The Information Technology and Innovation Foundation

Accessible Voting Technology Initiative

Working Paper Series

Working Paper #7

An Evaluation of Voting System Concepts for Los Angeles County VSAP Initiative: Accessibility Issues and Recommendations

Carrie Bell, Keith Kline and Brad Fain

Georgia Tech Research Institute

December 2013

The Information Technology and Innovation Foundation
1101 K Street NW, Suite 610
Washington, DC 20005
(202) 449-1351

NOTE: The Voting Systems Assessment Project (VSAP) initiative was launched by the Los Angeles Registrar-Recorder/County Clerk to determine the current and future needs of voters, to be addressed through the modernization of the County's voting system. This report is part of the ongoing design work of the VSAP, contributing to the refinement process.

This research was supported by the U.S. Election Assistance Commission (EAC) under grant number EAC110149B. Any opinions, findings, conclusions or recommendations expressed in this report are those of the authors and do not necessarily represent the views of EAC or ITIF.

Table of Contents

Executive Summary 3
Introduction 8
Accessibility Guidelines for Voting Systems 11
Accessibility Issues and Potential Solutions Associated with Voting System Hardware 14
Issues associated with reach and visibility 14
Issues associated with labeling 19
Issues associated with displays 23
Issues associated with touchscreen interfaces 32
Issues associated with buttons on panels and remote controls 37
Issues associated with card readers and ballot slots 52
Issues associated with ballot verification and output areas 60
Issues associated with audio output and headphone jacks 65
Issues associated with speech input 74
Issues associated with indicator lights 79
Issues associated with writing space and temporary storage areas 85
Accessibility Issues and Potential Solutions Associated with Voting System Software 87
Issues associated with displays 87
Issues associated with the system's response to user input 92
Issues associated with audio output 97
Major Findings and Recommendations 104
Universal Design: A Single System 104
Accessibility of the Tactile Control 104
Physical Accessibility of System Components 106
Ballot Verification 107
Next Steps in Design and Evaluation 108
References 109
APPENDIX A: Common assistive technologies (AT) used with voting systems 110
APPENDIX B: Section 508 Guidelines 115
APPENDIX C: Information and Communication Technology Standards and Guidelines 118
APPENDIX D: Help America Vote Act Requirements 125
APPENDIX E: Voting System Standards (VSS) and Voluntary Voting System Guidelines (VVSG) 126
APPENDIX F: LA County Voting System Concepts 131
APPENDIX G: Table of Figures 133

Executive Summary

GTRI has been working in coordination with Los Angeles County to understand the wide range of voter needs in the county and to ensure that those needs are addressed in the modernization of voting systems. GTRI was tasked with evaluating the accessibility of three new voting system concepts that were developed by IDEO, a human-centered design firm, for the LA County Voting Systems Assessment Project (VSAP) Initiative. The purposes of this document are to (1) describe the accessibility issues associated with each concept, which may partially determine which concept should be pursued for further development, and (2) describe accessibility issues that should be considered during future, detailed design activities.

We evaluated three IDEO voting system concepts and identified a number of design issues as they pertain to accessibility. We identify and describe high level design issues in more detail throughout the report. We focus on the following themes: 1) universal design; 2) accessibility of tactile control; 3) physical accessibility of system components; and 4) ballot verification. One of the most challenging and important issues we found across the three concepts relates to universal design. Many of the overarching issues across concepts pertain to limited reach and visibility, as well as adjustability of the system. Each concept is briefly described in this summary, highlighting major challenges and possible design solutions. See Table 1 for more details about In some cases, the drawings are not very specific, as is the nature of 'concepts', but in some cases, it is difficult to determine the intentions of the designer without further clarification. For instance, it was difficult to ascertain whether the ballot slot was an input slot, printout slot, or both. In these cases, we will note where we make assumptions or need clarification.

Concept 1:

- Posture: Seated vs. standing users. The design accommodates seated users, but would be difficult for a standing user to operate. *Is leg length adjustable? As shown, in its fully extended position, what furniture is needed to support it for a standing user?*
- Tilt: It is not clear whether a tilt feature is available in this design. Lack of adjustability in the angle/ tilt of the display may produce glare, reducing touchscreen visibility. Due to the uncontrolled environment of the polling place, this may be an issue.
- Position of ballot printout slot: Standing users may have difficulty finding the ballot printout area since it may not be visible or within reach. Moreover, a seated user's knees may obstruct the ballot insertion/printout slot located directly beneath the touchscreen.
- May require handling of ballot: There is not enough detail to clearly state whether this design is 'hands-free'. If the ballot only prints out when the voter makes a mistake and wants to discard that ballot, then that would not be an issue. However, if the ballot must be pulled from the slot and cast in another location, it would not be considered hands-free.
- *How will a user who is blind or low vision verify their ballot?*

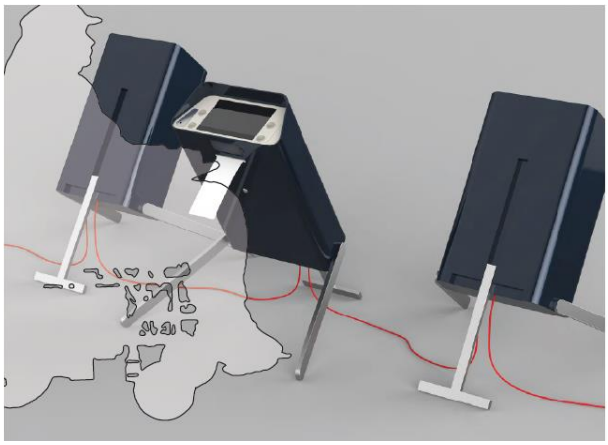


Figure 1. IDEO Concept 1

Concept 2:

- Posture: This design appears to be tailored toward standing users, given its display height and angle. Without adjustment, seated users would have difficulty viewing the display and reaching the ballot printout slot. Additionally, the legs look very unsteady and may not be suitable for wheelchair users due to space constraints.
- Adjustability: It seems feasible that the legs could become adjustable, making this a fairly easy modification for universality of physical height.
- Tactile control: Errors are more likely to occur if the tactile control is complex and button shapes/sizes are not easily discernible. We recommend a tactile control with fewer buttons, whose unique colors and shapes would provide essential, redundant indicators of their purpose (e.g., arrow-shaped buttons).
- Requires handling of the ballot: This design requires the voter to insert the ballot, and remove it, and cast it. This is not ideal for users who have upper mobility impairments.
- *How will a user who is blind or low vision verify their ballot?*

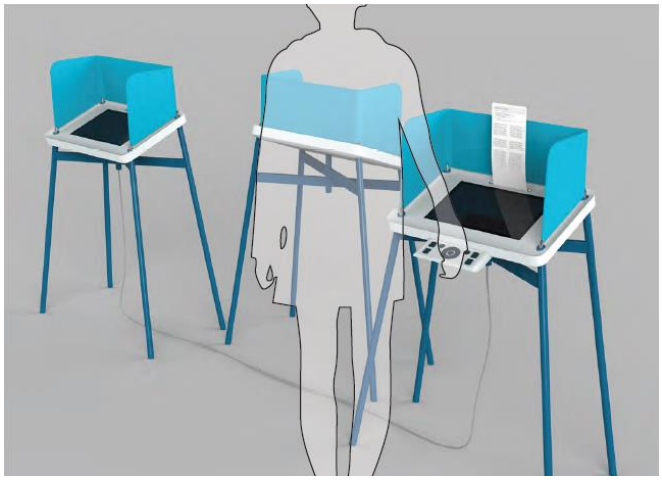


Figure 2. IDEO Concept 2

Concept 3:

- Posture: This design primarily accommodates seated users. This design cannot be set on a table, so *is it possible to make an extension for standing users?*
    - The shield may prohibit a standing user from viewing the ballot on the large vertical screen.
    - Ample knee clearance may be an issue for seated users as well.
- Tilt: The touch screen may have an adjustable tilt, but that is not clear based on the illustrations provided, and the upper vertical display cannot be tilted to accommodate standing users.
- Position of ballot printout slot: Seated users would have difficulty viewing and accessing the ballot input/output slot on the top of the machine.
    - *If seated users can reach the ballot slot, how difficult is it to pull out the ballot from the ballot slot on top of the machine? What keeps the ballot from going over the back of the machine as it finishes printing?*
- Tactile control is not shown: *Is there a tactile control?*
- Does not require handling of the ballot: This is the only concept that is clearly hands-free. Voters only have to handle the ballot if they made a mistake or want to discard it.
- Controls on ballot display screen: *What is the purpose of the raised portion on the left side of the ballot display screen*? *What are the functions of the red and green buttons shown to the right of the ballot display screen?* These elements are not provided in the concept description.
- *How will a user who is blind or low vision verify their ballot?*

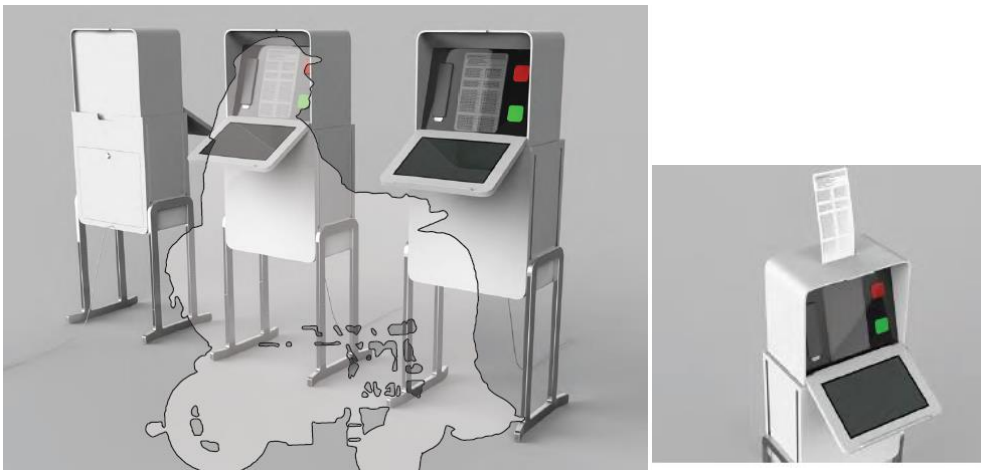


Figure 3. IDEO Concept 3

Common to All Concepts:

In order to meet universal design and overall accessibility requirements, the following four characteristics must be further scoped out: height adjustability, screen adjustability, design of the tactile controls, and ballot verification. Height and screen adjustability are essential, particularly if only one system is going to be chosen to accommodate both standing and seated users. If the legs cannot be adjusted, perhaps a modification that allows the machine to stand

alone or sit on a table or stand. This does not solve the tilt issue, however. Further modifications may be necessary, depending on the chosen design path.

When designing the tactile control, consider shape, color labels, and location of the controls. They are essential for minimizing complexity of the tactile control. The position of the control in Concept 2 is good. However, the control should be removable, such that a voter can place it in their lap. Raised buttons are important for users who are blind or have low vision, as this assists them with locating the buttons. Consider adding suitable shapes, such as arrows, to better define the action of each button. Numerous buttons add complexity, so breaking up functional elements of the tactile control panel would make it easier to understand and use. Perhaps separate the panel into two sections, one for adjusting settings such as volume control, speed, cadence, etc., and another section for navigation (e.g., Back, Next, Enter).

Headset jacks are not shown in any of the concepts. We recommend including the headset jack on the tactile control. This allows the tethered remote to keep from tangling with the headset wire and keeps the seated user from having to extend their reach to access a fixed headset jack on the voting machine.

All of the concepts provided by IDEO offer the voter paper ballot verification. However, this printout is not accessible to voters with vision impairments. If LA County chooses to implement a design that uses a paper ballot, ballot verification might be performed on the electronic ballot marking system where ballot marking AND verification take place at that same location, where affordances for accessibility can be provided. Concept 3, in which the printed ballot is displayed under glass, may be most amenable to this option. However, note that a single system for ballot marking and verification is more susceptible to tampering and fraud than two, independent systems. Guidelines in VVSG 1.1, Chapter 7.8 discusses the importance of using independent verification, stating that *"The verification processes for the two cast vote records must be independent of each other, and at least one of the records must be verified directly by the voter."*

As the VSAP initiative moves toward a design solution, the accessibility issues and proposed solutions contained in this document should be considered during the concept refinement phase of this project. Each of the concepts has positive design features, making it difficult to choose one over the others. The design team is most likely to achieve a single, universally accessible voting system by adopting the goodness from each of the concepts and enabling height and tilt adjustments. Perhaps there is a way to incorporate the goodness of each design into one new concept--a hybrid of the positive design qualities of each. Also, a separate system for ballot verification may be required to provide accessibility for voters with vision impairments. Additional modifications should be considered, based on the issues and potential solutions laid out in this report.

Table 1. Mapping of accessibility issues to the voting system concepts
Red boxes indicate that extensive design modifications would be necessary to address the accessibility issue. Yellow boxes indicate that the accessibility issue could be addressed by detailed design considerations during concept refinement. Green indicates no (or minimal) issue.

Accessibility Issue	Concept			Comments
	1	2	3	
Components may be difficult to reach.	X	✓	X	Concepts 1 and 3 may be too low for standing participants, and their heights do not appear to be adjustable. Concept 3: seated users may not be able to reach the ballot insertion/printout slot. Poll worker assistance may be required.
Components may be difficult to see.	?	?	?	Display angle cannot be adjusted to mitigate glare or accommodate different user heights. This may be more problematic for seated users who cannot easily adjust their viewing angle. Although Concept 3 appears to feature an adjustable electronic display, the printed ballot display is not adjustable. Concept 1: the ballot insertion/printout slot may not be visible to standing users.
Glare and parallax may cause difficulty for seated users.	✓	?	✓	The display is not perpendicular to a seated user's line of sight. The display cannot be tilted to mitigate glare or parallax.
LCD displays are visible from a limited range of viewing angles.	?	?	✓	LCDs are best viewed with a line of sight that is perpendicular to the display. Displays can be less visible or invisible from more extreme angles. The displays of Concepts 1 and 2 cannot be tilted to accommodate different viewing angles.
Remote controls may require two-handed operation.	?	✓	?	The tactile control should be mounted (or mountable) on the machine to enable one-handed operation. They should also be detachable for use in the lap. (Assuming Concept 2 is detachable.)
Buttons that are all shaped the same or that do not have shapes corresponding to their functions are more difficult for the blind to Identify and for the cognitively impaired to understand.	?	?	?	The tactile control (shown in Concept 2) features several buttons of the same shape.
The printed ballot, which may be used for voter verification, is not accessible to users with vision impairments.	X	X	?	Speech output should be provided for the ballot verification task. Only Concept 3 includes a mechanism for ballot verification, but it is not clear whether the mechanism would be accessible to voters with vision impairments. Verification should be conducted on another machine (different than the voting machine) to reduce susceptibility to tampering (VVGS 7.8).
The printed ballot is not accessible for people with upper mobility impairments that cannot insert/retrieve ballot from machine.	X	X	✓	The system should not require the voter to physically handle the ballot. Only Concept 3 provides a completely hands-free ballot (unless voter wants to discard it, then it would need to be removed from slot).

Introduction

Overview and Document Structure

Section 1 begins with the introduction of voting system accessibility and why it is important. Section 2 contains a description of accessibility guidelines and standards across a variety of documents (e.g., ADA, HAVA, VVSG 1.1., etc.). Relevant guidelines and standards are presented in appendices. Sections 3 and 4 describe accessibility issues associated with voting machine hardware and software, respectively. The description of each issue is accompanied by a list of LA County voting system design concepts to which the issue applies, as well as an explanation of why it is applicable. GTRI evaluated the voting system design concepts to address features and functionality that may or may not meet accessibility requirements for a voting system. In addition, recommendations are provided that would enable voters with disabilities to vote independently and privately. Accessibility issues within each subsection are presented in the order of importance and relevance to the design concepts. The final two sections of the report present prioritized, major findings and recommendations for next steps in the design and evaluation process.

This document contains descriptions of accessibility issues and potential solutions for voting systems. Some of these issues should be considered when determining which voting system concept should be pursued. Table 1 shows a summary of the accessibility issues and the corresponding IDEO voting concepts. These issues are discussed in more detail in the section entitled, "Accessibility issues and potential solutions associated with voting system hardware." There are many other accessibility issues described in the aforementioned section, as well as a section on voting system *software*, which should be considered during detailed design, but they do not provide a basis for discriminating among the existing concepts.

Voting Accessibility

In the United States, the ability to cast a vote in a public polling location is taken for granted by many. However, despite guidance from the Americans with Disabilities Act (ADA) and the ADA Amendments Act Accessibility Guidelines (ADAAG), many people with disabilities find accessibility at their polling places to be deficient. Barriers to voting can come from a number of interrelated facets including social, political, physical, and economic. The physical inaccessibility of polling places, in addition to the stigma associated with cognitive impairments, is enough to dissuade some voters from voting at the polling locations. In a recent study, when people with disabilities were polled regarding their voting experiences, three categories of environmental factors were identified 1) *social environment of polling places*; 2) *access to pre-election information*; and 3) *the physical environment of polling places*, including voting technologies and ballots (Harris et al, 2013). This report focuses on the issues that make up the third set of environmental factors—the physical environment and the design of voting systems for people with disabilities.

The ADA defines an individual with a disability as a person who: (1) has a physical or mental impairment that substantially limits one or more major life activities; OR (2) has a record of such impairment; OR (3) is regarded as having such impairment. It is not possible to list all diseases or conditions covered under the definition. However, common disabilities include those associated with vision, hearing, mobility, and cognition. Beyond the commonly listed terms are

hidden disabilities affecting a large portion of the population, including dyslexia, brain injuries, arthritis, and temporary disabilities due to an injury or medical treatment, etc. When designing new voting systems, it is important to keep in mind that system accessibility for people with disabilities improves usability for everyone, including those without disabilities and those with functional limitations that are not considered 'disabilities'.

An accessible voting machine is a type of interactive device that a voter with a disability (visual/hearing/mobility impairments, cognitive and/or functional limitations) can use to produce a marked ballot independently. Accessible voting machines can reduce interaction times and enhance privacy. Electronic voting systems often use complex user interfaces, have varying functionality, and may have a stigma associated with them (distrust, difficult to use, etc.). Physical dimensions and characteristics of an accessible voting system span a great range across the U.S.

Voting systems have potential accessibility issues in the following areas:

- Physical access
- Reach and visibility
- Labeling
- Displays
- Touchscreen interfaces
- Physical buttons
- Pointing devices/stylus
- Feedback
- Audio output
- Headphone jacks
- Ballot scanners
- Printer output and ballot verification
- Ballot slot
- Card readers for voter registration cards
- Writing areas and storage areas for personal belongings

These common accessibility issues will be addressed in subsequent sections of this document. Their applicability to the Los Angeles County voting system concepts will be described.

Voter Needs in LA County

GTRI has been working in coordination with Los Angeles County to identify hidden disabilities and to understand how the wide range of voter needs in this large and diverse county can be addressed. LA County has expressed a concern that hidden disabilities may be underrepresented in mainstream voting platform accommodations. In order to address these and other issues within the county, LA County formed the Voting Systems Assessment Project (VSAP) initiative.

VSAP seeks to address the diverse needs of Los Angeles County voters by modernizing the county's voting system. Working with the public, as well as a technical advisory committee, LA County has teamed with IDEO to conceptualize future voting systems, taking into account voting

system requirements, security, privacy, and accessibility, among other logistical considerations of the system, such as maintenance and storage.

This document provides an in-depth review of accessibility requirements for voting systems as well as an evaluation of the three design concepts developed by IDEO for the LA County VSAP initiative. The primary purpose of the task is to provide actionable recommendations to LA County concerning salient voting platform design issues for people with disabilities and to identify the utility of various design approaches and concepts that address accessibility in design. The information garnered from this evaluation, as well as subsequent activities identified in the conclusion of this report, will be used to ascertain the requirements necessary for generating an integrated voting system that addresses accessibility.

GTRI has developed a series of monographs that address accessibility in design. Many of the accessibility issues described in this report were extracted from a working draft of GTRI's Voting Accessibility Monograph and tailored to meet the needs of this project.

Accessibility Guidelines for Voting Systems

Recommendations in this report are based on guidelines and standards that are applicable to a variety of systems that are similar to voting machines, such as ATM machines and kiosks. The guidelines and standards are also applicable to the administration of federal elections, and they are regarded as a list of best practices that should be followed in non-federal elections as well. Each set of guidelines/standards can be categorized as compulsory or voluntary. The sources of the guidelines and standards are briefly described below. Lists of relevant guidelines and standards are presented in the Appendix.

Americans with Disabilities Act Guidelines (ADA)

The ADA guidelines are published in conjunction with the Architectural Barriers Act (ABA) guidelines as the ADA and ABA Accessibility Guidelines for Buildings and Facilities (see http://www.access-board.gov/guidelines-and-standards/buildings-and-sites/about-the-ada-standards/background/ada-aba-accessibility-guidelines-2004). The ADA guidelines apply to facilities in the private sector, and to state and local government facilities; the ABA guidelines apply to federally funded facilities. In addition to guidance for building accessibility, the ADA-ABA guidelines contain guidance that applies to automatic teller machines and fare machines and specifically excludes other types of interactive transaction machines from the scope of the guidance. However, the ADA-ABA guidelines represent best practices for accessibility, and are used in this document as recommendations for designing accessible voting machines. The complete ADA-ABA accessibility guidelines can be found at the link above; the sections of the guidelines are the most relevant to the design of voting machines are shown in Table 2.

Table 2. ADA-ABA Accessibility guidelines relevant to voting machine accessibility

Section	Title
306	Knee and Toe Clearance
308	Reach Ranges
309	Operable Parts
703.3	Braille
707	Automatic Teller Machines and Fare Machines
904.3.3	Check Writing Surfaces

Section 508 Guidelines

Originally added as an amendment to the Rehabilitation Act of 1986, Section 508 requires that all Federal information that is accessible electronically must be accessible for those with disabilities. Information must be accessible in a variety of ways, which are specific to each disability. Section 508 applies specifically to federal departments and agencies, although various state and local governments have also adopted legislation based on Section 508. Section 508 does not apply to procurement in the private sector. However, Section 508 does apply to private organizations that provide services for local, state, or federal governments. Furthermore, the Section 508 technical standards represent best practices for accessibility and are used in this document as recommendations for designing accessible voting machines. An Appendix lists the guidelines that are applicable to voting machines.

Information and Communication Technology (ICT) Standards and Guidelines

Section 508 is a federal law that requires agencies to provide individuals with disabilities access to electronic and information technology and data comparable to those who do not have disabilities, unless an undue burden would be imposed on the agency. Proposed updates to Section 508 and Section 255 (Disabled Persons' Telecommunications Access) were released for public comment on December 8, 2011; under the title "Information and Communication Technology Standards and Guidelines" (see http://www.access-board.gov/guidelines-and-standards/communications-and-it/about-the-ict-refresh/draft-rule-2011.) The guidelines address accessibility issues that have emerged from recent technological developments. They include guidance for the design of electronic documents which may be relevant to ballot design.

The ITC standards and guidelines provide guidance for systems with closed and open functionality. Systems with closed functionality are "locked down," preventing users from altering settings (e.g., font size); they also do not provide peripheral hardware connections. Voting machines should have open functionality, to the extent that users should be able to modify settings. However, voting machines should not require voters to attach assistive technology (see VSS 2.2.7.2(a), which states, "[The voting machine shall] not require the voter to bring their own assistive technology to a polling place"). Relevant ICT guidelines are presented in an Appendix.

Help America Vote Act of 2002 (HAVA)

HAVA was passed to modernize the administration of federal elections. HAVA provides federal funding for programs related to provisional voting, voting information, statewide voter registration lists and identification requirements for first time registrants, administrative complaint procedures, and updated/upgraded voting equipment. HAVA was critical in the development of voting system guidelines for people with disabilities. This act led to required improvements to the quality, reliability, accuracy, accessibility, affordability, and security of voting equipment, election systems, and technology.

Section 301 of HAVA (42 USC § 15481) sets forth requirements for voting systems used in federal elections. The requirements were amended by H.R.2239 (Voter Confidence and Increased Accessibility Act of 2003). The amended requirements are shown in an Appendix.

Voting System Standards and Voluntary Voting System Guidelines

A list of accessibility standards for voting machines and ballots is provided in Volume 1 of the Voting System Standards (VSS, Federal Elections Commission, 2002). The purpose of the standards is to help designers and evaluators ensure that voting systems are easy to use, accessible, and secure. The standards are based in large part on Section 508 standards, with adaptations to the voting context.

The standards set forth in the VSS (2002) were later updated and supplemented with the Voluntary Voting System Guidelines (VVSG). These updated guidelines (Version 1.1) reflect changes in technology and election practices. Both the VSS and the VVSG are voluntary, and are therefore listed separately from Section 508 standards, which are mandatory. Relevant VVSG guidelines are presented in an Appendix.

Human Factors Design Standard (HFDS)

Originally written as a set of guidelines for Federal Aviation Administration (FAA) systems, the Human Factors Design standard has since been expanded and modified to include technical operations systems as well and is widely used by human factors practitioners in a broad range of fields. In 2007 the FAA added draft updates related to interface design, including displays and non-keyboard input devices (e.g. mouse, joystick, touchscreen). The resulting set of standards can be tailored to meet the needs of the system or program at hand. The HFDS can be found at http://hf.tc.faa.gov/hfds/.

HFDS is a comprehensive set of human factors practices and principles that provides succinct and tactical, evidence-based information for designers. HFDS is organized such that users can easily locate specific design criteria. For example, chapters are arranged by overarching topics; general design requirements; automation; controls and visual indicators; computer human interfaces, etc.

ISO/IEC 71 Guide 71 (2001)

This set of guidelines was written to address the needs of both older people and people with disabilities. The main focus is to support the need for more accessible products and services. ISO/IEC 71 guidelines are useful for manufacturers, designers, service providers and educators who are designing products to meet standards for accessibility and usability. The guide applies to products, services and environments encountered in all aspects of daily life and intended for the consumer market as well as the workplace. As it provides general guidance only, consideration should be given to additional guidelines for more specific design detail.

Accessibility Issues and Potential Solutions Associated with Voting System Hardware

This section addresses accessibility issues that are associated with system hardware, including configuration, orientation, and physical features. A subsequent section of this report addresses system software.

Each accessibility issue below is designated as directly applicable to Los Angeles County voting system concepts (10/01/2013, see Appendix) or potentially applicable to future design iterations and refinements. Issues are segregated into subsections, each of which addresses a system component or function. Within each subsection, the issues are ordered according to their relevance to LA County voting system concepts.

Please note that the following sections depict illustrations that may or may not directly correlate to the concepts IDEO has provided. In many cases, the IDEO concept drawings did not provide the necessary detail to impart the issue, and thus, a more generic image is used to illustrate design solutions for accessibility.

Issues associated with reach and visibility

Voting machines have several components, such as displays, keypads, and smart card slots, which users must be able to see and/or physically interact with. The issues below are relevant to almost all types of voting machines, including the three LA County design concepts.

Some components of voting machines may be difficult to reach.

This issue applies to Concepts 1, 2, and 3.

Detailed Description: The display heights of Concepts 1 and 3 may be unsuitable for standing users. Concepts 2 and 3 have ballot insertion/printout slots that might be out of reach for seated users, and most seated users would not be able to see the slot on Concept 3.

Users of wheelchairs or other personal mobility devices may have limited reach capabilities. Some users have power wheelchairs that allow them to raise and lower their seats to increase their reach capabilities; however, many users have manual wheelchairs that do not allow for these sorts of adjustments. Some wheelchair users are unable to shift their upper bodies, limiting their access to only controls within arm's length. Thus, it is important that the interactive components of a voting machine are viewable *and* operable from a seated position, without requiring excessive leaning or reaching.

Populations Impacted: All users; especially those with upper or lower mobility impairments.

Potential Solutions: *Follow the ergonomic standards (including, but not necessarily limited to those described below) to determine where to position the controls to ensure easy access by all users.*

- The position of any operable control should be determined with respect to a vertical plane that is 48 inches in length, centered on the operable control, and at the maximum protrusion of the product within the 48 inch length (see Figure 4).

- Where any operable control is 10 inches or less behind the reference plane, the height shall be 48 inches maximum and 15 inches minimum above the floor.

- Where any operable control is more than 10 inches and not more than 24 inches behind the reference plane, the height shall be 46 inches maximum and 15 inches minimum above the floor.

- Operable controls shall not be more than 24 inches behind the reference plane.

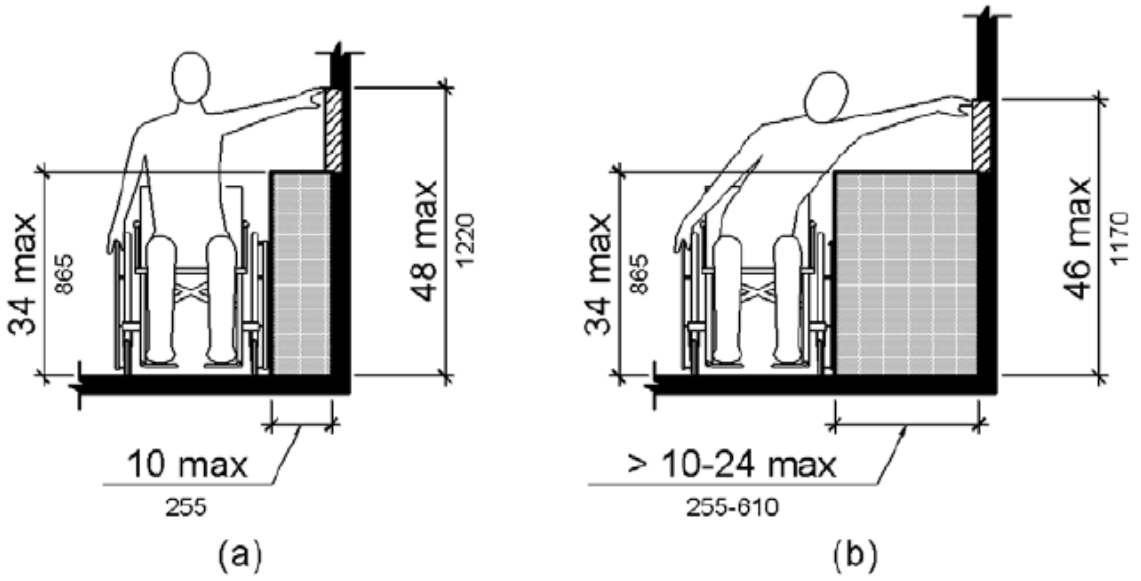


Figure 4. Obstructed high-side reach.

Allow adjustment of component positions. Where possible, allow users to adjust the position of components to meet their specific needs. Components should be adjustable between two or more discrete positions, or freely within a range of positions.

Provide area for knee clearance beneath the machine to allow a forward approach by wheelchair users. Sufficient knee clearance will allow a forward-approaching voter in a wheelchair to move closer to the machine. The knee clearance area beneath the machine should extend from 9 inches to 27 inches above the floor, with a minimum width of 30 inches. Regarding the depth of the clearance, the VVSG states the following:

- The minimum knee clearance depth at 9 inches (230 mm) above the finish floor or ground shall be either 11 inches (280 mm) or 6 inches less than the toe clearance, whichever is greater;
- Between 9 inches (230 mm) and 27 inches (685 mm) above the

finish floor or ground, the knee clearance depth SHALL be permitted to reduce at a rate of 1 inch (25 mm) in depth for each 6 inches (150 mm) in height. (It follows that the minimum knee clearance at 27 inches above the finish floor or ground shall be 3 inches less than the minimum knee clearance at 9 inches above the floor.).

Provide toe clearance area beneath the machine to allow a forward approach by wheelchair users. The toe clearance area extends 9 inches above the floor, with a depth of at least 17 inches and a width of 30 inches.

Applicable Guidelines:

ADA-ABA – 308.2.1, 308.2.2, 308.3.1, 308.3.2
Section 508 – 1194.25(j), 1194.31(f)
Section 255 – 1194.31(f)(2)(c)
ISO/IEC 71 – 8.3.1
ICT – 407.13, 407.14, 407.15, 302.8
VVS – 2.2.7.1 (b)
VVSG – 3.3.5.1-B.3, 3.3.5.1-B.4

Some components of voting machines may be difficult to see from a seated position.

This issue applies to Concepts 1, 2, and 3.

Detailed Description: Users who are seated in a wheelchair may be able to reach a component, but may be unable to adequately see it. For example, a user might be able to reach an input slot for a pre-marked ballot, but may be unable to see it from a seated position.

Populations Impacted: Users with lower mobility impairments.

Potential Solutions: *Allow tilting of the component.* The component should be adjustable between two or more discrete positions, or move freely within a range of positions.

Place components so that all users can see them. When designing a voting machine, consider the needs of both standing and seated users and attempt to place components in locations and orientations that are visible for all users. For example, a display placed with the screen perpendicular to the ground may be visible for both standing and seated users, although the height of the display and the viewing envelope of the display must also be considered.

Applicable Guidelines:

ADA-ABA – 308.2.1, 308.2.2, 308.3.1, 308.3.2, 707.7.1
Section 508 – 1194.25(j)
HFDS – 5.11.1, 6.4.1.27
ISO/IEC 71 – 8.3.1
VVSG – 3.3.5-C

Parallax may be a problem for seated users.

This might apply to Concepts 1, 2, and 3.

Detailed Description: Certain display and control configurations (for example, an inset display screen surrounded by soft keys) are susceptible to parallax errors. On-screen key labels are designed to align with the location of bezel keys when viewed from a certain angle (e.g., when standing in front of the display). When viewed from a different angle (e.g., when seated in front of the display), the parallax error causes misalignment between the labels and the keys, making it difficult to tell which label goes with each key.

Populations Impacted: Users with lower mobility impairments (seated users).

Potential Solutions: *Place the display and the soft keys on the same plane.* If the display and the soft keys are coplanar, parallax errors are eliminated.

Provide an adjustable angle display. If the vertical tilt angle of the panel containing the display and the soft keys is adjustable, users can reposition the screen to eliminate parallax errors.

Provide guide lines from soft keys to the edge of the display to provide additional visual association cues. Guide lines can visually "connect" soft keys to their on-screen labels, allowing users to follow the guide lines to determine the appropriate key to press.

Applicable Guidelines:

ADA-ABA – 707.7.1
HFDS – 5.1.2.6, 9.4.2.6

Issues associated with labeling

Labels include text and graphics that identify components of a voting machine and any instructional text located on the machine. The issues in this section are general, and are applicable to all three LA County design concepts. The issues did not appear to be clearly violated by any of the design concepts. They are presented here for guidance during refinement of the detailed design.

Icons used in place of text labels may be ambiguous.

This issue applies to the remote controls of Concept 1, 2, and 3, and might also apply to other components of the interfaces.

Detailed Description: Graphical icons may be used to identify controls in place of text labels for various reasons: to produce a device that is language-independent, to reduce the amount of space required to label controls and components, or to achieve a desired aesthetic effect in the design of the device. However, understanding icons, especially if the icons are very abstract and/or are unfamiliar to the user, can be difficult, especially for users with cognitive impairments.

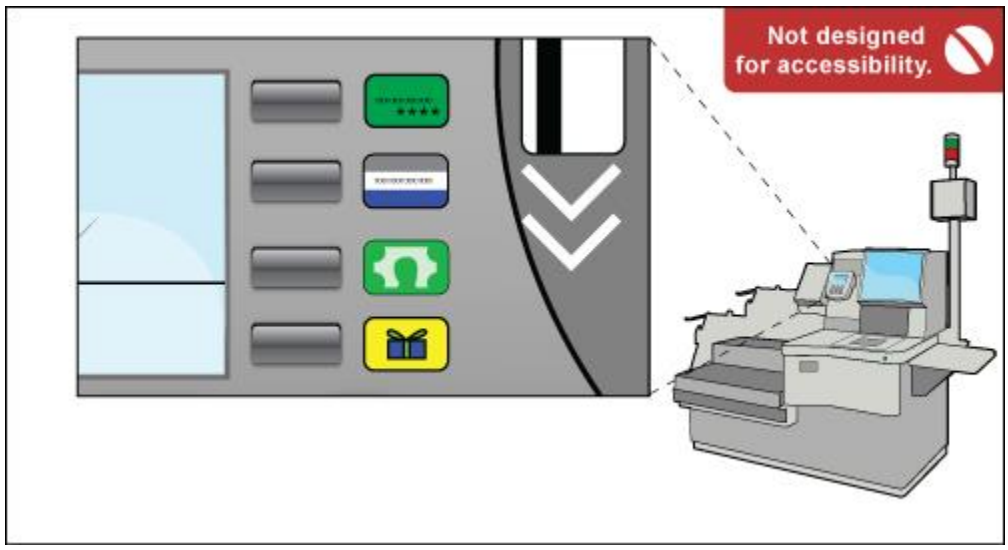


Figure 5: Buttons are labeled only with ambiguous icons.

Populations Impacted: All users with vision, especially those with cognitive impairments.

Potential Solutions: *Limit the use of icons.* Consider the use of icons carefully, and avoid using icons instead of text labels for the sake of aesthetics or other considerations to the detriment of usability. Consider supplementing icons with text labels for clarity, but avoid crowding.

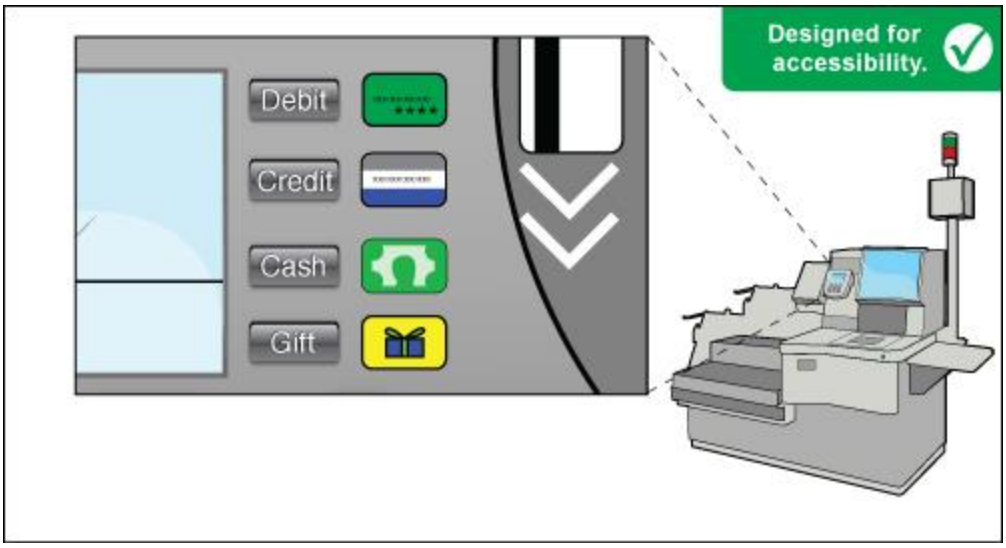


Figure 6: Buttons have text labels supplemented with icons.

Use standard or familiar icons. Icons representing certain functions or controls (such as stop, play, headphone output, volume, etc.) are widely used and are likely to be familiar to most users. Avoid deviating too far from the common appearance of those types of icons. Other icons (such as a depiction of a card next to a smart card slot) may be clear in the context in which they appear. The use of new icons to represent abstract concepts should be avoided.

When new icons must be developed, test the icons with members of the user population to ensure that the meaning of the icons is clear. User testing may provide insight into how to design clearer, more meaningful icons. Care should be taken to sample a representative portion of the targeted user population, including users with disabilities.

Applicable Guidelines:

HFDS – 8.13.3.1, 8.13.3.9, 8.13.3.10

Color coding should not be used as the sole means of conveying information.

This issue applies to Concept 3.

Detailed Description: Indicator lights or buttons that use only color as the sole method of conveying information may be difficult for color blind users and some users with low vision to discern. For example, if a two-state light is used, with green representing the ready state and red representing a fault state, a user with red/green colorblindness may not be able to determine if the device is ready or is in a fault state.

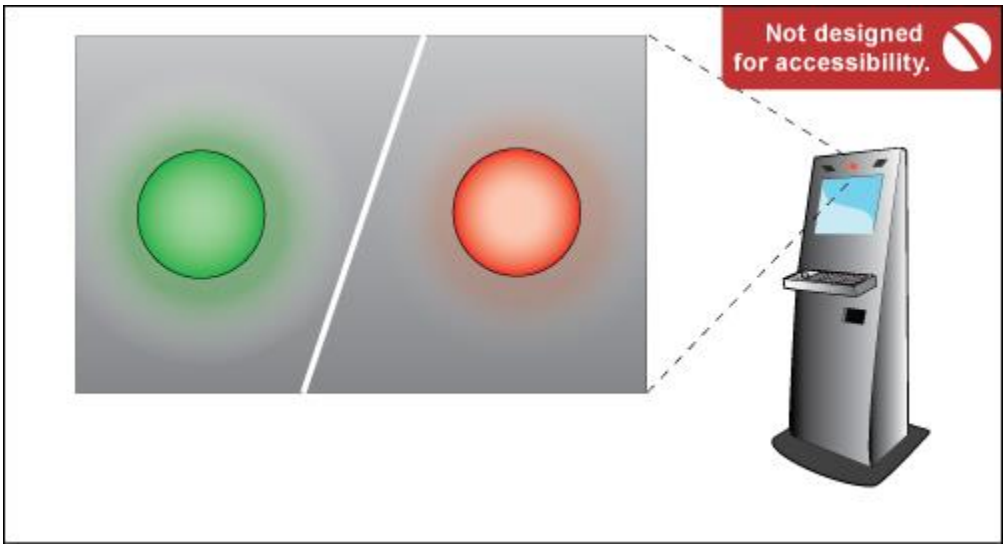


Figure 7: A single light illuminates red or green to indicate status.

Populations Impacted: Users who are color blind; users with low vision.

Potential Solutions: *Do not use color pairs that are easily confused by color blind users to convey information.* Red/green color blindness is most common; however, blue/yellow color blindness occurs occasionally. Total color blindness, where users are not able to perceive color and only see shades of grey, is extremely rare. Using color combinations other than red/green and blue/yellow to represent information will help avoid confusion among most users who are color blind.

Always provide a redundant alternative to color, such as text and/or location that conveys the same information that the color conveys. Anywhere color coding is used, the message conveyed by that color coding should be conveyed through text as well, in order to ensure that color blind users have access to the same information that other users do. For instance, in the example used above, a text indication that says "Ready" when the system is in the ready state could be provided. The text message would communicate the same information to a color blind user that the green light communicates to a non-color blind user.

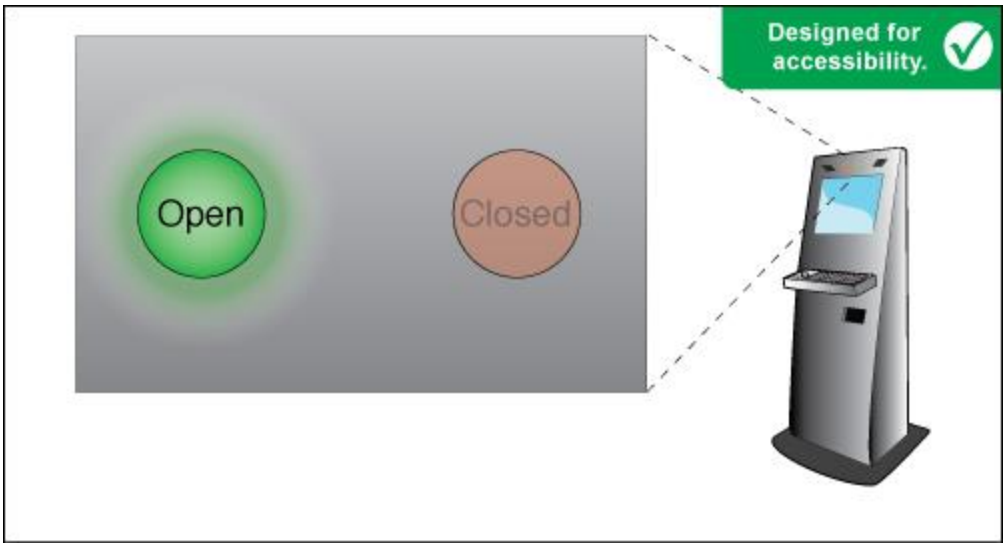


Figure 8: Information is conveyed redundantly through color and text.

Additional Comments: Although the solutions presented above will improve accessibility for those who are color blind (and for some with low vision), they in no way solve the problem for users who are blind and are therefore dependent on tactile or auditory differentiation of status information.

Applicable Guidelines:

Section 508 – 1194.25(g), 1194.31(a)
Section 255 – 1193.41(c)
HFDS – 8.6.2.1.5, 8.6.2.5.2
ICT – 302.1, 302.2, 302.3

Issues associated with displays

The LA County concepts provide output (i.e., ballot instructions and races) primarily through an electronic visual display. The display is a touchscreen and doubles as the primary user interface with the machine, although remote controls are also available.

Glare makes it difficult for some users to see the display.

This issue is most applicable to Concept 1, which does not have an adjustable display and appears to be intended for wheelchair users. It might also apply to concepts 2 and 3.

Detailed Description: Glare on displays from overhead lights or sunlight through windows may make it difficult for voters to view the display. If the displays are highly reflective, they are likely to produce substantial glare that will reduce visibility. This is particularly problematic for seated users who are less able to change their viewing angle.

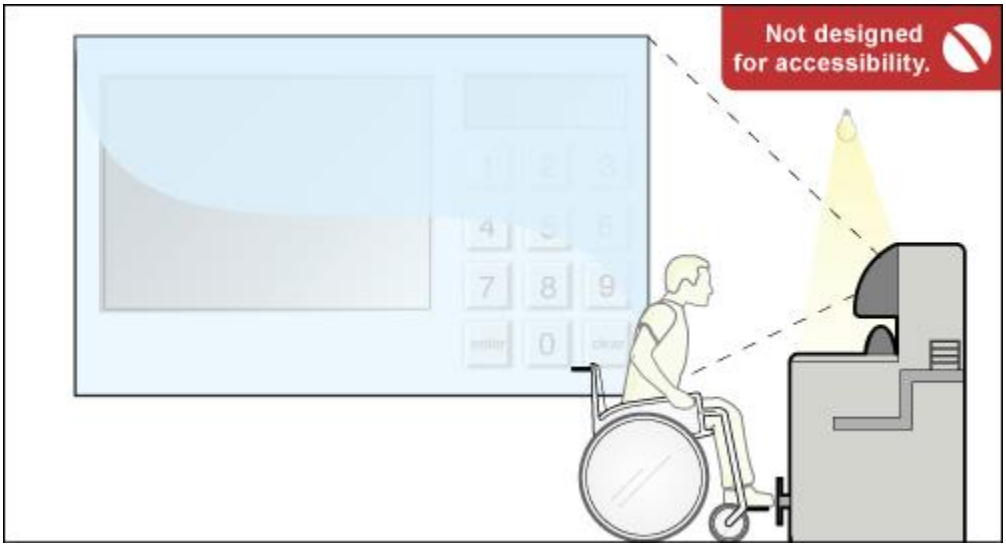


Figure 9: The angle of the display results in glare for a seated user.

Populations Impacted: Users with lower mobility impairments.

Potential Solutions: *Use an anti-glare display.* Matte finish displays reduce glare by making the surface of the display less reflective. Chemical coatings can also be used to reduce glare.

Provide an adjustable angle display. If the vertical tilt angle of the display is adjustable, users can reposition the screen to reduce glare, instead of having to change their physical position relative to the screen.

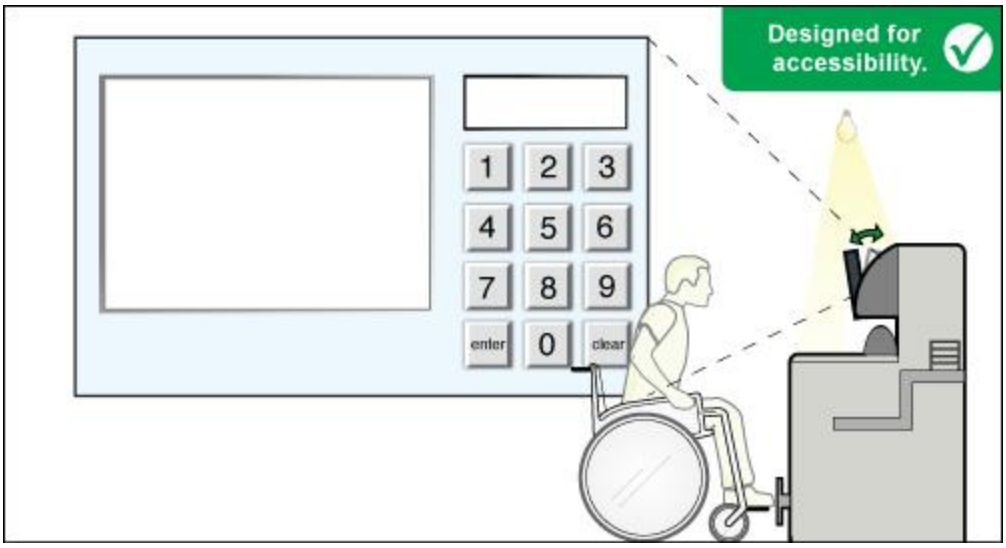


Figure 10: An adjustable display allows a seated user to adjust the display angle to reduce glare.

Use a hood to shield the display. A hood over the display can block direct light that causes glare. However, a poorly designed hood might also block visibility for tall users.

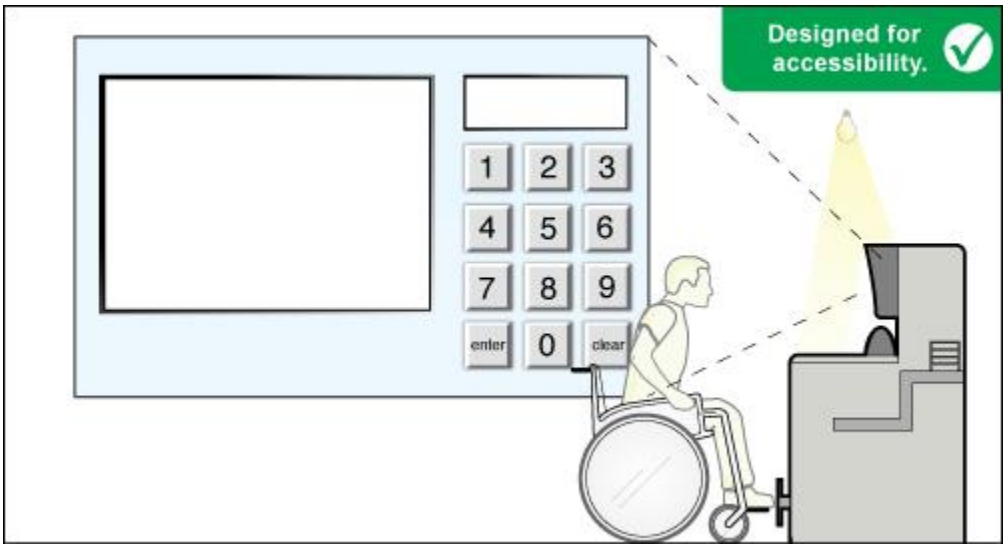


Figure 11: A hood shields the display from overhead lights, reducing glare for seated users.

Applicable Guidelines:

Section 255 – 1193.41(b)(2)(a)
HFDS – 5.2.3, 13.4.4
ISO/IEC 71 – 8.4.2, 8.4.4

LCD viewing angle limitations make it difficult to see the display from a seated position.

This issue applies to Concepts 1, 2, and 3.

Detailed Description: Many LCD screens are optimized for viewing from a particular angle, and demonstrate a sharp drop-off in contrast and readability when viewed at angles that are off-axis. If the display of a voting machine is optimized for standing users, users who are viewing the display from a wheelchair or other personal mobility device may have difficulty seeing the contents of the display.

Populations Impacted: Users with lower mobility impairments.

Potential Solutions: *Ensure that viewing envelope of the selected display accommodates both standing and seated users.* The viewing envelope of the display, which describes the range of eye positions from which the contents of the display are visible, can be determined via simple geometry based on the viewing angles of the display and the height and angle at which the display is mounted. Ensure that the display's viewing envelope includes the eye positions of both seated and standing users.

Allow users to adjust the angle of the display. A vertical tilt adjustment for the display will help to accommodate both seated and standing users.

Applicable Guidelines:

ADA-ABA – 707.7.1
HFDS – 5.1.2.6, 5.11.1
ICT- 407.14, 407.15

Small icons and text are difficult for users with low vision to perceive.

This might apply to Concepts 1, 2, and 3.

Detailed Description: Text and icons used in labels on voting machines may be difficult for users with low vision to read if the characters or graphics are too small.

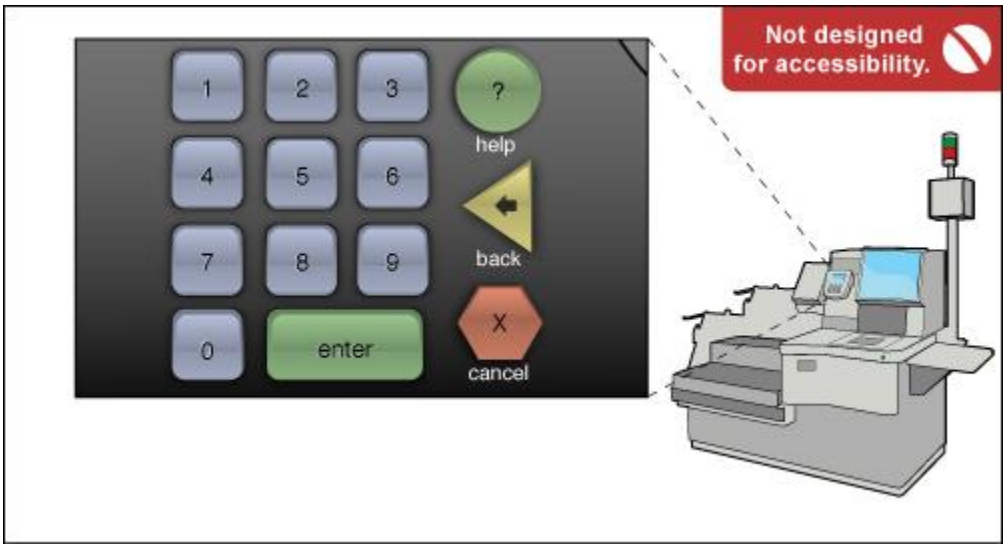


Figure 12: Very small labels and icons on a keypad.

Populations Impacted: Users with low vision.

Potential Solutions: *Ensure that the font size of the text is sufficiently large.* For 20/20 vision, the Human Factors Design Standard (HFDS) recommends that the height of characters occupy a visual angle of 16 to 24 minutes of arc. To compute the character height, use the following formula

$$h = 2dTan(x/2)$$

where h is the character height, d is the viewing distance, and x is the desired angle in radians. (One radian equals 3437.747 arc minutes, or 57.296 arc degrees.)

1194.31(b) of Section 508 states that a mode that does not require visual acuity greater than 20/70 must be provided. Multiplying the character height (h) calculated for 20/20 vision by 3.5 (70/20) yields the recommended character height for 20/70 vision for the specified viewing distance.

While this font size may not be possible for all instances of text on a machine, making the text as large as possible will increase the chance that users with low vision will able to read the labels.

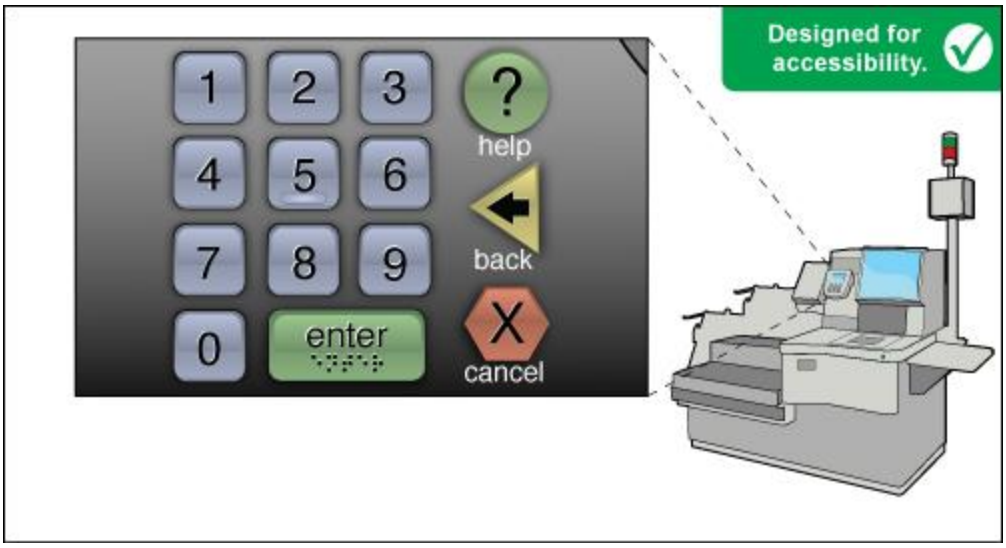


Figure 13: Large labels and icons on a keypad.

Ensure that icons are large enough for low vision users to see. The largest dimension (height or width) of icons should be at least as large as the character height calculated above. Icons should be made as large as possible, given the space available. Often, a control is fairly large, but the icon on the control is only a small fraction of the total size of the control. If a control will accommodate the same icon in a larger size, the larger size should be used to enhance visibility for those with low vision.

Applicable Guidelines:

Section 508 – 1194.31(b)
Section 255 – 1193.43(b)
HFDS – 8.2.5.6.5, 8.2.5.6.6, 8.2.5.6.9
ICT – 302.2, 402.4, 407.2

Raised or recessed lettering may be difficult to perceive.

This might apply to Concepts 1, 2, and 3.

Detailed Description: Raised or recessed lettering is often the same color as the background, so the contrast between the lettering and the background is insufficient. The lack of contrast makes it difficult for users with low vision or low contrast sensitivity to distinguish the lettering from the background surface.

Populations Impacted: Users with low vision.

Potential Solution: *Ensure that raised or recessed lettering is different in color from the control panel surface.* The contrast between the lettering and the background surface should be at least 3:1. If the machine is to be used in very bright lighting (which should be avoided), then a contrast ratio of at least 10:1 may be more appropriate. Using sufficiently contrasting colors will help users with low vision or low contrast sensitivity perceive and read the lettering.

Applicable Guidelines:

Section 508 – 1194.31(b)
HFDS – 9.6.7
ICT- 302.2, 407.2

Labels are not clearly associated with the components that they label.

This might apply to Concepts 1, 2, and 3.

Detailed Description: Labels that are not clearly associated with the components that they identify may cause problems for some users. Users may have difficulty locating components if they are not clearly labeled, causing them to spend time searching for a particular component. Users may erroneously associate a label with an incorrect component, causing them to commit errors when interacting with the machine. This can be particularly problematic with soft keys that are paired with adjacent screen elements. Users with low vision, who may have a limited field of view, may have difficulty associating components and their labels if they are not associated by proximity or some other type of coding technique.

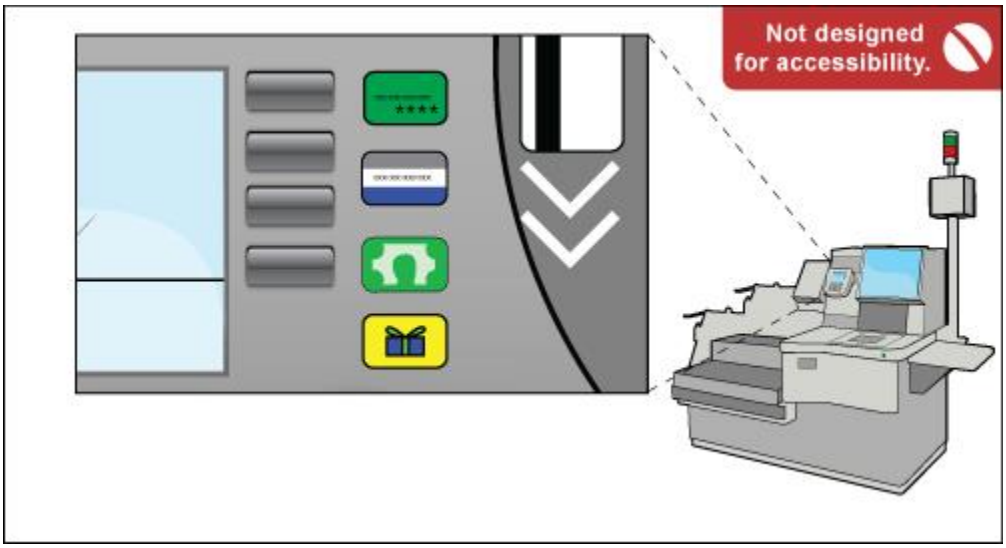


Figure 14: Icons are not clearly associated with their corresponding labels.

Populations Impacted: All users, particularly those with cognitive impairments or users with low vision.

Potential Solutions: *Place labels in close proximity to the components they identify.* If possible, place labels directly on the component being identified. If this is not possible, place labels as close as possible to the component being identified, and use spacing to ensure that the label is unambiguously associated with the intended component and no others.

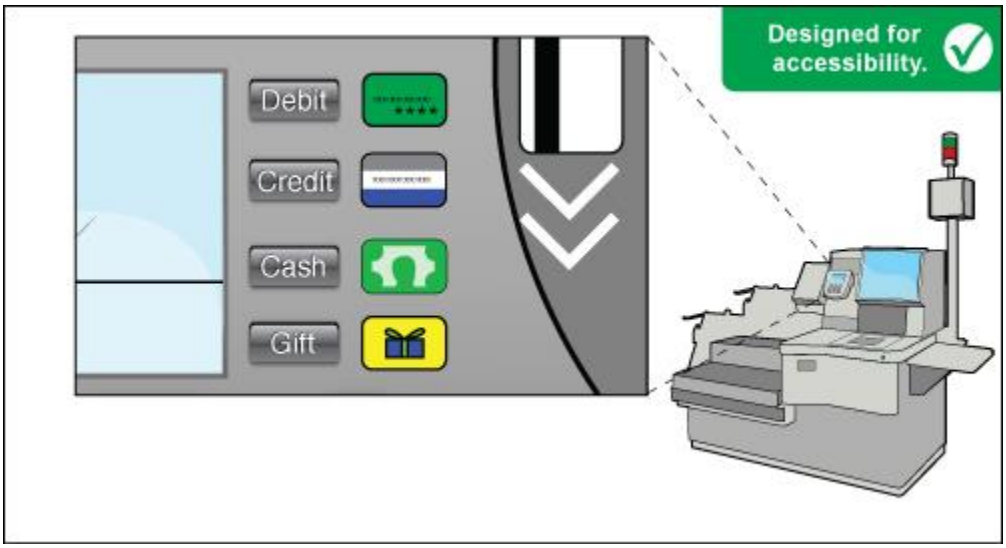


Figure 15: Icons are clearly associated (by proximity) with their corresponding labels.

Use grouping or other coding techniques to reinforce the association of labels to components. Bounding boxes encompassing labels and components or lines connecting labels and components may help to reinforce associations. The boxes or lines could be visual (printed on) and/or tactile (raised), as appropriate. Tactile markings are preferable to accommodate users with low vision. Other coding techniques, such as color coding or the use of icons, may also be used. However, color coding should not be used as the sole means of association, and coding techniques that rely on user vision are inaccessible to users who are blind.

Applicable Guidelines:

Section 508 – 1194.31(b)
HFDS – 6.1.2.2.3, 6.1.2.2.6
ICT – 302.1, 302.2, 407.3, 407.3.1, 407.16

Information presented in text labels is not accessible to users with visual impairments.

This might apply to the remote controls of Concepts 1, 2, and 3.

Detailed Description: Labels may appear on buttons, input and output slots, adjustable components, etc… Labeling information that is presented only as printed text is not accessible to users who are blind and to some users with low vision. It is important that all users have access to all of the information that is necessary for the operation of the machine.

Populations Impacted: Users who are blind; users with low vision.

Potential Solutions: *Provide tactile labels for controls and components.* Labels for controls and components should be provided in a tactile format, which could include Braille, raised lettering, or other raised markings that help identify controls.

Allow button shape and position to convey information. In some cases, button shape can unambiguously indicate button function. For example, if a control panel consists of only two arrows and an enter button, then the arrow buttons could be shaped like arrows or triangles, and the enter button could be rectangular. Up/down buttons should be aligned vertically, and left/right arrows should be aligned horizontally.

Provide critical instructions in Braille. Providing redundant labeling with at least the most important instructions in Braille will increase accessibility of information for users with visual impairments that are able to read Braille. (However, the percentage of users with visual impairments that are able to read Braille is fairly low, so other methods of providing information are also necessary.)

Provide information in an auditory format. The voting machine should be capable of outputting information in an auditory format (i.e., speech output). All text that is displayed onscreen should also be presentable aurally. Auditory information should include any necessary instructions on how to use the machine, and should also include feedback, such as repeating the name of a candidate after he/she is selected.

Applicable Guidelines:

ADA-ABA – 707.5
Section 508 – 1194.31(a), 1194.31(b)
Section 255 – 1193.43(a)(2)
ICT – 302.1, 302.2, 402.2, 407.3, 407.3.1, 407.16
ICT- 302.1, 302.2, 407.16

Issues associated with touchscreen interfaces

Touchscreens are the primary user interface on each of the LA County voting machines concepts. A touchscreen interface allows the designer to accommodate a wide variety of controls and functions in a relatively small area on the control panel, and allows users to interact directly with on-screen display elements.

Touchscreen controls are easily activated and do not provide tactile feedback, often resulting in unintentional control activations.

This issue applies to Concepts 1, 2, and 3.

Detailed Description: Touchscreens require very little pressure to activate controls. The low strength requirement is beneficial to users with limited upper body strength, but can cause problems for other users, especially if controls on the touchscreen are small or closely spaced. When controls are small or closely spaced, users who have upper mobility impairments or lack fine motor control will have difficulty activating specific controls without also activating adjacent controls. Users without vision may inadvertently activate touchscreen controls while moving their hands over the control panel to locate hardware controls. Because no tactile feedback is provided by touchscreen controls, if redundant visual and auditory feedback is not provided when controls are activated, these accidental activations may go unnoticed.

Populations Impacted: Users who are blind; users with upper mobility impairments.

Potential Solutions: *Ensure that buttons are large and are spaced far enough apart to minimize the possibility of accidental activation of adjacent buttons.* When designing a touchscreen interface, include adequate space between buttons. According to the Human Factors Design Standard (HFDS), touchscreen buttons should be between 0.75" and 1.5" along each side, with spacing between buttons of 0.13" to 0.25". This will help ensure that a user who does not have fine motor control is able to activate a button without accidentally activating adjacent controls.

Provide an alternate display mode with larger, widely spaced controls. If the normal display cannot be made accessible, providing an alternate display mode with larger, more widely spaced controls, even if it contains only the most frequently used controls, will be useful for users who lack fine motor control.

Provide alternatives to the touchscreen to facilitate interaction by users with disabilities. Touchscreen functionality could be replicated in a fixed or attached auxiliary control panel using control elements with functionality, position, and status that are easily discernible by touch. A voice display could be integrated with the control panel, so that feedback is presented in an auditory fashion as well. For example, using arrow keys as an input device, the user could navigate through options that are voiced, without having to rely on vision to perceive the screen contents.

Provide visual and auditory feedback when user input is received. Providing visual and auditory feedback when user input is received can make up for the lack of tactile

feedback, and helps users detect unintentional activations. Visual feedback can be provided in the form of salient visual changes in the display. Audible feedback might consist of simple tones or speech output when more descriptive feedback is needed.

Allow easy recovery from errors. A "Back" or "Undo" button should be provided to allow users to recover from accidental inputs. Note that a button labeled "Cancel" is somewhat ambiguous; a user may think that a "Cancel" button will cancel the entire transaction, rather than cancel only the most recent input.

Applicable Guidelines:

Section 508 – 1194.25(c), 1194.31(a), 1194.31(f)
Section 255 – 1193.41(a)(3)(e), 1193.31(e)(2)(e)
HFDS – 9.4.2.4
ICT – 302.1, 302.2, 302.7, 302.8 402.2, 407.3, 407.3.1, 407.16

Touchscreen controls are not tactilely differentiable.

This issue applies to Concepts 1, 2, and 3.

Detailed Description: Users with vision impairments navigate by touch, moving their hands over the control panel to determine where various controls are located. Touchscreens are inaccessible to users who navigate by touch, because controls displayed on touchscreens are not tactilely discernible - they are merely graphical controls displayed on a screen, and cannot be identified by touch.

Populations Impacted: Users who are blind; users with low vision.

Potential Solutions: *Provide an alternate interface, such as a secondary control panel with speech output.* The LA County voting concepts include a remote control that may provide an adequate solution if coupled with audible speech output, so that feedback is presented in an auditory fashion. Using the remote control, users should be able to navigate through options that are read aloud via headphones, without having to rely on vision to perceive the screen contents.

Provide hardware controls for basic functions. If possible, provide redundant, tactilely differentiable hardware controls for basic functions. This will allow users to perform those basic functions without having to interact with the touchscreen. For example, a voting machine might offer hardware controls for moving the cursor up and down and selecting an item; these controls would allow users to input necessary data and complete a simple step without using the touchscreen.

Applicable Guidelines:

Section 508 – 1194.25(c), 1194.31(a)
Section 255 – 1193.41(a)(3)(e)
VSS – 2.2.7.2(f)
ICT – 302.1, 302.2, 302.7, 407.3, 407.3.1

A touchscreen positioned for use by standing users may be difficult for users in wheelchairs to reach.

This issue applies to Concept 2.

Detailed Description: Users who are seated in wheelchairs or other personal mobility devices may be unable to reach portions of Concept 2's touchscreen, which appears to be positioned for standing users. This problem may be compounded if access to the machine by wheelchair is impeded by objects around the machine. Some wheelchair users are unable to shift their upper bodies, limiting their access to only controls within arm's length. Thus, it is important that controls be operable from a seated position, without requiring excessive leaning or reaching.

Population Impacted: Users with lower mobility impairments.

Potential Solutions: *Follow the ergonomic standards to determine where to position the touchscreen to ensure easy access by all users.*

- The position of any operable control should be determined with respect to a vertical plane that is 48 inches in length, centered on the operable control, and at the maximum protrusion of the product within the 48 inch length.
- Where any operable control is 10 inches or less behind the reference plane, the height shall be 48 inches maximum and 15 inches minimum above the floor. (See note below.)
- Where any operable control is more than 10 inches and not more than 24 inches behind the reference plane, the height shall be 46 inches maximum and 15 inches minimum above the floor.
- Operable controls shall not be more than 24 inches behind the reference plane.

Allow adjustment of the position of the touchscreen. A touchscreen that can be adjusted between two or more discrete positions, or freely within a range of positions, could accommodate the needs of both seated and standing users.

Provide an alternate interface that is within reach for seated users. The alternate interface could be a fully redundant interface to the touchscreen, or could consist of hardware controls that provide a method for interacting with the screen without touching it, but still require the user to look at the screen. In the latter case, care must still be taken to ensure that the touchscreen is comfortably visible for seated users using the alternate interface.

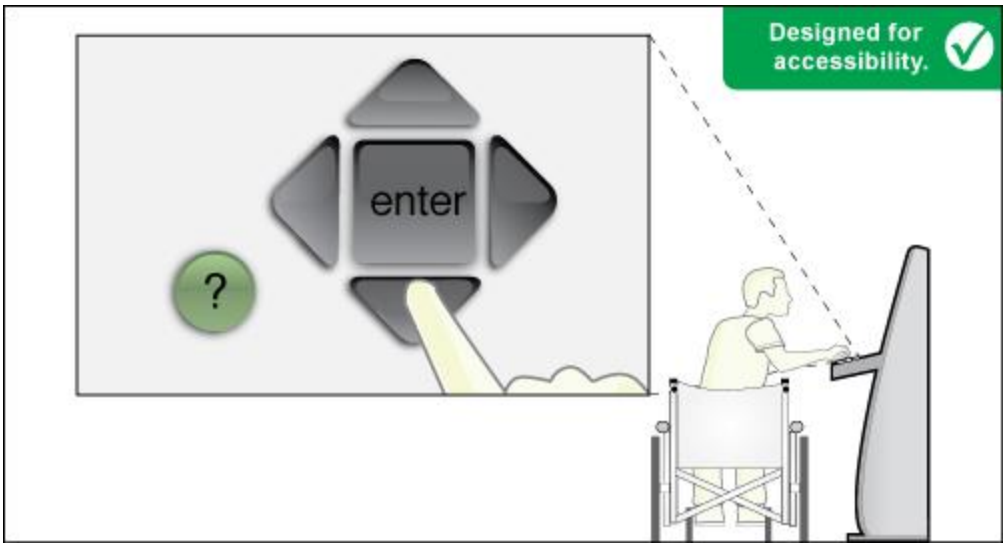


Figure 16: An auxiliary control interface placed within reach of a user in a wheelchair.

Applicable Guidelines:

ADA-ABA – 308.2.1, 308.2.2, 308.3.1, 308.3.2, 707.7.1
ISO/IEC 71 – 8.3.1
ICT – 302.8, 407.14

Issues associated with buttons on panels and remote controls

Control panel buttons are mechanically operated push buttons that are used to interact with the machine. These include physical buttons on the voting machine remote controls.

Remote controls may require two-handed operation.

This issue applies to Concepts 1, 2, and 3.

Detailed Description: Some remote controls are difficult to operate with one hand. It may be necessary to hold the control with one hand and operate the buttons with the other hand. Remote controls may be difficult to hold and operate for users with only one functional upper limb. Moreover, users without functional use of either upper limb may be unable to operate the remote controls with a mouth stick if the control is not secured at a suitable height and angle.

Populations Impacted: Users with upper mobility impairments.

Potential Solutions: *Design the remote control to be operable with one hand.* The remote control should be operable with only the right hand or the left hand. Users should be able to operate all buttons with the thumb, without needing to reposition the remote control in their hand.

Mount the remote control. The remote control could be mounted on the voting machine so that users have the option of keeping it mounted on the machine or holding it in their hand. The mounted solution would enable mouth-stick interaction for users without functional arms and hands.

Applicable Guidelines:

Section 508 – 307.4
ICT – 302.7, 302.8

Buttons mounted flush with the panel are difficult for users without vision or with low vision to detect.

This issue might apply to Concepts 1, 2, and 3.

Detailed Description: Users with vision impairments may navigate by touch, by moving their hands over the control panel in order to determine where controls are located. Buttons that are mounted flush with the surface of the control panel are difficult for users without vision and users with low vision to feel when they move their hands over the control panel. Furthermore, users without vision typically depend on behaviors such as counting to find a specific control, and this is problematic when there is insufficient tactile differentiation of the controls.

Populations Impacted: Users who are blind; users with low vision.

Potential Solutions: *Ensure that buttons are sufficiently raised above the control panel so they are tactilely discernible by users without vision.* Buttons should be raised at least 1/32" above the panel so that users can locate the buttons tactilely. This will improve the accessibility of the buttons to users with visual impairments.

Include Braille or raised large text on buttons that are flat to help users without vision or with low vision determine exactly what each button is. For devices where it is not possible to sufficiently raise the buttons on the control panel, consider providing Braille labels on the buttons so that users without vision will still have access to the buttons. Providing large, raised lettering would have the additional benefit of assisting those with low vision (or those who cannot read Braille) in identifying the functionality of the buttons.

Make the texture of the buttons is different from that of the control panel to make the buttons easier to distinguish tactilely. Providing a rougher texture on buttons if the control panel surface is smooth or providing a more rubbery texture on the buttons if the control panel is made of a hard material can help users without vision distinguish buttons from the control panel surface more easily.

Combining all of these approaches (providing sufficiently raised buttons with accompanying Braille labels or large raised lettering and a distinctive texture) would increase button accessibility significantly.

Applicable Guidelines:

ADA-ABA – 707.6.1, 707.6.3.2
Section 508 – 1194.23(k)(1), 1194.25(c), 1194.31(a)
Section 255 – 1193.43(a)(2)(b), 1193.43(a)(2)(c)
HFDS – 6.4.1.7, 6.4.1.18, 6.4.1.19, 6.4.1.20, 6 4.1.23, 6.4.1.28, 9.6.10
ICT – 302.1, 302.2, 407.16, 407.3, 402.7.3.1

Buttons that do not have sufficient contrast with the panel are difficult for users with low vision to detect.

This issue might apply to Concepts 1, 2, and 3.

Detailed Description: If buttons are the same color as the control panel, they may blend in with the panel, making it difficult for a user with low vision to distinguish the button from the surrounding surface.

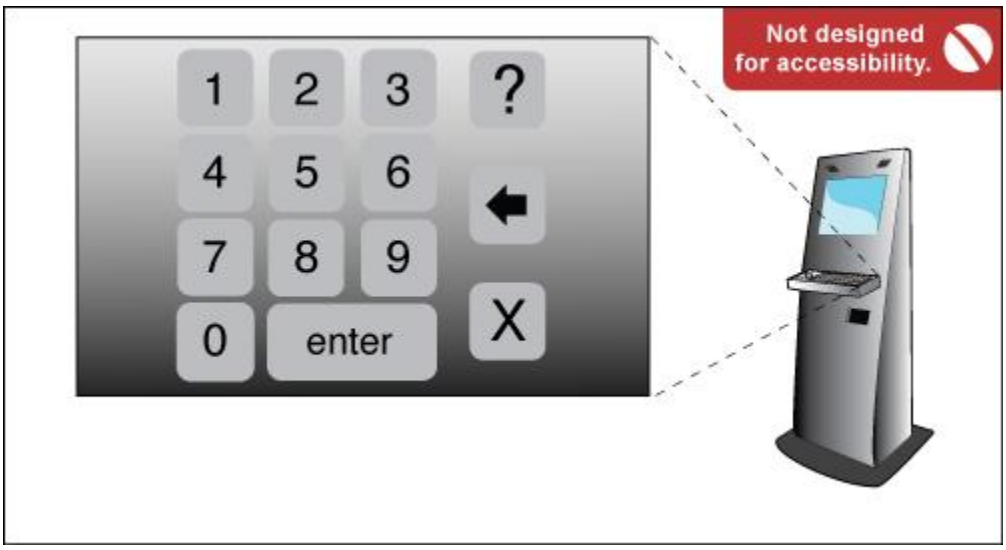


Figure 17: Buttons on a control panel have very little contrast with the control panel surface.

Populations Impacted: Users with low vision.

Potential Solution: *Ensure that buttons are different in color from the control panel surface.* Buttons should be colored differently from the control panel, making them easy for a low vision user to distinguish. Using sufficiently contrasting colors will aid users in distinguishing buttons from one another. For example, a bright green "Enter" button would be easily distinguishable from a dark gray control panel. Backlighting buttons may also help distinguish them from the surrounding surface.

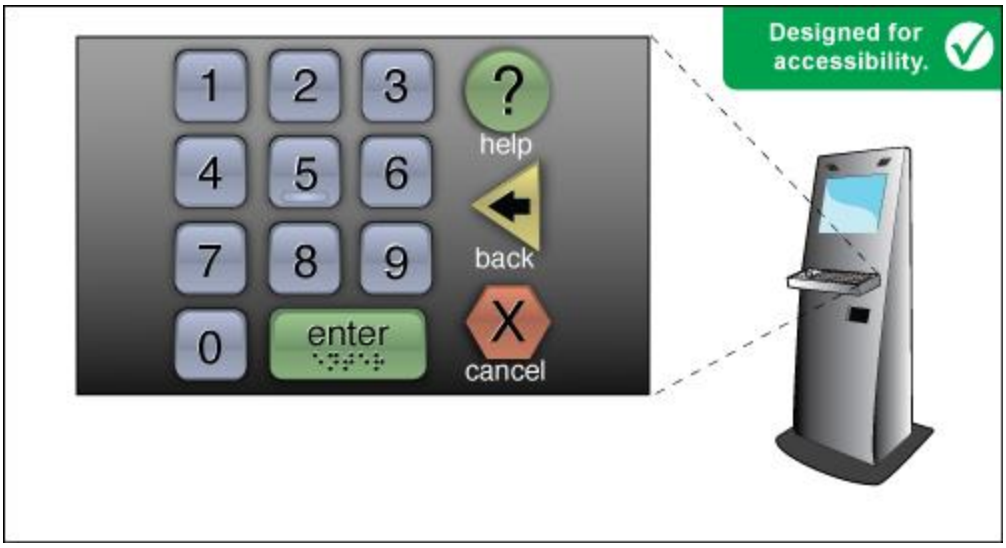


Figure 18: Buttons on a control panel have high contrast with the control panel surface.

Applicable Guidelines:

ADA-ABA – 707.6.3.1
HFDS – 6.1.1.4.12
ICT – 302.1, 302.2, 407.2

Buttons are not identifiable as operable controls.

This issue might apply to Concepts 1, 2, and 3.

Detailed Description: Buttons that are designed to appear "sleek" or "modern" may not be readily recognizable as operable controls. For example, users may interact with the device by touching backlit areas of the control panel surface that use electrostatic touch detection, rather than traditional mechanical controls. While these sorts of designs may be visually appealing, users may have difficulty identifying the operable controls on the device – particularly users with cognitive impairments, or users who are blind and rely on touch to perceive the presence and location of controls.

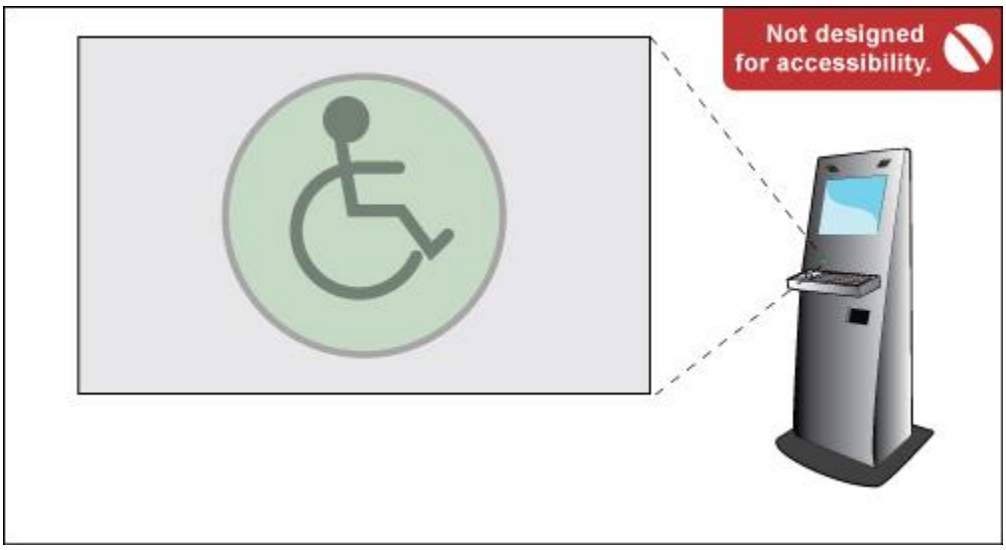


Figure 19: A stylized button is not identifiable as an operable control.

Populations Impacted: Users who are blind; users with cognitive impairments.

Potential Solution: *Ensure that buttons are readily identifiable as operable controls to all users.* Buttons should be easily identifiable as operable controls through their appearance, tactile characteristics, and/or labels. Buttons should stand out from the control panel by virtue of visual or physical characteristics so that users can identify them by sight or touch. Clear labeling and instructions ("Press here") may make it easier for users to identify non-traditional types of buttons.

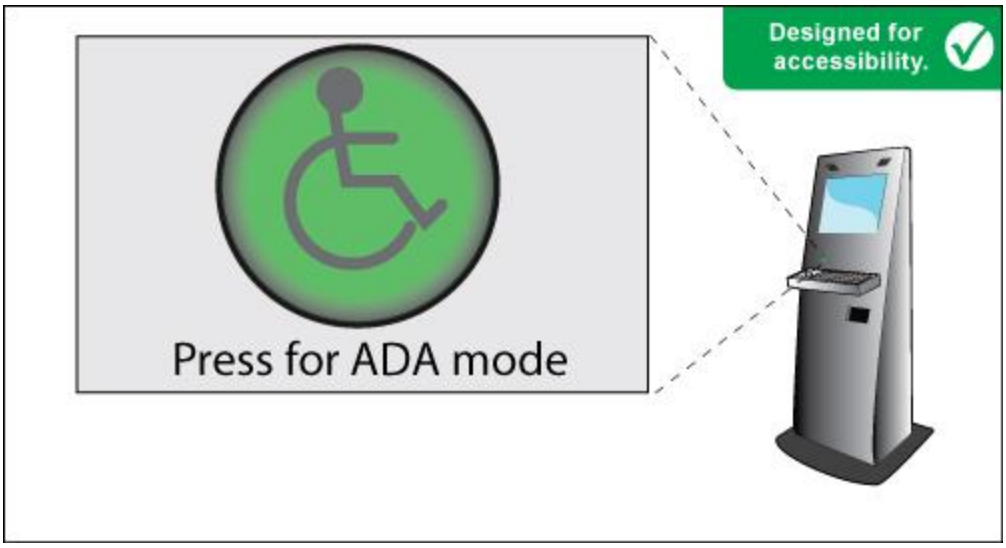


Figure 20: Design of the button and accompanying text help to identify the button as an operable control.

Applicable Guidelines:

ADA-ABA – 707.3, 707.6.1
Section 508 – 1194.23(k)(1), 1194.25(c), 1194.31(a)
Section 255 – 1193.41(a)(3)(b)
HFDS – 6.4.1.7, 6.4.1.18, 6.4.1.19, 6.4.1.20, 6 4.1.23
ICT – 302.1, 302.2, 407.16, 407.3, 402.7.3.1

Buttons that are small and close together may be difficult to differentiate or activate without activating adjacent controls.

This issue might apply to Concepts 1, 2, and 3.

Detailed Description: If control panel buttons are small and are placed too close together, they may be difficult for users without fine motor control to activate without accidentally activating adjacent controls. Small, tightly spaced control panel buttons are also more difficult for users who are blind to differentiate by feel.

Populations Impacted: Users with upper mobility impairments; users who are blind.

Potential Solution: *Ensure that buttons are large and are spaced far enough apart to minimize the possibility of accidental activation of adjacent buttons and to enhance tactile differentiation.* When designing the control panel for a voting machine, provide adequate space between buttons. According to the Human Factors Design Standard (HFDS), minimum spacing of 0.5" (with 2" preferred) is recommended for buttons that are not part of keyboards. Make sure that the diameter of the buttons is large enough (up to a maximum diameter of 1") that a user who does not have fine motor control is able to activate a button even if he or she does not hit the button directly in the center. Increasing button size and spacing will also aid those who need to differentiate the buttons by feel. Buttons with very little separation can be problematic for those who depend on the tactile quality of the buttons to find the ones they need.

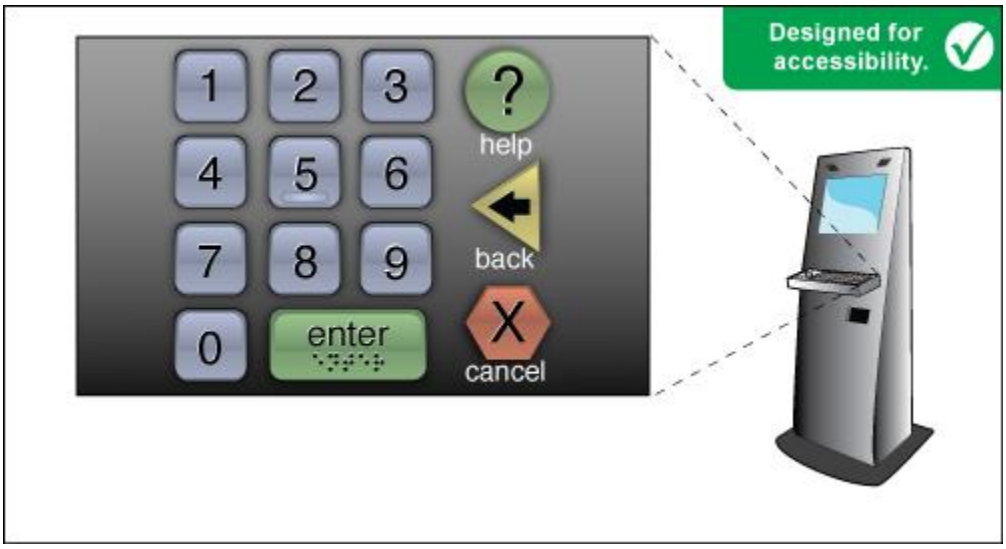


Figure 21: Buttons on a control panel are large and widely spaced.

Applicable Guidelines:

Section 508 – 1194.23(k)(1), 1194.25(c), 1194.31(a), 1194.31(f)
Section 255 – 1193.41(e)(2)(a), 1193.41(e)(2)(b), 1193.41(e)(2)(c)
HFDS – 6.1.1.3.8, 6.1.5.8.1, 6.4.1.1, 6.4.1.3, 6.4.1.14, 9.6.10
ISO/IEC 71 – 8.12.3.2

ICT – 302.7, 407.3, 407.3.1

Buttons that are all shaped the same or that do not have shapes corresponding to their functions are more difficult for the blind to identify and for the cognitively impaired to understand.

This issue might apply to Concepts 1, 2, and 3.

Detailed Description: For users with limited cognitive abilities or vision, it may be difficult to understand the difference between buttons that look and feel exactly the same. Button shapes should correspond to their functionality. Commonly used or important controls should be more prominent. Control panel buttons that are logically grouped together, such as on a numeric keypad, should all have the same shape and distinguishing features.

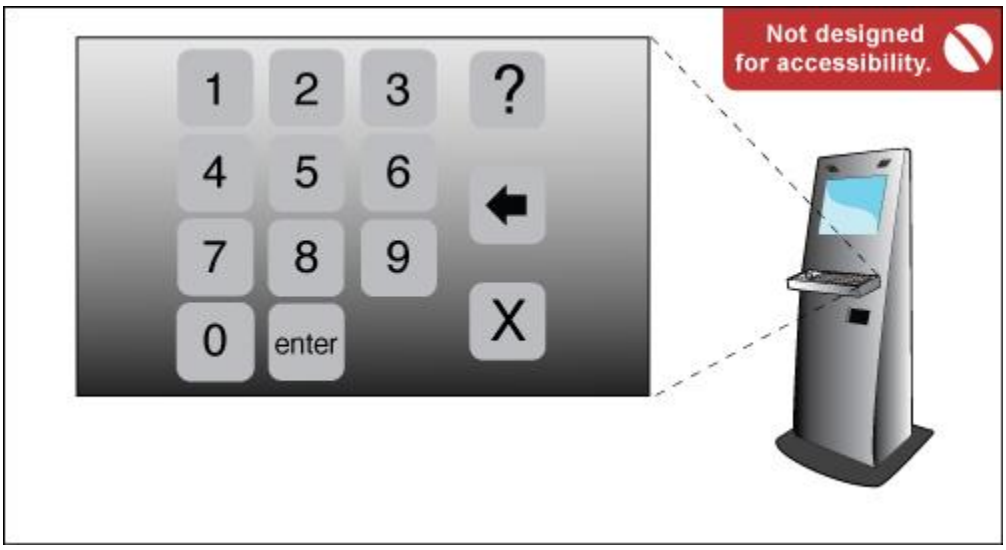


Figure 22: Buttons on a control panel are all shaped identically.

Populations Impacted: Users who are blind; users with cognitive impairments.

Potential Solution: *Design buttons with distinguishing features, including differences in shape.* Ensure that buttons with different functions are distinguished from one another in some way. For example, on many voting machines, the "Enter" button on the control panel is larger than all the other buttons because of its relative importance. It is also a good idea to associate buttons that have related functions by making them all the same shape. In addition to shape and size coding, color coding, tactile differentiation, and grouping can be used as distinguishing features for controls.

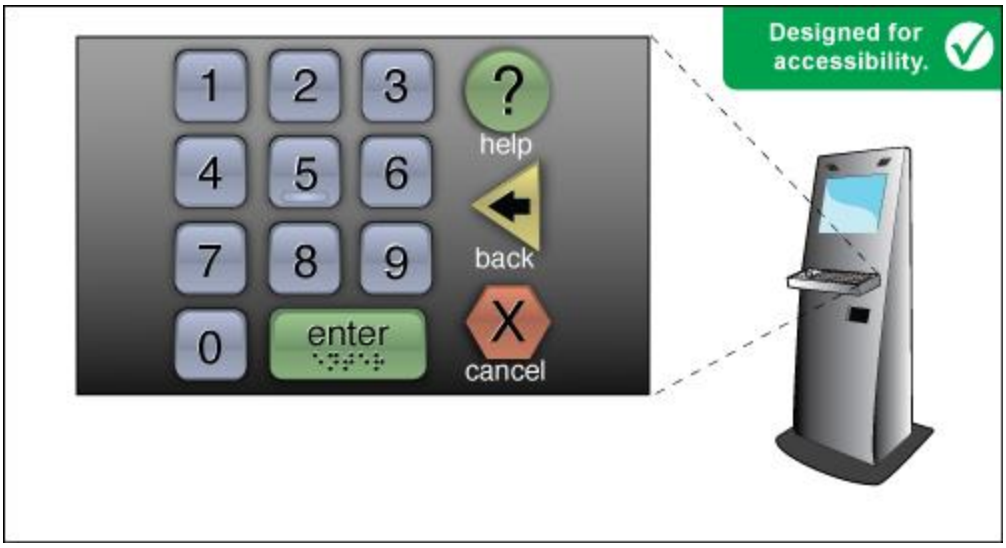


Figure 23: Buttons on a control panel are grouped and distinguished by size, shape, and color.

Applicable Guidelines:

ADA-ABA – 707.3, 707.6.1
Section 508 – 1194.23(k)(1), 1194.25(c), 1194.31(a)
Section 255 – 1193.41(a)(3)(b)
HFDS – 6.4.1.16, 6.4.1.18, 6.4.1.19, 6.4.1.22, 6.4.1.30
ICT – 302.1, 302.7, 407.3

Buttons do not provide a surface that facilitates button activation.

This issue might apply to Concepts 1, 2, and 3.

Detailed Description: Buttons that are slick or have no concave curvature are more difficult for some users to activate. Users without fine motor control or users that utilize manipulation sticks may have difficulty activating buttons that are slick and not curved inward, because their fingers or manipulation sticks may slip off the button and activate adjacent buttons.

Populations Impacted: Users with upper mobility impairments or limited dexterity.

Potential Solutions: *The buttons on the device should be concave.* Concave buttons help prevent users' fingers from slipping off the buttons.

The buttons on the device should be made from a high friction material. A rubberized coating or other high friction material helps prevent users' fingers from accidentally slipping off the controls.

Applicable Guidelines:

Section 508 – 1194.31(f)
Section 255 – 1193.41(e)(2)(g)
HFDS – 6.4.1.1, 6.4.1.7, 6.4.1.23
ISO/IEC 71 – 8.12.3.1
ICT- 302.7

Buttons requiring very little force to activate can increase the number of accidental activations.

This issue might apply to Concepts 1, 2, and 3.

Detailed Description: Buttons that are activated with very light forces are more frequently accidentally activated. This causes problems for users who are blind or who have low vision, because they may rely on touch to locate buttons, and may accidentally activate buttons if the activation force is too low. Users lacking fine motor control may touch buttons unintentionally, and accidentally activate them if the activation force is too low.

Populations Impacted: Users who are blind; users with low vision; users with upper mobility impairments or limited dexterity.

Potential Solution: *Buttons should require a sufficient activation force to reduce the number of accidental activations.* Button activation forces in the range of 0.22 to 1.8 pounds are recommended (Bullinger, Kern, and Muntzinger, 1987).

Applicable Guidelines:

Section 508 – 1194.31(a), 1194.31(f)
Section 255 – 1193.41(a)(3)(e), 1193.41(e)(2)(e)
ICT – 302.1, 302.2, 302.7, 302.8, 407.3.1

Buttons requiring high levels of force to activate can pose difficulties for users with limited strength.

This issue might apply to Concepts 1, 2, and 3.

Detailed Description: Buttons that require a great deal of force for activation may be difficult for users with limited strength to activate.

Populations Impacted: Users with upper mobility impairments.

Potential Solution: *Buttons should require moderate levels of force to activate.* ADA and Section 508 guidelines place an upper limit of 5 pounds on control activation forces, but this force is excessive for buttons, which are typically intended for fingertip operation. Button activation forces in the range of 0.22 to 1.8 pounds are recommended (Bullinger, Kern, and Muntzinger, 1987). However, button activation forces should not be too low, lest accidental activations (e.g., when a user with tremors brushes against a control) become a possibility.

Applicable Guidelines:

ADA-ABA – 309.4
Section 508 – 1194.23(k)(2), 1194.25(c)
Section 255 – 1193.41(f)(2)(d)
HFDS – 6.1.5.8.1, 6.4.1.2, 6.4.1.11
ICT- 302.7, 302.8

Buttons do not provide sufficient tactile feedback.

This issue might apply to Concepts 1, 2, and 3.

Detailed Description: Tactile feedback indicating the activation of mechanical buttons is a primary source of user feedback. If a button does not provide tactile feedback in the form of a mechanical click and/or perceptible displacement, users may be unsure whether they successfully activated the control. This can lead to multiple activation errors (where users press the button again because they were unsure if it was activated) and unintentional activations (where users do not perceive that a button was pressed by accident). This issue applies to all voting systems that feature a touchscreen, and may also apply to physical buttons that provide insufficient tactile feedback.

Populations Impacted: Users who are blind; users who are deaf; users who are hard of hearing; users with upper mobility impairments.

Potential Solution: *Ensure that buttons provide adequate tactile feedback when activated.* Buttons should provide "snap action" feedback, with a gradual increase in resistance prior to activation, followed by a sharp decrease in resistance after activation. Buttons with very low travel distances should be avoided; buttons should travel between 1.3 and 6.4 mm when activated. Providing visual and auditory feedback to supplement tactile feedback is also recommended.

Applicable Guidelines:

Section 508 – 1194.31(a), 1194.31(b), 1194.31(c), 1194.31(f)
HFDS – 6.1.5.8.5, 6.4.1.31
ICT – 302.1, 302.2, 407.3

Some types of buttons do not respond to touch from materials other than skin.

This issue might apply to Concepts 1, 2, and 3.

Detailed Description: Certain types of controls, such as electrostatic buttons, do not respond to touches from materials other than skin. Users with prosthetic limbs and users who use manipulation sticks are therefore unable to activate these buttons.

Populations Impacted: Users with upper mobility impairments.

Potential Solution: *Ensure that controls can be activated by materials other than skin.* Provide mechanically activated controls, or touch-sensitive controls that use a detection technology that responds to a variety of materials other than skin. However, care must be taken to ensure that the controls are not too sensitive, so that accidental activations become a problem.

Applicable Guidelines:

Section 508 – 1194.31(f)
Section 255 – 1193.51(c)
HFDS – 6.4.1.1

Issues associated with card readers and ballot slots

Direct recording electronic voting machines typically use smart cards to allow only registered voters to interact with the machine. Each voter receives an activated smart card from a poll worker after verifying their eligibility, and then activates the voting machine with the smartcard. Typically the card is fully inserted into the machine, rather than swiped through a slot. Although smart cards are typically used, some machines may use magnetic strip or RFID cards.

Ballot slots may be present on a ballot marking machine (e.g., Concept 2 includes a slot for voters to insert a blank ballot). Ballot slots may also be present on ballot verification machines, which read a marked ballot and enable voters to verify that their intentions were recorded correctly.

Users may have difficulty locating the card reader or ballot reader.

This issue applies to Concept 2, and might apply to Concepts 1 and 3.

Detailed Description: The card reader and ballot reader are often not in a central location, and are sometimes housed in a separate machine that is connected to the voting machine. Therefore, some users might have difficulty finding the card slot. Concept 2 depicts a blank ballot insert slot near the top of the display.

Populations Impacted: Users who are blind; users with low vision; users with lower mobility impairments.

Potential Solutions: *Ensure that the card/ballot reader is easy to distinguish from the rest of the machine.* The card/ballot reader should be prominently located and labeled on the machine, so that a searching user can find it quickly. It should also be tactilely identifiable as a card/ballot reader. For example, instead of providing only a small slot in the machine into which a card or ballot must be inserted, provide an interface that can be easily located and identified by touch. The visual appearance of the reader should also contrast with the machine, to assist users with low vision to locate it.

Provide visual and tactile labels. The card/ballot reader should be clearly marked and labeled with a Braille label, raised text, or other tactile markings.

Describe the location of the card/ballot reader to the user both visually and auditorily. Provide both on-screen text and/or graphics and auditory output indicating the location of the card/ballot readers to the user, making use of obvious landmarks on the machine to establish the location (i.e., "the ballot reader is located to the left of the display screen").

Use an indicator light to draw attention to the card/ballot readers. When a card or ballot must be read (for example, at a ballot verification station), illuminate an indicator light on the card/ballot reader to indicate its location and attract the attention of the user.

Applicable Guidelines:

ADA-ABA – 707.5

Section 508 – 1194.31(a), 1194.31(b)
Section 255 – 1193.41(a)(2)(b), 1193.41(i)(2)(a)
HFDS – 6.4.1.16, 6.4.1.18, 6.4.1.22, 6.4.1.28, 6.4.1.30
ICT – 302.1, 302.2, 302.7, 302.8, 407.13, 407.14, 407.15, 407.16

Determining the proper orientation for inserting a card or ballot may be difficult.

This issue applies to Concept 2, and might apply to Concepts 1 and 3.

Detailed Description: Concept 2 features a blank ballot insert slot. It is unclear whether Concepts 1 and 3 also include a ballot insert slot. All of the design might feature a card reader. Most card readers and ballot readers require users to insert the card or ballot in a specific orientation (e.g., face-up, or with the magnetic stripe up and to the left). Determining the proper orientation may be difficult for users with visual impairments (who may not be able to see orientation instructions) and users with cognitive impairments (who may not be able to understand orientation instructions).

Figure 24: The proper orientation for inserting a card is not shown.

Populations Impacted: Users who are blind; users with low vision; users with cognitive impairments.

Potential Solutions: *Provide a clear graphic on the card reader illustrating the proper card orientation.* Provide a simple graphic located adjacent to the card reader that shows the proper card illustration, using only one or two prominent features of the card (such as the magnetic stripe or the alignment arrow on a memory card) as landmarks. If possible, avoid perspective drawings that may require users to perform mental geometry to work out the proper card orientation.

Figure 25: The proper orientation for inserting a card is shown.

Provide a card/ballot reader that accepts multiple card orientations. If a card reader can successfully read a card in more than one orientation (for example, stripe up and stripe down), the likelihood of a successful insertion increases.

Provide redundant, non-visual cues and instructions describing the proper card/ballot orientation, for example, creating a notch on the corner of the voter card as well as an arrow, providing two directional cues. A voice message describing the proper card orientation (e.g., "insert card with the magnetic stripe facing down and to the left") will be helpful to users with visual impairments. The ballot could feature a clipped corner that is distinct from the other three corners. Users could be audibly prompted to "insert the short end of the ballot with the clipped corner on the right-hand side."

Applicable Guidelines:

ADA-ABA – 707.5
Section 508 – 1194.31(a), 1194.31(b)
HFDS – 8.18.3.2
ICT – 302.1, 302.2, 302.7, 302.8, 407.3, 407.16

Users lacking fine motor control may have difficulty aligning and inserting a card.

This issue might apply to Concepts 1, 2, and 3.

Detailed Description: Precisely aligning a card with a card reader slot for insertion or swiping can be difficult for users lacking fine motor control.

Populations Impacted: Users with upper mobility impairments or limited dexterity.

Potential Solutions: *Design the card slot so that it guides the card into the slot.* A slot design with an opening that tapers into the insertion slot or a design that provides a clear area for the user to rest the card before sliding or inserting it reduces the amount of fine motor control required to interact with a card reader.

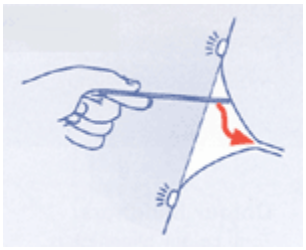


Figure 26: A tapered card slot facilitates insertion.

Provide a clear area around the card slot for users to brace their hands. Providing a space near the card slot where users can brace their hands to steady themselves and reduce tremors can help users perform actions more accurately.

Provide support for contactless card reading. Contactless cards (which use barcodes or RFID technology to store data) eliminate the need for the user to align and insert the card.

Applicable Guidelines:

Section 508 – 1194.31(f)
Section 255 – 1193.41(e)(2)(h)
HFDS – 6.4.1.1, 6.4.1.9, 6.4.1.16
ICT- 302.7, 302.8

The card reader does not eject the card far enough for users to grasp it.

This issue might apply to Concepts 1, 2, and 3.

Detailed Description: Card readers into which cards are fully inserted may not eject the card far enough for easy retrieval. Users with upper mobility impairments may find it difficult to grasp the edge of the protruding card.

Figure 27: The card is not ejected far enough to grasp easily.

Populations Impacted: Users with upper mobility impairments.

Potential Solution: *Ensure that the card is ejected a sufficient distance from the reader so that a large area of the card is available for the user to grasp.* The card should be ejected far enough so that users can easily grasp it between the thumb and lateral aspect of the index finger. Users should not be required to pinch the edge of the card with their fingertips.

Figure 28: The card is ejected far enough for easy grasping.

Applicable Guidelines:

ADA-ABA – 309.4
Section 508 – 1194.23(k)(2), 1194.25(c), 1194.31(f)
HFDS – 6.4.1.14
ICT- 302.7

Insufficient feedback is provided when a user forgets to retrieve a card.

This issue might apply to Concepts 1, 2, and 3.

Detailed Description: Users may forget to retrieve cards from card readers at the conclusion of the voting process, especially with card readers into which cards are fully inserted. When this occurs, the feedback provided by the voting machine may be unclear or insufficient.

Populations Impacted: Users who are blind; users with low vision; users with cognitive impairments.

Potential Solutions: *Require the user to remove the card before casting their vote.* Preventing the completion of the transaction until the card has been removed from the card slot will greatly reduce the likelihood of users forgetting to retrieve cards.

Provide a visual and audible alert to the user that the card has not been retrieved. The machine should remind users via an on-screen message as well as an auditory alert that the card has not been removed from the card reader. The alert should occur quickly enough (perhaps a few seconds after the card is able to be retrieved) that the user is notified before moving away from the machine.

Applicable Guidelines:

ADA-ABA – 707.5
Section 508 – 1194.31(a), 1194.31(b)
HFDS – 8.18.3.2, 8.18.4.1
ITC – 302.1, 302.2, 402.2

Issues associated with ballot verification and output areas

Many voting machines provide a paper print-out of a voter's selections, which enables the voter to verify that the vote will be cast as intended.

The printed ballot is not accessible to users with vision impairments

This issue applies to Concepts 1, 2, and 3.

Detailed Description: After completing a ballot, voters should be able to review their votes to ensure they will be cast as intended. The verification step may also ensure that the ballot's machine-readable code matches the human readable code (i.e., printed text). Many voting systems provide a method of ballot verification whereby an electronically marked ballot is printed, and the voter is permitted to review the printed ballot for verification. The voter then decides to cast the ballot or discard it and mark a new ballot. Printed ballots are not accessible to voters with vision impairments.

Populations Impacted: Users who are blind; users with low vision.

Potential Solutions: *Provide speech output for the verification function.* The ballot verification system should feature software for audio output and a headphone jack. The system should read aloud the ballot races and selected candidates. To reduce susceptibility to tampering, the ballot verification system should be entirely separate from the voting device.

Applicable Guidelines:

VVSG – 3.3.1-E.1
ICT – 302.1, 302.2, 402.2, 407.11, 502.2.9

Users may have difficulty locating the print-out area.

This issue applies to Concepts 1, 2, and 3.

Detailed Description: Because voters may be unfamiliar with voting machines, they may have difficulty locating the print-out area.

Figure 29: The printout/insertion slot on the top of the machine (right) is not clearly visible to seated users (left).

Populations Impacted: Users who are blind; users with low vision; seated users.

Potential Solutions: *Place the ballot insertion/printout slot in an accessible location.* Voters should be able to see and reach the slot so that they can use the machine without poll worker assistance.

Ensure that the output area is easy to distinguish from the rest of the machine. The output area should be prominently located on the machine, so that a searching user can find it quickly, and it should be tactilely identifiable. Avoid covering output with a door that the user must open; the door may hinder the ability of users to locate the output area by touch. The visual appearance of the output area should contrast with the machine, to assist users with low vision to locate it.

Provide visual and tactile labels. The output area should be clearly marked and labeled with a Braille label, raised text, or other tactile markings.

Describe the location of the output area to the user both visually and auditorily. Provide both on-screen text and/or graphics and auditory output indicating the location of the output area to the user, making use of obvious landmarks on the machine to establish the location (i.e., "printouts are dispensed below the keyboard").

Use an indicator light to draw a user's attention to the output area. When outputs are dispensed, illuminate an indicator near the output area to indicate its location and attract the attention of the user.

Applicable Guidelines:

ADA-ABA – 707.5

Section 508 – 1194.31(a), 1194.31(b)
Section 255 – 1193.41(a)(3)(b), 1193.41(i)(2)(a)
HFDS – 6.4.1.16, 6.4.1.18, 6.4.1.22, 6.4.1.28, 6.4.1.30
ICT – 302.1, 302.2, 407.3, 407.3.1, 407.11

Users are not sufficiently notified when outputs are present in the output area.

This issue might apply to Concepts 1, 2, and 3.

Detailed Description: On some voting machines, no indication that a print-out has been dispensed (other than mechanical sounds associated with the dispensing) is provided. This may result in users failing to realize that there is a print-out that needs to be retrieved, and leaving them behind when they finish voting.

Populations Impacted: Users who are blind; users with low vision; users who are deaf; users who are hard of hearing; users with cognitive impairments.

Potential Solutions: *Prompt the user to retrieve the print-out, both visually and auditorily*. Provide both on-screen text and/or graphics and auditory output indicating that a print-out has been dispensed, and describing the location of the output area to users. Consider providing a light in or near the output area that illuminates at the appropriate time to indicate the presence of the print-out.

Repeat prompts if outputs are not retrieved in a timely manner. If outputs remain in the output area after some period of time after the initial prompt (long enough to not be a nuisance to the user, but short enough that the user is notified before moving too far from the machine), prompt the user that there are still outputs that need to be retrieved. If the machine is attended, notifying the attendant may also be beneficial, so that the attendant can get the customer's attention and assist the customer with retrieving the items.

When possible, dispense all outputs into a single area. This enables users to retrieve all outputs at the same time, and avoids situations where users retrieve output from one area but forget to check other areas.

Ensure that outputs are clearly visible within the output area. Users should be able to tell at a glance if outputs are present in the output area. Outputs should be visible from either a seated or standing position.

Ensure that outputs are tactilely discernible within the output area. Design output areas so that users can quickly determine by touch if outputs are present. Ensure that outputs are ejected a sufficient distance from the machine to be tactilely located. Ensure that the output area does not provide any way for outputs to become hidden (for example, by slipping too far away from the opening of the output area).

Applicable Guidelines:

ADA-ABA – 707.5, 707.5.1
Section 508 – 1194.31(a), 1194.31(b), 1194.31(c)
HFDS – 6.4.1.12, 8.18.4.2
ICT – 302.1, 302.2, 402.2, 407.3, 407.16, 407.11

Users have difficulty retrieving outputs from the output area.

This issue might apply to Concepts 1, 2, and 3.

Detailed Description: Various aspects of the design of the output area, such as obstructions, the depth of the area, and the output ejection distance, may interfere with users' ability to retrieve outputs from the output area, especially for users with upper mobility impairments

Populations Impacted: Users with upper mobility impairments.

Potential Solutions: *Ensure that the outputs are ejected a sufficient distance from the machine to facilitate grasping by users.* When paper outputs such as verification ballots are output through a slot, ensure that enough of the item protrudes from the machine so that users can easily grasp it between the thumb and the lateral aspect of the index finger. Users should not be required to pinch the edge of the item with their fingertips.

Provide a cutout in output trays so that items can be grasped for removal. When paper outputs are dropped into an output tray, provide an open cutout in the tray that allows users to grasp the items from above and below for removal.

Ensure that the design of the output area does not interfere with removal of the outputs. Avoid covering the output area with a door that users must hold open while retrieving outputs. Ensure that there are no unnecessary lips or other obstructions around the output area that could interfere with the removal of outputs.

Applicable Guidelines:

ADA-ABA – 309.4
Section 508 – 1194.31(f)
HFDS – 6.4.1.12
ICT – 302.7, 302.8, 407.9, 407.11

Issues associated with audio output and headphone jacks

Many voting machines provide some form of audio output, ranging from simple beeps to speech output. Audio output should be provided through a headphone jack for privacy. Audio output can be used to greatly improve the accessibility of a voting machine, particularly for users with visual impairments.

A headphone jack on a voting machine allows users to connect a pair of personal headphones to the device in order to hear audio output from the device more clearly and more privately.

No headphone jack is provided on the device.

This issue might apply to Concepts 1, 2, and 3.

Detailed Description: Users with visual impairments often rely on audio output to interact with voting machines. Interference from ambient noise may make it difficult for users to perceive information provided via audio, especially for users who are hard of hearing. Use of headphones allows users to hear audio output more clearly and also enhances privacy. However, some voting machines do not provide a headphone jack.

Populations Impacted: Users who are blind; users with low vision; users who are hard of hearing.

Potential Solution: *Provide a headphone jack so that users can connect personal headsets to the device.* The headphone jack should use a standard headphone connector (a 3.5 mm pin is most common). External audio playback through speakers should be disabled when headphones are connected.

Figure 30: A headphone jack is provided for private listening.

Applicable Guidelines:

ADA-ABA – 707.5

Section 508 – 1194.25(e), 1194.31(a), 1194.31(b), 1194.31(c), 1194.31(d)
Section 255 – 1193.43(e)(2)(f)
HFDS – 8.18.4.2
ITC – 402.3.1, 406.1, 407.10

The voting machine does not support t-coil coupling.

This issue might apply to Concepts 1, 2, and 3.

Detailed Description: Assistive devices such as neck loops can transform electrical currents from headphone jacks to magnetic fluctuations. These magnetic fluctuations are transformed into sound by t-coils located inside hearing aids. Users who rely on audio output from the voting machine and who also have limited hearing may need to use t-coils to hear audio output.

Populations Impacted: Users who are blind and users with limited hearing.

Potential Solutions: *Equip the voting machine with a t-coil-compatible headphone jack.* The headphone jack should be the standard size of 3.5mm.

Applicable Guidelines:

VVSG – 3.3.3-C.2
ICT – 302.4, 406.1

Locating the headphone jack may be difficult for users with visual impairments.

This issue might apply to Concepts 1, 2, and 3.

Detailed Description: Headphone jacks are often used by users with visual impairments, who may have difficulty locating the headphone jack if it is not prominently located and tactilely discernible.

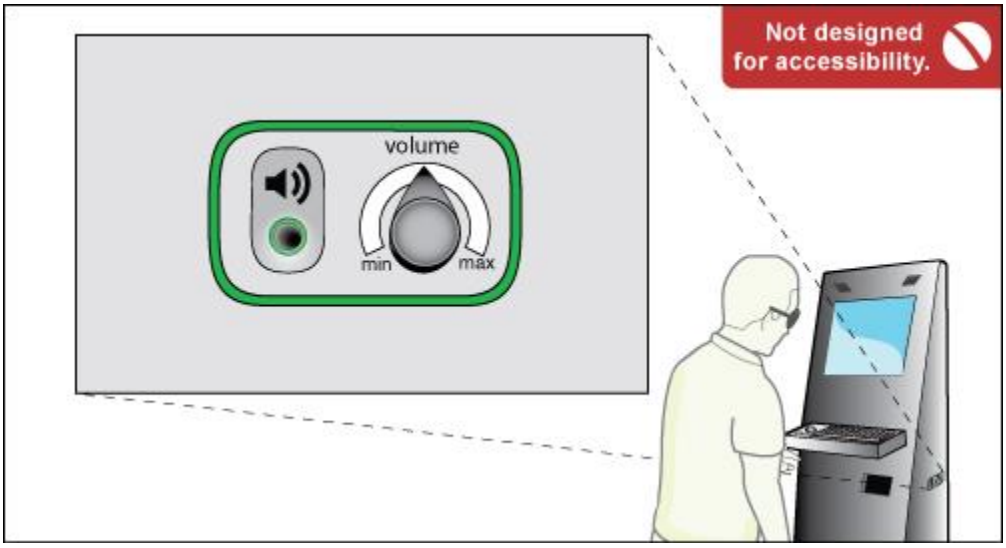


Figure 31: The headphone jack is located in an obscure location on the device.

Populations Impacted: Users who are blind; users with low vision.

Potential Solutions: *Place the headphone jack prominently on the device.* Place the headphone jack in a prominent location where users are likely to look or feel when searching for the jack. Avoid placing the jack in an obscure location (too low or too high on the device, on the side of the device, etc.).

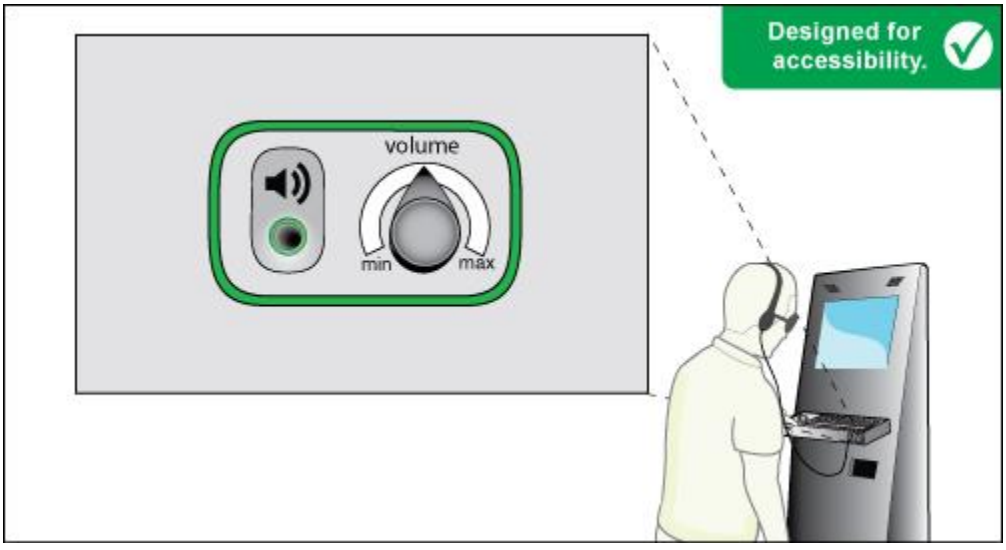


Figure 32: The headphone jack is located in a prominent location on the device.

Ensure that the headphone jack is tactilely discernible. The headphone jack should be identified with a Braille label or other raised marking. The jack itself should be raised above the surface of the machine (for example, surrounded by a raised ring). The jack should not be obscured behind a cover.

Ensure that the headphone jack is visually discernible. The headphone jack should be located in plain view on the device, and not hidden in an obscure location or behind a cover. Marking the headphone jack with a distinctive, high contrast color will also help users with low vision locate the jack.

Provide support for wireless headphone connectivity. The 3.5 mm connector (and to a lesser extent the 2.5 mm connector) are still the most common methods for connecting headphones. However, wireless technologies such as Bluetooth are becoming more prominent, and providing support for wireless headphone connectivity would help to eliminate many of the accessibility problems associated with headphone jacks.

Applicable Guidelines:

ADA-ABA – 707.5
Section 508 – 1194.31(a), 1194.31(b)
HFDS – 6.4.1.15, 6.4.1.18, 6.4.1.22, 6.4.1.28
ICT – 407.3, 407.3.1

The headphone jack does not use a standard connector.

This issue might apply to Concepts 1, 2, and 3.

Detailed Description: 3.5 mm headphone connectors are the most common, and are used for headphones for music devices. If the headphone jack does not support 3.5 mm headphone plugs, many users will be unable to connect their headphones to the device.

Populations Impacted: Users who are blind; users with low vision; users who are hard of hearing.

Potential Solution: *Provide at least a standard 3.5 mm headphone jack.* Support for other connectors, such as 2.5 mm headphone connectors or wireless technologies such as Bluetooth can also increase accessibility.

Applicable Guidelines:

ADA-ABA – 707.5
Section 508 – 1194.25(e)
Section 255 – 1193.51(b)
VVSG – 3.3.3-C.1
ICT – 302.4, 406.1

Users may have difficulty inserting a plug into a headphone jack.

This issue might apply to Concepts 1, 2, and 3.

Detailed Description: Inserting a small headphone plug into a headphone jack can be difficult, especially for users with visual impairments and users lacking fine motor control. The problem may be exacerbated if the headphone jack is located in a cramped space or if it is covered.

Populations Impacted: Users who are blind; users with low vision; users with upper mobility impairments.

Potential Solutions: *Do not cover the headphone jack.* Avoiding a cover on the headphone jack eliminates the requirement for users to open the cover before plugging in headphones, and also enhances visual and tactile discernibility of the headphone jack.

Avoid placing the jack too close to other controls, or in an area where access is obstructed. Users lacking fine motor control may find it easier to insert a plug if they are able to brace their hands while inserting the plug. Ensure that there are no obstructions around the headphone jack (for example, avoid placing the jack in an interior corner where two or more panel surfaces meet). Ensure that there are no controls near the headphone jack that may be accidentally activated when a user braces his or her hand.

Design the jack to help guide the plug into the jack. For example, provide a concave area around the headphone jack that helps to funnel the plug into the jack.

Applicable Guidelines:

ADA-ABA – 309.4
Section 508 – 1194.31(f)
HFDS – 6.4.1.1, 6.4.1.9, 6.4.1.12
ICT – 302.4, 302.7

The placement of the headphone jack causes the headphone cord to interfere with use of the machine.

This issue might apply to Concepts 1, 2, and 3.

Detailed Description: Headphones are typically attached to voting machines by a cord. The placement of the headphone jack could result in the headphone cord resting in an area where it interferes with the use of the machine (for example, the cord may hang over the controls). Moreover, if users must change positions to interact with different parts of the machine, headphone cords may restrict range of motion or become unplugged during movement.

Figure 33: The headphone jack location allows the cord to interfere with use of the machine.

Populations Impacted: Users who are hard of hearing, users who are blind; users with low vision; users with upper mobility impairments; users with lower mobility impairments.

Potential Solutions: *Consider the expected user interactions with the machine, and position the headphone jack so that the headphone cord does not interfere with use of the machine.* For example, the headphone jack could be placed on the front of the machine directly below the smart card slot.

Figure 34: The headphone jack location prevents the cord from interfering with use of the machine.

Position the headphone jack in a location that allows sufficient range of motion to perform all tasks. Consider the positions in which users, both seated and standing, will occupy when using the device, and place the headphone jack in a location central to those positions. Also consider wheelchair users who take either a forward or parallel approach. This will allow users the necessary range of motion so they do not accidentally unplug their headphones.

Provide support for wireless headphone connectivity. Wired connectors are still the most common methods for connecting headphones, but wireless technologies such as Bluetooth are becoming more prominent. Providing support for wireless headphone connectivity would eliminate interference from headphone cords.

Applicable Guidelines:

ADA-ABA – 308.2.1, 308.2.2, 308.3.1, 308.3.2
Section 508 – 1194.25(j)
HFDS – 6.4.1.12

Issues associated with speech input

Some voting machines enable complete user control through speech input. Voice commands operate controls that would otherwise be operated by buttons or a touch screen interface. Users who have difficulty operating controls and users with visual impairments may wish to use speech input. Issues in this section apply to all three LA County design concepts.

Speech input is not supported.

This issue applies to Concepts 1, 2, and 3.

Detailed Description: If a voting machine does not accept speech input, then some voters are required to use their upper limbs or a mouth stick to interact with the machine. The position of voting machines may make these options physically impossible or impractical for some users.

Populations Impacted: Users with upper mobility impairments; users who are blind.

Potential Solutions: *Enable speech input.* A speech input mode should be provided so that voters can interact with the machine without using their upper limbs or a mouth stick. A poll worker or a person selected by the voter should be able to easily activate the speech input mode.

Applicable Guidelines:

VVSG – 3.2.3.1
VSS – 3.2.4.1
ICT - 302.1, 302.2, 402.2, 402.2.1

The speech input mode is difficult to activate.

This issue applies to Concepts 1, 2, and 3.

Detailed Description: Voters may have difficulty finding and operating the control to activate the speech input feature. Users who need the feature typically have upper mobility impairments, which can impede their ability to activate small buttons placed in awkward positions.

Populations Impacted: Users with upper mobility impairments.

Potential Solutions: *Place a large mechanically operated button in a central location to activate the feature.* The button should be large enough and close enough to the user that he or she can activate it easily with a reaching aid or mouth stick.

Applicable Guidelines:

VVSG – 3.2.3.1
ICT – 302.7, 407.9

Speech input does not allow voter privacy.

This issue applies to Concepts 1, 2, and 3.

Detailed Description: If voters are required to speak the names of candidates, then their privacy will be compromised. Voters should be able to make their selections privately and without assistance.

Populations Impacted: Users who are blind or those with upper mobility impairments.

Potential Solutions: *Associate numbers or letters with candidates.* Allow voters to say the numbers or letters instead of candidate names. The system could say, for example, "To vote for Ross Perot, say 3." The condition (i.e., candidate) should be listed before the action (i.e. number). For example, the system should say "To vote for Ross Perot, say 3" rather than "Say 3 to vote for Ross Perot."

Allow voters to speak a common command as soon as they hear their candidate of choice. As an alternative to using numbers or letters, the system could allow voters to simply say "vote" or "select" when a candidate's name is presented. For example, the system could say, "To vote for Ross Perot, say vote." The candidate presentation order should be randomized.

Applicable Guidelines:

VVSG – 3.2.3.1
VSS – 3.2.4.1
ICT – 402.2, 407.10

No Microphone is provided.

This issue applies to Concepts 1, 2, and 3.

Detailed Description: The machine must be equipped with a microphone to accept speech input. Voters should not be required to bring their own personal assistive devices, such as a microphone, to the voting place.

Populations Impacted: Users with upper mobility impairments.

Potential Solutions: *Provide a built-in microphone in the voting machine.* The microphones should be positioned as close to the user as possible so that it can receive more sound from the user than from the surrounding environment.

Provide an external microphone that can be attached to the machine. An external microphone may be preferable to a built-in microphone, because the external microphone can be positioned on a boom near the user's mouth. This may provide better sound quality, resulting in fewer speech recognition errors.

Applicable Guidelines:

VSS - 2.2.7.2(a)
ICT – 302.7, 406.1

The speech recognition software does not allow easy correction of mistakes.

This issue applies to Concepts 1, 2, and 3.

Detailed Description: A voter may unintentionally select a choice, or the speech recognition software may erroneously process input. The voter should be able to easily and immediately correct the mistake.

Populations Impacted: Users with upper mobility impairments.

Potential Solutions: *Prevent mistakes by requiring voters to confirm selections.* Immediately after the software processes the speech input, the software should repeat the selection to the user and ask him or her for confirmation. For example, "You selected Ross Perot. If this is correct, say yes. If this is not corrected, say no."

Before the ballot is cast, provide a review screen that shows all of the voters' choices. Voters should be able to review their choices and make changes before casting the ballot. The review screen should be presented visually and audibly. Voters should be able to navigate the screen with voice commands (for example, by speaking a number or saying "down" to move the cursor). Instructions for screen navigation should be provided at the top of the screen. The instruction should be presented before (and while) the review is displayed, so that the voter can fully attend to the instructions first.

Applicable Guidelines:

VSS - 2.2.7.2(a)

Issues associated with indicator lights

Indicator lights on voting machines are lights that illuminate to convey information (such as system status) or to attract attention.

Information conveyed by indicator lights is not available to all users.

This issue might apply to Concepts 1, 2, and 3.

Detailed Description: Indicator lights depend on user vision to communicate information. Therefore, the information conveyed by indicator lights is not accessible to some users with visual impairments. The placement of indicator lights in certain locations on a voting machine may make it difficult for users in wheelchairs to see the lights. Additionally, indicator lights are not well suited to conveying complex information, and attempting to convey complex information via indicator lights may cause confusion for users, especially for users with cognitive impairments.

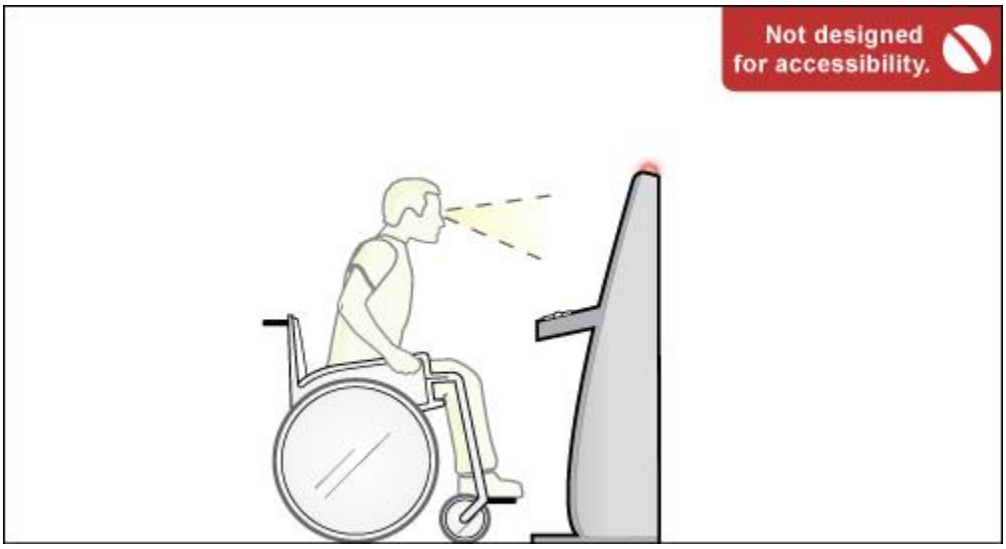


Figure 35: An indicator light is placed out of sight for a seated user.

Populations Impacted: Users who are blind; users with low vision; users with lower mobility impairments; users with cognitive impairments.

Potential Solutions: *Place indicator lights so that they are visible for both seated and standing users.* When placing indicator lights, consider the viewing angle of users who are accessing the machine from wheelchairs, and avoid placing lights in locations that are only visible from a standing position.

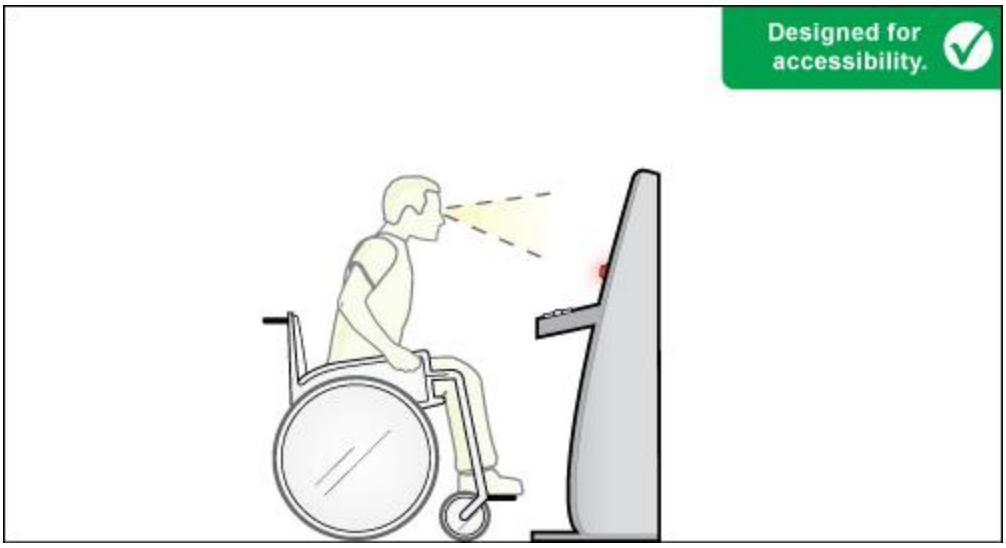


Figure 36: An indicator light is placed so that a seated user can see it.

Provide a redundant alternative to vision that conveys the same information that is conveyed visually. Providing audio output that communicates the same information that indicator lights convey will increase accessibility for users who cannot see the indicator lights due to visual impairments or due to the position from which they are using the machine. Simple audio output such as beeps can be used to indicate status, but the sounds must be recognizable and distinguishable to be effective. Voice output should be used to convey more detailed information.

Avoid communicating complex information via indicator lights. Indicator lights are well suited for conveying simple information that can be communicated by the presence or absence of a light. Using indicator lights to convey more complex information (for example, by requiring users to discriminate between flash rates or count a sequence of flashes) should be avoided. Complex information should be presented by means of text, graphics, or voice output.

Applicable Guidelines:

ADA-ABA – 707.5
Section 508 – 1194.31(a), 1194.31(b)
HFDS – 5.11.1, 5.1.2, 5.11.6, 5.11.8, 8.18.3.3
ICT – 302.1, 302.2, 502.2.9

Color coding should not be used as the sole means of conveying information.

This issue might apply to Concepts 1, 2, and 3.

Detailed Description: Indicator lights that use only a change of color (especially when the change is between red and green or between blue and yellow) as the only method of conveying information may be difficult for color blind users and some users with low vision to discern. For example, if a two-state light is used, with green representing the ready state and red representing a fault state, a user with red/green colorblindness may not be able to determine if the device is ready or is in a fault state.

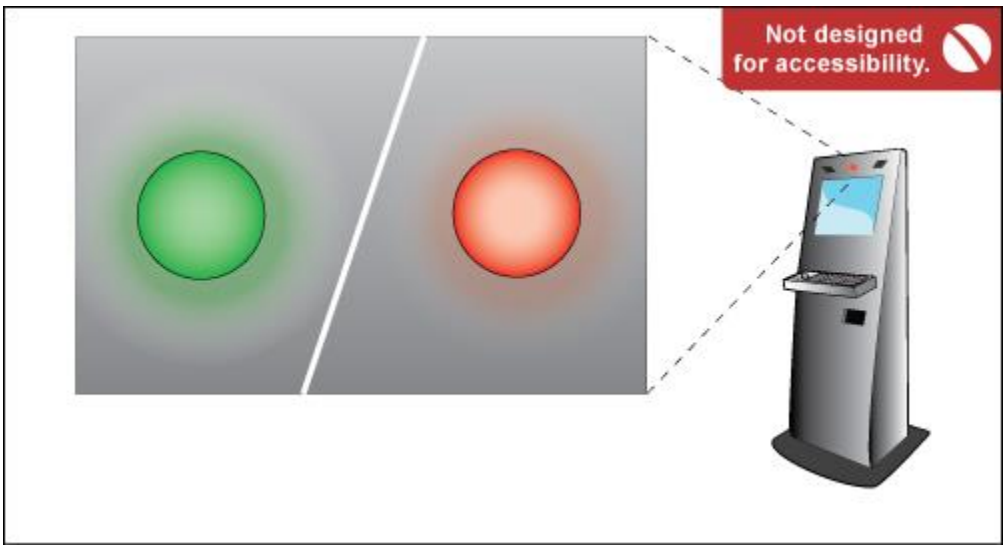


Figure 37: A single light illuminates red or green to indicate status.

Populations Impacted: Users who are color blind; users with low vision.

Potential Solutions: *Do not use color pairs that are easily confused by color blind users to convey information.* Red/green color blindness is most common; however, blue/yellow color blindness occurs occasionally. Total color blindness, where users are not able to perceive color and only see shades of grey, is extremely rare. Using color combinations other than red/green and blue/yellow to represent information will help avoid confusion among most users who are color blind.

Always provide a redundant alternative to color, such as text and/or location, which conveys the same information that the color conveys. Anywhere color coding is used, the message conveyed by that color coding should be conveyed through text as well, in order to ensure that color blind users have access to the same information that other users do. For instance, a text indication that says "Ready" when the voting machine is in the ready state could be provided. The text message would communicate the same information to a color blind user that the green light communicates to a non-color blind user.

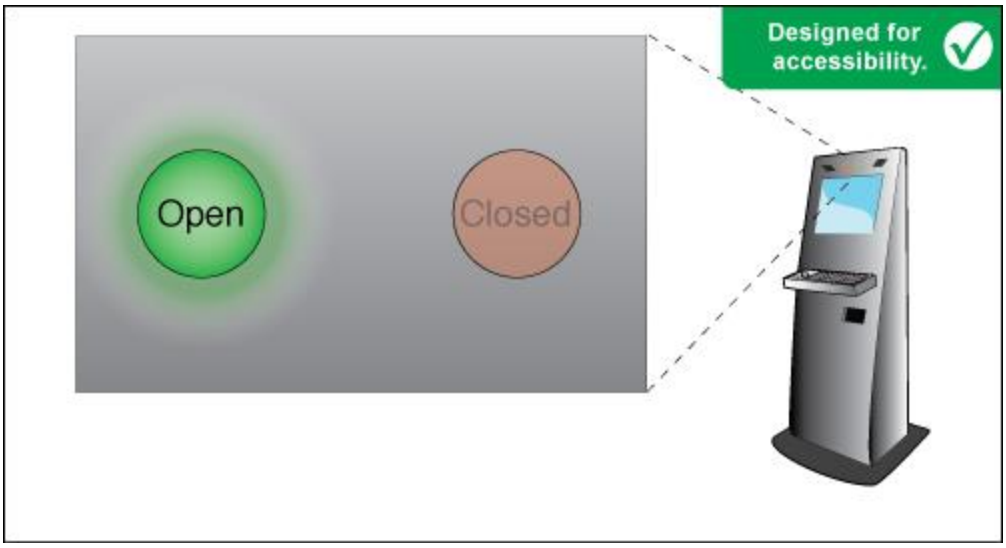


Figure 38: An example of redundant color coding and text.

Additional Comments: Although the solutions presented above will improve accessibility for those who are color blind (and for some with low vision), they in no way solve the problem for users who are blind and are therefore dependent on tactile or auditory differentiation of status information.

Applicable Guidelines:

Section 508 – 1194.25(g), 1194.31(a)
Section 255 – 1193.41(c)
HFDS – 8.6.2.1.5, 8.6.2.5.2
ITC – 302.1, 302.2, 302.3, 407.3, 407.3.1, 502.2.9

Overuse or misuse of indicator lights reduces their effectiveness.

This issue might apply to Concepts 1, 2, and 3.

Detailed Description: Indicator lights can be useful for communicating status to users or attracting the attention of users. However, overuse of indicator lights (especially lights with strong attention-getting qualities such as flashing or brightness) or misuse of indicator lights can be an irritation or a distraction to users, and can cause the lights to lose their attention-drawing power.

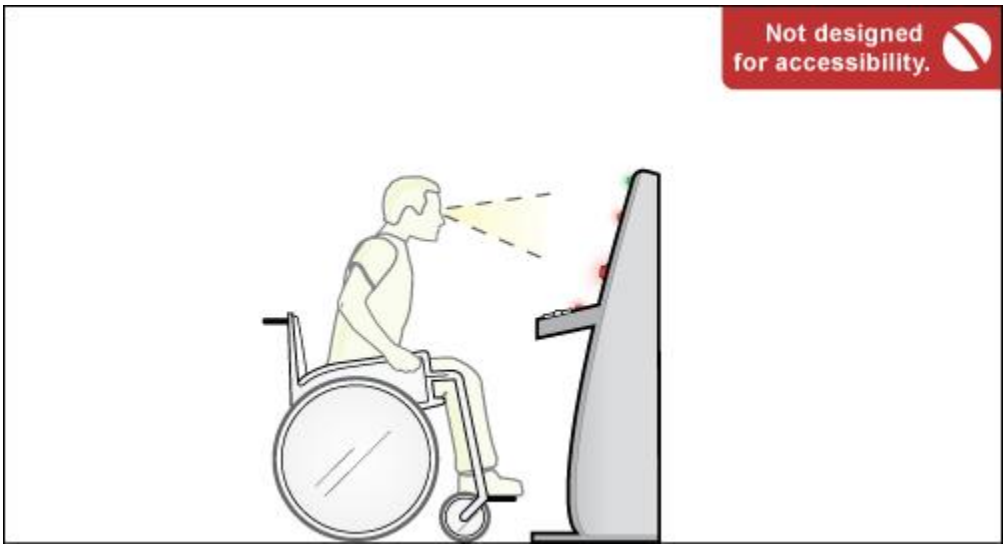


Figure 39: Overuse of indicator lights reduces their effectiveness for attracting attention or communicating information.

Populations Impacted: All users.

Potential Solutions: *Avoid overuse of indicator lights, particularly for non-critical information.* "Overuse" of indicator lights is subjective, and the threshold will vary from machine to machine. Generally, indicator lights should be used to communicate information that is important to the user (for example, that user input is required or that an error has occurred), and should not be used for decorative purposes, or to communicate information that is obvious in other ways (for example, a power light is unnecessary if it is obvious from the user interface that the machine is on).

The intensity of indicator lights should commensurate with their importance. The use of intense indicator lights (larger, brighter, flashing) should be reserved for situations where it is important to attract the user's attention (for example, when action is required or an error has occurred). More subtle (smaller, dimmer, non-flashing) indicator lights should be used for more mundane purposes, such as acknowledging successful user input.

Applicable Guidelines:

HFDS – 6.2.2.1.27, 6.2.2.3.3, 6.3.3.5

Flashing lights can trigger seizures in some users.

This issue applies to Concepts 1, 2, and 3.

Detailed Description: Lights that flash at certain frequencies may induce seizures in users with photosensitive epilepsy. Seizures are typically induced by flash rates between 2 Hz and 55 Hz, and flashing that occupies a large portion of the visual field is more likely to induce seizures.

Populations Impacted: Users with photosensitive epilepsy.

Potential Solutions: *Avoid flashing lights with flash rates between 2 Hz and 55 Hz.* If flashing indicator lights are used, ensure that the flash rate does not fall within these bounds.

Avoid flashing lights that occupy large areas. Flashing lights that occupy only part of the user's visual field are less likely to induce seizures than lights that fill the user's visual field. Therefore, flashing lights that cover large areas of the machine should be avoided.

Applicable Guidelines:

Section 508 – 1194.25(i)
Section 255 – 1193.43(f)
HFDS – 5.2.1.2
ICT- 302.9

Issues associated with writing space and temporary storage areas

Some voting booths provide a flat, clear space that users can use for temporary storage of personal items (purses or wallets, paperwork, etc.) while using the machine, or as a writing surface to mark paper ballots.

No space for temporarily placing belongings is provided.

This issue applies to Concepts 1, 2, and 3.

Detailed Description: Any user may have items in his or her hands when voting that they would like to temporarily set aside, such as a pre-marked ballot or a purse, in order to interact with the machine. Users with disabilities may have particular needs in this area – for example, a user with low vision might need to retrieve a magnifier from a bag, or a user with an upper mobility impairment might have only one functional hand to carry items and to interact with the machine.

Figure 40: A lack of space for temporary placement of belongings and paper ballots forces users to hold those items.

Populations Impacted: All users.

Potential Solutions: *Provide an area where users can temporarily place their belongings.* The storage area should be large enough to accommodate the sorts of items that users might typically carry in their hands (purses, umbrellas, etc.), and should allow users to place the items in a location that does not interfere with access to the machine. In terms of surface height, consider both standing users as well as those who may be in wheelchairs.

Figure 41: An area for writing or placing belongings is provided.

No space for writing is provided

This issue applies to Concepts 1, 2, and 3.

Detailed Description: Some voters may wish to bring pre-marked ballots to the polling place, and they may wish to modify them at the polling place before scanning and validating them. Voters may have difficulty making changes to their ballots without a writing surface.

Populations Impacted: All users.

Potential Solutions: *Provide a writing surface.* A writing area for seated users should be located at a height between 28" and 34" above the ground and no more than 10" behind the most forward point of the device surface. If the design of the machine does not allow placement of a single writing area that is usable by both seated and standing users, consider providing separate areas for standing and seated users. The area intended for seated users should conform to the location guidance above.

Applicable Guidelines:

Section 508 – 1194.31(f)
Section 508 – 1194.25(j)
HFDS – 6.4.1.1
ADA-ABA – 308.2.1, 308.2.2, 308.3.1, 308.3.2, 902.3, 904.3.3

Accessibility Issues and Potential Solutions Associated with Voting System Software

This section addresses accessibility issues that are associated with system software. These issues may not be directly relevant to hardware design, but they should be considered during software development. All issues below are applicable to all three LA County voting system concepts.

Issues associated with displays

The LA County Concepts provide output primarily through an electronic visual display. The displays are touchscreens and double as the primary user interface with the machine, although remote controls are also available.

Small text and icons are difficult for users with low vision to perceive.

This might apply to Concepts 1, 2, and 3.

Detailed Description: Text and icons on graphical user interfaces may be difficult for some users to read if they are too small.

Populations Impacted: Users with low vision.

Potential Solutions: *Ensure that the font size used for text is sufficiently large.* For 20/20 vision, the Human Factors Design Standard (HFDS) recommends that the height of characters occupy a visual angle of 16 to 24 minutes of arc. To compute the character height, use the following formula

$$h = 2d\text{Tan}(x/2)$$

where h is the character height, d is the viewing distance, and x is the desired angle in radians. (One radian equals 3437.747 arc minutes, or 57.296 arc degrees.)

1194.31(b) of Section 508 states that a mode that does not require visual acuity greater than 20/70 must be provided. Multiplying the character height (h) calculated for 20/20 vision by 3.5 (70/20) yields the recommended character height for 20/70 vision for the specified viewing distance.

While this font size may not be possible for all on-screen text (including control labels, ballot instructions, and other textual information), making the text as large as possible will increase the chance that users with low vision will able to read the text.

Ensure that icons are large enough for low vision users to see. The largest dimension (height or width) of icons should be at least as large as the character height calculated above. Icons should be made as large as possible, given the space available.

Provide contrast adjustment for the display. Although users with low vision prefer and generally require larger fonts, they may be able to read smaller fonts if the contrast is sufficiently high. Provide a range of contrast settings for the user to adjust through a hardware control. (Software controls are problematic, because if the contrast is insufficient for the user, the user may not be able to read the display in order to find the contrast adjustment controls.)

Provide an alternate display mode with larger fonts and high contrast options. A user-selectable alternate display mode that uses larger fonts and provides high contrast options, even if it contains only the most important information and controls, will be useful for users with low vision.

Provide alternatives to the visual display to facilitate interaction by users with low vision. A voice display should be integrated into the machine, so that visual content is presented in an auditory fashion as well. For example, using a set of hardware controls, the user could navigate through configuration menus that are voiced, without having to read the menus on the display.

Applicable Guidelines:

ADA-ABA – 707.5
Section 508 – 1194.31(b)
Section 255 – 1193.43(b)
HFDS – 5.11.1, 5.11.7, 8.2.5.6.5, 8.2.5.6.6, 8.2.5.6.9, 8.18.3.1
VSS – 2.2.7.2(b)
ICT – 302.2, 402.4, 407.2

Complex or inconsistent user interface screens may be difficult for users to understand.

This might apply to Concepts 1, 2, and 3.

Detailed Description: User interfaces that are complex (for example, displays that contain many controls associated with multiple tasks) can be difficult for users with cognitive impairments to navigate. Inconsistencies in displays, such as changes in control placement from screen to screen or inconsistent use of terminology, can be confusing to users with cognitive impairments. Similarly, inconsistent or excessive use of abbreviations can decrease reading comprehension for users with cognitive impairments. Maintaining consistency and keeping the interface as simple as possible are important usability considerations, and will improve the accessibility of the machine to all users.

Populations Impacted: Users with cognitive impairments.

Potential Solutions: *Reduce the complexity of user interface screens where possible.* Design screens around individual user tasks (for example, a voting machine might have one screen dedicated to each race). Avoid complex displays that contain a large number of options and controls.

Place common controls consistently throughout the user interface. If there are controls that appear on multiple screens, such as navigation controls, ensure that the placement of those controls is the same on every screen.

Use consistent terminology throughout the user interface. Ensure that names and abbreviations are applied consistently throughout the user interface.

Limit the use of abbreviations. Abbreviations (especially those that may be unfamiliar to users) should be used sparingly in the user interface.

Applicable Guidelines:

Section 255 – 1193.41(i)(2)(a)
HFDS – 2.3.1, 4.3.5.4.1, 8.2.5.4.4, 8.2.5.4.8, 8.2.11.1.2, 8.14.1.10
VVSG – 3.2.4-C

System time-outs may cause problems for some users.

This might apply to Concepts 1, 2, and 3.

Detailed Description: The user interface for voting machines may include system time-outs, which are situations where the user interface automatically changes states or resets if user input is not received within a certain time period. People with disabilities often require more time to respond than non-disabled users, so system time-outs can disrupt their transactions if they are not notified that a time-out has occurred and allowed to request more time.

Populations Impacted: Users with cognitive impairments; users with upper mobility impairments; users who are blind; users with low vision.

Potential Solution: *Alert users when a time-out occurs, and allow them to request more time.* When a system time-out occurs while the user is performing a task, the user should be alerted that the time-out has occurred, and given the option to request more time or cancel the task. The user should be given sufficient time to respond to the alert before it expires. A good rule of thumb for what constitutes sufficient time is 10 times the amount of time it would take an average user respond.

Applicable Guidelines:

Section 508 – 1194.25(b)
Section 255 – 1193.41(g), 1193.41(i)(2)(f)
HFDS – 8.18.2.2
VSS – 2.2.7.2(g)

When scrolling is required to see all candidates, the user is not notified that scrolling is possible.

This issue might apply to Concepts 1, 2, and 3.

Detailed Description: When there is too much information to fit on a single screen (for example, if the list of candidates is very long), users may be expected to scroll through the display.

Populations Impacted: Users with cognitive impairments.

Potential Solutions: *A clear indication that scrolling is available should be provided to users.* This can be accomplished by providing obvious scrolling controls as part of the visual interface, and by announcing the total number of candidates available in the audio interface. When a list of candidates is long enough to require scrolling, the presentation order of candidates should be randomized to offset presentation order effects.

Applicable Guidelines:

VVSG – 3.3.6(a)

Issues associated with the system's response to user input

It is important for the system to respond to user input in a timely and appropriate manner. A good interface must provide feedback to users. The user interprets feedback in order to determine whether input was received, whether the desired action was executed, and whether the desired consequences were achieved. Alerts and error messages are special notifications that indicate to the user when certain actions should or must be taken. Feedback is generally provided visually or audibly. Audible feedback should maintain voter privacy, and may consist of simple auditory signals that indicate acceptance of user input. Audible feedback should be provided through headphones only, so that users cannot hear feedback from adjacent voting machines.

The voting machine does not provide sufficient feedback to the user.

This issue might apply to Concepts 1, 2, and 3.

Detailed Description: Users with different disabilities have different needs for the amount and type of feedback provided by a voting machine. The feedback that is provided may be insufficient because it does not cover the full range of events for which feedback is required, or it may be insufficient because it is provided in a form that is not useful to a user with a particular disability (for example, visual feedback indicating that input has been accepted is not useful to a user who is blind). Providing feedback for a wide range of events and user actions in a variety of sensory modalities is beneficial for all users.

Populations Impacted: Users who are blind; users with low vision; users who are deaf; users who are hard of hearing; users with upper mobility impairments.

Potential Solutions: *Ensure that feedback is provided for all relevant events.* Provide feedback for all user inputs, system status changes, user or system errors, and other events that are relevant to the user's interaction with the machine. Feedback for different events should be distinct from one another and appropriate to the events represented. For example, a simple click may be sufficient to acknowledge a key press, but a more prominent tone may be necessary to indicate that an error has occurred.

Provide feedback in a visual format. Visual feedback is necessary for users with hearing impairments, but it can also be helpful for users with low vision (if the feedback is sufficiently large or if it also makes use of color or other visual cues), and for users with upper mobility impairments (to help the user determine when unintentional inputs have been made).

Provide feedback in an auditory format. Auditory feedback is necessary for users who are blind, and it can also be helpful for users with low vision and for users with upper mobility impairments. Beeps and other sounds help users know that input was accepted (e.g., a candidate was selected), and also serve to alert users if an unintentional input was made. Voice output of more complex data (such as, "Are you sure you want to submit

your ballot?") helps users with visual impairments verify transactions and allows them to operate voting machines more effectively.

Applicable Guidelines:

ADA-ABA – 707.5
Section 508 – 1194.31(a), 1194.31(b), 1194.31(c), 1194.31(d)
Section 255 – 1193.43(a)(2)(a)
HFDS – 2.6.1, 5.11.1, 5.11.2, 8.15.8.3, 8.18.3.2, 8.18.4.1
VSS – 2.2.5.2.2, 2.2.7.2(h)
ICT – 302.1, 302.2, 302.4, 502.2.9

Users cannot change cursor focus without making a selection.

This issue might apply to Concepts 1, 2, and 3.

Detailed Description: Users of screen readers sometimes move the cursor among screen elements so that the assistive technology will read aloud the elements that receive focus. Some interfaces are designed to automatically select the focused element. This prevents users of screen readers from being able to hear the elements without selecting them.

Populations Impacted: Users who are blind.

Potential Solutions: *Allow cursor movement without selecting items.* Provide a "select" button that is independent of the controls that move the cursor.

Applicable Guidelines:

ICT- 502.2.8, 503.2, 602.2

System response time to user input is slow.

This issue might apply to Concepts 1, 2, and 3.

Detailed Description: Users rely on timely feedback from the system in response to their inputs. If feedback is not provided in a timely fashion, users may conclude that their input was not accepted and try again, leading to multiple activation errors. This is a usability problem for all users, but it may exacerbate difficulties for users who are more prone to making input errors (e.g., users who are blind or who lack fine motor control).

Populations Impacted: Users who are blind; users with low vision; users with upper mobility impairments.

Potential Solutions: *Minimize system response lag time.* The system should provide timely feedback to the user. The system should provide some response to user input within 500 ms. If the system response to a user input takes longer than 500 ms, an interim "in progress" indication should be displayed to acknowledge that the input was received and is being processed.

Allow easy recovery from errors. A "Back" or "Undo" button should be provided to allow users to recover from multiple activation errors or accidental inputs. Note that a button labeled "Cancel" is somewhat ambiguous; a user may think that a "Cancel" button will cancel the entire ballot, rather than cancel only the most recent input.

Applicable Guidelines:

Section 508 – 1194.25(b), 1194.31(f)
HFDS – 2.6.1, 6.3.1.5, 6.3.1.6, 8.8.2.24, 8.15.8.13, 8.15.11.1.13, 8.15.11.1.14

The voting device changes the ballot automatically based on assumptions about user intent.

This issue might apply to Concepts 1, 2, and 3.

Detailed Description: Voting devices may attempt to streamline the voting process by providing default selections or by attempting to resolve errors automatically. Although these actions may sometimes be appropriate, care must be taken to ensure that final control over voting selections remains with the user.

For some electronic voting machines, the first option listed for a particular office is automatically selected by default. This may be confusing for users with cognitive disabilities, because it may appear that they have already made a selection. They may proceed to the next screen without realizing that they voted for a candidate.

Some voting devices automatically deselect options when voters attempt to make more than the maximum number of selections for a contest. This could be appropriate when there are mutually exclusive options for a contest, but should not occur when users can select more than one option for a particular contest.

Populations Impacted: Users with cognitive impairments.

Potential Solutions: *Options should not be pre-selected.* None of the options on the ballot should be selected without the user actively selecting those items. If the user does not actively select one of the items, then an undervote should occur.

Users should be notified that they have exceeded the allowable number of selections. When more than one selection is allowable, users should be notified if they have exceeded the allowable number of selections so that they can deselect candidates as desired before making additional selections.

Applicable Guidelines:

HFDS – 8.2.11.7, 8.12.1.13, 8.12.1.14

Issues associated with audio output

Many voting machines provide some form of audio output, ranging from simple beeps to speech output. Audio output should be provided through a headphone jack for privacy. Audio output can be used to greatly improve the accessibility of a voting machine, particularly for users with visual impairments.

The volume level is insufficient.

This issue might apply to Concepts 1, 2, and 3.

Detailed Description: Some users may have difficulty hearing audio output at default volume levels, particularly if the device is located in a noisy environment. Users with vision impairments may rely exclusively on auditory information to use the device, so it is important to ensure that the output volume can be adjusted to sufficient level.

Populations Impacted: Users who are hard of hearing; users who are blind; users with low vision.

Potential Solution: *Provide sufficient output volume and range of adjustment through the built-in speakers and the headphone output.* The range of volume available should be implemented as described in Section 508 guideline 1194.25(f). Controls that allow users to adjust the output volume within the range specified in 1194.25(f) should be provided.

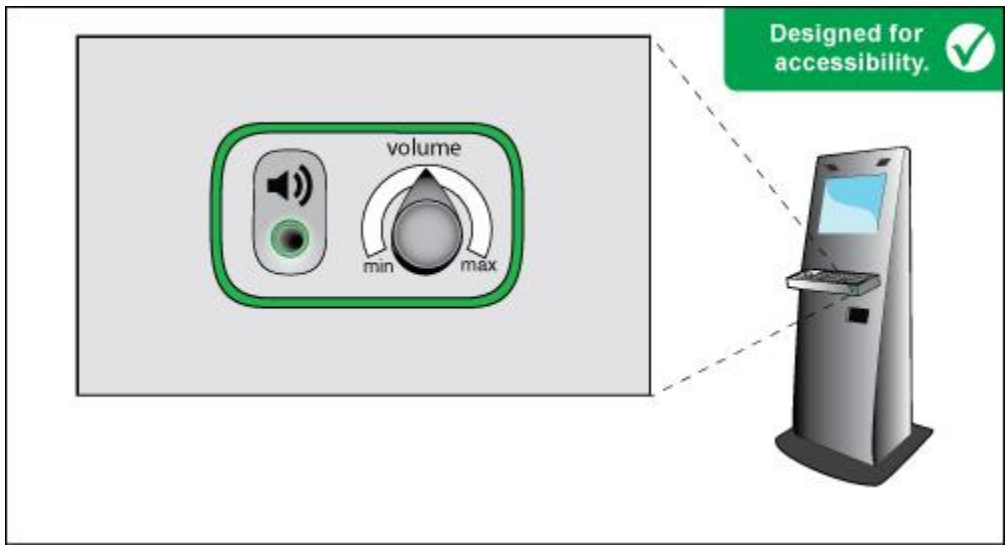


Figure 42: A volume knob is provided to allow the user to adjust the output volume.

Applicable Guidelines:

Section 508 – 1194.25(f), 1194.31(a), 1194.31(b), 1194.31(c), 1194.31(d)
HFDS – 8.18.4.2
ICT – 302.1, 302.2, 403.2.1, 408.2

Non-verbal audio output is not meaningful.

This issue might apply to Concepts 1, 2, and 3.

Detailed Description: In addition to verbal output, some voting machines use simple non-verbal audio output (i.e., beeps or tones) to communicate information to users. These tones may not be meaningful in the absence of accompanying verbal information, such as an on-screen message or graphic. Users with visual impairments may not have access to visual information, and may therefore have difficulty interpreting the meaning of non-verbal audio output. Users with cognitive impairments may also have difficulty understanding the meaning of non-verbal audio output.

Populations Impacted: Users who are blind; users with low vision; users with cognitive impairments.

Potential Solutions: *When possible, select sounds with characteristics that convey meaning.* It is difficult to convey meaning through simple sounds in a way that is universally understood, but it may be possible in some situations. For example, a "positive" sound (a "ding" or a rising tone) could be used to indicate that input has been accepted, and a "negative" sound (a "buzz" or a descending tone) could be used to indicate that input has been rejected.

Consider using non-verbal sounds only to convey very simple information. For example, a "click" sound could be used to indicate that a key-press has been accepted. The information is conveyed by the presence or absence of the sound, and not by the characteristics of the sound. When using sounds in this way, ensure that the sounds are temporally matched with the associated event, so that the relationship between the event (for example, a key-press) and the sound is clear.

Use verbal messages to convey information. When detailed information needs to be conveyed via sound, use verbal information to explicitly and unambiguously convey the information. This eliminates the requirement for users to interpret the meaning of the sound, and also serves as a redundant means of providing the information, which benefits users with visual impairments.

Applicable Guidelines:

ADA-ABA – 707.5
Section 508 – 1194.31(a), 1194.31(b)
HFDS – 7.2.1.2, 7.2.1.4, 7.2.1.7, 7.2.1.8
ICT – 302.1

Voice output is difficult to understand due to poor sound quality or interference.

This issue might apply to Concepts 1, 2, and 3.

Detailed Description: Voice output may be difficult for some users to understand because the device's speakers are not capable of reproducing the voice output clearly and without distortion, particularly at higher volumes. Other sounds that accompany voice output, such as background music, may also make it more difficult for users to understand the content of voice messages.

Populations Impacted: Users who are blind; users with low vision; users who are hard of hearing; users with cognitive impairments.

Potential Solutions: *Ensure that the device's speakers are capable of reproducing voice output legibly through the full range of output volumes.* The range of volume available should be implemented as described in Section 508 guideline 1194.25(f). The speakers used in the device should be tested to ensure that they are capable of reproducing voice output clearly and without distortion through the entire range of volume adjustments.

Avoid background music or other sounds that may reduce the legibility of voice output. Background music or other sound effects that are played back at the same time as voice output messages may be distracting, and may reduce the legibility of the voice output.

Ensure that information conveyed by voice is accompanied by a redundant visual presentation. Providing redundant visual information (for example, via on-screen text or graphics) may help users who are hard of hearing obtain the information.

Applicable Guidelines:

ADA-ABA – 707.5
Section 508 – 1194.25(f), 1194.31(a), 1194.31(b), 1194.31(c), 1194.31(d)
Section 255 – 1193.43(e)(2)(a), 1193.43(e)(2)(e)
HFDS – 7.3.2.1, 7.3.2.2, 8.18.4.1, 8.18.4.2
ICT- 402.3.2

The rate at which speech output is provided is not adjustable.

This issue might apply to Concepts 1, 2, and 3.

Detailed Description: Users who are accustomed to using speech output often become proficient at understanding speech output delivered at a very high rate. However, users with recent visual disabilities, especially when coupled with cognitive impairments, may not be as proficient with speech output systems

Populations Impacted: Users who are blind; users with low vision.

Potential Solutions: *The rate of audio output should be adjustable*. There are several things to address for this issue. The primary issue is that the rate of speech output is not adjustable. But other issues can also arise, even if the rate is adjustable. If not implemented properly, speech may become distorted at high or low speeds. Also, one system GTRI observed allowed users to adjust the "rate," which merely shifted the pitch of the voice, without actually reducing or extending the amount of time required to listen to the speech output.

Voice output is not repeated.

This issue might apply to Concepts 1, 2, and 3.

Detailed Description: Users may fail to hear or understand voice output messages when they are first presented. If the messages do not repeat, either automatically or under user control, then users may be unsure how to proceed with their interactions with the device.

Populations Impacted: Users with cognitive impairments; users who are hard of hearing; users who are blind; users with low vision.

Potential Solutions: *Repeat voice messages automatically if the user does not respond within some period of time.* If the user fails to respond or take action within a reasonable amount of time (a few seconds) after a voice message is presented, repeat the voice message.

Provide a control that allows the user to request that voice messages be repeated. This will allow users to listen to messages again if they did not hear or understand the message initially. Ideally, the repeat control should be a physical control (as opposed to an on-screen control) and should be tactilely discernible to increase the accessibility of the control for users with visual impairments.

Applicable Guidelines:

ADA-ABA – 707.5.1
Section 508 – 1194.25(e), 1194.31(a), 1194.31(b), 1194.31(c)
Section 255 – 1193.43(e)(2)(d)
HFDS – 8.18.4.2
ICT- 402.2

Audio output via speakers may be inappropriate due to privacy concerns.

This issue might apply to Concepts 1, 2, and 3.

Detailed Description: Audio output may be required for some users to interact with voting machines. The audio output may need to be at a relatively high volume to overcome ambient noise or to accommodate users who are hard of hearing. However, much of the information provided by voting machines should remain private, rather than being broadcast over speakers.

Figure 43: Potentially sensitive audio is output through speakers.

Populations Impacted: Users who are blind; users with low vision; users who are hard of hearing.

Potential Solutions: *Provide a headphone output.* An industry standard 3.5 mm headphone jack should be used.

Figure 44: A headphone jack is provided for private listening.

Avoid outputting potentially sensitive information through speakers. Due to privacy concerns, information regarding a user's votes should not be broadcast through speakers. Rather, it should be delivered only through the headphone jack.

Applicable Guidelines:

ADA-ABA – 707.4, 707.5
Section 508 – 1194.25(e), 1194.31(d)
Section 255 – 1193.43(e)(2)(e)
HFDS – 8.18.4.2
VVSG – 3.2.3.1-A.2, 3.2.3.1-A.3
ITC – 402.2, 402.2.1,407.10, 402.3.1

Major Findings and Recommendations

The voting system concepts are in an early stage of development at which many design decisions are unspecified. Therefore, the accessibility issues described above may serve as a prospective guide to further development, rather than retrospective guide to design revisions. However, some high-level design issues were identified in the Concepts, and these are summarized below in order of priority.

Universal Design: A Single System

One of the main goals of the VSAP initiative is to ensure a universal design. A system designed for seated reach and visibility is unlikely to be easy to use for standing voters, and vice versa. Each of the three design concepts appear to cater towards either standing users or seated users. Concept 2 appears to be designed for standing users, because the display is angled for standing but not seated users. Also, the ballot insertion/printout slot may be difficult to reach for seated users. Concepts 1 and 3 appear to be designed for seated wheelchair users, because their maximum heights are appropriate for seated users. They would limit the functional reach/range of standing users and make it more difficult for standing users to view the voter interface. Concept 3 might be suitable for standing users if placed on a table with the legs retracted, but Concept 1 is not amenable to this solution.

Concept 2, with a few minor design modifications, appears more likely to meet the needs of both seated and standing users than either of the other concepts, due to their rigidity. Concept 2 could feature adjustable, telescoping legs that could adjust the overall height. The display angle could also be adjusted by shortening the front legs only.

Universal design is crucial. The decision to create two separate systems would lead to two classes of voting systems – a heavily used standing system and a less frequently used seated system. The creation of two systems may lead to a situation in which county resources and poll worker attention are devoted more heavily to the standing system. Separate seated and standing systems might result in outdated seated systems (e.g., decreased use may result in decreased maintenance and software updates), insufficient numbers of seated systems at each polling place, less desirable positioning of seated systems, and a social stigma for seated users. A preferable design approach would be to create a single system that could be adjusted for seated or standing users. The systems should feature common hardware and software. Poll workers and/or voters should be able to easily adjust the system's height.

Design Recommendation: A single system should be designed with accessibility features and adjustments, rather than creating a standard system and a separate accessible system.

Accessibility of the Tactile Control

All three design concepts feature a remote control. A properly designed tactile control will provide access for users with visual impairments and upper mobility impairments. However, users with visual impairments may have difficulty determining the function of each button,

because they will be unable to see visual labels. Braille labels may be insufficient, given that many individuals with visual impairments cannot interpret Braille. Therefore, buttons should be intuitively shaped so that voters can tactilely discern their function, and the total number of buttons should be limited. Concept two depicted a control with 8 buttons, including a 4-directional button. This design is likely to be confusing to voters with visual impairments who may have difficulty discerning the different functions of the many buttons.

Very little research has been conducted on the optimal number of buttons needed for a tactile control, particularly for a voting system. A study of button configurations for texting on cell phones found that the optimal number of keys was 8 out of a total of 64 possible keys. (Maeda, Tani, Ito, & Miyakawa, 2001). The authors created a computational model that demonstrated the tradeoff between cognitive workload and operational workload. Cognitive workload increases when users must search a large number of buttons. Operational workload increases when additional operations must be performed (e.g., to type "C," press the "ABC" key three times). The authors presented evidence that overall workload, composed of cognitive and operational loads, was minimized with the 8 key configuration. Note that this optimal number (8) cannot be generalized and applied to the voting machine: With the exception of writing in a candidate's name, the number of input options on a voting machine is considerably less than 64. However, the principle of balancing cognitive workload with operational workload might be generalizable to the context of voting machine design.

We found no similar studies that were directly applicable to navigating on-screen options, such as candidates in an election. This prompted GTRI to conduct a series of studies to investigate further. The most recent of these studies (currently unpublished) showed that many older adults had difficulty using a button interface to navigate the ballot, and the level of difficulty increased as the number of buttons increased on the control interface (2, 3, and 5 button versions were evaluated). Many older participants reported that the additional buttons were confusing. This finding might generalize to other populations, such as those who are unfamiliar with computer interfaces, individuals with cognitive impairments, and individuals with vision impairments who may have difficulty differentiating the buttons and remembering button locations.

GTRI recommends a remote or tactile control with only 3-4 buttons. Two buttons should be dedicated to directional navigation through onscreen items; these should be shaped as arrows/triangles (see the example in Figure 45). The third button should correspond to "enter/select." An optional fourth button, which should be shaped differently than the "enter/select" button, could be used for accessing system help. Alternatively, system help could be accessed through an on-screen button.

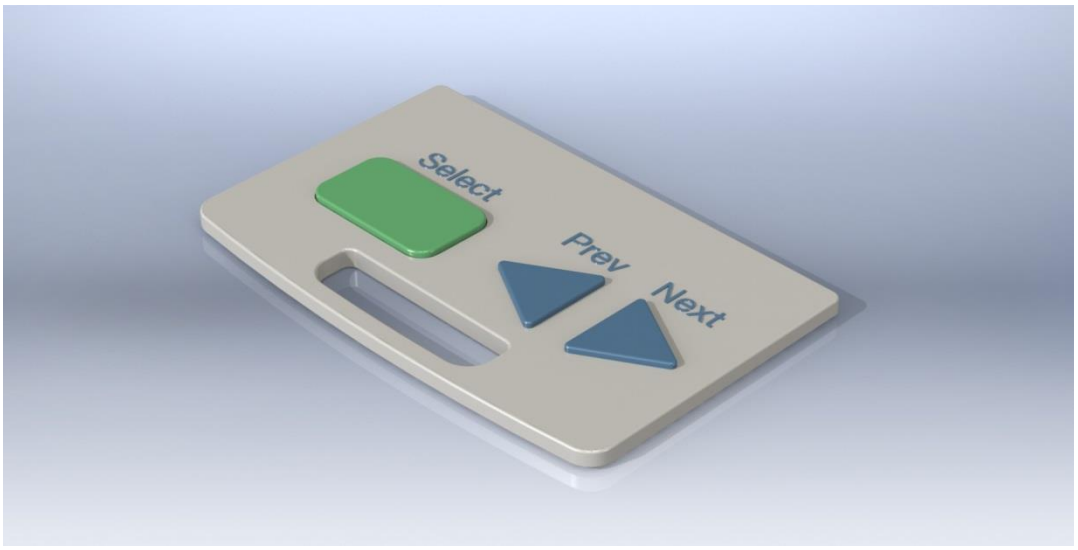


Figure 45. 3-button controller designed for GTRI's iPad case (in work)

As with most design decisions, the button configurations are not without tradeoffs. Note that the choice of only two directional buttons, which serve strictly linear navigation through the onscreen buttons, may be less efficient for some voters who might prefer four directional buttons (i.e., up/down/left/right). However, the 4-button solution may be more confusing for many users, and it may cause blind/low vision users to become disoriented.

Also note that a "next page" and "previous page" buttons could be provided to make navigation more efficient. Again there is a trade-off between navigation efficiency and interface complexity; increased complexity may cause confusion. Along these same lines, the software, as well as the tactile and/or touchscreen design should preclude unintentional navigation between contests. A review of current voting systems shows that users had difficulty with tactile controls that did not differentiate navigation between contests and between candidates (or voting options), sometimes causing accidental movement between contests. If only two directional buttons are provided, their function should be exclusively dedicated to moving an onscreen cursor. Navigation between pages should be accomplished by selecting and "pressing" onscreen buttons for *next page* and *previous page*.

Design Recommendation: Limit the number of buttons on the remote control. Make each button a distinct shape, and arrange the buttons in a configuration that intuitively reflects their functions.

Physical Accessibility of System Components

Each of the three design concepts included at least one system component that may be difficult to reach and view for seated users (see the section entitled, "Issues associated with reach and visibility"). Seated users should be able to reach and view all components with little or no torso movement.

Additionally, incorporating adjustability of both the software interface and the hardware is necessary for both seated and standing users. Parallax, glare, and other visibility limitations described in previous sections could be easily eliminated with the ability to tilt the touchscreen.

Design Recommendation: Ensure that all components of the system are reachable and viewable from a seated position, and ensure ample knee and toe clearance allows for a forward approach in a wheelchair.

Ballot Verification

Voting systems should feature a method for voters to verify that their ballots were marked as intended. If LA County will use a voter verifiable paper audit trail, then all voters should have the opportunity to verify the printed record. The most straightforward method for verification is for the electronic ballot marking machine to provide a printout to the voter, but this method is not accessible to voters with vision impairments.

The original IDEO voting system concepts for LA County (07/13) featured paper ballot verification methods that could have incorporated accessibility features. These concepts included a second voter station at which the voter would verify the ballot that was electronically marked and printed at the first station. Accessibility affordances could be provided at the second station (e.g., the system could audibly read the voter's selections). In contrast, the revised concepts (10/2013) do not provide an accessible method for voter verification of a printed ballot. Voters with disabilities should have the same opportunity for ballot verification that is afforded to voters without disabilities (VVSG 3.2.2.1(g)).

If the county chooses not to implement a voter verifiable paper audit trail, then ballot verification can be performed on the electronic ballot marking system (i.e., ballot marking and verification can occur on the same machine), and accessibility affordances can be provided. Note that, per VVSG 1.1, Chapter 7.8, a single system is more susceptible to tampering and fraud.

Design Recommendation: Provide a method of ballot verification that is accessible to users with vision impairments.

Next Steps in Design and Evaluation

Accessibility issues should be addressed throughout the design process. The three main accessibility evaluation techniques are **functional assessments, checklist evaluations, and user testing**. The accessibility evaluator may combine two or more of these techniques to produce results that meet the goals of the evaluation.

Formative evaluations of design concepts, which should be conducted early and/or iteratively during the design processes, may include functional assessments and user testing. Summative evaluations of the final or near-final design may include checklist evaluations and user testing. If the summative evaluations reveal deficiencies, then the design could be modified or polling place procedures could be adapted to address the deficiencies.

Functional Assessment. The goal of a functional assessment is to determine the human abilities needed to interact with the voting machine. The functional assessment should be performed at the task level. Required abilities should be identified for each task.

Checklist Evaluation. In order to perform a checklist evaluation, the evaluator must be skilled in using measurement equipment such as torque meters and force meters as well as the general operation of the device to be evaluated. Also, the evaluator must be prepared to use sound judgment and apply accepted principles when checklist items are ambiguous or ill-defined. In order to complete the evaluation, the evaluator first selects the requirements, standards, and design guidelines that both meet the evaluation goals and are applicable to the device. If the goal of the evaluation is to measure accessibility in general, then the evaluator should select a broad range of recognized design guidelines, standards and principles. The detailed accessibility issues identified in this report included references to design guidelines and standards from which checklists can be derived.

User testing. Accessibility evaluations should be conducted using participants who are properly trained and representative of the user population of interest. A typical accessibility evaluation might include representatives from the following user populations:

- Users with upper mobility limitations, including users with limited strength, limited reach, and limited fine motor control
- Users with lower mobility limitations, including users who use a manual wheelchair, a powered wheelchair, and users who use personal mobility aids such as scooters
- Users who are hard of hearing
- Users who are deaf
- Users who have visual limitations including users who are color blind, users with poor visual acuity, and users with central field obstructions
- Users who are blind
- Users who have speech limitations.

References

Bullinger, H., Kern, P., and & Muntzinger, W. (1987). Design of Controls, Handbook of Human Factors, pp. 577-600. Oxford, England: John Wiley & Sons, 1st Ed.

Harris, F., Sanford, J, Yang, H., & Bell, C. (2013). Understanding voting experiences of people with disabilities. Funded by the Information Technology and Innovation Foundation-Accessible Voting Technology Initiative. Working Paper Series.

Maeda, Y., Tani, K., Ito, N., & Miyakawa, M. (2011). Quantitative Analysis on Usability of Button-Input Interfaces. IEICE Transactions on Fundamentals of Electronics Communications and Computer Sciences, E94A(2), 789-794.

APPENDIX A: Common assistive technologies (AT) used with voting systems

Assistive technologies are pieces of equipment or software that are used to increase the capabilities of people with disabilities. The following is a list of AT that people might use to aid in interacting with an accessible voting system:

Magnifying glass - A magnifying glass or magnifier is a handheld lens that is used to increase the size of an image. Typical magnification powers range from 2x to 10x. Some magnifying glasses have an integrated light, which may increase visibility for some users.

- **Used by:** Magnifiers are used by people with low vision, who may require larger text and images to be able to read and understand content.
- **Used for:** On a kiosk, magnifiers are used to read labels and displays.
- **AT impact on voting machine operation (and voting procedures at the polling place):** Magnifiers allow people with low vision to obtain information that is presented in a text size that is otherwise too small for them to read. The use of a magnifier requires the user to get very close to the object of interest. On a voting machine, this may require the user to assume an uncomfortable position. The design of the device and the placement of the item to be viewed may prevent a user from getting close enough with a magnifier to read the information of interest.

Manipulation stick - A manipulation stick is a rod, typically a wooden dowel, used as an aid to increase a user's reach or strength. Common end attachments are rubber tips and hooks. Rubber tips are used to press against an object (for example, to close a cupboard door or activate a switch). Hooks are used to pick things up or to pull objects (for example, to open a drawer). It is not uncommon for a manipulation stick to have a rubber tip on one end and a hook on the other. Many people who use manipulation sticks have both a short stick and a long stick.

- **Used by:** Manipulation sticks are typically used by individuals who have limited strength in their hands or arms, or who have limited reach capability (i.e., people with upper mobility impairments).
- **Used for:** A manipulation stick can facilitate many tasks associated with use of a voting machine. Common tasks include activating controls, inserting or retrieving voter cards, and retrieving printouts.
- **AT impact on voting machine operation (and voting procedures at the polling place):** Manipulation sticks increase a user's reach. The manipulation stick can also increase a user's leverage. Manipulation sticks are sometimes used in combination with an electric wheelchair. The user positions the stick, and then uses the force generated by the wheelchair's motor to apply the necessary pressure to activate a control or open a drawer. Manipulation sticks are only useful when they are available to the user. Users who have both a short stick and a long stick may not carry both, and may find that they need the one that they don't have. Someone with a long manipulation stick may find that the stick is too long to use easily. For example, to use the longer stick, the user must often be at a further distance from the object being manipulated, which means that additional maneuvering may be required. Some polling locations will not provide enough room for a user to obtain the necessary distance, which may mean the user will be unable to use the stick. A greater degree of fine motor control may also be required to use a longer stick. Additionally, the ends of the stick may not be suitable for use with some devices. For example, the

rubber end of the manipulation stick may be too large to activate some controls, or the gap on the hook may be insufficient to grab onto some objects with adequate leverage.

Mouth stick - A mouth stick is similar to a manipulation stick, but it is held in the mouth. The mouth stick is held by the teeth and lips, and is controlled by neck and lip movement. Many mouth sticks are made of aluminum, and can be equipped with end attachments such as clips or rubber points.

- **Used by:** Mouth sticks are most commonly used by quadriplegics who have little or no ability to move their limbs.
- **Used for:** Mouth sticks are used to press buttons, manipulate lightweight objects, or hold items such as pens.
- **AT impact on voting machine operation:** Mouth sticks can be used to interact with a voting machine if the machine is at a proper height for a seated user. Voters might need assistance getting appropriately positioned at the booth. He or she might have limited reach with the mouth stick, depending on the extent of upper torso mobility, so upper or distant parts of the display might be inaccessible. Touch screens that respond to skin moisture are not compatible with manipulation sticks. Also, touch screens that discharge electrical current in response to touch are incompatible with some types of manipulation sticks (i.e., those that do not conduct electricity).

Reaching aid - A reaching aid is a 1 to 2 foot long device with a trigger handle used to open and close the end for the purpose of grasping objects that are difficult to reach. Figure 46 shows a typical reaching aid.

- **Used by:** Reaching aids are often used by people who use a wheelchair or who have an upper mobility impairment that limits their reach distance.
- **Used for:** On a voting machine, reaching aids are used to insert and retrieve voter cards, to manipulate ballots or other materials for scanning, and to retrieve outputs from the printer area.
- **AT impact on voting machine operation (and voting procedures at the polling place):** Reaching aids enhance the ability of people with limited reach to perform voting tasks that require the user to reach or grasp items. Such tasks may include inserting and retrieving voter cards, manipulating and scanning items, and retrieving outputs from the printer area.

Figure 46: Reaching aid.

Neck loop – Neck loops are assistive listening devices that transmit magnetic signals to t-coils inside hearing aids. The t-coils transform magnetic signals into sound. Most hearing aids allow users to switch between microphone mode and t-coil mode. When in t-coil mode, the hearing aid transmits sound only from the device connected to the neck loop (although it may also transmit noise from interfering magnetic fields). Neck loops typically have 3.5 mm plugs that are

compatible with common audio output jacks. Silhouettes and ear links provide the same functionality as neck loops.

- **Used by:** Neck loops are often used by individuals with hearing impairments – especially those who also have vision impairments.
- **Used for:** Neck loops can transmit audio from a machine to a user.
- **AT impact on voting machine operation:** Voting machines are often equipped with forms of audio output that make the machine accessible to users with visual impairments. However, this audio output is inaccessible to users who also have hearing impairments. Neck loops enable users with both vision and hearing impairments to receive information from the machine, provided that the machine is equipped with a 3.5mm audio output jack, because the neck loops interface with the user's hearing aid. The user can adjust the neck loop to amplify only the sound coming from the machine interface, so that ambient background noise is filtered. Any type of verbal information, alerts, or feedback can be provided through a neck loop.

Alternative Input Devices – A variety of input devices are available for individuals unable to use a standard keyboard and/or mouse. These alternative input devices may be used by individuals with upper mobility impairments, visual impairments, or cognitive impairments. Alternative mice inputs include a joysticks, trackballs, vertical mice, roller mice, or foot operated mice. A joystick and vertical mouse allow users to adopt a more comfortable hand position that does not require rotation of the wrist. Alternative devices for keyboards include on screen keyboards, ergonomic keyboards, expanded keyboards, miniature keyboards, and one-handed keyboards. A pointing device, such as a mouse, is used to select characters on an on screen keyboard. Ergonomic, expanded, miniature, and one-handed keyboards are designed for individuals with limited dexterity and fine motor control. There are a wide variety of ergonomic keyboards, each designed with a particular limitation in mind.

- **Used by:** Alternative input devices are typically used by individuals with limitations in dexterity, fine motor control, and range of motion. Users who cannot grip a traditional mouse may be able to use a trackball or roller mouse more effectively. A foot operated mouse provides point-and-click functionality for users with severe upper mobility impairments. It is also appropriate for users who can use a keyboard but cannot easily switch from the keyboard to the mouse.
- **Used for:** Alternative mice and keyboards are typically used to interact with personal computers. However, other machines (e.g., kiosks) can be equipped to enable input from these devices. Many of these devices connect via a USB cable.
- **AT impact on voting machine operation:** Alternative input devices can enable users to interact with a machine with greater comfort and fewer errors. Also, individuals with limited mobility may be unable to reach traditional controls, and may therefore require alternative input devices.

Input Switches – an assortment of input switches accommodate various disabilities. Switches can be activated by a hand, foot, head, or other body part. A sip-and-puff switch is controlled by the user's breath. Many switches have two input channels, allowing two actions (e.g., cursor advance and select). Switches must interface directly with the hardware to be activated, typically by wire, although wireless switches exist.

- **Used by:** Input switches are used by individuals with dexterity impairments and upper limb mobility impairments.

- **Used for:** Input switches act as accessible buttons when connected to another device whose controls are inaccessible. The functionality of the switch depends on the software of the other device. The device must be programmed to accept switch input, and might respond input by advancing a cursor among display items or selecting a display item. For example, a sip-and-puff interface can advance the cursor each time the user sips air through a tube, and select an item when the user puffs through the tube.
- **AT impact on voting machine operation:** Impaired coordination of upper limbs can cause users to make frequent mistakes as they interact with controls – particularly highly sensitive touch screens – as they often over- or under-shoot their intended targets. The use of an input switch can greatly reduce the number of errors that are committed. Also, input switches enable users with limited reach or other upper limb impairments to interact with electronic devices.

Touchscreens – There are several types of touchscreen technology in use including resistive, capacitive, infrared, and surface acoustic wave (SAW) touchscreens. A resistive touchscreen panel consists of multiple layers, two of which are electrically conductive layers separated by a small gap. When pressure is applied to the outer surface, the two layers make contact causing a change in the electrical current. Because this type of touchscreen relies on pressure to detect touch, the material with which the pressure is applied is irrelevant. However, resistive touchscreens typically offer only 75% clarity and may not be appropriate for users with low vision. A capacitive touchscreen detects touch based on the electrical properties of the object that is touching the screen. Certain types of objects (e.g., the tip of a pencil, gloved fingers, or a prosthetic arm) do not produce detectable touches because they are not grounded. Infrared touchscreens respond to both human touch and other objects such as styluses. However, these types of touchscreens can be problematic for users that hover their finger over a control before selecting it. SAW touchscreens also respond to both human touch and other objects such as styluses, but the technology may be too expensive to be a feasible solution.

- **Used by:** Touchscreens may be easier to use for individuals that experience difficulty using both a keyboard and a mouse. They may also be more user friendly for individuals with cognitive disabilities because of the one-to-one mapping between the control and the display. Since the controls and display are the same and can change from one screen to the next, touchscreen technology is also useful when space is limited.
- **Used for:** All interactions with a machine that might otherwise be supported by a keyboard, keypad, or buttons.
- **AT impact on voting machine operation:** Touchscreens may be easier to use for many users, including those without disabilities. However, certain disabilities make touchscreens inaccessible, including visual impairments, upper limb tremors, and dexterity impairments. Individuals with these impairments will need another type of assistive technology to supplement or replace the touchscreen, such as the remote control that was proposed in the three design concepts.

Scooter - A scooter is a motorized mobility device. Unlike a traditional wheelchair, the seat of a scooter can rotate left and right, approximately 90 degrees in either direction, giving the user more flexibility to interact within the voting environment.

- **Used by:** A scooter is typically used by individuals who have restricted use of their legs (i.e., people with lower mobility impairments).

- **Used for:** A scooter is not assistive technology to aid interaction with a device. Rather, a scooter is AT that assists the user with mobility, though it may limit them by inhibiting their access to certain devices or areas in the user's environment.
- **AT impact on voting machine operation (and voting procedures at the polling place):** The same limitations that apply to wheelchairs (described below) apply to scooters; however, scooter users typically have greater physical mobility, and can move forward on their seats or lean forward, which increases their reach capability over that of some wheelchair users. Whereas wheelchairs have a fixed seat, the rotating seat of a scooter allows the user to face the device without having the bulk of the mobility aid between the person and the device. This extra mobility increases the user's reach, and removes barriers created when approaching parallel to a device (see discussion of wheelchair impact, below). Consideration must be given to accessing a voting system using a scooter.

Wheelchair - A wheelchair is a device used for mobility. Both manual and electric models are available. Some electric wheelchairs allow the user to raise and lower the height of the seat. The seat itself is fixed in a forward facing position.

- **Used by:** A wheelchair is typically used by individuals who have restricted use of their legs (i.e., people with lower mobility impairments).
- **Used for:** A wheelchair is not assistive technology to aid interaction with a device. Rather, a scooter is AT that assists the user with mobility, though it may limit them by inhibiting their access to certain devices or areas in the user's environment.
- **AT impact on voting machine operation (and voting procedures at the polling place):** Voting systems are typically designed to be used by an individual of average height standing (or sitting) in front of the device. Wheelchair users are in a seated position, with an eye level considerably lower than that of a standing person. As a result, they may have difficulty seeing the displays and labels on the device, and may have difficulty reaching some device components. Wheelchair users vary in how they prefer to approach devices for interaction. Many people prefer a forward approach (with the chair oriented such that they are facing the device), but this approach increases the user's distance from the device, exacerbating the limitations already in place from being in a seated position. Others prefer to approach parallel to the device, but this approach also has problems: if the user approaches with his non-dominant hand closest to the device, he has to reach further to use his dominant hand, but if the user approaches with his dominant hand closest to the device, he may need to put his arm in an awkward position in order to manipulate the controls. Furthermore, many people in wheelchairs are unable to move forward on their seats, and some cannot lean their upper bodies forward, further limiting their functional reach. The design of voting systems and their placement in the environment may favor (or necessitate) one approach or the other.

APPENDIX B: Section 508 Guidelines

Table 3. Section 508 Guidelines that pertain to technical standards

508 Standard that may apply	Situations in which it could apply
1194.25(a) 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.	This standard applies if the device requires users to attach items of assistive technology (excepting audio headsets) to the device in order to access it.
1194.25(b) When a timed response is required, the user shall be alerted and given sufficient time to indicate more time is required.	This standard applies if there are any instances where the device limits the time allowed for users to perform an action or provide a response.
1194.25(c) Where a product utilizes touchscreens or contact-sensitive controls, an input method shall be provided that complies with 1194.23(k)(1) through (4). **1194.23(k)(1)** Controls and keys shall be tactilely discernible without activating the controls or keys. **1194.23(k)(2)** Controls and keys shall be operable with one hand and shall not require tight grasping, pinching, or twisting of the wrist. The force required to activate controls and keys shall be 5 lbs. (22.2 N) maximum. **1194.23(k)(3)** If key repeat is supported, the delay before repeat shall be adjustable to at least 2 seconds. Key repeat rate shall be adjustable to 2 seconds per character. **1194.23(k)(4)** The status of all locking or toggle controls or keys shall be visually discernible, and discernible either through touch or sound.	This standard applies if the device has a touchscreen or other non-mechanical, contact sensitive controls. Standard 1194.23(k)(3) only applies if key repeat is supported (e.g., keys repeat entry when pressed for a specified period of time). Note: A best practice would be to apply 1194.23(k) to all mechanically operated controls such as buttons, knobs, and switches, whether or not 1194.25(c) applies. Some believe this approach reflects the true intent of the guidelines.
1194.25(e) When products provide auditory	This standard applies if the device provides

output, the audio signal shall be provided at a standard signal level through an industry standard connector that will allow for private listening. The product must provide the ability to interrupt, pause, and restart the audio at anytime.	voice output.
1194.25(g) Color coding shall not be used as the only means of conveying information, indicating an action, prompting a response, or distinguishing a visual element.	This standard applies if color coding is used to convey information on the device.
1194.25(h) When a product permits a user to adjust color and contrast settings, a range of color selections capable of producing a variety of contrast levels shall be provided.	This standard applies if the device's display uses color and the device permits the user to adjust color and contrast settings.
1194.25(j)(1) Products which are freestanding, non-portable, and intended to be used in one location and which have operable controls shall comply with the following: The position of any operable control shall be determined with respect to a vertical plane, which is 48 inches in length, centered on the operable control, and at the maximum protrusion of the product within the 48 inch length on products which are freestanding, non-portable, and intended to be used in one location and which have operable controls.	This standard applies if the device is freestanding, non-portable, and intended to be used in one location and has operable controls.
1194.25(j)(2) Products which are freestanding, non-portable, and intended to be used in one location and which have operable controls shall comply with the following: Where any operable control is 10 inches or less behind the reference plane, the height shall be 48 inches maximum and 15 inches minimum above the floor.	This standard applies if the device is freestanding, non-portable, and intended to be used in one location and has operable controls. Note that this guideline was based on a previous version of the ADA guidelines; the most recent revision of the ADA guidelines reduced the height from 54 inches to 48 inches.
1194.25(j)(3) Products which are freestanding, non-portable, and intended to be used in one location and which have operable controls shall comply with the following: Where any operable control is more than 10 inches and not more than 24 inches behind the reference plane, the height shall be 46 inches maximum and 15 inches minimum above the floor.	This standard applies if the device is freestanding, non-portable, and intended to be used in one location and has operable controls.
1194.25(j)(4) Products which are freestanding, non-portable, and intended to be used in one location and which have operable controls shall comply with the following: Operable controls	This standard applies if the device is freestanding, non-portable, and intended to be used in one location and has operable controls.

shall not be more than 24 inches behind the reference plane.	
1194.31(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.	This standard always applies.
1194.31(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.	This standard always applies.
1194.31(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.	This standard always applies.
1194.31(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.	This standard applies if audio information is important for use of the device. For example, audio information (speech output, etc.) for which there is not a redundant visual alternative would be covered by this standard.
1194.31(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.	This standard always applies.
1194.31(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.	This standard always applies.

APPENDIX C: Information and Communication Technology Standards and Guidelines

Functional Performance Criteria
302 Functional Performance Criteria
302.1 Without Vision. Where a visual mode of operation is provided, ICT shall provide at least one mode of operation that does not require user vision.
302.2 With Limited Vision. Where a visual mode of operation is provided, ICT shall provide at least one mode of operation that magnifies, one mode that reduces the field of vision required, and one mode that allows user control of contrast.
302.3 Without Perception of Color. Where a visual mode of operation is provided, ICT shall provide at least one mode of operation that does not require user perception of color.
302.4 Without Hearing. Where an auditory mode of operation is provided, ICT shall provide at least one mode of operation that does not require user hearing.
302.5 With Limited Hearing. Where an auditory mode of operation is provided, ICT shall provide at least one mode of operation which improves clarity, one mode that reduces background noise, and one mode that allows user control of volume.
302.6 Without Speech. Where a spoken mode of operation is provided, ICT shall provide at least one mode of operation that does not require user speech.
302.7 With Limited Manipulation. Where a manual mode of operation is provided, ICT shall provide at least one mode of operation that does not require fine motor control or operation of more than one control at the same time.
302.8 With Limited Reach and Strength. Where a manual mode of operation is provided, ICT shall provide at least one mode of operation that is operable with limited reach and limited strength.
302.9 Minimize Photosensitive Seizure Triggers. ICT shall provide at least one mode of operation that minimizes the potential for triggering photosensitive seizures.
Hardware
402 Closed Functionality
402.1 General. Except for personal headsets and audio loops, ICT with closed functionality shall be operable without requiring the user to attach assistive technology and shall conform to 402 **Advisory 402.1 General.** Self-service machines, information kiosks, set-top boxes, and devices like printers, copiers, fax machines, and calculators have closed functionality because their functionality is self-contained. Their design precludes the user from adding peripherals or software to them. ICT has closed functionality for many reasons. These reasons include design or policy. ICT may have closed functionality in practice even though the manufacturer did not design or develop ICT to be closed. Computers which are “locked down” to the extent that end users cannot adjust settings are functionally closed. **Exceptions: 1.** Audible tones shall be permitted instead of speech for visible output that is not displayed for security purposes, including, but not limited to, asterisks representing personal

identification numbers.

402.2 Speech Enabled. ICT shall be speech enabled. Operating instructions and orientation, visible transaction prompts, user input verification, error messages, and all displayed information for full use shall be accessible to and independently usable by individuals with vision impairments. Speech shall be delivered through a mechanism that is readily available to all users, including, but not limited to, an industry standard connector or a telephone handset. Speech shall be recorded or digitized human, or synthesized. Speech shall be coordinated with information displayed on the screen.

402.2.1 User Control. Speech for any single function shall be automatically interrupted when a transaction is selected. Speech shall be capable of being repeated and paused.

402.3 Volume Control. ICT shall provide volume control complying with 402.3.

402.3.1 Private Listening. Where speech required by 402.2 is delivered through a mechanism for private listening, ICT shall provide a mode of operation for controlling the volume.

402.3.2 Speaker Volume. Where sound is delivered through speakers on ICT, incremental volume control shall be provided with output amplification up to a level of at least 65 dB. Where the ambient noise level of the environment is above 45 dB, a volume gain of at least 20 dB above the ambient level shall be user selectable. A function shall be provided to automatically reset the volume to the default level after every use.

402.4 Characters. Characters displayed on the screen shall be in a sans serif font. Characters shall be 3/16 inch (4.8 mm) high minimum based on the uppercase letter "I". Characters shall contrast with their background with either light characters on a dark background or dark characters on a light background.

403 Biometrics

403.1 General. Where provided, biometrics shall not be the only means for user identification or control.
Exception: Where at least two biometric options that use different biological characteristics are provided, ICT shall be permitted to use biometrics as the only means for user identification or control.

404 Preservation of Information Provided for Accessibility

404.1 General. ICT that transmits or converts information or communication, shall not remove non-proprietary information provided for accessibility or shall restore it upon delivery.

Advisory 404.1 General. This provision applies to conversion techniques, such as encoding, signal compression, and format transformation. Examples of ICT that encode, compress, or transform include firewalls, routers, and gateways.

One example of ICT preserving information provided for accessibility is a media player that displays embedded captions from a captioned video and does not strip out the captioning.

Another example of ICT preserving information provided for accessibility is converting a document into a new format while retaining information about the identity, operation, and state of the interface elements.

This provision does not require the addition or translation of information. For example, this is not a requirement to change voice mail to text or to vocalize captions.

406 Standard Connections
406.1 General. Where connection points are provided, at least one of each type of connection shall conform to industry standard non-proprietary formats. **Advisory 406.1 General**. The intent of this provision is to ensure compatibility with assistive technologies by requiring the use of standard connections on ICT. Examples of connection points include expansion slots, ports, and connectors for cables. Industry standard non-proprietary formats include wireless connections to ICT, such as infrared (IR) and Bluetooth.
407 Operable Parts
407.1 General. Where provided, operable parts of ICT shall conform to 407.
407.2 Contrast. Where provided, keys and controls shall contrast visually from background surfaces. Characters and symbols shall contrast visually from background surfaces. Visual contrast shall be either light-on-dark or dark-on-light.
407.3 Tactilely Discernible. At least one tactilely discernible input control shall be provided for each function. Where provided, key surfaces not on active areas of display screens shall be raised above surrounding surfaces. Where touch or membrane keys are the only method of input, each key shall be tactilely discernible from surrounding surfaces and adjacent keys. **407.3.1 Identification**. Operable parts shall be tactilely discernible without activation.
407.4 Key Repeat. Where an alphabetic keyboard with key repeat is provided, the delay before the key repeat shall be adjustable to at least 2 seconds and the key repeat rate shall be adjustable to 2 seconds per character.
407.5 Numeric Keys. Where provided, numeric keys shall be arranged in a 12-key ascending or descending telephone keypad layout. The number five key shall be tactilely distinct from the other keys. **Advisory 407.5** Numeric Keys. A telephone keypad and a keypad on a computer keyboard differ in one significant feature, ascending versus descending numerical order of the layout. Both types of keypad layout conform to this provision.
407.9 Operation. Operable parts shall be operable with one hand and shall not require tight grasping, pinching, or twisting of the wrist. The force required to activate operable parts shall be 5 pounds (22.2 N) maximum.
407.10 Privacy. ICT shall provide the opportunity for the same degree of privacy of input and output to all individuals.
407.11 Receipts, Tickets, and Transactional Outputs. Where receipts, tickets, or other outputs are provided as a result of a transaction, speech output shall include all information necessary to complete or verify the transaction. **Exception**: Operable parts of ICT that is portable shall not be required to conform to 407.13 through 407.16
407.13 Clear Floor Space. A clear floor or ground space conforming to 36 CFR Part 1191 Appendix

D, Section 305 shall be provided.
407.14 Height. Operable parts of ICT shall be placed within one or more of the reach ranges conforming to 36 CFR Part 1191 Appendix D, Section 308.
407.15 Visibility. Where a display screen is provided, it shall be visible from a point located 40 inches (1015 mm) above the center of the clear floor space in front of the ICT.
407.16 Braille Instructions. Where speech is required by 402.2, braille instructions for initiating the speech mode of operation shall be provided. Braille shall conform to 36 CFR Part 1191 Appendix D, Section 703.3.
408 ICT with Two Way Voice Communication
408.1 General. ICT that provides two way voice communications shall conform to 408. **Exception**: Where ICT is a closed system, conformance to standards other than ITU-T Recommendation G.722 shall be permitted where equivalent or better acoustic performance is provided and where conversion to ITU-T Recommendation G.722 at the borders of the closed system is supported.
408.2 Volume Gain. For transmitted voice signals, ICT shall provide a gain adjustable to a minimum of 18 dB. For incremental volume control, ICT shall provide at least one intermediate step of 12 dB gain.
408.3 Magnetic Coupling. Where ICT delivers output by an audio transducer which is typically held up to the ear, ICT shall provide a means for effective magnetic wireless coupling to hearing technologies.
408.4 Minimize Interference. Interference with hearing technologies (including hearing aids, cochlear implants, and assistive listening devices) shall be reduced to the lowest possible level and shall conform to 408.4.
408.4.2 Digital Wireline. ICT in the form of digital wireline devices shall conform to TIA 1083, Telephone Terminal Equipment Handset Magnetic Measurement Procedures and Performance Requirements (incorporated by reference in Chapter 1).
408.5 ITU-T Recommendation G.722. ICT shall transmit and receive speech that is digitally encoded in the manner specified by ITU-T Recommendation G.722 for encoding and storing audio information (incorporated by reference in Chapter 1).
408.6 Real Time Text Functionality. Where ICT provides real time voice communication, ICT shall provide real time text functionality and shall conform to 408.6.
408.6.1 Display of Real Time Text. Where provided, multi-line displays shall be compatible with real time text systems used on the network.
408.6.2 Text Generation. Where provided, features capable of text generation shall be compatible with real time text systems used on the network.
408.6.3 Interoperability. Where ICT interoperates outside of its closed system, or where ICT connects to other systems, ICT shall conform to 408.6.3.1 or 408.6.3.2.
Platforms and Applications
501 General

501.1 Scope. The provisions of Chapter 5 shall apply where required by Chapter 1 or where referenced by a requirement in this document. **Advisory 501.1 Scope.** Examples of platforms are desktop, embedded operating systems (including mobile), web browsers, plug-ins to web browsers which render a particular media or format, and sets of components which allow other applications to execute. Applications may be web-based or client-side software. Examples of applications are email clients, word processors, help desk systems, content management systems, e-learning courseware, and terminal emulation. **Exception**: Platforms and applications that have closed functionality and that conform to 402 shall not be required to conform to 502.
502 Interoperability with Assistive Technology
502.1 General. Platforms, platform software toolkits, and applications shall conform to 502.
502.2 Accessibility Services. Platforms and their software toolkits shall provide a documented set of accessibility services that support a mode of operation for applications running on the platform to interoperate with assistive technology and shall conform to 502.2. Applications that are also platforms shall expose the underlying platform accessibility services or implement other documented accessibility services.
502.2.1 Object Information. The object role, state(s), boundary, name, and description shall be programmatically determinable.
502.2.2 Row, Column, and Headers. The row and column an object is in, and the headers for the row and column for that component, if it is in a data table that has row or column headers, shall be programmatically determinable.
502.2.3 Values. The current value and any minimum or maximum values, if the component represents one of a range of values, shall be programmatically determinable.
502.2.4 Label Relationships. The relationship that a component has as a label for another component, or of being labeled by another component, shall be programmatically determinable.
502.2.6 Text. The text contents, text attributes, and the boundary of text rendered to the screen shall be programmatically determinable.
502.2.7 Actions. A list of actions that can be executed on an object shall be programmatically determinable. Applications shall allow assistive technology to programmatically execute available actions on objects.
502.2.8 Focus Cursor. Applications shall expose information and mechanisms necessary to track and modify focus, text insertion point, and selection attributes of user interface components.
502.2.9 Event Notification. Notification of events relevant to user interactions, including but not limited to changes in the component's state(s), value, name, description, or boundary, shall be available to assistive technologies.
502.3 Documented Accessibility Usage. Where platform documentation is available to application developers, platforms and applications shall conform to 502.3.
502.3.1 User Control of Accessibility Features. Platforms shall provide a mode of operation for user

control over platform features that are defined in the platform documentation as accessibility features.
502.3.2 No Disruption of Accessibility Features. Applications shall not disrupt platform features that are defined in the platform documentation as accessibility features.
503 Applications
503.1 General. Applications shall conform to 503.
503.2 User Preferences. Applications shall provide a mode of operation that allows user preferences for platform settings for color, contrast, font type, font size, and focus cursor. **Exception**: Applications that are designed to be isolated from their underlying platforms, including web applications, shall not be required to conform to 503.2.
503.3 Alternative User Interfaces. Where an application provides an alternative user interface that functions as assistive technology, the application shall use platform and other industry standard accessibility services to provide the alternate user interface.
503.4 User Controls for Captions and Video Description. Where ICT displays video with synchronized audio content, ICT shall provide user controls for closed captions and video description conforming to 503.4.
503.4.1 Caption Controls. Where user controls are provided for the selection of volume, ICT shall provide user controls for the selection of captions in at least one location that is comparable in prominence to the location of the user controls for volume.
503.4.2 Video Description Controls. Where user controls are provided for the selection of channels, ICT shall provide user controls for the selection of video description in at least one location that is comparable in prominence to the location of the user controls for channels.
503.4.3 On-screen Menus. Where an on-screen menu is provided for the selection of volume or channels, ICT shall provide for the selection of captions and video description at the same menu level as that of volume and channel selection.
Documentation and Support Services
602 Documentation
602.1 General. Documentation that supports the use of ICT shall conform to 602.
602.2 Accessibility and Compatibility Features. Documentation shall list and explain how to use the accessibility and compatibility features of the ICT that support the technical requirements of this document. Documentation shall include accessibility features that are built-in and accessibility features that provide compatibility with assistive technology. **Advisory 602.2 Accessibility and Compatibility Features**. One example of an accessibility feature is the ability to access commands and navigate using the keyboard. Voice recognition, screen readers, and alternative keyboards rely upon keyboard control of features for accessible and efficient operation. Keyboard navigation includes support for the following: cursor keys (up, down, left and right arrows), tab and shift-tab (to cycle through fields), enter or spacebar (to select or activate), hot keys, macros, and other keyboard acceleration mechanisms. Where ICT components are designed to be part of an integrated system, this provision requires that the documentation explains how to configure the system to support accessibility.

602.3 Materials. When ICT support services provide documentation, documentation materials shall conform to 602.3.
602.3.1 WCAG Conformant. Documentation in electronic format shall conform to all Level A and Level AA Success Criteria and all Conformance Requirements in WCAG 2.0 (incorporated by reference in Chapter 1).
602.3.2 Alternate Formats. Alternate formats shall be provided upon request.
603 Support Services
603.1 General. ICT support services including, but not limited to, help desks, call centers, technical support, and training services shall conform to 603.
603.2 Information on Accessibility and Compatibility Features. ICT support services and training shall include information on the accessibility and compatibility features required by 602.2 to be listed and explained in ICT documentation. **Advisory 603.2 Information on Accessibility and Compatibility Features.** A best practice is for ICT support services to provide training programs about the following topics: accessibility requirements for individuals with disabilities; methods of communication used by individuals with disabilities; assistive technology commonly used with ICT products; designing for accessibility; solutions for accessibility and compatibility of ICT with assistive technology; the use of people-first language; and sensitivity training concerning disability issues.
603.3 Effective Communication. ICT support services shall accommodate the communication needs of individuals with disabilities. **Advisory 603.3 Effective Communication**. To be effective, communication with individuals with disabilities should include alternate methods of communication for both in-person and remote communication. Examples of alternative methods are sign language interpreters, assistive listening systems, TTYs, real time captioning, and telecommunications relay services. Examples of telecommunication relay services are TTY speech-to-speech and video relay.
603.3.1 Materials Provided. When support services provide documentation, the documentation materials shall conform to 602.

APPENDIX D: Help America Vote Act Requirements

The following requirements for voting accessibility were mandated by HAVA 2002, as amended by H.R. 2239.

Paragraph	Text of Requirement
Title III(a)(3)(A)	The voting system shall be accessible for individuals with disabilities, including nonvisual accessibility for the blind and visually impaired, in a manner that provides the same opportunity for access and participation (including privacy and independence) as for other voters
Title III(a)(3)(B)	The voting system shall satisfy the requirement of subparagraph (A) through the use of at least one direct recording electronic voting system or other voting system equipped for individuals with disabilities at each polling place, and such voting system shall provide a mechanism for voter-verification of results which separates the function of vote generation from the function of vote casting in a manner analogous to that described in section 4 with respect to the separation of paper ballot generation and paper ballot verification and preservation, but does not require the use of paper.
Title III(a)(3)(C)	The equipment deployed in accordance with subparagraph (B) shall meet the voting system standards for disability access and voter-verification of results as outlined in this paragraph in accordance with the deadline set forth in section 5(a), provided that if it does not and an interim paper system is deployed in accordance with section 5(b), disabled voters shall have the option of using the interim paper system with the assistance of an aide of the voter's personal selection or using the voting system otherwise put in place for use by disabled voters at the time in question in accordance with the Help America Vote Act of 2002, as in effect prior to the enactment of this Act, except that the deadline set forth in section 301(a)(3)(C) of such Act (42 U.S.C. 15481(a)(3)(C)) is moved forward from January 1, 2007, to January 1, 2006
Title III(a)(3)(D)	Election officials shall be instructed in the rights of the disabled to vote with the assistance of an aide of their selection under the Voting Rights Act of 1965

APPENDIX E: Voting System Standards (VSS) and Voluntary Voting System Guidelines (VVSG)

Source & Section	Text of Standard / Guideline
General	
VSS 3.2.2.2	There is no restriction on space allowed for the installation of voting systems, except that the arrangement of these systems shall not impede performance of their duties by polling place officials, the orderly flow of voters through the polling place, or the ability for the voter to vote in private;
VSS 2.2.7.2(i)	Provide a secondary means of voter identification or authentication when the primary means of doing so uses biometric measures that require a voter to possess particular biological characteristics;
VVSG 3.1.1(1)	All eligible voters are to have access to the voting process without discrimination. The voting process must be accessible to individuals with disabilities. The voting process includes access to the polling place, instructions on how to vote, initiating the voting session, selecting among contest choices, review of the ballot, final submission of the ballot, and getting help when needed;
VVSG 3.2.4-C	Instructional material for the voter SHALL conform to norms and best practices for plain language;
VVSG 3.2.4-C.3	The system SHOULD use familiar, common words and avoid technical or specialized words that voters are not likely to understand;
VVSG 3.2.4-C.4	The system SHOULD issue instructions on the correct way to perform actions, rather than telling voters what not to do.
Physical Access	
VSS 2.2.7.1(a)	Where clear floor space only allows forward approach to an object, the maximum high forward reach allowed shall be 48 inches. The minimum low forward reach is 15 inches;
VSS 2.2.7.1(b)	Where forward reach is over an obstruction with knee space below, the maximum level forward reach is 25 inches. When the obstruction is less than 20 inches deep, the maximum high forward reach is 48 inches. When the obstruction projects 20 to 25 inches, the maximum high forward reach is 44 inches;
VSS 2.2.7.1(c)	The position of any operable control is determined with respect to a vertical plane that is 48 inches in length, centered on the operable control, and at the maximum protrusion of the product within the 48-inch length;
VSS 2.2.7.1(d)	Where any operable control is 10 inches or less behind the reference plane, [the control shall] have a height that is between 15 inches and 54 inches above the floor;
VSS 2.2.7.1(e)	Where any operable control is more than 10 inches and not more than 24 inches

	behind the reference plane, [the system shall] have a height between 15 inches and 46 inches above the floor;
VSS 2.2.7.1(f)	[The system shall] have operable controls that are not more than 24 inches behind the reference plane.
Machine Specifications	
VSS 2.2.7.2(a)	Not require the voter to bring their own assistive technology to a polling place;
VSS 2.2.7.2(g)	For a system that requires a response by a voter in a specific period of time, alert the voter before this time period has expired and allow the voter additional time to indicate that more time is needed;
VSS 2.2.7.2(h)	For a system that provides sound cues as a method to alert the voter about a certain condition, such as the occurrence of an error, or a confirmation, the tone shall be accompanied by a visual cue for users who cannot hear the audio prompt;
VSS 2.4.3.3(l)	Provide sufficient computational performance to provide responses back to each voter entry in no more than three seconds;
VVSG 3.2.3.1-A.3	The voting system SHALL issue all warnings in a way that preserves the privacy of the voter and the confidentiality of the ballot;
VVSG 3.2.3.2-B	No information SHALL be kept within an electronic CVR that identifies any accessibility feature(s) used by a voter;
VVSG 3.2.4-A	The voting station SHALL provide instructions for all its valid operations;
VVSG 3.2.4-B	The voting system SHALL provide a means for the voter to get help directly from the system at any time during the voting session;
VVSG 3.2.6-C.1	On touch screens, the sensitive touch areas SHALL have a minimum height of 0.5 inches and minimum width of 0.7 inches. The vertical distance between the centers of adjacent areas SHALL be at least 0.6 inches, and the horizontal distance at least 0.8 inches;
VVSG 3.2.6.1-D	If the system has not completed its visual response within one second, it SHALL present to the voter, within 0.5 seconds of the voter's action, some indication that it is preparing its response;
VVSG 3.3.1-A	The Acc-VS SHALL be integrated into the manufacturer’s complete voting system so as to support accessibility for disabled voters throughout the voting session.
General Ballot Design	
VSS 2.4.3.3(h)	Allow the voter, before the ballot is cast, to review his or her choices and, if the voter desires, to delete or change his or her choices before the ballot is cast;
VSS 2.4.3.3(i)	For electronic image displays, prompt the voter to confirm the voter's choices before casting his or her ballot, signifying to the voter that casting the ballot is irrevocable and directing the voter to confirm the voter's intention to cast the ballot;
VVSG 3.1.1(2)	Each cast ballot must accurately capture the selections made by the voter. The ballot must be presented to the voter in a manner that is clear and usable. Voters

	should encounter no difficulty or confusion regarding the process for recording their votes;
VVSG 3.2(a)(1)(A)(i)	Except as provided in subparagraph (B), the voting system (including any lever voting system, optical scanning voting system, or direct recording electronic system) shall permit the voter to verify (in a private and independent manner) the votes selected by the voter on the ballot before the ballot is cast and counted;
VVSG 3.2(a)(1)(A)(ii)	Except as provided in subparagraph (B), the voting system (including any lever voting system, optical scanning voting system, or direct recording electronic system) shall provide the voter with the opportunity (in a private and independent manner) to change the ballot or correct any error before the ballot is cast and counted (including the opportunity to correct the error through the issuance of a replacement ballot if the voter was otherwise unable to change the ballot or correct any error);
VVSG 3.2.2-A	If the voter selects more than the allowable number of choices within a contest, the voting system SHALL notify the voter of the effect of this action before the ballot is cast and counted;
VVSG 3.2.2.1-E	The VEBD (voter-editable ballot device) SHALL provide navigation controls that allow the voter to advance to the next contest or go back to the previous contest before completing a vote on the contest(s) currently being presented (whether visually or aurally);
VVSG 3.2.6-A	Voting systems SHALL NOT require page scrolling by the voter.
Controls	
VSS 2.2.7.2(f)(1)	For a device with touchscreen or contact-sensitive controls, provide an input method using mechanically operated controls or keys that shall be tactilely discernible without activating the controls or keys;
VSS 2.2.7.2(f)(2)	For a device with touchscreen or contact-sensitive controls, provide an input method using mechanically operated controls or keys that shall be operable with one hand and not require tight grasping, pinching, or twisting of the wrist;
VSS 2.2.7.2(f)(3)	For a device with touchscreen or contact-sensitive controls, provide an input method using mechanically operated controls or keys that shall require a force less than 5 lbs (22.2 N) to operate;
VSS 2.2.7.2(f)(4)	For a device with touchscreen or contact-sensitive controls, provide an input method using mechanically operated controls or keys that shall provide no key repeat function;
VSS 2.4.3.3(b)	Enable the voter to easily identify the selection button or switch, or the active area of the ballot display that is associated with each candidate or ballot measure response.
Visual Display	
VSS 2.2.5.2.2(b)	All error messages requiring intervention by an operator or precinct official shall be displayed or printed unambiguously in easily understood language text, or by means of other suitable visual indicators;

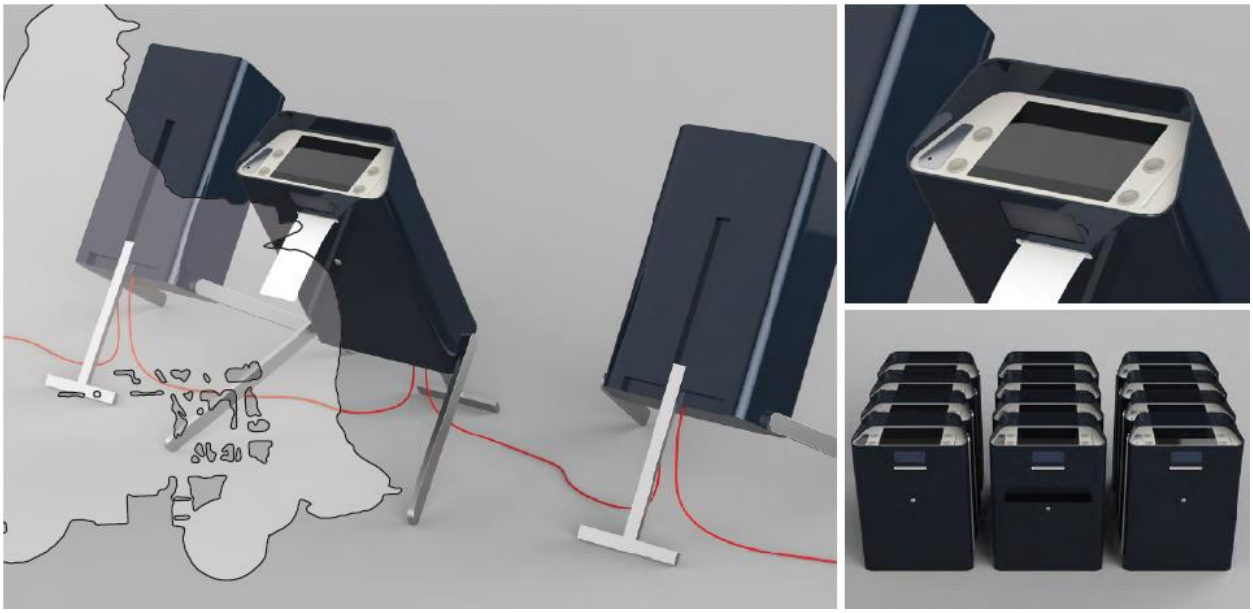
VSS 2.2.7.2(e)(1)	For electronic image displays, permit the voter to adjust the contrast setting;
VSS 2.2.7.2(e)(2)	For electronic image displays, permit the voter to adjust color settings, when color is used;
VSS 2.2.7.2(e)(3)	For electronic image displays, permit the voter to adjust the size of the text so that the height of capital letters varies over a range of 3 to 6.3 millimeters;
VSS 2.3.1.1(f)	Ensure that vote response fields, selection buttons, or switches properly align with the specific candidate names and/or issues printed on the ballot display, ballot card or sheet, or separate ballot pages;
VSS 2.4.3.1(a)	To facilitate casting a ballot, all systems shall provide text that is at least 3 millimeters high and provide the capability to adjust or magnify the text to an apparent size of 6.3 millimeters;
VSS 3.4.9(b)	Information or data displays shall be large enough to be readable by voters and operators with no disabilities and by voters with disabilities consistent with the requirements defined in Section 2.2.7 of the Standards;
VSS 3.4.9(d)	Color coding shall be selected so as to assure correct perception by voters and operators with color blindness; and shall not be used as the only means of conveying information, indicating an action, prompting a response, or distinguishing a visual element;
VVSG 3.2.4-F	The use of color by the voting system SHOULD agree with common conventions: (a) green, blue or white is used for general information or as a normal status indicator; (b) amber or yellow is used to indicate warnings or a marginal status; (c) red is used to indicate error conditions or a problem requiring immediate attention;
VVSG 3.2.4-G	When an icon is used to convey information, indicate an action, or prompt a response, it SHALL be accompanied by a corresponding linguistic label;
VVSG 3.2.5-E	A voting station that uses an electronic image display SHALL be capable of showing all information in at least two font sizes, (a) 3.0-4.0 mm and (b) 6.3-9.0 mm, under control of the voter. The system SHALL allow the voter to adjust font size throughout the voting session while preserving the current votes;
VVSG 3.2.5-G.2	The system MAY achieve legibility of paper records by supporting magnification of those records. This magnification MAY be done by optical or electronic devices. The manufacturer MAY either: 1) provide the magnifier itself as part of the system, or 2) provide the make and model number of readily available magnifiers that are compatible with the system;
VVSG 3.2.5-I	The voting station SHALL be capable of showing all information in high contrast either by default or under the control of the voter. The system SHALL allow the voter to adjust contrast throughout the voting session while preserving the current votes. High contrast is a figure-to-ground ambient contrast ratio for text and informational graphics of at least 6:1;
VVSG 3.2.5-J	The default color coding SHALL support correct perception by voters with color blindness;

VVSG 3.2.5-K	Color coding SHALL NOT be used as the sole means of conveying information, indicating an action, prompting a response, or distinguishing a visual element.
Auditory Display	
VSS 2.2.7.2(b)(1)	Provide audio information and stimulus that communicates to the voter the complete content of the ballot;
VSS 2.2.7.2(b)(2)	Provide audio information and stimulus that provides instruction to the voter in operation of the voting device;
VSS 2.2.7.2(b)(3)	Provide audio information and stimulus that provides instruction so that the voter has the same vote capabilities and options as those provided by the system to individuals who are not using audio technology;
VSS 2.2.7.2(b)(4)	Provide audio information and stimulus that for a system that supports write-in voting, enables the voter to review the voter's write-in input, edit that input, and confirm that the edits meet the voter's intent;
VSS 2.2.7.2(b)(5)	Provide audio information and stimulus that enables the voter to request repetition of any information provided by the system;
VSS 2.2.7.2(b)(6)	Provide audio information and stimulus that supports the use of headphones provided by the system that may be discarded after each use;
VSS 2.2.7.2(b)(7)	Provide audio information and stimulus that provides the audio signal through an industry standard connector for private listening using a 1/8 inch stereo headphone jack to allow individual voters to supply personal headsets;
VSS 2.2.7.2(b)(8)	Provide audio information and stimulus that provides a volume control with an adjustable amplification up to a maximum of 105 dB that automatically resets to the default for each voter;
VSS 2.2.7.2(c)	Provide, in conformance with FCC Part 68, a wireless coupling for assistive devices used by people who are hard of hearing when a system utilizes a telephone style handset to provide audio information;
VSS 2.2.7.2(d)	Meet the requirements of ANSI C63.19-2001 Category 4 to avoid electromagnetic interference with assistive hearing devices;
VVSG 3.2.3.1-A.2	During the voting session, the audio interface of the voting system SHALL be audible only to the voter.

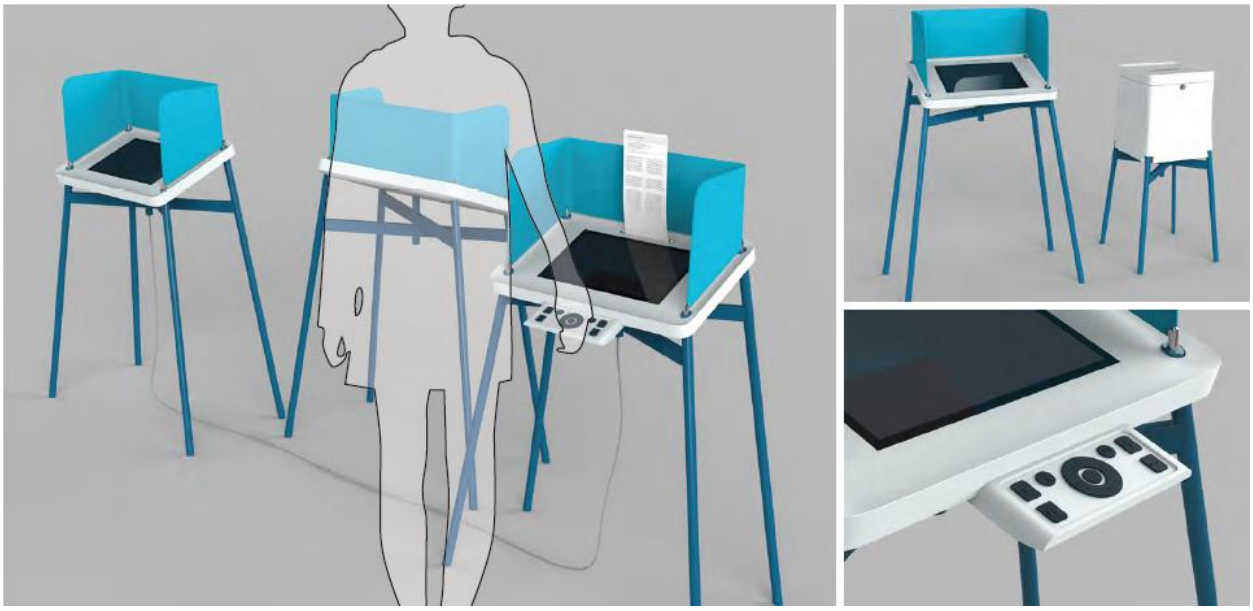
APPENDIX F: LA County Voting System Concepts

The images below were copied from the following report: "LAC Voting System, User Feedback Concepts, 10/01/13"

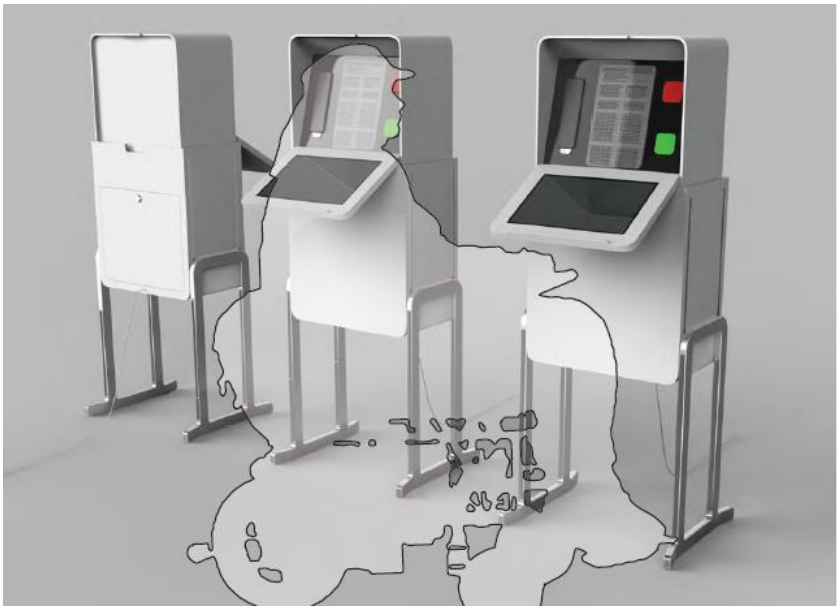
Concept 1:



Concept 2:



Concept 3:



APPENDIX G: Table of Figures

Figure 1. IDEO Concept 1 4
Figure 2. IDEO Concept 2 4
Figure 3. IDEO Concept 3 5
Figure 4. Obstructed high-side reach. 15
Figure 5: Buttons are labeled only with ambiguous icons. 19
Figure 6: Buttons have text labels supplemented with icons. 20
Figure 7: A single light illuminates red or green to indicate status. 21
Figure 8: Information is conveyed redundantly through color and text. 22
Figure 9: The angle of the display results in glare for a seated user. 23
Figure 10: An adjustable display allows a seated user to adjust the display angle to reduce glare. 24
Figure 11: A hood shields the display from overhead lights, reducing glare for seated users. 24
Figure 12: Very small labels and icons on a keypad. 26
Figure 13: Large labels and icons on a keypad. 27
Figure 14: Icons are not clearly associated with their corresponding labels. 29
Figure 15: Icons are clearly associated (by proximity) with their corresponding labels. 30
Figure 16: An auxiliary control interface placed within reach of a user in a wheelchair. 36
Figure 17: Buttons on a control panel have very little contrast with the control panel surface.... 39
Figure 18: Buttons on a control panel have high contrast with the control panel surface. 40
Figure 19: A stylized button is not identifiable as an operable control. 41
Figure 20: Design of the button and accompanying text help to identify the button as an operable control. 42
Figure 21: Buttons on a control panel are large and widely spaced. 43
Figure 22: Buttons on a control panel are all shaped identically. 45
Figure 23: Buttons on a control panel are grouped and distinguished by size, shape, and color. 46
Figure 24: The proper orientation for inserting a card is not shown. 54
Figure 25: The proper orientation for inserting a card is shown. 55
Figure 26: A tapered card slot facilitates insertion. 56
Figure 27: The card is not ejected far enough to grasp easily. 57
Figure 28: The card is ejected far enough for easy grasping. 58
Figure 29: The printout/insertion slot on the top of the machine (right) is not clearly visible to seated users (left). 61
Figure 30: A headphone jack is provided for private listening. 65
Figure 31: The headphone jack is located in an obscure location on the device. 68
Figure 32: The headphone jack is located in a prominent location on the device. 69
Figure 33: The headphone jack location allows the cord to interfere with use of the machine.... 72
Figure 34: The headphone jack location prevents the cord from interfering with use of the machine. 73
Figure 35: An indicator light is placed out of sight for a seated user. 79
Figure 36: An indicator light is placed so that a seated user can see it. 80
Figure 37: A single light illuminates red or green to indicate status. 81
Figure 38: An example of redundant color coding and text. 82
Figure 39: Overuse of indicator lights reduces their effectiveness for attracting attention or communicating information. 83

Figure 40: A lack of space for temporary placement of belongings and paper ballots forces users to hold those items. 85
Figure 41: An area for writing or placing belongings is provided. 86
Figure 42: A volume knob is provided to allow the user to adjust the output volume. 97
Figure 43: Potentially sensitive audio is output through speakers. 102
Figure 44: A headphone jack is provided for private listening. 103
Figure 45. 3-button controller designed for GTRI's iPad case (in work) 106
Figure 46: Reaching aid. 111