confirm the

magnitude of the voting-age population with disabilities and/or special language needs.

TABLE A1

U.S. VOTING-AGE POPULATION WITH DISABILITIES AND LANGUAGE NEEDS

People over 18 who:	Millions of people
Have trouble seeing ³¹	19.1
Have trouble hearing ³²	30.8
Experience physical difficulty, including trouble grasping or handling small objects ³³	28.3
Speak English less than “very well” ³⁴	17.8
Live in “linguistically isolated households” ³⁵	9.2

In addition, the accessibility of voting systems affects not only those with permanent disabilities, but also the millions of voters with temporary disabilities or conditions that would not formally be considered disabilities. For example, a voter with a broken arm who has limited use of her hand, or who has forgotten her reading glasses and cannot read small text, or who has minimal reading skills can vote more easily and effectively as a result of more accessible voting systems. With this impact in mind, the VVSG include many requirements for *all* voting systems (not just those considered “accessible”) that increase ease of access for people who are already fully able to vote without assistance.

At the same time, a voting system may provide accessibility to voters with various disabilities, yet still not be easy to use. For instance, an audio system may provide accessibility to voters with vision impairments, but if the system’s audio jack is hidden on the back of the machine, the system cannot be considered very usable. Similarly, when creating voting systems for individuals with vision impairments, considerations of accessibility alone are not enough. As Mary Theofanos and Janice Redish have described with respect to website accessibility, “the diversity of vision needs and the resulting adaptations that low-vision users require mean that there are no simple solutions to making web sites work for everyone.”³⁶ For the same reasons, it is difficult to make voting systems that work for all voters with vision impairments. Voting machines must enable voters with vision impairments to easily adjust the system to their particular needs to take full advantage of accessibility features.³⁷

METHODOLOGY

To assess the various voting system architectures, the Brennan Center’s team of consulting experts created a set of accessibility criteria drawn from existing accessibility guidelines (including both those specific to voting systems and general information technology guidelines), such as the VSS 2002,³⁸ Section 508 of the Rehabilitation Act,³⁹ and the VVSG (2005),⁴⁰ as well as additional considerations developed through team discussions. These criteria are posed as questions that can help election officials and advocates compare specific systems for use on Election Day.

Next, through a combination of group discussions and one-on-one interviews with the authors, the team of consulting experts provided their impressions of systems’ accessibility, which are reflected in this report. Experts considered not only how an individual feature might affect accessibility, but also how a system works as a whole. Many voting systems are only accessible if jurisdictions implement certain procedures or modify systems in specific ways. In evaluating systems, the team considered whether certain modifications or procedures are needed to render an otherwise inaccessible system accessible.

In addition, each system was first considered as a self-contained product that did not require the voter to bring her own special adaptive technology. If headsets are needed to hear an audio version of the ballot, for example, those headsets would need to be provided at the polling place in order for that voting system to be considered accessible without effort on the part of the voters. This assumption mirrors the Access Board’s definition of a “self-contained product” from 1194.25(a) of the Section 508 Standard:

Self-contained products shall be usable by people with disabilities without requiring an end-user to attach assistive technology to the product. Personal headsets for private listening are not assistive technology.⁴¹

Beyond the most basic accessibility features of a system, however, some observers believe that a voting system should allow a voter to use her own assistive technology, if desired (*e.g.*, by supplying standard ports to connect this equipment to the voting system). Others have raised three arguments against such an approach. First, some experts argue that voting systems are intended to be self-contained, and voters should not be required to bring any special equipment to the polling place. Second, very few industry standards presently govern the design of connections for assistive technology. At this time, the only standard jacks included in federal standards (either the VSS or VVSG) are audio jacks for personal headsets. Third, security concerns exist about including ports to connect uncertified equipment to a voting system, and the risks involved in installing the drivers or other software usually needed to allow assistive technology to operate. Without attempting to resolve this debate, we assessed the extent to which each system allows a voter to make use of personal assistive technology to reduce barriers to access.

Last, we offer an introductory sketch of accessibility features currently provided by vendors and an analysis of how those features might help ensure compliance with our accessibility criteria. To obtain this information, we first culled information from any available product information published by vendors. We then conducted initial telephone interviews with vendors and usability experts on the status and utility of available features. Next, we sent each vendor a written summary of all compiled research on their machines. Vendors commented upon those reports, and their changes or comments are reflected here.

VOTING ARCHITECTURE ANALYZED

This chapter analyzes the following six voting system architectures:

- Direct Recording Electronic (“DRE”)
- Precinct Count Optical Scan (“PCOS”)
- Ballot Marking Device (“BMD”)
- DRE with Voter-Verified Paper Trail (“DRE w/ VVPT”)
- Vote-by-Mail
- Vote-by-Phone

The specific design of these systems varies greatly with each manufacturer’s models. With respect to the voter’s experience, however, the systems can be categorized based upon the primary medium through which the voter interacts with the system to mark and cast the ballot. We consider the features of each type of system individually, but group the systems based on their primary interface as follows:

1. Computer-Based Interface:
 - DRE
2. Paper-Based Interface:
 - PCOS
 - Vote-by-Mail
3. Hybrid Interface:
 - BMD
 - DRE w/ VVPT
4. Telephone-Based Interface:
 - Vote-by-Phone

ANALYSIS

■ COMPUTER-BASED SYSTEMS

With certain exceptions, computer-based voting systems provide greater accessibility to all disabled voters than do paper-based systems. As discussed in greater detail below, the flexibility inherent in computer-based systems allows voters to choose and mix features, a capacity that dynamically increases accessibility for voters with disabilities. In particular, computer-based systems facilitate voting for people with visual impairments: The size of text can, for example, be electronically enlarged. Display screens can be set at a high contrast that clarifies and emboldens words and images. Computer-based systems can provide audio versions of instructions for voting and of the ballot itself. Other voters can also reap the benefits of computer-based systems. Voters who are not comfortable reading English can choose to read or hear their ballots instantly in a different language. Voters with limited motor capacity need not handle paper or pencil. Often, voters with disabilities can access these features and vote on their own without the assistance of a poll worker or personal aide.

Computer-based systems permit voters to use a range of visual, auditory, and tactile options simultaneously. For example, a voter who cannot read well may choose to hear instructions read out loud, but can retain the ability to select a candidate visually from the screen based on her recognition of a candidate's name. Drafters of the VVSG have recognized the potential of mixing modes in this fashion and include a requirement that accessible systems allow visual and audio streams to be used simultaneously.⁴² If designed to do so, computer-based systems can fulfill this requirement with relative ease.

Despite these considerable advantages, computer-based systems can present certain barriers for people with disabilities. Navigation of computer screens often requires that voters use controls that require hand-eye coordination – a touch-screen or a mouse – to select their choices. To operate these controls successfully, voters must have the visual facility to see a cursor move across a screen or to distinguish between virtual buttons on a display and the complementary motor-control necessary to move a mouse or press distant areas on a touch-screen.

The most popular computer-based DRE systems already provide an auxiliary control pad for voters with visual or mobility and coordination impairments. In theory, voters can discern each part of these auxiliary controls using only their sense of touch. The controls' utility varies from machine to machine. Designers can vary the shape of each control mechanism to allow voters to discriminate between controls without looking at them. Voters can activate such controls with minimal force and without fine motor control. Moreover, a button similar to a computer tab key can allow voters to click their cursor between one selection and another without having to move a mouse or touch a screen.

The following questions should be considered in assessing the accessibility of computer-based voting systems:

1. Can the system be physically adjusted to meet a voter's access needs?

The answers to this question depend on the ease with which a voter or poll worker can: (a) adjust the height of the computer screen, (b) tilt or rotate the screen, or (c) remove the screen and input controls from a tabletop surface so that a voter can hold the system in her lap and even vote outside the polling place, *i.e.*, “curbside.”

DREs fall into two categories: Certain systems, including Avante's Vote Trakker,⁴³ Sequoia's AVC Edge,⁴⁴ and Accupoll's Voting System 1000,⁴⁵ sit stationary on a table or stand. Voters cannot readily adjust a stand's or table's height, and such machines are only accessible to voters in wheelchairs if precincts set some surfaces at lower heights before polls open. Some of these systems, including Sequoia's AVC Edge,⁴⁶ also address height concerns by allowing their screens to tilt upward and downward. With the exception of Avante's⁴⁷ machines and the systems once manufactured by Accupoll,⁴⁸ such systems are sufficiently portable for a poll worker to set them up curbside if necessary.⁴⁹

Other systems, such as Hart Intercivic's eSlate,⁵⁰ ES&S, Inc.'s iVotronic,⁵¹ and Diebold's AccuVote-TSX unit,⁵² do not need to rest on a table. These systems can be set up to provide a lightweight tablet (ranging from roughly 10–15 lbs.) that the voter can place on her lap or other suitable surface. This portable module includes the screen and all of the necessary input controls. These systems are also sufficiently portable to allow for curbside voting.

2. Does the system allow voters to adjust the visual presentation of information contained in the ballot or in voting instructions?

Although all computer-based systems could offer a range of malleable viewing options, each DRE model differs in the alternatives it provides for users with vision impairments. The VVSG require that certified systems comply with certain requirements concerning the presentation and adjustability of visual outputs. In particular, the VVSG require that certified systems provide an enhanced visual display that includes a high-contrast presentation, a black-and-white display option, and at least two font size options of a minimum size.⁵³

Many models have already met the requirements prescribed in the VVSG. DREs produced by Sequoia,⁵⁴ Diebold,⁵⁵ Hart Intercivic,⁵⁶ ES&S, and Accupoll,⁵⁷ have high-contrast electronic image displays with a contrast ratio of 6:1 or greater. DREs manufactured by Accupoll,⁵⁸ Avante,⁵⁹ Sequoia,⁶⁰ and ES&S⁶¹ have electronic display options that allow for either a black-and-white-only display or a color display that provides the voter with a means to adjust colors. These features can be made available to voters using machines made by Diebold⁶² and Hart

Intercivic⁶³ but elections officials must ensure that they are incorporated in the ballot's design when it is initially developed.

DREs made by Accupoll⁶⁴ and Avante⁶⁵ provide at least two font sizes – one with capital letters of at least 6.3 mm and one with capital letters of between 3.0 and 4.0 mm – using a sans-serif or similar font. Models produced by Diebold,⁶⁶ Sequoia,⁶⁷ Hart Intercivic⁶⁸ and ES&S⁶⁹ can also vary font size, but officials must request that this feature be implemented during initial ballot design.

3. Does the system allow voters to adjust the audio presentation of information contained in the ballot or in voting instructions?

Audio outputs can be adjusted in four ways. First, systems can allow voters to adjust the volume of the audio playback. Indeed, the VVSG requires systems to do so.⁷⁰ DREs produced by Sequoia,⁷¹ Diebold,⁷² Hart Intercivic,⁷³ ES&S,⁷⁴ Avante⁷⁵ and Accupoll⁷⁶ provide volume adjustability as a standard feature: volume can be amplified up to a maximum of 105 dB SPL and automatically resets to a default level after each voter completes her ballot.

Second, auditory outputs can be recorded in either digitized or computer-synthesized speech. Digitized speech is produced by recording one or more human voices and then playing such recordings back through the computer's digital system. This type of speech is reportedly easier to understand than synthesized speech, a rendering that can sound flat and unfamiliar.⁷⁷ Digitized speech is already available on DRE systems manufactured by Sequoia,⁷⁸ Diebold,⁷⁹ Accupoll,⁸⁰ Hart Intercivic⁸¹ and ES&S.⁸²

Third, certain systems allow the voter to control the rate of speech in the audio output, as recommended in the VVSG.⁸³ People who are accustomed to interacting with technology through an audio interface can “listen faster” and thus expedite the otherwise potentially lengthy voting process. This feature is available on Avante's,⁸⁴ Sequoia's⁸⁵ and Diebold's⁸⁶ DRE systems. According to experts, speech control has until now been associated with systems that use synthesized speech. However technologies are now available to allow digitally recorded human speech to be played at different speeds without changing the tone or creating a high-pitched, chipmunk effect.⁸⁷

Finally, the use of different voices for instructions and for ballot selections – for example, a candidate's name – allows some voters to expedite the voting process. Voters accustomed to using audio interfaces can speed up audio recordings so that they can skim text for breaks or keywords that indicate a new contest. In this way, voters “scan with their ears” in the same manner that readers quickly scan and review a page of text.

This feature can be made available on systems manufactured by Avante,⁸⁸ Sequoia,⁸⁹ Diebold,⁹⁰ Accupoll,⁹¹ Hart Intercivic⁹² and ES&S,⁹³ but must be requested by election officials during ballot design.

4. Does the system provide an audio output/tactile input alternative access option to meet the needs of individuals with visual impairments or other difficulties reading?

Voters who cannot see or read information presented on a visual display need an alternate, non-visual way both to receive and to input information into DREs. All major manufacturers of DREs (Avante,⁹⁴ Sequoia,⁹⁵ Diebold,⁹⁶ Accupoll,⁹⁷ Hart Intercivic⁹⁸ and ES&S⁹⁹) address this issue by providing a version of their ballots through an Audio Tactile Interface (“ATI”). ATIs allow voters to hear candidate choices via an audio ballot, rather than seeing them on a display screen, and to make their choices without any cursor or touch-screen by using separate, tactilely discernible controls.

The 2002 VSS contained detailed criteria for audio ballots, all of which have been reiterated in the VVSG. The audio ballots were required to communicate the complete contents of the ballot via a device affixed to an industry standard connector of a 1/8 inch jack, provide instructions to the voter, enable the voter to review and edit her input, pause and resume the playback, confirm that the edits reflect her intent, and allow the voter to request repetition of any information provided by the system.¹⁰⁰ Still, those systems manufactured under the VSS have produced complaints of badly worded prompts, poorly recorded or poorly digitized speech, and poor navigation options, any of which can make an audio ballot difficult to understand or follow.¹⁰¹ Where possible, election officials should conduct testing with voters with visual disabilities to assess the audio ballots available on different machines prior to purchase.

5. Does the system provide controls suitable for voters with limited fine motor skills?

The touch-screen navigation that is required by most DRE systems poses significant barriers to access for persons with limited fine motor skills. Because the boundaries of selections on the screen are not tactilely discernible, and it is relatively easy to make an erroneous selection by touching the screen outside the boundaries of the intended “button,” voters who can use their hands but have limited fine motor control face significant difficulties in voting successfully and independently. For example, individuals with tremors or other movement disorders that require them to brace their hand when pointing or pressing a button may encounter difficulties with touch-screens because they cannot rest their hand on the screen to make selections. If a touch-screen requires direct touch from the human body rather than a push from any object made of any material, then individuals who use head sticks or mouth sticks would be unable to use the touch-screen. Thus, for voters without the use of their hands, the touch-screen cannot be used to make selections at all. In all these cases, there must be an alternative input control available.

Manufacturers solve this problem by allowing voters to input selections using the auxiliary control panel originally designed for ATIs. Voters can use the alternate

controls on this device to indicate their choices and, in certain machines, retain the ability either to see their ballot on a display screen or to hear their ballot through earphones. Hart Intercivic's eSlate goes a step beyond and makes its standard control panel accessible to voters with limited fine motor skills: Voters move between selections on an electronic screen by turning a dial; separate buttons exist for selecting a certain candidate or response and for casting a completed ballot.¹⁰²

Certain voters cannot input selections with their hands at all, however, and must use a separate device to input information. Some machines, including those manufactured by Accupoll,¹⁰³ Sequoia,¹⁰⁴ Hart Intercivic¹⁰⁵ and Avante,¹⁰⁶ include a "dual switch input option," a jack for a voter to insert such a device. Voters can, for example, attach a sip-and-puff device, which allows them to indicate choices by applying varying amounts of pressure to a straw inserted in the mouth. Other users may use a blink switch that allows them to operate one or two switches by blinking their eyes. In both cases the switches can be used to control the voting machine if it is set up to be controlled with one or two switches.

Switch input devices can present their own usability concerns for certain voters. Such devices require voters to use a control that can communicate a limited number of messages for two types of actions, ballot navigation and selection. A voter using a single, rather than dual, switch input device may not have the ability to scroll backward and forward to revisit earlier answers and might have to restart the ballot completely to change a choice. For this reason, voters benefit from voting systems that can interpret switches that transmit at least two discrete messages: forward/select and backward/select. This flexibility can increase the speed and usability of the voting system for voters using auxiliary devices. Election officials should ensure that dual switch input devices can be used on the system chosen.

6. Does the system allow simultaneous use of audio and visual outputs, in other words, can a voter to see and hear a ballot at the same time?

Many voters, particularly those with low literacy levels, limited English skills, or mild vision impairments, can benefit from both hearing and seeing a ballot. For that reason, the VVSG has required that all audio ballots and ATIs be synchronized with a standard visual output.¹⁰⁷ This feature is presently available on systems manufactured by Accupoll,¹⁰⁸ ES&S,¹⁰⁹ Diebold¹¹⁰ and Hart Intercivic.¹¹¹ According to its representatives, Sequoia plans to implement this feature sometime in 2006.¹¹²

7. Does the system allow voters to input information using a tactile control device while still receiving visual, rather than audio, output?

Voters with limited fine motor control may not need to listen to an audio ballot and may prefer to enter their selections using an auxiliary tactile control device,

while still receiving their ballot through a standard visual display. This feature currently exists on the DRE systems manufactured by Hart Intercivic,¹¹³ Diebold¹¹⁴ and Accupoll.¹¹⁵ According to its representatives, Sequoia plans to implement this feature sometime in 2006.¹¹⁶

8. Can a voter choose and change accessibility and language options without the assistance of a poll worker?

One of the advantages of a computer-based interface is that it can provide a range of options and can allow those options to be selected by the voter privately and independently. Similarly, the voter should be able to correct her unintended selection of a feature independently. For example, if a voter who has already made some but not all of her selections decides that she would prefer a larger text size, but must return to a preliminary screen to alter the size of the text to continue voting successfully, such a transition may be prohibitively confusing, require assistance from a poll worker, or lead to failure.

Some vendors have anticipated the need for flexibility and have designed systems that allow voters to choose and switch between features with ease. Accupoll allows voters to switch languages, adjust volume, and magnify or shrink text size at any time.¹¹⁷ Avante users can change visual and audio settings at any time.¹¹⁸ Diebold users can select and change visual features at any time, but cannot change audio features without poll worker assistance.¹¹⁹ ES&S's and Hart Intercivic's systems ask voters to select their preferred features at the beginning of the ballot, but do not allow voters to change features later in the voting process.¹²⁰ According to Sequoia's representatives, the updated version of the AVC Edge will allow voters to choose and manipulate all features at all times.¹²¹ With the exception of Hart Intercivic's eSlate and ES&S's iVotronic, computer-based systems require that ATIs be initialized by a poll worker each time a voter requests a change in the settings in use.¹²²

9. Is the system's audit function accessible to all voters?

All DREs allow voters to review an electronic record of their cast ballots. Those records can also be read back via audio inputs to blind voters and can be presented in an enhanced visual display to voters with vision impairments.

■ PAPER-BASED SYSTEMS

Paper-based systems, which include systems that use optical scan ballots and Vote-by-Mail ballots, create barriers to voters with disabilities that are not as easily remedied as those presented by computer-based systems. The barriers imposed by these systems result principally from four features of the voting experience. First, with both optical scan and Vote-by-Mail systems, the paper ballot itself must be printed prior to Election Day and cannot be adjusted to address the needs of a particular voter. For voters with visual impairments, requesting and using large-print paper ballots may sacrifice a measure of their privacy: officials

know who request large-print ballots, and if only a small number of individuals do so, officials can discern voters' personal selections after polls have closed. Like voters with vision impairments, voters who require alternate languages may need to request a different ballot pre-printed in their language and may encounter a similar privacy concern. In sum, despite the use of large-print ballots and assistive devices like magnifying glasses, many voters with vision impairments may still have greater difficulties reading the paper ballot than they would reading an enhanced electronic visual display.¹²³

Second, paper-based systems require voters to read the ballot. Some jurisdictions provide recordings of the ballot to facilitate voting for those with visual impairments.¹²⁴ Even when made available, auditory instructions for paper-based systems are presently produced by a cassette machine rather than by a computer-based audio system, and voters cannot change the speed of the audio recording nor skip forward or backward with ease. More importantly, voters with visual impairments cannot review their ballots for accuracy once they have been marked without another person reading the contents to them because no paper-based systems allow an auditory review of voters' input. For some voters with visual impairments this barrier can mean an absolute loss of privacy and independence.

Third, paper-based systems require voters to mark the ballot manually. Voters with coordination or vision problems may require significant assistance to complete this task. In addition, voters with cognitive disabilities have an especially difficult time marking ballots that ask voters to follow an arrow across a page and select a candidate. Many voters with learning disabilities may struggle to perform this kind of visual tracking successfully.

Finally, many paper-based systems require voters to feed their marked ballots into a scanner, and voters with impairments relating to vision, mobility, or coordination will experience difficulties in completing these tasks. To initiate and complete scanning, voters must have the visual and physical facility to grasp a ballot, walk across a polling station, and insert their ballot into a scanner. Many voters will find their privacy and independence threatened as they seek the assistance of another person in order to complete the scanning process.

The following questions should be considered in assessing the accessibility of paper-based voting systems:

1. Can the system be physically adjusted to meet a voter's access needs?

For those voters with disabilities that do not preclude them from handling or seeing paper, paper ballots are easy to position so that they can be seen and marked. The polling place need only include a selection of writing surfaces set at varying heights.

However, systems that require a voter to physically handle paper are fully inaccessible to those voters who have such profound motor coordination disabilities that they are unable to grasp or otherwise manipulate a paper ballot. Such voters cannot clutch a ballot handed to them by a poll worker or operate a pen or marking device. Nor can these voters transport a ballot across a polling station and feed the ballot into a tabulator. Because they are unable to execute the basic mechanics of paper ballot voting without considerable assistance, voters with significant motor control impairments are unable to vote in a private and independent manner.

Voters with significant visual disabilities have equally prohibitive difficulties with paper ballots. Without assistance, such voters are unable to read instructions and candidate choices or to mark their selections. No currently available physical adjustment to the paper ballot sufficiently lowers these barriers.

In addition, paper-based systems may pose specific barriers to certain voters who use wheelchairs. Most optical scan systems include a precinct-based scanner into which the voter must insert her ballot to be counted, and these scanners can be inaccessible to voters with high spinal cord injuries. Scanners, including those manufactured by Avante,¹²⁵ Diebold,¹²⁶ Sequoia,¹²⁷ and ES&S,¹²⁸ often sit atop a solid ballot box that stands at waist height. The scanner's feeder is situated at the front of the box, and no ballot box provides space under this feeder for a wheelchair. Thus, voters in wheelchairs cannot roll up to a scanner and face it. Instead, voters in wheelchairs must roll up beside a scanner, rotate their torsos, and place the ballot into the feeder slot. Many voters with high spinal cord injuries cannot move in this fashion and thus cannot vote without third-party assistance.

Though they present many of the accessibility concerns inherent in any paper-based system, Vote-by-Mail systems provide unique, physical benefits for voters with certain disabilities, particularly mobility impairments. These are the only systems that do not require travel to a polling place. The voter completes the voting process in her own physical environment with more accessible writing surfaces or assistive devices tailored to that voter's specific needs.

2. Does the system allow voters to adjust the visual presentation of information contained in the ballot or in voting instructions?

Once the paper ballot is printed, the size and contrast of the text can no longer be adjusted. To circumvent this limitation, jurisdictions can print ballots with a range of visual presentations, as any vote tallying system can be programmed to count ballots with enlarged print, different colors and contrast ratios, multiple languages, or other special options. Scanners must be programmed to read such ballots, and the jurisdiction must print any special ballots in advance and make them available upon request. In addition, though Vote-by-Mail systems provide certain advantages for voters with physical limitations, voters with visual impairments may struggle to complete the voting process without assistance. These

voters may not be able to read ballot instructions and candidate choices, or know what they have marked, and may need to sacrifice their privacy and independence to cast their ballots in a Vote-by-Mail system.¹²⁹

3. Does the system allow voters to adjust the audio presentation of information contained in the ballot or in voting instructions?

The advent of BMDs – which allow voters with vision disabilities and voters with limited motor skills to mark a ballot using an auxiliary tactile control – has effectively superseded most efforts to make paper ballots more accessible through audio recordings.¹³⁰ Without the kind of interface provided by a BMD, many voters with severe visual or motor coordination impairments cannot mark a paper ballot without assistance from another person. The use of “tactile ballots” with PCOS systems seeks to address this barrier as discussed below, but such devices do not allow voters to review their marked ballots.

4. Does the system provide an audio output/tactile input alternative access option to meet the needs of individuals with visual impairments or other difficulties reading?

Paper-based systems do not have audio output or tactile input, and without some additional component added to the system, cannot provide it. This is true for all of the systems – PCOS and Vote-by-Mail – that require the voter to mark a paper ballot. However, certain small-scale innovations have been developed to help people with visual disabilities to mark paper ballots, including “tactile ballots.” In such systems, a paper ballot is accompanied by an overlay with tactile markings and an audiotape with a description of the ballot to guide the voter in marking her ballot. The advantage of using such add-ons is that the marked ballot is indistinguishable from all of the others and, once cast, can be counted in the same manner.

The International Foundation for Election Systems has developed a tactile ballot template that can be used to accommodate voters with visual impairments.¹³¹ These templates are currently in use in Rhode Island, which uses optical scan systems, for blind and visually-impaired voters.¹³² When used with a Braille instruction sheet, tactile ballots allow some voters who are both blind and deaf to mark their ballots without third-party assistance.

There are, however, several disadvantages. The sequential audiotapes force voters to proceed through the ballot at the rate of the recorded playback, rendering the voting process slower for voters using these systems than for voters using a digital audio playback. More importantly, blind and certain low-vision voters cannot review the marked ballot, and must trust that it is marked correctly or obtain the assistance of another person to do so, with a consequent loss of independence and privacy.

Because Vote-by-Mail ballots are marked in the voter's home, she must have any special assistive systems already available if she wishes to vote without assistance. For example, a voter might have a system to scan a paper form and have it read back to them. But, as with tactile ballots, voters with severe visual impairments may not be able to review their marked ballots. For voters without any assistive devices, moreover, it may be impossible to vote without assistance.

5. Does the system provide controls suitable for voters with limited fine motor skills?

Paper-based systems do not have controls to mark the ballot and instead require the voter to use a pen or pencil to mark it. Such systems are thus inaccessible to many voters with limited fine motor skills. In addition, all of these systems (including BMD systems) require the voter to place the marked ballot into an optical scanner. Voting systems that require a ballot to be grasped, transported across a polling place, and fed into a scanner create obvious difficulties for voters without fine motor skills.

6. Does the system allow simultaneous use of audio and visual outputs, in other words, for a voter to see and hear a ballot at the same time?

Theoretically, election administrators could provide voters with a scanner of some kind that could convert ballot text into audible speech. No such scanner is currently on the market, however, perhaps because BMDs serve the same essential purpose at a lower cost.

7. Does the system allow voters to input information using a tactile control device while still receiving visual, rather than audio, output?

Unless a voter can use a tactile paper ballot, this feature is essentially inapplicable to paper-based systems, which are not amenable to fully tactile controls.

8. Can a voter choose and change accessibility and language options without the assistance of a poll worker?

Unlike a computer display, paper ballots cannot be dynamically altered to change the size, color, or language of the text at the time when a vote is cast.

With respect to language options, however, if all of the languages used in the precinct are printed on each ballot, the voter can make use of any of these options in a PCOS or Vote-by-Mail system. If not, she must request her desired language either at the polling place (PCOS or BMD) or in advance (Vote-by-Mail). Large text or other special versions must also be requested in the same manner.

Similarly, if a voter needs to change the format of the paper ballot he is using during the voting process, in most cases he must request a new, blank ballot. For example, a voter who discovers that she is having trouble reading the ballot might request a large-print version, if one is available. Similarly, if the voter has already marked the ballot erroneously, she must ask for a new ballot. Unlike most computer-based systems, paper-based systems require a voter to seek and obtain such assistance and to discard all work on the original ballot.

In a Vote-by-Mail system, requesting a new or different ballot can involve a trip to the elections office, requiring significant effort on the part of the voter. In Oregon, however, the only state that currently uses such a system, replacement ballots can be requested by calling a toll-free hotline or a County Board of Elections Office.¹³³ If a voter calls more than five days before an election, her ballot will be sent to her in the mail. If a voter calls within five days of an election, she must travel to a County Board of Elections Office to pick up her ballot. Such a trip could prove prohibitive for some disabled voters without transportation.

9. Is the system's audit function accessible to all voters?

Any voter who can see and read a paper ballot can audit the ballot simply by looking at it. Voters with vision disabilities or trouble reading may need a machine to translate markings on a paper ballot into an enhanced visual display or audible reading of those markings. No such scanner, other than the BMD systems described below, currently exists.

■ HYBRID SYSTEMS

To determine the accessibility of both hybrid systems analyzed in this section – BMD and DRE w/ VVPT – it is best to think of each hybrid system in terms of the system architectures they combine. BMD systems integrate a computer-based system with a defining feature of paper-based systems: namely, voters use a computer to mark a paper ballot they feed into a scanner to be processed and counted. Similarly, DREs w/ VVPT make use of both computer- and paper-based systems. DREs w/ VVPT incorporate a paper-based system as a means by which a voter can verify her selections prior to casting her vote.

■ ■ OVERVIEW OF BMD

Like a DRE, BMD systems allow a voter to make her selections on a computer. BMD systems print the marked ballot for the voter, who must then feed it into a scanner to be counted. BMDs thus provide the significant accessibility features of a DRE, but still require that voters overcome the barriers inherent in scanning paper ballots. Indeed, if the marking process were the end of the voting process, the use of paper ballots coupled with BMDs would present no greater barriers to voters with disabilities than DREs.

■ ANALYSIS OF BMD

1. Can the system be physically adjusted to meet a voter's access needs?

Once a BMD prints a marked ballot, the system poses unavoidable challenges to voters who cannot transport a ballot across a polling station. Prior to that point in the voting process, however, voters interact with a BMD exactly as they would with a computer-based DRE system. The voter has the same opportunities to (a) adjust the height of the computer screen, (b) tilt or rotate the screen, or (c) remove the screen and input controls from a tabletop surface to hold the system in her lap. ES&S's Automark includes a screen that can be tilted upward and downward,¹³⁴ and Populex's BMD system, at 15 lbs., can rest in a voter's lap or be easily transported to allow for curbside voting.¹³⁵

2. Does the system allow voters to adjust the visual presentation of information contained in the ballot or in voting instructions?

BMDs present all ballot information in an electronic format. In theory, voters can adjust this electronic ballot in all the ways one can adjust a DRE's presentation to allow greater access. Both the Automark and Populex BMDs have high-contrast electronic image displays with a contrast ratio of 6:1 or greater.¹³⁶ In addition, both machines allow for either a black-and-white display or a color display that provides the voter with a means to adjust colors.¹³⁷ Populex provides two font sizes, one with capital letters of at least 6.3 mm and one with capital letters of between 3.0 and 4.0 mm, both in a sans-serif or similar font.¹³⁸ The Automark's screen supports large-font displays and font sizes can be varied by the voter if elections officials request that this feature be implemented during initial ballot design.¹³⁹ Populex and Automark users can also magnify any part of their ballots by pressing a zoom button at any time.¹⁴⁰

3. Does the system allow voters to adjust the audio presentation of information contained in the ballot or in voting instructions?

Users can adjust the volume of the Automark and Populex BMDs to a maximum of 105 dB SPL.¹⁴¹ Volume is automatically reset to a default level after each voter completes her ballot.¹⁴² Both BMDs also allow voters to accelerate its audio recording in order to expedite the voting process.¹⁴³

4. Does the system provide an audio output/tactile input alternative access option to meet the needs of individuals with visual impairments or other difficulties reading?

Both the Automark and the Populex BMDs come with ATIs and have dual switch input capabilities.¹⁴⁴ On the Automark's ATI, four blue arrow keys are used to move between choices and surround a blue square button that is used to make selections. All buttons are also labeled in Braille.¹⁴⁵ Populex provides a modified

calculator keypad as its ATI.¹⁴⁶ For voters who cannot use a standard ATI, the Automark also provides dual switch input capacity.¹⁴⁷

5. Does the system provide controls suitable for voters with limited fine motor skills?

BMDs allow voters with limited motor skills to mark their ballots without the assistance of an aide or poll worker. Still, voters who need BMDs to mark their ballots often lack the dexterity necessary to complete the voting process independently once the ballot has been marked. Voters must retrieve their ballots from a BMD, travel to a scanning station, and feed their ballots into a scanner. Thus, many voters with limited motor skills may require a poll worker or aide to handle these tasks, and this assistance could diminish their privacy and independence.

BMD manufacturers have attempted to address the privacy concern by providing a cover sleeve that is placed over the ballot.¹⁴⁸ If a voter cannot clutch a ballot well enough to place it in a plastic sleeve, another person can insert the blank ballot into a privacy sleeve for the voter at the start of the voting process. The top two inches of the ballot protrude from the cover. The person who provides such assistance can then proceed with the voter to the BMD, insert the two-inch overhang into the feeder slot, and allow the machine to draw in the unmarked ballot. The privacy sleeve is left hanging off the lip of the feeder slot and, once a voter has finished marking the ballot, the BMD automatically inserts the marked ballot back into the privacy sleeve.

At that point, the person who is assisting the voter can transport the covered ballot across the polling place to a scanner, insert the front two inches of the ballot into the scanner, and allow the scanner to draw in and count the voter's ballot. According to ES&S and Vogue's representatives, at no point will that person see any of the markings on the voter's ballot.¹⁴⁹ Although cover sleeves may safeguard a voter's privacy, such protection could come at a stiff price for jurisdictions. Managing the use of privacy sleeves places a high burden on poll workers. Not only must workers manage the distribution of sleeves, but they must also shadow any voter who needs a sleeve through every step of the voting process. Nor does the privacy sleeve restore the independence lost by the voter who cannot complete the voting process without assistance.

6. Does the system allow simultaneous use of audio and visual outputs, in other words, for a voter to see and hear a ballot at the same time?

This feature is available on the Automark and Populex BMD systems.¹⁵⁰

7. Does the system allow voters to input information using a tactile control device while still receiving visual, rather than audio, output?

This feature is available on the Automark.¹⁵¹

8. Can a voter choose and change accessibility and language options independently without the assistance of a poll worker?

The Populex system allows the voter to magnify text and adjust the audio presentation at any time.¹⁵² The Automark allows voters to adjust the audio presentation at any time, and a button on its touch-screen allows voters to switch between two font sizes or magnify text.¹⁵³

9. Is the system's audit function accessible to all voters?

Both the Automark and Populex BMDs allow voters to review the marks on their ballots. According to Vogue and ES&S representatives, the Automark BMD is sold with a standard scanner that reviews the darkened bubbles on the ballot's face and translates those marks into an enhanced visual display or an audio rendering of a voter's choices.¹⁵⁴ A voter need only reinsert her ballot to activate this feature.¹⁵⁵ The Populex BMD prints its marked ballots with a barcode that reflects a voter's selections.¹⁵⁶ Voters can swipe this barcode under a scanner that converts its contents into an audio output that can be reviewed with headphones or on an enhanced visual display. To activate these features, a voter needs only the visual and physical dexterity to swipe her marked ballot under Populex's scanner. For voters with limited vision or limited fine motor control this final step may prove difficult and require assistance to accomplish when either system is used.

■■ OVERVIEW OF DRE w/ VVPT

While DREs w/ VVPT provide the accessibility benefits of a computer-based system, the voter must be able to read (or hear) the contents of the VVPT to verify her selections prior to casting her vote. For a voter with limited vision, the VVPT cannot be easily printed in a large-font for two principle reasons. First, in certain models, a VVPT prints into a hard case of a fixed size that may not accommodate a VVPT made larger by a larger font size. Second, ballots printed in a large-font by machines like the ones once manufactured by Accupoll, which printed out the VVPT on loose paper from an inkjet printer are, by definition, longer than other ballots. This may sacrifice the privacy of the voter's ballot selections because the large-font ballot's length would render it immediately distinguishable from other ballots.¹⁵⁷ For these reasons, voters with visual impairments may benefit from reviewing the VVPT via audio or on an enhanced electronic visual display so as to avoid the pitfalls of a large-print ballot.

As discussed below, technologies are just now being made available to allow blind voters to read such VVPTs by translating their text into audio. In the spring of 2005, Accupoll released its version of a barcode scanner that was mounted beside the DRE, read the VVPT barcode produced by the printer attached to the Accupoll DRE, and translated it into audio.¹⁵⁸ According to its representatives, Sequoia plans to release a similar mechanism early in 2006.¹⁵⁹ Scanning technology for VVPTs is still in its nascent development phase; it will be several years before thorough usability testing determines the efficacy of these scanners and their technology is fine-tuned.

■ ■ ANALYSIS OF DRE w/ VVPT

1. Can the system be physically adjusted to meet a voter's access needs?

To voters with disabilities that do not relate to their vision, DREs w/ VVPT provide essentially the same physical adjustability as DREs, discussed already. It is important to note, however, that if the paper record (*i.e.*, the VVPT) must be read behind a transparent cover as in most models, the position of that paper often cannot be changed. A voter with a narrow field of vision may need to reposition herself to see the paper record, placing the computer screen and possibly the controls out of reach for a time.

2. Does the system allow voters to adjust the visual presentation of information contained in the ballot or in voting instructions?

As with physical adjustments, DREs w/ VVPT systems can be adjusted just as DRE systems, except in that portion of the voting process that involves verification by the voter of her ballot. In all models, the print on the VVPT record is of a fixed size and appearance and is not subject to modification by the voter at any time. One system, Accupoll's AVS 1000, used to print the voter's selections on a full-sized sheet of paper (rather than a small strip) that a voter could handle and bring closer to her face.¹⁶⁰

VVPT systems manufactured by Diebold, and ones once manufactured by Accupoll, offer an additional display option that may be helpful to voters with cognitive or learning disabilities. In those systems, the ballot screen and the VVPT are displayed simultaneously on a DRE's screen to allow for a side-by-side visual comparison of the two images, thereby simplifying verification for voters who have difficulties reading rows of information on a printed page.

3. Does the system allow voters to adjust the audio presentation of information contained in the ballot or in voting instructions?

Last spring, Accupoll introduced an electronic scanner that, according to company representatives, could read back the text of a VVPT to a voter.¹⁶¹ Voters could adjust the speed and volume of the Accupoll scanner's playback. The elec-

tronic scanner rested next to a DRE. Each VVPT printed by the Accupoll DRE contained a barcode of the voter's selections, as well as a text version of those selections. A voter thus had to grasp the VVPT and swipe it under the scanner to verify her vote. Accupoll asserted that given the proximity of the scanner to the voting machine, blind voters should have had no trouble detecting the existence of a scanner with their hands and successfully completing the swipe. In theory, the only voters who would not have been able to verify their votes without assistance would have been voters with both physical and visual impairments. As of now, the barcode scanners once offered by Accupoll and promised by Sequoia are the only means for a voter to hear, rather than see, the contents of their VVPTs. Of course, only rigorous usability testing will be able to verify these predictions.

4. Does the system provide an audio output/tactile input alternative access option to meet the needs of individuals with visual impairments or other difficulties reading?

Every DRE w/ VVPT can be outfitted with an ATI. If a voter must take action in response to reviewing a VVPT, she can do so by using such an ATI.

5. Does the system provide controls suitable for voters with limited fine motor skills?

As long as voters have the visual facility to see a ballot and are provided with an ATI, DREs w/ VVPTs are fully accessible to such voters.

6. Does the system allow simultaneous use of audio and visual outputs, in other words, for a voter to see and hear a ballot at the same time?

DREs w/ VVPT allow the voter to see and hear the selections simultaneously during the initial phase of the voting process. Once the voter reaches the point at which she must verify her vote by reviewing the VVPT, however, the audio options are limited. As noted already, Accupoll offers audio rendering of VVPTs, and Sequoia might soon follow suit.

7. Does the system allow simultaneous use of visual displays and tactile input controls?

As long as a DRE w/ VVPT includes a set of auxiliary tactile controls, and the controls are programmed to input responses during the VVPT review process, VVPT systems can facilitate the simultaneous use of visual displays and tactile input controls.

8. Can a voter choose and change accessibility and language options independently without the assistance of a poll worker?

For DREs w/ VVPT, features selected for the initial computer-based portion of the voting process (*e.g.*, large-print or language options as well as audio options)

are not carried over into the voter's verification of the paper record. In the latter stage of the process, as discussed already, the only accessibility feature that has been on the market and may be in the future is a barcode reader that translates the paper record's contents into audio speech for verification.

VVPT could also encroach on the privacy of those voters who choose a language other than English to vote. In order for a voter to verify her ballot, the paper trail may need to be produced in her language of choice. This would reveal a special language choice on the printout – names of races would not be printed in English – and if the selection of a language other than English is rare in a particular precinct, a voter's privacy could be compromised should officials review ballots during a recount. Election officials could request that machines be configured to print every VVPT with labels written in both English and all other available languages, but this could require a sharp increase in paper use and cost and may be infeasible for other reasons. To date, no company has pre-programmed a machine to do so.

9. Is the system's audit function accessible to all voters?

Any voter that can read a VVPT is likely able to verify the accuracy of its text. As noted above, voters with visual impairments may require an enhanced visual display or audio rendering of their VVPTs in order to verify them. Ideally, enhanced visual and audio renderings of VVPTs would be derived from the same written text available to sighted voters. The only audio scanner once available for VVPTs, Accupoll's, read a barcode, not printed text.¹⁶² It is possible that the barcode, rather than the text, could be counted as the official ballot in the event of a recount. In states where this proves true, voters with visual impairments who use a scanner like Accupoll's will avoid verifying selections that do not reflect the ballot of record in an election.

Accessibility experts have suggested two alternatives to Accupoll's barcode scanner. First, certain scanners can read text printed in OCR fonts, and these scanners could prove helpful in reading VVPTs to voters. Scanners understand each letter, convert letters into words, and create a spoken version of a written word. VVPT printers could be programmed to use OCR fonts – indeed Accupoll's printers once did – and OCR scanners could be provided.¹⁶³ Second, some printers can read the words they produce, and VVPTs could be outfitted with such printers. Printers take note of each character they write and can sound out those characters into words. The accuracy of these audio renderings improves when there are limited options for what a word could be, such as a when a printer is choosing between two candidates in a race.¹⁶⁴

OCR fonts are standard monospaced fonts designed for "optical character recognition" on electronic devices, such as scanners.

■ TELEPHONE-BASED SYSTEMS

In telephone-based voting systems, voters use a touchtone phone to dial a phone number that connects voters to an audio ballot. Voters press specific telephone keys to indicate their selections, and the system's software interprets the tones of those keys to record choices.¹⁶⁵ Telephone-based systems can be designed in two ways. In one scenario, states can configure their Vote-by-Phone lines to accept calls from any phone so that voters can cast ballots from home using their own equipment. Alternatively, states can limit incoming calls to a discrete set of phones housed at polling places. In this case, voters must travel to the polls to vote and use phones provided by the state. Unless carefully designed, these telephones can be largely inaccessible to voters with disabilities.

The only existent Vote-by-Phone systems, New Hampshire's and Vermont's, follow the latter model.¹⁶⁶ The great accessibility promise of Vote-by-Phone systems, however, lies in the possibility of allowing voters to vote from home on Election Day. At home, voters could use customized phones already configured with any special keypads or other features they might need. Perhaps most importantly, voting from home would save voters from traveling to a polling place. Many disabled voters cannot drive and could escape the cumbersome task of arranging for transportation on Election Day if they could vote from home. In addition, if all voters voted by telephone, states would not need to invest in rendering old polling places accessible to voters in wheelchairs. Thus, when combined with a Vote-by-Mail system for voters with hearing impairments, Vote-by-Phone systems could level the playing field by giving all voters the same remote voting experience.

Unfortunately, all telephone-based systems present significant barriers to voters with hearing impairments. First, the voter's ability to vote by phone depends upon the quality and nature of their adaptive equipment that facilitates full use of the telephone. Although many voters with hearing impairments possess such technology, many voters do not. In theory, jurisdictions using Vote-by-Phone systems that require voters to vote from home could obtain Text Telephones ("TTYs" or "TDDs") to connect with voters that have TTYs in their homes.¹⁶⁷ Only a small proportion of voters who have trouble hearing have access to TTYs, however, and Vote-by-Phone systems would need to be used in conjunction with Vote-by-Mail systems to accommodate many of these voters.

At present, Vote-by-Phone systems do not offer TTY-capabilities as an option on their voting systems.¹⁶⁸ For now, Inspire's Vote-by-Phone system thus comes with "a full-featured Election Management System (EMS) which enables the jurisdiction to configure and print blank paper ballots. These blank ballots could be mailed to, or made available at the polling sites for, those who are deaf and cannot use the telephone."¹⁶⁹ This option may not, however, aid those voters with sight and hearing difficulties.

Second, while Vote-by-Phone systems may provide significant accessibility benefits to blind voters accustomed to responding to audio output using a standard phone keypad, this mechanism may prove cumbersome and unfamiliar for other voters with other accessibility needs: older voters who have vision impairments and are also hard of hearing may not be able to navigate a phone system with ease. Voters with limited mobility may not be able to use the telephone keypad unless it is specially designed for such voters.

■ ANALYSIS OF TELEPHONE-BASED SYSTEMS

1. Can the system be physically adjusted to meet a voter's access needs?

Standard telephones have a fixed cord length or range of operation, fixed keypad configuration, and fixed keypad size. If states insist that voters use telephones provided at a polling place, they may not be physically adjustable unless auxiliary features are provided. If voters cast ballots from their homes, however, they can use their personal phones. In all likelihood, these telephones will already be configured to accommodate the voter's needs and would not require physical adjustments.

2. Does the system allow voters to adjust the visual presentation of information contained in the ballot or in voting instructions?

All telephone-based systems use an audio, not a visual, ballot.

3. Does the system allow voters to adjust the audio presentation of information contained in the ballot or in voting instructions?

Although existent Vote-by-Phone systems in Vermont and New Hampshire do not allow voters to adjust the ballot's volume and speed, designers could program audio ballots to do so. In addition, many phones allow users to adjust a receiver's volume levels.

4. Does the system provide an audio output/tactile input alternative access option to meet the needs of individuals with visual impairments or other difficulties reading?

All Vote-by-Phone systems transmit information in audio form and ask voters to input information using tactilely discernible controls. However, Vote-by-Phone systems allow voters to access and enter information in only one way. Voters must enter their selections using a standard telephone keypad.¹⁷⁰ According to representatives of IVS, makers of Vermont's Vote-by-Phone system, if a voter cannot use a standard telephone for some reason, no alternative system exists for inputting ballot information using telephones.¹⁷¹

5. Does the system provide controls suitable for voters with limited fine motor skills?

A Vote-by-Phone system could be designed in two ways. In one scenario, a voter casts her ballots from home using her personal phone. In this case, the interface for a phone system is, by definition, the voter's own equipment and should be accessible to her.

In a second scenario, currently in practice in Vermont, the voter uses a phone to cast the ballot at a polling station where phones have been provided. Many voters with limited motor skills need a specially designed phone with an interface that is more accessible than a standard 12-key keypad. Indeed, these voters may need telephones to have an alternative switch input available or telephone end units adapted to their particular needs. As long a voter can access the unit, any adaptive technology which is able to replicate the tones of a keypad should be able to operate the Vote-by-Phone system. According to IVS, some of these adaptive technologies cannot meet this requirement, however, because they do not replicate the "distinct sounds generated by the telephone when its buttons are pressed."¹⁷²

6. Does the system allow simultaneous use of audio and visual outputs, in other words, for a voter to see and hear a ballot at the same time?

Telephone-based systems cannot currently provide such a feature.

7. Does the system allow simultaneous use of visual displays and tactile input controls?

Telephone-based systems cannot currently provide such a feature.

8. Can a voter choose accessibility and language options independently without the assistance of a poll worker?

Vote-by-Phone systems have a limited range of accessibility options because they do not have a visual display and are only as accessible as the telephone system used by the voter. As discussed already, this can be prohibitive for voters with hearing impairments who must, in many cases, vote by mail. Nevertheless, these systems do protect the privacy and independence of those voters who can use the telephone through assistive devices or other means.

Like a computer interface, language options can be made a part of the initial steps of the voting process in telephone-based systems, allowing independent and private selection. Election officials should ask that this flexibility be implemented during initial ballot design.

9. Is the system's audit function accessible to all voters?

Vote-by-Phone systems produce a paper ballot, and auditing this ballot presents many of the same accessibility concerns as VVPTs. Once a voter has finished entering her choices, the system prints a marked paper ballot either to a central location, such as the Secretary of State's office, or at the precinct itself. This paper ballot is treated as the ballot of record.¹⁷³

In the central location scenario, the voter cannot see her marked ballot. However, ballots are printed with a barcode that contains a voter's selections. This barcode can be scanned as it prints at the central office, translated into an audio ballot, and read back to the voter over the telephone. The voter can either reject or accept her ballot after hearing the barcode's contents. In jurisdictions where paper ballots, not barcodes, are the ballot of record, voters would review a proxy for a ballot, rather than the physical text that would be counted in an election.

By contrast, when ballots are printed at precincts, sighted voters can read the text printed on their ballots and verify its accuracy. Like with barcode scanners used with VVPTs, voters with vision impairments must have the visual and motor facility to use a barcode scanner to translate their ballots into an audio recording.

KEY FINDINGS

Our report reached several conclusions about the accessibility of each system:

- **COMPUTER-BASED SYSTEMS: DRES AND BMDs**
- **Accessibility of Computer-Based Systems:** Because computer-based interfaces allow voters to tailor a range of features to their individual needs instantly and without assistance from another person, DREs and BMDs offer the greatest accessibility to voters with disabilities, particularly those with visual impairments.
- **Audio and Enhanced Visual Display Capabilities for Voters with Visual Impairments:** Unlike paper-based voting systems that do not provide any means for voters to hear rather than see instructions or ballot information, most DREs and BMDs allow voters to hear such information through headphones and to adjust the volume and rate of the audio output. In addition, several systems provide digitized (*i.e.*, real recorded human voice), rather than computer-synthesized, speech, and use different voices for instructions and ballot selections to expedite comprehension and thus the voting process itself. For voters with mild vision impairments who might not need an audio ballot, computer interfaces provide an enhanced visual display that uses bigger and bolder text.
- **Alternative Input Devices for Voters with Motor/Coordination Impairments:** Navigation of computer screens often requires that voters use controls that require hand-eye-coordination – a touch-screen or a mouse – to select their choices. For voters without the use of their hands or with severe motor impediments, a touch-screen cannot be used to make selections at all. In both cases, there must be an alternative input control available. The most popular computer-based systems already provide tactilely discernable input controls, often as part of the Audio Tactile Interface designed for voters who cannot see. Frequently these tactile controls can be used by individuals with mobility and coordination disabilities so long as the visual display remains active when those controls are engaged. For those voters who cannot use their hands at all to input selections, certain machines include a “dual switch input option,” a jack for a voter to insert their own dual switch input device. Voters can, for example, attach a sip-and-puff device, which allows the voter to indicate choices by applying pressure to a straw or any other dual switch compatible with the scanning of the voting system.

■ PAPER-BASED SYSTEMS

■ PCOS

- **Limited Flexibility to Meet Special Needs:** First, with PCOS and Vote-by-Mail systems, the paper ballot itself must be printed prior to Election Day and thus cannot be adjusted to address the needs of a particular voter. In addition, despite magnifying lenses and other assistive devices provided by elections officials, voters with vision impairments still may have greater difficulties reading the paper ballot than they would reading a computer screen that allows fine contrast and size adjustments to be made. Paper-based systems do not have audio output or tactile input, and without some additional component added to the system, cannot provide it.
- **Tactile Ballots for Voters with Visual Impairments:** Certain small-scale innovations have been developed to help people with visual disabilities to mark paper ballots, including “tactile ballots.” However, many voters with visual impairments still cannot review the marked ballot and must trust that it is marked correctly or obtain the assistance of another person to do so, with a consequent loss of independence and privacy.
- **Inaccessible Auditory Instructions:** If made available at all, auditory instructions for paper-based systems are presently produced by a cassette machine, rather than by a computer-based audio system. In practice, voters with visual impairments can neither change the speed of the audio nor skip forward or backward during the voting process. More importantly, such voters cannot review their ballots once they have been marked without another person reading the contents to them.
- **Paper Ballots Inaccessible to Voters with Motor Coordination Impairments:** Paper-based systems that require voters to mark the ballot manually present significant challenges to voters with either or both coordination and vision problems. Paper-based systems do not have “controls” to mark the ballot and instead require the voter to use a pen or pencil to mark it. Such systems are thus inaccessible to many voters with limited fine motor skills.
- **Scanners Inaccessible to Many Voters with Visual, Mobility, or Motor Coordination Impairments:** Systems that require voters to feed their marked ballots into a scanner present barriers not only for voters with impairments relating to vision, mobility, or coordination, but even to non-disabled voters who have coordination difficulties.

■ Vote-by-Mail Systems

Vote-by-Mail systems provide unique benefits for voters with mobility impairments. These are the only systems that do not require travel to a polling place; the voter completes the voting process in her own physical environment with

more accessible writing surfaces or assistive devices tailored to that voter's specific needs. Nevertheless, voters with visual or motor coordination impairments still may be unable to vote independently using a paper ballot of any kind, including a mail-in ballot.

■ **HYBRID SYSTEMS**

■ ■ **DREs w/ VVPT**

While DREs w/ VVPT provide the accessibility benefits of a computer-based system, voters with visual impairments are presently unable to review and verify the contents of the VVPT prior to casting their votes. Voting system manufacturers have just started to release scanners that read back the text of a VVPT to a voter, and those technologies are as yet unproven. In addition, despite assurances from the manufacturer that visually-impaired voters should have no trouble detecting the existence of a scanner with their hands and successfully scanning their VVPTs, voters who have both visual and motor impairments are likely to need assistance in using such technology to read their marked ballots. Of course, only rigorous usability testing will be able to verify these predictions.

■ ■ **BMDs**

BMDs greatly augment the accessibility of paper-based systems. Indeed, if the marking process were the end of the voting process, the use of paper ballots coupled with BMDs would present no greater barriers to voters with disabilities than DREs. Moreover, both the Automark and Populex BMDs allow visually-impaired voters to review the marks on their ballots on an enhanced visual display or in audio format. To activate these features, a voter needs only the visual and physical dexterity to use the scanner. For voters with limited vision or limited fine motor control, this may prove difficult and require assistance to accomplish.

■ **TELEPHONE-BASED SYSTEMS**

Precinct-based Vote-by-Phone systems provide no greater accessibility than DREs or BMDs, and such systems may remain inaccessible to many voters. In particular, telephone-based systems may prove cumbersome for people with limited fine motor control and hearing impairments, especially those who have poor speech discrimination, or who rely on lip-reading, text, or other visual cues. To make a telephone voting system accessible for these individuals, audio signal enhancement and a text alternative would need to be available. Moreover, none of the currently available Vote-by-Phone systems allows the use of adaptive technologies to assist hearing-impaired voters, such as TTY phones. Finally, it is unclear to what extent other adaptive telephone end units could be used with current systems.

The future promise of Vote-by-Phone systems lies in the possibility of allowing Election Day voting from home, where voters could use customized phones already configured with any special keypads or other features they might need. Voting from home would save voters from traveling to a polling place. Thus, when combined with a Vote-by-Mail system for voters with hearing impairments, Vote-by-Phone systems could level the playing field by giving all voters the same remote voting experience. But the only existent Vote-by-Phone systems, New Hampshire's and Vermont's, require voters to vote at a polling place.

RECOMMENDATIONS

This report provides a template of key questions and preliminary answers to assess the accessibility of the various types of voting systems. More significant testing must be performed to provide fuller answers. In such assessments, elections officials should keep in mind five general points:

- **Assessments must take into account the specific needs of citizens with multiple disabilities.** For example, solutions that solve barriers faced by voters with visual impairments by providing an audio ballot do not help a voter who is both blind and deaf.
- **To determine accessibility, officials and advocates should examine each step a voting system requires a voter to perform, starting with ballot marking and ending with ballot submission.** Systems that may provide enhanced accessibility features at one stage of the voting process may be inaccessible to the same voters at another stage in that process.
- **Accessibility tests must take into account a full range of disabilities.** When selecting participants for system tests, officials and advocates should include people with sensory disabilities (*e.g.*, vision and hearing impairments), people with physical disabilities (*e.g.*, spinal cord injuries and coordination difficulties), and people with cognitive disabilities (*e.g.*, learning disabilities and developmental disabilities). Given the rising number of older voters, officials should take pains to include older voters in their participant sample.
- **All accessibility tests should be carried out with full ballots that reflect the complexity of ballots used in elections.** A simplified ballot with only a few races or candidates may produce misleading results.
- **Many features that ensure accessible voting are new to the market or still in development.** As election officials purchase systems today, they should obtain contractual guarantees from vendors that vendors will retrofit their systems with new accessibility features as such technology becomes available, and that these adjustments will be made at little or no extra cost.

ENDNOTES

¹ Help America Vote Act, 42 U.S.C. § 15481(a)(3)(A) (2002).

² Testimony of James C. Dickson, Election Assistance Commission, May 5, 2004 *available at* <http://www.eac.gov/docs/EAC%20Testimony.pdf>.

³ *Id.*

⁴ *Id.*

⁵ Election Assistance Commission, *Voluntary Voting System Guidelines* at 4 (2005), *available at* http://www.eac.gov/VVSG%20Volume_II.pdf, [hereinafter EAC VVSG] (Last visited May 31, 2006).

⁶ HAVA, 42 U.S.C. § 15481(a)(3)(D).

⁷ HAVA, 42 U.S.C. § 15481(a)(3)(A).

⁸ HAVA, 42 U.S.C. § 15481(a)(3)(B).

⁹ HAVA, 42 U.S.C. § 15481(a)(3)(C).

¹⁰ HAVA, 42 U.S.C. § 15481(a)(4).

¹¹ American with Disabilities Act, 42 U.S.C. § 12132 (1990). To establish a violation of Title II of the ADA, a plaintiff must demonstrate that: (1) he or she is a qualified individual with a disability; (2) he or she is being excluded from participation in, or being denied benefits of a public entity's services, programs, or activities, or is otherwise being discriminated against by a public entity; and (3) such exclusion, denial of benefits, or discrimination is by reason of his or her disability.

¹² Nondiscrimination Under Federal Grants and Programs, 29 U.S.C. § 794(a) (1998).

¹³ Nondiscrimination on the Basis of Disability in State and Local Government Services, 28 C.F.R. § 35.151(a), (b) (1993).

¹⁴ *American Association of People with Disabilities v. Hood*, 310 F. Supp. 2d 1226, 1235 (D. Fla. 2004).

¹⁵ *Id.*

¹⁶ *American Association of People with Disabilities v. Shelley*, 324 F. Supp. 2d 1120, 1126 (D. Ca. 2004).

¹⁷ Federal Election Commission, *2002 Voting Systems Standards* at 1-2, *available at* http://www.eac.gov/election_resources/vss.html, [hereinafter 2002 VSS] (Last visited June 24, 2006).

¹⁸ *Id.*, *supra* note 17 at §§ 2.10 – 2.12.

¹⁹ *Id.*

²⁰ EAC VVSG, *supra* note 5 at 54.

²¹ *Id.*, at D-4.

²² *Id.*, at 54.

²³ *Id.*

²⁴ *Id.*, at 55.

²⁵ *Id.*, at 56.

²⁶ *Id.*, at 57.

²⁷ *Id.*, at 54.

²⁸ *Id.*, at 57.

²⁹ U.S. Census Bureau, *Profile of Selected Social Characteristics, Table DP-2: 2000*, at http://factfinder.census.gov/servlet/QTTable?_bm=y&-geo_id=D&-qr_name=DEC_2000_SF3_U_DP2&-ds_name=D&-_lang=en&-redoLog=false&-format=&-CONTEXT=qt (Last visited June 26, 2006).

³⁰ Gregg C. Vanderheiden, *Thirty-Something Million: Should They Be Exceptions?* 32 HUMAN FACTORS 383 (1990), available at http://park.org/Guests/Trace/pavilion/30_some.htm.

³¹ National Center for Health Statistics, *Summary Health Statistics for U.S. Adults: National Health Interview Survey*, 222 VITAL AND HEALTH STATISTICS at 36, Table 11, available at http://www.cdc.gov/nchs/data/series/sr_10/sr10_222acc.pdf.

³² *Id.*

³³ *Summary Health Statistics*, *supra* note 31 at p. 50, Table 18.

³⁴ U.S. Census Bureau, *Summary Table QT-P17: Ability to Speak English*, available at http://factfinder.census.gov/servlet/QTTable?_bm=y&-geo_id=01000US&-qr_name=DEC_2000_SF3_U_QTP17&-ds_name=DEC_2000_SF3_U&-_lang=en&-_sse=on (Last visited June 26, 2006).

³⁵ *Id.*

³⁶ Theofanos, M. F. and Redish, J. C., 2005. "Helping Low-Vision and Other Users with Web Sites that Meet Their Needs: Is One Site for All Feasible?" 52 SOCIETY FOR TECHNICAL COMMUNICATION at 9 (Feb. 2005) available at <http://www.ingentaconnect.com/content/stc/tc>.

³⁷ Indeed, the Trace Research and Development Center at the University of Wisconsin has suggested that "by extending and enhancing the usability of mainstream voting machines it may be possible to address the needs of as much as 99% of voters." Gregg C. Vanderheiden, *Using Extended and Enhanced Usability to Provide Access to Mainstream Electronic Voting Machines*, 10 INFORMATION TECHNOLOGY AND DISABILITIES (Dec. 2004), available at <http://trace.wisc.edu/docs/2005-EEU-voting/index.htm>.

³⁸ 2002 VSS, *supra* note 17.

³⁹ U.S. Access Board, *Section 508 Homepage: Electronic and Information Technology*, at <http://www.access-board.gov/508.htm> (Last visited June 26, 2006).

⁴⁰ EAC VVSG, *supra* note 5.

⁴¹ Subpart C – Functional Performance Criteria
1194.31 Functional performance criteria.

(a) At least one mode of operation and information retrieval that does not require user vision shall be provided, or support for assistive technology used by people who are blind or visually impaired shall be provided.

(b) At least one mode of operation and information retrieval that does not require visual acuity greater than 20/70 shall be provided in audio and enlarged print output working together or independently, or support for assistive technology used by people who are visually impaired shall be provided.

(c) At least one mode of operation and information retrieval that does not require user hearing shall be provided, or support for assistive technology used by people who are deaf or hard of hearing shall be provided.

(d) Where audio information is important for the use of a product, at least one mode of operation and information retrieval shall be provided in an enhanced auditory fashion, or support for assistive hearing devices shall be provided.

(e) At least one mode of operation and information retrieval that does not require user speech shall be provided, or support for assistive technology used by people with disabilities shall be provided.

(f) At least one mode of operation and information retrieval that does not require fine motor control or simultaneous actions and that is operable with limited reach and strength shall be provided.

⁴² EAC VVSG, *supra* note 5, at § 3.2.2.1.f.

⁴³ Email from Dave Alampi, Avante International Technology, Inc., (Jan. 11, 2006) (on file with the Brennan Center).

⁴⁴ Email from Michelle Shafer, Vice President of Communications and External Affairs, Sequoia Voting Systems, (Jan. 23, 2006) (on file with the Brennan Center).

⁴⁵ Email from Pat Gorman, Vice President of Operations and Deployment, Accupoll Inc., (Jan. 5, 2006) (on file with the Brennan Center). (Note: Accupoll Inc. filed for Chapter 7 bankruptcy on January 30, 2006. To date, no company has bought the rights to their technologies.).

⁴⁶ *Id.*

⁴⁷ Email from Dave Alampi, *supra* note 43.

⁴⁸ Email from Pat Gorman, *supra* note 45.

⁴⁹ The VVSG recommend that the size and weight of the system allow for portability and curbside voting. By the standard set out in the guidelines, the DRE models manufactured by Sequoia, Diebold, Hart and ES&S are all portable for curbside voting.

⁵⁰ Telephone Interview with Phillip Braithewaite, Vice President of Sales and Marketing, Hart Intercivic, (Jan. 18, 2006).

⁵¹ Email from Rob Palmer, Director of Marketing and Communications, Election Systems and Software, (Jan. 16, 2006).

⁵² Email from David Bear, Spokesperson, Diebold Election Systems, (Jan. 16, 2006).

⁵³ EAC VVSG, *supra* note 5, at §§ 3.2.2.1(b)-(d).

⁵⁴ Email from Michelle Shafer, *supra* note 44.

⁵⁵ Email from David Bear, *supra* note 52.

⁵⁶ Telephone Interview with Phillip Braithewaite, *supra* note 50.

⁵⁷ Email from Pat Gorman, *supra* note 45.

⁵⁸ *Id.*

⁵⁹ Email from Dave Alampi, *supra* note 43.

⁶⁰ Email from Michelle Shafer, *supra* note 44.

⁶¹ Email from Rob Palmer, *supra* note 51.

⁶² Email from David Bear, *supra* note 52.

⁶³ Telephone Interview with Phillip Braithewaite, *supra* note 50.

⁶⁴ Email from Pat Gorman, *supra* note 45.

⁶⁵ Email from Dave Alampi, *supra* note 43.

⁶⁶ Email from David Bear, *supra* note 52.

⁶⁷ Email from Michelle Shafer, *supra* note 44.

68 Telephone Interview with Phillip Braithewaite, *supra* note 50.

69 Email from Rob Palmer, *supra* note 51.

70 EAC VVSG, *supra* note 5, at 58.

71 Email from Michelle Shafer, *supra* note 44.

72 Email from David Bear, *supra* note 52.

73 Telephone Interview with Phillip Braithewaite, *supra* note 50.

74 Email from Rob Palmer, *supra* note 51.

75 Email from Dave Alampi, *supra* note 43.

76 Email from Pat Gorman, *supra* note 45.

77 In March of 2003, Manhattan Borough President C. Virginia Fields and the Center for Independence of the Disabled in New York asked 130 disabled voters to use eight different DREs and comment on the machine's accessibility. According to the report, "testers commented that computer generated voices were difficult to understand, while no tester cited difficulty understanding the human voice ballots." Office of the President of the Borough of Manhattan, *Voting Technology for People with Disabilities* at iii (April 3, 2003) available at http://www.eff.org/Activism/E-voting/Benavidez/20040518-benavidez-Amicus-Exh_C.pdf.

78 Email from Michelle Shafer, *supra* note 44.

79 Email from David Bear, *supra* note 52.

80 Email from Pat Gorman, *supra* note 45.

81 Telephone Interview with Phillip Braithewaite, *supra* note 50.

82 Email from Rob Palmer, *supra* note 51.

83 See EAC VVSG, *supra* note 5, at § 3.2.2.2(c) ix.

84 Email from Dave Alampi, *supra* note 43.

85 Email from Michelle Shafer, *supra* note 44.

86 Email from David Bear, *supra* note 52.

87 Email from Gregg Vanderheiden, Feb. 28, 2006 (on file with the Brennan Center).

88 Email from Dave Alampi, *supra* note 43.

89 Email from Michelle Shafer, *supra* note 44.

90 Email from David Bear, *supra* note 52.

91 Email from Pat Gorman, *supra* note 45.

92 Telephone Interview with Phillip Braithewaite, *supra* note 50.

93 Email from Rob Palmer, *supra* note 51.

94 Email from Dave Alampi, *supra* note 43.

95 Email from Michelle Shafer, *supra* note 44.

96 Email from David Bear, *supra* note 52.

97 Email from Pat Gorman, *supra* note 45.

98 Telephone Interview with Phillip Braithewaite, *supra* note 50.

99 Email from Rob Palmer, *supra* note 51.

¹⁰⁰ See EAC VVSG, *supra* note 5, at §§ 3.2.2.2 (b)-(c).

¹⁰¹ According to a 2004 report by VotersUnite, for example, “the Diebold speech quality and response time were so poor that elderly voters and others with hearing problems would have serious difficulties understanding the speech of the systems.” Similarly, in a letter to the registrar of voters of Santa Clara County, members of the Silicon Valley Council of the Blind criticized Sequoia’s DRE voting machines, citing poor sound quality, delayed response time, and awkwardly-positioned Braille. The VotersUnite report also cited complaints that Avante’s synthetic text-to-speech system was difficult for many users to understand. Voters Unite!, *Mythbreakers: Facts About Electronic Elections* at 59 available at <http://www.votersunite.org/MB2.pdf> (Last visited June 26, 2006).

¹⁰² Telephone Interview with Phillip Braithewaite, *supra* note 50.

¹⁰³ Telephone Interview with Frank Wiebe, Chief Operating Officer, Accupoll Inc. (Oct. 19, 2005).

¹⁰⁴ Email from Michelle Shafer, *supra* note 44.

¹⁰⁵ Telephone Interview with Phillip Braithewaite, *supra* note 50.

¹⁰⁶ Telephone Interview with Dave Alampi, Sales and Marketing at Avante (Oct. 21, 2005).

¹⁰⁷ See EAC VVSG, *supra* note 5, at 56.

¹⁰⁸ Email from Pat Gorman, *supra* note 45.

¹⁰⁹ Telephone Interview with Rob Palmer, Director of Marketing and Communications, ES&S Voting System (Oct. 28, 2005).

¹¹⁰ Telephone Interview with David Bear, Spokesperson, Diebold Election Systems, (Oct. 25, 2005).

¹¹¹ Telephone Interview with Phillip Braithewaite, *supra* note 50.

¹¹² Telephone Interview with Alfie Charles, Media Relations, Sequoia Voting Systems (Oct. 18, 2005).

¹¹³ In its default setting, the eSlate requires all voters to use a standard set of tactilely discernible controls to input selections while viewing a visual ballot.

¹¹⁴ Telephone Interview with David Bear, *supra* note 110.

¹¹⁵ Email from Pat Gorman, *supra* note 45.

¹¹⁶ Telephone Interview with Alfie Charles, *supra* note 112.

¹¹⁷ Email from Pat Gorman, *supra* note 45.

¹¹⁸ Email from Dave Alampi, *supra* note 43.

¹¹⁹ Email from David Bear, *supra* note 52.

¹²⁰ Email from Rob Palmer, *supra* note 51.

¹²¹ Email from Michelle Shafer, *supra* note 44.

¹²² Email from Rob Palmer, *supra* note 51; Email from Pat Gorman, *supra* note 45; Email from Dave Alampi, *supra* note 43; Email from David Bear, *supra* note 52; Email from Michelle Shafer, *supra* note 44; Telephone Interview with Phillip Braithewaite, *supra* note 50.

¹²³ According to experts, the case of magnifying lenses highlights the burden certain inflexible assistive devices can place on both election officials and the voter: Lenses are made in different strengths. Officials may need to match lenses to a voter’s vision disability and any current glasses they are wearing. Once given to the voter, she must place the lens at an appropriate distance from her eyes and have the facility and coordination to adjust the lens’ placement as she reads.

¹²⁴ See, for example, Rhode Island's accessible voting options at *Guidelines for Braille and Tactile Ballots*, available at <http://www.sec.state.ri.us/elections/voting/blindordisabledvoters/BrailleTactileBallotGuidelines.html> (Last visited June 20, 2006).

¹²⁵ Email from Dave Alampi, *supra* note 43.

¹²⁶ Telephone Interview with David Bear, *supra* note 110.

¹²⁷ See a photo of the Sequoia scanner at <http://www.sequoiavote.com/photo.php?photo=InsightFrontView.jpg&title=Insight%20Front%20View>.

¹²⁸ Telephone Interview with Rob Palmer, Director of Marketing and Communications at Election Systems and Software (Oct. 28, 2005).

¹²⁹ In Oregon, for example, where Vote-by-Mail systems have been in use since 1998, it is often difficult for voters with visual impairments to vote privately and independently. According to a 2002 speech by Oregon's Secretary of State Bill Bradbury to the Association of the Bar of the City of New York, the counties' election offices send bipartisan teams to the homes of voters with visual impairments to provide assistance with the Vote-by-Mail process. As of 2002, one county offered ballots in Braille and thirty-five counties offered both the Instruction Pamphlet and ballot on audiotape. However, sending in a team to assist these voters deprives them of their ability to vote privately. At the time of the speech, Secretary Bradbury stated that Oregon was looking for ways to solve these privacy issues: "Instead of sending a team to assist a voter, we could send a person and something as small as a Palm Pilot. The voter could put on earphones and record their ballot electronically, rather than having to tell election officials how they want to vote." Secretary Bradbury's speech is available at <http://www.sos.state.or.us/executive/speeches/111802.html>.

¹³⁰ Of course, experts note, not all voters with vision limitations are comfortable, or even able, to use an audio ballot. They may simply be unfamiliar with this kind of technology, or may have difficulty processing instructions from an audio recording.

¹³¹ For a full description of the tactile ballot, see the International Frontier for Election Systems' web site at http://www.electionaccess.org/Bp/Ballot_Templates.htm (Last visited June 26, 2006).

¹³² See Elections and Civics Division of the Office of the Secretary of State of Rhode Island, *Am I Eligible to Vote by Using Braille or Tactile Ballot?*, at <http://www.sec.state.ri.us/elections/faq/braille-or-tactile.html> (last visited June 26, 2006).

¹³³ State of Oregon Elections Division, *Requesting a Replacement Ballot*, at http://www.uhava.vote.org/elect_q_a/ballots/ballot_rep.html (Last visited June 26, 2006).

¹³⁴ Email from Rob Palmer, *supra* note 51.

¹³⁵ See Populex Digital Paper Ballot System Overview at http://www.populex.com/DPB_Overview.htm.

¹³⁶ Email from Rob Palmer, *supra* note 51; Email from Sandy Morganstein, President and Founder, Populex Corporation (Jan. 13, 2006).

¹³⁷ Telephone Interview with Liz Miller, Public Affairs Liason, Populex Corporation (Oct. 24, 2005); Email from Rob Palmer, *supra* note 51.

¹³⁸ Email from Sandy Morganstein, *supra* note 136.

¹³⁹ Email from Rob Palmer, *supra* note 51.

¹⁴⁰ A photo of the Automark unit is available at <http://www.automarkts.com> (Last visited June 20, 2006). Email from Sandy Morganstein, *supra* note 136.

¹⁴¹ Telephone Interview with Rob Palmer, *supra* note 128; Email from Sandy Morganstein, *supra* note 136.

¹⁴² Email from Rob Palmer, *supra* note 51; Email from Sandy Morganstein, *supra* note 136.

¹⁴³ *Id.*

¹⁴⁴ *Id.*

¹⁴⁵ Email from Rob Palmer, *supra* note 51.

¹⁴⁶ Email from Sandy Morganstein, *supra* note 136.

¹⁴⁷ Email from Rob Palmer, *supra* note 51.

¹⁴⁸ Telephone Interview with Richard Vogel, President, Vogue Election Systems (Nov. 1, 2005); Email from Rob Palmer, *supra* note 51; Email from Sandy Morganstein, *supra* note 136.

¹⁴⁹ Telephone Interview with Richard Vogel, *supra* note 148; Email from Rob Palmer, *supra* note 51.

¹⁵⁰ Email from Rob Palmer, *supra* note 51; Email from Sandy Morganstein, *supra* note 136.

¹⁵¹ Telephone Interview with Rob Palmer, *supra* note 128.

¹⁵² Email from Sandy Morganstein, *supra* note 136.

¹⁵³ Email Interview with Richard Vogel, President, Vogue Election Systems (Jan. 11, 2006).

¹⁵⁴ Telephone Interview with Richard Vogel, *supra* note 148; Email from Rob Palmer, *supra* note 51.

¹⁵⁵ Email from Rob Palmer, *supra* note 51.

¹⁵⁶ Telephone Interview with Liz Miller, *supra* note 137.

¹⁵⁷ Telephone Interview with Frank Wiebe, *supra* note 103.

¹⁵⁸ *Id.*

¹⁵⁹ Telephone Interview with Alfie Charles, *supra* note 112.

¹⁶⁰ From product demo, *available at* <http://www.accupoll.com/Presentation/10/>.

¹⁶¹ Telephone Interview with Frank Wiebe, *supra* note 103.

¹⁶² Accupoll maintains that its barcode scanner renders a VVPT accessible to blind voters. In Accupoll systems, a VVPT's text is derived from the barcode printed on it, not from selections stored in the memory card inside a DRE. Thus, according to Accupoll representatives, all voters are treated equally because sighted voters read the barcode's contents and voters with visual limitations hear it. Telephone Interview with Frank Wiebe, *supra* note 103.

¹⁶³ Telephone Interview with Gregg C. Vanderheiden, Director, Trace Center, University of Wisconsin-Madison (Nov. 9, 2005).

¹⁶⁴ *Id.*

¹⁶⁵ Telephone Interview with Gail Hart, Vice President of Communications and External Affairs, IVS LLC (Nov. 3, 2005). *See also* the "Vote by Phone" section on the IVS website *available at* <http://www.ivsllc.com>.

¹⁶⁶ For a description of New Hampshire's vote-by-phone system, *see* New Hampshire Public Radio, *State Tests New Accessible Voting Machines* (March 21, 2006) *at* <http://www.nhpr.org/node/10439>. For a description of Vermont's system *see* Burlington Free Press (Aug. 11, 2005) *at* <http://www.burlingtonfreepress.com/apps/pbcs.dll/article?AID=/20050811/NEWS01/508110314/1009&theme>.

167 In the mid-1990s, there were over 4 million TTY users, 3 million of whom had some sort of hearing impairment and 1 million of whom had some sort of speech impediment. However, this is only 13% of the 30.8 million adults who reported having trouble hearing. Michigan State University, *What is a TTY*, at <http://www.captions.com/tty.html> (Last visited June 26, 2006).

168 Email from Gail Hart, Vice President of Communications and External Affairs, IVS LLC (Jan. 18, 2006).

169 See IVS' website at <http://www.ivsllc.com> (Last visited June 26, 2006).

170 Email from Gail Hart, *supra* note 168.

171 Telephone Interview with Gail Hart, *supra* note 165.

172 See the "Vote by Phone" section of IVS' website at <http://www.ivsllc.com>.

173 Email from Gail Hart, *supra* note 168.

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