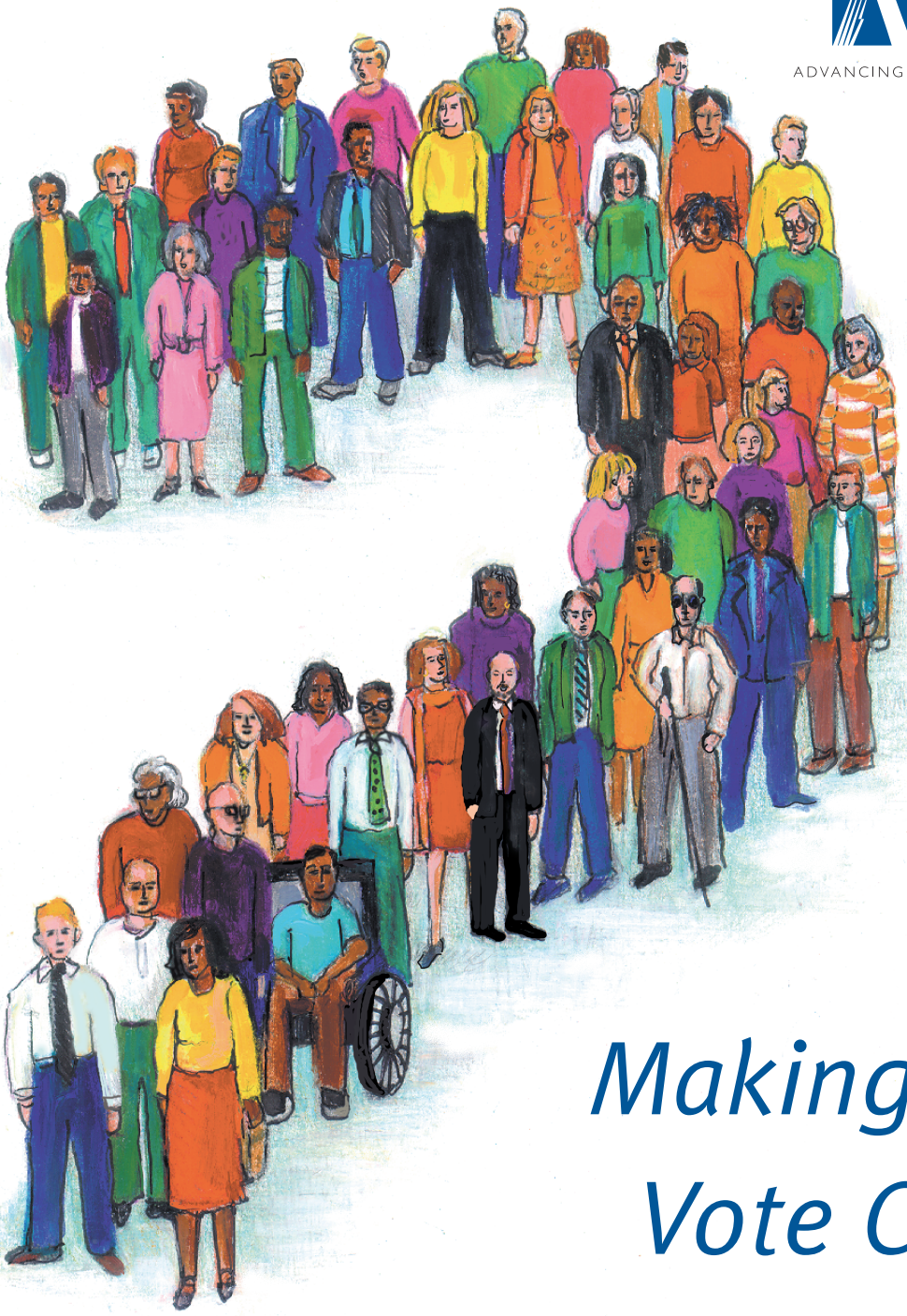
AAAS

ADVANCING SCIENCE, SERVING SOCIETY



Making Each Vote Count: A Research Agenda for Electronic Voting

MAKING EACH VOTE COUNT

A RESEARCH AGENDA FOR ELECTRONIC VOTING

A Report by the
American Association for the Advancement of Science

Prepared by

Mark S. Frankel

Contributing Authors
Tova Jacobovits and Adrianne Kroepsch

October 2004

The preparation and production of this report were supported by Grant #SES-0449615 from the National Science Foundation. The views expressed in the report are based on a collaboration between AAAS staff and those experts convened to advise on its preparation, and do not represent the official positions of AAAS or the National Science Foundation.

Cover: Designed and created by Ann Willliams at the American Association for the Advancement of Science

Acknowledgments

This report reflects a collaboration among many. First and foremost are the experts who participated in the AAAS workshop on electronic voting technology and made valuable intellectual contributions to the content of this report. Neither the workshop nor this report would have been possible without a grant (#SES-0449615) from the National Science Foundation. Officials from the Foundation's Directorate for Social, Behavioral and Economic Sciences also offered very helpful suggestions related to the organization of the workshop.

Several AAAS staff played important roles. Barbara Rice and Kelly Gayden took lead responsibility for arranging the webcast of the workshop, and along with Monica Amarelo and Ed Lempinen coordinated the release of the Interim Report and related materials on the AAAS website. Kevin Alleman designed the project's website, and Tova Jacobovits assisted with the posting of pre-workshop materials. Kevin, Chickona Royster-Edwards, and Adrianne Kroepsch handled the logistics associated with organizing and convening the workshop. Tova, Adrianne, Allison Chamberlain, Rachel Gartner, and Clinton Musil provided essential research, and both Adrianne and Tova made substantial contributions to the writing of the report. Ann Williams designed and produced the artwork that is the report cover.

As those chiefly responsible for organizing the workshop, we developed a very efficient workplan that enabled us to provide a quick turnaround of the findings and recommendations appearing in this report. We have come a long way in a period of only four months, testimony to our success in feeding off of each other's ideas and energy. We are grateful to all those mentioned above, as well as to each other for a very positive experience. We hope that our effort will contribute to a voting system that engenders public trust and confidence in its outcomes. The American people deserve no less.

Mark S. Frankel, Ph.D
Shirley Malcom, Ph.D.
Stephen Nelson, Ph.D.

Table of Contents

"The core of our American democracy is the right to vote. Implicit in that right is the notion that the vote be private, that the vote be secure, and that the vote be counted as it was intended when it was cast by the voter. And I think what we're encountering is a pivotal moment in our democracy where all of that is being called into question."

Kevin Shelley
California Secretary of State
December 2003

Introduction

Central to the election of the political leadership in any democratic country is a voting system that confers legitimacy on its political leaders, and maximizes public participation, trust, and confidence. The presidential election of 2000, where the winner was not to be declared until several weeks after the polls closed and even then was decided by a narrow margin in the U.S. Supreme Court, drew public attention in a most dramatic fashion to weaknesses in our voting system. Recounts were undertaken not only of votes but also of "intended votes," and terminology such as "butterfly ballots" and "hanging chads" became common vocabulary in discussions in the daily news. The 2000 election came breathlessly close to creating a constitutional crisis.

The roller-coaster events of that election led to new initiatives and funding to modernize the voting process in order to reflect recent technological advances. As a result, various electronic voting systems have been proposed or adopted in several states and localities, and used by some jurisdictions in the spring 2004 primary elections. The experiences have been mixed. In some instances, voting, and all of the procedures associated with it, have proceeded without a hitch. In other cases, there have been accusations of tampering and fraud, and litigation challenging the accuracy and reliability of the voting systems used. Serious concerns remain about the design, use, and impact of electronic voting methods, even as we move inexorably toward the November 2004 general election.

In America, voting is considered both a right and a responsibility. It is a private, personal act within a large, complex and highly visible system. At its best, the system generates public trust and confidence in the electoral process and legitimizes the outcomes; at its worst, it fuels cynicism, distrust, and, in the extreme, efforts to overturn the election. It is not a trivial matter, therefore, to introduce new technologies into the system with the claim that they will "make a difference." To make sound decisions about the future of electronic voting that enhance the system's performance while minimizing potential problems, we need to know more about technology's impact on the voting system, from voter registration, to balloting, to counting, and to certifying elections. Informed by such knowledge, the country can move toward developing appropriate, effective, and trustworthy mechanisms for fostering public participation in and protecting the accuracy, integrity, and privacy of the voting process.

What We Don't Know

During the AAAS workshop, participants identified a number of very basic questions about the U.S. voting system for which there was insufficient data to answer. Below is only a brief selection of those questions. Nevertheless, they offer a good indication of how little basic knowledge we have about one of our most important activities as a nation.

How many people cannot vote or do not have their votes counted, and what are the main causes?

How much of the problems experienced with new voting technologies are due to inadequate voter understanding, faulty administration, or to the technology? How does the extent of the problem or its causes vary across different groups of people (e.g., the less educated, the elderly, persons with disabilities, ethnic language minorities)?

How well or poorly do voters adapt to the introduction of new voting technologies? What factors affect voters' ability to adapt?

What parts of the voting system are most/least vulnerable to error, tampering, accidental data loss, poor administration, inadequate voter accessibility or interface with the technology?

What are the economics of conducting elections? To what extent do new voting technologies affect the costs of elections? How are the costs managed?

For a matter as critical to the functioning of our society as public elections are, it is distressing how little knowledge exists in order to make evidence-based reforms in our voting system (see sidebar). To help remedy the paucity of data, the American Association for the Advancement of Science (AAAS), with support from the National Science Foundation, convened a workshop on September 17-18, 2004, that included experts in cybersecurity and voting machine technology, election officials, social and behavioral scientists, legal scholars, and representatives from public interest groups. (See Appendix A for a list of the participants.) With the assistance of these invited experts, AAAS issued an Interim Report on September 21, 2004 (http://www.aaas.org/spp/sfrl/evoting/report.pdf) that highlighted a set of recommendations for research on various aspects of electronic voting, pointing researchers and those who fund research toward potentially fruitful avenues of study and interdisciplinary collaboration. The report was accompanied by a webcast of the discussions at the workshop that helped shape the recommendations. (The webcast can be found at http://www.aaas.org/spp/sfrl/projects/evoting/webcast.shtml)

The discussions at the workshop were informed by the range of experience and perspectives represented by the invited experts. Prior to the workshop, the experts were asked to prepare a brief synopsis of what they considered to be the most pressing issues requiring further study. (The synopses are posted at http://www.aaas.org/spp/sfrl/projects/evoting/participants.shtml) These writings helped to provoke discussion at the meeting and were valuable inputs in producing the final report.

This report builds on the interim one by providing more context for appreciating the problems encountered as the country struggles with the introduction of new voting systems in a highly charged political environment. By making the report widely available, AAAS seeks to facilitate dialogue on these important issues among researchers, government officials, and the general public. This effort should help to

target finite resources toward the most promising areas of research in order to improve understanding of the comparative advantages and disadvantages of various voting systems and to produce knowledge that can inform critical personal and policy decisions about voting in the United States.

As one of the participants at the workshop observed about the voting system, "There is a lot we don't know that could get us into trouble." The post-2000 election experience indicates that "trouble" has already occurred. Solutions must be grounded in better knowledge than exists now. Research has the potential to improve the functioning of the voting process and increase the legitimacy of voting outcomes. The political will is required to invest adequately in research and to act on findings in a non-partisan manner.

"When you look at what occurs on any given election day and the magnitude of the event, it is incredible that it comes together at all."

AAAS Voting Technology Workshop Participant
September 17-18, 2004

Voting Technologies and the U.S. Voting System

Currently, five different kinds of voting technologies are used: hand-counted paper ballots, mechanical lever machines, computer punchcards, optical scan forms, and direct recording electronic systems (DRE's). Before paper ballots, people used small balls to vote (where "ball" comes from in the word "ballot"). Early colonial Americans used different colored beans or kernels to cast votes. For years, citizens would stand in front of an election clerk and call out their choices while the clerks tallied them; candidates could stand near the tallying clerks to campaign face to face with voters and keep track of who voted for whom. The first known use of paper ballots in an election in the U.S. was in 1629, to select a church pastor.[1] Paper ballots made it possible for Americans to vote in secret. In the beginning, voters created their own ballots by simply writing down their choices on a piece of paper. The first standardized paper ballots, printed at the government's expense and distributed to the polling places, were introduced in Victoria, Australia in 1858. It was not until 1888 that the "Australian ballot" was first used in the U.S., in New York and Massachusetts.[2] Vote-counting scandals, like ballot box stuffing or stealing, plus a desire to make the process more efficient, eventually led officials to move away from hand-counted paper ballots.

Over the course of the twentieth century, voting equipment has evolved to speed up the count and to minimize tampering with the process. As a result, the systems for casting ballots and counting ballots have been integrated. (All current technologies, except paper ballots, can manage large counts rapidly once polls are closed.) Jacob H. Myers, an inventor and maker of safes, was the first to integrate casting and counting into one system by inventing the mechanical lever voting machine to "protect mechanically the voter from rascaldom, and make the process of casting the ballot perfectly plain, simple and secret."[3] These lever machines came onto the scene around 1890 and became popular throughout the U.S. by the 1950's. Lever machines have been out of production since 1982, but are still in use in some districts, meaning that you could be voting on the same machine that put Dwight D. Eisenhower in office.

Punchcards came into vogue in the 1960's as a blending of new and old technology to address the mechanical lever machines frequent breakdowns and the lack of a voter record that made a vote-by-vote recount impossible. Standardized punchcard ballots sped up the counting process even more, while also leaving a paper artifact that could make a recount possible. By the late 20th century, punchcard voting systems were prevalent in the U.S. Although problems with punchcard technology have been known

since the late 1960's, it was not until the 2000 election that they became front-page news. The problem with punchcards lies in the punching of the hole. Certain punch positions within a punchcard machine are particularly prone to the development of "chad jams" that prevent the machine from cleanly punching a hole. The problem with these dimples during a hand recount (or even by the machine) is that it is difficult for a person looking at such a dimple to determine a voter's intent – whether she began to punch and hesitated, or whether she intended to punch all the way through.[4]

Optical scan systems were adapted from the world of standardized testing to solve the hole-punch problem. These systems have disadvantages of their own – such as requiring a particular writing instrument or jamming up/malfunction of the automated counting mechanisms. Overall, however, optically scanned ballots are less error-prone than punchcards. Over the past four presidential elections, the "residual vote" rate (this rate is the primary yardstick for reliability; it is the difference between the number of voters who turn up at polling stations and the total number of votes allocated to the candidates) was 2.1 percent for optically scanned ballots and 3 percent for punchcard ballots. (Hand-counted paper ballots and lever machines rang in at 1.9 percent residual vote rates, aligning with optical scans, while DRE's 2.9 percent residual vote rate was right up there with punchcard's 3 percent error.)[5] More than one kind of technology is at use in nearly all states (see map--Type of Voting Equipment by County – 2004 in Appendix B).[6]

The disputed 2000 presidential election led to a nationwide move toward electronic voting technologies that would eliminate punchcard machines. In the 2004 election, it is estimated that approximately 30 percent of U.S. ballots will be cast using some type of Direct Recording Electronic systems,[7] or DRE's, which directly record votes only on electronic media (chips, cartridges, or disks) with no paper or other tangible form of backup. That is nearly triple the number of electronic votes cast in 2000.[8]

DRE's eliminate the ballot "middle man" all together by displaying the ballot, storing the vote, and generating the tally all in one machine. A typical design involves a machine with a touch-screen interface and a slot designed for a card that resembles a hotel key card. Voters put the card in the slot and select the candidates of their choice by touching the screen. Once a candidate is selected, it is recorded on the machine's hard disk and the system locks to prevent voters from voting twice. Some machines have a built-in printer to record the machine's vote totals when the polls close. Other machines produce a paper copy behind a window that voters can inspect to verify their vote. Still others only store the votes on the hardware of the machine or on disks without the print-out audit trail. Many of these machines are also equipped with a modem so the vote totals can be encrypted and sent through ordinary phone lines.[9] When the polls close, an election worker inserts an "ender" card that tells the DRE it is time to aggregate the votes. The machine saves the number in its internal memory and copies it to a flash memory card, which the poll worker removes and takes to a separate server for the official count.[10]

Internet Voting

Internet voting could be the future. Americans have grown accustomed to shopping, banking, even paying taxes and finding dates online. Internet voting would be a logical extension of current voting practices. It might reverse the historical downward trend in voter turnout by making it more convenient to vote, especially for persons with disabilities and those living abroad. A public opinion poll conducted by *Business Wire* supports the notion that younger voters are especially enthusiastic about voting online (61% favor it) and that their notoriously-low rates of participation might be reversed.*

However, as experience with a major Internet voting initiative planned by the Department of Defense indicates, there are problems that must be overcome. Internet voting was supposed to make its grand debut during the 2004 presidential election with a Department of Defense sponsored project aimed at the military. The $22 million Secure Electronic Registration and Voting Experiment, monikered SERVE, was cancelled in February, citing security concerns. Members of a panel of scientists asked by the government to assess the project's security recommended that it be canceled because any system based on off-the-shelf personal computers and run over today's Internet is inherently insecure. "There really is no good way to build such a voting system without a radical change in overall architecture of the Internet and the PC, or some unforeseen security breakthrough. The SERVE project is thus too far ahead of its time, and should wait until there is a much improved security infrastructure to build upon," said the panel.+

* Fischer, Eric A. *Voting Technologies in the United States: Overview and Issues for Congress*, Congressional Report Service, March 21, 2001.

+ A Security Analysis of the Secure Electronic registration and Voting Experiment (SERVE), January 20, 2004. www.servesecurityreport.org

The movement toward electronic voting has fueled a major debate among various stakeholders. For some, the urgency of moving forward in light of past problems makes electronic voting the only option in the digital age. "It will be a pity if electronic voting is discredited. Electronic voting in itself makes sense: it's faster, more accurate, and easier than any alternative."[11]

Others view electronic voting as a way to expand voting opportunities for citizens who have historically been disenfranchised. "Electronic voting technology is making voting possible for citizens that have traditionally been disenfranchised, such as many disabled individuals and those for whom English is not their native language."[12]

There are those, however, who, while not fans of paper ballots, worry that we are moving too quickly in putting our faith in technology. The systems are far from flawless, as evident from recent experience. For example, in Rio Arriba County, New Mexico, the November 2000 electronic voting systems were secured with a "three-step audit process of voting results" (later cited as a "best practice" by the Election Assistance Commission (EAC) in 2002). However, the system was subject to electronic voting errors due to incorrect computer programming. Out of 203 people who showed up in one of Rio Arriba's voting districts, "0" votes were recorded for Gore or Bush. In another district, only 188 of the 569 voters cast a presidential vote.[13]

During Florida's state gubernatorial primary in July 2002, widespread problems with electronic voting initiated delays for a final count. Janet Reno lost by 4,794 votes, but a study found that 8.5 percent of voters had no votes recorded. When the Miami-Dade Election Reform Coalition requested the audit data, officials reported that almost all of the data had been lost in two computer crashes. In 2004, the data were thought to be lost, but were recovered some time later, burned onto a CD and tucked away, said an elections official. If the audit data had never been requested, the 8.5 percent of voters may never have been accounted for.[14, 15]

The new voting machines have not been subjected to adequate testing, according to critics, and most of them have no capacity for performing an independent recount. At least with paper, election officials have something tangible to use if a recount is necessary. Moreover, even testing the machines, whatever the standards, does not ensure that the system tested is the one that shows up at the polling place on election day. The current voluntary testing process for certifying voting machines is voluntary and not all the states have signed on; and the testing that leads to certification is financed by the machine vendors, raising questions of conflict of interest. Standards for certifying voting technologies and for defining the proper metrics to assess the machines against those standards are not yet available, although as noted below, a major effort is underway. In the face of all these concerns, the American Civil Liberties Union and other advocacy groups have sued the State of Florida, arguing for better recount guidelines. "This time, the outrage wouldn't be over dimpled, pregnant and hanging chads; the state banned the maligned punch cards after 2000. Instead, it would almost certainly be directed at those who decided on the touch-screen machines."[16]

The Help America Vote Act

The Help America Vote Act (HAVA, Public Law 107-252) is the federal government's response to the 2000 voting crisis. This significant reform of federal election law was signed into law in 2002, and gives increased power and funding to the states to adopt electronic voting systems by 2006.

HAVA embraces the use of electronic voting as a means to revamp and restore voting integrity in each state, authorizing $3.9 billion for states over a three-year period to fund 95 percent of the HAVA mandates, replacing the punchcard and lever voting machines by 2006. It also seeks to remedy incomplete and fragmented voter registration lists by mandating the creation of statewide registration electronic databases, to minimize the possibility that registered voters would be left off the list and to decrease the prevalence of fraud based on double or wrongful registrations.

The legislation established the Election Assistance Commission (EAC) to oversee the reforms. At HAVA's behest, the EAC (comprised of four Senate-confirmed presidential appointees, two Republicans and two Democrats) monitors and assists in federal elections, helps to administer and update federal election laws and programs, and ensures implementation of the reforms recommended under HAVA.[17] As a measure of progress, the EAC is charged with submitting an annual report to Congress summarizing its research findings, funding allocations, and recommendations each year. In September 2004, the Senate Appropriations Committee approved $10 million for EAC activities in fiscal year 2005 (beginning October 1, 2004), much less than the EAC had requested and had expected to receive in July 2004, when the House Appropriations Committee reported a bill that would provide $15 million. Despite the budgetary constraints, members of the EAC "are determined to continue to distribute federal funds to states and support them in their effort to implement federally-ordered improvements to elections."[18]

With the passage of HAVA, the EAC took over the responsibilities of the Federal Election Committee (FEC), which was responsible for overseeing election reforms and

for developing electronic voting machine standards and equipment certification between 1990 and 2002. The FEC standards had not been thoroughly tested for security, however, and were only voluntary guidelines, with just 37 states abide by them. HAVA designated the Commerce Department's National Institute of Standards and Technology (NIST) to develop more stringent voting systems criteria than the recommended standards set by the FEC and used until 2002.

The process of testing voting machines, certifying equipment, and designing standards, are performed in NIST accredited labs, including one at NIST. A report of NIST research findings and recommendations for improvements in testing and assessing voting systems must be submitted to the EAC. At the December 2003 Symposium on Building Trust and Confidence in Voting Systems hosted by NIST, attendees from across the electoral spectrum agreed that improving the voting process, especially in conjunction with the new voting technology, depended upon an analysis of the entire voting system from beginning to end.[19] Congress appropriated a separate $500,000 for the NIST effort, but the funds were depleted by December 2003.[20] HAVA legislation does not, however, mandate states to follow any guidelines, basic requirements, and technical standards recommended by NIST for voting machines until January 1, 2006, even though federal funds were available for states to replace their punchcard and lever machines with the new electronic machines by the November 2004 election.

In addition to standards development and equipment certification, NIST is specifically mandated by HAVA "to ensure the usability and accuracy of voting products and systems, including methods to improve access for individuals with disabilities (including blindness) and individuals with limited proficiency in the English language and to reduce voter error and the number of spoiled ballots in elections."[21] NIST has focused its efforts on assessing "the areas of human factors research and human-machine interaction," with special attention to access for individuals with disabilities or limited proficiency in the English language. It documented its findings and recommendations in a report submitted to Congress in April 2004 on "Improving the Usability and Accessibility of Voting Systems and Products."[22] The report describes how research and best practices from the human factors, human-machine and human- computer interaction, and usability engineering disciplines can improve usability and accessibility of electronic voting machines. The new machines, however, are not required to meet the specific standards developed for the disabled until January 1, 2007. NIST will receive $2.5 million specifically targeted for research in fiscal year 2005, even though EAC commissioners requested $10 million from appropriators in July 2004.

The 2005 fiscal year budget shortages will impact EAC's operations. The reduced funding will translate to fewer staff, travel limited to polling places using electronic voting machines for the first time and to states that are experiencing many problems, fewer hearings on best practices and military overseas voting, less guidance to states who have recently implemented new HAVA standards, and reduced research.[23]

HAVA's nationwide push toward electronic voting technologies will have a noticeable effect on the coming election. A 2004 national voting equipment study by

Election Data Services[24] shows that there has been progress towards the elimination of punch cards, lever machines, and hand-counted paper ballots since the previous election. The 572 counties that used punch card systems in 2000 will have dropped to 307 in November 2004. By fall, punch cards will have disappeared entirely from 11 states. The study also found that of the 434 counties that used lever machines in 2000, 270 are expected to use them in 2004. The number of counties expected to use hand-counted paper ballots exclusively in 2004 is 299, down from 370 counties in 2000. All told, the study concludes that just over 50 million registered voters are expected to cast ballots on DRE's this fall, with an additional 55 million using optical scan systems.[25]

Although HAVA has led to greater use of electronic voting technologies, many voters will still not be using them in the 2004 election. For example, 32 million voters in 19 states will still be using punch cards. In Ohio, 72 percent of registered voters – more than 5 million people – will be using punch cards to vote, and in Missouri, two-thirds of registered voters will punch their votes as well.[26] Ohio was moving toward electronic voting until consultants found serious security flaws in the DRE technology offered by four of the nation's top vendors, and decided to delay deployment of electronic voting systems.[27] Concerns extend to machines that have not been open to the public for testing and analysis, to fragmented standards, the lack of a reliable audit/accountability system, no mandatory backups in place or problem recovery/preparedness procedures, and unprepared poll-workers.

Examining the U.S. Voting System

We begin with two observations that reflect the diversity that characterizes America's population and the way it governs itself. The first is that there is no such thing as an "average voter." Voters include people with differences in their motor and cognitive abilities, with their grasp of English, with their skills and comfort related to technology, and with a host of other cultural and physical differences. Any reforms in the voting system must, therefore, be sensitive to this diversity, and must be evaluated according to how responsive they are to the characteristics and special needs of subpopulations with the U.S.

The second observation is that the U.S. voting system operates in and is overseen by an extensive, decentralized administrative structure. Election regulations, practices and voting technologies are specific to each of the 50 states. In most states, elections are run at the county level; however, in some, they are administered by townships or other county subdivisions. This adds up to elections administered through approximately 10,000 jurisdictions at the county level or below.[28] The practice of entrusting the states with the responsibility of running elections, established by the U.S. Constitution, makes for hundreds of different decision makers determining the where's, how's, and why's of Election Day. Very little is known about decision-making process of election officials regarding, for example, how they choose one voting machine over others, how they estimate the number of machines needed at each polling place, or the basis on which they allocate their limited funds. Whether one considers this decentralized system an obstacle to overcome or a strong force against the vulnerability of centralized systems to large-

scale fraud or manipulation, it nevertheless means that the capacity of states to implement reforms will vary according to available resources and political predisposition.

The discussion that follows illustrates the powerful role that these two sources of diversity play in attempting to initiate, implement, and assess reforms for the voting system. It also reflects the interplay between technology and human behavior. This interaction is the source of many of the problems plaguing the voting system today. It is also key to understanding how to develop effective solutions.

Registration

Before a voter can vote, he or she must be registered. Voter registration is a basic check on the integrity of voting because it controls who votes by allowing only those who are eligible and authenticated to actually cast a vote. Registration is a daunting task, especially considering that the number of potentially eligible voters in the United States is over 200 million[29] and that it occurs in a system that is decentralized, and in most states, managed by local governments with limited resources. As a result, the final product is imperfect. Whereas the registration process is the first check on voting integrity, it is also the first opportunity for error within the system. The Census Bureau estimates that in the 2000 election, 1.5 to three million *registered* voters did not vote because of problems with their registrations.[30]

The National Voter Registration Act (NVRA), or "Motor Voter," was enacted in 2003 to make it easier for Americans to register and exercise their right to vote. While expanding voter registration opportunities to the motor vehicle department and other designated state agencies that provide federal services, NVRA also limited the amount of information states could require in the registration process and made it more difficult for election officials to purge registration lists. NVRA lowered many barriers to registration and addressed many civil rights problems, but in doing so, it has exacerbated registration database management problems.[31] Because voters can register in so many different places, there may be holes in the system and registrations can be lost when transferring documents from state agencies to the local election office. This means that some people believe they are registered when they are not. In its 1999-2000 report on the impact of the NVRA, the Federal Election Commission noted that many states "reported problems in the timely transmittal of voter registration applications to their offices from motor vehicle and public assistance offices [and] difficulties in readily determining whether applications were new or merely duplicative, or else changed in name and address."[32]

The president of the League of Women Voters, Kay J. Maxwell, told *The Washington Post* that registration problems could prove to be the "sleeper issue" of 2004, observing that "there's been so much discussion about voting machines, but this could turn out to be equally if not more important."[33] During the 2000 Florida recount, it was discovered that a flawed list used to purge dead people and felons from the voter rolls wound up disenfranchising thousands of eligible voters in Florida.[34] A study sponsored by the *Atlanta Journal and Constitution* discovered that 15,000 deceased persons were on Georgia's voter rolls, and that, over a twenty year period, 5,412 dead people had "voted"

in Georgia.[35] In St. Louis, Missouri, a study of voter lists by the Secretary of State initially showed that 2,214 "qualified voters" were registered to vote from vacant lots. Closer examination by the *St. Louis Post-Dispatch* revealed that the city's assessment records were out of date, listing the majority of the addresses as vacant lots erroneously.[36]

One of HAVA's broadest 2006 mandates was the creation of statewide registration databases that might remedy the confusion and inefficiency of the current highly decentralized registration system. Election officials expect statewide databases to help ensure that voters are not left off the rolls, while also preventing double or wrongful registrations and out-of-date voter lists by better tracking the movement of voters within a state. There will be 15 states with statewide registration systems up and running for the November 2004 election.[37] Complaints against the statewide registration systems have already arisen in West Virginia, Pensylvania, Minnesota, and Rhode Island, namely that eligible voters are being rejected because of differences between the information applicants put on the forms and existing state records, or that glitches in the new system make processing applications extra laborious and time-consuming.[38]

Perhaps one of the most partisan disputes regarding the voting system to emerge this year has centered on new voter identification. In general, Republicans support identification (ID) requirements when citizens arrive at the polls in order to prevent fraudulent voting, while Democrats argue that ID requirements disenfranchise poor and minority voters who might not have a driver's license or other acceptable documents. HAVA strikes a compromise by mandating that any first-time voter who registers by mail must either include a copy of an acceptable ID or show it at the polls. States are free to make the requirements more strict, however, resulting in a confusing mix of identification laws.[39] Another HAVA reform mandates that all states give voters a provisional ballot when they arrive at a polling place and their names are not on the rolls. Voters who believe they are registered can cast a ballot and election officials can research their eligibility after Election Day. This has raised concerns about a system that could disenfranchise voters after they voted and questions about what checks are built in to ensure that this process works properly.

Absentee Voting

Over the past two decades, there has been a dramatic increase in the use of absentee balloting, as many sates have relaxed access to absentee ballots. Twenty-five states, plus the District of Columbia**,** require voters to provide a reason, such as military service, travel, illness, disability, or religious holiday observance, to explain their inability to vote at a polling place on Election Day, while twenty-five states allow voters to cast "no-excuse" absentee ballots by mail. In California, the percentage of ballots cast by absentees has increased steadily, from 3% in 1962 to 25% in 1998.[40] In Oregon, the entire November 2000 election was conducted by mail-in ballot. Along with the availability of provisional voting, some estimate that as many as 20 percent of voters will cast their ballots before Election Day.[41]

Doubts about the security of voting machines could impact absentee voting rates. Several organizations have encouraged voters to cast absentee ballots instead of going to the polls. Others argue that absentee voting is far less secure than DRE systems or other technologies. Because mail-in voting occurs outside of the polling place, with no assurance of the secrecy and buffer zones provided at the polls, coercion is more of a concern. The fact that mail-in ballots are delivered using the postal system, which is essentially unsecured, makes fraud and security major concerns. An often cited example of absentee ballot fraud occurred in Miami in 1997, when a mayoral election was overturned by an appellate court after the discovery of thousands of forged absentee ballots. All of the absentee ballots were thrown out, with the winner declared solely on the basis of the machine vote.[42]

Accessibility

Voting technologies need to be accessible to all demographic groups, from persons with disabilities to illiterate citizens. The Voting Rights Act of 1965, as amended, requires that ballots and other relevant materials be provided in the language of citizens from non-English-speaking minorities who constitute a sufficiently large population in a state or political subdivision.[43] There are more than 40 million eligible voters with disabilities in the U.S., and many cannot participate in the voting process because ballots, voting machines, and polling are not equipped to accommodate them.[44] "If people with disabilities voted at the same rate as those without disabilities, there would have been 3.2 million additional voters in 2000, raising the overall turnout rate by 1.7 percentage points."[45] The HAVA legislation requires enhanced accessibility for voters with disabilities and the availability of alternative languages by 2007.

DRE systems provide the greatest flexibility with respect to accessibility, and one of the most significant promises of switching to electronic voting is the increased ability to accommodate citizens with various physical disabilities, non-English speakers, and voters who cannot read or write. Some precincts in Southern California print paper ballots in Spanish, Korean, Vietnamese, and Tagalog, among other languages, leaving election officials guessing how many of each they might need in advance. Electronic voting machines can provide limitless ballots in any language, pictures of candidates for those who have difficulties reading, audio head-sets with voice ballots for blind or visually-impaired voters, color coded and easily displayed elements on a clear screen, rapid error-checking with feedback to the voter to prevent unintended votes so that over-voting is impossible. HAVA requires states to have at least one direct recording electronic voting system or other system per polling place that is equipped for persons with disabilities. However, it is uncertain whether the federal government will be able to provide the funding to reach this goal.

User-Friendly Technology

Certainly the most publicized of the problems with voting technologies have involved the interaction between voters and technology, including machines and ballot designs. The ability of voters to use effectively the technology they encounter is critical.

If they cannot cast their ballots with confidence that their vote has been recorded as intended, then what transpires afterwards will do little to restore their trust in the system.

Ballot design is neither an exact science nor an easily produced work of art, and different voting technologies place different constraints on the way that a ballot can be designed to improve its clarity and ease of use. Ballot design standards are subject to state law or regulation, and vary from state to state.[46] When designing ballots, issues of clarity and fairness must be weighed against problems of ballot fatigue or voter fall-off (the phenomenon of voters completing only the first part of the ballot and quitting). The central challenge is finding a way to present the choices both clearly and fairly, while avoiding a design that is too long or complex. Clarity and fairness may not always be compatible, however. A clear, readable ballot may incorporate a larger typeface or wider spacing that causes the candidates to be split between pages, begging the question of which candidates should be on the first page and which ones should be on the second, for example.

Some states require that candidates be presented alphabetically on a ballot, while others require that the list be rotated for different parties from one election to another, or even among precincts during the same election.[47] The long list of candidates on the Florida ballots in Palm Beach and Duval counties in 2000 required that the candidate names be split among multiple pages. On the Duval County ballots, the list of candidates was split between two separate pages of a ballot book, leading some voters to inadvertently vote for candidates on both pages. In Palm Beach County, the list of candidates was split and placed on facing pages (creating the so-called "butterfly ballot"), causing some voters to vote for a candidate other than the one intended or to punch two adjacent holes. Punchcard ballots are prone to alignment errors as well, as voters must align the ballot with the appropriate hole to be punched, and ambiguous designs can make the appropriate hole difficult to discern. As a remedy, optical scan ballots may require voters to complete an arrow pointing exactly to the candidate, or a lever machine may be designed so that pulling a lever points it directly at the name of the candidate. Again, different voting technologies place different constraints on the way a ballot can be designed. One focus of the current debate on ballot design is whether a need exists for more standardization. The adoption of a standard national ballot might require the adoption of a single voting technology as well.

Many concerns also exist with regard to the features of the new DRE systems, ranging from problems with readability, organization, and size. In the "User Feedback" section from "A Report on Disabled Voters' Experiences," conducted in March 2003 by The Center for Independence of the Disabled in New York, disabled testers had difficulties with the new machines. Problems range from dark touch screens, indistinguishable characters on the screen, confusing and cumbersome buttons with no Braille labels, audio ballots that were difficult to hear and understand, and difficulty in casting write-in votes.

Casting/Recording Votes

At least three kinds of outcomes may occur when casting or recording a vote: 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. An undervote is a vote for fewer than permitted, such as voting for no candidate for President. An overvote is usually considered an error, while an undervote may or may not be. A voter who undervotes might have tried to vote for a candidate, but was unsuccessful in marking the ballot, or the voter may have chosen not to vote for any candidate. An unintended choice means voting for the wrong candidate by accident. As in ballot design, voting technologies differ in how they record votes in order to prevent or correct errors.

Overvoting can be prevented with lever machines and DRE systems by mechanisms that make it impossible for a voter to select more than one choice. Overvoting can be prevented by optical scan systems that have a "smart ballot box," which checks ballots for overvotes before they are submitted. No system can prevent undervoting, as voters may not wish to vote for a particular office. DRE systems can potentially reduce undervoting by guiding the voter through a multipage ballot electronically, reducing the risk of inadvertent page-skipping. Punchcard ballots reduce mismarked undervotes (like circling a candidate on an optical scan ballot instead of marking the appropriate box) because the vote is a punched hole rather than a pencil mark – but a punched hole is only better than a pencil mark when the voter cleanly punches the right hole in the right place. Unintended choices cannot be completely prevented either. Ballot design and interface usability play a crucial role here. Voter-verifiable balloting that allows voters to review a summary of choices before submitting the ballot, electronically or otherwise, may reduce the number of unintended votes. Voting technologies vary with respect to voter verifiability. Both lever and DRE systems make it possible for voters to review their choices and make changes before exiting the voting booth. With punchcard and optical scan systems, voters who wish to make a change must leave the booth and obtain a new ballot.

Counting Votes

The accuracy of different systems counting votes varies. Pre- and post-election tests are widely performed on the different voting systems to check for accuracy. In addition, manual audits may be performed routinely on a small number of ballots as a check on the validity of the machine count. Voting systems with no ballot document, such as DRE and lever machines, make accurate operational tests the most difficult.

Vote counting may be done either in individual precincts or at a central location within the jurisdiction, or both. It may be performed by machine, human, or both. Votes may be counted and saved as they are cast (by DRE's or lever machines), or they may be counted post-election (punchcards, optical scans, hand-counted paper ballots). The accuracy of a vote count depends on many factors, human and otherwise. Since paper ballots are counted manually, human error or malice are distinct possibilities. The

improper purging of legitimate votes has prompted many voters in black communities to support the move toward electronic voting, believing that their votes are more protected and accurately accounted for by electronic equipment than by inexperienced poll workers or those who have agendas of their own.[48] Lever machines, punchcard machines, optical scanners, and DRE's, which reduce human error, may undergo mechanical problems, hardware malfunction, or software failure. Incomplete punches or ambiguous marks may be read differently by a tabulating machine. DRE systems, which eliminate human error in counting by recording each vote electronically as it is cast, may undergo software or hardware failure as well as being susceptible to security breaches.

Vote Recounts

Voting technologies affect recounts significantly. With lever machines and DRE systems, recounts are generally limited to checking the vote totals recorded by each machine. Critics of these technologies consider this a disadvantage because they do not allow for a ballot-by-ballot paper audit trail. Proponents of DRE's find this to be an advantage, contending that it limits the potential for human error to affect the recount. Whether hand recounts are more accurate than machine recounts has been the subject of much debate.

State laws vary with respect to when manual recounts are appropriate and what standards are used. In most states, the courts or the state election officer decide whether a recount is appropriate because there is no set standard for an automatic recount. Some states do have provisions for automatic recounts – typically when the election is closer than one-half of one percent of ballots cast.[49] Some DRE systems can produce electronic audit trails by storing anonymized electronic ballots for voters, while others can print a paper document that the voter deposits in a ballot box to be retained for audit paper-trails.

Security

This election day, the security of DRE's is likely to crease many a brow with worry. Fraudulent hacking, programming, "security patching," viruses, and the like are all of general concern in DRE vote-recording and vote-counting. The security of electronic voting technologies has been the subject of heated debate since election officials began using them. In order for an electronic voting machine to remain secure against the most vicious attempts to "hack" it, correct implementation of quality control features and external checks on the system are vital. Aviel Rubin, Professor of Computer Science and Technical Director of the Information Security Institute at The John Hopkins University and a leading expert in security technology, points out that ensuring the security of a DRE machine is completely separate from maintaining its functionality. Functionality and proper behavior of a system can be tested and retested, while security is the behavior of the system under "unanticipated circumstances with an active, dynamic adversary trying to subvert it."[50]

Much of the difficulty with ensuring that the software on the machine is adequately secure is related to the secrecy and propriety of the software's source codes written by industry vendors. It is inaccessible to independent technology experts, election officials, or to the general public to assess whether the system incorporates the proper cryptographic safeguards. This is not a hypothetical problem. When the source code for a voting machine manufactured by Diebold was unintentionally posted on a website in 2003, Rubin and a group of computer science experts were able to download and analyze it. Rubin and colleagues published a scathing report,[51] criticizing Diebold for many things, including: using the same unencrypted administrator log-in password repeatedly (which would make it easy for a voter to log in and vote more than once or prematurely close out a DRE machine); using an outdated data encryption standard; and running it all on an insecure operating system. "They made mistakes I wouldn't expect an undergraduate in computer security to make," Rubin told *Wired Magazine*.[52]

Standards for Testing and Certifying Voting Technologies

There are two issues that arise regarding the security of voting technologies: the literal security of the code (making sure it cannot be tampered with or tweaked) and the public perception of security, which is just as important. For elections to work, people must believe that their votes are being counted accurately and are secure from tampering. Strict standards for the testing and certification of voting technologies can help in both arenas.

The voting machine industry is fragmented, and without a mature body of industry-wide standards in place. With passage of HAVA in 2002, NIST was designated to test and oversee the testing of electronic voting machines in order to create standards for machine accuracy and security of the software and hardware to be implemented by 2006.[53] There are still two years before electronic voting machine vendors will have federal, centralized standards in place with which they must comply.

There are at least 19 known DRE vendors,[54] with the largest three--Diebold, Election Systems & Software Inc, and Sequoia Voting Systems--dominating 80 percent of the market.[55] Since 2000, that market has mushroomed. A midsize state needs around 20,000 machines in order to go digital, at about $3,000 each, plus service contracts and upgrades. Georgia spent more than $50 million on DRE technology in 2002. The manufacturers have been shopping around as well. ES&S bought Business Records, one of the original purveyors of optical scan systems, in 1997. De La Rue, a British provider of banknotes and other secure documents, paid $23 million for Sequoia in 2002.[56]

With so much money on the line, conflicts of interest are bound to occur. Concerns have surfaced over the political connections of the companies that produce electronic voting machines. Election companies and election officials alike, once relatively anonymous in the pre-2000 era, find themselves in the front-page news these days. For example, public outcry followed remarks by Diebold Inc. CEO, Walden O'Dell, promising in a fund-raising letter to "deliver Ohio's electoral votes" to President George W. Bush.[57] Research by *Electiononline.org* has found, however, that while political contributions are indeed a reality, total monies have been close to even-handed and there is no industry-wide partisan trend among the largest election system companies.[58] But there is more. Other topics of controversy include: the close ties many of the companies have with each other, the positions some election officials have held in these companies and vice versa, and the "home-state advantage" some companies have been finding – or not finding – in DRE system procurement as state contracts are won or lost.[59]

Accountability

Our votes are personal, and we want our anonymity preserved. At the same time, the system needs to be sufficiently transparent for audits to uncover errors, fraud, or malfunctions. This tension is reflected in debates over re-countable paper trails. With lever machines and most DRE systems, recounts are limited to checking the vote totals recorded by each machine. There is essentially an "audit gap" between the voter's finger and the electronic medium on which the votes are recorded. The machines do not allow for a ballot-by-ballot recount because there is no ballot-by-ballot paper trail. This hampers conducting recounts in contested elections as well as the ability to audit the election. If the integrity of elections rests on blind faith that votes are recorded by DRE's as they are cast, then who can be held accountable for the final numbers - the vendors, the independent testing authorities, the election officials - and how? Furthermore, if we mandate vote-by-vote paper trails to remedy concerns about the auditability of DRE machines, as they do in California, will we undermine anonymity? If vote-by-vote paper trails are produced at the end of the day, in order of voting, then it might be possible to link votes with voters. Further, if voter-verifiable ballots are printed out like receipts that can be pocketed and taken home, then concerns about vote buying or voter coercion could be hightened, as voters could document their vote to an old fashioned vote-buyer. The desire for secrecy-in-voting led to the introduction of the paper ballot in the first place. Will a paper trail mandate turn the tables so that the voting process threatens voter anonymity?

A number of vendors have been working to design voter-verifiable DRE ballots to preserve anonymity. While some manufacturers have developed machines that produce a voter-verifiable ballot that gets dropped in a "lock box" at the polling place, other machines take it a step further by printing an encrypted receipt that can assure the voter that her vote was counted properly, but cannot be used to pass that assurance along to anyone else.[60]

A general push for openness and transparency of the entire system would also help. Michael Shamos, Professor of Computer Science at Carnegie Melon University, testifying before the House Subcommittee on Environment, Technology, and Standards in June: "I propose that standards for the process of voting be developed on a completely open and public participatory basis…. Members of the public should be free to contribute ideas and criticism at any time and be assured that the standards body will evaluate and respond to them."

Assessing Electronic Voting
A Research Roadmap

To deal effectively with the issues described above will require a renewed commitment of intellectual and financial resources. Social and behavioral scientists must be joined by computer scientists and legal scholars in a program of research that enriches our understanding of the interplay of human and technological factors in the functioning of the U.S. voting system. The research roadmap that follows is a step in that direction. We offer it as a guide for researchers, funders, policy makers, election officials, and the general public to use when considering where our voting system should be in elections to come. To do that, however, means also acquiring a better understanding of current practices, technologies, and behaviors, something that is sorely missing from the existing knowledge base.

Setting the Context for Research

To guide the development of a research program on electronic voting, workshop participants identified a series of contextual "givens" that constitute the backdrop of whatever studies are undertaken. This context includes the following:

- Research must take into account the goals of the voting system, identified by the workshop participants as: maximizing voter participation; maximizing the probability that votes are captured as the voter intended; maximizing voter trust and confidence in the system; and achieving simplicity in the voting process while maintaining the accuracy, integrity, and privacy of the system.

- Voting in the U.S. must be understood as a complex system. Components include the factors that motivate citizens to engage the system, the process of voter eligibility and registration, the casting of ballots, recording and counting of those ballots, the recounting of ballots, if necessary, and certification of the election. The introduction of new technologies, laws, or practices at any point in the system will affect the way the system is perceived and actually works. By understanding the risks and opportunities presented by such changes, ways can be found to optimize behavior of the system in line with its goals.

- Since the voting system in the U.S. is highly decentralized, including more than 10,000 election jurisdictions, with responsibilities distributed among national, state, and local governments, voting is affected by an exceedingly diverse set of legal requirements, procedures, and practices. This decentralized system will affect not only the introduction of new voting technologies, but also the conduct of research. On the one hand, it presents challenges to the collection and analysis of data from states and localities that can differ greatly in the manner by which they accumulate, format, and archive their data. On the other hand, it offers an excellent opportunity for researchers to focus on the states as a "living laboratory" and take advantage of their variation to identify some of the best and worst practices. Recent redistricting initiatives have compounded the complexity by imposing more demands on the

system related to, for example, the greater number of ballots that must be introduced and counted, and the number of election workers who must oversee the counting.

- The voting system's decentralization and diversity signal the need to be attentive to the characteristics of voters. There is no "average voter". People engage the voting system with different levels of education and technical skills, cultural backgrounds, languages, accessibility issues related to a disability or socio-economic circumstances (e.g., income or transportation availability), and so on. Research must take into account those differences, carefully scrutinizing the relationship between the voting system and various subpopulations.

- The U.S. is not alone in introducing new technologies into the voting system. Some countries have had more experience and fewer problems. Researchers and policy makers should examine models used in other democratic venues to see what lessons might be applied to similar efforts in this country.

- The same accuracy, integrity, and respect for voter rights and interests must be integral to the conduct and reporting of research. Adherence to accepted research practices and ethical guidelines is essential if findings are to be seriously considered in what is often a highly partisan environment.

Establishing Research Requirements

Workshop participants identified three overarching goals for research on the voting system: (1) to improve understanding of the current system; (2) to contribute to the assessment of how different components of the system interact; and (3) to help the system prepare for change, including anticipating and responding to mistakes or mischief.

To maximize the value of any research conducted, workshop participants acknowledged the importance of achieving a common understanding across research fields of key concepts on which further study should focus, and of identifying useful data and research methods. They recommended a set of 13 key concepts that warrant clearer definitions and more precise methods for measuring them and assessing their impact on the voting system:

- *accessibility* and *equal protection* regarding all components of the voting system;

- *accuracy* as it applies to recording and counting votes;

- *anonymity* and *privacy* as they relate to the casting of a vote, as well as to efforts undertaken to ensure accountability in voting systems;

- *error* and *fraud* with regard to their occurrence throughout the system;

- *intent* with respect to determining whether voting technologies capture the vote as it was intended;

- *transparency* in terms of maximizing accountability while preserving legitimate privacy rights;

- *vulnerability, threat*, and *risk* so that comparative assessments can be made of alternative voting technologies and other proposed changes to the voting system; and

- *usability* to evaluate how any technology can be assessed for ease of use by voters or other actors in the system.

Useful data to collect include those that would lead us to an understanding of how the current voting system operates and is perceived by all stakeholders. Examples cited were: which voting technologies were being used and where; the problems encountered in their use by voters, election officials, and poll workers; how frequent were "overvotes" and "undervotes" in the various election jurisdictions; who is or is not voting and why; perceptions of voters, election officials, and political leaders and their attitudes toward current voting technologies and procedures; which election laws are applicable in various jurisdictions; the extent of documented fraud and error, and where in the voting system they occur; and the cost and economics of the voting process, from voter registration to election certification. This is by no means an exhaustive list, but participants made clear that without such baseline data researchers and policy makers cannot draw sound conclusions about how well the current system works in achieving its goals and how it responds to change.

A wide range of research methods was endorsed by the workshop participants, including survey research, ethnographic studies, field and laboratory experiments and testing. Comparative risk assessments of alternative versus current technologies were viewed as potentially very valuable. Participants saw rich opportunities for collaborative, multidisciplinary research, with teams of researchers joining forces with election officials in developing and executing research protocols. Factors that would facilitate or impede such collaborations also should be examined.

The creation of national data sets and data archives on voting behavior, laws, technologies used, etc., was recommended to bring critical data together in formats accessible to researchers across disciplines. Such aggregate data would help to overcome some of the obstacles posed to researchers by the decentralized voting system.

Potential constraints on research posed by secrecy related to the engineering of voting technology and copyright restrictions on software also should be studied to determine if changes in intellectual property law should be considered.

Research on Voting Technologies

Several research questions were identified related to the design, adoption, use, evaluation, and certification of alternative voting technologies. "Electronic voting technology" means more than just the particular voting machine used. It also

encompasses the databases used for voter registration, the ballots used on election day, and the techniques used to test and evaluate the performance of the voting machines. Participants strongly recommended a comparative assessment of different types of voting technologies, their design, and their use. More research is also needed on performance expectations and standards of voting technologies. A number of research questions were identified to contribute to a comparative assessment.

- What does it mean for a voting technology to perform 'up to standard'? What are the proper metrics to use for measuring performance? What should be included in a standards-setting process for voting technologies? What are the best ways for developing and monitoring standards, and how should various stakeholders be involved? How can voting technologies best be tested in the field for meeting performance standards?
- What is the error rate of existing technologies, and how susceptible are they to tampering, fraud, and lost ballots? At what stages (e.g., voter registration databases, the casting of ballots, the counting or recounting of ballots) are fraud and mistakes most likely to occur, and with what frequency? How possible is it that tampering with voting technology software could be undetectable? How can technologies be engineered to withstand physical abuse, software malfunctions, and human mistakes, and to protect against error and fraud? How often are recounts done, and how accurate are they? What are the impacts of various system designs on voter privacy?
- In making voting technologies more secure, are there lessons to be learned from other venues where secure technologies are critical, such as ATM machines in banking, or gaming technologies in legalized gambling?
- What are the trade-offs in relying on either open source or proprietary software in the design and evaluation of alternative voting technologies?
- How does ballot design affect voter understanding? To what extent are inaccuracies in casting, recording, or counting ballots because of design or human error?
- How can the usability of alternative voting technologies, documentation, and training of users be evaluated?

Research on Voter Knowledge, Perception, and Behavior

A recurring reminder that surfaced during the workshop was that the voter is the central stakeholder in the system. Research should be aimed at discovering ways in which the voting system does or does not serve the needs of the voter.

- What factors discourage or encourage citizens to engage the voting system? What impact is the provisional ballot having on voter participation?
- When voter turnout in a specific jurisdiction is underestimated, how does it affect voter access to the polls? How are lines of voters managed and how long a wait are people willing to tolerate in order to vote?
- From where do voters acquire information about the voting system? What are the strengths and weaknesses of alternative strategies for disseminating voting information?
- What is the extent of high or low voter satisfaction with the voting system, and why?

- How are people's perceptions and participation affected by concerns raised about the voting process, for example, through the media, lawsuits, or legislative hearings?
- Does a person's facility and comfort with voting technology correlate with his or her skill level and experience in using other technologies? Are there tools to help citizens "practice" voting on the technologies as they evolve?

Research on Election Administration

One of the more overlooked components of the voting system by researchers has been how the voting process is administered. It is estimated that the typical polling place handles 400 to 500 voters on election day, and that there are approximately 200,000 such polling places in the U.S., staffed by around 700,000 employees hired just for the day.[61] Key players include election officials (some appointed and some elected), the political administration in power at the state and local levels, poll workers (who are typically volunteers paid only a nominal stipend, and in some cases, politically appointed), and the legion of support personnel, from computer technicians to electricians, to keep the local voting infrastructure operating. Workshop participants identified this "management group" as a subject requiring more research.

Workshop participants noted the increasing responsibilities that the voting system places on election officials. Questions surrounding their role, preparation, and resources received considerable attention.

- What is the level of professionalism among election officials? How do differences in skill sets affect their performance, and with what impact?
- What efforts are taken by election officials to help voters navigate the voting system?
- Who makes decisions about which voting technologies to adopt, and what factors are considered? What is the nature of the relationship between technology vendors and election officials? Is there oversight of the relationship; if so, by whom?
- As election officials seek to centralize and link voter databases to achieve greater efficiencies, what are the implications for voter privacy and system security?
- Do election jurisdictions differ in their capacities to support the work of election officials, and if so, what consequences do those differences have for election administration?
- How can the results of research most effectively be disseminated to those responsible for administering the voting process?

The need for poll workers to interact with voters who may differ considerably in their capacity to navigate the voting system and with increasingly sophisticated technology led participants to consider a series of research questions.

- What are the backgrounds of poll workers with regard to their education, skill, and experience that bear on their role in the voting process? What methods are there to train them effectively in a role that only surfaces every few years? Who should do the training?

- What are the effects of their demographic features (e.g., age, socio-economic status) on a technologically driven voting process, where technology evolves quickly?
- What strategies are used to recruit and retain poll workers from one election to the next, and how effective are they? How are poll workers supervised and held accountable?

For both election administrators and poll workers, participants asked,

- Is there a need to establish a credentialing system for them? If so, what should be the content of a training program and level of performance expected, for example?
- How does a change in a jurisdiction's political leadership affect election administration?

Research on Accountability Mechanisms

Holding people and technology accountable is critical to conducting and certifying elections and to generating public confidence in the system. Workshop participants identified several research issues associated with investigating the impact and effectiveness of various accountability mechanisms.

- How can voters be assured that their votes were cast and counted as intended?
- What are the "best practices" for auditing elections, and who should be involved?
- What are the means by which voting technologies can be designed to provide effective audit trails (e.g., paper or computer images)? How can they be tested and validated?
- How well do different methods, paper and electronic, work to verify votes cast? How would they affect voter privacy?
- Are there ways to verify that the software used in voting technology on election day is what was certified previously?
- If problems are found, what enforcement tools are available? How often have they been used and with what results?
- To what extent do proprietary claims by voting technology vendors affect accountability efforts?

Research on Alternative Future Voting Scenarios

Participants noted a number of future voting scenarios that warrant careful assessment. While some of the proposals for altering the voting landscape are already being touted as "inevitable" or as "solutions to all current problems," none has been subjected to rigorous analysis on how they would work and what impacts they might have. Research on how innovation of new voting technologies is affected by and affects the existing voting system is needed if we are to better positioned to shape our "alternative future."

"Voting anywhere" refers to voting that is not confined to a specific location. It usually means voting via the Internet on a personal computer, but may also include voting from a hand-held device.

- What impact would this approach have on voter participation, especially those subpopulations with minimal access to or experience with the types of technologies that could be used?
- What security and privacy issues are raised by such a distributed voting system?
- What effects would this have on efforts to influence people's votes?

Alternative models of voting registration were also discussed by workshop participants, including both registering and voting on election day. Recent incidents involving the purging of legitimate voters from registration rolls in some states have led to consideration of how best to protect the integrity of voter registration lists and databases.

- What criteria should there be and what documentation required for registering on the day of the election?
- How could challenges to a person's same-day registration attempt be handled in a just and expedited manner?
- What impact would same-day registration have on voter participation?

The failure to develop a research program on the voting system following the 2000 national election has left the nation with many more questions than answers about what to expect in the 2004 election, only days away. We should begin now to prepare for future elections, guided in part by the research roadmap presented here.

Endnotes

[1]PBS.org Online News Hour. "The Primary System: History of Voting Technology," December 15, 2003. http://www.pbs.org/newshour/vote2004/primaries/sr_technology_history.html
[2] Jones, Douglas W. "A Brief History of Voting," Department of Computer Sciences, University of Iowa, 2001.
[3] PBS.org Online News Hour.
[4] Jones, Douglas W. "A Brief History of Voting." Department of Computer Sciences, University of Iowa, 2001.
[5] Caltech/MIT Voting Technology Project. *Residual Votes Attributable to Technology: An Assessment of the Reliability of Existing Voting Technologies*. March 2001.
[6] Election Data Services. *2004 Voting Equipment Study*, February, 2004. http://www.electiondataservices.com/EDSInc_VEstudy2004.pdf
[7] Election Data Services. Quoted in *Election Preview 2004: What's Changed, What Hasn't and Why* by electiononline.org.
[8] Cherry, Steven. "The Perils of Polling," *IEEE Spectrum*, October, 2004.
[9] *Ibid*.
[10] O'Donnell, Paul. "Broken Machine Politics," *Wired News,* January, 2004.
[11] Pinson, Jason. "Technology and Democracy," *Technology Review*, November 2004.
[12] The Rights Task Force of the Consortium for Citizens with Disabilities (CCD). Letter to Congress, May 3, 2004. http://www.c-c-d.org/HR2239VoterRights.htm
[13] Keating, Dan. "Lost Votes in N.M. a Cautionary Tale," *The Washington Post*, August 22, 2004.
[14] Goodnough, Abby. "Lost Record of Vote in '02 Florida Raises '04 Concern," *The New York Times*, July 27, 2004.
[15] Goodnough, Abby. "Office finds disk holding voting data from 2002," *The New York Times*, July 31, 2004.
[16] Konrad, Rachel. "Integrity of Florida e-voting in Doubt," *Associated Press*, October 24, 2004.
[17] Help America Vote Act (HAVA) 2002, Public Law 107-252.
[18] Schneider, Elizabeth. "Election Assistance Commission Disappointed in Latest Congressional Appropriations," Electionline Weekly at *electionline.org*, September 16, 2004.
[19] Semerjian, Hratch (NIST). Testimony before House Government Reform Subcommittee on Technology, Information Policy, Intergovernmental Relations and the Census, "The Science of Voting Machine Technology: Accuracy, Reliability, and Security," July 20, 2004.
[20]NIST Fact Sheet, September 15, 2004. http://www.nist.gove/public_affairs/factsheet/voting_symposium.htm.
[21] HAVA, 2002.
[22] National Institute of Standards and Technology (NIST), "Improving the Usability and Accessibility of Voting Systems and Products," April 2004. http://www.eac.gov/finalhfvotereport-4-29-041wcover.htm
[23] Schneider, Elizabeth. "Election Assistance Commission Disappointed in Latest Congressional Appropriations," Electionline Weekly at *electionline.org*, September 16, 2004.
[24] Election Data Services. *2004 Voting Equipment Study*, February, 2004.
[25] *Ibid.*
[26] Becker, Jo and Dan Keating. "Problems Abound in Election System," *The Washington Post*, September 5, 2004.
[27] Compuware Corporation, "Direct Recording Electronic Technical Security Assessment Report." November 21, 2003. Commissioned by Ohio Secretary of State, J. Kenneth Blackwell. http://www.sos.state.oh.us/sos/hava/files/compuware.pdf
[28] Fischer, Eric A. "Voting Technologies in the United State: Overview and Issues for Congress." *Congressional Report Service*. March 21, 2001.
[29] US Census Bureau, *Voting and Registration*. http://www.census.gov/population/www/socdemo/voting.html
[30] Caltech/MIT Voting Technology Project. *Voting: What is. What Could Be*. July, 2001.
[31] Internet Policy Institute, *Report of the National Workshop on Internet Voting*, March, 2001.

[32] Federal Election Commission, 2000. http://www.fec.gov/pages/nvrareport2000/nvrareport2000.htm
[33] Becker, Jo and Dan Keating, "Problems Abound in Election System," *Washington Post,* September 5, 2004.
[34] United States Commission on Civil Rights. *Voting Irregularities in Florida During the 2000 Presidential Election*, 2001.
[35] Davis, Jingle. "Even death can't stop some voters; Records: Illegally cast ballots not rare." *The Atlanta Journal and Constitution*, November 6, 2000.
[36] Mannies, Jo and Jennifer LaFleur. "City mislabled dozens as voting from vacant lots," *St. Louis Post-Dispatch*, November 5, 2001.
[37] Electiononline.org. *Election Preview 2004: What's Changed, What Hasn't and Why*. October 2004.
[38] Johnson, Curtis. "Voting system causes issues," *News and Sentinel Online,* January 15, 2004. Issac Peterson, "Kiffmeyer's rush creates worry," *Minnesota Spokesman Recorder*, September 1, 2004. Daniel Barbarisi, "State will delay enforcing new voter registry," *The Providence Journal,* September 22, 2004. Gilliland, Betsy. "County wants to postpone voter registry implementation," *The Daily Local,* May 26, 2004.
[39] Becker, Jo and Dan Keating, "Problems Abound in Election System." *The Washington Post.* September 5, 2004.
[40] Fischer, Eric A. "Voting Technologies in the United State: Overview and Issues for Congress." *Congressional Report Service*. March 21, 2001.
[41] Nussbaum, Paul. "Millions to vote before Election Day," *Knight Ridder Newspapers,* as published in *The State*, August 31, 2004.
[42] Caltech/MIT Voting Technology Project, *Voting: What is. What Could Be*. July, 2001.
[43] U.S. Department of Justice, Civil Rights Division. *The Right to Vote: How Federal Law Protects you.* September 2000. www.usdoj.gov/crt/voting/misc/voterev.htm.
[44] Bennett, Stephen. "More Election System Flaws." *The Washington Post*. September 21, 2004.
[45] http://www.accessiblesociety.org/topics/voting/voterturnout.htm
[46] Congressional Research Service, RL30773. March 21, 2001.
[47] *Ibid.*
[48] David Pogue, "Reconsidering E-Voting," *NYtimes.com*, July 15, 2004.
[49] National Commission on Federal Election Reform, 2002. Pages 343-346.
[50] Rubin, Aviel D. Testimony to the U.S. Election Assistance Commission, May 5, 2004.
[51] Rubin et. al, Aviel D. "Analysis of an Electronic Voting System." February 27, 2004. http://avirubin.com/vote.pdf
[52] O'Donnell, Paul. "Broken Machine Politics," *Wired Magazine*, January 2004.
[53] NIST Fact Sheet, September 15, 2003. http://www.nist.gove/public_affairs/factsheet/voting_symposium.htm
[54] Federal Election Commission list of established vendors of computerized vote tabulation systems as of February 20, 2003. http://www.fec.gov/pages/vendorslist.htm
[55] Cherry, Steven. "The Perils of Polling," *IEEE Spectrum*, October, 2004.
[56] O'Donnell, Paul. "Broken Machine Politics," *Wired Magazine,* January 2004.
[57] Electiononline.org. *Election Reform Briefing: The Business of Elections*, August 2004.
[58] *Ibid.*
[59] *Ibid.*
[60] Adler, Jim. Testimony to the House Government Reform Committee, Subcommittee on Technology, Information Policy, Intergovernmental Relations and the Census, July 20, 2004.
[61] Caltech/MIT Voting Technology Project, *Voting: What is. What Could Be*. July, 2001.

APPENDIX A

AAAS E-VOTING TECHNOLOGIES WORKSHOP

Washington, DC

September 17-18, 2004

Steve Ansolabehere
Political Science Professor, MIT and Chair, Voting Technology Working Group of the Election Reform Initiative of the Constitution Project

William A. Arbaugh
Assistant Professor, Computer Science, University of Maryland at College Park

Henry E. Brady
Director, UC Data Archive and Technical Assistance, and Professor of Political Science and Public Policy, University of California, Berkeley

James Dickson
Vice President, American Association of People with Disabilities

George Gilbert
Director of Elections, Guilford County, North Carolina

Thad Hall
Assistant Professor of Political Science, University of Utah

Paul S. Herrnson
Director, Center for American Politics and Citizenship, and Professor of Government and Politics, University of Maryland

Susan Inman
Director of Elections, Pulaski County, Arkansas

Linda H. Lamone
Administrator, Maryland State Board of Elections

Sharon Laskowski
Computer Scientist and Manager, Visualization and Usability Group, Information Technology Laboratory, NIST

Herb Lin
Senior Scientist and Senior Staff Officer at the Computer Science and Telecommunications Board, National Research Council of the National Academies

Peter Maggs
Law Professor, University of Illinois at Urbana-Champaign

Scott Robertson
Associate Professor, College of Information Science and Technology, Drexel University

Ted Selker
Co-Director of the Caltech/MIT Voting, and Associate Professor of Media Arts and Sciences at MIT and Director of the Context Aware Computing Lab

Michael Shamos
Distinguished Career Professor, School of Computer Science, Co-Director, Institute for E-commerce and Director, Universal library at Carnegie Mellon University

Barbara Simons
Co-Chair, U.S. Public Policy Committee Association for Computing Machinery

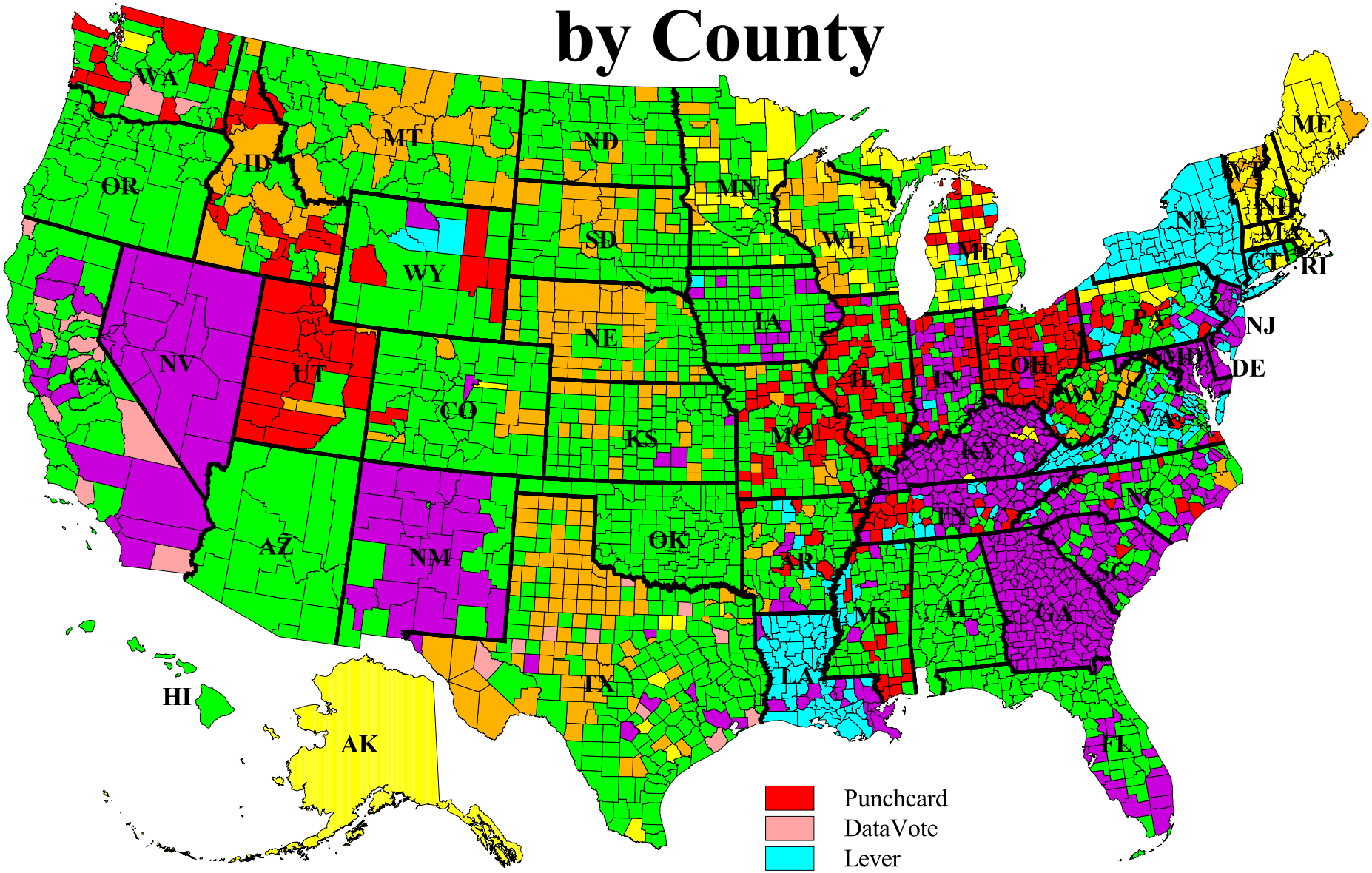
Michael Traugott
Professor of Communication Studies and Political Science, University of Michigan

Dan Wallach
Assistant Professor, Department of Computer Science, Rice University

APPENDIX B

MAP

Type of Voting Equipment by County



Punchcard
DataVote
Lever
Paper
Optical
Electronic
Mixed Systems

Election Data Services

Data: Expected November 2004
Printed: 9/27/04