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The Study of Electronic Voting

The 2000 U.S. presidential election, especially in Florida, involved a set of circumstances that evolved into the perfect storm and exposed serious flaws in the American electoral system. The events surrounding the casting of the votes, their tabulation, and the recount came close to creating a constitutional crisis. The election was already unusual because the candidate who won the popular vote nationwide did not become president—only the fourth time this has happened in U.S. history.¹ Exacerbating this situation was the extremely tight presidential race in Florida along with the confusing and now infamous “butterfly ballot” used in Palm Beach County, the undecipherable punch card ballots that made *hanging*, *dimpled*, and *pregnant chads* household terms, and faulty voter registration lists, which denied some qualified citizens the ability to vote. Debatable decisions about military ballots and ambiguous recount procedures that were applied inconsistently across Florida counties also contributed to the debacle.

The conditions in the Sunshine State created chaos for those directly involved in administering the election there. It also wreaked havoc on the presidential candidates and their transition teams, generated anxiety among many Americans, and unnerved some of our nation’s allies and other countries that look to the United States for international leadership. When the eventual outcome was determined in the U.S. Supreme Court, it only added to the confusion and concern.²

2 THE STUDY OF ELECTRONIC VOTING

Why did the election of 2000 produce such a crisis in confidence? One reason is that elections are the keystone of democracy, and their results confer legitimacy on those selected to govern. The seamless transition from the loser to the winner or from one administration to the next is a hallmark of a democratic system. Another reason is that an important principle underlying elections rests on a fundamental belief among citizens that when they go to the polls to cast their votes, their ballots will be recorded as they intended and then tabulated fully and accurately. For many Americans and others who follow American politics, the events associated with the 2000 presidential election cast doubt on whether that election, and by extension other U.S. elections, lived up to the principles that underpin American democracy.

It is difficult to overestimate the impact of the 2000 election debacle in Florida on the development and adoption of new voting technologies and the implementation of other election reforms. That election—with its voting system, ballot format, recount, and other problems—led a number of states to move quickly to replace old technologies and led Congress to pass the Help America Vote Act of 2002 (HAVA), a provision of which has funded the purchase of new voting systems to replace punch card and lever systems. The effect of the 2000 election also was evident in terms of research on voting reform. While there was a large, well-developed literature on the so-called democratic dilemma of low and unequal levels of voter turnout, research on voting systems had not progressed much beyond its infancy—perhaps because most presidential elections have not been close enough for voting systems to alter the outcome of an election.³ The 2000 election served as a catalyst for increased research and funding for studies of voting systems.

While the Help America Vote Act and the actions of various states led to improvements in the voting process, elections since 2000 have not been entirely reassuring. The 2006 election in Florida's Thirteenth Congressional District, for example, did little to inspire confidence. In that race, decided by fewer than 370 votes, more than 18,000 of the ballots cast in one county were missing a vote for a congressional candidate.⁴ The apparent cause of the problem was a poorly formatted ballot.⁵ The outcome left many wondering whether the candidate with the most recorded votes—who ultimately claimed the congressional seat—would have emerged victorious if citizens had cast their ballots on a voting system with a better ballot design.

News reports covering other recent elections describe lost and uncounted votes, failed voting machines, sloppy administrative procedures, technologically handicapped election officials, and lack of security for equipment. The media have also documented differences in the quality and the number of voting

machines provided to various precincts, raising civil rights issues. While some of the media stories are exaggerated or contain false rumors, there are enough documented problems to raise serious concerns over the voting process. As the former president Jimmy Carter and the former secretary of state James A. Baker note in the introduction to their report from the Commission on Federal Election Reform (one of many such reviews undertaken after the 2000 election), “If elections are defective, the entire democratic system is at risk. . . . Americans are losing confidence in the fairness of elections, and while we do not face a crisis today, we need to address the problems of our electoral system.”⁶

Some of these problems can be overcome by improving existing voting systems and developing new ones. If electronic systems are to be used for voting, we need to have a better understanding of how voters use them and react to them. More knowledge is also needed about the impact of ballot formats—their length, layout, and the options they present to voters—and how these interact with voting systems.

This book is a first step in the research needed to understand how voters interact with voting systems. By documenting how voters respond to these systems, including voters’ confidence in them and their abilities to cast their votes as intended, we lay the foundation for improving the way citizens vote. We report the results of a variety of studies intended to determine citizens’ reactions to new electronic voting equipment, comparing electronic voting systems with each other and with a paper ballot/optical scan system. We also consider a variety of vote verification/election audit systems (hereafter referred to as vote verification systems), including one with a paper trail.⁷

Our focus is on what is called usability, or human factors research—that is, the degree to which individuals find it easy and satisfying to use systems and to perform the expected tasks accurately and within a reasonable amount of time.⁸ Most of the subjects in our study are ordinary voters—people with various degrees of familiarity with and interest in voting and electronic systems. The ballots used are realistic, posing challenges that voters often face: partisan and nonpartisan offices, multicandidate races, and ballot questions; and provisions for correcting an error and casting a write-in vote. By examining how voters interact with these ballots, using both laboratory and field studies, and by measuring their reactions as well as their ability to cast their votes as they intended, our research represents an important departure from a literature that has relied on aggregate or other election returns for the examination of the so-called residual vote, or lost votes.⁹ Because we study several voting systems under identical conditions, our research helps to explain what it is about those systems that builds voter satisfaction and confidence and what it is that leads to voter confusion, frustration, and errors.

In this chapter we discuss the context in which voting in the United States occurs, particularly the complex and partisan nature of election administration; provide background on the evolution of voting systems; and indicate in more detail why research is necessary—especially usability research. In light of the movement toward requiring a paper record for electronic voting systems, we also indicate why it is useful to study systems with and without such a feature. Our research is forward looking, focusing not on the defects of punch card and lever technologies of the past but on new systems and prototypes of systems under development. Our research is also broad based in that it considers how a wide range of citizens rate and react to the voting systems.¹⁰ In this way, it seeks to provide a basis for turning the task of voting into one that is comprehensible, satisfying, accurate, and trusted.

Election Administration in the United States

Elections in the United States have many unique features that are worthy of brief examination. Some, such as the complexity of the ballot and the decentralization of administration, are informed by the institutional design of the political system. Others, such as the need to register properly in order to vote, are the result of reforms that followed alleged and actual incidents of corruption. Still others, including the central role of partisan officials in the administration of elections, are a long-standing practice that probably ought to be revisited. One distinctive feature is a reliance on private industry for providing the election equipment and services central to the election process.

A Decentralized System

Perhaps the defining feature of election administration in the United States is decentralization. Presidential elections—the only office for which voters in all fifty states and the District of Columbia cast a ballot—forcefully remind us that we do not have truly national elections in the United States. Instead, we have simultaneous state and local elections; these are held on the same day under a variety of administrative regulations and procedures as well as a variety of state and local laws. In most states the administration of elections is carried out by officials employed by one of more than three thousand county governments or by even smaller units. This means there is a great deal of variation in how elections are conducted. The implications of this variation were front and center in 2000 after some ill-advised decisions about ballot design made by Theresa LePore, elections supervisor of Palm Beach County, had implications that became national in scope. Decentralized election administration also makes it difficult,

if not impossible, to enact reforms that lead to nationwide uniformity in the conduct of elections.

The effects of decentralization are felt throughout the electoral process, beginning with registration, the first step in our two-step voting process. In all but one state, North Dakota, eligible citizens must register before being given the opportunity to vote. Unlike in most other countries, not only is the burden of registration placed on the individual citizen, the rules regarding registration vary considerably, most notably in the date by which citizens must register in order to vote in a given election.¹¹ The states also differ with respect to policies regarding absentee voting, early voting, and voting by mail.¹² An example of the depth of decentralization in the United States is that even the list of candidates running for president is not identical from state to state.¹³ Beyond that, such features as the length of the ballot, the offices and ballot issues voted on, the way in which voters indicate their preferences, the use and form of a straight-party feature, and whether write-ins are permitted vary from state to state. And because of the many offices citizens vote on, and especially the cross-cutting nature of legislative districts in many states, the number of distinct ballots in a given county or metropolitan area may be quite large. Add to this the requirement under the Voting Rights Act that some jurisdictions have ballots available in languages other than English and the requirement under the Help America Vote Act that voting systems accommodate the disabled, and one begins to see the complexity of election administration in the United States.

Partisan Election Officials

A second important aspect of the administration of U.S. elections is that most decisions, at either the state or local level, are made by partisan politicians. In some nations, including Australia, Canada, Costa Rica, Great Britain, and New Zealand, election administrators are nonpartisan civil service employees.¹⁴ In the United States, on the other hand, the top election officials in thirty-nine of the states are selected in partisan elections, and most of those in the remaining eleven states are political appointees. The chief election officers in forty-one of these jurisdictions serve a four-year term that coincides with that of the governor. In most states and the District of Columbia, the secretary of state has some responsibility for the electoral process, whether in the form of certifying candidates, certifying the candidates who won their party's nomination, or certifying the results of elections. In states that allow them, the secretary of state is usually the official that oversees initiatives and referenda. In thirty-seven states the secretary of state is responsible for approving the purchase of voting systems and other election devices.¹⁵

Of course, having top election officials chosen in partisan elections or by partisan appointments can lead to partisan decisionmaking and behavior. A number of recent episodes underscore this point. Secretaries of state Katherine Harris of Florida and J. Kenneth Blackwell of Ohio had the ultimate responsibility for certifying the winners of elections in their state while each simultaneously served as the director of the George W. Bush election campaign in their state—Harris in 2000 and Blackwell in 2004. Although Harris's role in certifying presidential votes in the 2000 election is the most well known of their actions, both Harris and Blackwell were responsible for certifying other close elections and making other decisions that had a substantial impact on the election process. Charges of partisan behavior and general mismanagement of funds were leveled against Kevin Shelley while he was secretary of state of California. Among other things, he was blamed for improperly spending HAVA money and state funds on efforts to raise his own profile and to promote turnout in a heavily Democratic assembly district.¹⁶ New Mexico secretary of state Rebecca Vigil-Giron also was attacked for her interpretation of the law with respect to voter identification requirements.¹⁷ Partisanship also can lead election officials within a state to treat administrative procedures differently. For example, in the 2004 election Blackwell instructed local election administrators not to distribute provisional ballots to citizens whose registration address was contested; Democratic election officials in Cuyahoga County (Cleveland) continued to distribute provisional ballots to anyone who requested one.¹⁸ It is a matter of record that the decisions of partisan election officials often result in candidates who are affiliated with their party enjoying significant advantages over an opponent, and this can be traced to the earliest days of U.S. history.¹⁹

Another result of having partisan election officials is that they are typically involved in decisions about electoral reform and the purchase of voting equipment. This creates the potential for issues related to voting procedures and systems to become an element of a party's or candidate's political strategy, even when such decisions follow the recommendation of nonpartisan administrators. These forces were at work in Maryland in 2006, where Governor Robert Ehrlich, a Republican who initially supported the decision of the state's bipartisan election board to use the Diebold AccuVote-TS voting system statewide and vetoed a bill allowing early voting, later urged voters not to use the systems, citing problems with their implementation in the 2006 primaries. Instead, the governor encouraged citizens to cast their general election votes early by using absentee ballots. The Maryland Republican Party sought to capitalize on his exhortations by mailing 600,000 applications for absentee ballots to likely GOP voters. Some of the state's leading Democratic politicians called Ehrlich's state-

ments and actions hypocritical and designed to confuse people and discourage them from voting, but other Democrats urged voters to use absentee ballots as well. The state Democratic Party, however, did not follow up by mailing targeted absentee ballot applications. The controversy over the voting system contributed to a record number of Marylanders applying for absentee ballots, with proportionately more Republicans requesting them than Democrats. Ultimately, the governor lost his bid for reelection, and it was not clear whether either party benefited from the controversy over the state's voting procedures and new voting system.²⁰ Nonetheless, the affair injected partisan politics into the voting process and did little to help instill confidence among Maryland voters.

Privatization of the Election System

Questions about the privatization of portions of the election process arose as early as the 1960s and were connected with the computerization of voting systems. The concerns were initially about counting prescored punch cards and whether computer programs could be relied on to count the votes accurately. Occasionally the question was raised as to whether computer programs could be altered on purpose to produce false counts. Although originally raised in connection with punch card systems, these questions became salient only when the use of electronic systems became more widespread.

Other questions about privatization are rooted in principled concerns that also have partisan undertones. One example involves a possible conflict of interest for Senator Chuck Hagel, Republican of Nebraska. Before being elected to the Senate, Hagel was the chairman of American Information Systems, the predecessor company to Election Systems and Software (ES&S)—one of the major manufacturers of voting machines—and he remains an investor in ES&S through its new parent company, the McCarthy Group.²¹ ES&S was responsible for counting 85 percent of the votes cast in Hagel's 1996 and 2002 election victories.²² Although no criminal wrongdoing has been alleged, some people have raised questions about the propriety of a candidate's owning a significant portion of stock in the company that manufactures the voting system that will count votes in his or her election.

Concerns about privatization and partisanship also were raised by the actions of Walden O'Dell, the former chief executive of Diebold, which also manufactures voting systems. In 2003, while still heading Diebold, O'Dell was named a "pioneer" by President Bush's reelection campaign for raising at least \$100,000 for the president's reelection effort. During the campaign, O'Dell also wrote a fundraising letter in which he states that he was "committed to helping Ohio deliver its electoral votes to the president next year."²³ O'Dell's partisan political

activities were completely within the bounds of his rights as a private individual; but coupled with concerns raised independently about the security and performance of Diebold's voting systems, his involvement raised concerns about the trustworthiness of electronic voting.²⁴

The creation and maintenance of statewide voter registration lists are other aspects of elections that have been contracted to private firms. If done properly, these processes can purge the names of deceased voters, voters who have moved, voters who are incarcerated, and others who for whatever reason, including felony convictions in some states, are no longer eligible to vote in a given election jurisdiction. If not performed correctly, these processes can result in the removal of the names of legally eligible voters from the voter rolls. In some cases, the result is that these voters have to cast a provisional ballot, which ultimately may not be counted.²⁵ Moreover, when errors are made, the privatization of elections can weaken the degree to which those public officials who are responsible can be held accountable. The maintenance of voter rolls by private firms also raises issues of privacy in the administration of elections.

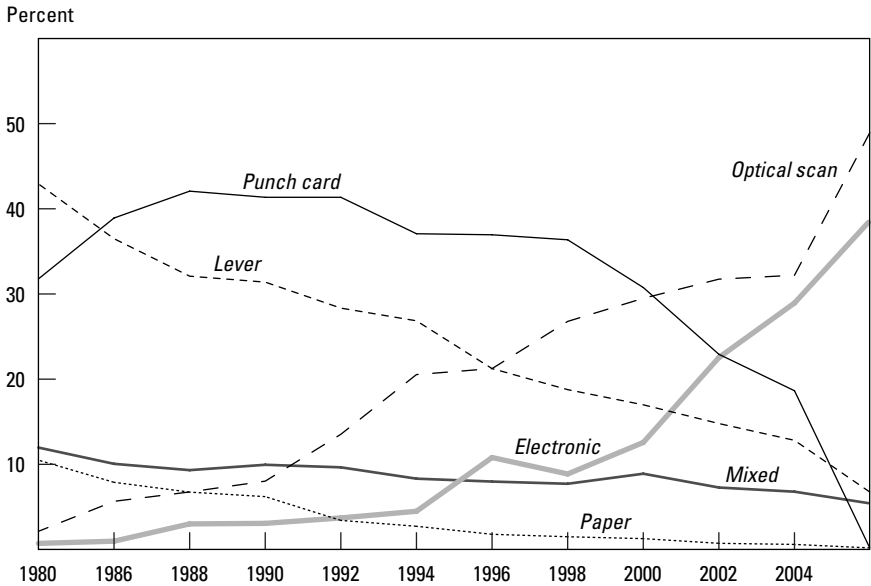
The Evolution of Voting Systems

Over the years there have been major changes in the way Americans cast their votes. In the precolonial period, voting was often *viva voce*—publicly and out loud. This began to change quickly after independence. Population growth, increased suffrage, and public pressure made voting by voice unwieldy and unpopular. As a result, various states and localities adopted printed ballots, though unorthodox methods also were used, such as using beans or corn to stand for different candidates. Even with printed ballots, voting often remained public, as ballots of different sizes or colors were printed by the political parties and included only the names of that party's candidates.²⁶ Toward the end of the nineteenth century the secret, or "Australian," ballot (named after the country of its origin) became common. This government-printed ballot, containing the names of all of the candidates, was filled out in private and dropped into a designated box. Accompanying the introduction of paper ballots, including secret ones, was an onslaught of problems, including bribery, fraud, stolen ballot boxes, and all forms of counting irregularities. In some elections the vote totals bore little relation to the number of votes cast.²⁷

Changes in Voting Equipment over Time

Just as systemic changes in society and reformist impulses created pressure for changing the way citizens vote, technological innovations have made the

Figure 1-1. Share of Registered Voters Using Each of Six Types of Voting Systems, 1980–2006^a



Source: Compiled from Election Data Services, Inc., 2006 Voting Equipment Study, October 2, p. 2.
a. Estimates as of October 2006.

modernization of voting systems possible. At about the same time that the secret ballot was being widely adopted, mechanical lever systems were introduced into polling places. Designed to eliminate voting irregularities and to improve vote counting, these systems did away with individual paper ballots. Instead of writing on paper, voters flipped down levers that moved a series of gears that recorded the votes submitted for individual candidates and kept running tallies of all of the votes cast. The vote totals were read from vote counters inside each machine when it was opened at the end of election day. If a recount was required, the lever machines were reopened and the totals reread. After an initial period of adjustment during which citizens became used to voting on a system that lacked a physical ballot, these systems became widely accepted and favored by election officials. Mechanical lever systems were the most frequently used voting system in the United States until the mid-1980s (figure 1-1).

Punch card systems, first used in 1961, were made possible by Herman Hollerith's earlier invention of the punch card and by the development of the

electronic card tabulator. These systems were the first to incorporate computerized vote counting into the election process. They quickly gained popularity with election officials and voters, and by 1986 they overtook lever machines as the most frequently used system. Although punch card systems reintroduced the practice of voting on a tangible medium, and thus made it once again possible to physically recount ballots, they were not without their shortcomings. As voters learned in the 2000 election, chads did not always fall cleanly from the punch cards, and the character of the holes made in the ballots could change when they were run through a computerized card reader a second or third time. Thus recounts could lead to discrepancies in vote tallies when chads fell out of the ballots or when ballots were examined closely by hand.

Optical scan voting systems were first used in the 1960s. These systems rely on computers to read paper ballots, on which votes are recorded on a paper sheet by filling in a circle or an oval or by connecting the parts of a broken arrow. The adoption of optical scan systems took off after 1980, and these systems are now used by more voters than any other type. Some but not all optical scan systems include reading and counting equipment stationed at individual precincts.

Direct recording electronic voting systems, often referred to as DRE voting systems or DREs, the most recent innovation in voting technologies, were introduced in the mid-1970s. Although they vary substantially in terms of the types of interfaces they present to voters, the systems all have in common the fact that they directly record individuals' votes in an electronic format without first requiring individuals to record their votes on a physical medium such as a piece of paper or a punch card. Touch screen voting systems, the most recent generation of these systems, were introduced in the late 1990s. The use of DREs increased moderately until the 2000 election. That election served as a major stimulus for their expanded use—a trend that the Help America Vote Act reinforced—and they now rank second in the number of voters who use them.

The use of DREs may have suffered a major setback, however, when a technical advisory committee to the National Institute of Standards and Technology recommended to the U.S. Election Assistance Commission that its voluntary voting system guidelines for certification consider only voting machines in which the audit process is independently verifiable.²⁸ This recommendation is not the same as an endorsement of a paper trail, but it may hinder subsequent adoptions of direct recording voting technology. The commission itself did not immediately take up this issue, and as of early 2007 it remained an open question whether existing DREs—purchased at great expense—would be grandfathered to allow for continued use.

The Help America Vote Act of 2002 and the Future

In 2002 Congress responded to the 2000 election debacle in Florida by passing the Help America Vote Act. Among other things, the act established the U.S. Election Assistance Commission to help administer federal elections and to provide other forms of assistance. It also established minimum election administration standards for the states and the units of local government responsible for the administration of federal elections. The commission's charge includes revising existing voluntary voting system guidelines and implementing a national testing and certification program for both the hardware and software of voting systems.²⁹

The 2000 act also requires numerous changes in election processes: provisional ballots for individuals who claim to be incorrectly left off voter registration rolls; a single, statewide computerized registration roll; identification specifications for new registrants, especially those who register by mail; ballots in several languages (if required under the Voting Rights Act); and voting systems accessible to voters with disabilities.

Particularly relevant here is that the Help America Vote Act provides the states with funds to replace punch card and lever voting systems. Some states responded to the 2000 election early, independently of federal efforts and before passage of the voting act. Florida, Georgia, and Maryland were particularly proactive. Each enacted comprehensive reform, including the purchase of new voting equipment; Georgia and Maryland adopted a single system statewide. Roughly three dozen other states enacted some noteworthy improvements in the way they conduct elections.³⁰ The law also provides for an auditable record of all votes cast, including a provision for voters to be able to review their preferences before their ballot is cast. Of importance, however, is that the requirement of an audit trail has not been interpreted to mean that DREs need to have voter-verifiable paper backup or any other record that can be checked by voters and produced independent of the computer.

Although there has been little outcry among the public for voter-verifiable paper ballots, a number of activist groups have been pressuring policymakers to require them in light of a few instances in which it is alleged that an electronic voting system did not properly record votes as cast. Reacting to this pressure, twenty-seven states by mid-2007 had adopted a paper trail requirement, according to the leading advocacy group.³¹ And in December 2006 the Technical Guidelines Development Committee, an advisory board to the Election Assistance Commission and the National Institute of Standards and Technology,

unanimously passed a resolution recommending that new voting systems have an “independent voting record” that “all voters can verify.”³² This “software independent” audit function (that is, independent of the software controlling the computer) could be performed by a variety of vote verification/election audit systems, including a paper record.

Research on Voting Systems

If the ballots used in the United States were simple and short and included only a few candidates or parties and were free of complexities, such as elections that allow selection of more than one candidate for a given office or opportunities for write-in votes, there would be little need to conduct research on voting systems. If voting systems and ballots were better publicized so citizens would know the exact appearance of the paper ballot or electronic screen they would be voting on ahead of time, there also would be less need for research on voting. The same would be true if citizens were given more opportunities to practice voting before entering the voting booth or if voting technology and ballot formats had remained unchanged over the generations.

However, this is not the case, and it would be a mistake to assume that all voters will know how to complete and cast their ballots properly, particularly when new voting equipment is introduced. This point, raised following the widespread adoption of punch card voting systems, has become even more relevant as the result of the introduction of a large number of voting systems, each having its own unique design.³³ Research is needed to help guide the development of new voting systems so that citizens can cast their ballots easily and with confidence, to improve those systems currently in use or on the market, and to identify the best ways to educate voters about how to have a successful experience in the voting booth.

The administration of elections also could benefit from additional research. The hardware and software incorporated into contemporary voting devices—whether electronic, optical scan, or other—are not simple to set up the morning of an election, operate over the course of a typical sixteen-hour election day, or disassemble at the end of that day. These devices are complex and nonintuitive, and because no system is perfectly reliable, problems inevitably arise. Similarly, computerized election rolls, containing the names and identifying information of eligible voters, also require poll workers to have a minimum knowledge of computerized technologies and some specific training on the technology in use. Research could identify ways to simplify the tasks poll workers are expected to perform, to ascertain the minimum skill levels needed to perform them, and to

develop strategies for recruiting individuals with the requisite skills to work as poll workers. More research also would probably benefit a variety of election-related processes, including those used to create and maintain the accuracy of voter registration rolls.

Further research into election security is also important. Some computer scientists argue that, because electronic voting systems are in fact computers, they are vulnerable to breakdowns and attacks that could compromise the recording and counting of votes.³⁴ They maintain that, in some cases, software problems may not be readily apparent or easy to fix. For example, a computer code can be written to alter the vote and to then erase itself.³⁵ A much publicized analysis of an early version of the computer program used in a Diebold electronic voting system resulted in that system being heavily criticized for its vulnerability.³⁶ A team of computer scientists at Princeton University distributed a video providing a compelling demonstration of how easily the system could be hacked, causing further condemnation of the Diebold system.³⁷ Research demonstrates that, given unfettered access to a computerized voting system in a laboratory setting, with the system bereft of the security protocols normally used to protect election equipment, a highly trained team of individuals could wreak havoc on at least one type of electronic voting system. If such a team could break into the warehouses storing the systems, breach the physical locks and seals on the systems, and alter the system's code in the precise manner necessary, it could interfere with the integrity of an election. For such a plot to succeed it would have to go undetected; some computer scientists and election experts believe they have devised techniques to prevent such an occurrence.³⁸

Regardless of one's position in this debate, it makes sense to extend vulnerability studies to other systems. This would enable computer scientists to provide voting system manufacturers with factual details they could use to improve their products, election officials with knowledge they could use to make informed purchases, and voting reform advocates and public officials with information they could use to influence policy in this important area.

A reading of the popular press, other news media, and many election-related blogs would lead to the conclusion that security is the main issue in evaluating and ultimately in improving electronic and other voting systems. Reflecting the problems journalists have in reporting on risk versus harm, the news often consists of stories about unpleasant things that could happen if security were breached, ignoring the fact that no such event has actually happened.³⁹ In contrast, numerous problems have arisen regarding the usability of election systems, including those associated with the infamous butterfly ballot. There was no problem of security associated with this incident; instead, it was a matter of the layout

of the ballot that resulted in misunderstandings that led some citizens to cast a vote for the Reform Party nominee, Patrick Buchanan, when they intended to vote for the Democratic nominee, Al Gore. It can be argued that usability is probably the most real and pressing problem associated with voting systems.

Not surprisingly, given the problems associated with the 2000 presidential election, much of the research conducted in its immediate aftermath concerns issues related to the usability of voting systems. Estimates of the residual vote have been used to assess the impact of voting systems on the propensity of citizens to spoil their ballots, either by overvoting (casting more votes than permitted for an office) or by casting a ballot that could not be counted (for example, by circling names on a paper ballot rather than filling in the oval next to the name).⁴⁰ Since then, research has been undertaken on the effects of various voting systems and ballot characteristics on undervoting (not casting a vote for a given office) as well as on the differential reaction of minorities and others to system characteristics.⁴¹ Moreover, the National Institute of Standards and Technology recognizes the necessity of including usability standards in the voluntary guidelines for machine certification, although specific standards have yet to be established.⁴²

What we undertake in this book goes a step further in that we place primary emphasis on comparing citizens' experiences with various voting systems and ballot formats. We use an interdisciplinary approach to identify what voting system, ballot, and individual characteristics influence voters' satisfaction, confidence, and ability to vote without requiring help. This is also the first study to gauge the accuracy of voting—that is, the extent to which the votes that citizens intend to cast match the votes recorded on voting systems. Finally, we mount the first comparative study of vote verification/election audit systems as well as one of the first studies of a system with a voter-verifiable paper audit trail.

Organization of the Book

This book reports the results of two collaborative research projects designed to investigate the impact of new voting technology on voting behavior and voter satisfaction. The first project focuses on electronic voting systems, the second on vote verification systems, both drawing on the field of usability (also known as human factors research), which assesses how design affects how individuals interact with complex systems.

In chapter 2 we describe five commercially available voting systems plus a prototype; these six systems represent the major design principles incorporated into current voting systems. The ES&S Model 100 represents the standard

paper ballot/optical scan system. Given this system's relatively long use, its incorporation of a tangible medium in the voting process, and citizens' frequent use of optical scan technology, it serves as a baseline for much of the analysis. The Diebold AccuVote-TS is one of two systems that use a touch screen interface. The Avante Vote-Trakker is representative of touch screen voting devices that produce a paper record and have programming options designed to move the voter through the balloting process at an accelerated rate. The Hart InterCivic eSlate has a mechanical interface with a dial and buttons, which voters use to select and enter their choices. The Nedap LibertyVote is representative of systems that present the voter with the entire ballot at one time. Finally, the Zoomable prototype system, developed specifically for this analysis, uses a touch screen that provides voters with a visual overview of the full ballot and allows them to zoom into and out of the details of any individual race at any point in the voting process. Each of the systems was analyzed using two ballots: one organized by political office and another organized by political party affiliation.

We used three methodologies to assess the voting systems. First, we tasked a group of human-computer interaction experts, including some with expertise in voting systems, to identify the strengths and weaknesses of the interfaces on each of the voting systems. Second, we conducted a laboratory experiment designed to study in detail how citizens, including those with little experience using computers, used the six voting systems. The laboratory experiment enabled us to record the number of physical movements and the amount of time required to vote on the different systems. Perhaps more important, the lab study enabled us to pinpoint how the designs of the voting systems and ballots influenced voters' assessments of those systems, their need for assistance when voting on them, and the number of errors they committed when casting their ballots. Finally, we ran large-scale field studies involving 1,540 voters drawn from diverse locations in three states. These field studies provide insights into the impact that voters' background characteristics have on the voting experience and yield quantitative assessments of voters' satisfaction with the voting systems as well as their need for help and their confidence that their votes were accurately recorded. A unique feature of our design enabled us to assess the degree to which voters in the field studies were able to cast their votes as intended.

Are voters satisfied with their experiences using the voting systems? Are they able to vote without asking for help? Which voting systems are the most difficult for voters to use, and which aspects of those systems pose the greatest challenges? We address these questions in chapter 3, reporting that voter satisfaction and the need for help vary across voting systems. Although voters reported fairly

positive experiences on all of the voting systems, some of the less positive evaluations should give pause to voting system manufacturers, election officials, voters, and others involved in the electoral process. The findings for the effect of ballot design, in particular, demonstrate that certain aspects of voter interfaces have a major impact on the voting experience.

Chapter 4 addresses the question, Are voters able to cast their votes as intended? This was the central issue raised after the 2000 presidential election in Florida, and it reemerged in several elections since then, including the 2006 election for Florida's Thirteenth Congressional District. We addressed the issue of voter accuracy by instructing the participants in our study to record their voting intentions in voter information guides; we then compared their voting intentions with the votes they cast. Participants cast most of their votes as intended, but they had more success voting accurately on some voting interfaces than on others. The findings also show that some tasks that voters are routinely asked to do are prone to error; for example, accuracy diminished when participants tried to change a vote, to select more than one candidate for an office, and to cast a write-in vote. Voters also had significantly more difficulty casting their votes accurately when using a ballot with a straight-party option or a party column design than when using a standard office-bloc ballot.

Democratic theory may posit that everyone's vote should count equally, but in reality the products of decisions made by those who manufacture, purchase, and program the voting systems on which individuals cast their ballots could create inequalities in the abilities of voters to participate meaningfully in the electoral process. Chapter 5 investigates whether this is indeed the case. Do factors associated with the so-called digital divide, such as computer experience and education, result in groups of citizens having dissimilar voting experiences? Our study demonstrates that this is true in several areas of the voting process, including whether voters feel the need to get help while voting and their ability to accurately translate their voting intentions into votes.

Chapter 6 discusses the results of our study of vote verification/election audit systems. These add-on units have been developed in response to concerns that computer scientists, political activists, and politicians have raised about the security of electronic voting systems. We analyzed the impact of four verification systems on the voting experience, using an expert review process and a large-scale field study similar to those used in the first study. The vote verification systems are the Diebold AccuVote-TSx with AccuView Printer Module, which produces a voter-verifiable paper record; the VoteHere Sentinel, which uses a cryptographic-based technique for vote verification and election auditing; the Scytl Pnyx.VM system, which allows the voter to visually compare the results

that appear on its small computer monitor with those that appear on the voting system's monitor; and the MIT Audio System, which relies on a set of headphones attached to a voice-activated portable cassette tape recorder to produce an audio record during the voting process.⁴³ Once again, our main criteria for evaluation were voter satisfaction, the need for help, and the ability to cast one's votes as intended. We compare a voting system that has been mated with each of these verification devices to a voting system that has no verification device. Ironically, our results show that none of these vote verification units substantially improved any aspect of the voting process, and some even detracted from it.

In chapter 7 we flesh out the implications of our results and provide policy recommendations, the implications of which are relevant for voting system manufacturers, election officials, legislators, researchers, and voters. We highlight improvements that could be made with minimal financial cost and discuss those that would be possible only with the passage of certain political reforms. We also identify the normative implications of our results and discuss some new directions for future research.