

# CRS Report for Congress

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## **Voting Technologies in the United States: Overview and Issues for Congress**

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# Voting Technologies in the United States: Overview and Issues for Congress

## Summary

The 2000 presidential election raised questions about whether changes are needed in the voting technologies used in the United States, and what should be the federal role. Elections are administered by states and localities through approximately 10,000 jurisdictions at the county level or below. The main federal agency involved is the Office of Election Administration, which is part of the Federal Election Commission and assists state and local election officials. In 1990, the FEC released voluntary standards for computer-based voting systems. The standards were developed in response to congressional direction and have been adopted in whole or in part by thirty-two states. Updated standards are in development.

Currently, five different kinds of voting technologies are used: hand-counted paper ballots, mechanical lever machines, computer punchcards (Votomatic and Datavote), marksense forms (also called optical scan), and direct recording electronic systems (DRE). The last three systems are computer-based. All systems except lever machines and DRE use document ballots on which the voter records choices. Punchcard systems are the most common, used by about one-third of registered voters, with marksense systems used by about one-quarter. In all but a few states, more than one kind of technology is currently in use.

For some of the technologies, concerns have been raised about ballot design, voter errors, and counting accuracy. Effective ballot design involves balancing the fairness and clarity of presentation, as well as goals such as promoting completion of the entire ballot by voters. Different technologies place different constraints on ballot design. The three basic kinds of error are overvote, undervote (not necessarily an error), and unintended choice. Technologies differ in how they help voters prevent or correct such errors, and consequently, the incidence varies with the technology employed. It may also depend on the condition of equipment and the demographics of the population. Vote counting involves issues such as the accuracy of the counting methodology, its speed, its integrity and security, and recounting where necessary. Those depend on many factors, including the characteristics of the technology used, the design and condition of the equipment and software, and human behavior. Reports on the accuracy of different systems vary. Questions have also been raised about the impacts of remote voting, including absentee and mail-in balloting. Another form of remote voting currently in development is Internet voting, which so far has been used only on a very limited basis. The overall prevalence of remote voting is increasing, raising concerns in particular about potential compromises to ballot secrecy. A central issue is what role the federal government should play in addressing the concerns that have been raised about voting systems. Current debate centers on several questions: What is the extent of congressional authority to regulate voting technology and procedures? Should national standards be voluntary or mandatory? Should the scope of the standards be broadened to include ballot design, counting procedures, and other aspects of election management? Should a uniform technology be adopted nationally or on a state-by-state basis? Should federal funding be made available to states or local election jurisdictions for upgrading voting systems? Significant legislative activity is expected in the 107th Congress (see the CRS Election Reform Electronic Briefing Book).

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# Voting Technologies in the United States: Overview and Issues for Congress

The Presidential election of the year 2000 has raised several issues about the voting technologies used in the United States. This report provides an overview of the technologies used and the issues raised, including a brief history and characteristics of the different methods, the design of ballots, kinds and sources of voter error, vote counting, and standards. It discusses whether changes may be needed, what those changes might be, what is the federal role, and legislative initiatives in the 106<sup>th</sup> and 107<sup>th</sup> Congresses.

## Kinds of Voting Technology

Elections in the United States are administered at the state and local level, and the federal government does not set mandatory standards for voting technologies. There are approximately 10,000 election jurisdictions that administer major federal elections at the county level or below. In most states, elections are run at the county level. However, in some, they are administered by townships or other county subdivisions.<sup>1</sup> Currently, five different kinds of voting technologies are used: paper ballots, lever machines, punchcards, marksense forms, and electronic systems (see **Table 1**). Votes in federal elections are categorical — a voter chooses only one candidate per office. Some countries, however, use other approaches, such as ordinal voting, where voters rank candidates.<sup>2</sup> Despite the wide range of alternative voting

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<sup>1</sup>As of 1988, of the approximately 3,140 counties and independent cities in the United States, 2,870 in 41 states conducted state and federal elections. In nine states (Connecticut, Maine, Massachusetts, Michigan, Minnesota, New Hampshire, Rhode Island, Vermont, and Wisconsin), 7,610 minor civil divisions, which are county subdivisions such as townships, ran those elections (Roy G. Saltman, *Accuracy, Integrity, and Security in Computerized Vote-Tallying*, National Bureau of Standards Special Publication 500-158, August 1988, 48; no more recent sources on minor civil divisions were available for this report, but county data are also listed in Election Data Services, “1998 Voting Equipment Study Report,” [<http://www.electiondataservices.com/content/vote equip.htm>], n.d.; however, some observers say that because of consolidation of responsibilities, the total number of election jurisdictions is approximately 6,800 for federal elections rather than 10,000). Delaware has a state-run system.

<sup>2</sup>Categorical voting is used in a first-past-the-post system, in which the candidate with the plurality of votes wins, or in a two-round system, in which a run-off election is held if no candidate receives a majority of the vote. Ordinal or preferential voting provides a way of ensuring that the winning candidate has a majority, not just a plurality, of the votes cast without holding a run-off election. This system is used in Australia. For more information,

(continued...)

technologies that are now used in the United States, the use of categorical voting has remained a basic feature.

**Table 1. Types of Voting Technologies Used in the United States, 1998**

<i>Voting Method</i>	<i>Document Ballot?</i>	<i>Computer-Assisted Tabulation?</i>	<i>Number of Counties</i>	<i>Percentage Using Method</i>	
				<i>Voters<sup>a</sup></i>	<i>Precincts</i>
Paper ballot	Yes	No	410	1.6%	2.9%
Lever machine	No	No	480	18.6%	21.8%
Punch Cards:					
<i>Votomatic type</i>	Yes	Yes	578	31.0%	33.4%
<i>Datavote</i>	Yes	Yes	57	3.3%	4.0%
Marksense	Yes	Yes	1,217	27.3%	24.7%
Electronic	No	Yes	257	9.1%	7.3%
Mixed system <sup>b</sup>	–	–	141	9.1%	5.9%

**Source:** Numbers are from Election Data Services, “1998 Voting Equipment Study Report,” [http://www.electiondataservices.com/content/vote equip.htm], n.d.

<sup>a</sup> Registered voters.

<sup>b</sup> A mixture involving more than one kind of voting technology used in a county. Numbers listed do not reflect the actual percentages of precincts or voters using mixed systems, but rather the percentages of voters registered in and precincts located in counties that Election Data Services has identified as using mixed systems.

**Paper Ballots.** For the first 100 years of the Republic, only one voting technology was available — paper ballots.<sup>3</sup> The first major technological change to those ballots came with the invention of the Australian secret ballot in 1856. Prior to its adoption, U.S. voters obtained printed ballots containing the names of the candidates for whom they wished to vote and placed those ballots in the ballot box. Such a ballot, called a prox or ticket, was printed by each political party or other

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<sup>2</sup>(...continued)

see Administration and Cost of Elections Project, *Way of Voting*, [http://www.aceproject.org/main/english/es/esc05/default.htm], 21 September 1998.

<sup>3</sup>All voting technologies using document ballots use paper or cardstock, but the term *paper ballot* generally refers to those that are designed to be read by humans rather than machines. The main alternative to paper ballots before the 1890s was voice vote, which was used in some states as late as 1888 (S.J. Ackerman, “The Vote that Failed,” *Smithsonian Magazine*, November 1998, 36).

faction that had candidates in the election.<sup>4</sup> A version of the ticket ballot is still used in a few countries.

The basic ballot used in the United States is the Australian or mark choice ballot, which lists the names of all candidates. Voters mark their choices on the ballot. The most common form of this ballot type lists candidates by office (the office group or Massachusetts ballot). One variant gives voters the option of choosing an entire slate with a single mark (the party column or Indiana ballot), or choosing a slate with exceptions. The Australian ballot was adopted in the United States beginning in the 1880s, after a series of scandals involving vote-buying and other problems. Paper ballots are still used in about 3% of precincts, mostly in less populous areas. The percentage of voters using paper ballots has declined by half since 1992.<sup>5</sup> All voting technologies used in federal elections employ ballots with the basic characteristics of the Australian ballot — all possible choices are displayed for all offices, the voter marks choices through some mechanism, and those choices are secret. Also, only ballots provided by the relevant election office can be used, and controls ensure that a voter submits only the ballot that he or she was issued.

**Lever Machines.** The next technological advance in voting came with the introduction of the lever voting machine in 1892. In this technology, there is no document ballot. A voter enters the voting booth and chooses candidates listed on a posted ballot by pulling a lever for each candidate choice. The votes are recorded by advances in a counting mechanism that are made when the voter leaves the booth. The lever machine therefore eliminates the need to count ballots manually. Instead, poll workers read the numbers recorded by the counters. Because there is no document ballot, recounts and audits are limited to review of totals recorded by each machine. Write-in votes, however, must be recorded on separate document ballots. About 22% of precincts currently use lever machines. That percentage has declined substantially since 1992 and is expected to continue to decrease, because the machines are no longer manufactured, although parts are still available.

**Punchcards.** The first technological approach utilizing computers to count votes was the punchcard system, first used in 1964. In this system, the voter records choices by punching holes in appropriate locations on a paper computer card that is later fed into a computer reader to record the vote. The piece of card that is punched out is called a *chad*. The computer card serves as the document ballot on which the votes are recorded. As with other document ballots, punchcards can be manually recounted and audited.

There are two basic types of punchcard system. In one, numbered boxes are printed on the card, with each box corresponding to a particular ballot choice. The choices corresponding to those numbered boxes are indicated to the voter in a posted

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<sup>4</sup> S.J. Ackerman, “The Vote that Failed,” *Smithsonian Magazine*, November 1998, 36,38; Richard Reinhardt, “Tapeworm Tickets and Shoulder Strikers,” *American West* 3 (1966): 34–41, 85–88.

<sup>5</sup>Data on the use of voting technologies in 1992 cited here and for other systems is from Kevin J. Coleman, Thomas H. Neale, and Joseph E. Cantor, *The Election Process in the United States*, CRS Report 95-800, 6 July 1995, 69.

ballot in the form of a booklet attached to a voting machine, with the appropriate places to punch indicated for each candidate or other ballot choice. A voter slips the card into the “throat” of the voting machine, where it rests on a set of rubber strips under the ballot book. A simple stylus is used to punch out the chad for the box(es) corresponding to the candidate(s) chosen for each race or other item on the ballot. Turning a page in the booklet exposes another set of boxes on the card, corresponding to another set of ballot choices. The card may be prescored — partially cut through — at the locations within each box where a hole can be punched. The Votomatic<sup>6</sup> system used in Palm Beach County, Florida, and elsewhere is an example of this system. Write-in choices are not placed on the card itself but are written elsewhere, such as on the envelope in which the card is placed. If the card used is not prescored, a special, spring-loaded stylus is used to punch the holes. About 33% of precincts use this type of system. It is therefore the most widely used voting technology at present. The number of voters using the system has declined since 1992, and that decline is expected to continue.

In the other kind of punchcard system, called Datavote, voters punch holes next to the names of candidates or other ballot choices that are printed on the cards themselves — there is no ballot book. The voter places the ballot card in a voting apparatus that has a stapler-like punching mechanism on a slide. The cards are not prescored. Write-in votes can be placed directly on the card. About 4% of precincts use the Datavote system, and usage of this system has also declined.

**Marksense Forms.** This technology, also called **optical scan**, has been used for decades in scoring standardized tests. It first became available for use in voting in the 1980s. In this system, a voter using a paper form and an appropriate writing instrument<sup>7</sup> fills in a box or oval or completes an arrow corresponding to each candidate choice. The completed ballot is then read by a computerized device that senses and records the marks. Write-in votes can be placed directly on the ballot. About 25% of precincts use marksense voting systems. The percentage of voters using this technology has almost doubled since 1992, and that increase is likely to continue.

**Electronic Voting.** This technology was first introduced in the 1970s.<sup>8</sup> Called direct recording electronic (DRE) technology, this system is somewhat analogous to (although more sophisticated than) the lever voting machine. Rather than marking a paper ballot, the voter chooses candidates from a posted ballot. Depending on the equipment used, the ballot may be printed and posted on the voting machine, or it may be displayed on a computer screen. Voters make their choices by pushing a button, touching the screen, or using a similar device. The voter submits those choices before

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<sup>6</sup> Originally a brand name, the term *Votomatic* has passed into general usage to refer to this kind of technology, of which there are now several different models by different manufacturers.

<sup>7</sup>For example, some systems have required the use of a #2 pencil, while others can read ink.

<sup>8</sup>Peter A. Schocket, Neil R. Heighberger, and Clyde Brown, “The Effect of Voting Technology on Voting Behavior in a Simulated Multi-Candidate City Council Election: A Political Experiment of Ballot Transparency,” *Western Political Quarterly*, 45 (June 1992): 522.

leaving the booth, for example by pushing a “vote” button, and the votes are directly stored in a computer memory device such as a removable disk or nonvolatile memory circuit. If the voting equipment has a keyboard, write-in votes can be recorded electronically. Otherwise, they must be recorded separately on a document. About 7% of precincts use DRE voting systems. As with marksense systems, the percentage of voters using DRE has almost doubled since 1992 and is expected to continue to increase.

One form of electronic voting currently in development is Internet voting, in which voters make their choices online. Internet voting differs from DRE systems in several ways. First, it is often done using a general purpose personal computer rather than a custom-designed voting machine, although such machines can also be used. Second, results are not accumulated at the polling place but are sent to the tabulating computer when cast. Third, results (ballots or counts) are not sent over a direct modem connection or physically transported to the central tabulator, but are sent over the Internet. Those features make Internet voting a promising technology in some ways but pose special challenges for ensuring authentication, secrecy, and security in the voting process.<sup>9</sup> The use of Internet voting is currently limited to demonstration projects. For example, for the November 2000 election, voters in several counties in California cast nonbinding votes online, from online voting machines placed in central locations.<sup>10</sup> In the same election, 84 overseas military personnel cast their actual votes via the Internet through a small pilot project run by the Federal Voter Assistance Program (FVAP).<sup>11</sup>

## Remote Voting

The voting technologies described above were designed primarily for use at designated polling places. The systems using document ballots — those that are paper- or card-based — permit remote voting via absentee or other mail-in balloting. Lever-machine and DRE systems cannot accommodate remote balloting, so in those cases a document-based alternative must be used. However, Internet voting could change that. If used in the polling place, it would be analogous to DRE. However, it could also provide the possibility of voting from home or another location. If used in that way, it would be analogous to mail-in balloting.

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<sup>9</sup>See Kevin Coleman and Richard M. Nunno, *Internet Voting: Issues and Legislation*, CRS Report RS20639, 16 January 2000. A recent report sponsored by the National Science Foundation has cautioned against the use of Internet voting until problems associated with security and other issues are resolved (Internet Policy Institute, *Report of the National Workshop on Internet Voting: Issues and Research Agenda*, March 2001, [[http://www.internetpolicy.org/research/e\\_voting\\_report.pdf](http://www.internetpolicy.org/research/e_voting_report.pdf)]).

<sup>10</sup>California Secretary of State, *Online Voting Demonstrations*, [[http://www.ss.ca.gov/elections/elections\\_online\\_demo.htm](http://www.ss.ca.gov/elections/elections_online_demo.htm)], 21 November 2000.

<sup>11</sup>This program is run by the Department of Defense. See *Federal Voter Assistance Program (FVAP)*, [<http://www.fvap.ncr.gov/>], 15 November 2000.



Remote voting can be very convenient for the voter and therefore may increase turnout. While states vary in the circumstances for which they permit mail-in ballots, an increasing percentage of voters use such remote balloting. For example, Oregon conducted its November 2000 election entirely by mail-in ballot. In California, the percentage of ballots cast by absentees has increased steadily, from 3% in 1962 to 25% in 1998.<sup>12</sup> The Uniformed and Overseas Citizens Absentee Voting Act of 1986 (P.L. 99-410) contains provisions to improve absentee voting for U.S. citizens and military living abroad.<sup>13</sup>

## Federal Agency Activities

The Office of Election Administration of the Federal Election Commission assists state and local election officials on matters related to election administration. Activities of other agencies are limited. The National Science Foundation has undertaken a study of Internet voting. The Department of Defense, through its Federal Voting Assistance Program office, and in cooperation with several states, undertook a test, mentioned above, of Internet voting during the November 2000 federal election.<sup>14</sup> The National Institute of Standards and Technology does not have any current activities in voting technologies, although its predecessor, the National Bureau of Standards, had undertaken studies of this matter.<sup>15</sup>

## Issues

The presidential election of the year 2000 has drawn attention to several issues relating to the voting technologies currently in use. Issues discussed below include the following: ballot design, prevention and correction of voter errors, vote counting, standardization, and upgrading voting systems.

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<sup>12</sup>Data are from a table listing historical absentee ballot use in California (California Secretary of State, *Casting a Ballot*, [[http://www.ss.ca.gov/elections/elections\\_m.htm](http://www.ss.ca.gov/elections/elections_m.htm)], 2 November 2000).

<sup>13</sup>See Kevin J. Coleman, *The Uniformed and Overseas Citizens Absentee Voting Act: Background and Issues for the 107<sup>th</sup> Congress*, CRS Report RS20764, 21 February 2001.

<sup>14</sup>See Coleman and Nunno, *Internet Voting*, 6, for details.

<sup>15</sup>Roy G. Saltman, *Accuracy, Integrity, and Security in Computerized Vote-Tallying*, National Bureau of Standards Special Publication 500-158, August 1988; this report is still widely cited. See also Roy G. Saltman, *Computer Science and Technology: Effective Use of Computing Technology in Vote-Tallying*, National Bureau of Standards Special Publication 500-30, April 1978.

## Ballot Design

Ballot design<sup>16</sup> is not a simple art, and standards vary from state to state. Concerns raised in the presidential election about the design of ballots, in particular those used in the Florida counties of Palm Beach and Duval, have led some observers to call for improvements in ballot design. A central question is, how can a ballot best be designed to ensure both a fair and clear presentation of choices? Issues of fairness include factors such as the order of presentation of candidates and the use of uniform typefaces. Those are often addressed by state law or regulation. For example, some states require alphabetical presentation of candidates, and some require that the order of presentation be rotated for different parties from one election to another or even among precincts during the same election. Another question is how to minimize ballot fatigue, also called voter fall-off, or roll-off, which refers to a voter completing only the first part of a ballot. The length, complexity, and manner of presentation of the ballot (which depends in part on the voting technology used) may all have some effect on the prevalence of this well-documented phenomenon, and even on the percentage of voters who complete the first ballot item. Roll-off may even vary depending on whether the ballot items are all placed on one page or several pages, and the position of an item on the page.<sup>17</sup>

The issue of clarity is perhaps more difficult, as it requires the ballot designer to weigh potentially conflicting design goals. For example, election officials may wish to enhance the readability of a ballot by using a fairly large typeface. If, however, there is a long list of candidates for an office, that may require splitting the list between two separate pages of a ballot book, as was done in Duval County, or placing them on facing pages — the so-called butterfly ballot used in Palm Beach County. Both approaches could, however, contribute to errors by voters. With the former approach, some voters may inadvertently vote for candidates on both pages (thereby invalidating their vote for that office), and with the latter some may inadvertently vote for a different candidate than the one intended, or punch two adjacent holes. The kinds of errors cited for the butterfly ballot particularly can be a problem if the ballot is not designed to unambiguously guide the voter to the appropriate hole to punch, or if there is any misalignment of the ballot in the voting machine that makes it difficult to discern the appropriate hole. The feature of some marksense ballots that requires voters to complete an arrow pointing to the candidate of choice is an example of a design that might serve to substantially reduce the risk of such ambiguity. Similarly, a lever machine may be designed so that pulling a lever points it at the name of the candidate. Such a feature is not possible with punchcard systems. The example therefore illustrates that different voting technologies place

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<sup>16</sup>As used here, the term *ballot design* refers to both document and posted ballots — that is, it refers not only to the ballots themselves, but also to the presentation of candidate choices. That includes the voting booklets used in Votomatic and similar punchcard systems, and the identifying information placed next to levers or other choosing devices in lever and electronic voting machines.

<sup>17</sup>R. Darcy and Anne Schneider, “Confusing Ballots, Roll-Off, and the Black Vote,” *Western Political Quarterly* 42, No. 3 (1989): 347–364; Stephen M. Nichols and Gregory A. Strizek, “Electronic Voting Machines and Ballot Roll-Off,” *American Politics Quarterly* 23, No. 3 (1995): 300–318.

different constraints on the way a ballot can be designed to improve its clarity and ease of use.

There are a number of views on ballot design. One is that no broad improvements are necessary, because it is the responsibility of the voter to mark the ballot properly and to get help if there is a problem. Another approach would be the development of a standard national ballot for federal elections. Such a common ballot would eliminate the risk of problems that might arise from local differences in designs and is discussed further below in the section on standardization. A third alternative would be the development of uniform voluntary standards for ballot design that are based on well-established design principles widely used in other interactive applications, such as Internet Web sites. Such standards might also include guidelines for using established procedures to test ballots for usability.<sup>18</sup>

## Voting Errors

There are three basic kinds of error that a voter might make: overvote, undervote, and unintended choice. An overvote is a vote for more candidates for a particular office than is permitted, such as voting for two candidates for President, and is usually considered an error. An overvote on a ballot item invalidates the vote for that item. An undervote is a vote for fewer than permitted, such as voting for no candidate for President. An undervote may or may not be an error — a voter might, on the one hand, have tried to vote for a candidate but was unsuccessful in marking the ballot unambiguously, or might, on the other hand, have chosen not to vote for any candidate.<sup>19</sup> An unintended choice is inadvertently voting for a candidate other than the one intended. The use of secret balloting precludes determining whether an observed overvote, undervote, or counted vote is an error or intentional. In this report, the combination of overvotes plus undervotes will be referred to as *roll-off*.<sup>20</sup>

Voting technologies differ in how they help a voter prevent or correct errors, and consequently, the incidence varies to some extent with the technology employed.<sup>21</sup> Lever machines can prevent overvoting through the use of interlocking mechanisms that prevent a voter from pulling a lever for more than one candidate for a given office. Electronic systems can prevent overvoting through an electronic equivalent of such a mechanism. Some marksense systems can reduce overvoting by permitting

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<sup>18</sup>There appears to have been little research to date on ballot design with respect to usability. See, however, Susan King Roth, “The Unconsidered Ballot,” *Visible Language* 28, No. 4 (1994): 48–67; and Susan King Roth, “Disenfranchised by Design: Voting Systems and the Election Process,” *Information Design Journal* 9 (1998): 1–8, available at [<http://www.informationdesign.org/pubs/roth1998.html>].

<sup>19</sup>Undervotes associated with ballot fatigue are an example of the latter.

<sup>20</sup>Other terms used for this include fall-off, no-vote, uncounted vote, residual vote, and even undervote. Undervotes are also sometimes called blank ballots and overvotes, spoiled ballots (although ballots can be spoiled in other ways, such as by having marks that could potentially be identifying). This proliferation of terms can be potentially confusing.

<sup>21</sup>See, for example, George B. Mather, *Lost Votes: Effects of Methods of Voting on Voter Participation*, (Iowa City: University of Iowa, 1986).

a ballot to be checked by the tabulator (sometimes called a “smart ballot box”) before submission and indicating if there is an overvote; the voter can then be given a new ballot.

No system can prevent undervoting, but electronic systems can potentially reduce them by indicating via a light or other mechanism the offices for which a voter has not yet cast a vote,<sup>22</sup> or by guiding the voter through a multipage ballot electronically, thereby reducing the risk of inadvertent page-skipping. Paper or marksense ballots can easily be mismarked, for example by a voter circling the name of a candidate rather than marking the appropriate box. Such a mismatch would likely be read by machine as an undervote. That kind of mismatch is probably less likely with a punchcard ballot, since it is marked with a stylus, not a pen or pencil. Marksense systems that use smart ballot boxes can potentially reduce undervotes if the tabulator is set to check for them, but that may be impractical if the incidence of ballot roll-off is high.

Unintended choices also cannot be prevented. However, how often they occur depends in part on the clarity of the ballot design and functioning of the voting equipment. For example, concerns have been expressed that misalignment of punchcard ballots in voting machines may lead to mistaken choices. Some touchscreen electronic systems can potentially reduce the risk of unintended choice by allowing the voter to review a summary of the choices made before submitting the ballot.

The incidence of errors may also depend on the condition of voting equipment and the demographics of the voting population. For example, a faulty lever or mechanical counter on a lever machine or a problem with a circuit on an electronic system may cause a failure to record a vote. A malfunctioning stylus or deteriorated equipment in a punchcard voting machine might increase the risk that a punch would be incomplete. Also, some studies have found that inexperienced and elderly voters tend to make more errors with punchcard than with other systems.<sup>23</sup> There is even some evidence that the height of a voter can affect the frequency of ballot roll-off with lever machines.<sup>24</sup>

Voting technologies also vary with respect to how voters can review their choices and correct any errors they might have made. With both lever and electronic systems, voters can review their choices and make changes before they leave the voting booth, although they have no way of checking to ensure that their choices were accurately recorded by the voting machine. With other systems, voters who wish to make a change must leave the booth and obtain a new ballot. With marksense systems where tabulation is done at the precinct, ballots may be checked by the tabulator for some kinds of error before being submitted. However, marksense systems where tabulation is done at a central location do not permit such machine-

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<sup>22</sup>Stephen M. Nichols and Gregory A. Strizek, “Electronic Voting Machines and Ballot Roll-Off,” *American Politics Quarterly* 23, No. 3 (1995): 300–318.

<sup>23</sup>Schocket, “Effect of Voting Technology.”

<sup>24</sup>Susan King Roth, “The Unconsidered Ballot,” *Visible Language* 28, No. 4 (1994): 48–67.

assisted error correction. With paper ballots and punchcards, voters must check the ballots for errors, although some precinct-based card readers can also be programmed to check for errors. Some observers contend that such error-checking does in fact reduce the incidence of overvotes and spoiled ballots.

Differences between the Votomatic and Datavote systems illustrate some of the error-handling trade-offs involved in ballot design. A Votomatic ballot usually requires only a single card. If a voter wants to check the ballot to make sure that a vote was not miscast, he or she has to find the hole that was punched out, find the corresponding number, and check that against the number in the ballot book. That must be done for each ballot item, a complex process. A Datavote ballot may require several cards and may need to be marked on both sides. That raises the possibility that a voter might miss a card or fail to vote on both sides. However, because the names of candidates are printed on the cards, a voter can more easily check a Datavote ballot for errors.

## Counting

The counting of votes after they are cast involves several issues, including the accuracy of the counting methodology, its speed, and its integrity and security. Counting may be done either in individual precincts or at a central location within the election jurisdiction, or both. It may be performed by a machine, or by human inspection, or both. Paper ballots are counted manually, usually at the precinct. With lever machines and electronic systems, there are no document ballots. Counts are taken at the precinct from lever machines. With marksense or electronic systems, counts can be performed electronically at the precinct and sent electronically via modem or by other means to a central location. With punchcard systems, ballots are usually taken to a central location for machine counting and are tabulated by precinct. However, they may also be counted at the precinct in some cases.

The accuracy of a vote count depends on many factors, including the characteristics of the technology used, the design and condition of the equipment and software, and human behavior. For example, since paper ballots are counted manually, the accuracy of the count depends on the performance of the people doing the counts. Lever machines reduce some kinds of human error, but problems with counts may occur as a result of malfunctioning machines or from errors made by the poll workers who read them. Punchcards and marksense forms are read by machine, reducing some kinds of human error. Other problems may arise from software or hardware errors, or from the ballots themselves. For example, with prescored cards, voters may not completely remove chad when punching the cards. Such incompletely removed (hanging or swinging) chad, or even detached chad that is loose in the counting device, may block punched holes and be read by the counting machine as undervotes. With marksense systems, voters might make ambiguous marks that a tabulating machine may read differently depending on factors such as the alignment of the ballot sheet when it is fed into the machine. Since DRE systems record each vote electronically as it is cast, there is no risk of human error in counting, and voters cannot make ambiguous or unreadable choices. Problems might still arise from other sources such as software or hardware failure, however.

Reports on the accuracy of different systems vary. For example, some have claimed that punchcard readers can have an error rate as low as 1 vote out of each 10,000 counted under ideal test conditions.<sup>25</sup> Error rates as high as 1 in 100 have been reported from prior elections, and some experts believe that Votomatic punchcard systems using prescored cards may be the least accurate of the available technologies.<sup>26</sup> However, estimates from actual elections are based on roll-off (ballots for which votes were not counted) and cannot distinguish errors that occur because of inherent limitations of the technology from roll-off resulting from mistakes (voter error) or intentional actions by voters.<sup>27</sup> Assessment of the accuracy of a particular voting technology should also take into account other factors that might affect the observed roll-off, such as population size or other demographic variables. Voting systems that reduce or eliminate overvoting (lever machines, DREs, and precinct-tabulated marksense or punchcard systems) would be expected to produce lower total roll-off rates than those that do not (paper ballots and centrally tabulated systems). Some results support that expectation, but others do not.<sup>28</sup> Also, the accuracy of a

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<sup>25</sup>Saltman, *Accuracy, Integrity, and Security in Computerized Vote-Tallying*, 5, recommended a maximum error rate of 1 in 100,000.

<sup>26</sup>Ford Fessenden and Christopher Drew, “Alas, Vote-Count Machines Are Only Human,” *The New York Times*, Friday, 17 November 2000, Sec A, 1, 25. The error rate of a particular technology can be of concern especially in a very close election, where the margin of victory is very small. For example, the final margin of 537 votes out of almost 6 million cast in the 2000 presidential election in Florida was equivalent to about 1 out of every 11,000 votes cast, which suggests that an ideal error rate might best be considerably smaller than 1 in 10,000.

<sup>27</sup> For example, about 180,000 ballots, or 3%, of all those cast in Florida did not have any vote counted for President (that roll-off includes overvotes, undervotes, and otherwise uncounted ballots) (Governor's Select Task Force on Election Procedures, Standards and Technology, *Revitalizing Democracy in Florida* [final report of the task force], 1 March 2001, 32, [[http://www.collinscenter.org/usr\\_doc/50114.doc](http://www.collinscenter.org/usr_doc/50114.doc)]). The rate in counties using punchcards was 3.8%, whereas in counties using marksense systems it was 1.3% (Pam Iorio, President, Florida State Association of Supervisors of Elections, “Election Reform in the Aftermath of Florida’s 2000 Presidential Election,” Remarks to the Governor’s Select Task Force on Election Procedures, Standards and Technology, Tallahassee, Florida, 8 January 2001). There is no way to determine the degree to which machine error, voter error, intentional voter action, and other factors each contributed to those numbers.

<sup>28</sup>For example, in Florida, counties using precinct-tabulated marksense forms had much lower average roll-off for the presidential race (<1%) than counties using centrally tabulated marksense forms (6%) or punchcards (4%) in the November 2000 election (Governor's Task Force, *Revitalizing Democracy in Florida*, 31–32). Those differences were highly significant statistically. In contrast, in the neighboring state of Georgia, the average roll-off was 4–5% for each of the technologies most widely used (lever machines, punchcards, and precinct- or centrally tabulated marksense forms) (Georgia Secretary of State Cathy Cox, *The 2000 Election: A Wake-Up Call for Reform and Change: Report to the Governor and Members of the General Assembly*, January 2001, 7, available online at the Secretary of State's web site [[ftp://www.sos.state.ga.us/elections/2000\\_election\\_report.pdf](ftp://www.sos.state.ga.us/elections/2000_election_report.pdf)]). In addition, a recent preliminary analysis of voting systems used across the United States found that DRE systems had higher roll-off than marksense systems, lever machines, or even paper ballots. However, the study did not analyze precinct- versus central-tabulated systems and did not attempt to

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system in a given election may depend as well on the particular design and condition of the voting and counting equipment and the degree to which technical procedures and specifications are followed by the election administrators.

Pre- and postelection tests are widely performed on voting-machine systems to check for accuracy and also to guard against tampering. In addition, manual recounts may be routinely performed on a small percentage of ballots as a check on the validity of the machine count. Accurate operational tests are most difficult with electronic and lever-machine systems, where there is no ballot document and the count is recorded at the voting booth. A thorough test would require hundreds of simulated votes to be placed on each machine.

Voting technologies may also affect recounts. With lever machines and, in many cases, DRE systems, recounts are limited to checking the vote totals recorded by each machine. Some observers consider that an advantage because it limits the potential for human or machine error to affect the recount. Others consider it a disadvantage, because it does not allow for a ballot-by-ballot paper audit trail.<sup>29</sup> With punchcard and marksense systems, machine recounts may not produce fully repeatable results — tallies may vary slightly if recounts are repeated.<sup>30</sup> Whether hand recounts are more accurate than machine counts has been the subject of considerable debate. Some observers claim that machine tabulators may miss valid votes, misidentifying them as undervotes or overvotes, and that manual counting can detect more accurately the voter's intent. Others assert that manual counting is less objective and that voters should be required to follow instructions for properly marking ballots. State laws vary with respect to when manual recounts are appropriate and what standards are to be used.

All current technologies except paper ballots can produce large counts rapidly once polls are closed. Systems in which ballots are counted electronically as they are submitted in the precinct can probably produce the most rapid results. With Votomatic systems, accuracy may be increased if the cards are manually inspected to remove loose chad before counting, but that will sacrifice some speed.<sup>31</sup>

Security requirements and measures also vary among the technologies used. Document ballots require security measures and controls from the initial printing of

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<sup>28</sup>(...continued)

determine the causes of the observed results (R. Michael Alvarez and others, "A Preliminary Assessment of the Reliability of Existing Voting Equipment," 1 February 2001, [<http://www.vote.caltech.edu/Reports/report1.pdf>]).

<sup>29</sup>DREs, however, can record a ballot-by-ballot audit trail electronically.

<sup>30</sup>This issue has been known for many years with respect to votomatic-type punchcard systems (see, for example, Saltman, *Accuracy, Integrity, and Security in Computerized Vote-Tallying*, 110). A major source of the variability is loose or hanging chad, which may or may not block punchholes when fed through the reader. However, marksense readers may also produce some variability, for example if some ballots are marked in a way that is close to the readability limits of the tabulator.

<sup>31</sup>Fessenden and Drew, "Vote-Counting Machines," 25.

the ballots through counting and storing them. However, the ballots can serve as a basis for an audit trail, which is not available for lever machines. DRE systems can produce electronic audit trails by storing anonymized electronic ballots for each voter, or by printing a document with ballot choices that the voter deposits in a ballot box but which is retained solely for audit or recount purposes.<sup>32</sup> Experts differ on the importance of such a paper audit trail for ensuring the security and integrity of the voting process. Special measures and controls have also been developed for both hardware and software used in computer-based systems.

Some observers believe that the very diversity and decentralization of the voting systems used in the United States enhance the integrity of the voting process by making widespread tampering more difficult. Not only are there five different basic kinds of voting technology in use, but dozens of different models are used. That makes tampering much less feasible than if a single system were used. Furthermore, election jurisdictions differ in how they configure their voting equipment to meet the requirements of the particular election being administered. That includes how ballots are arranged and, therefore, how votes are recorded.<sup>33</sup> That variability makes widespread tampering with software or computerized counting machines much more difficult.

One important aspect of security is maintaining ballot secrecy. This is a concern particularly for remote voting and has increased as that form of voting has become more common. Ballot secrecy is widely considered a crucial mechanism for preventing vote tampering and fraud. The rapid, widespread adoption of the Australian ballot in the United States at the end of the 19<sup>th</sup> century came about because of scandals resulting in part from the fact that the ticket ballot was not secret.<sup>34</sup> Modern polling-place voting ensures that voters cast secret ballots in two ways. First, voter identification and ballot casting are performed in two separate steps. Second, ballots are cast in private. Remote voting, such as by mail or the Internet, can increase voter participation but can potentially create problems for ballot secrecy. Two basic aspects of ballot secrecy are first, that once a ballot is cast, it cannot be traced by a second party to an individual voter, and second, that a voter cannot demonstrate to others how he or she voted. Failure to maintain those aspects of ballot secrecy is of concern because it can facilitate corruption. While controls can be put in place that can greatly reduce the risk of traceability, it is not clear how to prevent remote voters from proving how they voted.<sup>35</sup>

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<sup>32</sup>At least one system also provides the capability of electronically checking the printed ballot against the electronically recorded one. However, a DRE system that also provides a printed ballot is likely to be expensive, as each voting booth must include a printer as well as the voting machine.

<sup>33</sup>Ballot configurations may also vary within jurisdictions. For example, Hillsborough County, Florida had 82 different versions of the ballot in the November 2000 election, to accommodate different intracounty races (Iorio, "Election Reform").

<sup>34</sup>Ackerman, "The Vote that Failed."

<sup>35</sup>For example, in casting absentee ballots, it is common practice that the ballot is placed in an unsigned envelope that is then placed inside the mailing envelope, which is signed. Election



## Accessibility

Federal law sets some requirements for elections with respect to accessibility. The Voting Rights Act of 1965, as amended, requires that ballots, other relevant materials, and assistance be provided in the language of citizens from non-English-speaking minorities who constitute a sufficiently large population in a state or political subdivision (42 U.S.C. 1973aa-1a).<sup>36</sup> In some jurisdictions, materials and assistance will need to be provided in several languages. Assistance must also be allowed for voters who are blind, disabled, or unable to read or write (42 U.S.C. 1973aa-6). The Voting Accessibility for the Elderly and Handicapped Act of 1984 (42 U.S.C. 1973ee) requires that election jurisdictions make available accessible polling places and aid to elderly and disabled voters. Some states may also have additional requirements for accessibility and assistance.

Voting technologies differ in how easily they can accommodate those requirements. DRE systems provide the greatest flexibility. For example, with touch-screen systems, each machine can be programmed to display ballots in any required language. Electronic systems can also be designed to accommodate wheelchair-bound voters and to provide auditory assistance via headphones for blind voters. With other technologies, special ballots may need to be printed and individual assistance provided.

## Standardization

States, not the federal government, regulate the voting technologies they use. However, in response to concerns raised in the 1970s and 1980s about the then largely unregulated voting-technology industry,<sup>37</sup> Congress directed the Federal Election Commission to develop voluntary standards for computer-based voting systems.<sup>38</sup> The standards, developed in collaboration with the National Association of State Election Directors and approved in 1990, had been adopted in whole or in part by 32 states as of November 2000.<sup>39</sup> They were developed for both hardware

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<sup>35</sup>(...continued)

officials can then check to ensure the identity and eligibility of the voter without seeing how the person voted. However, a voter could still photocopy the ballot or show it to another person before mailing it, thereby proving how he or she voted. Also, the ballot may not be filled out in private.

<sup>36</sup>For a discussion of the Voting Rights Act, see Garrine P. Laney, *The Voting Rights Act of 1965, as Amended: Its History and Current Issues*, CRS Report 95-896, 14 February 2001.

<sup>37</sup>See, for example, Saltman, *Accuracy, Integrity, and Security in Computerized Vote-Tallying*.

<sup>38</sup>Federal Election Commission, *Frequently Asked Questions about Voting System Standards*, [http://www.fec.gov/pages/faqs/vss.htm], 10 July 1988.

<sup>39</sup>Specifically, those states have adopted either the “standards or the testing of systems against the standards by independent testing authorities (ITAs) designated by the National Association of State Election Directors,” (FEC, *FAQs about Standards*). Standards testing has not been

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and software and include functional and documentation requirements, performance characteristics, and testing procedures for punchcard, marksense, and DRE systems. Updated standards are expected next year.

One focus of current debate is whether a need exists for more standardization. Some have suggested that mandatory, rather than voluntary, standards be adopted nationwide for existing voting technologies. Others have proposed adoption of a single voting technology nationwide, and still others creation of a standard national ballot for presidential elections. The adoption of mandatory national standards might provide more uniformity in the performance of different kinds of voting technology. Such standards might also be expanded in scope from the current set, which is limited to computer-based systems and does not address issues such as to what extent a system reduces voter error. New standards might cover all technologies and other aspects of election administration, such as election management and ballot design. However, such standards are unlikely to anticipate all circumstances under which a technology is actually used, and their adoption by states may not resolve problems caused by such circumstances or by other differences that the standards do not address.<sup>40</sup>

Adoption of a standard national ballot would likely require adoption of a single technology as well, since different types of voting systems require different ballot designs. Either of those two approaches would make the development of standards easier and would eliminate the risk of problems arising from local differences in voting technology. For example, in a close statewide election in which different election jurisdictions use different technologies, some observers have expressed concern that the outcome of the election could be affected by differences in the accuracy of the systems used. The economies of scale associated with national adoption of a single technology could reduce per-unit cost and improve efficiencies in other ways.<sup>41</sup>

Concerns have been raised about adopting a uniform national technology or a standard national ballot. The extent of congressional authority to impose such a system on local election jurisdictions, as well as its desirability, is a subject of some debate. While the U.S. Constitution gives Congress authority to regulate congressional elections,<sup>42</sup> election jurisdictions must hold state and local elections as

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<sup>39</sup>(...continued)

applied to all such systems, however; for example, some older systems already in use when the standards were adopted and were “grandfathered in.”

<sup>40</sup>For example, Florida is one of the 31 states listed by the FEC as adopting the standards or tests using them. Yet, the use of those standards did not prevent the kinds of problems widely cited in Florida with respect to the November 2000 election. Among those problems, some were arguably caused by differences in the voting technologies used, and others occurred with respect to aspects of election administration, such as ballot design, not covered by the current standards.

<sup>41</sup> While many other countries use a standard national system, in many of those cases, paper ballots and manual counting are used (see Note 32).

<sup>42</sup> Article I gives Congress authority to regulate congressional elections, but it is less clear that  
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well. Elections are often consolidated, with ballots listing federal, state, and local candidates, and other ballot items such as referenda. A standard national technology might reduce the flexibility of local governments to respond to local circumstances, and converting to such a system would probably be expensive. Jurisdictions would be unlikely to adopt a technology for use solely in federal elections if it could also be used for local elections. Some observers also argue that adoption of a common system could greatly reduce the market for new voting technologies, thereby reducing economic incentives to develop further advances.<sup>43</sup> Others claim that the very diversity of the voting systems used in the United States makes systematic tampering more difficult, as discussed in the previous section of this report.

Some observers have proposed that, rather than developing national standards, each state should be encouraged to adopt a uniform voting technology for the entire state. Currently, almost all states use more than one voting technology, and a few use all five discussed in this report. This proposed approach might ease some of the concerns associated with adopting a single technology, but the potential benefits might also be reduced. Some observers have argued that a uniform statewide system might be necessary to avoid future election challenges based on violation of the equal protection clause of the U.S. Constitution. For example, concerns have been raised that voting technologies thought by some observers to be particularly prone to voter error, such as Votomatic punchcards, may be disproportionately used by minority or poor populations. However, a recent analysis found little support for that assertion with respect to the nationwide distribution of voting equipment.<sup>44</sup>

Other observers recommend modernization rather than adoption of uniform systems, arguing that many improvements are best left to the election jurisdictions themselves. The National Association of Secretaries of State established a National Election Standards Task Force that drafted a resolution, adopted in February 2001, calling on state and local governments to work toward modernizing the voting

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<sup>42</sup>(...continued)

Article II provides such authority for selection of the presidential electors. For discussion of this issue, see Kenneth R. Thomas, *Congressional Authority to Standardize National Election Procedures*, CRS Report RL30747, 27 November 2000. See also General Accounting Office, *The Scope of Congressional Authority in election Administration*, GAO-01-470, 13 March 2001.

<sup>43</sup>The Canadian system provides an interesting example. The Canada Elections Act [<http://canada.justice.gc.ca/en/laws/E-2/text.html>] provides for a uniform voting system for national elections. That system has codified the use of a single technology — paper ballots. Therefore, there is no significant incentive to develop or adopt new technologies for use in national elections. Nevertheless, some jurisdictions may use other technologies for local elections. For example, in a recent election for mayor and certain other offices, residents of Toronto voted using either a marksense form or touchscreen DRE system (“Toronto Vote 2000 Frequently Asked Questions,” [<http://www.city.toronto.on.ca/vote2000/faqs.htm>], 17 October 2000). That election was held two weeks before the national election on November 27, 2000.

<sup>44</sup>Stephen Knack and Martha Kropf, *Who Uses Inferior Voting Technology?*, January 2001, (available from the authors).

process, including voting technology, but calling for uniform standards and procedures within states only for recounts and contested elections.<sup>45</sup>

The National Association of Counties and the National Association of County Recorders, Election Officials, and Clerks established a National Commission on Election Standards and Reform in November 2000. The Election Center, an association of election and voter registration officials, has established an Elections Reform Task Force to review concerns about election systems and recommend changes. Both groups are currently deliberating.

Several states have also examined the issue of modernization and adoption of standards. On December 14, 2000, Governor Bush of Florida established by executive order the bipartisan Select Task Force on Election Procedures, Standards, and Technology.<sup>46</sup> The task force examined several issues associated with election administration and has issued its recommendations. Several other states have established task forces or are otherwise examining voting technologies and procedures.<sup>47</sup> A privately funded National Commission on Federal Election Reform, cochaired by Presidents Carter and Ford, is also examining a wide range of issues relating to voting technology and election administration.<sup>48</sup>

## Upgrading Voting Systems

A decision to upgrade a voting system inevitably involves trade-offs among different goals, such as cost-efficiency, speed, and accuracy. Paper ballot technology is the most labor-intensive alternative and may cost several times as much to operate as computer-based systems, but it requires little technological infrastructure and comparatively low maintenance costs. Lever machines are no longer made, although replacement parts are available; maintenance, storage, and transportation costs can be high. Costs of other systems vary depending on the vendor and features. Given the variety of systems available, the varying needs and circumstances of different election jurisdictions, and the uncertain effect of economic factors such as economies of scale, accurate estimates of the costs of the different technologies could not be devised for this report. However, punchcard systems have often been considered among the most economical and efficient, especially for jurisdictions with large

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<sup>45</sup>National Association of Secretaries of State, "Election Reform Resolution, [[http://nass.stateofthevote.org/pubs/pubs\\_electionres.html](http://nass.stateofthevote.org/pubs/pubs_electionres.html)], 6 February 2001.

<sup>46</sup>Governor Jeb Bush, *Executive Order 00-349*, 14 December 2000. See also "Select Elections Task Force," [<http://www.collinscenter.org/info-url2660/info-url.htm>], n.d.

<sup>47</sup>Among them are Arizona, California, Colorado, Georgia, Indiana, Iowa, Kentucky, Maryland, Minnesota, Missouri, New York, Ohio, Oregon, Pennsylvania, Washington, Wisconsin, and the District of Columbia (Karen Pierog, "States Shocked into Voting Reform after Florida," *Reuters*, 22 January 2001; see also National Association of Secretaries of State; "State Election Reform Information," 13 March 2001, [[http://nass.stateofthevote.org/Issues/issues\\_elections.html](http://nass.stateofthevote.org/Issues/issues_elections.html)]).

<sup>48</sup>"Former Presidents Carter and Ford to Oversee Bipartisan National Commission on Federal Election Reform," News Release, The Miller Center of Public Affairs, 30 January 2001 [[http://millercenter.virginia.edu/pdf/press\\_releases/natl\\_comm.pdf](http://millercenter.virginia.edu/pdf/press_releases/natl_comm.pdf)].

populations. DRE systems have often been considered the most expensive (except perhaps for lever machines), but they are also arguably the most adaptable, with the greatest potential for speed and accuracy. In any case, replacing an existing system will usually require a substantial capital expenditure by the relevant jurisdiction. Figures cited are often a million dollars or more for a jurisdiction, depending on the kind of system and population size, among other factors. Upgrading may therefore be considered a low priority compared to other needs, such as schools and roads. Some also argue that the nature of the market for voting technologies affects their development and cost. The market is relatively small and is highly regulated, and that might result in higher costs and less incentive for industry research on voting systems.

Some states have already committed to or are expected to upgrade their voting systems. For example, the Florida Election Task Force has recommended that marksense systems be leased for use throughout the state in the 2002 elections.<sup>49</sup> The Florida Secretary of State has reportedly recommended in addition the statewide adoption of a DRE system by 2004.<sup>50</sup> The District of Columbia is replacing its Datavote system with precinct-tabulated marksense technology.<sup>51</sup>

Currently, no federal programs specifically provide funding for upgrading voting systems. Recent estimates are that a nationwide upgrade would cost from \$2–9 billion.<sup>52</sup> However, substantial improvements could probably be made at considerably lower cost by focusing, for example, on upgrading those systems that have the highest documented rates of roll-off or other problems. Should Congress decide that federal assistance is necessary, there are at least two options for providing funding: discretionary grants, in which funding would be based on the specific proposals submitted by the relevant jurisdiction; or block or formula grants, in which the amount of funding would be tied to population or some other relevant factor. Congress could designate particular eligibility requirements, such as adherence to national standards or that only certain kinds of voting systems would be eligible for replacement under the program. Such a funding program might stimulate research by private industry

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<sup>49</sup>Governor's Select Task Force on Election Procedures, Standards and Technology, *Revitalizing Democracy in Florida* [final report of the task force], 1 March 2001, 30, [[http://www.collinscenter.org/usr\\_doc/50114.doc](http://www.collinscenter.org/usr_doc/50114.doc)]. Leasing is estimated to cost \$20 million.

<sup>50</sup>Mark Silva, "Elections Chief Offers Electronic Vote Plan," *Miami Herald*, 21 February 2001. The estimated cost is \$200 million.

<sup>51</sup>See [<http://www.dcboee.org/htmldocs/optech.htm>] for an illustration of the system, which was reported to cost \$1 million to purchase (Jim Willard, "How Well Intentioned Requirements Paved the Road to Election Hell," *News & Analysis @ Govcon*, 26 Dec. 2001 [<http://www.govcon.com/content/news/article.asp?DocID={98A020A3-DB49-11D4-A76E-00D0B7694F32}>]).

<sup>52</sup>See, for example, Alan C. Miller and Nick Anderson, "Voting Reforms Join Race for Funding," *Los Angeles Times*, 13 December 2000, Part A, 1. The basis for the estimate was not provided, however. Total costs would depend in part on the technology adopted. For example, adoption of DRE systems could cost several times as much as adoption of marksense technology. According to Doug Lewis, Executive Director of The Election Center, recent estimates are \$3.5–5 billion to replace all current voting equipment with new technology that provides full accessibility for persons with disabilities (testimony before Senate Committee on Rules and Administration, Hearing on Election Reform, 14 March 2001).

on further improvements in voting systems. In addition, Congress might consider federal research in this area. Such research might be performed by the National Institutes of Standards and Technology, or by the National Science Foundation, or both.

Two private efforts have been announced to develop improved voting technologies. On December 14, 2000, the California Institute of Technology and the Massachusetts Institute of Technology announced a joint effort to develop an “easy-to-use, reliable, affordable and secure” voting machine for use in U.S. elections.<sup>53</sup> On January 11, 2001, three major information technology companies — Unisys, Dell, and Microsoft — announced a joint effort to provide an integrated system for the management of elections.<sup>54</sup>

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<sup>53</sup>“Caltech and MIT Join Forces to Create Reliable, Uniform Voting System,” Press Release, [<http://www.caltech.edu/events/mitcit/citmit.html>], 20 December 2000.

<sup>54</sup>Michael Orey, “Unisys, Dell and Microsoft To Jointly Create Electronic Voting System,” *The Wall Street Journal*, 11 January 2001, sec. B, 1, 6. See also “Bye-Bye, Chad,” Unisys Press Release, [<http://www.unisys.com/news/releases/2001/jan/01117039.asp>], 11 January 2001.