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IMPROVING VOTING TECHNOLOGIES:
THE ROLE OF STANDARDS

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BEFORE THE

COMMITTEE ON SCIENCE
HOUSE OF REPRESENTATIVES

ONE HUNDRED SEVENTH CONGRESS

FIRST SESSION

MAY 22, 2001

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IMPROVING VOTING TECHNOLOGIES: THE ROLE OF STANDARDS

TUESDAY, MAY 22, 2001

House of Representatives,

Committee on Science,

Washington, DC.

The committee met, pursuant to call, at 10:05 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Sherwood L. Boehlert (chairman of the committee) presiding.

Committee on Science

U.S. House of Representatives

Washington, DC 20515

Hearing on

Improving Voting Technologies:

The Role of Standards

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Tuesday, May 22, 2001

Witness List

Dr. Stephen Ansolabehere

Professor of Political Science,

Massachusetts Institute of Technology;

Director, Caltech-MIT Voting Project

Mr. Roy Saltman

Consultant on

Election Policy and Technology

Dr. Rebecca Mercuri

Assistant Professor,

Bryn Mawr College

Dr. Doug Jones

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Professor of Computer Science,

University of Iowa;

Member, Iowa Board of Examiners for

Voting Machines and Electronic Voting Systems

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HEARING CHARTER

COMMITTEE ON SCIENCE

U.S. HOUSE OF REPRESENTATIVES

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Improving Voting Technologies:

The Role of Standards

TUESDAY, MAY 22, 2001

10:00 A.M.–12:00 NOON

2318 RAYBURN HOUSE OFFICE BUILDING

I. Purpose

As a result of the 2000 presidential election, Congress has undertaken a review to implement significant election reforms. As Congress considers legislation to reform the voting process, a number of issues have emerged as part of the debate, such as whether changes are needed in the voting technologies used in the United States, and what should be the appropriate federal role.

As part of this congressional review, the House Science Committee is examining the role of standards in improving voting technologies. On May 22, 2001, the Committee will convene a hearing to ascertain the problems of our current election system and to explore potential solutions.

The issues to be addressed at the hearing include:

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(1) What problems have been identified in the various voting systems used throughout the United States?

(2) Which of these problems can be addressed by developing or improving standards for voting equipment? What kinds of standards need to be developed or improved, and why?

(3) What different types of research, testing, or data-collecting activities are necessary in order to develop effective voting standards?

(4) What are the major concerns, such as computer security, auditability, accountability, testing, certification, and accreditation, for new voting technologies?

II. Background

A. General Background:

Reports of problems in Florida and elsewhere in the nation during the 2000 election raised concerns about specific failures of voting technologies. One focus of current debate is whether more rigorous standards can provide useful guidance to elections officials. After election day, the media focused attention on specific problems with punch card voting. In the months since then, however, broader questions have arisen about error rates, costs, counting standards, and other issues with all types of voting technologies.

In the 1980s, the Federal Elections Commission (FEC) began developing voluntary standards for computer-based voting systems (see http://www.fec.gov/elections.html). Thirty-two states have now adopted all or parts of those standards, which were issued in 1990. However, the FEC standards have many critics, who consider them to be inadequate, suggesting that national standards must be expanded in scope to address factors such as ballot design, election management, and voter error. Solutions are likely to consider such diverse factors as cost, speed, accuracy, security, reduction in voter errors, and ease of use.

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B. Voting Technologies Used in the Last Election:

In the past election cycle, there were five different types of voting technologies in use around the country: Hand-counted ballots, mechanical lever machines, computer-tabulated punchcards, computer-tabulated optical scan ballots, and computer-based direct recording electronic (DRE) systems. Across the country, punchcard systems were the most common, used by about one-third of registered voters, while optical scan systems were used by about one-quarter.

The following is a description of each of the five types of voting technologies:

1. *Paper Ballots.* The oldest technology, paper ballots are still used in about 3% of precincts, mostly in rural areas. Paper ballots are counted manually. The percentage of voters using paper ballots has declined by half since 1992.

2. *Lever Machines.* First introduced in 1892, lever machines have no document ballot. Instead, a voter enters the voting booth and chooses candidates listed on a posted ballot by pulling a lever for each candidate choice. The votes are recorded by a counting mechanism in the back of the machine, eliminating the need to count ballots manually. Instead, poll workers read the numbers recorded by the counters. Since there is no document ballot, recounts and audits are limited to review of totals recorded by each machine. Write-in votes must be recorded on separate document ballots. About 22% of precincts currently use lever machines. That percentage has declined substantially since 1992 and is expected to continue to decrease because the machines are no longer manufactured, although parts are still available.

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3. *Punchcards.* The first technological approach utilizing computers to count votes was the punchcard system, introduced in 1964. In this system, considered among the most economical and efficient, especially for jurisdictions with large populations, the voter records choices by punching holes in appropriate locations on a paper computer card that is later fed into a computer reader to record the vote. The computer card serves as the document ballot on which the votes are recorded. As with other document ballots, punchcards can be manually recounted and audited. There are two basic types of punchcard systems:

VotoMatic type: A voter is given a ballot printed with numbered boxes, each box corresponding to a particular ballot choice printed in a booklet attached to the voting machine. The voter slips the card into the "throat" of the voting machine, where it rests on a set of rubber strips under the ballot book, and uses a simple stylus to punch out the chad for the box(es) corresponding to the candidate(s) chosen for each race or other item on the ballot. Turning a page in the booklet exposes another set of boxes on the card, corresponding to another set of ballot choices. This was the kind of system used in Palm Beach County, Florida. Write-in choices are not placed on the card itself but are written elsewhere, such as on the envelope in which the card is placed. About 33% of precincts use this type of system, the most widely used voting technology at present. The number of voters using the system has declined since 1992, and that decline is expected to continue.

DataVote type: A voter punches holes next to the names of candidates or other ballot choices that are printed on the cards themselves—there is no ballot book. The voter places the ballot card in a voting apparatus that has a stapler-like punching mechanism on a slide. Write-in votes can be placed directly on the card. About 4% of precincts use the Datavote system, and usage of this system has also declined.

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4. *Optical Scan.* This technology, which is also known as a "marksense" or "bubble" ballot system, has been used for decades in scoring standardized tests and first appeared for use in voting in the 1980's. In this system a voter, using a paper form and an appropriate writing instrument, darkens in a box or oval or completes an arrow corresponding to each candidate choice. A computerized device that senses and records the marks then scans the completed ballot. Write-in votes can be placed directly on the ballot. About 25% of precincts use marksense voting systems. The percentage of voters using this technology has almost doubled since 1992, and that increase is likely to continue.

5. *Direct Recording Electronic (DRE) Voting.* This technology, first introduced in the 1970's, is an electronic version of the lever voting machine, in which a voter's choice is recorded not on paper or a by a mechanical counter, but electronically by the computer. Depending on the equipment used, the ballot may be printed and

posted on the voting machine, or it may be displayed on a computer screen. Voters make their choices by pushing a button, touching the screen or key pad, or using some other device. The voter submits those choices before leaving the booth, for example by pushing a "vote" button, and the votes are directly stored in a computer memory device such as a removable disk or nonvolatile memory circuit. If the voting equipment has a keyboard, write-in votes can be recorded electronically, otherwise, they must be recorded separately on a document. DRE systems have often been considered the most expensive (except perhaps for lever machines), but they are also arguably the most adaptable, with the greatest potential for speed. About 7% of precincts use DRE voting systems. Like the marksense systems, the percentage of voters using DRE has almost doubled since 1992 and is expected to continue to increase.

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The following table indicates the types of voting technologies and the incidence of their use in the U.S. in 1998.

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C. Internet Voting:

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

D. Current Standards for Voting:

In 1982 Congress directed the FEC to develop national standards for computer based voting systems that states might voluntarily adopt. In 1990, the National Association of State Election Directors (NASED) approved FEC's voluntary standards, which, at the time of the November 2000 elections, had been adopted in whole or part by 32 states, including Florida, although many states (including Florida) grandfathered in technologies introduced before the standards were developed. These standards were developed for both hardware and software and include functional and documentation requirements, performance characteristics, and testing procedures for punchcard, marksense, and DRE systems. The FEC plans to update these standards next year.

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Some have pointed to the occurrence of Florida's elections problems despite the state's adoption of FEC's standards as evidence that the standards are inadequate. They argue that such standards should be updated to include more robust standards for computer security, integrity, and accuracy of the election process. They also urge that the standards be expanded to include performance-based standards that address voting errors made in real voting situations that arise from such factors as voting machine design, ballot design, and election

management (including maintenance). Such standards, for example, could require that a voting system prevent or reduce overvotes, or votes for more than one candidate.

Testing of voting equipment is performed at the national level by two independent labs overseen by the Elections Center, the professional association of election officials. These labs test voting machines, according to the vendor's specifications, to determine if they meet FEC hardware and software standards. Voting machines generally are not tested for their ability to meet performance-based standards under election-like conditions. In addition, while some states require that voting technologies meet requirements beyond those required by the FEC, few states have independent testing laboratories to certify voting equipment.

Additionally, the National Institute of Standards and Technology (NIST) has performed research on voting technologies for 30 years, including issuing reports in 1978 and 1988 detailing major problems with punchcard systems and other technologies. NIST's past voting expertise and ability to conduct standards research has led to proposals for NIST to create thresholds for accuracy, maintenance, and usability of voting systems. NIST has no ongoing role in setting the FEC standards.

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E. The Response of States, Localities, and Others:

The responses of state and local election officials since November have been mixed. While state and local groups have welcomed Federal financial assistance, they have warned Congress about mandating "one-size-fits-all" solutions. For example, the National Association of Secretaries of State adopted a February, 2001, resolution calling for updated, voluntary national standards and federal funding for voting system modernization, among other actions. The National Association of State Election Directors also adopted a resolution in February calling for increased federal funding to develop updated and expanded standards.

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

The National Conference of State Legislatures has also established an Elections Reform Task Force to restore public confidence in state election systems, and is attempting to identify model practices and laws for states to consider. Reform legislation is pending in all 50 states, with more than 1,400 bills introduced in state legislatures this year on a wide range of election reform issues.

In December 2000, Florida Governor Jeb Bush established by executive order the bipartisan Select Task Force on Election Procedures, Standards, and Technology. The task force examined several issues associated with election administration and has issued its recommendations. As a result, Florida recently enacted major election reform legislation that eliminates punchcard ballots. Additionally, the legislation mandated a uniform election ballot design. At least four more states (Georgia, Maryland, Iowa, and Missouri) have proposed adopting a uniform statewide voting system, as well as other election reforms, and several have also proposed adopting systems that help prevent voter error.

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More than a dozen states have established task forces or other efforts to examine election reform needs, and some have produced recommendations. Also, a privately funded National Commission on Federal Election Reform, co-chaired by Presidents Carter and Ford, is examining a wide range of issues relating to voting technology and election administration. The bipartisan Constitution Project has established an Election Reform Initiative to develop consensus about improvements in election administration. And the California Institute of Technology and the Massachusetts Institute of Technology are engaged in a joint effort to determine how to improve the performance and reliability of voting systems.

III. Witnesses

There will be one panel of four witnesses:

(1) Dr. Stephen Ansolabehere, Professor of Political Science at the Massachusetts Institute of Technology and the Project Manager of the Caltech-MIT Voting Project. The Voting Project was created in December 2000 to prevent a recurrence of the problems that threatened the 2000 elections. Specific tasks of the project include evaluating the current state of reliability and uniformity of U.S. voting systems, and proposing uniform standards and quantitative guidelines for performance and reliability of voting systems. The Voting Project just completed a March 30, 2001 preliminary assessment of the reliability of existing voting equipment.

(2) Dr. Rebecca Mercuri, Assistant Professor of Computer Sciences at Bryn Mawr College, is a nationally recognized expert on voting technologies and standards. In October 2000, she successfully defended her Ph.D. thesis, "Electronic Vote Tabulation Checks & Balances."

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(3) Dr. Doug Jones, Associate Professor of Computer Science at the University of Iowa, has served on the Iowa Board of Examiners for Voting Machines and Electronic Voting Systems since 1994, and has chaired the board since the fall of 1999. This board, appointed by the Iowa Secretary of State, must examine and approve all voting machines before they can be offered for sale to county governments. The board meets whenever a manufacturer wishes to offer a new voting machine or a new modification of an existing machine for sale in the state of Iowa.

(4) Mr. Roy Saltman is a consultant and a retired employee of the National Institute of Standards and Technology (formerly, the National Bureau of Standards) who authored the 1988 National Bureau of Standards report, "Accuracy, Integrity, and Security in Computerized Vote-Tallying," that first raised the difficulties of using punch cards and other machine-readable ballots. He also authored the 1978 National Bureau of Standards study, "Science & Technology: Effective Use of Computing Technology in Vote-Tallying."

Improving Voting Technologies: The Role of Standards

Chairman **BOEHLERT.** The Committee will now come to order. The Committee will now consider a request from the Ranking Minority Member regarding Subcommittee assignments. Mr. Hall.

Mr. **HALL.** Thank you, Mr. Chairman. First, I hereby notify the Committee that Congresswoman Lynn Woolsey has relinquished her seat on the Subcommittee on Research. And second, by direction of the Democratic Caucus of the Committee on Science, I have been asked to nominate Mr. Honda to fill the vacant Democratic seat on the Research Subcommittee. His personal background in K–12 education and science education makes him a very strong addition to that panel. And I have read some of his resume, and the thing that struck me first is that he

raised almost $2 million to run on. And I am going to ask him to be my treasurer for the next go-round. And if he turns me down I am going to ask his opponent who is behind him with $1.3 million, and in my district that ain't bad. So—but I think he is a fine Member of Congress, a great American, and it's an honor to have him here. And I know that he will be supported, hopefully, on both sides of the aisle. Mr. Chairman, I ask unanimous consent that the nomination of Mr. Honda be ratified.

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Chairman **BOEHLERT.** Hearing no objections, so ordered. I have had the pleasure of sitting down and having a conversation with Mr. Honda and enjoy his enthusiasm and welcome him with open arms to the Committee. This is a very productive committee, and I am sure you will make valuable contributions. We look forward to your service.

Mr. **HONDA.** Thank you very much, Mr. Chairman.

Chairman **BOEHLERT.** I would like to welcome everyone today to the Science Committee's first look at what I consider to be one of the most important aspects of election reform: ensuring that voting technologies are secure, reliable and accurate. Last November, as the world placed Florida under a microscope to scrutinize its election, America saw for the first time the extent to which one of our most sacred tenets of democracy was vulnerable to error. As the problems with the now-infamous punch card ballot unfolded, America watched in amazement, and the rest of the world watched in amusement. They watched as America, the most technologically advanced nation in the world, who preached democracy to others, tripped on its own shoelaces. Now, several months later, Congress is beginning to respond. And while it is tempting to criticize this institution for not acting sooner, I would suggest that the meantime has not been wasted.

We have learned many things about our nation's various voting technologies. And we have begun to answer many questions about how to fix our voting systems. For example, the problems that plague Florida also affected many other states and counties across the country. But would banning punch cards solve the problems for these areas? It turns out that it depends on what technology you replace the old punch cards with, for some are just as bad. Should states simply embrace the future and move to adopt voting by Internet? Probably not. For there still seems to be too many uncertainties over security, privacy and equal access to ensure that this potential solution would be fair or problem-free. How about electronic voting machines with touch screens or push buttons that automatically tabulate votes. Should states buy those? That is not really clear either, for some studies have shown those machines to be as error-prone on average as punch cards.

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So while our election problems are undeniably pressing, the last few months have shown us that we must proceed carefully in order to get the answers right, and not set ourselves up for potentially bigger problems down the road.

So what can the Federal Government do to help? First, let me state clearly what the Government should not do. It should not mandate a one-size-fits-all solution. It should not insist, for example, that every voting precinct in all states buy the same technology for its elections. Nor should it trample on the rights of localities and states to conduct elections in ways that make the most sense for them.

But the Federal Government can and should offer states the kinds of information that it is best suited to provide. For example, I believe the Federal Government should conduct research, not just into ways of improving the inner workings of voting machines, but also into how people interact with them to make sure that voting equipment is user friendly for ordinary people. It can also develop robust technical standards for voting equipment manufacturers to meet. And it can accredit labs around the country to help certify that voting equipment meets those standards so that states can confidentially choose voting technologies that are secure, reliable and accurate.

As the Committee that oversees the National Institute of Standards and Technology, I believe we have an important role to play in these areas. Next month we plan to work together in a bipartisan way to report out legislation that will help ensure that the Federal Government plays its proper role in strengthening our election systems.

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Obviously, there are other important ways the Federal Government can help, too. For example, by providing money to help states and localities upgrade their voting systems. As a former county executive, I can tell you how tight the budgets of local governments are stretched and how low a priority elections are as a result. Because they are competing with roads and so many other projects that traditionally are the main responsibility of local government.

But now it is time for elected officials who often like to lecture voters about how important voting is to our democracy to put our money where our mouths are. This is a complex problem with complex solutions. Solving it will take some time, some effort, and some investment. But in the end it is worth it. After all, in this case, it is no exaggeration to say that nothing less than our democracy is at stake.

I look forward to the testimony of our witnesses and to a productive discussion. The Chair now recognizes Mr. Hall.

Mr. **HALL.** Mr. Chairman, that was a good statesman-like rendition of your opinion of it, and I subscribe to it. I can add some things to it because, like you, I have had experience at the local level as county judge for twelve years of a small county, and the Texas Senate 10 years. I have observed the voting process. As a matter of fact, the absentee votes in our home county, they put them in a box and they had 3 keys and 3 locks on there. One for me, as county judge, 1 for the District Clerk, and 1 for the Sheriff. Now they could have been safe if they would have just had a fourth key and given that to Mother Theresa. But that is—without throwing it away to be absolutely sure that somebody wasn't going to look at some of those boxes.

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We—I add my welcome to you who are—have given your time and travel and all that to this hearing this morning. And I want to thank Chairman Boehlert for holding this hearing on election technology and the role of standards.

I think before November a lot of people reading this hearing title might have wondered about the connection between elections and standards. But the last election highlighted that we need to improve our voting equipment across the country. And I think our voting equipment has to be accurate and has to reliable. And good standards play a great role in that. I believe that the Science Committee can make a contribution to the ongoing debate of improving voter technology. This is especially true in the area of standards for voting technology and the research required to support the development of those new technologies.

The Chairman has assembled a very capable group of witnesses. And I want to thank him for working with us on this hearing. I also want to thank the witnesses for taking time from their busy schedules to appear before the Committee today. I understand that the legislature in Florida has passed some legislation. I am sure you have all studied that. Someone from a standpoint of humor said that they had a motion to reconsider and that they didn't know how it came out because they were down there in Florida and they were still counting. I am not sure that that's true, but you might expect that of Republicans. Because us Democrats, like up in Chicago the mayor said, every time two democrats voted they counted all 4 of them, by golly. And so there is a lot of improvement on both sides of the docket.

I think this Chairman is going to lead us into that improvement. It is going to take a little time, but we thank you for being a part of this this morning. I yield back my time unless you want some more of my stories. Yes, I do. Mr. Barcia is here and I am not sure I have any time to yield to him. But if I do, I want to yield the balance of my time to Mr. Barcia. He has been working on this issue and has a bill on this issue. And I support his bill. I think I am on the bill with him. And I yield you 15, 20 minutes, Mr. Chairman.

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Chairman **BOEHLERT.** The Chair is pleased to recognize Mr. Barcia.

Mr. **BARCIA.** Mr. Chairman, I will try to be brief. But I want to, of course, thank Ranking Member Hall and also for those kind comments. And I also want to thank you, Chairman Boehlert, for holding this very important and timely hearing. After the last election 1 issue that was highlighted was the need to improve the accuracy, integrity and security of the voting products and systems used in Federal elections. I felt that this was something that needed to be addressed immediately as states and local municipalities were likely to rush to replace existing voting equipment with newer equipment. I was struck also by the lack of objective information on how voting equipment performs. And that we lack a set of up-to-date, comprehensive standards for voting equipment. I believe that we need a set of comprehensive, voluntary, technology neutral standards that address the accuracy, integrity, and security of voting products and systems. In addition to the development of these standards, we should have an independent certification procedure as well as the means to accredit independent labs to certify voting equipment.

Finally, we need to—we need research on voting technology. This should include things like human factors, security and authentication issues surrounding Internet voting, and open standards, to name but a few. For 100 years we have relied on the National Institute of Standards and Technology, or NIST, to ensure our systems of weights and measures are accurate and reliable. And in that effort NIST has done an outstanding job. Common sense indicates that they could play a significant role in assisting in the development of standards for voting technologies. As far as back as 1975, NIST has been reporting on voting technology. And if we had heeded the recommendations in the 1975 report, and a subsequent 1988 report, we likely would not be holding this hearing today. I do not believe that NIST can be the sole arbiter of election standards, but by working with the industry, the FEC, and state and local officials, I do believe that a comprehensive set of voting standards can be developed.

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That is why I, along with a number of my Science Committee colleagues introduced H.R. 1165, the Election Voting Systems Standards Act. This bill authorizes NIST to work with the FEC to establish a commission to

develop voluntary technology neutral voting standards, and an accreditation certification procedure for use by state and local election officials. The legislation is not meant to replace the current system of standards set by the FEC, but to strengthen the standard setting process.

In addition, the bill establishes a national research lab on voting technologies. The jointly chaired NIST/FEC commission would decide on the structure of the lab. This lab would not only fund research grants, but would serve as a central repository for research that would be open to all. We consider this legislation to be the first step in addressing this important issue.

Again, I would like to join Ranking Member Hall in commending Chairman Boehlert and also Ranking Member Ehlers for holding this timely hearing. I look forward also to the witnesses' views on the role of standards for improving our election equipment. And I want to thank them for appearing before the Committee today.

Chairman **BOEHLERT.** Thank you very much for that statement. Do you yield back the balance of your time? All right. Thank you. The Chair was somewhat indulgent on the opening statements. And all other members will have leave too with opening statements in the record.

At this juncture we will go to our first and only panel of the day, a very distinguished panel, I might add. Dr. Steven Ansolabehere, Professor of Political Science, Massachusetts Institute of Technology, and Director of the Caltech-MIT Voting Project. Dr. Rebecca Mercuri, Assistant Professor at Bryn Mawr College. Dr. Roy Saltman, Consultant on Election Policy and Technology. And Dr. Doug Jones, Professor of Computer Science, University of Iowa, Member of the Iowa Board of Examiners for Voting Machines and Electronic Voting Systems.

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And I might add as, is customary in this Committee, all of our panelists are very distinguished and have outstanding reputations. And, therefore, we are most appreciative of you being willing to serve as resources for this Committee as we are trying to come to grips with something that is very important to all of us.

With that, let me say we would ask that you try to summarize your statement in 5 minutes or so. I will not be arbitrary because you have got a lot to say and we have got a lot to hear, hopefully. And then we will open it up to questions. And we look forward to a productive couple of hours. Doctor, you are up first.

STATEMENT OF DR. STEVEN ANSOLABEHERE, PROFESSOR OF POLITICAL SCIENCE, MIT; DIRECTOR, CALTECH-MIT VOTING PROJECT

Dr. **ANSOLABEHERE.** Thank you for inviting me to speak today. I would like to begin by telling you a little bit about our project, and then tell you some specific findings of our project as they relate to technical standards and innovation in voting technology.

The week after the 2000 election President David Baltimore of Caltech called President Chuck Vest of MIT with an idea. And the idea was that our two institutions should collaborate to develop new voting technology. The problems observed in counting the vote in Florida and elsewhere ultimately originated with technology and often computing technology. Presidents Vest and Baltimore assembled a team of computer scientists, mechanical engineers and social scientists. The Carnegie Corporation and our two institutions have funded this endeavor.

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I am Steve Ansolabehere, a Professor of Political Science at MIT. I am one of the social scientists, and co-director of this project. My counterpart at Caltech is Tom Palfrey, an economist. Our team spans many different fields. The engineers bring expertise in electronic security, user interface design, machine design and performance standards. I speak for the group.

We are in the initial phase of our project, which I consider the learning phase. Over the last four months we have met with many voting machine manufacturers and elections administrators to ascertain where the problems are and to explore some ways that we may contribute to the solutions.

We have also conducted studies of voting machine performance and design, the public finances of election administration, and voter registration practices. A complete report of our work over the last 4 months will be out July 16.

What are the problems with voting technology? Well, there are many detailed problems you could list. But we are going to focus on 4. First, is the high rates of spoiled, unmarked and uncounted ballots, such as we saw in Florida. Our first step in this project was to assess the performance of existing equipment in order to establish some benchmarks. I have distributed a report, which is the second version of a report that we issued in the end of March on the extent to which equipment affects the rate of uncounted, unmarked and spoiled ballots. The report shows or finds that punch cards, indeed, performed relatively badly compared to the other technologies, according to the standard of uncounted, unmarked and spoiled ballots. Surprisingly, electronic equipment did as well. Paper ballots that are hand-counted, lever machines and optically scanned ballots performed best by this metric.

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In our assessment, these differences are due to ballot and user interface designs more than they are due to the durability of the counting process. We feel that greater private or government research and development is required to improve ballot design and user interface design in this regard.

The second problem, errors in the voter registration data bases. Voter registration is a very large data base management problem, and as such, a technical problem. The roles must have high levels of integrity and they must be accessible at the polling places. An audit of Michigan's voter roles, after they went to a qualified voter file at the state level, revealed that 1 million voters had duplicate registrations out of about 9 million. According to the 2000 census, 7 percent of voters who did not vote reported registration problems as the reasons for not voting. So we see that there are some big issues with access to the poles and the quality of the data or the integrity of the data that need to be addressed.

The third issue, accessibility. Put simply, blind people really can't vote without assistance.

The fourth issue, security of ballots and tabulation. The traditional process is having many eyes on the process to check the quality of the tabulation. As we move to electronic equipment that is becoming impossible. So the natural check on the integrity of the count is being lost. Today we are on the verge of Internet voting. Simply put, we need standards for secure electronic voting and we see those as lacking.

What are standards and how can they help? The first set of standards is minimum criteria. We have those and the existing standards that are implemented by NASED, minimum criteria for accuracy of tabulation and durability of equipment. We think that there need to be minimum criteria for usability, accessibility and

auditability.

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Second, best practices. There are model programs out there for registration, for equipment maintenance, equipment development, and this should be developed further. A Federal agency should compile and distribute information about equipment performance, cost, and administration. That is essential if counties are to become smart consumers of equipment.

The third standards are specifications. Our group is against the idea of uniform equipment, which in the extreme is a specification that everybody must use the same form of equipment. However, there are areas where uniform specifications might help, such as in electronic security. Here, we see a special role for NIST and the Science Committee. Internet voting is on the verge of being here and will grow over the next 10 years, the pressures are very strong. The biggest objections have to do with security. And one thing we feel strongly about is that this Committee and NIST begin a process now to develop standards for secure Internet voting.

Chairman **BOEHLERT.** Thank you very much. Dr. Mercuri.

STATEMENT OF DR. REBECCA MERCURI, ASSISTANT PROFESSOR, BRYN MAWR COLLEGE

Dr. **MERCURI.** Thank you and good morning. I am Dr. Rebecca Mercuri of Lawrenceville, New Jersey, an Assistant Professor of Computer Science at Bryn Mawr College, and also president of Notable Software, Incorporated, a New Jersey computer consulting firm. Thank you for the opportunity to address your committee on this important matter.

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Over the last decade I have investigated voting systems with particular emphasis on the electronic equipment used to collect and tabulate ballots. Through this research I have identified numerous flaws inherent to the application of computer technology to the democratic process of elections. As it turns out, these flaws are both technologically as well as sociologically based, so a quick or even long-term fix is not readily apparent. For example, present and proposed computer-based solutions are not able to resolve, and in some cases, may even increase the likelihood of vote selling, coercion, monitoring, disenfranchisement, and fraud in the election process. Some of the problems with electronic balloting and tabulation systems are identified as follows:

First, fully electronic systems do not allow the voter to independently verify that the ballot cast corresponds to that one that was actually recorded, transmitted or tabulated. Any programmer can write code that displays one thing on the screen, records something else, and prints out something else as an entirely different result. I have freshmen, by the way, who can do this. There is no known way to ensure that this is not happening inside of a voting system.

Number two. Electronic balloting and tabulation makes the tasks performed by poll workers, challengers, and election officials purely procedural and removes any opportunity to perform bipartisan checks. The process is thus entrusted to the small group of individuals who program, construct, and maintain the machines.

Number three. Although, in many states, convicted felons and foreign citizens are prohibited from voting in U. S. elections, we don't have any laws regarding voting system manufacturers, programmers and administrators in

that regard.

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Fourth, each election season, newly deployed voting equipment fails to perform properly in actual use. Communities will continue to run the severe risk that they will administer an election whose results may be contested.

Five, electronic balloting systems without individual printouts for examination by the voters do not provide a wholly independent audit trail. As all voting systems are prone to error, the ability to perform a manual hand-count of the ballots is essential.

Six, some new electronic systems actually make the balloting process more lengthy, tedious, and confusing. The use of such devices has been viewed by some as a modern-day literacy test.

Seven, encryption cannot be relied on to provide end-to-end privacy assurance. Nor can it assure the accuracy of ballot data recorded and tallies rendered.

Eight, Internet voting provides avenues to the entire planet for malicious denial of service attacks. Off-site Internet voting also creates unresolvable problems with authentication, leading to possible loss of voter privacy, and increased opportunities for vote selling. Internet voting may make it easier for the techno-savvy elite to cast ballots, while potentially disenfranchising or creating a digital divide for poor, elderly, rural and disabled voters.

And ninth, it is not possible to construct a standardized voting system that could be used in all municipalities without treading seriously on states' rights issues, and without mandating changes in many conflicting election code laws to provide conformity.

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I could go on, but these are just some of my concerns, many, many more exist. Now the computer industry has already established standards for secure certification mandated by Congress under the Computer Security Act of 1987. NIST typically administers this certification for devices purchased by the Department of Defense. But Congress, though, exempted itself from compliance with the Act, and has never certified the accuracy and integrity of computer-based voting systems used in Federal elections under this code. This loophole should be changed. The existing standards such as the ISO Common Criteria or its predecessor, TCSEC/ITSEC, are not perfect, but they are the best assurance mechanism that the computer industry has at present.

I have long recommended that the NIST standards be applied to voting systems. As a part of my Doctoral Dissertation at the University of Pennsylvania, I performed a detailed analysis of the Common Criteria against the features that I thought should be necessary in voting systems. The painstaking description in the thesis provides an excellent starting point for the development of a voting standard. I have provided it to the Committee.

I have also formulated a list of questions that voting system vendors should be required to answer about their products. I would suggest that first a trial standard be developed, along with an assessment procedure. And then voting systems applying different state requirements should be constructed and assessed to see what level of conformance is possible using current technologies.

In conclusion, I would like to remind the Committee that technology can not and does not, at present, provide a solution to the balloting and tabulation problem. Our society has become increasingly enamored with computers, yet we have all experienced, first-hand, their sometimes catastrophic failures in the products that we use every day. The same will be true and is true for computer-based voting systems. But here there are no warranties, and there is no insurance if we have some problems with the results.

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It is, therefore, crucial that we continue to maintain and impose human checks and balances throughout our election process. This is the only way to ensure that our democracy does not become one that is by the machines, of the machines and for the machines. Thank you.

Chairman **BOEHLERT.** Thank you very much, Dr. Mercuri. Boy, you gave us something to ponder on. I am glad you weren't like David Letterman and went through a top ten list. I am glad you stopped at nine. It was getting discouraging.

Dr. **MERCURI.** I stopped at nine. Thanks.

Chairman **BOEHLERT.** But thank you very much for an outstanding testimony.

Dr. **MERCURI.** Thank you.

Chairman **BOEHLERT.** Mr. Saltman.

STATEMENT OF ROY SALTMAN, CONSULTANT ON ELECTION POLICY AND TECHNOLOGY

Mr. **SALTMAN.** Mr. Chairman and and members of the Committee, thank you for permitting me this opportunity to present my views. I want to first indicate to you my background. As Mr. Barcia has mentioned the two reports of the National Institute of Standards of Technology, and it is important for you to know that I was the author of both of those reports.

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It is interesting to note, however, that the money for those reports did not—was not appropriated to NIST. The first report was sponsored by the General Accounting Office with the approval of Mr. Staats, the Controller General at the time, Sam Hughes, the Assistant Controller General, and the Office of Federal Elections, which was then the predecessor of the Federal Election Commission and was in the General Accounting Office.

The second report was sponsored by—in 1988 was sponsored by the John and Mary R. Markle Foundation. And the reason was that there had been some New York Times articles that said that fraud was a possibility and due to computer program manipulation. And the Markle Foundation wanted to know what was the issue. So that money came from there. At no time did NIST ever appropriate any money for the—for projects on election administration.

I want to tell you what I think the Federal Government could do in this area. Surely, the Federal Government should not conduct elections. But in other civil—areas of activity like education and health and highway

transportation, the Federal Government has significant activities but does not undertake the delivery of services.

Specifically, the Federal Government should do this. It should undertake data collection, analysis and reporting. It should carry out research. It should establish robust national standards. It should accredit independent testing laboratories. It should support state-wide voter registration systems. And it should have a grant program for states and local governments.

Specifically, documentation is needed for equipment—reports of equipment performance and incidents of difficulties with either machines or procedures. Data concerned with the ability or inability of voters to use voting machines successfully with collection of under-vote and over-vote data, for example, it would be useful to obtain on an organized basis.

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In research, studies of the ease of use, that is, voter usability of different vote-casting methods should be undertaken. Product independent research into new types of voting systems and use of the Internet should be undertaken. Analysis of techniques for improving the capability of sight-limited voters to vote without assistance should be done. And development of new methods of voter identification that could be applied to precinct located voting or to remote voting should be undertaken.

I agree that the standards established by the Federal Election Commission need some updating. That process is underway. But it also requires significant amounts of resources to undertake and continue the undertaking of that project.

The accreditation of independent testing laboratories is one area where NIST could be of value. Their national laboratory—or their National Voluntary Laboratory Accreditation Program is perfectly suited to assist in this effort.

State-wide voter registration systems need considerable support. As Professor Ansolabehere mentioned, there is a significant problem. I believe that it can only be solved through state-wide voter registration systems with Federal assistance, with county-level voter registration systems coming off that, and with terminals from two of the precincts and from the precincts during election administration on election day.

I want to point out that I do not have the same concern about fully electronic voting that Dr. Mercuri does. However, I have always stated that the auditability problem of non-ballot systems is a serious matter that must be undertaken with great care to assure that the public has confidence in the results produced by an all electronic system.

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I have proposed in my 1988 report two items for the design of these direct recording electronic systems one of which was introduced into the Federal Election Commission standards and the second was not. The second involves recording the non-voting possibilities of voters and will allow a second chance effort by voters to replace their under-votes.

Thank you for your discuss—for your listening. I have in my written testimony my discussion of the

advantages, disadvantages and recommendations for change of the different voting systems. Thank you for your attention.

Chairman **BOEHLERT.** Thank you very much, Mr. Saltman. Dr. Jones.

STATEMENT OF DR. DOUG JONES, PROFESSOR OF COMPUTER SCIENCE, UNIVERSITY OF IOWA; MEMBER, IOWA BOARD OF EXAMINERS FOR VOTING MACHINES

Dr. **JONES.** Thank you. I am very glad to be here and hope that my testimony is useful. Going last I feel that is rather difficult to say more than amen. But there are few things which I have to contribute, which are different.

In 1992 I was appointed by the then Republican Secretary of State, Paul Pate, to the Iowa Board of Examiners for Voting Machines and Electronic Voting Systems, and I have served on that board now for 9, going on 10 years, and in that time I have had the opportunity to examine a large number of voting machines. In this position, I have dealt with the regulatory process as a unit, the combination of Federal regulations and state regulations. And I have had numerous opportunities to deal directly with vendors, representatives, to directly speak to vendors, software people and hardware people. And to deal with a fair number of county elections officials and state elections officials within the State of Iowa. I now chair that commission. And it is in that role that I am here.

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I have over the past almost a decade of experience looking at voting machines, seen a large number of systems come before our board that have been deficient, that we have turned down for one reason or another. And almost every one of these systems has been—has passed the current Federal Election Commission Voluntary Certification Process, has been examined by Wile Labs, which is the only independent testing authority currently approved. Almost every one of these systems that we have had difficulty with has been approved for use in a large number of states. I don't believe that we set unreasonable standards. In fact, I don't believe that we can set the standards we ought to right now because we cannot turn down a machine for use if it does—if it passes the legal requirements. And there have been many occasions where I wished we could turn down a machine.

Because of this, I think we have to look very carefully at several issues. I want to very strongly back the—Rebecca Mercuri's comments about electronic voting, fully computerized voting systems where there is no independent record of the voter's action which the voter could—which the voter could check before depositing a ballot in a ballot box, is extremely problematic. I don't believe it is impossible. I think I am more optimistic than Rebecca is about that. But I don't want to encourage people to rush for computerized voting systems. And here I refer to direct recording electronic voting systems.

Internet voting is even worse. I would, quite frankly, like to forbid Internet voting until we have some really solid standards in place. I feel very strongly, as Mr. Saltman does, that we need much harder audit requirements. I believe that the over-votes and under-votes in every race should be included as part of the official canvass brought forward to the level where it is included, so that you can verify that the sum of votes for each candidate, plus under-votes for that race, plus over-votes for that race equals the number of ballots. That is such a trivial accounting trick. And it would account for a huge number of the lost ballot boxes and strange things like that that we find in typical recounts.

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It is very important to realize that Mark Twain was right when he said that democracy is the worst of all systems, except for all the others. It is fair to say as a corollary that every approach we have to conducting a democratic vote is bad, except that the alternative is worse. There is no perfect voting technology available today. Because of this, I am very wary about the current rush to abandoned the "old tech" voting systems, and immediately adopt the highest tech that we can find. I would find it very inappropriate for the Federal Government, for example, to fund a massive emergency purchase of new voting technologies in counties across the country. Because I feel that in doing so we might be simply replacing the bad system we know we have with the system whose failings we don't understand yet.

I recommend that we slowly phase out, deliberately, voting systems whose problems are clearly worse than the others. And among these I would say punch card voting is clearly bad. And I would suggest that we move cautiously forward on new technologies. I don't like the idea of declaring an emergency and throwing a lot of money at purchase of new hardware, only to discover we have made a mistake. Thank you.(see footnote 1)

In my experiments with this machine, I was able to reproduce some of the problems reported in the press that led voters to complain that even when they hammered on the punch, they were unable to cleanly punch their ballot. The cause of this problem is chad accumulation between braces inside the machine and the back of the ballot. This problem only occurs where the voting position is over these braces.

I strongly recommend that, if Votomatic voting machines remain in use, the voting positions above these internal braces should never be assigned to candidates!

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See http://www.cs.uiowa.edu/jones/cards/chad.html for photos and additional documentation of this issue. I will update this web page as I learn more.

DISCUSSION

Chairman **BOEHLERT.** Thank you very much. You are quoting Mark Twain. I will quote Pogo. We have met the enemy and he is us. You know, Mr. Saltman, you said that NIST didn't appropriate any money for your studies. Well, NIST doesn't appropriate, we do. And shame on us for not doing what we should have done before. But we are not going to concentrate on the past, we are going to look to the future.

But how many days, 1,275 to the next election? Can we do it in time? I am talking about the presidential election. Is that a realistic goal to establish, that we take corrective action to prevent a repeat of year 2000 in the next 1,275 days? Or is this going to require longer? Does anyone have any comment on that? Dr. Jones.

Dr. **JONES.** It will take considerably longer to put new standards in place and see a new generation of voting systems that satisfy the requirements of those standards.(see footnote 2)

I believe that the root of our disagreement rests in the height of the goals we inferred from Chairman Boehlert's question. I agree with Dr. Mercuri that we can indeed take some corrective actions quite quickly—we can get rid of the worst of our current voting systems, for example. I am not so optimistic about the speed of the federal or state rulemaking processes, though. Some of the changes we must make involve legislation in the 50 states, and if we have a new voluntary standard, it will take time for the states to adopt this standard.

I am also not optimistic about the ability of the voting system vendors to meet a new standard. There is a shortage of technical manpower in the world of secure systems, and this is the manpower pool we must tap if we are to insist on voting systems that meet the Common Criteria, as Dr. Mercuri has advocated so effectively. My experience is that few of the vendors have much software expertise in this domain, so my guess is that, even if we promulgate a perfect standard and all 50 states adopt it, we would see few new products that meet our demand.

Chairman **BOEHLERT.** You—do you others agree with that or do you think we can do it? Dr. Mercuri.

Dr. **MERCURI.** I am actually rather optimistic. I have been pushing since the early 1990's to apply the NIST standards that are already in place for secure computer systems. These standards are the best that we have, and we can apply these to voting systems. It is just that nobody has mandated it and nobody has voluntarily done it. I have spoken directly with a number of the vendors and asked them to voluntarily comply with it.

In my analysis there are seven levels of the Common Criteria. And in my analysis I said we could get up to satisfying level four with some systems. There are systems out there that are used for the Department of Defense that do satisfy level four. So we could theoretically come up with some system that I would actually feel comfortable with. I am not as harsh about it as I might have sounded.

Chairman **BOEHLERT.** Mr. Saltman. Yes, sir.

Mr. **SALTMAN.** First, permit me to apologize for using the word appropriation. What I meant was internally appropriated funds.

Chairman **BOEHLERT.** You don't have to apologize. I just wanted to put the blame where the blame——

Mr. **SALTMAN.** Oh, okay.

Chairman **BOEHLERT** [continuing]. Should rest, and that is with Congress.

Mr. **SALTMAN.** What I am distinguishing between is internally assigned money for projects as opposed to other agency funds of which NIST has considerable amounts of. That is what I am distinguishing.

Chairman **BOEHLERT.** Okay.

Mr. **SALTMAN.** But in addition, I think the problem is that we have a many older systems in the United States. We have 19 percent of the voters vote on lever machines, and——

Chairman **BOEHLERT.** Which incidentally, if I may interrupt here——

Mr. **SALTMAN.** Yeah.

Chairman **BOEHLERT** [continuing]. Interject reading some of your material, some of the advanced testimony. The lever machines seem to be the least error-prone. And they are not even manufactured anymore.

Mr. **SALTMAN.** The problem with lever machines is as I was told by a very astute election administrator, who I am sorry, Connie Morella, isn't here right at this moment. But she knows very well a Marie Garber who was the election director of Maryland's Montgomery County and later State Director of Maryland Elections. And Marie told me that the problem with lever machines is that they hide their errors.

There is a problem there that—a test was done on lever machines and it was found that the number of votes equaling 99 for any candidate was more likely than any other number. And that shouldn't be on a random basis. And the reason is that the inertia of the counters turning from the units to the tens to the hundreds positions is more—is greater. The inertia is greater and the issue is that it would be more——

Chairman **BOEHLERT.** We don't want to get too technical.

Mr. **SALTMAN.** I am sorry.

Chairman **BOEHLERT.** So we shouldn't all just jump on lever machines right now.

Mr. **SALTMAN.** Yes.

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Chairman **BOEHLERT.** They are the most accurate of the various——

Mr. **SALTMAN.** They have their own errors. All right. In addition, we would like to get rid of prescored punch cards, most of us would here at this panel. But I am told, for example, by Connie Morella—I am sorry, Connie McCormack of Los Angeles County, that—which is the largest user of prescored punch cards in the nation, that she likes them. And it would take an enormous amount of money to replace them with electronic machines. So it—the likelihood of there being taken out in a short time is very small.

Chairman **BOEHLERT.** You know what boggles, I think, people that I talk to back home all the time, I am sure my colleagues go through the same experience, I can go virtually any place in this country today, from a major urban center to a small four-cornered town, and get cash instantly out of a machine for a modest service fee. Now we don't want people to have to pay to vote. But the issue is the technology. I mean, the technology is there, it is basically very secure. I can only get cash from—all right. Dr. Mercuri.

Dr. **MERCURI.** I totally beg to disagree with you on that. The banking industry loses billions of dollars at those ATM's. The difference is, and I sort of alluded to that in my concluding statement, that the banking industry is insured. They also have auditing. And when you go to the bank to deposit money or take it out, it is registered to you. But we don't do that with our votes. And in fact, if we recorded them and had a little camera there, then that would not be exactly what we want to have in the way of an anonymous ballot.

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Chairman **BOEHLERT.** Yes.

Dr. **MERCURI.** So the way that banks actually audit their banking systems, we can't do. So it throws it into this sort of dark, gray area where the electrons are taking this away. And we have to be assured that the electrons are going in the right pockets and in the right holes. And so it is not at all the same. I do address that quite at length in my thesis.

Chairman **BOEHLERT.** Oh, good.

Dr. **MERCURI.** So please read that section.

Chairman **BOEHLERT.** Okay. I will.

Dr. **MERCURI.** It is not at all the same.

Chairman **BOEHLERT.** My time is up but I will let you respond to my question before I go to my colleagues. Mr. Saltman and then Dr. Ansolabehere.

Mr. **SALTMAN.** The point I wanted to make is that the advantage of a banking system is that every depositor has an account and is always avail—capable of obtaining the value of the amount of money in the account. Unfortunately, in elections this is not the case. If you try to analyze elections with banking in somebody else's account, the candidate's account, not your own. And, therefore, there is no way of determining by yourself how many votes were deposited in that account. And that is a difficulty with the election system which makes it even more difficult than the banking system in the terms of an auditability situation.

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Chairman **BOEHLERT.** Dr. Ansolabehere, did you want to——

Dr. **ANSOLABEHERE.** I wanted to address your first question.

Chairman **BOEHLERT.** Okay.

Dr. **ANSOLABEHERE.** There is a constant change in technology. Counties are constantly upgrading. The industry is about $150 to $200 million in sales a year. So you don't get that at small business, but you don't get that much revenue without there being something going on on an annual basis. The map over here of voting equipment by counties is going to change a lot by 2002, not just 2004. So there will be no more punch cards in Florida, we already know that one. There will be no more punch cards in Indiana. There will be—a lot of California uses punch cards and those are being phased out. So the states are working right now to phase out punch cards. Florida was enough of an embarrassment that people have lost confidence. That leaves really Ohio and Illinois as the two large population centers—large population states that are still using it. And I think those will teeter.

By 2004 then I think punch cards will largely be gone. And in their place will be one of two types of machines, either optical scan or electronics. And the big question is, how much confidence do we have in each of those. That is a short-run solution. Then there are the long-run solutions that have to do with developing new technology. And it is pretty clear that even these two newer technologies are not what we want them to be.

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Chairman **BOEHLERT.** I have got as many questions as votes were disallowed in Florida. But my time has

expired and I go to Mr. Hall.

Mr. **HALL.** Mr. Chairman, thank you. I have always heard, I don't particularly believe it, but everybody—that people that live on the ocean and live on the sea don't like fish. Now you are all computer experts. And yet, if I understand your testimony, none of you recommend computer-based equipment. And there has been a push in my area to upgrade voting equipment with computer-based equipment. All of you seem to suggest that local officials shouldn't rush to purchase new equipment. Well, I don't know how they are going to get it if they don't purchase it. Or how they are going to upgrade their equipment if they don't turn to computers. So what do you see as the most common downfall in their turning to computers?

Dr. **ANSOLABEHERE.** I think it is the user interface design of the computer. The ballots are somewhat confusing to voters and a lot of voters seemed to be intimidated by them. There are a lot of people who walk out of the ballot——

Mr. **HALL.** Well——

Dr. **ANSOLABEHERE.** So improving the user interface is a very important thing. There is no standard ballot toolbox. So if you are a county administrator, you have to format. In LA County you have to format 5,000 ballots for five different languages. All right. Very big task. The computer company has to do it. There was recently a bake-off in LA County. And of the five computer companies that were trying to sell these machines only one of them could meet that goal. So just formatting the ballots in a user-friendly way is very difficult.

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And with hand—with printed paper ballots it is a much easier task a lot of the time. Not always.

Dr. **MERCURI.** My concern is the technology itself. I think because we are all so familiar with the technology and we live with it every day, we know the corruption that can actually occur internally. The fact is that we have no way of eradicating viruses in our own industry. And that people in businesses are plagued by this on a daily basis and it costs millions of dollars to eradicate some of these huge viruses. We don't want to see that type of thing happening with our election systems.

And so it is the technology, the underlying technology itself. And to come up with a way where we can mitigate these problems that are just in the computer industry and to try to eliminate them in our election systems. If we could do that in our industry itself, we could do it for election systems. But we are at a loss to be able to do that.

Mr. **HALL.** Gentleman, yes.

Mr. **SALTMAN.** I wanted to reiterate my insistence on the importance of the auditability issue in non-ballot systems such as DRE's. I fully agree with Rebecca that Internet voting is way beyond our capabilities at this particular moment. However, I think that the use of DRE's in inevitable and will increase in this country very soon. Because of that case, it is extremely important that we establish a very tightly established set of procedures to assure that first all of the computer programs that are used in DRE equipment are fully tested for correctness. That security procedures be used to assure that that—those computer programs are not manipulated or tampered with. Third, that the——

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Mr. **HALL.** Is that the major danger that you see?

Mr. **SALTMAN.** Excuse me?

Mr. **HALL.** Is that the major danger that you see, manipulation or fear of tampering?

Mr. **SALTMAN.** I see it as a danger. I couldn't say that it is a major danger. I think that simple computer bugs are probably more likely than deliberate manipulation. But computer bugs do happen all the time. And people tend to——

Mr. **HALL.** You got some buggy people counting votes, too.

Mr. **SALTMAN.** Well, yes. That is true. In any way, we want to be sure that the computer programs that are used in the computer are the same ones that are tested exactly. And I think security techniques can be sure of that.

And in addition, that we apply to the machines a procedure, and I think Doug Jones mentioned it, that the cross-check between the number of people using the machine and the number of people who voted for different candidates or didn't vote or over-voted are equal to each other. So that is a good cross-check. And that also makes it possible to apply the second-chance opportunity for voters to try again if they fail to vote in a race that was important to them.

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Mr. **HALL.** Yes, sir, Dr. Jones.

Dr. **JONES.** I think that the question of what is the greatest problem with electronic voting systems has two sides to it. The human factor side is the greatest immediate risk of adopting this technology. Because in the very short-run this technology is—has a poorly developed set of user interfaces. Our track—our experience is not very great on how to do it right. In the long-run we risk creating a situation where we end up putting our democracy in the hands of a small number of programmers with poor oversight. And any time you put your democracy in the hands of a small number of people, those people will emerge as the Praetorian Guard eventually and select a new emperor without consulting the people.

Mr. **HALL.** Well, my time is up. But let me just point out, Mr. Chairman, in an article by Florence Olsen, that I think Dr. Ansolabehere is familiar with, the lever machines showed only a 1.6 percent of ballots spoiled while electronic voting, that you are downing down here today and criticizing, had the same percentage as punch card voting. Each of them 3 percent of ballots spoiled. And lever machine 1.6, the lowest of all. And the paper ballots, that everybody is complaining about, was lower than either the punch card or the electronic voting. So it doesn't get right down to whether or not they are honest and whether or not people are counting the votes or given the number of votes that one candidate has to get. And I found most people were most upset over the fact that the military people weren't getting to vote. And you can cure that by sending them to them early and getting them back early. And setting a time certain to cut them off.

But I don't know, it seems like we need to improve on people more than we need to improve on the method of voting.

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Chairman **BOEHLERT.** The Chair now recognizes Dr. Ehlers.

Mr. **EHLERS.** Thank you, Mr. Chairman. And I will have to be fairly brief because I am due on the Floor to speak on the education issue. But I have a lot of experience at voting, as many do here. I have served at the local level as well as the state and Federal levels. And a problem that most Americans don't recognize is that there are a lot of people out there deliberately trying to subvert this system, or at least change the result. We tend to have a great faith in fellow human beings, especially fellow Americans. And so it is a huge surprise when it happens. But it does happen. I was just talking to one of my colleagues from a state recently and he commented that one of his county chairman got in trouble because not only had he voted in two different precincts but his dog had voted in three different precincts. And he said, the public was not upset that his dog voted, but that his dog voted three times. That was just—that was going beyond the pail. So this is—happens far more regularly than people think.

Let me just—I want to get on the record what I think is the problem. First of all, we need more accurate registration. We haven't talked about that here at all. I think probably the greatest fraud occurs in the registration process in terms of felons registering and non-citizens registering and so forth. Then we need an accurate people-friendly, fool-proof voting system. And I would emphasize the people-friendly and fool-proof more than I would the accuracy. We can solve the technical problems fairly easily. The human factors of voting are important.

As an example in the electronic voting that you have discussed, one of the problems is you only get one shot at it. And even Regis Philben always says, "Is that your final answer?" And we should do the same in voting on the display. Every time you vote, "Is that your final vote?" We also, of course, should print out a sheet for the voter, but also one for the tellers so there is a dup—paper duplicate of the electronic tally.

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We need accurate, honest counting. And that is a factor that is often overlooked as well. It—we have poll workers who are the salt of the earth. They are wonderful people, I know many of them. But they only do this once or twice a year. And it is easy to forget the instructions, procedures and so forth. So we have to develop very accurate and honest methods of counting.

Finally, we certainly need public confidence in the result. And I am afraid that we do not have that at this point. I think we probably had too much public confidence in the result in the past. The public wasn't aware of the many errors and illegal activities that occur. Now we have gone the other way and the public doesn't have much confidence.

I—just one final comment in response to the criticism I have heard here of punch card systems. I am a little surprised at that. Because properly maintained, the punch card system, and properly designed books to go on it, is surprisingly good. And in fact, in my community, my major community, Grand Rapids, Michigan, they not only have a punch card system but they also have tabulators right at the polling booth that the voter puts in the—their ballot in the tabulator. It is counted immediately. If they have over-counted it is rejected and they get a second shot. So you correct one common error right at the polling place. I think properly operated punch card is valid and probably more valid than the electronic systems given the present state of electronic systems.

I will be happy to hear any comments or criticisms of these statements from anyone here. Yeah.

Dr. **ANSOLABEHERE.** I think you are exactly on target that giving voters lots of feedback is the first thing you want to try to build into a system. Punch card counters and scanners are very important innovations. The optical scan systems that work best are ones where you can scan your ballot right in the precinct. It is not, you know—anywhere that they have worked perfectly. But that degree of feedback is very important for solving these human issues.

Mr. **EHLERS.** And it is also, if I may interrupt, it is very important to have a paper trail, too.

Dr. **ANSOLABEHERE.** And public confidence, I think that is why we are all here, to get the public confidence back. And so that people are using a machine that they believe in is very important.

Mr. **EHLERS.** Mr. Saltman.

Mr. **SALTMAN.** I think your comments are very well taken, sir. However, and I would say that my written testimony talks that precinct counting is far better than central counting for the very reason that you have indicated. However, it is my feeling about prescored punch cards that the whole requirement that makes them good, which is that election administrators and their poll workers have to sit around and personally remove the chad. It seems to me to be a contradiction of computerized voting. I know that they do this in Washington State before they run the machine—the card through the machines. And of course, it is certainly true that the difference between a hole and a no-hole when they are totally obvious is certainly very easy for a computer reader to do. However, when there is chad and it is not removed, and a lot of voters just simply fail to do that, that creates a problem. And in my opinion, it creates much of a problem—more of a problem than optical scan cards, which are not destroyed in the process of voting them. And always are there for the voter intent to be determined and you are never—and you can be sure, as you can't in prescored punch cards, that some chad has either fallen out or not fallen out or pressed back in. So I think in general, my feeling is that optical scan cards are superior in their use.

Mr. **EHLERS.** Dr. Jones?

Dr. **JONES.** I share this feeling about punch cards. I agree that properly maintained and operated they are probably not as bad as some people hold today after the previous election. But they should be phased out and deliberately.

However, I would like to go back to an earlier comment you said about issuing receipts to voters so that the voter can be assured of how they voted. That receipt can become a commodity which can be sold to the party willing to pay the highest for that vote. Vote buying and selling is something none of us would like to believe exists, but it has happened in the United States since we began voting. If you provide the voter with any sure-fire way to prove that they followed the instructions of their union boss or their employer or anyone else who was trying to buy their vote, then you produce something very dangerous. In fact, it is the absolute prohibition of this receipt that is required in order to maintain the integrity of our system, which leads to so many of the problems with electronic voting.

Mr. **EHLERS.** I agree with that. That receipt has to be handed in before they leave the room. Dr. Mercuri, very quickly. My time has expired.

Dr. **MERCURI.** I would like to also state my support for the scanned machine—the scan-type of machines. Because they do provide the voter with some tangible way of looking at the ballot that they prepared. It is much better if the names of the people are actually listed on that ballot. One of the problems we have with the punch card is you just have this encrypted bunch of holes and you can't identify it yourself. So if you have that visual feedback, then that is really good.

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But our entire government is based on a system of checks and balances—what we don't have and what we lose when we feed those ballots in and they are read by a single machine. We don't know that they are being tallied correctly. I like the fact that the press got involved in Florida and decided to do their own recount. I would like to see that various agencies, the different parties, the League of Women Voters, maybe the press, they each submit their machines for tallying. They have to be certified in advance, and then there is multiple recounts. And if there is some huge percentage difference then we maybe go to a manual recount of those ballots. I think that would also give us that checks and balances, and the feeling that these ballots aren't just whisked away and there is the total and you have to be stuck with it. That you actually do get the competing parties, they submit them in advance and that type of thing. I would like to see that happen.

Mr. **EHLERS.** My time has expired. Thank you, Mr. Chairman.

Chairman **BOEHLERT.** Dr. Jones, except for the good of the cause, we will very briefly.

Dr. **JONES.** I have been advocating for a while the idea that selected—that there should be a mandatory hand recount of at least one race in at least one precinct of every jurisdiction after each election using recountable ballots of any kind. Simply number one, to keep people skilled in the art of hand recounts. If you do it after every race with one race in one precinct, there will be people who have done it before. And also simply to keep track, to do a quality control check on the voting machines that we are using to automatically count those ballots.

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Chairman **BOEHLERT.** It boils down to dollars, doesn't it? Mr. Barcia.

Mr. **BARCIA.** Thank you, Mr. Chairman. I will try to be brief. Dr. Jones, in the 10 years since the FEC issued its standards, only 20 states have opted to require a conformance. Why have most states not required conformance with the current FEC standards? And when the FEC issues its revised standards, do you believe there will be wider acceptance by state authorities?

Dr. **JONES.** I—there is a mistake in that figure. When you are trying to prepare testimony with three day's notice you don't always proofread carefully. It is actually a small majority of the states. We are over 30 now. But it has taken a decade to get there. I think the states have been hesitating to sign onto this process, number one, because signing onto this process requires that you tell your state election authority that their inspections haven't been adequate. And most states would like to believe they are doing just fine. It also means that the state is handing over something that is traditionally the state authority to the Federal Government. Although, signing onto a standard from 1990, if that standard is revised, the state would have to enact the revision into the law, too.

But the fact is, voluntary standards, I don't think that a lot of states are anxious to increase the complexity of the process. Incidentally, one very serious problem with the current standards is that people keep talking about having multiple laboratories around the country certified to test the machines. We have had this standard for a decade now and there is only one laboratory that is certified to do testing under that standard.

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I seriously doubt we are going to find much competition in this field, even if we made a mandatory Federal standard. It is simply a very onerous job to test the machines. And machines aren't being introduced quickly enough to make it worthwhile for more than a few—more than one, maybe two laboratories to be involved.

Mr. **BARCIA.** Well, if I would ask one more question of you. Do state officials, in your opinion, or the FEC have the technical expertise to address the security and accuracy issues you have raised? If not, who do they rely upon should they not have it?

Dr. **JONES.** Well, it—I can only speak for Iowa. And I have only had indirect contact with people from other states. I believe that by-and-large, the election directors and the state legislature feel that by signing onto the FEC standards they—they don't have to do any more. They view this not as a minimum standard. It is not the minimum acceptable standard. I think this: Most of the states that have signed on view this as the insurance they need, as setting a very high standard. And that the need to legislate anything beyond that standard is viewed with great caution. Because after all, the Federal—the FEC knows what it is doing.

Now my own feeling is that the FEC may not have been bringing in the right people. I think by-and-large, given the fact that all of the new voting systems offered for sale are heavily computerized, it is very evident that the standard has only involved a few people involved with computers. And that the standard has not been updated, as I believe it must be, on a fairly regular basis to reflect our growing experience with the systems that are out there. And do reflect changes in the technology that is being offered.

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Chairman **BOEHLERT.** Let me interject. What would be a fairly regular basis, Dr. Jones? You said, updated on a fairly regular basis.

Dr. **JONES.** Oh, that is a tough question. It is very expensive——

Chairman **BOEHLERT.** Give me a tough answer.

Dr. **JONES.** It is a very expensive thing to do a complete rework of a standard on a regular basis. You can't afford to do that more than once a decade. On the other hand, when problems are—when problem come up, someone has got to notice that there is a pattern in the problems that leads to a need for revision. Right now what I am afraid is, is that people—that when we have incidents involving problems with voting machines, very frequently they are not being reported to anybody. Or if they are reported, they are reported to the state administrator of elections who dumps them in the file marked incidents and they disappear there. Someone should be going over those incident reports probably nationwide in consolidating the big picture of which systems are proving troublesome, what kinds of problems are showing up.

Similarly, someone has got to go out there and look at the numbers for recounts. Because if you look at recounts, that is the best accuracy test we have for any of the ballot counting systems around. When you find errors in a recount—when you recount the votes on a different machine, you get a measure of the accuracy of the machines involved. Those figures should be consolidated. Someone needs to be watching in order to see if problems are being disclosed by this.

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Chairman **BOEHLERT.** You know, it has been suggested in the cloakrooms, if I may use that phrase, that while Florida was under the microscope, far greater problems existed elsewhere, only they weren't as visible.

Dr. **JONES.** When you have got a vote that comes within 5,000 votes statewide, problems are disclosed. If the margin is bigger, much bigger problems may never be noticed.

Chairman **BOEHLERT.** Thank you. Mr. Barcia.

Mr. **HALL.** Mr. Chairman?

Chairman **BOEHLERT.** Sir?

Mr. **HALL.** Forty years ago we had an entire precinct vote alphabetically in Terrance County. And nothing was done. We think if they are slow counting the votes down in Miami, and when you get right down to it, Gore didn't lose the election in Miami, he lost it in his home state.

Chairman **BOEHLERT.** And I am sure you have some interesting stories about Linden's great victory.

Mr. **HALL.** It wasn't Linden. It was in a governors race.

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Chairman **BOEHLERT.** The Chair recognizes Ms. Morella.

Ms. **MORELLA.** Thank you, Mr. Chairman, and thank you for holding this hearing. I very much appreciated the testimony from our experts on this panel. You all presented it very succinctly with a lot of information and rather provocative. And again, I am trying to get a handle sort of on this whole standard concept. And much has been mentioned in the last questions that were asked. But, Dr. Jones, you have made many statements in your testimony about the difficulty, the problem with current standards. Do you—and mention was made of the need to revise the FEC standards. One of the questions I would like to ask is, you mentioned that there is a contract with the American Management Systems to come out with recommendations. You seem to imply that this would be something worthy of looking at very closely. Maybe you would like to comment on that.

Dr. **JONES.** Are you questioning the role of American Management Systems?

Ms. **MORELLA.** I am wondering about—about what they will be coming out with.

Dr. **JONES.** Well, it is extremely important that we examine the new FEC standard. We expect the standard to be released in a month for public comment. Part one in a month, part two I think in October. I don't remember the exact dates. And I am extremely interested to examine that standard and see whether—see how that standard

would have treated the problems that I have encountered over the past decade. It might be a good standard. It might be what we are looking for. I don't think I am that optimistic in hoping that it patches all the problems. But I suspect it will make a significant improvement.(see footnote 3)

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After completing this exercise, I have concluded that the new proposed FEC standard is an improvement over its predecessor, but it is far from perfect. The most glaring problem, and one it admits outright, is that it does not address human-factors issues, and, as was made very clear in Dr. Ansolabehere's testimony, this is an area where we are in desperate need of standards.

The new draft standard does not incorporate the Common Criteria, as Dr. Mercuri has strongly advocated, and it is generally weak in the area of security and auditability.

As I have noted in note 2 above, there is a shortage of expertise in the entire field of secure systems, and this has an effect not only on the staffing problems faced by voting system vendors, but also on the staffing available to standards organizations and the FEC. If we hope to correct this shortage, we must revitalize certain research fields that have been stagnant for most of the last 20 years.

Ms. **MORELLA.** If the Federal Government were to try to mandate a uniform set of standards, what would you like them to be? And I might ask the rest of you to pick up on that question also.

Dr. **JONES.** Well, I have certainly mentioned some of the things I would like to see.

Ms. **MORELLA.** Yeah.

Dr. **JONES.** I would like to see counting of all those over-votes and under-votes brought forward, all the way through the canvassing process. I would like to see standards governing electronic communication between voting machines. I would like to see standards covering the fault tolerance that is used. Right now the standards suggest that—require duplicate copies of the totals to be maintained, either paper ballot and an electronic count, or two separate electronic counts.

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But there is no rule about how to deal with the duplication in the case you find a problem. If you have a direct recording electronic voting machine, there are no reconciliation rules in the event that you find your two sets of ballot images differ. That is a very important area to cover.

I would like to see standards governing the testing of voting machines. I would like to see standards that govern the recounting. A very bad practice right now is that people insist when they do a recount, they will use exactly the same machine to count the ballots on the second time as on the first time. Because they know if they counted on a different machine they will get different totals because the photo sensors on the different optical mark-sense machines are calibrated differently. The fact is, that calibration difference is something that we should be exposing not sweeping under the rug.

Ms. **MORELLA.** Are we capable of coming up with standards, such as all of you have articulated in different

ways, federally? I mean, is this plausible, practical, or is it elusive? Dr. Mercuri?

Dr. **MERCURI.** We actually do have the standard which is called the Common Criteria. It is actually an international standard and there are various levels. You deploy the level that you need for the types of things that you are trying to certify. It is really a full end-to-end type of standard. Because even if we did test it, let us say in the lab, a voting system, how do you know that that voting system actually is the one that the people purchased or you got 200 copies of that.

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Let me just—bear with me for a second. I just want to run down just the types of things that the Common Criteria deals with. System requirements, functionality, correctness, accuracy, accountability, disclosability, reliability, integrity, availability, fault tolerance so that—you know, you would be able to recover in case it has a problem, data requirements, confidentiality. Just a few more. Retention and recountability, user requirements, administrator requirements, interface usability, documentation testing, paths, facility management, recovery, system distribution and compliance with laws and regulations. And these are all in the Common Criteria. And NIST does administer this. I would like to see that direction and that level. It is a 700-page standard. So we do have that. It is at our disposal to use. And I would like to see it be used in a way that directs it toward the——

Ms. **MORELLA.** So what roles do you see for us, for the Federal Government, for the legislative branch?

Dr. **MERCURI.** I would like to see some agency charged with the responsibility of actually creating a standard that would be a modified, perhaps, Common Criteria, but that is specific to voting systems.

Ms. **MORELLA.** Do you see NIST as the laboratory to do that?

Dr. **MERCURI.** Yes, definitely. Toward that end, I had started doing that myself. But in the recommendation was that NIST would administer it, and that NIST would actually be responsible for it. Because NIST is responsible for administering the Common Criteria right now.

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Chairman **BOEHLERT.** Does the gentlelady yield on that point?

Ms. **MORELLA.** Yes, indeed.

Chairman **BOEHLERT.** Is there any disagreement? We—the Committee are looking to NIST. And that is our mindset. Is there anyone that disagrees? Mr. Saltman.

Mr. **SALTMAN.** My hope is that there will be a unified agency that can undertake the Federal responsibility in election administration. What I mean is that policy direction, determination of what research projects and subjects there should be, what data should be collected, how should the Federal Government assist the states and local governments. All of those issues deserve to be carried out from a unified single agency, which I believe should be bipartisan.

Yes, it is certainly true that technical skills in computers information processing, measurement technology and industrial psychology for use—for ease of use activities need to be part of that process. And in 1993 I wrote an article that has been—it is on the web because it was published by Computer Professionals for Social

Responsibility mentioning that—and I said in that article that Congress lacks the scientific assistance that it needs to assist it in election administration.

Now I think that this certainly is an organization that has some of this capability available. Whether it is the only organization that could do this is not clear to me. But the need to have a unified policy direction and research direction and standards direction certainly requires, in my opinion, control from the top in a bipartisan manner.

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The problem right now is that NIST is a member of the Executive Branch. And the Executive Branch is headed by a person of a single party who appoints his cabinet officers to be supportive of that party. I don't see how the Executive Branch, in my opinion, would be the proper place for policy direction for election administration because it is a bipartisan issue.

Ms. **MORELLA.** You would see the FEC also falling into that category, too.

Mr. **SALTMAN.** It has members of the Commission who are, six right now who supposedly are three of each party. One of the problems has been that the commissioners in the past have represented the issue of campaign finance, which they know very well. Danny McDonald, of course, was a former election administrator. And he is very conversant with the problems. And the other commissioners have made it clear that they understand the issues now, and they are willing to push—put forward the problems of election administration and have submitted a supplemental appropriation.

They all but one attended the recent advisory panel meeting of the Office of Election Administration in Baltimore. And it would appear that they understand the need for improvements in their efforts toward election administration.

Chairman **BOEHLERT.** Thank you very much, Mr. Saltman.

Ms. **MORELLA.** Thank you, thank you, Mr. Chairman.

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Chairman **BOEHLERT.** Thank you, Ms. Morella. Mr. Weiner.

Mr. **WEINER.** Thank you, Mr. Chairman. You know, frequently we are seduced by the capabilities of technology. And we sometimes expect it to do things that perhaps it is not best suited to do. It seems to me in the evolution of the technology we have gotten an increasingly technical, increasingly electronic, and increasingly fallible.

And I would ask the panel, is the move toward increasingly sophisticated technology out of a desire to count faster, tally things more quickly? And is that what has been driving the move of technology? Because I don't think anything is as user-friendly and as impervious to fraud as the older technologies. I mean, the person putting an "X" next to a box, a person going into a—those beat-up booths that the Chairman and I use in New York. You know, there are—it is cumbersome and it is clumsy, and the little flipper things fall off frequently, which make it impossible to vote for anyone in that case. But in terms of its fallibility, according to your testimony, those earlier systems are the least fallible. Dr. Jones, you are shaking most vehemently.

Dr. **JONES.** Well, the MIT-Caltech report pointed out correctly that lever machines have the smallest under-vote and no over-votes on the top of the ticket issues. But it turns out that there is another piece of research, I forget the author. I am sorry. That shows that the—that the fall-off in the vote, that is the participation on tail of the ballot issues, falls off far more rapidly on lever machines than on paper ballots. And this research was done long enough ago that paper ballots are—were the only competing technology studied.

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Mr. **WEINER.** Well, yeah—if I could just interrupt you. But you are addressing a different point than perhaps this Committee is even considering today. I mean, if you want to—if you are trying to encourage participation or you are trying to get involvement, I am sure you would come up with a different design of the polling—of a polling device than you would use if you wanted to reduce fraud. The Internet is an example of that. You would have far greater participation, far greater incidents of fraud. But if you can focus on my point, which is the fallibility of the system, which is the system screwing something up and people's votes not being counted, it seems that we are going—we have two lines. We have a line of fallibility and a line of technicality. And is there anyone on the panel who would disagree with the reason we are going in that direction is to make it more quickly that we can calculate everything. And if not, what would you say is leading us in that direction, except just our lure for things with bells and whistles. Mr. Saltman.

Mr. **SALTMAN.** I think you raise a very fundamental, philosophical issue that deserves far more discussion than we can give it at this particular moment. However, yes, the move to computers, and even the move to lever machines from paper ballots, was certainly done to improve the speed and supposedly the accuracy of the methods of tallying votes. Now you know the well-known point that of the three, speed, quality and what is the other one? Speed—and cost. You can get any two of the three, but you can't get all three.

Unfortunately, we are in a situation where low cost has been a hallmark of what we do because the Federal Government has not put in a sufficient amount of money to this area. Nor have the states, for that matter. Yes, every system has its advantages and disadvantages. And I—if you would go through my 1988 report, you would see that even lever machines, as I tried to say but it is too technical to point out in short—in a short time, they have their own problems. And transcription errors is not—is one of the major ones. And one of the——

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Mr. **WEINER.** Right. But, you know, being something—and I'm sure Congressman Boehlert is as well, being something of an expert on lever ballots. Even transcription errors, there is a way you go back and check. You know, the poll watchers who reported on election night sometimes flip numbers. But unlike an electronic machine where at a certain point the bits can be compromised. I mean, the technology is not getting us closer to the infallible standard. And I would say, and perhaps this is heresy in the Committee on Science to say such a thing, that perhaps the more ancient technologies, the more basic pen-to-paper, the lever that gets a click and can't be clicked twice, perhaps this is the kind of things, as ironic as it might be, should be a future standard.

Because, frankly, it is—if our concern is spoiled and unmarked ballots, if our concern is over-votes, New York, which has plenty of problems, we don't have that problem. Now sometimes we have machines that disappear on the way to the warehouse, machines that show up with my name not on them. That is a whole other thing. But I think if we are concerned about the fallibility of the system, it is interesting to note the more bells, the more whistles, the more computer chips, the more zero-to-1 digital codes, the more mistakes that are getting made.

Thank you, Mr. Chairman.

Chairman **BOEHLERT.** Thank you very much. Mr. Johnson.

Mr. **JOHNSON.** I think you probably all each collectively or individually addressed this issue. What—looking, you know, three or four decades down the line, which I suppose is beyond any of our likely tenures or your testimony, to a nirvana, what would you like to see—either each of you individually or collectively—in a system that is not only a system that is workable and fair, but something that in light of technology and economics over the course of these next few decades is probably feasible as well? I know that is almost a Pollyanna question, but I would be interested to know your response.

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Dr. **ANSOLABEHERE.** Did you ever talk to a computer organization and they—one of the questions was just along these lines. And one of the answers was, well, next we are going to go to all electronics and Internet voting. And after that fails, we are going to go back to paper and pens or maybe chads. So it is outside of my realm. That is way too far in the future. Especially as a social scientist, I am used to looking backwards rather than forwards. So I will pass that up.

Dr. **MERCURI.** I really want to see the human aspect maintained in the election process. The whole system that we have of poll workers and individuals, the human factors of stepping up to the poll where somebody from your neighborhood remembers that you moved out six months ago and really shouldn't be there voting anymore. That type of, you know, bio-identification, it is right there and we have it at the precinct. It is not perfect, but I would like to see that maintained. The fact that we need to have some way of actually manually doing the recounts. And in the future not to abandon that, that humans always be involved with that at a very deep level.

Mr. **SALTMAN.** If I might add something. I think, yes, the human factor is extremely important. And despite the fact that all electronic systems are becoming wide-spread, and I have recommended considerable amounts of protections for them, optical scan balance allow for personal view of what you have accomplished. And you can see, look at the card before you drop it in the ballot box. It does allow—precinct voting I think is a significant social—of particular social importance. People who have—many people have—thoughtful people have talked about the fact that Internet, remote Internet voting would destroy this public situation where we come and meet our neighbors at the precinct. I think that is a very important issue. I have—the importance of the human factor, the management factor about election administrators, the need to do research undertake and probably by psychologists. Not by information technologists and computer scientists about what is best for the voter in terms of the type of system to be used. All of those factors mitigates the use of totally electronic systems. Although they are coming in, and if the protections are there, I believe we can.

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Dr. **JONES.** I would like to hope that 30 years down the road we still have at least two distinct—two technologically distinct voting methods in use across the country. And I hope that they are used—that each of them is used by a lot of voters. Let us not let one technology have more than h of the voters voting on it. I mean, that those voters who use one system and then move to another should notice the difference, should be marking with pencils on one and be touching a screen on the other, or dropping clay balls in pots in another to go back to ancient Athens. Technologically completely distinct methods.

And I want there to be at least four different vendors so that no vendor controls more than g of the market place. I really distrust the idea that we would allow a monopoly to emerge. And I speak not only of vendors for the final system, but of the manufacturers of the components. If we had two different technologically independent voting approaches that both rested on one particular software product, maybe Microsoft Windows, then the possibility that the monopoly vendor of that component could find some way to use that component to control an election outcome is something that concerns me. I really don't want to see a monopoly emerge. And in my best world, we would have significant protection against such a monopoly.

Mr. **JOHNSON.** This concluding—Mr. Chairman, I am a new member of this Committee. But this seems to me, just to attribute to your leadership of the Committee, that we are able to consider these kinds of issues under the ambit of this—of the Committee on Science. And I really commend you and the leadership of the Committee on being willing and able to innovate and expand the scope. This is really what this Committee is all about. And I am appreciative of it.

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Chairman **BOEHLERT.** The gentleman is recognized for an additional hour. Thank you very much. Ms. Woolsey.

Ms. **WOOLSEY.** Thank you, Mr. Chairman. I wanted to say the same thing. I love this Committee. It is so non-partisan and such a difference in listening to our witnesses. And thank you very much for all your input. I represent a district just north of the Golden Gate Bridge, north of San Francisco. My district has an 85 percent voter turn-out. There isn't a person that votes that doesn't think their vote counts. And if they thought their vote didn't count, they would go ballistic. And they want their vote—their people, their friends, the other in our district, Democrats. But it wouldn't even matter to them, as long it was democracy. They want votes counted everywhere in this nation, not just in their district.

My district is very high-tech. It is really wine, dairy and technology, information systems, information technology. They would tend to think that Internet voting, computer voting would be good, but they are too smart to think that it is right yet. And so I want to ask you, what are we going to do in the interim? I mean, we have an interim here where—and the other thing, when we look at voting and the human factor, it is almost impossible to find poll workers and precinct workers anymore. And the human is going to go out of it just because young people aren't going into it. And these wonderful old people that sit at these pre—the polling booths every year, I go—I walk in. But the other thing in my district is absentee voting. Huge numbers of people vote absentee. So as an interim to encourage people to vote, and to ensure democracy, what do you suggest? I mean, there has got to be things we do that aren't the final. Why don't we start down here with you, Dr. Jones, and we will go the opposite direction.

Dr. **JONES.** I am not sure I have an answer to that question. Because I think it is a much bigger sociological question you are asking than one that is specific to the kind of voting technology expertise I have. The fact is, we need to encourage people to participate in all forms of public discourse. And right now we are in a society that is moving toward increased privatization, where people are—where forums for public gathering are becoming privatized. You can't go—you can't go campaigning out on the street corner anymore because no one is out on the street corner. They are in the shopping mall, which is private property and where campaigning is forbidden by the rules.

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The lack of poll workers is, I think, just one dimension of this problem. And it is a big social problem which I don't think we are going to succeed in addressing with our discussion of voting machines.

Mr. **SALTMAN.** I think that the precinct worker issue is an important one. You asked a question about the interim. Well, every time is an interim time. And we do best, I think, societies do best, democratic societies, with incremental change. As a person with a degree in public administration that was one of the things that was pushed into me. That incremental change works and global change very often doesn't. I think we saw that in the health issue a couple of Congress's ago. Incremental change about precinct workers is an issue that is a institutional issue, a policy and not a scientific issue.

Yes, we need—everybody who is involved with elections say we need more precinct workers, more poll workers. We need to provide incentives for middle-aged people who go to work every day to take the day off and serve as poll workers. So that we will not have a population of retired people, some of whom have been there for many, many, many years are the only people who are poll workers. Now those incentives could be with tax breaks either to the persons who do it or to the companies they work for. Or some other kind of incentive which would allow us to provide additional poll workers.

Dr. **MERCURI.** As someone who has been a poll worker for 15 years, I would like to say that if you could just split shifts it would be a great relief. Because you get there at 6:00 a.m. Sometimes you are not out of there until 9:00 or 10:00 p.m. That is barbaric by any stretch of the imagination, especially with the type of pressures on election day.

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But I would like to address the issue of absentee voting because I really have a strong feeling about that. When we just even begin with the tip of the iceberg of, you know, all the different types of special interest groups, agencies, grass roots type of things, and even talk about domestic partner abuse and the ways in which people can be coerced into casting their ballot a certain way. It very much makes me afraid to go to an entire system of absentee balloting. I do not want to see us go to Internet balloting where, yes, we could vote from anywhere. Can't we establish some way that in the country perhaps people can still do anonymous balloting, but of the ballot that perhaps they received in some way. And then it is transmitted maybe not via the Internet, but it would be transmitted by mail. Yes, we won't have our election returns at 11:00 p.m. on Tuesday night. But I think that the pressures may be from the press to have us do this. Now that they see they can play this up for weeks and maybe even months and get that type of coverage, I think maybe they won't pressure so much, you know. We could have these elections going on for a few days until the ballots are all collected.

But I would like to see some way, maybe we could figure out some system whereby the votes could be transmitted, not necessarily electronically. The ballots could be sent electronically over the Internet. But then they are deposited and the person does go to some center. I have also thought that for the military and for people in foreign countries we do have embassies and there would be ways that people could, again, vote anonymously. But have it not go through the mails necessarily but go through some sort of courier service. So I would like to see that. We do oversee the mail service. So maybe there is some way of doing this in a courier.

Chairman **BOEHLERT.** Does the gentlelady yield? I have said a lot about the absentee ballot potential. And there is also the potential for great damage, for fraud. I mean, I—an enterprising club of any party could have

everybody show up at point "A" at a given time. And you get $25 bucks. You fill out the ballot. You seal it in front of the guy and then the guy takes the ballot and drops them all in the mail. I mean, that type of thing happens ——

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Dr. **MERCURI.** I am sure it is going on.

Chairman **BOEHLERT** [continuing]. Too much today.

Dr. **MERCURI.** Yes. I am sure that it is going on. I work in grass roots politics, I know that hustling the absentee ballots is one way of making sure that you have certain numbers at the end.

Chairman **BOEHLERT.** And then the other thing—continuing and I will yield back to you. The poll workers, I mean, it is an embarrassment. I don't know what—in New York, I think they are paid $60 for a 15-hour day. I mean, that is an embarrassment, too. You have to be—I mean, it is like a charitable donation. That takes care of your lunch and the cookies that the politicians bring in. And I agree that we have to have more participation. And then you talked, Dr. Jones, about more public discourse. Yeah, I would like to see that. And I would like to see more civil public discourse. And we are moving in the opposite direction. The time is yours, Ms. Woolsey.

Ms. **WOOLSEY.** Thank you. I—we have one more, and then——

Dr. **ANSOLABEHERE.** The way we are thinking about this is the following. Suppose we have a certain amount of money to spend. That is in the interim, right? There are no budget constraints. Where do you distribute your money? And I don't think it is actually that clear. We have done a little analysis of North Dakota, and we found that doubling your poll workers in North Dakota across precincts would reduce the rate of uncounted, under—unmarked ballots by about 30 percent. So you can do that. That is a fix to some of the machine problems. So there is a lot of stuff that happens in the poll where the poll plays—polling place that might help on the machines and so forth. And those are solutions that just need to be explored right now. And because this was an issue that was, you know, so undiscussed in the public that it is one that really hasn't gotten enough careful attention to these questions of: we have a pot of money, how are we going to distribute it. How much do you want to put on machines, how much do you want to put on poll workers, how much do you want to put on voter education and so forth.

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I think the absentee voter issue is very important, as Doug said earlier, sociological phenomenon, which that is people want convenience. Turnout isn't going up but absentee voting is going up. People are switching from going to the polls to voting at home. In California, what, you hit 30 percent this year. Florida was about 20 percent. Nationwide it was about 14 percent absentees according to the census. So that is a big chunk. And that is about double what it was about 10 or 15 years ago. So there is a big shift. Turnout didn't go up, right? We all know that. Turnout has been flat or going down. So what is happened is people are stay—people are voting through other means. And that is something that is outside of this Committee's jurisdiction. But as election administrators, states are really grappling with how to think about that. Do they close the door on absentee voting? Some states are. Do they open it up? Oregon is the case where they have 100 percent mail.

Ms. **WOOLSEY.** Thank you, Mr. Chairman. Thank you very much.

Chairman **BOEHLERT.** Thank you.

Ms. **WOOLSEY.** Thank you, panel.

Chairman **BOEHLERT.** Just to follow-up by the Oregon experience, what have you heard about that? It was 100 percent mail-in, right?

Dr. **ANSOLABEHERE.** Yeah. The first time they did it they had tons of problems. But then they developed some nice administrative procedures to make sure it worked out better. And it seemed to work, you know, reasonably well from the——

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Chairman **BOEHLERT.** Were there any reported incidents that you are aware of the fraud that I fear?

Dr. **ANSOLABEHERE.** I haven't really heard of any. I mean, you know, the famous vote fraud cases with absentees are like the Georgia case where there was vote buying in the county courthouse and stuff like that. I haven't really heard that many reports from Oregon. Maybe others have kept up on——

Chairman **BOEHLERT.** Any of the other panel members heard anything about that in Oregon? Because there was 100 percent mail-in ballot, right? Yeah.

Mr. **SALTMAN.** This isn't from Oregon, but I know of, you know, the issue of nursing home absentee ballots, which is not necessarily from Oregon. But there is a lot—there are many stories about people who are not totally competent in every way being forced or being told what they—how they are going to vote. And this is very unfortunate. And this is a human problem more than it is a technical problem. And I certainly think that absent—more—the more absentee ballots we allow the more possibility there is that that is the case.

Chairman **BOEHLERT.** Folks, we are never going to get to perfection. But speaking about perfection, go now to Ms. Hart, who has been perfect in her faithfulness to this hearing.

Ms. **HART.** I yield my time back to the Chairman. Just kidding. Thank you, Mr. Chairman. I come from Pennsylvania and I served in the State Senate where I served in a state senate with a gentleman, I will use that term loosely, who actually committed vote fraud to get there. Served with me for several months and then was thrown out as a result of absentee ballot fraud where his folks took advantage of the non-English speaking community and told them that they had "lunvava formar devotar", and basically went door-to-door in the Spanish-speaking community and voted for them by absentee ballot.

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I like absentee ballots because I think it gives college kids and people with busy lives a chance, if they may be on business, out of state, for whatever, to vote. As well as people who aren't able to get in and out of the voting places. For years my brother was committee man at a precinct where they had very poor handicap access. And so a lot of people ended up really having no choice. So I think there are ways that we can secure that. I just want to throw that in there.

But my concern, and I have been voting all my life in this same county, and we vote by machine where they do ask you, is that your final answer before you press the button. And then everything is recorded. Where we have had very little manipulation of votes in that way because the machines have been working pretty well. And the biggest manipulation has been through absentees.

I am obviously a supporter of getting as many people out there and involved in voting as we can. And I agree with Ms. Woolsey about the issue of having neighbors come to the poll to vote. So I am not, you know, one part of me thinks on-line is a great way to go. But the other part of me says, no. Because if you—if you are voting for people for office you ought to have a little more knowledge about the community. So I think having people come out and vote is a good thing.

Throughout the district I represent we have all kinds of different—we have paper ballots, we have the little computer in the—I don't know what they actually call that one in the voting place. And then we have these machines. And people aren't put off by the voting machines, nor are they put off by the paper ballots. But I can tell you that senior citizens don't like the computers. I think that there is a chilling effect if there is too much technology involved in people getting to vote.

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And so what I want to ask you is, because in my experience that is what I have seen, have you seen a technology that seems to be the most people-friendly as well as being pretty accurate? That maybe we ought to also take into consideration that issue. And is that something that has come across as you have done your studies, kind of a concern about people just being uncomfortable or just disliking a certain technology?

Dr. **MERCURI.** California had done a study. They were actually considering going to a computerized style. And they had done a study and they came up with the same data, actually had hard numbers on that. As you know, as you increased in age, your interest in wanting to use computers or that style of technology to vote actually decreased. And it dropped off fairly rapidly. It was well over the majority, in the 60 percents, of the elderly who did not want to vote in that style.

And getting back to the other issue, the absentees, I think it is also a sociological phenomenon. Oregon is a very, you know, people live much further apart. Doug Kellner, and I know he won't mind me quoting him, he is the head of the Board of Elections in New York City. And he told me after Oregon's vote, he said, yeah, if we did this in New York, we wouldn't have 100 percent turnout, we would have 120 percent turnout in New York. So—and that is a problem. I mean, you really—Oregon is Oregon and New York and Chicago and Philadelphia, not to defame any of them, I love Philadelphia myself, born and bred. But to look at some of the bigger cities I think you would really have problems if you went to that type of Internet or just remote absentee balloting style.

Mr. **SALTMAN.** I was down in Brazil in 1996 in a project to evaluate their new push button direct recording voting system. I thought that they did a marvelous job in training. And I can give you some reasons why it was successful. First of all, it is a country of much higher illiteracy rate than the United States. And also there—obviously consistent with that, there are fewer people who are conversant with computer technology. Yet they were able to carry this election out. And I observed people at precincts who were clearly from the lower social classes being able to vote quite well. And the reason is, for one thing they had a universal system. There was only one system installed, not five or six.

Second, they used television extensively to educate the people on what would happen at the polling place. I think that we don't do enough of that in this country. That we need to consider an extensive education and training system for voters much more than we have. We assume that, well, yeah, we have these now. Everybody goes to these automatic check-out things and we all use ATM machines and all of that. We put our credit cards in the machine and, you know—but it isn't true. That is half or j of the population maybe. But what about the lower 25 percent who have all the difficulties. We need to consider those people in a much greater way than we do now.

Dr. **JONES.** There are several ideas here. One of them is this discussion of absentee voting, and the other one is this question of human factors that you just raised. The human factors issue is one thing to be very clear on is that any time you change your voting technology, whether you are moving from paper ballots to lever machines, or whether you are moving from lever machines to direct recording electronic machines, any change of voting technology is going to cause significant voting problems. And in many cases, the problems that people observe with the computer interface is with people that have never used it. It is an unfamiliar technology. Education can counter this. And we invest a huge—a pathetic sum on voter education in the United States. I think it was Governor Bush in Florida during the Civil Rights Commission hearings who said that it is embarrassing to realize that they spend more money promoting the state lottery and training people on how to use the state lottery machines to cast—to buy lottery tickets than they do on how to vote. That is going to be true in every lottery state in the country. And it is horribly embarrassing.

On the absentee voting issue, something that has been going on increasingly in Iowa is the discovery that our absentee voting law allows for what they call a satellite polling station, which is almost run like a regular polling place, where you are issued a ballot, you vote in the privacy of a voting booth, and then instead of putting it in the voting vote counter, you seal it in an envelope and it is counted as an absentee ballot. We have a number of counties in Iowa that are running satellite polling places in hospitals, in large employers' workplaces, central locations like public libraries, and technically it is an absentee ballot, but in fact, it is being cast under many of the controls of a polling station. And I think this is a wonderful institution. I think the states, and it is almost certainly a matter of states at this point, should investigate ways to do this formally to enable, for example, precinct count—ballot counters to work at a satellite polling place and detect the over-votes and give the voter a second chance.

Chairman **BOEHLERT.** Also to make sure it is handicap accessible, for example.

Dr. **JONES.** Yes.

Chairman **BOEHLERT.** Which is a problem with a lot of polling places.

Dr. **JONES.** Well, that should be solved at all polling places.

Chairman **BOEHLERT.** I know it, but it isn't.

Dr. **JONES.** Satellite or not.

Chairman **BOEHLERT.** We are dealing with reality here.

Ms. **HART.** Thank you, Mr. Chairman. I just want to make one comment. I know I have used up all my time. But I think one of the biggest issues again is I think was mentioned by someone earlier. It is not just the concern about security of the technology, but I do believe that we have armed the system to some degree when we prevented—when we did the motor voter we prevented the—I think a reasonable amount of time of purging those election records. In communities where people are more transient. What we see now are like three and four families who are eligible to vote at the same residence. That is a mistake. And I think we have invited a lot more fraud. I think that is also an issue perhaps for a future committee hearing. But one that I just wanted to bring up because I see it happening in some of the communities I represent. Where you look at the voter list and you see several families at the same—and I think Dr. Jones has a comment on that one, if he has time.

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Chairman **BOEHLERT.** Well, that—we have got a couple more. And we are running late.

Ms. **HART.** Okay. I am sorry. I will talk to him outside——

Chairman **BOEHLERT.** And that is something that is outside the Committee's jurisdiction.

Ms. **HART.** It is outside the hearing.

Chairman **BOEHLERT.** But definitely, within our zone of interest.

Ms. **HART.** Okay. Well, we can converse about it outside the hearing.

Chairman **BOEHLERT.** All right. Thanks——

Ms. **HART.** Thank you, Mr. Chairman.

Chairman **BOEHLERT.** Thank you, Ms. Hart. Mr. Lampson.

Mr. **LAMPSON.** Thank you, Mr. Chairman. I am a former voter registrar for a very long time. And I have had been involved to some extent those activities both as a voter, obviously, as an election official and as a candidate. But I have tried to move around my district and visit with some of the different counties. One of them particularly, presently has a task force where they are looking at the voting system that they have had most of—probably the most prevalent form or means of voting in my congressional district happens to be the punch card system. Where we have had at least two elections turned around in one county of the several counties that make up the district. And there are, and continue to be, significant problems that is old technology, in my opinion.

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There are a lot of wonderful ideas and examples of better voting technology. We do need to raise some cautions as we go through these things, in my opinion. That is obviously clear. My district includes a couple of counties where there is a very small population. One rural county has a very low density of population. It is going to mean, obviously, extra challenges for modernizing a voting system. They are concerned with the extended costs, how are they going to pay for these things over a longer period of time, whether or not there is assistance with funding to get into the system. And the smaller counties often have very little money. All of them rely on what we have been talking about as the larger number of temporary workers. With the high technology equipment, and one of my

people down there referred to some as the Ferrari's of election machines. Can the equivalent of the local auto body shop—automobile repair shop handle fixing and maintaining them? Who is going to maintain, where are we going to get the funding to maintain these electronic—this electronic equipment. And the secondly, I will let all of you response to this, will the mini-precinct locations be able to handle high-tech equipment? We still have trouble in some of the precincts in Texas, having places where there are lights, and restrooms, and heat. Obviously, when we have summertime you don't need them in southeast Texas. But we need air conditioning. Your comments, please on those two things and then I have another one. Go ahead and start, Dr. Jones.

Dr. **JONES.** It is personal computers today are one sense at the extreme of high-tech, and in another sense remarkably low tech devices. As long as you are not worried about understanding what is inside that CPU chip, as long as you are not worried about understanding how the disk drive works, as long as you are not worried about understanding what is inside those funny little single in-line memory modules. They are not something which is daunting. I remember about a decade ago being somewhat surprised to discover that the University's maintenance man who had a space in the basement of my building was running a personal computer repair office out of that. He was a retired farmer who had a night job as a janitor. And in his idle hours where he was waiting for something to break that he had to fix, he would sit there and disassemble old PC's and rebuild them into new PC's by replacing this and that and consolidating pieces and upping the configuration. This is a retired farmer with no special technical education. I think exactly your auto body shop level of technology is to be used.

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Mr. **LAMPSON.** Would he be able to perform the services necessary to maintain the equipment?

Dr. **JONES.** That's right.

Mr. **LAMPSON.** At a low cost?

Dr. **JONES.** Right. It is important to notice that today's direct recording electronic voting systems are just a standard PC mother board with a standard PC chip in it, a standard PC disk drive, a standard PC MCIA credit card.

Mr. **LAMPSON.** Now are they going to be available to us at lower costs? Because right now these companies are trying to sell them at very high costs.

Dr. **JONES.** Well, $5,000 is coming an awful lot down from what it was.

Mr. **LAMPSON.** Per machine. And how many machines do you need——

Dr. **JONES.** I know.

Mr. **LAMPSON** [continuing]. Per precinct. And when you have 120 precincts in one of several counties, we are talking about a significant amount of dollars. You all—you are down there nodding your heads. I don't want to run out of time because I want to ask some questions about voter registration so go quickly.

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Mr. **SALTMAN.** Yes. There are many counties in this country that are very rural. And the appropriate type of

election equipment for those counties might still be hand-counted, hand-marked paper ballots.

Mr. **LAMPSON.** Mix it up.

Mr. **SALTMAN.** Yes.

Mr. **LAMPSON.** Do what is best for the local area?

Mr. **SALTMAN.** Do what is best, yes. Yes. There are places in this country where there isn't electricity in the polling place. And you may have to use hand-counted, hand-marked paper ballots. Now Brazil understood that and they provided that their machines would work on 12-volt batteries. And that you could run it, if you had an automobile, you could run the election machine off this 12-volt automobile battery, which might be around. I will —I think Doug Jones answers the rest of it very well.

Mr. **LAMPSON.** Okay. Dr. Mercuri?

Dr. **MERCURI.** I—in my contacts in New York, Richard Wagner, who maintains the lever machines, he is the head of that division there in the City of New York. And they are maintaining the lever machines indefinitely. They believe that they can. They can maintain their parts just like you said, with an auto body shop type of environment. And they feel that they can maintain these. Buying the whale oil to lubricate them has been a little difficult. But there is a synthetic substitute apparently. That is the standard that was used. So as far as some of these types of systems, yes, you can maintain them indefinitely.

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I disagree with Doug though, with regard to the standard PC format. When we build a computer system it is intended for pretty much five days a week type of use. It is not intended for use twice a year, kept in weird environments, warehouses with a lot of water and condensation, fired up and recharge the batteries, that type of thing. They are intended to be used. If you bought a laptop you know you have owned it for about two years and then you throw it out and you buy a new one. If we do that with all of our voting machines, I think the voters will be very panicked. But that is what that technology is intended actually for. So I disagree. I have a problem.(see footnote 4)

I don't think this disagreement changes the level of expertise required in the voting system maintainer. The more durable components required to meet the standard advocated by Dr. Mercuri will generally be designed for a similar level of maintenance expertise. I also agree with Dr. Mercuri that voting systems do require standards of durability that are quite distinct from those that the PC marketplace demands, and that, therefore, we must look at standard PC components with a significant degree of suspicion.

Mr. **LAMPSON.** Thank you. We are out of time. Let—I do have a question about voter registration and I won't ask it. But will you all write us and tell us at least some of the technical solutions that you might propose for the problems that we are facing with voter registration, where there are duplications, where there is a failure to communicate between or among counties as people move. And what are the viable solutions that might survive that test. And you cannot answer now. I would appreciate it in writing. Thank you, Mr. Chairman.

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Chairman **BOEHLERT.** Thank you. Ms. Jackson Lee.

Ms. **JACKSON LEE.** Mr. Chairman, you can tell that you have hit a goal with this hearing. Let me applaud you for your leadership on this hearing. I had the privilege, I guess, of testifying before Senator McCain's Committee. And of course, he chairs the Commerce Science Committee on the Senate side. And I am absolutely ecstatic that you have staked out your jurisdiction and our jurisdiction for this very important issue.

If you would indulge me, Mr. Chairman, I just want to acknowledge that in the room are students from Texas Southern University School of Science and Technology. And I thought it was appropriate that they would be in the room as we are discussing the technology of voting. And I thank you for indulging me and allowing me to acknowledge.

Chairman **BOEHLERT.** Could they raise their hands, the students?

Ms. **JACKSON LEE.** There they are.

Chairman **BOEHLERT.** Welcome.

Mr. **LAMPSON.** Can I throw in that Dr. Carol Lewis is also here with them. And she has been participating in another task force——

Ms. **JACKSON LEE.** Task Force of Transportation.

Mr. **LAMPSON** [continuing]. Very beneficial to us in Southeast Texas.

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Ms. **JACKSON LEE.** All engaged. That is why we like our chairman. He is a leader on these issues and I applaud him greatly for his commitment and energy around these issues.

Let me just say to the panelists, thank you very much. I may not have heard all of your testimony. I was in another hearing dealing with an unscientific story on racial profiling. Of course, there are many issues that we are dealing with in this Congress. But I have traveled around the country listening to citizens, if you will, from around the country talking about election day 2000. I think what we can appreciate is the fact that the sun light finally shown on what we were doing as it relates to elections. Let me also ask the Chairman if I might submit into my—into the record my full statement.

Chairman **BOEHLERT.** Without objection, so ordered.

Ms. **JACKSON LEE.** Let me quickly say because the time does pass, as I looked at the Committee's memo, it is interesting to note that lever machines are 1892, punch cards are 1964, and it only took a very erratic and unbelievable election to open our eyes to what had been occurring on a regular basis. But I want to throw this out for you as I have gone around the country. And I am not opposed to technology. I think that as we move in this century it is inevitable that we change from an 1892 process, that I think even New York may be still using, the lever system, that we advance ourselves. But might I refer you back to the South African election that had paper ballots and pictures and a 95 percent turnout. And of course, it seemed that what we were most proud of during that time frame is little fraud and the election was successful and President Mandella was elected. At the same time the punch card problem in Florida was less the punch card dimples and chads, was more the lack of money

and counties that did not clean up the machines. A simple process that the cleaning brigade could have assisted us in. I heard someone mention the question of purging. Let me say that though I am not trying to get beyond the jurisdiction of this Committee, but purging can be done technologically because you can kick people off. But purging has a disproportionate impact on inner cities. And a disproportionate impact on minorities. And I am absolutely opposed to random purging of people who rightly thought that they were registered. We had a case, Congressman Lampson, Chairman, in San Antonio. A Hispanic woman did not speak any English when she became a citizen. And it wasn't 50 years ago, a couple of years back. She registered to vote. That was her right. But of course, missed one or two elections, not 10, but missed one or two. But when she got excited about this presidential election she came forward to vote and of course was turned away because she had been purged.

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And then finally this question on fraud, having experienced a city election, I always think you can catch fraud. I think the Congresswoman from Pennsylvania mentioned someone was engaged in fraud but he was caught. So my question to you, and we had a fraudulent situation in Houston in a mayor's race where the counting people down at the county, some gentleman, a volunteer, was plugging the holes for the opponent in that case.

Let me just say that I would like to ask the question of the value of Federal involvement in this: why is it relevant for us to be involved on this issue? And what is the value of uniform standards? Have we become—is it—have we been mandated by Bush v. Gore, because it elevated elections to a Federal level, if you will, the determination, to engage, to develop national standards for elections, or at least national standards for federal elections? And if all of you could answer that. I thank the Chairman very much. I have a litany of questions, but if my time has run out I will do so. I see the light is still on the middle one. But I would appreciate the answering of those questions. And again, I am really—this is not excessive, Mr. Chairman. But I am enthused that you have had this hearing. And I thank you very much.

Chairman **BOEHLERT.** I am enthused that you are enthused. The witnesses will be given an opportunity to respond.

Ms. **JACKSON LEE.** Dr. Saltman—Mr. Saltman, thank you for your work as well.

Mr. **SALTMAN.** Thank you. I want to tell you that from the very first report that I wrote we always said, well, that, yes, these reports concern vote counting and vote tallying. Yet we always said that we know that the whole system includes voter registration. And a real honest, complete study would involve voter registration. And it always has disturbed me as I see both sides of the aisle here. One side of the aisle says, we want people to be able to register easily and to remain registered if they are allowed to be by law. And the other side of the aisle says, we want an absolutely, completely accurate system. So I want to say that I agree with both sides of the aisle. I want to see an accurate and complete system of voting registration where there are no fraudulent registrants. And yet on the other side of the aisle I certainly want to see people being able to be registered and not purged incorrectly as we saw in the horrible situation in Florida.

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And this is a difficult situation. And I notice that very often these two people—types of people with these two types of views do not talk to each other. I have—in the Constitution Project that I am involved with, which is studying election reform, there are both types of people. And conservatives will say, yes, we need a totally

accurate system. And the liberals said, well, I am very pleased with the NVRA, and it caused a lot of good things. And the conservatives say, no, it is horrible. And I don't know what to do about it, excepting the—I have a hope that these two groups who have—both of whom have the best interest of the United States at heart will get together. And they will agree on some sort of system that will assure that both sides of the aisle will be satisfied. Because I think it is very important to carry that out.

And you asked about Federal involvement. Yes, I believe there should be Federal involvement. And my list of things that the Federal Government should be doing include participation and providing grant money to states to upgrade their voter registration systems. I think also we need a systematic study of the process of people moving and people dying and people being born and becoming 18 in an information systems point of view so that all of those records that the post office has, that the Health Department has, that the various movers have, if they can be involved, all of those records come together in a way that will improve our system of voter registration.

Chairman **BOEHLERT.** Dr. Jones, you wanted to respond?

Dr. **JONES.** We can build a system which is absolutely resistant to fraud. But where the costs of entry into the voting machine market place is outrageous because of the investment to be made in testing and passing through the certification process is beyond anyone's affording. Where voters when they enter the polling place are subject to embarrassing and inconvenient tests of identity in order to prove that they are who they say they are. Where voter registration is accessible only to those who have very difficult to produce identification and we will have a terrible electoral system. Or we can produce, we can have a system where voting is poorly controlled, where the manufacturers of voting machines are poorly controlled, where it is very easy to come out with a new voting machine on a shoestring budget. And we will have a terrible system.

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Both extremes are bad. The problem is to produce a compromise, to find that middle road, the moderate path, which allows new technologies to emerge without setting insurmountable barriers. Which allows the market place to produce cheaper voting technologies. Which allows the turnout on election day to reflect the actual sentiment of the legitimate electors. And which allows—where you don't turn people away on the one hand by making it hard to be registered to vote, or turn people away on the other hand by making it embarrassing. By making—let me start that sentence again. You don't turn people away on the one hand by making it intimidating. And you don't turn people away on the other hand by allowing fraud which cancels their vote.

The perfect system probably will tolerate a little bit of fraud in order to make that turnout possible, as long as the added turnout gives a more accurate representation of the electorate than the slight amount of fraud that occurs. This is an uncomfortable thing to admit that some fraud may be better than none. Because if you have no fraud you will turn people away by having embarrassing and annoying——

Chairman **BOEHLERT.** Dr. Jones, you have just written a new chapter in the moderates manifesto. And I applaud you for doing so. The extremes usually are very sure of themselves and they are usually wrong. Let me thank—are you going to prolong it?

Ms. **JACKSON LEE.** Only to find out whether the other two had any brief comments. I thank you, Mr. Chairman.

Chairman **BOEHLERT.** Dr. Mercuri, sure.

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Dr. **MERCURI.** Briefly, I think your point is well taken that, will fraud will be found? And in the old systems, the paper and even the lever, yes, the fraud is found because you have to do it the old-fashioned way. One machine, one ballot box at a time. What happens with the new technology is that we now have the possibility of globally affecting the election. When you have a certain penetration of a particular type of system or operating system or even computer chips, and we know the dates of the elections well in advance, we can rig a time bomb, perhaps rigged by some computer chip, that will occur on the first Tuesday in November in four years or eight years or 12 years, it depends if those chips are being used. And we have no way of controlling that. And that is where I think that the Government needs to be involved. I think that if we do set the types of standards that we need in this technology, then we can help to prevent and mitigate that type of global wholesaling of the fraud and the election.

These are electrons, they are invisible. If that type of fraud happens we may have no clue when it even happened or who did it. And that is what scares me the most.

Chairman **BOEHLERT.** Dr. Ansolabehere, do you have any?

Dr. **ANSOLABEHERE.** Brazil did it, we can do it. Brazil had a much worse system than we did, rife with fraud, rife with unusable machinery and so forth. And they initiated a process of just investing in research and development. It doesn't have to be a Federal process. Maybe it could be done by private institutions.

Chairman **BOEHLERT.** Do you have any specifics on that Brazil opportunity?

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Dr. **ANSOLABEHERE.** They set up a consortium of engineers. And——

Chairman **BOEHLERT.** I mean, is there an article you could refer us to——

Dr. **ANSOLABEHERE.** The Foundation—yeah, I can get some information on that.

Chairman **BOEHLERT.** Would you mind doing that? I mean, I think we would all like to——

Ms. **JACKSON LEE.** Yes.

Chairman **BOEHLERT.** Ms. Jackson Lee and all of us would be interested in that.

Dr. **MERCURI.** Can I interject? I have a number of articles, many of them in Portuguese from professors down in Brazil.

Chairman **BOEHLERT.** Since I am not fluent in Portuguese——

Dr. **MERCURI.** They have been translated. Who take the opposite stance. There were many anomalies and problems in the Brazil election.(see footnote 5)

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Dr. **ANSOLABEHERE.** Sure. You are dealing with a system where basically the votes were made up before. To a system in which there is some integrity in the voting process, where there is blind accessibility, where there are all the things that we have been talking about to a greater degree than it was before. And that is what we should be focusing on, is degrees of improvement rather than absolutes.

Chairman **BOEHLERT.** Here is what I hope is evident to all of you. First of all, in concluding this hearing, let me say thank you. Because you serve as resources and you are very valuable. And this hearing could go on all day.

Unfortunately, we have other things that we have committed to. But I hope you detect sincerity on the part of all of us up here, Republicans and Democrats alike, to really come to grips with this issue in a most responsible and timely way. We have jurisdictional considerations. I mean, we talk about motor voter, that is not something that this Committee deals with. For example, Mr. Saltman, you talked about the three elements as dealing with speed, cost and quality. And you said you can get two out of three right. I would like you to think a little bit about and subsequently share in writing your thoughts on this, all the panelists. If we can get two out of three right, let us deal with quality and costs and consider having maybe three days of voting, so you don't have to have speed.

I mean, I know we have the lever machine in New York and I stand in line and I am waiting my turn. And like everybody else I am looking at my watch, waiting to go. And somebody is in there for 90 seconds. And you say what is taking them so long. And then invariably I go in trying to rush and I almost forget to vote on some of the amendments or propositions because they are in a different place on the machine. So this is a society where we are all in a hurry. So if start with every level, maybe we ought to think in terms of having, as has been suggested by minds greater than mine, 3 day, you know, weekend voting. There are a whole lot of things.

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But I would appreciate it if you would back from whence you came and any articles that you think would be very helpful to us, if you would share them with us. And I also would like you to think about if there is any other system any place else that you think is something we should look at. Is it Denmark or it is Malaysia, whatever. I don't know. If you would point us in that direction.

But I want you to know, we are thinking in terms of doing something very specific with legislation and we will share it with you and ask for your comments. But in short order because I think we have a responsibility. We have to have a greater degree of comfort with the American electoral process than we have right now as a result of the last election.

And once again, let me point out, Florida is under the microscope, so we all have paid attention to that. But whether it is New York or Texas, we have got our share of problems. And we are trying to be part of the solution. So let me thank all of you for outstanding testimony. I think you saw our very active participation today. And we appreciate it. This hearing is adjourned.

[Whereupon, at 12:20 p.m., the Committee was adjourned.]

Appendix 1:

Opening Statements

PREPARED STATEMENT OF CHAIRMAN SHERWOOD L. BOEHLERT

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I'd like to welcome everyone today to the Science Committee's first look at what I consider to be one of the most important aspects of election reform: ensuring that voting technologies are secure, reliable, and accurate.

Last November, as the world placed Florida under a microscope to scrutinize its election, America saw for the first time the extent to which one of our most sacred tenets of democracy was vulnerable to error. As the problems with the now-infamous punch card ballot unfolded, America watched in amazement—and the rest of the world watched in amusement. They watched as America, the most technologically advanced nation in the world, who preached democracy to others, tripped on its own shoelaces.

Now, several months later, Congress is beginning to respond. And while its tempting to criticize this institution for not acting sooner, I would suggest that the meantime has not been wasted. We have learned many things about our nation's various voting technologies and we've begun to answer many questions about how to fix our voting systems. For example, the problems that plagued Florida also affected many other states and counties across the country. But would banning punch cards solve the problems for these areas? It turns out that it depends on what technology you replace the old punch cards with, for some are just as bad. Should states simply embrace the future and move to adopt voting by Internet? Probably not, for there still seems to be too many uncertainties over security, privacy, and equal access to ensure that this potential solution would be fair or problem-free. How about electronic voting machines, with touch screens or push buttons that automatically tabulate votes? Should states buy those? That's not really clear, either, for some studies have shown those machines to be as error-prone on average as punch cards.

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So while our election problems are undeniably pressing, the last few months have shown us that we must proceed carefully in order to get the answers right and not set ourselves up for potentially bigger problems down the road.

So what can the federal government do to help? First let me state clearly what the government should not do. It should not mandate a one-size-fits-all solution. It should not insist, for example, that every voting precinct in all states buy the same technology for its elections. Nor should it trample on the rights of localities and states to conduct elections in ways that make the most sense for them.

But the federal government can and should offer states the kinds of information that it is best suited to provide. For example, I believe the federal government should conduct research, not just into ways of improving the inner workings of voting machines, but also into how people interact with them—to make sure that voting equipment is user-friendly for ordinary people. It can also develop robust technical standards for voting equipment manufacturers to meet. And it can accredit labs around the country to help certify that voting equipment meets those standards, so that states can confidently choose voting technologies that are secure, reliable, and accurate.

As the Committee that oversees the National Institute of Standards and Technology, I believe we have an important role to play in these areas. Next month, we plan to work together, in a bipartisan way, to report out legislation that will help ensure that the federal government plays its proper role in strengthening our election

systems.

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Obviously, there are other important ways the federal government can help, too, for example by providing money to help states and localities upgrade their voting systems. As a past county executive, I can tell you how tight the budgets of local governments are stretched, and how low a priority elections are as a result. But now it's time for elected officials, who often like to lecture voters about how important voting is to our democracy, to put our money where our mouths are. This is a complex problem, with complex solutions. Solving it will take some time, some effort, and some investment. But in the end, it is worth it. After all, in this case it is no exaggeration to say that nothing less than our democracy is at stake.

I look forward to the testimony of the witnesses and a productive discussion.

PREPARED STATEMENT OF REPRESENTATIVE RALPH M. HALL

I want to add my welcome to everyone at this morning's hearing.

I also want to thank Chairman Boehlert for holding this hearing on election technology and the role of standards. Before November many people reading this hearing title might have wondered about the connection between elections and standards. However, the last election highlighted that we need to improve our voting equipment across the country. Our voting equipment must be accurate and reliable and good standards play a key role.

I believe that the Science Committee can make a contribution to the on-going debate on improving voting technology. This is especially true in the area of standards for voting technology and the research required to support the development of new technologies.

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The Chairman has assembled a very capable group of witnesses and I want to thank him for working with us on this hearing.

I also want to thank the witnesses for taking time from their busy schedules to appear before the Committee today.

Now I would like to yield the balance of my time to Mr. Barcia who has been working on this issue.

PREPARED STATEMENT OF REPRESENTATIVE CONSTANCE MORELLA

Mr. Chairman, I want to thank you for calling this hearing. Given the outcome of the recent Presidential election, it is both appropriate and reasonable for the Science committee to review the technology we currently use to elect our representatives in government. I think we can all agree that the problems associated with the 2000 election desperately need to be avoided in future contests.

America has a great democratic tradition. We are the gold standard for freedom. Many budding democracies around the globe look to us as a guide and model for their own reforms. And we spend a good deal of money helping them institute these reforms and assure the sanctity of their own elections. So it is particularly

embarrassing when we encounter such problems of our own.

But we shouldn't fix the problem because we don't want to look silly in front of the world community; we should fix the problem because the American people deserve better. We should fix the problem, because after 200 years of free election we should be able to guarantee the American people a fair and accurate vote count. We should fix the problem, because it is the right of every American to vote and have their vote counted. And clearly this does not always happen.

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We have a crisis of confidence in the voting system and it needs to be addressed. However, it would be unwise to rush headlong into the issue without establishing the parameters for the discussion. That is why this hearing is so important. We have a problem with voting in this country, but we don't want the cure to be worse than the disease. New technologies and voting reforms can do much to solve our problems, but they can also create new ones. The Science committee has the responsibility to cut through the rhetoric and look at the technology that can be reasonably brought to bear. I thank the panel for their willingness to come to Washington to discuss this topic and I look forward to their remarks.

PREPARED STATEMENT OF REPRESENTATIVE JERRY F. COSTELLO

Thank you, Mr. Chairman, for calling this hearing. I feel strongly we need to take advantage of the interest in last year's election to re-examine the basic tenets of our electoral system. We have many issues that need to be examined, including improving election technology, increasing voter participation, and the continued existence of the Electoral College. Above all else, we need an election system in which all Americans can believe. I hope to get a clearer idea of what works the best and what is needed in terms of elections not only in the nation but also in my district. I have held town hall meetings in my district to gather a better understanding of what is needed for my constituents. Their suggestions and comments will be at the forefront of my mind as I participate in this hearing.

I welcome our panel of witnesses and look forward to their testimony.

PREPARED STATEMENT OF REPRESENTATIVE SHEILA JACKSON LEE

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I want to thank Chairman Boehlert and Rank Member Hall for convening this important opportunity to discuss our Nation's need to improve voting technology.

This is an issue that I, along with the constituents I serve, and many members from both parties are greatly concerned with. Voting is not just a right of passage from childhood to adult in our society; it is the principle of democracy expressed by everyone who exercises their free will to be heard on Election Day or equally their choice of not casting a 'vote on Election Day.

We are here today to discuss the clear and evident failure of voting technology. However, we cannot ignore the clear and evident failure of the people charged with the legal and ethical responsibility of the administration of elections to do so in a nonpartisan unbiased manner. More than anything else the flaws in our nation's election process stemmed from a lack of commitment on the local level to not only the spirit, but the letter of law that

supports our democracy. The arbitrary and capricious nature of modern electoral administration is too chilling for many to contemplate after over 220 years of freedom.

We cannot call ourselves the leaders of the free world, a is a title reserved for those who work earn it, through actions and not words based on truth and justice for all.

At the start of the 21st Century, three percent of the precincts in the United States still use the oldest form of election technology, the paper ballot. Lever Machines, first introduced in 1892 are used in 22% of today's precinct level elections across our country. The notorious punch card ballot, introduced in 1964, has two forms the VotoMatic type found in 33% of the nation's precincts and the DataVote type used in four percent of the nation's precincts. The Optical Scan, "mark-sense" or "bubble" ballot system introduced in the 1980s is used by 25% of the precincts and is found to have the greatest accuracy of all voting methods when joined with verification of intent at the voting location. Finally, the direct recording electronic (DRE) voting technology first introduced in the 1970s is an electronic version of the lever voting machine and is used by about seven percent of our nation's precincts.

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The most popular form of voting in the United States if the mark-sense or bubble ballot system with over 1,200 counties currently using this method.

Securing the Franchise for all Americans—voting rights from the beginning of the United States has been a right conveyed under condition. Today the issue of access to the ballot box is complicated by the fact that there are fifty states with the underlying bureaucratic complications of hundreds of county governments who administer the voting roles for their respective states.

Currently, there are seven voting methods that are available for county governments to select from: datavote punch card, other punch card, lever machine, paper ballot, mixed system, optical scan, and electronic.

A democracy is only as strong as its people, *all of its people*, and therefore for America to prosper its entire people must prosper!

I introduced the following bills to address the problems associated with the last presidential election: H.R. 60 the Secure Democracy for All Americans Act; H.R. 934 Presidential General Elections Would Become National Public Holidays; and House Concurrent Resolution 5, which expresses a sense of Congress that the election process in this country should be uniform.

It is my goal along with many of my colleagues to pursue national voting policies, which are not prone to bias, corruption or disruption. The most sacred and important process of our democracy is the act of voting.

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Universal suffrage means that everyone should have an equal opportunity to vote, regardless of rank, social status, race, or social background. But over the past three decades studies have found increasing biases in turnout. In particular, people without college degrees have become less likely to go to the polls partly because the types of employment they are able to find offers little flexibility to visit the polls during working hours. Should Election

Day during Presidential Election years become a public holiday, private employers would be strongly encouraged to also allow their employees to have that day as a holiday so that millions of voters would be free to vote anytime throughout that important day.

It may be difficult to reach agreement on the specifics of what should be done to improve our nation's system of electing the President, but everyone can agree that something should be done based on what we have learned from the last presidential election:

I would offer that this attempt to refine and create standards for the various methods of voting has merit. By creating standards that are federally regulated the nexus between voting rights, legislative action, and judicial review might be strengthened.

I would like to thank Mr. Saltman for his work as a specialist with the former National Bureau of Standards, now known as the National Institute of Standards and Technology (NIST). In the report you authored, in 1988 titled Computer Science and Technology: Accuracy, Integrity, and Security in Computerized Vote Tallying it was stated that National Elections are conducted by 2,870 county-level government agencies, and by some 7,630 other local government agencies. In some 1005 of the 3140 counties and county equivalents, vote tallying is completely computerized.

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At some point a computerized machine counted most of the votes cast in last November's election. In the end it was deemed necessary and mandated by Florida State Law that a recount was necessary. This process went from a machine recount to a manual recount with numerous court challenges to the process. Misuse and abuse was uncovered along with unrepentant partisan activity, with some wanting to dismiss this disgrace with a mention of Chicago, Illinois in the 1960 elections.

I for one do not find it excusable that the current system for choosing elected government in this country cannot better manage a close election.

What ever is done to address the issue of fairness in national, state, and local elections must address the need to restore confidence that the voters' collective will is done.

I look forward to the contributions of today's witnesses to this process and thank them for taking the time to offer insight into this important area. Thank you.

PREPARED STATEMENT OF REPRESENTATIVE EDDIE BERNICE JOHNSON

I am pleased to join the Chairman in welcoming our witnesses to today's hearing on *Improving Voting Technologies.*

As Chair of the Congressional Black Caucus, we held the first hearing in this House on Election Reform. Witnesses at our hearings discussed the need for improved technology, uniform poll closing times, voter education efforts, and restoring the franchise for ex-felons. As we look back on the 2000 elections, let us remember that before the election, there were dire predictions about the low level of voter turnout. Pundits espoused a conventional wisdom that Americans had become complacent about democracy and that many had opted out of the system. Yet, the people proved the pundits wrong. In the last election, there were record numbers of people who showed up at the polls. Now this very committee has the jurisdiction—the opportunity—to ensure that the

will of the people is met this upcoming election and every election from here on out.

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Mr. Chairman, I am proud to be a Member of this Committee as we pave a new road that will ensure the American people that we understand their suffering, we feel the threat to basic democracy, and that we acknowledge that there is something we can do. I welcome the witnesses participating in this hearing and look forward to hearing what they have to offer in regards to improving voting technologies and ensuring that everyone's vote will count. We must also remember that improving voting technologies is a small but helpful step in ensuring that the problems encountered in the 2000 election remain problems of the past. We must also keep in mind that much more comes with election reform, such as education, uniform poll closing times, restoring the rights to vote for ex-felons and expansion of voter registration.

Appendix 2:

Written Testimony, Biographies, Financial Disclosures, and Answers to Post-Hearing Questions

PREPARED STATEMENT OF STEPHEN ANSOLABEHERE

Thank you for inviting me to speak today.

I'd like to begin by telling you a little bit about our project. Then, I'd like tell you about some specific findings of our project as they relate to technical standards and innovation in voting equipment.

Overview of the Caltech/MIT Voting Technology Project

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A week after the 2000 presidential election, David Baltimore, the president of Caltech, called Charles Vest, the president of MIT, with an idea. Our two institutions should collaborate to develop improved voting technologies—a new voting machine. The problems observed counting the vote in Florida and elsewhere originated with technology.

Presidents Vest and Baltimore assembled a team of computer scientists, mechanical engineers, and social scientists. The Carnegie Corporation and our two institutes have funded our endeavors.

I'm Steve Ansolabehere, a professor of Political Science at MIT, and co-director of the Caltech/MIT voting technology project. My counterpart at Caltech is Tom Palfrey, a professor of Economics. Our team consists of 11 faculty and many students, and our central goal is to develop new voting technology. The engineers bring expertise in electronic security, user interface design, machine design, and performance standards. The social scientists bring expertise in voter behavior, operations design, and public finance.

We are in the initial phase of our project, which I consider the learning phase. Over the last four months we have met with many voting machine manufacturers and election administrators to ascertain what the problems are and to explore ways that we can contribute to solutions. We have also conducted studies of voting machine performance and design, the public finances of election administration, and voter registration practices. A complete report of our work over the last four months is due out at the beginning of July. It will include our

assessment of existing voting processes in the United States. The report will also offer specific recommendations for the industry, governments, and universities to pursue.

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The second phase of our project focuses on design. We've identified a number of user interface and security features of existing equipment that can be improved upon. We have identified specific practices in voter registration and polling place administration that can be improved at minimal cost or with cost savings with the use of computer technology. We have also identified the need for a process that would involve industry, government, and universities in continual innovation in voting equipment and software.

What is Voting Technology?

We break voting and voting technology into four components: voter authentication, ballot preparation, verification and deposit of the vote, and tabulation of votes.

Authentication

A voter comes to the polling place and is authenticated, usually this means checked on the registration roll. Some voting machines use electronic equipment to authenticate the voter. Also, some counties, such as Orange County, Florida, have already experimented with making voter registration databases accessible at the polling places via the Internet. Security standards are needed for these technologies. Internet voting, if it is to happen, will require a different technology than checking a piece of paper. What is that? How can we guide its development?

Ballot preparation

A voter is given a ballot, goes to a private area or into a booth, and chooses the candidates and ballot questions that he or she would like to vote for. Ballots today range from pieces of paper to levers to user interfaces on touch screen computers.

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Verification and deposit

Once the ballot is prepared, the voter checks the ballot or a machine checks the ballot for invalid votes. For example, precinct based optical scanners catch over and under votes and voters can fix problems with their ballots. Lever machines and DREs do not permit overvoting, which is another "self correcting" mechanism. The voter then submits the ballot—by putting it in the ballot box, pulling the lever, or pushing a "vote" button.

Tabulation

Election administrators or machines tally the votes. Some equipment, like lever machines, makes a tally on the machine, which must be transcribed to a record and then summed. The newer scanners and electronic voting machines can transmit tallies to a central locale via a modem or the Internet.

At each stage errors can occur. Voters may have registration problems. Voters may mark their ballots incorrectly or the ballot may fail to register the vote correctly, such as with dimpled chads. The ballot box may have a paper jam or a power outage or may simply not be secure. The tally may have errors due to errors in hand

counting, transcription, or programming.

Reducing errors at each of these stages will improve the overall voting process and increase voters' confidence.

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From the perspective of setting standards, it is useful to consider what we want from each of these components separately, as we might want to employ different sorts of standards for different parts of the process.

What are the Problems?

1. High rates of uncounted, unmarked, and spoiled ballots—what we call residual votes. The average incidence of such votes is about 2 out of 100 ballots cast over the last four presidential elections. These ballots vary by state. Massachusetts and Maryland have fairly low rates of residual votes—less that 1 percent. New Mexico, South Carolina, Georgia, and Illinois had high residual vote rates—above 3 percent of all ballots cast. Some counties have residual vote rates in presidential elections as high as 20 percent or 30 percent of all ballots cast.

Our project has examined what one of our group calls the "epidemiology of voting." I have distributed to the committee one of our reports that examines the extent to which the residual vote rate depends on equipment used in the counties. Counties using punch cards average the highest residual vote rate, approximately 3 percent of ballots cast. Counties using electronic equipment also post relatively high average residual vote rates. Counties using paper, lever machines, and optical scanners average 2 percent or less.

We should lower the residual vote rate. Getting rid of punch cards is probably a good first step. But even 2 percent seems too high. Our project's goal is a residual vote rate of one-half of one percent, which approximately 10 percent of counties currently achieve. There are many ways that this could be accomplished—more poll workers, voter education, better machines.

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2. Errors in voter registration data bases. In response to NVRA a number of states and counties have undertaken considerable projects to develop computerized voter registration systems and clean up their voter registration rolls. In doing so, these states have estimated the number of duplicate or incorrect registrations. Michigan, for example, encountered 1 million duplicate registrations out of approximately 9 million registered voters. Los Angeles County audited their rolls and estimates that 25 percent of all registrations have some sort of problematic or incorrect information.

According to the Current Population Survey conducted by the U.S. Census, in the 2000 election approximately 3 million registered voters did not vote because of registration problems.

We should set standards for quality of data bases and fund efforts to clean the data bases and make these data electronically accessible at polling places.

3. Security of electronic voting. Two new technologies—scanners and electronic voting equipment are growing very quickly. By 2002 they will cover over half of all voters in the U.S. Some machines up load ballots and transmit votes over the Internet or modems. Standards for securing these transactions are required. Also, several counties have experimented with Internet based voting systems, such as that of VoteHere.Net. Standards should be

developed for the security of electronic voting procedures to prevent problems and also to foster development in this area.

4. Usability and Accessibility. There are no unified standards for the ease of use of equipment or handicapped accessibility. Many state laws do dictate ballot formats; these affect usability—sometimes for the good and sometimes not. A study of state laws as they apply to ballot design is needed as a first step to assessing usability requirement.

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What Are Standards, And How Can They Help?

We see three different kinds of standards possible for voting equipment: (1) Minimum Criteria, (2) Specifications, and (3) Best Practices.

1. Minimum Criteria

We currently expect of voting equipment a minimum level of performance. The existing standards amount to minimum criteria for reliability. The equipment must work under a variety of circumstances; it must guarantee the voter privacy and anonymity; it must have a very low rate of tabulation errors. Although the federal standards are voluntary, they have been widely embraced. "NASED Certified" is a sort of "Good Housekeeping" seal of approval for vendors and election administrators.

The standards should probably be expanded to require some degree of accessibility. This criterion may not be imposed on all equipment, but instead should be a criterion imposed on each polling place. All polling places should contain accessible equipment. Not all equipment at each polling place has to be the same.

We need to establish standards that will lower errors in voter registration data bases. We also need standards that ensure the security of registration databases and equipment used to access voter registration data bases at the polls.

2. Specifications

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Specifications mean that the equipment must have an exact set of features, such as a certain sort of computer processor or a certain kind of cabling. An extreme form of standards would be uniform voting equipment. We do not think uniformity would be easy to implement in the U.S., or even beneficial.

We see standard specifications as very important in the area of security of the vote deposit and the tabulation. If these parts of the process, which are largely invisible to the voters, can be standardized, then this part of the equipment could be tested and certified separately. The user interface and ballot design components could then evolve more quickly and could remain proprietary.

One difficulty with the existing standards regime is that firms are reluctant to change parts of their machines, such as the user interface, because they have would have to go through the certification process again.

A second sort of specification is possible. For each type of equipment (touch screens, scanners, etc.), we could develop and certify ballot tool kits that all companies could use in developing ballots for jurisdictions. The explosion in the number and variety of ballots adds to the lead time in preparing even electronic ballots, and can serve as a barrier to entry. Los Angeles County recently held a "bake off" for electronic voting. Vendors were given one month to demonstrate that their machines could handle the 5000 different ballots and many different languages in the county. Only one vendor, which had already conducted a pilot test in the county, could do so in the time allotted. Common ballot tool kits could reduce these problems.

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3. Best Practices

The most important standard that we can imagine today is to build to the "best of breed." Rather than have a laundry list of criteria that equipment must pass, voting equipment should be used if it is demonstrated to work extremely well for voters and administrators. Our study of equipment performance effectively established a best of breed of existing equipment—optical scanners and hand counted paper—if the goal is to reduce the number of unmarked, uncounted, and spoiled ballots. That is the equipment to beat, but it is far from perfect.

To build to the best of breed, though, requires public information about the performance of existing equipment. There needs to be information about what technologies for voting and voting registration are available, about how those technologies worked, and about how much the implementation of these systems cost.

The implementation of central voter files in Kentucky, Maryland, Michigan, and Oklahoma suggests that we can establish best practices in the area of voter registration roll maintenance and accessibility.

Three Ways to Proceed

1. Revise the existing standards process. Set specifications for security and tabulation. Set minimum criteria for accessibility, even if voluntary. Provide for multiple testing labs, not just one for hardware and one for software. There should be more federal oversight and involvement in the process. There should be more than one lab testing equipment and definitely more than one or two people testing software integrity. Checking code is very difficult, and is often done by many different people, not by one or two. Making the security and tabulation code of the equipment open source has the benefit of more thorough checking for bugs.

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2. Develop an information clearinghouse about existing equipment. This clearinghouse should be placed in a federal agency, perhaps NIST, the FEC, or a new agency, and should provide information to states and counties about the performance and cost of existing equipment.

3. Invest in independent research on voting systems. Ten years ago Brazil faced much worse problems than the U. S. does. Lack of integrity of the counting of ballots threatened the very legitimacy of that democracy. Brazil set up a consortium of engineering schools to develop new equipment designed to be highly reliable and usable by illiterate and blind voters. All innovations are public. The U.S. could follow a similar path. Competitive federal research grants could be offered to independent third parties, such as independent research labs or universities, to develop new security systems, new registration software, and new user interfaces, and to stress existing equipment before it is taken to market. The goal of such a process is not to certify machines, but to give the industry feedback

and the public information about what works and what doesn't.

What are the constraints?

Money.

In the counties for which we have detailed budget information, registration and overhead consume the lion's share of this. Equipment acquisition and maintenance accounts for about 20 percent and polling place operations about 10 to 20 percent.

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This is a small industry. Total revenues range between $150 million to 200 million annually. Equipment sales are highly decentralized: firms bid on contracts in each of the 3,100 counties. As a result, the industry has had to emphasize its sales force. That likely takes away from R&D within the industry. Our sense is that research on ballot design and user interface design has suffered. Smallness of the industry may also limit the profitability of the testing business.

This is a small part of government currently. We estimate that in 2,000 counties and municipalities spent $1 billion on all aspects of election administration. That's $10 per voter. That pays for all aspects of election administration locally.

Finally, there are significant financial constraints on the Office of Election Administration in the FEC. That office is one of the logical places to perform the sort of information distribution that we see as necessary in order to establish best practices and to improve the information that counties have when they purchase equipment.

Perhaps the most important accomplishment of our group so far has been demonstrating that it is possible and feasible to develop such information. Within our own group the study that I distributed sparked a heated debate over paper versus electronics. But that debate quickly settled into a design challenge. Can our engineers do better than optically scanned paper ballots? Can we as a country push the technology frontier out—making equipment more secure, more accurate, and more accessible? Brazil accomplished this through public investment. We are confident that the U.S. can too, and carefully crafted standards can stimulate innovation.

ABSTRACT

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An Assessment of the Reliability of Existing Voting Equipment

This report examines the use of voting equipment and the incidence of spoiled and unmarked ballots associated with that equipment. We call the rate of spoiled and unmarked ballots the residual vote rate. It is not purely error, should be unrelated to equipment if voting technologies are not producing voter mistakes or confusion. The study covers election results from over 2700 counties and municipalities in the 1988, 1992, 1996, and 2000 presidential elections.

The United States uses five general types of election technologies: hand-counted paper ballots, lever machines, punch cards, optically scanned paper ballots, and electronic machines (called direct recording electronics). There

are variations within each of these types of technology, but those are beyond the scope of this investigation.

Over the last two decades there has been a strong trend away from lever machines and hand-counted paper ballots and toward electronic machines and optically scanned paper ballots.

Approximately 2 percent of all presidential ballots are spoiled or unmarked.

The incidence of residual votes (spoiled and unmarked ballots) is highest for voters in counties using punch cards and electronic machines and is lowest for voters in counties using lever machines, optically scanned paper ballots, and hand-counted paper ballots.

The same pattern holds once we statistically control for all features of individual counties (including county literacy rates and income), the year of the election, total turnout, whether there was a shift in technology, and the presence of other candidates on the ballot.

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Optically scanned ballots look to be a viable alternative to older technologies. We see room for improvement with electronic machines, especially the newer touch screen technologies. We find the performance of punch cards to be alarming: punch cards are an established technology and the residual vote rate of this technology is nearly double that of alternatives.

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EDUCATION

Harvard University, Ph.D., Political Science 1989

University of Minnesota, B.A., Political Science 1984
B.S., Economics

ACADEMIC POSITIONS

1999–present — Professor, Department of Political Science, MIT
1993–1999 — Associate Professor, Department of Political Science, MIT
1989–93 — Assistant Professor, Department of Political Science, University of California, Los Angeles

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FELLOWSHIPS AND HONORS

Carnegie Corporation Fellowship, 2000–02
Goldsmith Book Prize for *Going Negative.* 1996
National Fellow, The Hoover Institution, 1993–94

Olin Research Associate, Graduate School of Business, Stanford University, 1987–88
Harry S. Truman Fellowship, 1982–86

PUBLICATIONS

Books

Going Negative: How Political Advertising Divides and Shrinks the American Electorate (with Shanto Iyengar). The Free Press, 1996.
The Media Game: American Politics in the Television Age (with Roy Behr and Shanto Iyengar). Macmillan, 1993.

Articles

Publications in various journals, including the *American Political Science Review*, the *American Journal of Political Science*, the *British Journal of Political Science*, the *Journal of Politics*, *Legislative Studies Quarterly*, *Public Opinion Quarterly*, *Chance*, and *The Quill.*

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PREPARED STATEMENT OF REBECCA MERCURI

Good Morning. I am Dr. Rebecca Mercuri of Lawrenceville, New Jersey, an Assistant Professor of Computer Science at Bryn Mawr College in Pennsylvania, and President of Notable Software, Inc. (a New Jersey computer consulting firm). My testimony today represents my own opinions and not those of my employers or any professional organizations with which I am affiliated. Thank you for the opportunity to address your Committee on this important matter.

For the last decade, I have investigated voting systems, with particular emphasis on electronic equipment (hardware and software) used to collect and tabulate ballots. Through this research, I have identified numerous flaws inherent to the application of computer technology to the democratic process of elections. These flaws are both technologically and sociologically based, so a quick (or even long-term) fix is not readily apparent. For example, present and proposed computer-based solutions are not able to resolve (and in some cases even increase) the likelihood of vote-selling, coercion, monitoring, disenfranchisement, and fraud in the election process.

Some of the problematic issues with electronic balloting and tabulation systems are as follows:

Fully electronic systems do not provide any way that the voter (or election officials) can truly verify that the ballot cast corresponds to that being recorded, transmitted, or tabulated. Any programmer can write code that displays one thing on a screen, records something else, and prints yet another result. There is no known way to ensure that this is not happening inside of a voting system.

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Electronic balloting and tabulation makes the tasks performed by poll workers, challengers, and election officials purely procedural, and removes any opportunity to perform bipartisan checks. Any computerized election process is thus entrusted to the small group of individuals who program, construct and maintain the machines. The risk

that these systems may be compromised is present whether the computers are reading punched cards or optical scanned sheets, or are kiosk-style or Internet balloting systems.

Although (in many states) convicted felons and foreign citizens are prohibited from voting in U.S. elections, there are no such laws regarding voting system manufacturers, programmers and administrative personnel. Felons and foreigners can (and do!) work at and even own some of the voting machine companies providing equipment to U. S. municipalities.

Each election season, newly deployed voting equipment fails to perform properly in actual use. Communities that rely on promises of security and accuracy when purchasing such systems, run the severe risk that they will administer an election whose results may be contested. Even worse, system defects may be revealed years after an election, making all earlier results questionable.

Electronic balloting systems without individual print-outs for examination by the voters, do not provide a wholly independent audit trail (despite manufacturer claims to the contrary). As all voting systems (especially electronic) are prone to error, the ability to also perform a manual hand-count of the ballots is essential.

Some electronic systems actually make the balloting process more lengthy, tedious and confusing, by requiring additional keypresses or transactions. The use of such devices has even been viewed, by some, as a modern-day literacy test.

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Encryption can not be relied on to provide end-to-end privacy assurance. Nor can it assure the accuracy of ballot data recorded and tallies rendered. Cryptographic systems, even strong ones, can be cracked or hacked, thus leaving the ballot contents (and possibly also the identity of the voter) open to perusal.

Internet voting (whether at polling places or off-site) provides avenues to the entire planet for malicious denial-of-service attacks. If the major software and hardware manufacturers in the United States are incapable of protecting their own companies from repeated Internet attacks, one must understand that voting systems (created by these firms or others) will be no better (and likely far worse) in terms of vulnerability.

Off-site Internet voting also creates unresolvable problems with authentication, leading to possible loss of voter privacy, and increased opportunities for vote selling. Furthermore, Internet voting may make it easier for the techno-savvy elite to cast ballots, while potentially disenfranchising or at least creating a digital divide for the poor, elderly, rural, and disabled voters who do not have equal access to the Web.

It is not possible to create a standardized voting system that could be used in all municipalities (as has been proposed by some members of Congress), without treading seriously on States' rights issues, and without mandating changes in many conflicting election code laws to provide conformity. (For example, in some States, one can cast a "straight party" ballot in a general election; some States require full-face ballots, etc.)

These are but some of my concerns, many more appear in articles and papers I and other computer industry experts have written on this subject over the last few years. (Most of which are accessible via my web site at http://www.notablesoftware.com/evote.html or http://mainline.brynmawr.edu/rmercuri) These concerns are not new—Roy Saltman noted many of these issues in his 1988 NBS report.

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Now the computer industry has already established standards for secure system certification, mandated by Congress under the Computer Security Act of 1987. NIST typically administers this certification for devices purchased by the Department of Defense. Congress, though, exempted itself from compliance with the Act, hence they have never certified the accuracy and integrity of any computer-based voting systems used in Federal elections. This loophole must be changed. The existing standards are far from perfect, but they are the best assurance mechanism that the computer industry has at present. (It is important to understand that the Federal Election Commission does not now have voting system standards in place. Instead, the purchasers and vendors use an obsolete set of suggested practices that were never adopted by all of the States.)

To date, no electronic voting system has been certified to even the lowest level of the U.S. government or international computer security standards (such as the ISO Common Criteria or its predecessor, TCSEC/ITSEC), nor has any been required to comply with such. No voting system vendor has voluntarily complied with these standards (although voluntary compliance occurs within other industries, such as health care and banking), despite the fact that most have been made aware of their existence and utility in secure product development. There are also no required standards for voting displays, so computer ballots can be constructed to give advantage to some candidates over others.

I have long recommended that the NIST standards be applied to voting systems. As a part of my Doctoral Dissertation at the University of Pennsylvania, I performed a detailed evaluation of the Common Criteria against the features of voting systems. The painstaking description in the thesis provides an excellent starting point for the development of a voting standard. (I have provided the House Science Committee with a complete copy of my thesis, additional copies may be ordered from me via the contact information at the end of this testimony.) I have also formulated lists of questions that voting system vendors should be required to answer about their products. (Two of these lists are attached to this testimony—it should be noted that the answers are non-trivial and may require months of effort to produce validating documentation, as would be necessary for a Common Criteria evaluation.)

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I would suggest that first a trial standard be developed, along with an assessment procedure. Then, voting systems (applying different state requirements) should be constructed and assessed against the standard to see what level of conformance is possible using current technologies. It is important that any new systems maintain a human-readable independent auditing mechanism, and that off-site voting not be used (for reasons mentioned above). All new systems must be subjected to real-world testing conditions (not simulations) to determine usability and discover risks.

In conclusion, I would like to remind the Committee that technology can not and does not, at present, provide a solution to the balloting and tabulation problem. Our society has become increasingly enamored with computers, yet we all have experienced, first-hand, their (sometimes catastrophic) failures in products we use every day. The same is true for computer-based voting systems, but here, there are no warranties and insurance provided if we have problems with the results. It is therefore crucial that we continue to maintain and impose human checks and balances throughout our election process. This is the only way to insure that our democracy does not become one that is by the machines, of the machines and for the machines. Thank you.

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ABSTRACT

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There are numerous flaws inherent to the application of computer technology to the democratic process of elections. These flaws are both technologically and sociologically based, so a quick (or even long-term) fix is not readily apparent. Some issues have been identified as follows:

1) Fully electronic systems do not provide any way for the voter (or election officials) to verify that the ballot cast corresponds to that being recorded, transmitted, or tabulated;

2) Electronic balloting and tabulation makes the tasks performed by poll workers, challengers, and election officials purely procedural, and removes most opportunities to perform bipartisan checks;

3) Convicted felons and foreign nationals are permitted to work at and own voting system companies;

4) Voting equipment failures occur even with new equipment;

5) Manual recount capabilities must be provided for independent auditing;
6) Some electronic systems may make balloting more difficult rather than less;

7) Encryption does not guarantee privacy or accuracy;

8) Internet voting increases possibilities for tampering, and creates unresolvable problems with voter authentication and vote selling;

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9) Conflicting State election requirements make standardized voting systems unimplementable.

Security assessment procedures (such as the ISO Common Criteria administered by NIST) exist, but these have not heretofore been required for voting systems. Prior extensive work by Rebecca Mercuri can likely be incorporated as a basis for the establishment of Common Criteria-style balloting and tabulation standards. Although standards will certainly help improve voting systems, human checks and balances will continue to be necessary in order to ensure that technologies are properly applied.

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Rebecca Mercuri's Statement on Electronic Voting

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I am adamantly opposed to the use of fully electronic systems for use in anonymous balloting and vote tabulation applications. The reasons for my opposition are manyfold, and are expressed in my writings as well as those of other well-respected computer security experts. To briefly summarize my opinion (based on a decade of research) on this matter I state the following:

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Fully electronic systems do not provide any way that the voter can truly verify that the ballot cast corresponds to that being recorded, transmitted, or tabulated. Any programmer can write code that displays one thing on a screen, records something else, and prints yet another result. There is no known way to ensure that this is not happening inside of a voting system.

Electronic balloting systems without individual print-outs for examination by the voters, do not provide an independent audit trail (despite manufacturer claims to the contrary). As all voting systems (especially electronic) are prone to error, the ability to also perform a manual handcount of the ballots is essential.

No electronic voting system has been certified to even the lowest level of the U.S. government or international computer security standards (such as the ISO Common Criteria or its predecessor, TCSEC/ITSEC), nor has any been required to comply with such. Hence, no current electronic voting system has been verified as secure.

There are no required standards for voting displays, so computer ballots can be constructed to be as confusing (or more) than the butterfly used in Florida, giving advantage to some candidates over others.

Electronic balloting and tabulation makes the tasks performed by poll workers, challengers, and election officials purely procedural, and removes any opportunity to perform bipartisan checks. Any computerized election process is thus entrusted to the small group of individuals who program, construct and maintain the machines.

Although convicted felons and foreign citizens are prohibited from voting in U.S. elections (in many states), there are no such laws regarding voting system manufacturers, programmers and administrative personnel. Felons and foreigners can (and do!) work at and even own some of the voting machine companies providing equipment to U. S. municipalities.

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Encryption provides no assurance of privacy or accuracy of ballots cast. Cryptographic systems, even strong ones, can be cracked or hacked, thus leaving the ballot contents along with the identity of the voter open to perusal. One of the nation's top cryptographers, Bruce Schneier, has recently expressed his concerns on this matter, and has recommended that no computer voting system be adopted unless it also provides a physical paper ballot perused by the voter and used for recount and verification.

Internet voting (whether at polling places or off-site) provides avenues of system attack to the entire planet. If the major software manufacturer in the USA could not protect their own company from an Internet attack, one must understand that voting systems (created by this firm or others) will be no better (and probably worse) in terms of vulnerability.

Off-site Internet voting creates unresolvable problems with authentication, leading to possible loss of voter

privacy, vote-selling, and coercion. Furthermore, this form of voting does not provide equal access for convenient balloting by all citizens, especially the poor, those in rural areas not well served by Internet service providers, the elderly, and certain disabled populations. For these reasons, off-site Internet voting systems should not be used for any government election.

It is a known fact that the computer industry does not have the capability, at present, to assure a safe, reliable election using only electronic devices. Thorough investigation of vendor claims (such as those performed by New York City on DRE products), and failures of performance in actual elections, have demonstrated the existence of major flaws. Communities that rely on promises of security and accuracy when purchasing such systems, run the severe risk that they will administer an election whose results may someday be contested—but they will not be able to provide an independent audit which can ascertain the content of the true ballots cast. In short, Florida all over again. Even worse, system defects may be revealed years after an election, making all earlier results questionable.

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It is therefore incumbent upon all concerned with elections to REFRAIN from procuring ANY system that does not provide an indisputable paper ballot which can be checked-by the voter visually before deposit and used by the election board in the case of recount.

Generic Security Assessment Questions

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Certain generic questions emerge in the evaluation of secure products. These are not particular to the voting setting, but can be used as the basis of an assessment methodology for electronic vote tabulation systems. The list presented here can be augmented with additional items or finer detail, as necessary. Purchasers of secure systems should work with independent testing agencies that have demonstrated the high level of expertise necessary in order to evaluate vendor responses to these questions.

1. What are the assets that require security protection?

2. What security risks have been identified, and what is the likelihood of each?

3. What countermeasures have been specified to deal with the identified risks?

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4. What security assurance level has been selected for the system? Justify the appropriateness of this rating. How has conformance been established?

5. What assumptions are made about the operating environment in order for it to be deemed secure?

6. What are the policies and rules required to enforce security?

7. What are the specified security functions and assurance measures? Have these been traced back to the

functional requirements to insure that coverage is comprehensive?

8. Has a security requirements rationale document been presented? Does it demonstrate consistency with the security objectives for the system? Is the rationale comprehensive and consistent? Are any objectives unsatisfied, and if so, why?

9. What are the integrity concerns, and how have these been addressed?

10. What procedures are in place for secure system development? How have these been enforced and documented?

11. What are the resource allocation, priority of service, and fault tolerance policies and procedures?

12. What are the data requirements, and how are these implemented and enforced?

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13. What are the data retention policies and procedures?

14. Have all communication paths been identified and secured as appropriate?

15. What are the confidentiality requirements, and how are these implemented and enforced?

16. What are the user roles? How are rules applied and enforced with the roles?

17. What are the authentication, authorization, and access control policies? How are these applied and enforced?

18. What are the administrative tasks and responsibilities?

19. Have the interfaces been assessed as to their appropriateness and correctness?

20. Are all administrator and user guidance documents complete and usable?

21. What are the startup, shutdown, recovery, and rollback policies? Which roles are responsible for these tasks?

22. How is the system delivered, installed, and generated? Which roles do this?

23. What tests are performed in order to insure correctness? When are these tests done? Who is responsible for conducting these tests?

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24. How is the system validated for acceptance and compliance? Who does this?

25. What are the facility requirements, including physical protection of the system? What roles have been assigned responsibility for facility aspects?

Questions for Voting System Vendors

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The following questions can be used in conjunction with the generic security questions in order to elicit information regarding any electronic balloting and/or tabulation system under assessment. Answers should include thorough documentation and independent evaluation and testing to support vendor claims. Additional questions pertinent to the particular system being investigated should be added as necessary.

1. What means is used to separate voter identity from voted ballot?

2. How is the balloting process secured such that voter submissions can not be observed, or recorded in any way that is traceable to the individual voter?

3. What actions on the system are audited?

4. How is the auditing process precluded from associating voters with cast ballots?

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5. How is the audit trail accessed and used?

6. Who is permitted to access the system (through all aspects of handling)?

7. What facilities are provided for recount purposes?

8. How are voters authenticated and authorized to cast ballots?

9. What access controls are in place to ensure single ballot per voter per election?

10. If multiple systems are deployed, how are voters tracked so the same person does not vote in different formats?

11. What controls are used to ensure that the correct ballot is provided to the voter?

12. What controls are provided to ensure that each ballot item is voted properly?

13. How are all forms of tampering detected and prevented?

14. How is vote confirmation provided without ballot-face receipt?

15. How is the voter prevented from retaining a copy of the cast ballot?

16. How does the system assure that each ballot has been correctly recorded?

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17. How does the voter know that a cast ballot has been accepted?

18. How is vote tabulation correctness assured?

19. What features are employed to ensure operability of the voting system throughout the election?

20. How are downtimes handled in the event that they do occur?

21. What alternative balloting system is available for voters when the system is down?

22. How do the poll workers and system administrators know that the system is operating correctly?

23. How is the voting system precluded from use when deemed inoperable?

BIOGRAPHY FOR REBECCA MERCURI

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Dr. Rebecca Mercuri is a member of the Computer Science faculty at Bryn Mawr College, and President of the consulting firm Notable Software, Inc. Her specialties in the computer field include: real-time and interactive programming, security and risks, and forensic investigations.

Rebecca holds advanced degrees in Computer Science and Engineering and has worked for numerous Fortune 100 firms (AT&T, Intel, Merck, RCA Corp) and government agencies (Federal Aviation Administration, United States Army). As an expert witness, Dr. Mercuri has performed civil, criminal and municipal case work, and patent reviews. For the recent Florida recount, she was requested to submit an affidavit which was presented before the 11th Circuit Court of Appeals in Atlanta, and referenced in one of the U.S. Supreme Court briefs.

Rebecca's interest in voting systems and elections dates to the late 1980's, with extensive writings on this subject, including testimonies and investigations of elections and equipment in seven states. She has served as a committeewoman and poll worker in Bucks County, PA, and is currently an election official in Mercer County, NJ. Dr. Mercuri's Ph.D. thesis at the University of Pennsylvania, "Electronic Vote Tabulation: Checks and Balances," explains why there are inherent flaws in assuring confidentiality and auditability in computerized elections, and provides a list of criteria for the evaluation of election equipment. Information about the thesis and Rebecca Mercuri's other papers and activities are available on her electronic voting webpage at: http://www.notablesoftware.com

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PREPARED STATEMENT OF ROY G. SALTMAN

The Importance of Research and Standards in Effective Election Administration

1. Summary of Responses to Specific Questions in Chairman's Letter:

(1) What kinds of problems have been identified in the various voting systems used throughout the United States?

A**NSWER**: *Ease-of-use issue:* In general, all voting systems require that voters understand how to use them, or voters will not transcribe their choices correctly. The excessive number of overvotes and undervotes in the recent Presidential contest has been identified as a demonstration that many voters are not knowledgeable of the correct use of voting machinery. In my opinion, pre-scored punch card voting systems are the worst type from an ease-of-use perspective. In addition, pre-scored punch card systems allow voters more of an opportunity to make ambiguous voting attempts where the voter's intent is not clear, or to make incorrect choices by mistake, or to have their intents misstated through hanging chad that is pushed back into the ballot card by the process of ballot stacking. Also, pre-scored punch card systems are more susceptible to creating voter error due to poor maintenance or poor preparation by administrators for use in voting. With optical scan voting systems, there is a "voter's intent" issue, but it is not so severe as with pre-scored punch cards. *Undervote/Overvote issue:* Associated with ease-of-use is the apparently excessive numbers of overvotes and undervotes cast in the Presidential election. Re-design of voting machinery, as well as better and more intensive voter education, could overcome some of this problem. *Assurance of correctness issue:* With direct-recording electronic systems, there is no voter intent issue, and overvotes are prevented, but there is an issue of assurance of correctness because of the lack of a hard-copy audit trail. It is important for public confidence to assure that the outcomes reported by direct recording electronic systems can be shown to be correct. Software and hardware must be assured to be correct. *Equipment reliability issue:* Equipment failures on election day cause loss of public confidence. It is essential that all equipment work correctly on election day, and that contingency plans be in place for equipment that fails. *System management issue:* In some cases, administrators are not fully prepared, and do not have all systems and equipment in place on election day. Handling of hardware and software to assure security is important. *Disabled voter issue:* Voters having disabilities, such as sight-limitations and mobility limitations, complain that they cannot vote without assistance. (See also Section 5. Current Vote-Casting Systems.)

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(2) Which of these problems could be addressed by developing or improving standards, and what kinds of standards, if any, would need to be developed or improved?

A**NSWER**: More explicit standards for preparation, testing and checkout of voting equipment and assurance of spare parts and of fallback contingency planning would reduce the incidence of difficulties on election day. Standards on the requirements for voting equipment to have acceptable characteristics of voter ease-of-use would reduce the incidence of overvoting, undervoting and mistaken voting. Standards requiring voting equipment to be precinct-located instead of centrally located would make it possible for voting equipment to inform voters of unintended overvotes and undervotes, and standards on providing this extra information to voters should be implemented. Equipment designs to eliminate overvoting and to give voters a second chance to reduce undervoting could be included in standards. (See Section 3.3 Establishment of Robust National Standards, and Section 5.1 Precinct Count versus Central Count.)

(3) What kinds of research, testing, or data-collecting activities do you think are necessary in order to develop effective voting standards?

A**NSWER**: See Section 3 Appropriate Federal Functions, including Section 3.1 Data Collection, Analysis and Reporting, 3.2 A Research Program, 3.3 Establishment of Robust National Standards, 3.4 Accreditation of Independent Testing Laboratories; also Section 4 Essential Criteria for Research and Standards.

2. A New Opportunity

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The several types of difficulties that occurred in the Presidential election in Florida in November, 2000, have created an opportunity for a general reconsideration of the overall Federal role in election administration. This opening has occurred because political decision-makers at the highest national levels, as well as other nationally influential organizations and individuals, are now sensitized to the issue. Before November 7, 2000, there was very little recognition by members of this group that there was a problem, and no significant reconsideration was possible.

As a consequence of the new situation, proposals for changes in the Federal role are being widely considered, as this hearing demonstrates. A discussion of the Federal role implies concern with the institutional organization of the Federal Government for the function of election administration, the delineation of responsibilities and their assignment to appropriate agencies, the specification of requirements for special competencies of Federal management and professional-grade personnel, and the determination of short-range and long-term resources to be appropriated for the function.

3. Appropriate Federal Functions

In my view, the following election activities should be carried out by the Federal Government. Note that the list does not include the direct administration of elections. In several areas of civil activity, the Federal Government undertakes activities similar to those discussed below, while the states and local governments actually deliver the services. This occurs, for example, in highway transportation, in public education, and in public health. In all these areas, the Federal Government collects data, undertakes research, and provides grants-in-aid, while not actually delivering the services.

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3.1 Data Collection, Analysis, and Reporting: Documentation is needed for reports of equipment performance and incidents of difficulties with either machines or procedures. Data concerned with the ability or inability of voters to use voting machines successfully (such as collection of undervote and overvote data) also would be useful to obtain on an organized basis. Such data would serve a valuable information exchange function for election administrators, and could provide the basis for a research agenda and for standard-setting.

3.2 A Research Program: A coherent national effort could include (1) studies of the ease-of-use of different vote-casting methods, (2) product-independent research into new types of voting systems, including ATM-like terminals and use of the Internet, (3) analysis of techniques for improving the capability of sight-limited voters to vote without assistance, and (4) development of new methods of voter identification that could be applied to precinct-located voting or remote voting.

3.3 Establishment of Robust National Standards: The FEC issued national voluntary standards in 1990, and

while an updating effort is underway, a draft revision has not yet been released. These standards should be updated at more frequent intervals, and this can only be accomplished with the availability of more financial resources. The 1990 standards, although adopted in Florida, did not prevent the November, 2000, difficulties in that state because there are no rules contained in them on human factors or on vote-entry devices. Additionally, significant quantities of election equipment were "grandfathered," allowing them to circumvent the requirements of the standards. Subjects that might be covered in more robust standards include security, integrity and accuracy of election processes, documentary proof of correctness in non-ballot systems, hardware and software certification and re-certification, pre- and post-election checkout of equipment, election management activities, human factors in voting including design of vote-entry equipment, transmission and acceptance of absentee and mail ballots, and recounting procedures including definition of a vote in any system in which "voter's intent" could be an issue.

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3.4 Accreditation of Independent Testing Laboratories: The FEC has carried out this process to enable vendors to have their equipment certified for use in states that have adopted the national standards. Given the resources available, the FEC has done a reasonable job, but the activity would be better assigned to a highly experienced agency that has recognized expertise in the field.

3.5 Support for Statewide Voter Registration Systems: The high mobility of the U.S. public, both interstate and intrastate, suggests that the application of computer and communications technology would assist the maintenance of accurate and complete voter registration lists in every state, and would enable state databases to interchange information. Standards for electronic data interchange could be developed and applied.

3.6 Grant Programs: Such programs would provide some of the necessary resources to permit states to upgrade election equipment as well as vote summarizing and reporting systems. They could also assist the development of statewide voter registration databases capable of interstate electronic data interchange, and develop county-wide voter registration databases with precinct-located terminals to smooth election-day voting authority verification. Additionally, they could be used for training voters, poll workers, election administrators and personnel who test and maintain election equipment.

4. Essential Criteria for Research and Standards

4.1 Public Confidence: A fundamental requirement that we should keep in mind when considering what improvements to propose and carry out is "public confidence" in the voting process. We should be aiming to assure a voting system with very strong fraud-prevention characteristics, with strong assurance of accuracy, integrity, user-friendliness, and reliability, and which produces results that are unambiguous and demonstrable with supporting documentation. There must be in place clear procedures and instructions that both voters and poll workers can easily carry out. We should be aiming for a system design causing our voting process to be "transparent," so that recourse to the courts, as we have just witnessed in Florida, will be extremely rare. We cannot assure 100% system operability at all times, but we can have in place fallback mechanisms and procedures that anticipate almost all unplanned possibilities.

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4.2 Issues in Vote-Casting and Vote-Counting: The accuracy of the voting system in use is extremely important when the difference in vote totals between the major candidates is small. The standardization of procedures to

determine voter's intent should be a priority so that they are the same for the use of the same system anywhere. The user-friendly quality of the voting system must be very high so that the likelihood is maximized that the voter will be able to correctly transcribe his or her intent into commands that the computer will interpret exactly as the voter intended.

4.3 Voter Registration and Identification Systems: It is important to recognize that the adoption of the most effective methods of vote-casting and vote-tallying are not the only requirements for public confidence. States need to review their current voter registration and voter identification systems for possible improvement. This review cannot be undertaken without considering the Federal Government, since there is extensive Federal law on voter registration. Additionally, application of new technology for voter identification may require considerable funds for research and development, for which Federal assistance could be available in the future. Furthermore, maintenance of an up-to-date list of registered voters, given the situation of our very mobile population, will require extensive use of data processing techniques and considerable interstate cooperation, hopefully fostered with Federal Government assistance and involvement.

5. Current Vote-Casting Systems

A voter in the U.S. now may use one of the following mechanical or electronic systems in casting votes, depending on the selection by the local jurisdiction of the voter's residence: a lever machine, a pre-scored punch card (PPC) system, a Datavote punch card system, an optical scan (mark-sense system), a push-button direct-recording electronic (DRE) system or a touch-screen DRE system. (A few voters, about 1%, continue to vote with hand-marked, hand-counted ballots, because that system is cost-effective in rural, lightly populated areas.) Let us assume that any lever machines now in use will not be considered in future standards, even though 19% of U.S. voters currently use them. Such machines are likely to be "grandfathered" so that no changes will be demanded of them. I have stated my opinion about PPC systems, i.e., their use should be ended, and I continue to assert that point. The remaining systems, Datavote, optical scan and DRE, have advantages and disadvantages; there is not one "best" system. However, future research on human factors in vote-casting may show that some of these systems are more user-friendly than others, although I have no good data on this, currently. Some characteristics of the major types of systems are given, following the discussion on the need for precinct counting.

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5.1 Precinct Count versus Central Count: With ballot-tallying systems, i.e., either mark-sense or Datavote, I propose that only a precinct-count process be used in the future, rather than the current mixed use of both precinct count and central count. With the latter system, voted ballots are not counted at the precincts, but are collected and transported to a central location where they are counted. (DREs are typically designed only for precinct count.) Precinct counting allows for a voter to be informed of overvotes and to correct his or her ballot. Precinct counting may be used also to inform the voter of undervotes and give the voter a second chance to vote on additional contests, if the voter so chooses. Precinct counting also minimizes the insecurity of transportation of voted but uncounted ballots, permits local precinct officials and workers to receive the results quickly, and eliminates the uncertainty of having the ballots counted (and possibly altered) somewhere else. Although precinct counting is more expensive than central counting, requiring a machine in each voting location, the advantages in risk reduction, elimination of overvoting, and increase in public confidence are worth the extra cost, in my opinion. It appears to me that the historic inability to apply sufficient resources to elections has disadvantaged both administration and the voters, and has hurt public confidence.

5.2 PPC Systems: Positives, Negatives and Recommended Changes

Positives

IBM card readers were widely available at the time that the system was introduced.

The distinction between the presence of a completely punched out hole and the complete absence of a hole is easy for a ballot-reader to make.

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Central-counting of ballots is inexpensive.

A large, central computer is the only computer required to process ballots.

Negatives

Accurate results that are repeatable depend on the complete removal of chad, an activity which many voters fail to carry out; hanging chad can be forced back into the card during the card stacking process, misstating the voter's intent.

Excessive handling or bending of the ballots can cause extra chad to pop out, misstating the voter's intent.

Incorrect insertion of the ballot card into the ballot holder, or misinterpretation of the ballot-holder instructions, may cause the voter to punch out unintended holes or fail to punch out the intended ones, thereby causing a misstatement of the voter's intent.

Failure of the administrators to adequately maintain the ballot-holders or to assemble their parts correctly in preparation for their use, may contribute to the inability of the voters to correctly record their choices; "pregnant" or "dimpled" chad may result.

The failure of the ballot-card to have the names of the candidates on the card (names are only on the pages of the ballot-holder mechanism) prevents voters from assuring that the intended choices have been made after the voter removes the card from the ballot-holder and before the voter drops the card into the ballot-box.

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Inherent difficulties in the presentation of the candidate names and their relationships to their hole location makes the system extremely voter-unfriendly.

Recommended Changes

The system is inherently flawed. No changes, in my opinion, will improve it to the point of it being sufficiently voter-friendly. Use of the PPC system should be ended.

5.3 Datavote Systems: Positives, Negatives and Recommended Changes

Positives

If the ballot is properly fixed in the holder, the voter can only punch in a voting location.

All punches are the same size, and no hanging or dimpled chad results from punching, minimizing the likelihood of a "voter-intent" issue.

Other "positives" are the same as for mark-sense systems, except that Datavote is not as good for absentee ballots.

Negatives

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A voter may not fix the ballot properly in the holder, making incorrect punches possible.

The small size of the ballot card requires the use of several ballot cards for each voter, and requires higher speed card readers. The extra cards provide the potential for voters to forget to vote all cards or to forget to turn over the cards to vote the other sides.

Other "negatives" are the same as for mark-sense systems.

Recommended Changes

Precinct count rather than central count should be used, and the card readers should be redesigned so that a wider, single ballot card such as is available with mark-sense ballots, could be used. The number of pieces of paper handled would be considerably reduced.

A small percentage of precincts should be hand-counted to verify computer-based results.

5.4 Optical Scan Systems: Positives, Negatives and Recommended Changes

Positives

Overvotes can be prevented in a precinct located system if an overvoted ballot is returned to the voter by the computer, and the voter is offered the opportunity to correct errors of this type.

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The likelihood of voter waiting lines is very small as many voters can fill out their ballots simultaneously.

A maximum of one computer is required per voting location.

If all ballots are accounted for, a paper audit trail is available.

The hard-copy ballot is an automatic fallback mechanism if the local computer fails.

Write-in voting is easy to accomplish.

It is a good system for absentee balloting.

Negatives

A voter may disregard instructions and not correctly fill in the voting location, or forget to turn the ballot card over to complete the voting process.

A voter should request a new ballot if an error is made. (Erasures may confuse the computer.)

"Voter intent" may have to be determined in a very close election.

Informing the voter of unintentional undervotes is not possible, in general.

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Ballot stub numbering and special precinct procedures must be used to prevent "ballot stuffing" and "chain voting."

The cost of ballots may be an issue; ballots cannot be reused.

Card stock must be carefully selected, and printing must be precise.

Recommended Changes

A small percentage of precincts should be hand-counted to verify computer-based results.

5.5 DRE Systems: Positives, Negatives and Recommended Changes

Positives

No "voter-intent" issue exists, as each voting action is immediately converted to a standard electronic form.

Re-programming is easier than re-printing for hard-copy ballots if a court should order a change in ballot very soon before an election.

No hard-copy ballots are used, except for fallback and absentees; this saves costs.

Overvotes are automatically prevented by computer logic.

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Negatives

Each voter monopolizes the use of the DRE machine while voting; this may create waiting lines.

The elimination of waiting lines requires the use of more than one DRE machine per precinct; this is clearly a more expensive implementation than the use of a single computer and reader to receive and count hard-copy ballots.

There is no automatic fallback. Spare DRE machines must be available, or hard-copy ballots must be made available if machines fail.

The write-in process may be more difficult than for hard-copy ballots. A keyboard may have to be provided.

The assurance of machine correctness is very difficult to prove, as there is no paper audit trail.

DREs cannot be used for absentee ballots; a hard-copy ballot must be used, until such time as remote on-line voting is possible and generally available for all absentees.

Recommended Changes

DRE machines should be redesigned to allow for pre-voting checkout at the precinct, to make sure that the machines are operating correctly before being allowed to be used by the voters.

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DRE machines should be designed to separately store, in a write-only-once memory, the "electronic ballot image" (EBI) of each voter's choices; the requirement of retaining EBIs is included in the Federal Election Commission voluntary standards.

EBIs should be stored on removable diskettes, and a small percentage of precincts should be recounted on an independently programmed computer.

DRE machines should be programmed to inform the voter, after a first press of the final "vote" indicator, that he or she has neglected to vote on some contests, if that is the case, giving the voter the option to go back and vote additionally or to ignore the message and press the final "vote" indicator a second time. Such a message may assist a forgetful voter, and gives a second chance to a voter who has mistakenly pressed the final "vote" indicator sooner than he or she intended.

ABSTRACT

The Importance of Research and Standards

in Effective Election Administration

by Roy G. Saltman, M.S., M.P.A., Consultant on Election Policy and Technology, 5025 Broken Oak Lane, Columbia, MD 21044; Phone: 410–730–4983; Fax: 410–997–4355; e-mail: rsaltman@alum.mit.edu

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Problems seen by voters using different voting systems are described, and suggested subjects of improved standards and research are indicated. Appropriate Federal functions for election administration are discussed. These functions include (1) data collection, analysis, and reporting; (2) a research program; (3) establishment of robust national standards; (4) accreditation of independent testing laboratories; (5) support for statewide voter registration systems; and (6) grant programs. Essential criteria for research and standards include maintenance of public confidence and assurance of the accuracy and voter-friendliness of voting systems. Current voting systems are described, and their advantages and disadvantages are listed. Recommended changes in each system are discussed, except that use of the pre-scored punch card system should be ended. The advantages of precinct-counting of ballots over central counting is discussed.

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Work Objective:

Consulting on election processes, in areas of public policy, system planning, technology and equipment selection, standards development, voter ease-of-use, costing, integrity and security, implementation and evaluation, dispute litigation.

Recent Consulting Experience:

2001: participating in Constitution Project and Caltech/1VBT election reform studies; also consulted for a law firm in litigation; *2000:* consulted for an election software vendor; also participated in the National Science Foundation-sponsored Internet Voting Workshop; *1999:* evaluated new Japanese election equipment at request of the manufacturer; *1999, 1998:* for International Foundation for Election Systems (IFES), worked with the Government of Ecuador to plan computerization of elections, including equipment selection; *1998,1997:* evaluated competitive election equipment prepared for sale to Venezuela; *1996:* for Inter-American Development Bank and Government of Brazil, wrote a requested report evaluating Brazil's new computerized voting system on criteria including voter ease-of-use and security.

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Government Work Experience:

With National Institute of Standards and Technology (NIST, formerly NBS) *1969–1996* (now retired), as a computer scientist concerned with information systems standards and policies; worked with many Federal agencies, U.S. states and local governments, the private sector, national governments, and the UN.

Authored two nationally distributed reports *(1975, 1988)* on the integrity and security of computerized vote-tallying in national elections; called on for assistance or comments on the integrity of the vote-counting process by governmental bodies, candidates, and public-interest organizations; interviewed and quoted by the media as a result of the 2000 Presidential election.

Promoted adoption, within the Government as well as nationally and internationally, of a standard system of electronic data interchange (EDI) that facilitates electronic commerce; investigated and recommended security for EDI; authored the Federal regulation on EDI use.

Private Sector Experience:

Worked for Sperry Gyroscope and IBM for 9 and 5 years respectively *(1955–1969);* carried out logical design of computers, designed and wrote applications software, made presentations on features and applications to prospective customers.

Presentation Experience:

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Academic Credentials:

Master of Public Administration in Public Policy from American University *(1976);* Professional, Master's and Bachelor's Degrees in Electrical Engineering respectively from Columbia University *(1962),* Massachusetts Institute of Technology *(1955),* and Rensselaer Polytechnic Institute *(1953).*

Examples of Reports and Publications:

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Examples of Public Speaking:

"Election Reform: Need and Prospects," Common Cause, annual leadership meeting, Washington, DC, 3/2/01.

"Planning for Computerization of Elections in Ecuador", *Andean Subregional Conference on Automation of Civil Registries and Electoral Procedures*, Quito, Ecuador, 8/18/99; conference sponsored by Organization of American States (OAS).

"Electronic Voting: Advantages and Disadvantages", *First International Convention on Electoral Processes*, Lima, Peru, 1/20/99; (text available from IFES, Washington, DC)

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"Security Issues in Electronic Benefits Transfer," *U.S. Computer Systems Security and Privacy Advisory Board*, 9/14/94, Gaithersburg, MD.

"Computerization of the Election Process," invited lecture at a graduate course in "Computers, Freedom and Privacy," *George Washington University*, 11/3/92, Washington, DC.

"Security in the Interchange of Electronic Documents," *Information Systems Audit and Investigations Roundtable of the President's Council on Integrity and Efficiency*, 9/23/92, Washington, DC.

"Use of Cryptographic Techniques in Computerized Voting," *Conference on Government Cryptography Policy*, Computer Professionals for Social Responsibility, Washington, DC, 6/10/91.

"Non-Cryptographic Techniques for EDI Security," *Conference on EDI and the Law '91*, Data Interchange Standards Association, Washington, DC, 2/26/91.

"Computerized Elections: The Quest for Public Confidence," invited seminar lecture at *University of Maryland, Institute of Urban Studies*, 10/27/90, Baltimore, MD.

"Automation of Elections," *RAND Corp*. 6/27/89, Santa Monica, CA.

"Improving Public Confidence in Computerized Election Outcomes," *International Association of Clerks, Recorders, Election Officials and Treasurers* (IACREOT), annual meeting, 6/26/89, San Diego, CA.

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PREPARED STATEMENT OF DOUGLAS W. JONES

Problems with Voting Systems and the Applicable Standards

Indexed on the web at http://www.cs.uiowa.edu/jones/voting/

Introduction

Elections are a defining feature of democratic government, but all too frequently, we take the actual mechanics of the election for granted. We speak at length of such issues as who is allowed to vote, how campaigns are conducted, and how they are financed, but prior to the events in Florida last November, most people's understanding of the actual voting process was something like the following: "You go to the polls, cast your vote, and then they count it and they announce the winner."

Here, my focus is on how you cast your vote, who *they* are who count it, how *they* go about counting it, and how the winner is determined. I will begin by discussing this in a historical context, and then I will discuss the regulatory environment that controls this process, I will give examples of significant shortcomings in this regulation, and finally, I will discuss changes that might be made.

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Some of the material here duplicates material that I presented in testimony before the United States Civil Rights Commission hearings in Tallahassee last January 11, but here, my focus will be on the relationship between the problems we have with today's voting machines and the current system of Federal and state standards that govern the use of these machines.

A Very Brief History of Voting Machines

Paper Ballots

When most people speak of voting on paper ballots, they imagine that they are speaking of an ancient technology, and in a sense, this is true. Hand written paper ballots were first used in Rome in 139 BCE, and their first use in America was in 1629, to select a pastor for the Salem church. These early paper ballots offered only modest voter privacy and they were fairly easy targets for various forms of election fraud.

The modern system of election using paper ballots was first used in 1858 in Australia. The great Australian innovation was to print standardized ballots at government expense, distribute them to the voters at the polling places, and require that the voters vote and return the ballots immediately. Today, the security against election

fraud this provides seems obvious, but in the 19th century, it was not obvious to most observers, and it was not until 1888 that this ballot was used in the United States.

A properly administered Australian paper ballot sets a very high standard, assuring voter privacy, preventing voters from revealing how they voted, and assuring an accurate and impartial count. It sets such a high standard that voters from many parts of the world find it remarkable that we in the United States are willing to trust our votes to anything else. This is particularly true of the British Commonwealth, where paper ballots remain the rule.

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The search for alternative voting methods in the United States was motivated by two factors. First, the entrenched political machines of late 19th century America learned quite quickly how to craft the laws governing the counting of votes under the rules of the Australian ballot so that those laws favored the entrenched political machine.

One of the classic approaches to subverting any election technology is to take control of the vote count. In the case of any physical ballot involving marks on paper, there will be marks that are on the borderline between acceptable and unacceptable votes, and vote counting rules that allow selective counting of marginal marks lie at the heart of a broad class of election rigging.

The most widely used approach to this is based on "objective and uniform standards for counting votes," a phrase heard often in discussions of the recent Supreme Court decision. If carefully chosen, these standards allow a skilled participant in the vote count to disqualify votes based on technicalities even when there is a clear indication of voter intent. Michigan's law governing the validity of ballot markings on hand counted paper ballots illustrates this approach remarkably well (See MCL 168.803).

By carefully controlling the makeup of the vote counting teams, the party in power can use these objective rules to selectively exclude votes for the opposition. Specifically, the party in power must ensure that the representatives of the opposition on each vote counting team are relatively poorly trained, while their own representatives trained to aggressively apply the rules only to ballots containing votes for the opposition while accepting obvious voter intent on ballots favoring their side. According to the 1910 Encyclopedia Britannica entry for voting machines, it was common in many jurisdictions for as many as 40 percent of votes to be excluded in the count!

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The second problem unique to the American system is the institution of the general election. Paper ballots are easy to count if there are only a few offices on the ballot, with only a few candidates per office, as is the norm in most parliamentary democracies. In our general elections, it is common to find well over 30 candidates on one ballot, divided between 8 to 15 offices, and this was the case even before the advent of ballot initiatives! An accurate hand count for ballots of this complexity is both difficult and time consuming.

Lever Voting Machines

Lever voting machines were first used in 1892 in New York, and were slowly adopted across the country. Typically, large urban centers began to use them first, and in states such as Iowa, a few smaller rural counties

never abandoned paper ballots. In other states, particularly where there were serious charges of election fraud in the first half of the 20th century, lever voting machines were installed statewide. This happened in Louisiana, for example, in the 1950's.

Lever voting machines were so pervasive by the mid 20th century that those of us born in mid-century generally grew up assuming that all voting machines were and would always be lever machines. Today, although they have been out of production since 1982, these machines are still in extremely widespread use. They completely eliminate most of the approaches to manipulating the vote count that were endemic a century ago, and they can easily be configured to handle a complex general election ballot.

Lever voting machines offer excellent voter privacy, and the feel of a lever voting machine is immensely reassuring to voters! Unfortunately, they are immense machines, expensive to move and store, difficult to test, complex to maintain, and far from secure against vote fraud. Furthermore, a lever voting machine maintains no audit trail. With paper ballots, a it is possible to recount the votes if there is an allegation of fraud. With lever voting machines, there is nothing to recount!

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In effect, lever voting machines were the "quick technological fix" for the problems of a century ago; they eliminated the problems people understood while they introduced new problems. Because they are expensive to test, complete tests are extremely rare. The mechanism is secure against tampering by the public, but a technician can easily fix a machine so that one voting position will never register more than some set number of votes, and this may not be detected for years.

In effect, with lever voting machines, you put your trust in the technicians who maintain the machines, and if you want to rig an election, all you need to do is buy the services of enough of these technicians. This is quite feasible for a metropolitan political machine.

Punched Cards

The first new technology to effectively challenge lever voting machines was the now infamous Votomatic voting machine. Punched card data processing dates back to the 1890's, but IBM did not introduce the Votomatic punched card voting system until 1964. The Votomatic ballot and the more recent mark-sense ballot both represent a return to the Australian secret ballot, but with the added benefit of an automated and, we hope, impartial vote count produced using tabulating machinery.

With this return to paper ballots, we gained the ability to recount the vote in the event there is a challenge, but we also introduce the question of how to interpret marginal votes. Almost everyone is an expert at interpreting marks on paper. We have been making and interpreting such marks since kindergarten. As a result, we can easily distinguish intentional marks from smudges or defects in the paper. This expertise is a key element in our ability to conduct a hand recount of paper ballots, and it fails utterly when the time comes to recount punched cards. With a punched card, a piece of dangling or pregnant chad is the analog to a smudge or an accidental pencil tick. None of us have the wealth of experience interpreting chad that almost all of us have with marks on paper!

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From a legal perspective, a ballot is an instrument, just like a deed or a check. When the ballot is deposited in the ballot box, it becomes anonymous, but just prior to the moment when the ballot is deposited, it ought to be possible to hand the ballot to the voter and ask "does this ballot properly represent your intent?". Votomatic punched card ballots fail this simple test! While the ballot is in the Votomatic machine, the voter can punch holes in it but is unable to see the ballot itself. Once removed from the machine, the voter can see the holes, but without the ballot labels printed on the machine, the voter is unable to tell what those holes mean.

The problems with Votomatic ballots were severe enough that, by the early 1970s, IBM abandoned the technology, and in 1988, the National Bureau of Standards published a report by Saltman recommending the immediate abandonment of this technology. By that time, punched card voting was the most widely used voting technology in the United States, and problems quite similar to many of the problems encountered in Florida during the last election had been encountered in many local elections.

There are alternative punched card technologies that eliminate most of the problems with the Votomatic system, and there have been many improvements to the Votomatic voting machine and punching stylus since Saltman's report. While I recommend phasing out punched card voting, my suspicion is that, with proper maintenance and up-to-date voting mechanisms, it is possible to conduct a vote with the Votomatic punched card machines that lives up to reasonable standards of accuracy and resistance to fraudulent counting.

Optical Mark Sense Ballots

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Optical mark-sense voting systems were developed in the early 1970's by American Information Systems of Omaha, alternately in competition with and in cooperation with Westinghouse Learning Systems of Iowa City. The latter was the licensee of the University of Iowa's patents on the optical mark-sense scanning machine. Essentially the only advantage of mark-sense technology over punched card technology is that it uses marks on a printed paper ballot. This is an important advantage! This means that no special machines are required to vote on the ballot, it means that, with proper ballot design, a voter can easily verify that the markings on the ballot exactly convey his or her intent, and it means that, during a hand recount, no special expertise is required to interpret the intent of the voters.

Unfortunately, the first generation of optical mark-sense voting machines was extremely sensitive to the particular type of pen or pencil used to mark the ballot, and to the exact details of the mark itself. As a result, early machines, including many still in use today, had real difficulty distinguishing faint deliberate marks from smudged erasures, and they tended to have mark sensing thresholds that required a fairly dark mark.

The newest generation of optical mark-sense readers uses visible wavelength image processing technology instead of simple infrared sensors to read the marks. Many of the more recent offerings use either FAX machine scanning mechanisms or computer page-scanning devices to obtain the image of the ballot, and they operate by finding each marking target before they search the target for acceptable marks. Such machines can easily ignore relatively dark smudged erasures while catching relatively faint deliberate marks.

Precinct Count versus Central Count Systems

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Both punched-card and optical mark-sense technology were originally developed for use with centralized ballot counting machines. These machines were typically large and cumbersome, this remains true, even with the smaller machines of today, Counties could rarely afford more than one, so when the polls closed, the ballot boxes were transported to the central counting center to be tabulated. By the late 1970's, it became feasible to build mark-sense and punched-card readers that could be installed in each polling place, but despite this, central count technology remains in widespread use with both punched cards and optical mark-sense ballots.

Because there need be only one central-count machine per county, complete and exhaustive pre-election calibration and testing is possible, as is complete post-election testing. It is quite reasonable to expect, prior to each election, that a technician will spend a good part of the day running test ballots through such a machine while monitoring the outputs of each sensor and adjusting the sensitivity to meet the requisite standards.

Precinct-count ballot tabulating machines are typically seen by the voter as somewhat complex ballot boxes. To the county, they are expensive ballot boxes that also count the ballots as they are deposited in the box, and offer immediate vote totals for the precinct when the polls are closed. Furthermore, the more recent precinct count systems offer the option of detecting overvotes and other ballot problems before the voter leaves the polling place, thus allowing the voter to correct the problem instead of leaving it uncorrected or leaving it to the judgment of the tally team during a hand recount.

Because there must be large numbers of precinct-count machines, we cannot afford to have complete and detailed calibration and testing of such machines prior to each election. The most we can typically afford is a general visual inspection and cleaning of each machine before the election, with detailed spot checks of only a few machines. Prior to opening the polls, polling place workers to run some simple self-tests, and well designed machines can auto-calibrate their sensors as they read each ballot. The use of image processing technology based on FAX machine mechanisms significantly reduces the need for measuring absolute brightness, and this, in turn, significantly reduces the calibration problems that plagued early mark-sense readers.

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Hand Recounts

Unfortunately, because punched-card and optical mark-sense ballots are machine readable variations on the Australian ballot, the introduction of these technologies raises many of the problems that led to the large-scale abandonment of paper ballots during the first half of the 20th century. When punched-card and mark-sense ballots are subject to a hand recount, all of the shenanigans that we hoped to eliminate with lever voting machines have begun to reappear.

Thus, we have the option of instituting "uniform and objective standards" that allow the plain and obvious intent of a voter to be ignored. We must guard against attempts to do this without safeguards that account for all ballots excluded under such standards!

Furthermore, we must guard against many other threats. Voters might add marks identifying their ballots so that dishonest observers of the count can determine how they voted and provide appropriate bribes. We guard against this by laws that exclude ballots with stray marks on them, but clever marking schemes will always be possible. There is the possibility that vote counters might surreptitiously mark or punch ballots (a carefully trimmed fingernail or a bit of pencil lead under the fingernail is all it takes), so we insist on the rule that all ballots be

handled in plain sight by people with freshly manicured fingernails. We must prevent voters from smuggling blank ballots out of the polling place or smuggling pre-voted ballots in, so we require elaborate care in accounting for all ballots.

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Direct Recording Electronic Voting Systems

The newest voting technology uses direct-recording electronic voting machines. These were developed after microcomputers became sufficiently inexpensive that they could be incorporated into a voting machine. The first of these was developed by Shoup in 1978; The Shoup Voting Machine Company was one of the two companies that had been making lever voting machines for much of the century. Their new electronic voting machine was built to have the "look and feel" of a lever voting machine, thereby minimizing the voter education problems that always accompany changes in voting technology.

Much of the rhetoric today about voting system reform asks why we can't have voting machines that are as ubiquitous and convenient as automatic teller machines. This turn of phrase is a reference to the newest generation of direct-recording voting machines; these make no attempt to emulate earlier technology; physically, they are little more than repackaged personal computers with touch screen input and special software to make them function as voting systems.

All of today's direct-recording voting machines attempt to offer far stronger audit and security tools than the old lever machines they functionally replace. Instead of simply storing vote totals on odometer wheels inside the machine, they store an electronic record called a *ballot image* recording each voter's choices, and they store an audit trail of all actions involving the machine, from pre-election testing to the printing of vote totals after the polls close. These records are stored in duplicate form, for example, in a hard drive in the machine as well as in a removable memory pack of some kind or on an adding machine tape inside the machine. Should any disaster strike or should a recount be requested, it should be possible to recover all votes that have been cast on such a machine.

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Unlike any system resting on paper ballots, none of the information stored inside a direct-recording electronic voting machine can be said to have the status of a legal instrument. Instead, the record is created by the software within the voting machine in response to the voter's actions, and the record is only as trustworthy as the software itself. It is far from easy to test and inspect software to assure that it functions as advertised, and it is far from easy to assure that the software resident in a machine today is the same software that was authorized for use in that machine months or years ago.

Current Status

Today, only about 1 percent of the population votes at polling places on hand counted paper ballots, but this figure is misleading. There are many elections conducted on optical mark-sense ballots that are actually hand counted, and many jurisdictions that use lever voting machines process absentee ballots by hand.

Hand-counting of mark-sense ballots is common in small local elections where a small turnout is expected and there are only a few issues on the ballot. When this is the case, the cost of hand counting may well be less than the

cost of programming and testing the vote tabulating machinery. The actual ballots used and the instructions to voters need not reveal what counting technology is being used.

Today, lever machines are used by about 19 percent of the population. While these machines have not been made for many years, they are built to last, and it takes only a moderately skilled mechanic to keep them in good working order. Because these machines have been phased out by many counties over the past 45 years, surplus machines are widely available as a source of replacement parts.

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Nationally, about 31 percent of voters use punched card ballots; most of these use the Votomatic machine. This number is in rapid decline since the most recent election! Many jurisdictions that have used punched cards without question prior to that election are now committed to move to other voting technologies.

The use of punched card voting machines has never been legal in Iowa, the state where I have voted for the past 21 years; by the time there were counties in Iowa that were interested in moving to this technology, the problems with punched-cards were widely enough known that the law was changed to effectively prohibit their use for any but absentee ballots; the same revision to the law allowed the use of optical mark-sense and other electronic vote counting methods.

Punched card ballots are used for absentee voting in many counties where direct-recording voting machines are used at polling places. When used for absentee voting, no voting machine is used; instead, the voter's instructions indicate, for each candidate or position on an issue, exactly which hole should be punched. Absentee voting using this method is too time consuming for use at polling places, but it allows the voter to verify that the ballot does correctly represent his or her intent, and as such, the punched card ballot becomes an appropriate legal instrument.

About 27 percent of voters nationally use optical mark-sense ballots, and many of the states that have just abandoned punched cards will be moving to this technology. In my home state of Iowa, the figure is 80 percent because counties that might have used punched cards had they been in other states moved to mark-sense technology instead.

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Direct recording electronic voting machines are used in about 9 percent of the nation. The adoption of this new technology has been slow, largely because it is expensive; direct-recording electronic voting machines typically cost upward of $5000 each. Another reason for the slow adoption is that many people are rightly suspicious of any voting technology that puts the entire election system in the hands of a few highly skilled computer programmers.

New Technologies

Aside from hand counted paper ballots and lever voting machines, all of today's voting technologies rest on the use of computers, and two suggestions follow quite naturally from this: First, why should these computers operate in isolation? Why not interconnect them using some kind of network technology, and second, why not let me use my own computer to vote instead of making me use a publicly owned machine in a polling place.

Today, an increasing fraction of the direct-recording electronic voting machines on the market include

provisions to network all of the voting machines in one polling place. This allows each machine to store vote totals in the memory of the others, and at the close of the polls, it allows a single report for the entire precinct to be created instead of one report for each machine.

Today, all new precinct-count voting machines are offered with communication options; this includes direct-recording voting machines, optical mark-sense ballot readers, and punched-card ballot readers. These allow the machines to electronically communicate the vote totals to a machine at the county level that computes county wide vote totals within minutes of the close of the polls.

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In most cases, this option centers on a modem incorporated in the machine, but where modem use is impractical, the machines will electronically record the vote totals on a memory pack or diskette that may be hand carried to the county's tabulating center, and some machines even offer a wireless option, so that the machines transmit vote totals over the air.

It is worth noting that many polling places are in building lobbies that have no telephone connections or in township halls that have never been wired for telephone service. Even if every polling place had a phone line, the idea that each voting machine in a large urban county might simultaneously attempt to phone in its totals when the polls close is daunting! This is one reason that wireless communications options are appealing.

Most proposals for allowing voters to use their own machines to vote in general elections suggest that this be done via the Internet. Usually, the term E-voting is used as a synonym for Internet voting, but the term could just as well be applied to all of the electronic voting technologies introduced since 1960. Furthermore, there are many non-Internet options for using personal computers to vote. For example, voters could use modems to connect by telephone directly to the county offices when they vote.

There are several companies that are aggressively attempting to sell Internet voting, most notably Safevote, of San Rafael, California, but this technology has many problems to overcome. In effect, Internet voting can be classified as the use of direct-recording voting machines provided by the voter for absentee voting, with ballot transmission electronically over a public communications network. Thus, before we can accept this technology, we must assure ourselves that we trust direct-recording voting technology and that we trust electronic transmission of ballots, and having surmounted these hurdles, we must assure ourselves that we trust the voters to provide, maintain and secure their own voting machines!

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The Regulatory Environment Today

Today, the technology we use for voting is regulated by numerous branches of government! In Iowa and most states, the counties individually own, pay for and administer the voting machines used locally. The states regulate the voting machines that may be purchased by the counties, and state laws and administrative rules determine how these machines are used. These state rules have, on many occasions, been overruled by Federal court decisions, and where civil rights issues have arisen, there has been direct Federal control of local elections. Finally, the Federal Election Commission has established voluntary standards governing voting systems, and these standards include a testing and certification process for voting equipment. These standards have been incorporated into law

by a large and growing minority of the states, so they are not as voluntary as they appear at first glance.

In Iowa, voting machines must be certified by the Iowa Board of Examiners for Voting Machines and Electronic Voting Systems. Iowa law requires that all new machines offered for sale in the state comply with Federal Election Commission standards prior to our examination. I have served on the Iowa Board of Examiners since 1994, and I have chaired the board since 1999; I feel that we have been moderately effective in setting reasonable standards for the voting systems used in Iowa.

You will note that I did not say that we assure perfection or even that we have set excellent standards! The criteria on which we can disqualify a machine are weak! We can only disqualify machines if we find that they do not meet the conditions set by state law, and in many cases, I would have liked to disqualify machines but I was forced to vote for their approval because I had no legal grounds for disqualification.

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The Federal Election Commission *Performance and test Standards for Punchcard, Mark-sense, and Direct Recording Electronic Voting Systems,* released in January 1990 and revised in April of that year were developed in response to the problems reported from various quarters in the mid 1980's. In addition to defining terms and setting basic requirements for some of the machinery used in elections, these standards require testing of new voting systems by an independent testing authority—independent of both the jurisdiction using the machines and the manufacturer. Unfortunately, a decade after these standards were introduced, only Wyle Labs of Huntsville Alabama is available an independent testing authority.

These standards have two major weaknesses. First, they are voluntary! A voting machine manufacturer who conforms has a marketing advantage over a non conforming manufacturer, but in most states, conformance is not required. Over the past decade, over 20 states have opted to require conformance, but unless things have changed since I last checked, the majority of the states have not opted in.

The other problem with these standards is that they simply fail to cover many issues, and in my experience evaluating voting machines for use in Iowa, I find that many inadequate designs and marginal features have made it through the standards process with no comment. I must note that the Federal Election Commission is currently in the process of producing a major overhaul of these standards; Volume I of the new standard is scheduled for preliminary release on June 29, and Volume II is scheduled for October 31.

Examples of Problem With the Current Standards

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In the following subsections, I will document some of the shortcomings of the current standards, with illustrations from my experience evaluating voting machines for use in the state of Iowa.

Accuracy Standards, a Mark Sense example

The current Federal Election Commission standards require a recording accuracy of "one part in one million" (Section 3.2.4.2.7 for direct-recording electronic voting machines, 3.2.5.2.1 for punched-card and mark-sense machines).

On the face of it, this standard appears to be objective and measurable, but it is not! There are two basic problems. First, the standard specifies no measurement methodology, and second, the standard itself, "one part in one million" appears with no justification; it appears to be a number pulled out of thin air!

In actual practice, we have one useful measure of voting system accuracy, provided by the institution of the recount. Recounts detect other things as well, but when you exclude recounts that have found lost ballots and clerical errors, the difference between the first count and the recount represents the actual error level in the voting system.

In my home county, Johnson County Iowa, we currently use 16-year-old Optech II precinct-count mark-sense machines made by Business Records Corporation (now Election Systems and Software). Tom Slockett, the Johnson County Auditor (in his role as county election commissioner), has told me that, in a typical machine recount in Johnson County, the results are rarely off by more than 1 in 10,000 from the original count and are frequently the same. At the United States Civil Rights Commission hearings in Tallahassee on January 11, Witness Dan Gloger cited figures from the Dade County Florida punched-card recount last November suggesting an error rate of 1 in 6000.

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These figures, 1 in 6000 or 1 in 10,000 come nowhere near the 1 in 1,000,000 required by the Federal Election System standards, but I believe they are an accurate reflection of the accuracy achieved by real ballot counting mechanisms. These counts involve real ballots punched or marked by real people, with loose chad that might be knocked into or out of holes in punched cards, and with ballot markings that may be very close to the voting machine's threshold for determining whether a mark is or is not counted.

In one of the first voting system tests I was involved with, in 1994, if my memory is correct, we tested the central count optical mark-sense vote counting system being offered to count absentee ballots in counties using Microvote's Direct Recording Electronic voting system. This used an optical mark-sense reader sold by the Chatsworth company, and it is noteworthy that the Chatsworth mark-sense reader is specifically cited as an example of hardware that is not subject to qualification test and measurement procedures because it has "a history of performing successfully under conditions equivalent to the election use" and has a "demonstrated compatibility with the voting system" (Section 7.1.2 of the FEC Standards).

In order to test this system, I took several hundred ballots out on the street and asked random people to mark the ballots as I instructed, quoting the marking instructions from the Chatsworth and Microvote documentation I had been given. When we counted and recounted my test deck, we found that the reader rarely came within a few percent of the count it had previously given. Thus, we are speaking of an accuracy of significantly worse than 1 in 1000! This for a voting system that had been accepted for use in Arkansas, Michigan and North Carolina, and that had passed through the FEC certification process.

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When we asked about these problems, the vendor's representative cited the FEC Standard, Section 3.2.5.2.1, that "valid punches or marks shall be detected, invalid punches or marks shall be rejected," and turned this on its head. In effect, if the machine detects a mark, it is valid, and if the machine fails to detect a mark, it is invalid. Thus, in effect, the machine sets the criteria for what is and is not a vote, entirely independent of how a human looking at the marked ballot would interpret it! The solution, in this case, involved changing both the ballot

marking instructions and the specific model of ballot reader used; with these changes, we were able to approve the system.

The root of the problem was twofold. First, under the original marking instructions, voters had been free to use any pen or pencil. Indeed, the Chatsworth reader was able to read most pen and pencil marks, but some colored pens and hard-lead pencils produced marks very near to the threshold for the reader. The other problem was that the reader was nominally able to read ballots in any of four orientations (reversed top-to-bottom or front-to-back or both). As a result, any given mark on the ballot might be seen by any of 4 different sensors, and the sensing thresholds of these sensors were obviously not equal!

Some elections administrators deal with this problem of near-threshold marks on mark-sense ballots by requiring that, on a recount, all ballots be recounted by the same machine that was used in the first count. In fact, I believe that this is a serious mistake! If counts on two different machine reveal significantly different counts, then either the standards for adjusting the sensitivity of the sensing mechanisms on those machines are inadequate or the ballot marking instructions are inadequate, leading to too many near-threshold marks!

Accuracy Standards, Direct Recording Electronic Examples

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When we examined the Global Election Systems Model 100 Electronic Ballot Station in 1998, as the examination progressed from the sales presentation to the actual qualification test, we were warned by the sales representative that we would have difficulty testing the machine and that, in fact, a useful hand test of such a system was generally difficult. I do not want to single out Global; Fidlar-Doubleday has a system that is both similar looking and subject to the same problems.

These machines use a touch screen for voting, and I imagine that, as a voter, I would have immense confidence in them, both because they are excellent representatives of current technology and because the computer interfaces on these machines are generally very well designed.

During testing, however, we quickly learned that the warning from the sales representative was correct. Casting one ballot on this machine is something of a peak moment, psychologically, but to perform an interesting test, it is necessary to cast several hundred ballots. After casting five or ten ballots on this machine, the job became tedious, and after casting twenty or thirty, it became a stressful exercise. By the end of the test, two of the three examiners had made so many mistakes that their test plans were of little use. I made it through my test plan without error but with sore fingers from poking at the touch screen and with a splitting headache and a sore neck.

In discussing our tests, the vendor's representative said that, really, we should not expect to make realistic tests, that, in effect, we just had to trust the testing done by the vendor and by Wyle Labs. We could not duplicate the human factors present at a real polling place in our tests, and we should trust the vendors and the labs to do that for us. Trust, however, is a dangerous thing in the world of elections. Every step in the election process needs to be testable, and with direct-recording machines, testing is becoming extremely difficult! In this particular case, I suspect that the large scale testing was done with robotic fingers touching the screen in pre-determined patterns, and this too does not duplicate the human factors elements in real voting, as no humans are involved!

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Exempt Software, A Direct Recording Electronic Example

Another problem that came up in the test of both the Fidlar-Doubleday and Global Election Systems Direct Recording Electronic voting machines is a consequence of the fact that these machines are essentially repackaged IBM PC compatible computers running versions of the Microsoft Windows operating system.

Under Section 7.1.2 of the FEC Standards, software qualification testing for the operating system running in a voting system is not required unless the operating system has "been modified for use in the vote counting process." Thus, because these voting machines use off-the-shelf versions of Windows, the operating system is exempt from inspection.

If I recall correctly, during our first test of the Global Election Systems Model 100 Electronic Ballot Station early 1998, we found an interesting and obscure failing that was directly due to a combination of this exemption and a recent upgrade to the version of Windows being used by the vendor in their machine.

In effect, the machine always subtly but reliably revealed the previous voter's vote to the next voter using the same machine! This was because, whenever a particular set of "pushbuttons" was displayed on the screen, the button most recently pressed was shown with slightly different shading. Such a set of buttons is frequently referred to as a *radio button widget.* As far as the developers of Windows were concerned, this new feature of radio button widgets was intended to help computer users remember what they'd done the last time they encountered a particular menu on their computer screen. I want to emphasize here that Microsoft did not intend any violation of voter privacy, and in fact, that this feature of their software was developed without reference to the possibility that it might be used in elections.

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In the vendor's original tests, this feature had apparently not yet been added to Windows, and since the new version of Windows did not contain any notices indicating features that might have been relevant to the voting application, this problem was left for us to find. Had the operating system not been in the exempt category, I suspect we would have never had this problem.

The use of a proprietary Microsoft operating system in a voting machine and the fact that the current standards provide us with no control over this use is particularly troublesome! Microsoft is currently in the midst of an antitrust case—which is to say, it is in an adversary relationship with the Federal government! Thus, the company has great reason to be interested in the outcome of elections.

In fact, about a year ago, I remember hearing a Microsoft representative state that he hoped to delay hearings on their antitrust case until after the election because he believed that Microsoft would receive a more favorable hearing from a Bush administration, and I remember that, when asked about this, then candidate Bush confirmed that he did not favor the antitrust litigation.

Thus, we are in the bizarre situation that our current standards exempt large portions of software in voting machinery from inspection, where those portions happen to be made by an organization that has taken a partisan position in an upcoming political race!

I do not believe that Microsoft has abused our trust by incorporating code into Windows that could be used to falsify the vote totals for a race, but I do object to our extending such trust. It would be remarkably easy to

program the window manager component of any operating system to rig elections, and testing to prove the absence of such programming would be impossible! For example, a clever programmer could add code that only operated on election day (the first Tuesday after the first Monday of years divisible by two), so that, whenever the text "STRAIGHT PARTY" appeared in the same window as a radio button widget, and that widget had buttons labels containing "DEMOCRAT" "REPUBLICAN" and "GREEN", the first and last of these labels would be exchanged one time in ten. The net result would be to throw ten percent of the Democratic party's straight-party votes to the Green party! This could easily swing an election.

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Today, there are numerous operating systems and window managers available that could be used as alternatives to Microsoft Windows for voting machines based on PC compatible software. Furthermore, at least two of these, Linux and FreeBSD, are open-source systems, that is, operating systems where the code of the system is available for inspection by anyone. There is no preference built into the current standards to favor the use of such open-source systems!

What Software is Running

The current FEC standards include a *System Escrow Plan for the Voting System Standards Program* also released in January 1990 and revised in April 1990. Section 3 of this plan justifies the escrow process by noting that storing in escrow a copy of the software approved for use on a machine can allow verification that the software installed is indeed the software that ought to run on that machine, and it allows customers to protect the value of their equipment in the event that a vendor goes out of business.

This is true, but there is a major shortcoming of the current system! Section 5.5 of the primary FEC Standard does require that no tools be resident on the voting system for altering the software, but there is no requirement for provisions supporting the verification that the software loaded on a voting system is indeed the software authorized on that machine.

This is not an easy problem to solve! The requirement that the resident software print out the ID of that software may be trivially met by modifying whatever software is actually resident on the machine to print out whatever report is expected. There are cryptographic tricks that could be applied to this, but effective solutions to this problem are subtle and I have yet to see any voting system that offered even a partial solution to this problem.

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What is a Voting Machine, A Direct Recording Electronic Example

One of the most perplexing problems posed by the current generation of direct-recording electronic voting machines is the question of exactly what is a voting machine? On the face of it, even the fact that such a question should arise is alarming.

I first encountered this question in the examination of the Fidlar-Doubleday (then Fidlar and Chambers) EV 2000, but the same problem is present in the machines made by Global Election Systems. In both cases, these machines are designed to allow networking of all the machines in a single polling place, with many functions that are traditionally connected to individual machines connected, instead, to the cluster of machines.

Current FEC standards require that each voting machine have a public counter (Sections 2.2.2.9 and 3.2.4.2.3) that indicates, to the public, the number of ballots cast on that machine during that election, and a protective counter (Sections 2.2.2.10 and 3.2.4.2.4) that indicates the total number of ballots cast on the machine during its lifetime.

The problem is twofold: First, when does a machine come into existence? If the machine is essentially a personal computer, each component inside the case can be replaced independently of all the others. The CPU can be replaced, the disk drives can be replaced, and the display screen can be replaced. There is no component analogous to the odometer mechanism that is included to serve as the protective counter in a classical lever machine, so generally, the protective counter is stored on disk or some equally replaceable component.

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When the system component containing the protective counter is replaced, must the counter be set to the original value in order to conform to the letter of the FEC Standards? If so, there must be software that allows setting the counter, and if this is the case, the value of this counter for protecting against fraud becomes questionable! If there is no such software, then the counter must automatically reset to zero whenever the component that contains it is replaced or reinitialized. In this case, in order to conform to the FEC Standards, we must consider that replacement to have manufactured a new voting machine! This is very strange.

The second problem arises as a result of the networking option allowed by Section 2.2.3.3 of the standard. This allows, but does not require, the interconnection of the voting machines in a polling place so that they produce a single report of the results of an election. When machines are interconnected, it is natural to consider the total set of machines as a single system that comes into existence when the machines are plugged together at the start of election day, and that is destroyed after the polls close.

In the case of the Global Electronic Ballot Station, it appears that they have met the FEC requirement for redundant storage of ballots (Section 3.2.4.2.5) by taking advantage of this networking within the polling place. Each voting machine records a copy of the votes cast on that machine not only in its own memory, but also in the memory of one of the other machines that are part of the same network of machines.

Technically, there is nothing at all wrong with this, except that the current standards do not seem to have anticipated this; neither did Iowa law, and as a result, after a long argument, we decided that, for purposes of Iowa law, the only way we could approve this system was if we viewed the system of machines installed at a polling place as a single machine. This is clumsy!

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Secret Ballots, Problems With Write-In Votes

A very interesting problem came up last fall, in an examination of an upgrade to the Fidlar-Doubleday EV 2000 system. Processing write-in votes is difficult on any voting system, and under the laws of many states, including Iowa, it is sometimes necessary to check for certain other votes on the ballot before accepting a write-in vote.

The specific rule that causes problems is that write-in votes for candidates names who are already on the ballot are not counted, unless the write-in vote is an overvote for a candidate that has already been voted for normally, in

which case, the write-in is discounted and it is not an overvote. On direct-recording machines, this causes no problems for vote-for-one offices, but on a vote-for-three office, for example, a voter could vote for two candidates normally and then write in the name of one of them in an attempt to cast two votes for that candidates.

Many election administrators have apparently asked Fidlar-Doubleday (and other vendors, I suspect) to print a special report when the polls are closed, listing all write-in votes with enough added information to allow the polling place workers to apply the above rules. This is one of the enhancements we were asked to evaluate last fall.

Unfortunately, Fidlar-Doubleday implemented this feature by including the entire coded ballot image of every ballot containing a write-in vote as an appendix to the report printed by the voting machine when the polls close. Under Iowa law, this entire report must be posted publicly, so the net result was that the coded ballot image of every ballot containing write-ins was made public.

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The write-in votes themselves were in plain readable text in this coded image, and each vote cast on the same ballot was coded as a random number, using a code that was fixed for that precinct. It only took me a minute to discover a foolproof way to crack this code, and using this, someone intent on bribing voters to vote in a particular way could simply assign a nonsense name to each voter, asking them to write in that person's name for a specified minor office in order to force the public disclosure of their ballot in order to prove that they had earned their bribe.

Had Fidlar-Doubleday arranged to print only the other votes, if any, for the office where the voter cast a write-in vote, the problem would have been considerably less severe and we would have approved the machine. As it is, we had to forbid the use of this feature in Iowa (fortunately, it could be disabled), despite the fact that Wyle Labs had found no problems in their software audit and despite the fact that some of the election officials requesting this feature had been from Iowa.

Vote Transmission by Wire and Radio

The current FEC Standards cover the machinery and software of central count mark-sense and punched-card ballot counters, and they cover the machinery and software of precinct-count and direct-recording electronic machines, but they have not been used to cover central counting systems used in conjunction with precinct-count or direct-recording electronic machines.

The problem is, all of the recent precinct-count and direct-recording voting machines that I have seen offered for sale have included communications options that will electronically transmit ballot either images or vote totals from the voting machine to a central location, and then tabulate the results from all machines reporting in. Most machines offer to do this using modems and the public telephone network. All machines also offer to do this using removable memory packs of some type (diskette or electronic), yet no aspect of this appears to be adequately covered by the current standards!

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All of these electronic communication options raise severe security problems, which the current FEC Standard addresses very briefly in Section 5.6. How do you prevent some hacker from using his personal computer to report false totals for some precinct by phone or radio? If hand-carried memory packs are used, how do you prevent a

dishonest election worker from switching a false memory pack for the pack that came from the voting machine. Today's memory packs are frequently about the size of a credit card! It takes only modest skills at sleight-of-hand to swap two cards that size, even in the presence of suspicious witnesses.

When I have asked vendor's representatives about the security they offered, some have flatly refused to discuss any details, stating that to do so would compromise their security. As a general rule, those in the computer security business are very hesitant to accept such statements, because history shows us that the most secure systems are strong enough to stand up to detailed inspection of their mechanisms!

When I was involved in the examination of the new modem option for the Business Records Corporation (now Election Systems and Software) Optech Eagle in 1996, I asked about this, and after some confusion, learned that the system was secure, but that this security was accidental and not a matter of design. One of the fields stored in the voting machine when it was set up for a particular election was the time and date of the setup, and when that machine transmitted its results back to the central location for counting, the time and date were included in the transmission and checked against the original. Had this information just been the day on which the machine was programmed, it would have offered no security, and had it been the day, hour and minute, it would have been fairly easy to guess, particularly when the actual setup of voting machines is itself subject to observation by witnesses for each party. In this case, however, the value used happened to be accurate to the millisecond! It was that fact that made the transmission secure against forgery.

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In another case, I believe it involved the Global Electronic Ballot Station, when I asked about security, they assured me that they used the United States Government approved Data Encryption Standard. This standard is moderately good, but it requires that the transmitter and receiver of a particular piece of data each have identical keys, one used to encrypt the data, and the other used to decrypt. So, I asked how the company was handling the key management problem.

The answer I got scared me! The company's sales representative phoned their technical expert and handed me the phone. I asked my question again, to the expert, and he said that he was surprised that I should ask about key management because, really, there was no problem. The reason for this turned out to be that there is only one key —company wide, and incorporated into every voting machine they build! This fact was not, apparently, considered worth noting in any of the examinations conducted under the current FEC standards.

Because of these problems, we in Iowa do not allow electronic vote reporting for anything other than reporting early totals to the press. For the official canvass, we still require that the totals for each precinct to be printed in duplicate at the polling place, then signed and witnessed by the precinct election workers, with one copy publicly posted and the other copy hand delivered to the county offices. If you are suspicious about the accurate transmission of your precinct's totals, you can go to the polling place as the polls close, take notes from the posted totals, and then check these with the totals reported later for the official canvass.

Before we allow such electronic transmission, I want to see open standards for interconnection of voting systems. Proprietary protocols, where the voting system vendor cannot inform the examiners of any details of the protocol for fear of compromising a system's security must not be allowed! On the other extreme, genuinely open protocols that allow voting machines made by different manufacturers to be used together would make the marketplace far more competitive because it would allow counties to phase in a new make of machine instead of forcing an all or nothing change. Such protocol development must be overseen by an organization that

understands the issues of security and reliability far more clearly than the vendors or testing authority with whom we deal today.

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Fault Tolerance, A Direct Recording Electronic Example

Section 3.2.4.2.5 of the FEC Standard requires that each direct-recording voting system incorporate multiple memories, so that, in the event of failure, any disparity can be detected. Unfortunately, the standard says nothing about what to do when there is a problem!

The fundamental problem extends far beyond this section of the standard, into the laws of many states. If we have two documents, one an original and the other a photocopy, the original has far higher standing in law than the copy, and rightly so. If someone were to photocopy a stack of ballots and then somehow manage lose those ballots, there would be interesting arguments about the legal standing of those copies!

In the case of direct-recording voting machines, we have no original document; rather, the ballot images stored within the memory of the machine are all copies! If the duplicate copies are the same, the standards grant them considerable weight. If, on the other hand, the duplicate copies to differ, there is no guidance to suggest how the correct copy should be determined.

In fact, there is a technical solution to this problem! This relies on storing, with each ballot image, an electronic signature of that image (the simplest such signature is the checksum, the simple sum of the binary representations of the data bytes of the image). In the event that two copies of a ballot image disagree, the one with the bad checksum should be disregarded in favor of the one with the correct checksum. This is mentioned in the current FEC Standards, section 5.6, but it is applied only to data communication.

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In all of the voting systems I have examined, it appears that, where redundancy is used, it is left to the human user's judgment to decide what to do in the case of disagreements between the redundant copies. This is not acceptable! I admit, however, that I base my observation of current practice on sales literature, discussions with manufacturer's sales representatives, and very sketchy and infrequent contact with technical people within the vendors' organizations.

Vote Counting

Section 4.8.2.4 of the current FEC Standards requires that the voting system count ballots, and for each office or measure, that it count votes overvotes and undervotes. This is excellent, but most states (including Iowa) appear to ignore much of the information that could be obtained from this, and the FEC Standards do not even suggest some extremely productive ways to use this to ensure the accuracy of the count within a voting machine.

In general, for a vote-for-one office or a yes-no ballot issue, the sum of the number of votes for each candidate, the number of overvotes (if any) and the number of undervotes should equal the number of ballots counted. Therefore, if each of these items is brought forward independently through the entire vote count, from the moment the ballot is inspected until the final canvass is published, it should be possible to check this sum at every level in

the process to detect errors.

If we can guarantee that the components of this sum are genuinely brought forward independently, for example, that some part of the system counts ballots without access to any record of the votes cast, and if we can guarantee that the count for each candidate is made without the ability to inspect or modify the count for any other candidate, then we have a system that is very secure against falsification of the count. Section 2.3.2 of the current FEC Standards requires part of what is suggested here, but the follow through is weak.

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The current FEC Standards, in Section 7.4.2, require a source code audit of all software in the voting machine, but the criteria given to the auditors are all generic criteria that could be applied to video games and payroll software as easily as to voting systems. It would be extremely valuable to incorporate into this audit a review of the independence of the counting of ballots (enforcing Section 2.3.2) and votes for each office; such an audit requirement would materially change the way system designers approach the problem and would make all vote counting software more trustworthy.

I also suggest that this same rule be applied to manual vote counting, and that some component of the count always be carried forward outside the machine. Most systems of polling place administration require that the polling place produce a count of the number of voters allowed to vote. In Iowa, for example, each voter must sign an affidavit of eligibility in order to receive a ballot, and these are numbered. It is therefore very easy to count the number of ballots issued entirely outside of any computer system, and I strongly urge that this count be brought forward into the official canvass by hand, even if everything else is handled by computers!

Prospects for Change

The flaws in today's voting systems exposed by general election last fall have moved counties, states and the Federal government to action. In addition, the Supreme Court decision that put an end to the recounts moved great areas of election law into the Federal domain, bringing it quite properly under the umbrella of Civil Rights law.

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While I wasn't too thrilled with the process that led up to this court decision, nor was I thrilled with the pragmatic considerations that led both sides to take the positions they took, I find myself in agreement with the court decision and look forward to the unfolding of its consequences.

The Risks of Monopoly

There is one possible interpretation of the Supreme Court decision that worries me. The court declared that the equal protection clause requires that states adopt uniform, state-wide standards governing the interpretation of votes, but it is possible to interpret this as a demand for a uniform state-wide standard voting technology, and it is hard to see why the same argument the court used to support uniform standards within a state should not be extended to uniformity from state to state, which is to say, a single uniform Federal standard voting machine.

I am extremely wary of granting any monopoly in the field of voting machines! Today, we have a diverse marketplace, and the competition in this marketplace has fueled the development of a number of interesting new ideas. Unfortunately, as things stand right now, none of the available voting technologies are perfect. If we had a

monopoly, as the result of a national standard voting technology, this progress would end and we would be forced to accept a system with known flaws.

To my knowledge, none of the flaws with new voting technology, have been widely exploited for the purpose of vote fraud, but if we freeze the technology, I have no doubt that somebody will eventually begin to exploit them. Furthermore, having frozen development by accepting one of the available technologies as a standard, we will have eliminated the competition! Had punched cards been the national standard last year, we would not be able to abandon them, as Florida has recently done!

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Finally, if we create a monopoly, a crook intent on subverting the system must only subvert that one monopoly. If there are 4 makers of voting systems, the gain to be had by subverting one is limited. If there is only one maker, it may only be necessary to subvert only one or two people to rig next year's elections nationwide! The fewer people you have to trust, the more vulnerable you are to the subversion of any one of those people! Dispersed authority is resilient in the face of challenges, while centralized authority is vulnerable to corruption!

Change at the State Level

Unfortunately, the legislative response, at both the state and national levels, has been chaotic. Numerous voting system reform bills have been introduced in states across the country, and there are many proposals before the Federal government.

In Florida, with the nation's eyes on the state, an election reform task force began work in January, and the changes they proposed have already been signed into law. The political pressure on Florida to make big changes and make them quickly was immense, so I sympathize with the decision that the Florida Task Force made—given the alternatives available today, optical mark-sense ballots are probably the best technology, if properly administered. That is a big if, however, and the decision to switch the entire state to one technology now is sufficiently expensive that it may preclude any additional change over the next decade.

In Iowa, the creation of the Secretary of State's Election Reform Task Force, of which I am a member, led to the failure of various election reform legislation that was introduced this spring. This was a good thing! We are not in a hurry, we do not need to hastily adopt random changes to our law, and the budget in Iowa is tight enough that state investment in an emergency update of our election machinery is out of the question. By this coming fall, we should have a proposal in place for reasoned changes to Iowa's election laws, and these changes are likely to require the phased replacement of some of the older election machinery in the state.

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Redefining the Role of the Federal Election Commission

As I stated earlier, the need to revise the Federal Election Commission Standards was widely recognized before the chaos surrounding the general election last fall! The Commission has contracted with American Management Systems, a major management and software consulting house, to undertake such a revision, and a revised standard should become available for public comment soon. I eagerly await a chance to read this revision, and I hope that it addresses some of the problems I have outlined above.

Even while this revision is in progress, I understand that there are proposals before Congress to completely change the role of the Federal Election Commission with regard to the Federal regulation of voting machinery!

Under the Supreme Court decision of last fall, it would appear to be within the authority of Congress to mandate significant binding standards governing the counting of votes during Federal elections. If this is done, significant areas of the Federal standards governing voting machines would no-longer be voluntary. I have high hopes for this, but as I understand the current focus of legislation before Congress, the focus is elsewhere, on the possibility of funding massive changes in election machinery in the states, something I strongly discourage, and on changing the role of the Federal Election Commission.

H.R. 1165, the *Election Voting System Standards Act of 2001*, is one of the more moderate proposals to strip the Federal Election Commission of its authority over voting machines. More radical proposals would give this authority to the National Institute of Standards with very little direction, while H.R. 1165 would create a new commission to oversee the development of new standards and the establishment of a new National Election Systems Standards Laboratory.

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I am not certain how much of the push to strip the Federal Election Commission of its authority over voting systems standards stems from the inadequacies of the current standards and how much comes from a general dislike of the Commission. Those who have had to file campaign finance disclosure reports generally don't enjoy the process, and it is easy to see how this could lead to a general dislike of the Commission.

While I feel very strongly that our current system of standards needs to be updated and strengthened, and I feel that such updates should be done far more frequently than once a decade, I am not sure that this justifies stripping the Federal Election Commission of its role in promulgating such standards. The strongest argument for such a change may be that the regulation of the conduct of elections and election campaigns requires expertise quite different from that required to regulate the mechanisms by which we conduct elections.

Furthermore, it is important to note that many state and local election officials do not seem to feel a pressing need to change the current system. When I mentioned H.R. 1165 to Iowa's Director of Elections, Sandy Steinbach, she was shocked; it is worth noting that she is on the committee that is overseeing the revision of the FEC Standard. When I have talked about these issues with some of the county auditors (who serve as commissioners of elections), they have been universally surprised by the idea that the role of the FEC itself was being questioned. Their typical reaction was "if it ain't broke, don't fix it!" or "it it's broken, fix it, don't tear it down and start over."

Conclusion

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In sum, it is worth recalling Mark Twain's quote, that "Democracy is the worst of all systems, except for all of the others." One could go on to say that every approach to conducting a democratic vote is bad, but the alternative is worse.

The current system of regulation for voting machinery suffers from significant flaws. Many systems have been approved for use in many states that plainly fail to meet the requirements of the standards we have set, and the

standards do not cover many features that have become common on modern voting machines.

Given this, I cannot recommend large-scale funding for immediate modernization of voting systems across the country. To do so now would be to rush into the purchase of large numbers of systems that I hope will be found failing by the standards we ought to have in place!

Furthermore, there are many aspects of current standards that ought to be subject to constant reexamination. How accurate our ballot counting machines with real ballots cast by real voters? How do the different user interfaces of different voting machines change the way voters respond to the machinery? How can we realistically test direct-recording machines, and how can we develop open standards for electronic storage and communication of votes?

An answer to these questions may require, but does not necessarily require, a change in the oversight process for our voting machine standards. An answer to these questions does require that we invest more effort into ongoing studies of the problems with voting machinery, something that might be done if we establish the kind of voting systems laboratory envisioned in H.R. 1165.

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ABSTRACT

In my role on the Iowa Board of Examiners for Voting Machines and Electronic Voting Systems, I have had occasion to examine and test a number of voting machines since 1994. In conducting these examinations, I have found many instances where the machines have had significant shortcomings that illustrate flaws in the current regulatory system, including the current Federal Election System Standards from 1990. In my written testimony, I outline the history of the voting technologies in use in the United States today, I describe the current state of affairs across the country, with examples from my home state of Iowa, and then I work through examples of the problems I have encountered in the voting systems I have examined, making specific reference to chapter and verse of the Federal Election Commission Standards where appropriate. My written testimony ends with an examination of the prospects for change, at both the state and the Federal level. I strongly recommend regular review and revision of whatever voting system standards that we put in place. A voting systems laboratory would be useful for this, but I have questions about the need to take the authority for this away from the Federal Election Commission. I strongly urge that the Federal government undertake no large scale funding of voting system upgrades until an effective update to our voting system standards in place.

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EDUCATIONAL AND PROFESSIONAL HISTORY

1. Higher Education

University of Illinois at Urbana Champaign, 1973–1980, Computer Science, MS 1976, Ph.D. 1980.

Carnegie-Mellon University, 1969–1973, Physics, B.S. 1973.

2. Professional and Academic Positions

Associate Professor, 1988–, University of Iowa Department of Computer Science.

Assistant Professor, 1980–1988, University of Iowa Department of Computer Science.

Teaching Assistant, 1980, University of Illinois Physician Computer Science Training Program.

Research Assistant, 1973–1980, University of Illinois Medical Computing Laboratory.

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Resident Visitor, 1973–1974, Bell Telephone Laboratories Acoustics Research Department, Murray Hill.

Programmer, 1973–1974, Com Share Incorporated, Ann Arbor.

3. Honors and Awards

University of Iowa Office of Services for the Handicapped Certificate of Recognition, 1980.

Tau Beta Pi, the National Engineering Honor Society, 1980.

The Honor Society of Phi Kappa Phi, 1980.

4. Memberships

Association for Computing Machinery.

American Association for the Advancement of Science.

Computer Professionals for Social Responsibility.

TEACHING AT THE UNIVERSITY OF IOWA

1. Teaching Assignments

Page 194 PREV PAGE TOP OF DOC

Topics in Systems and Networks, Discrete Event Simulation

Advanced Operating Systems

Topics in Operating Systems

Introduction to System Software

High Performance Computer Architecture

Computer Organization and Assembly Language Programming

Digital Systems and Computers

Programming Language Concepts

Introduction to Programming and Problem Solving in Pascal

Discrete Structures

SCHOLARSHIP

1. Publications or Creative Works

For multi-authored work, the following marks indicate

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** = senior author, major contribution*
*** = secondary contribution*
**** = equal contribution*
***** = minor contribution*

1. Refereed

Books

Handbook of Small Electric Motors, William H. Yeadon* and Alan W. Yeadon, eds. McGraw Hill, 2001 (1071 pages, 39 contributors). D.W. Jones*** contributed section 5.2.10 (16 pages) and sections 10.8 to 10.10 (27 pages).

Articles

"Integrating Concurrent and Conservative Distributed Discrete-Event Simulators" H.R. Hoeger* and D.W. Jones** *Simulation,* 67 5 (Nov. 1996) 303–314.

"Concurrent Operations on Priority Queues," *Communications of the Association for Computing Machinery*, 32, 1 (Jan. 1989) 132–137.

"The Design and Implementation of a Dynamic Binding Feature for a High-Level Language," R.E. Gantenbein** and D.W. Jones*, *The Journal of Systems and Software*, 8, 4 (Sept. 1988) 259–273.

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"An Empirical Comparison of Priority Queue and Event Set Implementations," *Communications of the Association for Computing Machinery*, 29, 4 (Apr. 1986) 300–311.

2. Non-refereed

"The Digital PDP–8 Story," a 3-part series, *Historically Brewed, Newsletter of the Historical Computer Society*, 7, 8, 9 (Sept-Oct 1994) 7–10, (1995) 7–10, (1996) 11–14.

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"How (Not) to Code a Finite State Machine," *Association for Computing Machinery Special Interest Group on Programming Languages Notices*, 23, 8 (Aug. 1988) 19–22.

"The Ultimate RISC," *Computer Architecture News*, 16, 3 (June 1988) 48–55.

"A Minimal CISC," *Computer Architecture News*, 16, 3 (June 1988) 56–63.

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3. Web Based

Computer Control of Stepping Motors, http://www.cs.uiowa.edu/jones/step/, originally posted 1990, major revisions 1995 and 1998.

A Tutorial Introduction to Bookbinding, http://www.cs.uiowa.edu/jones/book/, originally posted 1995. Judged "Information Value of the Week" by the Austria Information Switchboard, July 12, 1997, "one of the best 3,000 sites of interest for New Zealanders," by the Internet Phone Book, June 1998, " 'Free Stuff' Best of the Web," by C&T Publishing, November 1999, "Selected Instructional Site," WannaLearn.com, June 2000, and added to the Swedish Schoolnet Link Larder, Dec 2000.

The Prairie Paper Project, http://www.cs.uiowa.edu/jones/prairiepaper.html, originally posted 1995. Judged "Web Draw Site of the Week," February 10, 1997, by PulpandPaper.net.

2. Grants

External:

Basic Telepresence Incorporated, (Summer Support), 1997, 1999, 2000.

Army Research Office Contract MDA903–90–C–0154 (Summer Support), co-PI, 1991, 1992.

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University of Iowa Department of Physics, subcontract under NASA Contract NAS5–30316 (Summer Support), 1989.

3. Invited Lectures and Conference Presentations

"Counting Votes with Computers," keynote address to the League of Woman Voters of Johnson County, Iowa City, Iowa, May 16, 2001.

"Evaluating Voting Technology," Testimony before the United States Civil Rights Commission, Tallahassee, Florida, January 11, 2001.

"E-Voting—Prospects and Problems," 31st Annual Tau Beta Pi Paul D. Scholz Symposium, University of Iowa, April 13, 2000.

Step Motor Course, an intensive 3-day short course, H.D. Chai***, D.W. Jones*** and W.H. Yeadon***, Small Motor Manufacturer's Association Motor College, August 6–8 1996, San Jose. (Chapters 4, 6 and 8 are by Jones.)

Invited Presentation, Workshop on Expanding and Refining High School Computing, March 22, 1995, Coe College, Cedar Rapids.

"Simulation of Information Flow in Organizations," *Proceedings of the 1993 Winter Simulation Conference*, Dec. 12–15, 1993, Los Angeles, 1388–1389.

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"Practical Evaluation of a Data Compression Algorithm," *Proceedings of the 1991 Data Compression Conference*, Snowbird, Utah, April 8–10 1991, 372–381.

"Concurrent Simulation of Queueing Networks: Limitations and Potentials," S.C. Bruell***, C.C. Chou***, D.W. Jones***, W. Zhang***, D. Renk***, *Proceedings of the 21st Annual Pittsburgh Conference on Modeling and Simulation,* May 3–4, 1990, Pittsburgh, 1189–1193.

"Experience with Concurrent Simulation," D.W. Jones***, Chien-Chun Chou***, Debra Renk***, S.C. Bruell** *Proceedings of the 1989 Winter Simulation Conference,* Dec. 4–6, 1989, Washington DC, 756–764.

"The Iowa Logic Specification Language," a colloquium, June 9, 1988, CERN, Geneva Switzerland.

SERVICE

1. Department

Chair, Undergraduate Committee, 1999–.

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Member, Recruiting Committee, 1991–1992.

Member, Graduate Committee, 1991–1992.

Associate Chairman, 1989–1990.

2. College

Member, Liberal Arts Faculty Assembly, 1993–.

3. University

Secretary, Governing board of the Aliber-Hillel student center, 1998–2001. (Hillel serves the needs of Jewish students at the University of Iowa.)

Member, Governing board of the Aliber-Hillel student center, 1994–. (Hillel serves the needs of Jewish students at the University of Iowa.)

Member, Advanced Computing Facilities Committee, 1990–1996.

Member, Presidential Scholarship Selection Committee, 1991–1994.

Member, Search Committee for Associate Vice President for Research and Director of the Office of Information Technology, 1992–1993.

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Member, Goldwater Scholarship Selection Committee, 1991.

Faculty Representative, Waste Management Committee, 1990–1991.

4. Profession

Session Chair, Winter Simulation Conference, Dec. 1993, New Orleans.

Session Chair, Winter Simulation Conference, Dec. 1990, New Orleans.

Session Chair, Winter Simulation Conference, Dec. 1986, New Orleans.

Referee for: *Communications of the Association for Computing Machinery, Computing Surveys, ACM Transactions on Computer Systems, ACM Transactions on Modeling and Computer Simulation, Institute of Electrical and Electronics Engineers Transactions on Computers, Institute of Electrical and Electronics Engineers Transactions on Distributed Systems, Institute of Electrical and Electronics Engineers Software, Software—Practice and Experience, International Journal of Parallel Programming, Journal of Systems and Software, Algorithmica,* the National Computer Conference, the Association for Computing Machinery Computer Science Conference, the Institute of Electrical and Electronics Engineers International Symposium on Software Reliability Engineering

Reviewed textbook manuscripts for: SRA, John Wiley and Sons, Reston Publishing Company, West Publishing Company. Benjamin Cummings.

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Reviewed grant proposals for: National Science Foundation, International Science and Technology Center (operating in Moscow, funded by the U.S. State Department).

5. Community

Member, Iowa Election Reform Task Force, 2001.

Chair, Iowa Board of Examiners for Voting Machines and Electronic Voting Systems, 1999–

Member, Iowa Board of Examiners for Voting Machines and Electronic Voting Systems, 1994–

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Appendix 3:

Additional Material for the Record

SUBMITTED TESTIMONY FROM THE FEDERAL ELECTION COMMISSIONS

Improving Voting Technologies: The Role of Standards

Mr. Chairman, Congressman Hall, Members of the Committee, the Federal Election Commission (FEC) is pleased to submit this testimony for the record in connection with this very important hearing on Voting Technology and the Role of Standards.

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There has been considerable discussion about the need for federal assistance to the state and local election administrators responsible for acquiring, installing, operating and maintaining the nation's voting machinery. The 2000 Presidential election raised issues about both the adequacy of voting machines and the standards used by local election officials, who, in some cases, are not trained election administrators. Apparently, there is a general consensus the federal government could provide valuable and timely assistance to the states to improve their election administration. We believe the FEC is well positioned to provide that assistance.

The federal government already has taken steps to help state and local election officials make informed decisions about voting equipment. In response to requests from states for technical assistance, Congress authorized the FEC to develop national Voluntary Voting Systems Standards (VSS) for computer-based systems. These standards, first published in 1990, established minimum performance requirements for reliable voting systems. The FEC has established an Advisory Panel of election officials from around the country to assist with this and other election administration projects.

Despite limited funds, the FEC's Office of Election Administration (OEA) is in the process of updating the existing standards. In fact, the FEC began this modification of VSS in 1999, long before the 2000 election. The

FEC plans to release Volume I (Technical Standards) of the updated VSS for public review and comment in June 2001. Volume II (test criteria) will be released for public comment in October 2001, with the FEC issuing the final updated standards (Volumes I and II) in April 2002.

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The VSS currently are being used in a national testing effort overseen by the National Association of State Election Directors (NASED), who have established a process for vendors to submit their equipment for evaluation under these national standards. States are free to adopt the VSS. Thirty-six states have done so, either wholly or in part. The standards do not dictate a particular type of design for voting equipment; instead they measure the reliability of existing voting equipment, without stifling future innovation.

While establishing the VSS was a useful initial step toward raising the quality of voting systems, the problems in the 2000 election illustrate the need to expand the VSS in two crucial areas. First, the standards should be enhanced to address human interface with the voting system to prevent, for example, a poorly designed ballot from causing confusion at the polling place. Thoughtful and logical ballot layout should use time-tested elements borrowed from the graphic and communication design communities to make voting a more natural, intuitive function. Second, the VSS should be expanded to include certain standards for operation, for example in the area of maintenance. While a machine may meet a particular standard when it is new, repeated use without proper maintenance can render a machine ineffective or useless. Other areas of interest to election officials include operational standards for testing and measuring performance of equipment, acquiring new systems, and security.

In addition to updating and expanding the VSS, the FEC also believes, the federal government should make a sustained commitment to help state and local election officials gather and compare data about the nature of any equipment failures that occur. As numerous witnesses have testified, the lack of consensus among the states about the pros and cons of punch-card, optical scan, and direct recording electronic (DRE) voting systems is fueled, in part, by insufficient comparative data. As members of the technology and design communities have noted, there is no formal mechanism for systematically reporting voting equipment failures. Until there is a national commitment to track the performance of voting equipment over time, voters and election officials will find it difficult to determine whether their jurisdiction's equipment is performing as well as it should.

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For the Commission's efforts to update and enhance the existing standards to be successful, there must be participation from the interested public, including election officials and the technology and design communities. The contribution of citizen organizations also will be critical to the ultimate success of the standards. Setting standards essentially is a matter of identifying what works and what does not. And, it emanates from the collective experience of vendors and purchasers, of experts and end users.

With several hearings held by both the Senate and House this year to address voting technology and election reform issues, we hope Congress will continue to examine how the federal government can contribute to improving election systems nationwide. Coupled with an on-going commitment to gathering data on actual voting equipment performance, up-to-date standards can go a long way toward ensuring the quality of voting systems, while still allowing innovation and improvement to occur.

The FEC believes an objective, comprehensive approach is the best solution to the current issues about federal election administration. While an immediate response might be for Congress to provide federal funds to acquire

new voting machinery, that approach alone would not address the establishment of ballot design standards and operation standards for testing and performance measurement of voting equipment, maintenance, acquisition procedures for voting systems, and system security practices.

The FEC has submitted a proposal to Congress which is designed to accomplish the objectives noted in this testimony as noted by several witnesses. We believe the most efficient way to accomplish these objectives for improving the nation's voting systems is to build upon the work begun by the FEC's OEA. Any federal initiatives to improve election administration should be located at the FEC, both to leverage existing expertise and to build on existing relationships with state and local election officials. This is a critical advantage if swift and meaningful assistance to state and local officials is sought for future elections.

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We have submitted for the record a copy of the Federal Election Commission's proposal for an enhanced FEC/ OEA mission. It was prepared in response to the numerous calls for reform of election administration. This enhanced support for OEA is sought to assist state and local election administrators to develop election administration standards and guidelines.

We also submit for the hearing record various resolutions in support of the FEC's enhanced OEA budget request. Organizations that have adopted resolutions are:

The Election Center

The National Association of State Election Directors

The National Association of Secretaries of State

The International Association of Clerks, Recorders, Election Officials and Treasurers

The Council of State Governments

The National Conference of State Legislatures

The National Association of Counties and the National Association of County Recorders, Elections Officials and Clerks

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We thank the Chairman and members of this committee for holding this hearing. The FEC welcomes any questions you may have.

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EXECUTIVE SUMMARY

Residual Votes Attributable to Technology

An Assessment of the Reliability of

Existing Voting Equipment

The Caltech/MIT Voting Project(see footnote 6)

Version 2: March 30, 2001(see footnote 7)

American elections are conducted using a hodge-podge of different voting technologies: paper ballots, lever machines, punch cards, optically scanned ballots, and electronic machines. And the technologies we use change frequently. Over the last two decades, counties have moved away from paper ballots and lever machines and toward optically scanned ballots and electronic machines. The changes have not occurred from a concerted initiative, but from local experimentation. Some local governments have even opted to go back to the older methods of paper and levers.

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The lack of uniform voting technologies in the U.S. is in many ways frustrating and confusing. But to engineers and social scientists, this is an opportunity. The wide range of different voting machinery employed in the U.S. allows us to gauge the reliability of existing voting technologies. In this report, we examine the relative reliability of different machines by examining how changes in technologies within localities over time explain changes in the incidence of ballots that are spoiled, uncounted, or unmarked—or in the lingo of the day the incidence of "over" and "under votes." If existing technology does not affect the ability or willingness of voters to register preferences, then incidence of over and under votes will be unrelated to what sort of machine is used in a county.

We have collected data on election returns and machine types from approximately two-thirds of the 3,155 counties in the United States over four presidential elections, 1988, 1992, 1996, and 2000. The substantial variation in machine types, the large number of observations, and our focus on presidential elections allows us to hold constant many factors that might also affect election returns.

The central finding of this investigation is that manually counted paper ballots have the lowest average incidence of spoiled, uncounted, and unmarked ballots, followed closely by lever machines and optically scanned ballots. Punchcard methods and systems using direct recording electronic devices (DREs) had significantly higher average rates of spoiled, uncounted, and unmarked ballots than any of the other systems. The difference in reliabilities between the best and worst systems is approximately 1.5 percent of all ballots cast.

We view these results as benchmarks for performance. It is our hope that the information here is helpful to manufacturers as they improve equipment designs and to election administrators who may wish to adopt new equipment. Our results apply to broad classes of equipment; the performance of specific types of equipment may vary. Where possible we test for possible differences (such as different types of punch cards).

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We do not attempt to isolate, in this report, the reasons for differential reliability rates, though we offer some observations on this matter in the conclusions. Our aim is measurement of the first order effects of machine types on the incidence of votes counted.

Machine Types and Their Usage

We contrast the performance of five main classes of technologies used in the U.S. today. The technologies differ according to the way votes are cast and counted.

The oldest technology is the *paper ballot.* To cast a vote, a person makes a mark next to the name of the preferred candidates or referendum options and, then, puts the ballot in a box.(see footnote 8) Paper ballots are counted manually. Paper ballots enjoyed a near universal status in the U.S. in the 19th Century; they remain widely used today in rural areas.

At the end of the 19th Century, mechanical *lever machines* were introduced in New York state, and by 1930 every major metropolitan area had adopted lever machinery. The lever machine consists of a steel booth that the voter steps into. A card in the booth lists the names of the candidates, parties, or referenda options, and below each option is a switch. Voters flick the switch of their preferred options for each office or referendum. When they wish to make no further changes, they pull a large lever, which registers their votes on a counter located on the back of the machine. At the end of the voting day, the election precinct workers record the tallies from each of the machines. Lever machines automate both the casting of votes and the counting of votes through mechanical devices.

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Punch card machines automated the counting process using the computer technology of the 1960s. Upon entering the polling place the voter is given a paper ballot in the form of a long piece of heavy stock paper. The paper has columns of small, perforated rectangles (or chads). There are two variants of the punch card—one, the DataVote, lists the names of the candidates on the card; the other (VotoMatic) does not. In the booth (for VotoMatics), the voter inserts the card into a slot and opens a booklet that lists the candidates for a given office. The voter uses a metal punch to punch out the rectangle beside the candidate of choice. The voter then turns the page, which lists the options for the next office and shifts the card to the next column of rectangles. When finished, the voter removes the card and puts it in the ballot box. At the end of the day, the election workers put the cards into a sorter that counts the number of perforations next to each candidate.

Optically scanned ballots, also known as "marksense" or "bubble" ballots, offer another method for automating the counting of paper ballots. The form of the optically scanned ballot is familiar to anyone who has taken a standardized test. The voter is given a paper ballot that lists the names of the candidates and the options for referenda, and next to each choice is small circle or an arrow with a gap between the fletching and the point. The voter darkens in the bubble next to the preferred option for each office or referendum, or draws a straight line connecting the two parts of the arrow. The ballot is placed in a box, and, at the end of the day, counted using an optical scanner. Some versions of this technology allow the voter to scan the ballot at the polling place to make sure that he or she voted as intended.

Direct recording electronic devices, DREs for short, are electronic versions of the lever machines. In fact, the first widely used electronic machine (the Shouptronic 1242) was modeled on the lever machine and developed by one of the main lever machine manufacturers. The distinguishing feature of a DRE is that an electronic machine

records the voter's intentions, rather than a piece of paper or mechanical device. To the extent that there is a paper trail it is generated by the machine, not the voter. Electronic machines vary along a couple of dimensions, having to do with the interface. First, there are many devices used to register the vote: the interfaces are either push button (e.g., the Shouptronic) or touch screen (e.g., Sequoia Pacific's Edge or Unilect's Patriot) or key pads (see the Brazillian machine). Second, the ballot design is either full-faced or paginated. With full-faced ballots, common among push button equipment, the voter sees the entire ballot at once. With paginated systems, common among touch screen devices, the voter views a page for each office or question on the ballot. A voting session goes roughly as follows. Upon entering the polling place, the voter is given a card that is inserted into the machine to activate the individual voting session. When finished the touches the name on the screen to register his or her preference and, typically, the voter may review the entire session (or ballot) to check the vote. Like lever machines it is not possible to vote twice for the same office (i.e., overvote). Each electronic machine tallies the votes locally and the tallies, usually on a disc, are sent to a central location.

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Each type of technology involves many variations based on specifications of manufacturers, ballot formats, and implementation. Our focus is on the five main types of machines, as we hope to learn which mode of voting looks most promising. In almost all states county election officials decide which machinery to use, so counties are, almost everywhere, the appropriate unit of analysis. Some counties do not have uniform voting technologies. In these situations, municipalities and, sometimes, individual precincts use different methods. These counties are called *Mixed Systems.* They occur most commonly Massachusetts, Michigan, Maine, New Hampshire, and Vermont, where town governments usually administer elections.

We examine the variation in usage across counties and over time. Our data on voting equipment come from the Election Data Services and from state, county, and municipal election officials. We appreciate the helpfulness of election administrators and the EDS in our data collection efforts.

The data do not distinguish centrally counted and precinct counting of ballots sufficiently well that we could estimate with confidence the difference in performance between central and precinct counting. Some states provide information about which administrative units count the ballots for some machine types. Precinct and central counting of optically scanned ballots became quite controversial in the Florida 2000 election.

Even without this additional level of detail, the pattern of equipment usage across the United States looks like a crazy quilt. Americans vote with a tremendous array of types of equipment. Table 1 displays the wide variation in machines used in the 1980 and 2000 elections. The first two columns present the average number of counties using various types of equipment in each year. The last two columns report the percent of the population covered by each type of technology in the 1980 and 2000 elections.

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In the most recent election, one in five voters used the "old" technologies of paper and levers—1.3 percent paper and 17.8 percent levers. One in three voters use punch cards - 31 percent of the VotoMatic variety and 3.5 percent of the DataVote variety. Over one in four use optically scanned ballots. One in ten use electronic devices. The remaining 8 percent use mixed systems.

Within states there is typically little uniformity. In some states, such as Arkansas, Indiana, Michigan,

Pennsylvania, and Virginia, at least one county uses each type of technology available. The states with complete or near uniformity are New York and Connecticut with lever machines; Alaska, Hawaii, Rhode Island and Oklahoma with scanners; Illinois with punch cards; Delaware and Kentucky with electronics.

As impressive and dramatic have been the changes in technology over time. The third column of the table reports the percent of the 2000 electorate that would have used each machine type had the counties kept the technologies they used in 1980. The data are pretty clear: out with the old and in with the new. Optically scanned ballots and DREs have grown from a combined 3.2 percent of the population covered to 38.2 percent of the population covered. There has been little change in the mixed and punch card systems. Paper ballots have fallen from 9.7 percent of all people in 1980 to just 1.3 percent in 2000. Lever machines, by far the dominant mode of voting in 1980, covered 43.9 percent of the electorate. Today, only 17.8 percent of people reside in counties using lever machines.

A somewhat different distribution of voting technology across counties holds, owing to the very different population sizes of counties. Punch cards and electronic devices tend to be used in more populous counties, and paper ballots tend to be used in counties with smaller populations.

Table 1

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Three comments about the change in equipment are in order. First, this is an industry in flux. Between 1988 and 2000, nearly half of all counties adopted new technologies (1,476 out of 3,155 counties), and over the twenty-year period between 1980 and 2000, three out of five counties changed technologies. These changes have occurred without any federal investment.

Second, there is a clear trend toward electronic equipment, primarily scanners but also electronic voting machines. This trend, and the adoption of punch cards in the 1950s and 1960s, reflects growing automation of the counting of votes. Punch cards, optical scanners, and DREs use computer technology to produce a speedy and, hopefully, more reliable count. An influential 1975 report sponsored by the General Accounting Office and subsequent reports by the Federal Elections Commission called for increased computerization of the vote counts and laid the foundation for methods of certification.(see footnote 9)

Third, voting equipment usage has a strongly regional flavor. The Eastern and Southeastern United States are notable, even today, for their reliance on lever machines. Midwestern states have a penchant for paper. And the West and Southwest rely heavily on punch cards. In 1980, almost all eastern and southeastern states used levers, and levers were rare outside this region. Notable exceptions were the use of paper in West Virginia and punch cards in Ohio and Florida. In 1980, Midwestern counties used hand counted paper ballots. Illinois was a notable exception with its use of punch cards. And in 1980, almost all counties along the pacific coast and in the Southwest used punch cards. Notable exceptions to the pattern were the use of levers in New Mexico.

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This historical pattern of usage evidently had a legacy. As counties have adopted newer technologies over the last twenty years, they have followed some distinctive patterns. Counties tend to adopt newer technologies that are

analogous to the technology they move away from. Optical scanning has been most readily adopted in areas that previously used paper, especially in the Midwest. Where counties have moved away from lever machines, they have tended to adopt electronic machines—for example, New Jersey, Kentucky, central Indiana and New Mexico. These tendencies are strong, but they are not iron clad. In assessing the performance of technology, we will exploit the changes in election results associated with changes in technology. This allows us to hold constant features of the county and it's population.

Residual Votes: A Yardstick for Reliability

Our measure of reliability is the fraction of total ballots cast for which no presidential preference was counted. We call this the "residual vote."

A ballot may show no presidential vote for one of three reasons. Voters may choose more than one candidate—commonly called an over vote or spoiled ballot. They may mark their ballot in a way that is uncountable. Or, they may have no preference. The latter two possibilities produce under votes or blank ballots. The residual vote is not a pure measure of voter error or of machine failure, as it reflects to some extent no preference. Consequently we prefer the term residual vote instead of error rate or uncounted vote.

The residual vote does provide an appropriate yardstick for the comparison of machine types, even though it is not purely a measure of machine error or voting mistakes. If voting equipment has no effect on the ability of voters to express their preferences, then the residual vote should be unrelated to machine types. To measure such effects, we estimate the average residual vote associated with each machine type, and we assess whether these averages differ significant across machine type. Averaging guards against idiosyncratic results, and measures what we expect to happen in a typical case.(see footnote 10)

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In our data, the residual vote in the average county equaled 2.3 percent.(see footnote 11) In other words, in the typical U.S. county from 1988 to 2000, 2.3 percent of ballots casts did not register a presidential preference, for whatever reason. Because county populations vary dramatically, this does not equal the fraction of people who cast an under or over vote for president in these years. This figure is somewhat smaller: 2.1 percent of people who cast ballots did not register a presidential preference. There is considerable variation around this average. Our aim in this report is to assess whether machine types explain a statistically noticeable amount of the variation around this national average residual vote.

We examine the residual vote instead of just the over vote because technology can enable or interfere with voting in many ways. Some technologies seem to be particularly prone to over voting, such as the punch card systems implemented in Florida in the 2000 election. Lever machines and DREs do not permit overvoting voting. Some technologies may be prone to accidental under votes. Lever machines either lock out a second vote or register no vote when the person switches two levers for the same office. Also, paper ballot are sometimes hard to count owing to the many ways that people mark their ballots. Finally, some technologies might intimidate or confuse voters. Many Americans are unaccustomed to using an ATM or similar electronic devices with key pads or touch screens, and as a result DREs might produce more under voting. Also, it may be the case that we react differently to paper than to machines. We are trained in school to answer all of the questions as best as possible, especially on standardized tests similar to the format used for optically scanned voting. Improper installation or wear and tear on machines may lead to high rates of under voting. In Hawaii in 1998, 7 of the 361 optical scanners failed to operate properly.

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In depth study of particular states and of contested elections may provide insight into the components of the residual vote or more specific problems related to voting equipment. A number of papers published on the Internet examine the effects of machine types on over votes and on under votes separately for the Florida 2000 election. (see footnote 12)

One important caveat is in order in this analysis. There are errors that we cannot count. There is no way to measure whether voters accidentally cast ballots for the wrong candidate. We know of no statistically acceptable measures of fraud. And we know of no studies that attempt to measure the incidence and magnitude of errors in the counting of votes produced by transcription errors or programming errors. Residual votes provides the best available measure of the extent to which technology enables or interferes with the ability of voters to express their preferences.

Many other factors may explain under and over voting beside machine types. Other prominent offices on the ballot, such as senator or governor, might attract people to the polls who have no intention to vote for president. A large turnout might make it difficult for election administrators to tend to voter education at the polls. Demographic characteristics of the county's electorate might explain the incidence of people prone to make mistakes. The wealth of the county might account for expenditures on election administration. New machinery might produce elevated levels of voter confusion, simply because people make mistakes more with unfamiliar tasks.

We examine total ballots cast and ballots cast for President in the 1988, 1992, 1996, and 2000 elections. The data cover approximately 2,800 counties and municipalities, though not for all years. All told, there are approximately 7,800 counties and municipalities for which we have been able to identify the machines used and to collect data on total ballots and presidential ballots cast. As with the voting equipment data, our data on elections returns come from the Election Data Services and from the relevant election commissions of particular states, counties, and municipalities. The large number of observations produces high levels of precision in estimating average residual vote rates associated with each machine type. Studies of one election in one state may not have yield sufficiently large samples to determine whether there are significant differences across voting equipment.

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We examine the presidential vote in order to hold constant the choices voters face. Within each state one might also examine residual votes in Senate and governor races, with the caveat that these offices have higher "no preference" and thus higher residual votes.

We examine the data at the level of the county or municipality that reports the information. Within each of these jurisdictions, the same voting equipment is used and the administration of the election is under the same office (e. g., has the same budget, etc.). Counties and municipalities are a useful level of analysis because they allow us to hold constant where the equipment is used when we measure which equipment is used. This is of particular concern because equipment usage today is correlated with factors such as county size. We do not want to attribute any observed differences in reliability to equipment, when in fact some other factor, such as county demographics, accounts for the pattern.

To hold constant the many factors that operate at the county level, we exploit the natural experiment that occurs

when locales change machinery. We measure how much change in the residual vote occurs when a county changes from one technology to another. The average of such changes for each technology type provides a fairly accurate estimate of the effect of the technology on residual voting, because the many other factors operating at the county level (such as demographic characteristics) change relatively slowly over the brief time span of this study.

To guard against other confounding factors, we also control for contemporaneous Senate and gubernatorial races on the ballot, total turnout, and year of the election.

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Results

Typical Counties and Typical Voters

A simple table captures the principle results of this investigation. Table 2 presents the average residual vote rate for each type of voting equipment. The first column of numbers is the average; the second column is the margin of error associated with this estimate; the third column is the median residual vote rate; and the final column is the number of observations (counties and years) on which the estimate is based. The average is the arithmetic mean residual vote across counties. The median is the residual vote such that half of all counties have lower values and half of all counties have higher values. A lower median than mean reflects skew in the distribution of the residual vote produced by a few cases with exceptionally high rates of under and over votes. These averages do not control for other factors, but they reveal a pattern that generally holds up to statistical scrutiny.(see footnote 13)

Two clusters of technologies appear in the means and medians. Paper ballots, lever machines, and optically scanned ballots have the lowest average and median residual vote rates. The average residual voting rates of these technologies are significantly lower than the average residual voting rates of punch card and electronic voting equipment. The differences among punch card methods and electronic voting equipment are not statistically significant. Punch cards and electronic machines register residual voting rates for president of approximately 3 percent of all ballots cast. Paper ballots, lever machines, and optically scanned ballots produce residual voting rates of approximately 2 percent of all ballots cast, a statistically significant difference of fully one percent. Or to put the matter different, the residual voting rate of punch card methods and electronic devices is 50 percent higher than the residual voting rate of manually counted paper ballots, lever machines, and optically scanned ballots. This pattern suggests that simply changing voting equipment, without any additional improvements, could lower the incidence of under and over voting substantially.

Table 2

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Another take on the average reliability of equipment is the percent of all ballots cast for which no presidential vote was registered. This is displayed in the fourth column of numbers: this is the weighted average of the county residual vote, in which we weight by total ballots cast in the county. All of the figures shrink toward zero but the same general pattern holds. In fact, optical scanning seems to do particularly well by this measure. Only 1.6 percent of all ballots cast with optical scanners showed an overvote or no vote over the years 1988 to 2000.

Approximately, 1.8 percent of voters cast an over vote or no vote using paper ballots or lever machines. Slightly more than 2 percent of voters cast an over vote or no vote with punch cards or electronics.

It has been suggested to us that we isolate specific years. Also, one media report claims that a separate analysis of the EDS data reveals that electronics did particularly well in 1996. We present the residual vote rates for each year of our data as a point of comparison. It should be noted that year-to-year one expects more random variation in the numbers simply by chance. Every time someone votes on a machine they have a small chance of making a random error. Taking averages over many cases gives us a more precise measure of the typical behavior. This is especially true for categories of equipment for which there are relatively small numbers of observations, namely DataVote and Electronics.

Even with this statistical caveat, the yearly averages bear out the same general pattern as the overall averages. In each year, except perhaps 2000, paper ballots and lever machines on the whole have lower residual vote rates than the other technologies. In 2000, paper and levers had relatively low residual vote rates, but so too did scanners and electronics.

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Electronics did relatively poorly in 1988, 1992, and 1996.(see footnote 14) 2000 was the banner year for electronics, but in that year paper ballots and optically scanned ballots had noticeably lower average residual vote rates.

Votomatic punch cards have consistently high average residual vote rates. In 1988, 1996 and again in 2000, punch cards had substantially higher rates of over and under votes than other available technologies. This is of particular concern because approximately one in three voters use punch cards. If election administrators wish to avoid catastrophic failures, they may heed the warning contained in this table and the last. It is the warning that Roy Saltman issued in his 1988 report. Stop using punch cards.

Electronic machines look similarly prone to high residual vote rates, except for 2000, which offers a glimmer of promise for this technology.

Table 3

Effects of Technology Adoption on Residual Vote Rates

Of course many other factors might explain the observed pattern, including features of the counties and specific elections. The difference between the county and population-weighted averages suggests that county size strongly affects residual vote rates: larger counties typically have lower residual vote rates than smaller counties. We clearly need to hold constant where equipment is used in order to gauge accurately the effects of equipment types on residual vote rates. There are certainly many other factors, such as county literacy rates, education levels, election administration expenditures, other candidates on the ballot, years in which shifts in technology occur.

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We hold constant turnout, shifts in technology, other statewide candidates on the ballot, and all factors at the county and state level that do not change dramatically over the period of study, such as literacy rates. To hold these other factors constant we performed a multiple regression of changes in the residual voting rate at the county level on changes in the machine used at the county level, controlling for the year of the election, whether there was a switch in technology in a specific year in a given county, and the total vote in the county. This approach removes the effects of all factors that distinguish the counties, changes in turnout levels within counties, and some features of the election in the state.

In essence, our statistical approach is that of a "natural experiment." We observe within each county how residual votes change when counties change machine technologies. Between 1988 and 2000, slightly more than half of all counties changed their voting equipment.

The effect of specific technologies on residual votes is expressed relative to a baseline technology. We chose lever machines to serve as this baseline for the contrasts, because levers were the modal machine in 1988. The observed effects contrast the change in residual vote associated with a specific technology compared to a baseline technology. By making multiple comparisons (e.g., paper to lever, scanners to lever, etc.), we measure the relative performance of existing equipment.

We omit counties with Mixed Systems, as it is unclear exactly what technologies are in use. The exceptions are Massachusetts and Vermont, where equipment is uniform within towns: we have collected the information at the town level for these states.

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Table 4 reports the observed difference between lever machines and other machine types, along with the "margin of error" (i.e., a 95 percent confidence interval) associated with the observed differences. The complete regression analyses are available upon request. Positive numbers mean that the technology in question has *higher* average residual vote than lever machines and negative numbers mean that the technology in question has lower average residual vote than lever machines. The wider the margin of error, the less certainty we have about the observed difference. A margin of error in excess of the actual effect means that the observed effect could have arisen by chance.

Table 4 presents results from two separate analyses. One analysis, presented in the first two columns, contains all valid cases. A second analysis, presented in the last two columns, trims the data of extreme cases. To guard against outliers and typographical errors, we omit the cases with lowest 5 percent of residual vote and highest 5 percent of residual vote.

Table 4 bears out the same patterns as Tables 2 and 3. After introducing considerable statistical controls, we reach the same conclusions about the relative performance of different equipment types.

Two clusters of technologies appear in Table 3. Paper ballots, optically scanned ballots, and lever machines appear to perform noticeably better than punch card methods and electronic devices. Paper might even be an improvement over lever machines and scanners.

Table 4

(a) This is the 95 percent confidence interval for the estimated effect; the half-width of the confidence interval equals 1.96 s/n, where s is the estimated standard error of the estimated coefficient for each machine type.

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First consider the contrast between Paper and Levers. Looking at all counties (the first two columns of the table), the estimated effect of using paper ballots rather than lever machines of is to lower the residual vote rate by approximately one-half of one percent of all ballots cast (i.e., and estimated effect of –0.55). This effect is larger than the margin of error of .37, so the effect is unlikely to have arisen by chance. Omitting extreme cases, the evident advantage of paper ballots over lever machines shrinks: the effect becomes two-tenths of one-percent of ballots cast and this is not statistically different from zero difference between levers and paper.

Second consider optical scanning. The difference in the residual vote rate between scanners and levers is trivial once we hold constant where equipment is used, how many people voted, the year, other statewide candidates on the ballot, and technological changes. In both analyses, the difference between optically scanned ballots and lever machines is quite small and statistically insignificant. Levers and paper and scanned ballots appear to offer similar rates of reliability, at least as it is measured using the residual vote.

The third contrast in the tables is of punch cards to lever machines. Punch card methods produced much higher rates of residual voting. The VotoMatic variety of punch cards produced residual vote rates more than one-percentage point higher than what we observe with lever machines. In our examination of all cases, punch cards recorded 1.3 percent of all ballots less than lever machines did. The estimated effect remains in excess of one-percentage point even after we exclude the extreme cases. The DataVote variety of punch cards looks extremely similar to the Votomatic variety. Because DataVote punch cards have the candidates names on the card, they were widely believed to be superior to the VotoMatic cards. We find no evidence to support this belief.

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A final contrast in the table is between DREs and lever machines. Electronic machines registered significantly higher residual vote rates than lever machines (and, by extension, paper ballots and optically scanned ballots), but DREs do not do as badly as punch cards. Direct Recording Electronic devices had a residual vote rate that was almost one percentage point higher than lever machines, holding constant many factors, including the county. In other words, a county that switches from Levers to DREs can expect a significant rise in residual votes of approximately one percent of total ballots cast. Excluding extreme observations, the effect is somewhat smaller, two-thirds of one percent of all ballots cast. But that is still highly significant from a statistical perspective, and we find it to be a substantively large effect.

One final note about the estimated effect of the DRE performance is in order. Because this machine does not permit over voting, the observed difference in residual vote rates is due to a very significant rise in under voting attributable to electronic devices.

We checked the robustness of our results in a variety of ways. We tried various transformations of the dependent variable, and we split the data into counties of different sizes (under 5,000 votes, 5,000 to 100,000 votes, and over 100,000 votes). The pattern of results is always the same.

Perhaps the most instructive check on the robustness of our analysis comes when we track changes in

equipment usage over time. What happened in the counties that used levers in 1988 in the subsequent three presidential elections? Some of those counts continued to use their lever equipment over the succeeding three presidential elections. Approximately half decided to adopt other technologies and almost all of those that changed went to either electronics or scanners. How did the residual vote rates in these counties compare to 1988?

Table 5

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Baseline Residual vote rate is 1.8 percent in 1988 for counties with lever machines.
Standard Deviation is approximately 0.16 for each group in the first column and 0.17 for each group in the second column.

What Is Wrong With DREs?

We were very surprised by the relatively high residual vote rate of electronic equipment. When we began this investigation we expected the newer technologies to outperform the older technologies. Considering some of the glowing reports about electronics following the 2000 election, we expected the DREs to do well. They did not, especially compared optically scanned paper ballots, the other new technology.

We are not pessimistic about this technology, however. It is relatively new, and we see this as an opportunity for improvement. In this spirit we offer four possible explanations for the relatively high residual vote rates of electronic voting machines.

First, the problem may be inherent in the technology. One speculation is that people behave differently with different technologies. Electronic machines may be simply a less human friendly technology.

Second, the problems may reflect existing interfaces and ballot designs. The results might stem from differences between touch screens and push buttons or between full-face and paginated ballots (paper and levers are full faced).

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Third, there may be a technology curve. As the industry gains more experience with electronics they may fix specific problems.

Fourth, we may be still low on the voter learning curve. As voters and administrators become more familiar with the newer equipment errors may go down. Also, as more people use electronic equipment in other walks of life, such as ATM machines for banking, residual votes may drop.

Fifth, electronics may be harder to maintain and less reliable than a piece of paper or a mechanical device. Power surges, improper storage, and software errors may affect DREs.

There is simply too little data from existing equipment usage to say with confidence what exactly accounts for the relatively high residual vote rate of DREs that we observe. We observe approximately 480 instances of

electronic machine usage. As we begin to divide them in terms of interface, there are too few cases to gain much leverage on the questions of interface design. Half of the observations in our data are Shouptronic 1242 machines; another one-quarter are Microvote machines. These are push button, full faced machines. One-in-six are Sequoia AVC Advantage machines. There is not enough variety in machines used or enough observations to accurately measure whether some features of the interface explain the results. Careful, systematic laboratory testing may be required to identify the importance of the interface.

Year-by-year analysis casts some doubt on the notion that there is a voter learning curve. The residual vote rate does not fall steadily for counties using DREs, but jumps around. This variation may owe to the small number of observations in each year. But a learning curve does not clearly appear in the data.

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Conclusions

Paper ballots, lever machines, and optically scanned ballots produce lower residual vote rates on the order of one to two percent of all ballots cast over punch card and electronic methods over the last four presidential elections.

Lever machines serve as a useful baseline: they were the most commonly used machines in the 1980s, the starting point of our analysis. The incidence of over and under votes with Lever machines is approximately two percent of all ballots cast. The incidence of such residual votes with punch card methods and electronic devices is forty to seventy percent higher than the incidence of residual votes with the other technologies.

We have not analyzed why these differences in residual votes arise. We believe that they reflect how people relate to the technologies, more than actual machine failures. State and federal voting machine certification tolerate very low machine failure rates: no more than 1 in 250,000 ballots for federal certification and no more than 1 in 1,000,000 ballots in some states. Certification serves as an important screen: machines that produce failure rates higher than these tolerance levels are not certified or used. We believe that human factors drive much of the "error" in voting, because the observed differences in residual voting rates that are attributable to machine types are on the order of 1 to 2 out of 100 ballots cast. Given the stringent testing standards for machinery in use, these differences are unlikely to arise from mechanical failures.

We have also not examined many details about the implementation of the machinery, such as manufacturer or precinct versus central counting of ballots or specific ballot layouts.

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A final caveat to our findings is that they reflect technologies currently in use. Innovations may lead to improvements in reliability rates. In particular, electronic voting technology is in its infancy during the period we are studying, and has the greatest room for improvement. It seems the most likely technology to benefit significantly from new innovations and increased voter familiarity.

In the wake of the 2000 election, many state and local governments are reconsidering their choices of and standards for voting equipment. Many manufacturers are seeking to develop or improve machinery. This report identifies a performance standard in practice—an average residual vote not in excess of 2 percent of total ballots

cast. With this benchmark in mind, we wish to call attention to the excellent performance of the optically scanned ballots, the best average performance of the newer methods, and especially to the older methods of voting—lever machines and paper ballots.

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(Footnote 1 return)

Dr. Jones adds: Since the date of the hearing, Larry L. Mandel, president of Governmental Business Systems Inc.

has sent me a Votomatic voting machine with a replica of the Palm Beach County "butterfly" ballot.

(Footnote 2 return)
Dr. Jones adds: Dr. Mercuri and I disagreed on the likelihood that we could take corrective action to prevent a repeat of the 2000 general election by the 2004 election. She was optimistic, while I was not.

(Footnote 3 return)
Dr. Jones adds: Since the hearing, Part I of the FEC's draft standard has been released I have taken the time to read it in detail and send detailed comments to the FEC on the draft.

(Footnote 4 return)
Dr. Jones adds: In my testimony, I pointed out that many new direct-recording-electronic voting systems are little more than repackaged off-the-shelf PC components, and that the level of technical expertise it takes to maintain such a system is about that of the auto repair shop work that Mr. Lampson mentioned. Dr. Mercuri disagreed with me about the appropriateness of using off-the-shelf PC components in voting systems.

(Footnote 5 return)
See article on "The Importance of Recounting Votes" in Appendix 3.

(Footnote 6 return)
The Caltech/MIT Voting Project is a joint venture of the two institutions. Faculty involved are Michael Alvarez (Caltech), Stephen Ansolabehere (MIT), Erik Antonsson (Caltech), Jehoshua Bruck (Caltech), Steven Graves (MIT), Nicholas Negroponte (MIT), Thomas Palfrey (Caltech), Ron Rivest (MIT), Ted Selker (MIT), Alex Slocum (MIT), and Charles Stewart (MIT). The principal author of this report is Stephen Ansolabehere; communications about this report can be directed to him at *sda@mit.edu*. We are grateful to the Carnegie Corporation for its generous sponsorship of this project.

(Footnote 7 return)
This version updates our initial report in three ways. First, we have expanded the data set considerably: increasing the number of valid cases from roughly 5500 to 8000. We have added complete data for several states, such as Kentucky, Massachusetts, and Vermont, and nearly complete coverage of the available data from the 2000 election. Second, we present more detail about the data, such as yearly averages, and examine possible technology curves and other hypothesized relationships. Third, we incorporate more speculation about the performance of DREs. The next version of the report will integrate data from 1980 and from the 1980, 1990, and 2000 censuses, which will allow us to examine possible interactions between machine performance and demographic characteristics of county populations.

(Footnote 8 return)
How we mark ballots has changed over time. In the middle of the 20th Century, many states required that the voter cross out the options not chosen. See for example, The Book of the States, 1948.

(Footnote 9 return)
See Roy Saltman's 1988 report.

(Footnote 10 return)
Some analyses focus on extreme cases—under- and overvotes in specific elections in particular counties. Indeed, much of the analysis of Florida falls into this category. Such case studies can be misleading, especially if they reflect outcomes peculiar to a locale, or a local machine failure. Another advantage of averaging is that it washes out the effects of typographical errors, which are inevitable in data, even official government reports.

(Footnote 11 return)
We exclude from the analysis all cases in which the official certified report shows more presidential votes cast than total ballots cast, that is, cases with negative residual vote rates. We have tried to resolve all of these cases. They do not appear to be due to absentee votes or other votes being excluded. Instead, they appear to be typographical errors in the data reported by the counties and secretaries of state. This affects about 2 percent of the counties in our analysis. Including these cases changes the numbers reported, but does not affect the pattern of results that we observe.

(Footnote 12 return)
The site http://www.bestbookmarks.com/election/#links provides a list of many studies with links; there are similar sites. The papers are not products of or endorsed by the CalTech/MIT Voting Project.

(Footnote 13 return)
The data in the table only include counties with positive residual vote rate. Approximately 2 percent of counties report negative numbers; these are the figures in the official certified vote. Including counties with negative residual vote rates changes the numbers slightly but does not change the results.

(Footnote 14 return)
It should be noted that our data for 1996 come almost entirely from the EDS. When we analyze just the EDS data, we arrive at the same pattern of means, with electronics producing a relatively high average residual vote.
