HEARING ON TECHNOLOGY AND THE VOTING PROCESS

Hearing

BEFORE THE

COMMITTEE ON HOUSE ADMINISTRATION HOUSE OF REPRESENTATIVES

One Hundred Seventh Congress

FIRST SESSION

Hearing Held in Washington, DC, May 24, 2001

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TECHNOLOGY AND THE VOTING PROCESS

THURSDAY, MAY 24, 2001

HOUSE OF REPRESENTATIVES,
COMMITTEE ON HOUSE ADMINISTRATION,
Washington, DC.

The committee met, pursuant to call, at 11:00 a.m., in Room 1310, Longworth House Office Building, Hon. Robert W. Ney (chairman of the committee) presiding.

Present: Representatives Ney, Ehlers, Doolittle, Hoyer, and Fattah.

Staff present: Jeff Janas, Professional Staff; Reynold Schweickhardt, Technology Director; Roman Buhler, Counsel; Paul Vinovich, Counsel; Chet Kalis, Professional Staff Member; Sara Salupo, Staff Assistant; Robert Bean, Minority Staff Director; Matt Pincus, Minority Professional Staff; and Keith Abouchar, Minority Professional Staff.

The CHAIRMAN. The committee will come to order. I want to thank the witnesses for coming to the committee. I would note we have several things going on in a conference on the Majority side, so the members will be coming in. Also the ranking member has a previous commitment, but he will be here; and a couple of the other members will also be coming in at different times. We do have Mr. Fattah and myself, So we appreciate you coming.

Our witnesses are Christopher Baum, Vice President/Research Director of the Gartner Group, Stamford, Connecticut; Thomas Palfrey, Professor of Economics and Political Science, Co-Director MIT Voting Technology Project, California Institute of Technology, Pasadena, California; David Woods, Professor, Institute for Ergonomics, Associate Director of the Midwest Center for Inquiry on Patient Safety of the Veterans Health Administration, from my alma mater, Ohio State University. I attended there when we used to beat Michigan regularly, years ago. And Ronald Rivest, Viterbi Professor of Computer Science, Laboratory for Computer Science, Massachusetts Institute of Technology, Cambridge, Massachusetts.

I want to welcome all the witnesses. As you are probably aware, we have had different panels on election reform, and I think they have been interesting panels as this has progressed. This is the fourth hearing in a series of hearings. Your panel brings a different, I think, perspective to the hearing process. The first panel we had were secretaries of state, State legislators, county commissioners, disabled community, and American Legion.

Our second hearing had the local election officials, who were on the front line of this, and then the third hearing included the vendors. And now we have the technology exposition. And now I think

from the academic side and the technological side, you will bring a different perspective for us.

Mr. Fattah, do you have a statement?

Mr. FATTAH. Thank you, Mr. Chairman. Let me thank you for your continuing role in this to tackle this issue that is critically important to the lifeblood of our democratic process. I have an opening statement that I would like to submit into the record on behalf of the ranking member, the gentleman from Maryland, and I would like to do that if there is no objection.

The CHAIRMAN. Without objection.

[The statement of Mr. Hoyer follows:]

STENY H. HOYER
5TH DISTRICT, MARYLAND

CO-CHAIR
'CRATIC STEERING COMMITTEE

COMMISSION ON SECURITY AND
COOPERATION IN EUROPE

Congress of the United States
House of Representatives
Washington, DC 20515–2005

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AND EDUCATION

LEGISLATIVE

COMMITTEE ON
HOUSE ADMINISTRATION

Opening statement
Electoral reform hearing:
Voting technology
May 23, 2001

Mr. Chairman, members of the committee.

This is the fourth hearing that the House Administration Committee has held on electoral reform in as many weeks.

Today's hearing is also the second in the Committee's series on technology and the voting process.

Last week we kicked off the technology series by hosting a 2-day exposition on the latest in voting technology, during which 13 vendors demonstrated their wares.

We heard from the manufacturers who actually build the sophisticated, durable equipment that Americans use to exercise their right of franchise.

I found last week's focus on technology to be enormously instructive, for three reasons:

First, I was able to try a wide range of machines that the voting equipment industry is developing now to ensure that our democracy, and democracies all over the world, are conducted accurately and honestly: Optiscan, DRE, even voting by telephone.

Second, I learned about sophisticated software and hardware devices to ensure that voting is accessible to all Americans, that votes are counted accurately and completely, and that voters have a chance to correct mis-marked ballots before they are cast.

Third, I was able to learn a great deal about the voting machine industry. Specifically, whether it has the capacity to manufacture top-quality, FEC certified equipment in short order – in time for the 2002 elections.

But of course, like any profit-driven industry, the voting machine industry is not a disinterested party when it comes to talking about itself and its products.

That's why I am looking forward to today's hearing. I expect our panel of distinguished academics and computer experts to describe in objective terms the quality of voting technology choices today and how they compare with one another.

I also hope our panelists will comment on how easy and accessible today's voting technologies and ballot designs are for all voters and poll workers to use, based on rigorous research they conducted following last November's election.
I will also welcome their thoughts on how research and development of new voting technology can best be facilitated by Congress, and how the system for testing and certification of new machines can be improved.

And last but not least, I will welcome their expert views on just how secure today's new voting technologies are and to what extent they guarantee voter privacy.

Today's hearing continues a learning process we began on April 25. It is additional proof of just how determined House Administration is to learn what state secretaries, county officials, state legislators, local elections administrators, and technical experts are doing right now in the area of electoral reform and how Congress can help.

Chairman Ney and I are already using this knowledge to craft a bipartisan electoral reform measure that recognizes the legitimate role Congress can play modernizing our democracy's infrastructure without infringing on the rights of state and local communities.

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Mr. FATTAH. And I would like to thank our witnesses today and I look forward to their testimony. I have a particular interest in the Caltech-MIT project, but I am sure that each of our witnesses will have testimony that will help us grapple with this issue. Thank you, Mr. Chairman.

The CHAIRMAN. And thank you, Mr. Fattah.

And we will begin with the first witness, Christopher Baum.

STATEMENT OF CHRISTOPHER BAUM, VICE PRESIDENT/RESEARCH DIRECTOR, GARTNER GROUP, STAMFORD, CONNECTICUT

Mr. BAUM. Mr. Chairman, distinguished members of the committee, Gartner is honored today to give testimony on the trends in voting technology. The events of last November point clearly to a crisis in confidence in the American electoral system. However, there is no clear consensus on how to fix the problem. Some believe that electronic voting is the only way to go. After all, it is the same technology that worked so well in the banking industry. However, there are other opinions. Last week I was present at an election site in Boiling Point, Pennsylvania, where voters were invited to try a new computerized system in a "shadow election." after they had cast their official ballot on the regular system. I saw one gentleman who declined to try the new system. I asked him why. He said, if you aren't smart enough to vote on paper, you shouldn't be allowed to vote.

However, Gartner believes that computer-based voting technologies, with appropriate supporting processes and infrastructure, can significantly reduce election problems and restore the public trust. The public has already demonstrated its faith in electronic systems using ATMs to make deposit and filing taxes electronically. Computerized voting appliances can significantly improve both the balloting and tallying processes, increasing accuracy both in the votes cast and the vote count.

Gartner recently completed a survey on the intentions of the United States' largest voting districts in the aftermath of the 2000 Presidential elections. The findings of the survey have been submitted to this committee; but, in summary, we would like those present to consider the following:

Forty percent of the districts surveyed have already either implemented new technology or have begun major new voting technology projects.

Those favoring Federal guidance on purchasing and implementing new technologies are evenly matched with those opposed to such guidance, about 45 percent on each side, with 10 percent abstaining.

One quarter of those opposing Federal guidance specifically listed implementation problems with the Americans With Disabilities Act, ADA, and the National Voter Registration Act, "Motor Voter Act," as examples of why Federal intervention is not warranted.

However, 50 percent of those in favor of Federal guidance cited the need for uniformity in Federal elections. The most cited example was guidance in establishing proper unit trails that can support recounts, but do not impinge on privacy.

While desires for overall Federal involvement is mixed, 65 percent favored a specific Federal role in the valuation of new voting technology.

And, not surprisingly, 75 percent reported that their jurisdictions would require increased fundings to acquire new technology.

As a result of this survey, Gartner believes that the local voting jurisdictions are willing to purchase and implement new voting technologies in time for the 2004 Presidential election, if the Federal and State funds are made available by mid-2002. Gartner predicts that if Federal and State funds are not available by mid-2002, no more than 40 percent of the voting precincts currently using antiquated systems will successfully implement new voting technologies in time for the 2004 elections.

By comparing the survey results with buying trends, voting system life cycles, voting appliance costs, and projected funding, Gartner has created a projection of voting technology for the next 3 Presidential elections. These projections have been submitted to the committee.

In the short term, optical scan technology will experience a quick growth, as it is the easiest alternative to implement, and offers a single solution for both polling place and absentee voting. Eventually, however, direct record electronic, or DRE, and the closely-related i-voting technology also win out.

There are a number of stumbling blocks in addition to funding. First and foremost, is the vast number of different procurement procedures used throughout the country. These processes are at best cumbersome and lengthy. This is not just another technological purchase. There are significant political pressures at work as well. For example, Philadelphia recently signed its contract for new voting technology in April, capping off a process that began in 1995. Also daunting, is the fact that no single standard exists to certify voting technologies. There is an opportunity for the Federal Government to provide guidance and promote innovation in this area.

While this hearing focuses on voting technology, it is critical to realize that there is more to an election than casting a ballot. Without rational improvements in voter registration, authentication, Election Day planning and operations, and the ballot tallying process, we run the risk of fixing Election Day but not improving the voting process.

Thank you for your attention.

[The statement of Mr. Baum follows:]

Testimony to the United States House of Representatives, House Administration Committee

By Christopher Baum, Vice-President and Research Area Director, Electronic Government, Gartner, Inc.

Distinguished Members of the Committee,

Gartner is honored today to give testimony on the trends in of voting technology. The events of last November point clearly to a crisis of confidence in the American electoral system. However, there is no clear consensus on how to fix the problem. Some believe that electronic voting is the only way to go, after all, it is the same technology that works so well in the banking industry. However, there are other opinions. Last week, I was present at an election site in Boiling Point, PA. Voters there were invited to try a new a new, computerized system in a "shadow election" after they had cast their official ballot on the regular system. I saw one gentleman who declined to try the new system. I asked him why. He said, "If you aren't smart enough to vote on paper, you should not be allowed to vote."

Gartner believes that the computer-based voting technologies, with appropriate supporting processes and infrastructure, can significantly reduce election problems and restore the public trust. The public has already demonstrated its faith in electronic systems, using ATMs to make deposits and filing taxes electronically. Computerized voting appliances can significantly improve both the balloting and tallying processes, increasing accuracy in both the voter's cast and the vote count.

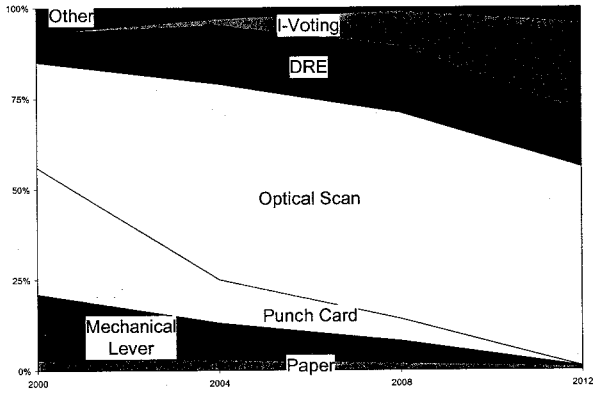
Gartner recently completed a survey on the intentions of the United States' largest voting districts in the aftermath of the 2000 presidential election. The findings of the survey have been submitted to this committee, but in summary, we would like those present to consider the following:

- 40% of the districts surveyed have already either implemented new technology or have begun major new voting technology projects.
- Those favoring federal guidance on purchasing and implementing new technology are evenly matched with those opposed to such guidance, about 45% on each side with 10% abstaining.
- One quarter of those in opposition specifically listed implementation problems with the Americans with Disabilities Act (ADA) and the National Voter Registration Act ("Motor Voter") as examples of why federal intervention is unwarranted.
- 50% of those in favor of federal guidance cited the need for uniformity in federal elections. The most cited example was guidance for establishing proper audit trails that can support recounts but not impinge on privacy.

- While desires for overall federal involvement is mixed, 65% favored a specific federal role in evaluation of new voting technology.
- Almost 75% reported that their jurisdiction would require increased funding to acquire new technology.

As a result of this survey, Gartner believes that local voting jurisdictions are willing to purchase and implement new voting technologies in time for the 2004 U.S. presidential election if federal and state funds are made available by mid-2002. Gartner predicts that if federal and state funds for voting technology are not available by mid-2002, no more than 40% of the voting precincts currently using antiquated systems will have successfully implemented new voting technology in time for the 2004 elections. (0.7 probability).

By comparing the survey results with buying trends, voting system life cycles, voting appliance costs, and projected funding, Gartner created the following projection of voting technology for the next 3 presidential elections:



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In the short term, Optical Scan technology will experience the quickest growth as it is the easiest alternative to implement and offers a single solution for both polling place and absentee voting. Eventually, however, Direct Record Electronic (DRE) and the closely related i-Voting will win out.

There are a number of stumbling blocks in addition to funding. First and foremost is the vast number of different procurement procedures used throughout the country. These processes are at best cumbersome and lengthy. This is not just another technology purchase, there are significant political pressures at work. Philadelphia signed its contract for new voting technology in April 2001, capping off a process that began in 1995. Also daunting is the fact that no single standard exists to certify voting technologies. This is an opportunity for the federal government to provide guidance and promote innovation.

While this hearing focuses on voting technology, it is critical to realize that there is more to an election than casting a ballot. Without rational improvements in voter registration, authentication, election day planning and operations, and the ballot tallying process, we run the risk of fixing election day but not improving the voting process.

Thank you for your attention.

Christopher H. Baum

Christopher H. Baum VP, Research Director Christopher Baum is a vice president and lead analyst in Gartner Research, where he specializes in e-government (state and local) strategies. He has a strong interest in government procurement and electronic voting. Prior to joining Gartner, Mr. Baum was vice president, research and analysis director for the data networking and healthcare information systems teams at Datapro.Mr. Baum earned a bachelor of arts degree in mathematics from the University of Texas at El Paso and a master's degree in business administration from the University of Phoenix.

The CHAIRMAN. Appreciate your testimony.
And next, Mr. Palfrey.

STATEMENT OF THOMAS R. PALFREY, PROFESSOR OF ECONOMICS AND POLITICAL SCIENCE, CO-DIRECTOR/MIT VOTING TECHNOLOGY PROJECT, CALIFORNIA INSTITUTE OF TECHNOLOGY, PASADENA, CALIFORNIA

Mr. PALFREY. Mr. Chairman, and members of the House Administration Committee, thank you for letting me speak to you today. I am Thomas Palfrey, professor of economics and political science at Caltech, and codirector of the Caltech/MIT voting technology project. My counterpart at MIT is Stephen Ansolobehere who is a political science professor there.

A week after the 2000 Presidential election, David Baltimore, the President of Caltech, called up Charles Vest, the President of MIT, with an idea. The idea was that our two institutions should collaborate to develop improved voting technologies. 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, process engineers, systems specialists, and social scientists. The Carnegie Corporation and our two institutes have funded our endeavors.

We are in the initial phase of our project, which is a study phase and will culminate in a report this summer, which will include a number of public policy recommendations. You will hear some of those recommendations today.

First, what is voting technology? Voting technology is usually and incorrectly equated with voting machines. In fact, voting technology encompasses a wide range of issues related to conducting an election, and the Caltech/MIT voting project has been addressing all of these issues collectively. Voter registration systems, ballot and voter-interface design, security, absentee ballots, voter education, polling place practices, and recounting procedures are some of the important components of the overall technology of voting systems.

First, what are some of the problems that we have identified? First of all, the high-risk rates of uncounted, undermarked, and spoiled ballots, what our preliminary study called residual votes. The average incidence of such votes is on the order of 2 percent and has been there for about half a century, as far as we can go back and measure. Counties using punch cards average the highest residual vote rate of about 3 percent, but even if you exclude these, we are still over 1½ percent in residual vote rate. That converts to 1½ million votes or more in the most recent Presidential election.

Our project identifies what we think is a realistic goal of shooting at about a half a percent, because we must understand that some of these uncounted ballots are intentionally uncounted in the sense that the voters did not actually cast a vote.

What are some of the other problems? There is a poor monitoring in the system. There is very little systemwide data. Something we noticed when we began our study is when we began to look for numbers, they aren't all there. So, we basically contacted thou-

sands of counties directly to try to get information about undervotes and overvotes, absentee ballots, how much they spend on election polling place practices, and so forth, and it is not collected in the systematic way.

This lack of monitoring makes it difficult to provide feedback for industry and for voting administrators to improve the system.

There is flawed and haphazard recount procedures. Some States have nothing in place. Other States have rules that are so vague that it is very difficult to implement in a systematic and uniform way. We discovered that with Florida.

Lack of uniform standards for usability and accessibility. Many of the systems that exist now do not conform to typical standards that we have acquired under ADA. The user interfaces on some of the newer machines—some of the older machines—make it very difficult for the voter to figure out how to correctly cast the vote. Examples like the butterfly ballot are the most obvious ones, but one can find other examples in large numbers.

Finally, there are shortcomings in the voter registration system. The system of cleaning or not cleaning, and purging or not purging voter registration rolls, has created problems at the polling places.

What sort of recommendations do we have in mind? Well, the first and most obvious is probably to phase out at some pace—we are not sure what the right pace is—what we call dominated technologies. These are technologies that are underperforming and do not have significant enough cost advantages to justify them.

The second complementary recommendation is to phase in undominated technologies. The current leading technologies right now appear to be precinct-counted optical scanning equipment and two forms of electronic voting. The first form being what I would call integrated touch screen machines. That is, a big box, so they are basically modern lever machines, except they are electronic and have a touch screen interface, and modular systems which have a touch screen, and then it is connected to more off-the-shelf type of equipment. So the architecture is actually different.

All three of these have advantages, however some of them have disadvantages. The electronic technologies are really in their infancy, so innovation is playing a big role in the development of these. It is an ongoing process and it needs to be encouraged.

Third, the transition from old machinery to newer machinery has to be done at a measured pace. It is not something that can be done overnight. We are talking about a relatively small industry, that in a good year, might have $150 million to $200 million in revenue. We are talking about over 3,000 counties who have strapped budgets. We are talking about complicated ways of providing Federal funding through grants processes and things like that.

This is not something that can be done overnight. It has to be done in such a way that there is a lot of thought and study that goes into it, and it should be done as an ongoing process.

Finally, along with Federal funding, we think it would be advisable to have set up an independent Federal agency, independent from the FEC, that oversees election administration in the country, helps administer these grants, administers research grants to research institutions in universities, and organizes the data, serves as an information clearinghouse.

Thank you for the opportunity to speak today.
The CHAIRMAN. Thank you.
[The statement of Mr. Palfrey follows:]

Prepared Remarks for
The House Administration Committee

Thomas R. Palfrey, Caltech

May 24, 2001

Chairman Ney and Members of the House Administration Committee, thank you for inviting me to speak at your hearing today. I'm Thomas Palfrey, Professor of Economics and Political Science at Caltech, and co-director of the Caltech/MIT voting technology project. My counterpart at MIT is Stephen Ansolobehere, Professor of Political Science. Between the two universities we have a team of 11 faculty and several students, and our central goal is to improve the performance of voting technology. The engineers bring expertise in electronic security, user interface design, systems, machine design, and performance standards. The social scientists bring expertise in voter behavior, election history, operations management, industrial organizational, and public finance.

Let me start by giving you a little background on the Caltech/MIT Voting Technology Project. Then, I will go into some of the findings of our project as they relate to machine performance and directions for improvement. Finally, I will comment on the 5 bullet items of the joint press release of Congressmen Ney and Hoyer, in regards to the legislation that they are co-sponsoring.

Overview of the Caltech/MIT Voting Technology Project

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. 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.

We are in the initial phase of our project, which I consider the learning phase. Over the last five 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 report of our work in this phase will be available in July. It will include our assessment of existing voting processes in the United States. The report will also offer some specific recommendations for the industry, governments, and universities to pursue.

The second phase of our project focuses on design, and more detailed recommendations for improving the system. 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 of voting equipment and software.

What is Voting Technology?

Voting technology is usually, and incorrectly, equated with "voting machines." In fact, voting technology encompasses a wide array of issues related to conducting an election, and the Caltech/MIT project looks at all these issues collectively. Furthermore, there is a strong interaction between technology issues and people/process issues that requires simultaneous consideration of both dimensions. Voter registration systems, ballot and voter-interface design, security, absentee ballots, voter education, polling place

practices, and recounting procedures are all important components of the overall technology of voting systems. However, for this testimony I will focus most of my remarks on those issues most closely related to voting machines.

Performance criteria

A voting machine is an instrument, or collection of instruments, for generating, recording, and counting votes. In order to guarantee that outcomes of elections reflect the will of the people, and ultimately to ensure voter confidence in the democratic process, the voting process has to be designed to work efficiently, accurately, and fairly under difficult circumstances. Many criteria must be satisfied. What are these criteria that voting machines should be expected to meet? In no particular order, the criteria that we have considered in our study are:

- voter-friendliness; it should be easy to learn to use;
- pollworker-friendliness; it should be easily deployed, maintained, and stored
- Secrecy: to avoid vote-buying and coercion
- Accessibility: make it easy to vote for everyone
- Standard and reliable ballot design; avoid mistakes like a butterfly ballot
- Reliability/maintenance; machine cannot fail during performance, or backup must be available
- Security; opportunities for fraud and tampering should be minimized and detectable
- Voter feedback; voter should have an opportunity to clearly review ballot before casting it
- High bandwidth: to avoid lines and reduce cost
- Error blocking; to avoid overvotes and undervotes
- Counting and recounting speed; to ensure a timely decision on the outcome
- Counting accuracy
- Affordability
- Audit trail: to permit reliable recounts
- Indelibility of the ballot; to avoid spoilage or modification after the vote has been cast
- Upgradability; to take advantage of technological innovations

Why is this the order of priorities? In making their purchases, election administrators respond to the current reality and the priorities and constraints that are set for them by others. Cost is always a problem. Voters and the media are impatient for results. Bandwidth and logistical deployment are problematic in all major elections. As such, they are high visibility problems and hence high priority items. Contrast this with accuracy, security, indelibility, recount process, ballot design and voter feedback. All of these issues share the feature that failures are detected rarely-- typically only in elections that are extremely close. "Virtual ties", like we saw last year in the presidential race, are not common in mass elections with many voters. Largely for this reason, problems of this sort are only occasionally brought to the greater public's attention. For example, we have had a residual vote rate of around 2% for at least half a century. How many voters knew this before January 2001? How many election workers knew that? How many voters knew anything at all about overvotes and undervotes. When we started our study in December 2000, there was almost no published research that systematically compared the accuracy of different voting technology. Upgradeability is rarely raised as an issue because significant upgrades are themselves rare events, at least under the current system. This is not to say election administrators don't care about accuracy or security or upgradeability, etc. They do indeed! But for practical reasons it often has to take a back seat to the simpler objectives like low cost and high speed.

What are some of the Problems?

High rates of uncounted, unmarked, and spoiled ballots – what our preliminary study called residual votes. The average incidence of such votes is about 2 out of 100 ballots cast over the last four presidential elections. These rates vary significantly by state. For example, Massachusetts and Maryland have fairly low rates of residual votes – less that 1 percent. New Mexico, South Carolina, Georgia, and Illinois have a history of high residual vote rates – above 3 percent of all ballots cast. Some counties have had instances of residual vote rates in presidential elections as high as 20 percent or 30 percent of all ballots cast. Within states, there is significant variation across counties. For example, in California, Riverside

County tends to have much lower residual rates than Los Angeles County. Many factors are at work simultaneously, and part of the goal of our study is to identify the leading factors. Some residual votes are due to intentional abstention or intentionally spoiled ballots. All the evidence point to this as being very rare in presidential elections, with all parties agreeing it is well below 1%. Based on our work, we believe it to be less than one-half of one percent.

Our project has examined what one of our group calls the "epidemiology of voting." Our intial report in March (published in PDF format on our website, http://vote.caltech.edu) examined the extent to which the residual vote rate depends on equipment used in the counties. A copy of that preliminary report is being distributed to Committee Members as a supplement to my testimony.

Counties using punch cards average the highest residual vote rate, approximately 3 percent of ballots cast. Counties using electronic equipment, primarily full-face DREs, also experience relatively high average residual vote rates. Counties using paper, lever machines, and optical scanners average 2 percent or less. Within each of these categories, there is significant variation across counties and across time.

Taken as a whole, these residual vote rates are inexcusably high. Phasing out punch-cards is a good first step. But even without punchcards, the national average is over 1.5%. This translates into more than 1,5000,000 ballots in the presidential race. Our project identifies a realistic short term accuracy goal as a residual vote rate of one-half of one percent, which approximately 10 percent of counties currently achieve. Simply using better machines and ballot interfaces is a start, but other factors are involved. There are many ways that we can move in the direction of this goal – more poll workers, poll worker training programs, voter education, etc.

Errors in voter registration databases. 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 responses the Current Population Survey conducted by the US 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. Integration of up-to-date and accurate voter registration databases with the actual voting machines is another goal that we believe is within reach in the next couple of years.

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 US. 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. There are also deficiencies in the software verification and certification process that need to be addressed. Software verification is a very difficult area because bugs (intentional and non-intentional) are hard to detect.

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. Some uniformity of these standards is desirable, and adherence to such standards should be required as a condition for federal funding.

Auditability. An audit of the vote is needed in cases of challenged elections. The ability to conduct such an audit varies across technologies. Audit trails can take several different forms, from dual media recording (e.g. electronic with a paper trail), to indelible physical media (CD's), to delible physical media (paper and punchcards), to virtually no audit trail at all. Lever machines and some of the older vintage electronics have the lowest levels of auditability—virtually no audit trail at all. Lever machines record a tally of the votes for each candidate on the back of the machine. If the device that moves the counter forward is broken, then all votes for that candidate are lost; they cannot be reconstructed through an audit. If the counter is manipulated or readjusted after the fact (like an odometer), there is no reliable way to detect such mischief. Some newer electronic machines make a separate recording of each voting session, and CD technology or other indelible media could conceivably be used via peripheral devices. This is an improvement over older DREs and lever machines and points to one of the major advantages of electronic computer voting technology: upgradeability. However, software problems introduce another possible

source of audit failure in these systems. Paper ballots, scanned ballots, and punch ballots have relatively high levelsof auditability, but lack a second independent record and also lack indelibility.

Dominated Technology

The question of what is the best current technology is not easy to answer, because several current technologies either perform very well now, or are new technologies that have the promise to perform well in the future. An easier question is: Which technologies currently in use are dominated by other technologies? We can identify four technologies that are candidates for this category. We would be reluctant to recommend adoption of any of these.

- *Punchcard systems* have many known flaws and no advantages whatsoever other than cost and speed.
- *Lever machines and some full-face DREs* lack many key ingredients that we believe should be in a voting system. Specific weaknesses include lack of an audit trails, maintenance problems, security, accessibility, obsolescence, and upgradeability.
- *Centrally counted optical scanned ballots* are dominated by precinct counted op-scan. The residual rate is much higher, probably due to lack of error blocking
- *Hand-counted paper ballots* are impractical except in sparsely populated areas. Besides well known security problems (stuffing the ballot or defacing ballots), hand-counted paper ballots lack error blocking and indelibility. There is a bandwidth problem with large ballots. It is hard to scale-up to large numbers. Ballot storage is expensive and can be problematic. Dominated by precinct counted op-scan, which is virtually the same as paper ballots, just not hand counted..

Undominated and developing technologies

Precinct counted optical scanning is among the most accurate. It has other weaknesses, the main one being that it may soon be outmoded. If electronic voting technology progresses as expected, optical scanning technology could be in the dominated category before long. For this reason, and some other reasons given below, we are hesitant to recommend uniform conversion to this system.

The newer technologies on the block are all varieties of electronic touch-screen voting systems. These are highly promising technologies that are in their infancy. Virtually all of the new entrants in the industry are in this category. There is no question that this is the next generation, and we need to start preparing now for an eventual transition to such systems. They don't have much of a track record, and the track record that exists is mixed. As a result cautious election officials may shy away in favor the older/proven optical scan technology. Those who are do shy away should do what they can to keep their options open for the future. For example, they should seriously consider relatively short term leasing agreements with full service contracts, so that they will be poised to make the next transition in a timely fashion.

It is useful to distinguish two significantly different architectures of systems of this category: integrated and modular. They are distinguished both in terms of the hardware they use and how they deploy it. Both have advantages and disadvantages. Both could benefit from new innovations in the very near future. Modular systems have more flexibility and would seem to be more easily upgradeable.

- *Precinct counted optical scan systems*. These were the choice in Florida to replace punch-cards. It is a relatively safe technology, provides blocking of overvotes, is user-friendly and pollworker-friendly and allows for recounts. Familiar task. It has some weaknesses. It is not easily upgradeable to incorporate newer technology. Paper storage creates problems. Ballot printing is expensive. Ballots can be spoiled. Possible mechanical failures.
- *Integrated touch screen systems*. Ballot design and user interface more complicated. Familiar task. Voter and pollworker education required. Expensive. Proprietary operating systems. No multiple use. Inflexible. Hardware is the core of the system. "A modern day lever machine." Audit trail issues not fully resolved.

- *Modular touch screen systems*. Same advantages of integrated systems, but without some of the disadvantages. Can be put together from standard "off the shelf" equipment. Upgradeable. Multiple use could lead to cost savings and efficiency. Software is the core of the system. Virtually no track record. Same audit trail issues as integrated systems. Logistical issues with installation.

Remote and early voting:in ternet; absentee; kiosks.

Internet voting is a hot topic. Absentee voting is a booming business. Both processes deliver convenience to those voters who use it. To a small number of voters remote voting it is a virtual necessity, because of difficulty or impossibility in getting to the polls. Unfortunately, there are serious security holes with absentee voting. Perhaps the most serious is the lack of enforced privacy, which creates easy opportunities for vote-buying and coercion (and difficult to detect). Early voting should be considered as a possible alternative to "on-demand" absentee voting. Internet voting has all of the problems of absentee voting. In addition, there are serious security problems that remain unresolved, as well as accessibility issues related to the digital divide.

Standards and Certification

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.

The standards could be expanded in several ways. First, human testing should be required, since many of the weaknesses of existing technology are related to problems of human interface. Second, there should be standard requirement related to 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 databases. We also need standards that ensure the security of registration databases and equipment used to access voter registration databases at the polls.

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 at that level would be easy to implement in the US, or even beneficial. However, I see standard specifications as 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.

Related to the concept of specifications is the idea of establishing standard toolkits to streamline some of the administrative tasks. For example, for each type of equipment (touch screens, scanners, etc.), ballot toolkits could be developed that all companies could use in laying out 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, who had already conducted a pilot test in the county, could do so in the time allotted. Common ballot tool kits could reduce these problems.

Financial issues

There are significant financial and economic impediments to a rapid wholesale upgrade of our country's voting technology. First, counties bear most of the costs, and they are more constrained fiscally than are higher levels of government. Moreover, many of the offices and ballot items are state or federal. Finally, voter confidence is a national problem, not a county problem. The federal government should play some role, the only question is how big a role.

Here is a brief picture of the current situation. This is a remarkably small part of government currently, in terms of expenditures. According to our estimate, in the year 2000, all U. S. counties and municipalities combined spent on the order of $1 billion on all aspects of election administration. That's $10 per voter. That pays for most aspects of election administration, with state governments picking up the rest of the tab. 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 10-20 percent and polling place operations another 10 to 20 percent.

The industry is also remarkable for its small size. Total revenues are in the range of $150 million to $200 million annually. There are significant revenue and cash-flow cycles induced by election cycles. Revenues are highly uncertain, with occasional contracts from big counties necessary to keep companies afloat. The industry is highly concentrated. The largest vendor has 60% of the market, and the top three have more than 80%. Equipment sales are highly decentralized: firms bid on contracts in each of the 3100 counties. Some contracts are made at an even lower level. As a result, a major part of the industry is its sales force. Expenditures on salesforce limits the resources available for 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 extensive product testing in experiments with human subjects. Finally, except for a few new entrants, the business model is hardware-driven using a "sell and manufacture", although there are trends toward lease rather than sale. While speculative, we foresee the industry as evolving in the future in the direction of being more software and service-delivery oriented, although hardware leases and/or sales may remain a significant component of revenues for a long time.

Given the current size and sales volume of this industry, it is unclear how quickly or efficiently the industry could mobilize to meet the demand created by a sudden injection of money in the form of federal grants. Furthermore, if the transition is made too quickly, this would place new ideas, new technologies, and new entrants at a disadvantage. The effect would be to dampen innovation, at a time when innovation should be encouraged. A preferred approach would involve a more gradual and on-going process for administering grants to counties and localities to help them replace deficient technology in a methodical and carefully studied way that would create options for future system upgrades or conversions. This will certainly not be the last time the country will need to upgrade its voting technology.

Finally, there are significant financial constraints on the Office of Election Administration in the FEC. That office is one of several 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. An alternative is to create a Election Administration Commission that is independent from the FEC. In many ways this independence would make more sense, in order to separate issues of campaign finance from those of election administration. In addition to serving as an information clearinghouse, such a commission could oversee federal grants to counties for voting equipment, grants to conduct research on voting equipment, and head up an office of standards and certification.

Federal Legislation

Congressmen Ney and Hoyer outlined five principles that were listed in a recent press release, and which were referred to as a guide crafting a final bill. My reactions to these principles are all positive, and are given below. We need to upgrade for "the present" (2004) without losing sight of what is further down the road.

- **"The elimination of punch-card voting systems"**

Yes, punch-card voting systems need to be phased out. However, we believe this is true of several of the other technologies, as well. Machines that have a record of high residual votes, or are obsolescent, need to be replaced with newer technologies. At the same time, we advise caution with respect to the pace of the transition. If it is done too quickly, it could stifle the recent surge of new ideas and new entrants into the industry, and lock us into technologies that will soon be outdated themselves.

- **"The necessity of federal assistance to States and localities that want to replace unreliable or outdated equipment"**

Federal assistance would be of great value. The existing structure of public finance in voting administration, particularly with respect to the financing of election equipment expenditures, is in need of a fix. It creates systemic problems. Federal assistance, with an appropriate set of incentives and requirements, could change this. This assistance should not be "one shot." It should be spread out over time and part of a continuing process. It should be designed to encourage leasing arrangements rather than purchase, for efficiency reasons, to encourage innovation, and in order to retain the flexibility to take advantage of emerging frontier technologies. The funding should be contingent on adherence to federal standards and certification procedures, as described above.

· **"The recognition that the federal government should not mandate solutions. States and localities have expertise and practical experience, and the federal government should work with them to ensure the integrity of the process"**

Mandating the use of one and only one voting machine everywhere in the country may simplify the process and reduce economic costs in the short run, but with significant long run costs of reducing innovation and flexibility. Different states and localities need the flexibility to choose from several options, and variety is valuable because it encourages competition and innovation. However, the federal government should not shy away from its unique role and responsibility for creating and enforcing a uniform set of standards and certification procedures, which would include human testing of voting equipment, and careful monitoring of performance in the field. A new federal agency, independent of the FEC, should be created for these purposes.

· **"The fact that real reform requires more than just a mechanical fix. The federal government also can assist states and local jurisdictions by providing funding for voter education, poll worker training, the development of a model election code, and research and development grants for equipment manufacturers."**

Yes, it is essential to realize that voting technology reform involves more than just a mechanical fix. The new federal agency can play a role in this, and universities can contribute to the research and development. Incentives could also be provided that would encourage the development and spread of new ideas in the private sector, but these would have to be structured in such a way that they are not just give-away programs. Recently, entrants have also been successful in attracting capital in the VC market, as well as direct investment from some of the industry giants.

A key function of the agency should be to serve as an information clearinghouse for data on about existing equipment and best practices. This clearinghouse would provide information to states, counties, and researchers about the performance and cost of existing equipment.

I cannot emphasize enough the need for federal funding to develop and maintain standards and for certification, including human interface issues such as ballot design and best practices in polling places and recount procedures (viz. "the model election code").

· **"The fact that our election system requires constant maintenance and vigilance"**

Yes, hence the need for a federal agency to oversee the nation's election infrastructure, to collect data about cost and performance, and to provide funding to counties and municipalities as an ongoing process rather than as a one-shot infusion of cash.

THOMAS R. PALFREY
Professor of Economics and Political Science
Executive Officer for the Social Sciences
Co-director Caltech/MIT Voting Technology Project
California Institute of Technology
Pasadena, CA 91125
(626) 395-4088 (Office); (626) 432-1726 (Fax); trp@hss.caltech.edu (Email)

OTHER ACADEMIC APPOINTMENTS

Chargé de Mission, INSEE-CREST, Laboratoire d'Economie Industrielle, 1995–96
Chercheur Invité, Ecole des Ponts et Chaussées, CERAS, 1995–96
Visiting Professor of Economics, Université d'Aix-Marseilles, LEQAM, 1995, 1998
Texas A&M University, Kirby Distinguished Visiting Professor, 1992
Visiting Professor of Economics, Université de Toulouse, GREMAQ, 1990, 1996
Carnegie-Mellon University, Professor of Economics and Political Economy, 1985-86, Associate Professor 1983-86, Assistant Professor 1980-83

EDUCATION

University of Michigan (Political Science) B.A.1975, M.A. 1976
California Institute of Technology (Social Science) Ph.D 1981.

AREAS OF RESEARCH SPECIALTY

Elections, Voting, Game Theory, Experimental Economics, Industrial Organzation

PROFESSIONAL SERVICE AND HONORS

Economic Science Association: President 1995–97, Executive Board 1990–99.
Econometric Society: Program Chair, North American Summer Meetings, 1997, Program Committee, 1990 World Congress.
Editorial Boards: Games and Economic Behavior, 1992-present, Economic Theory, 1995-1998, Economic Design, 1992-present, Econometrica 1989- 1998, Experimental Economics 1998-present, Journal of Public Economics 1998-present.
NSF Advisory Panel for Economics: 1987–89
Refereeing: Articles, books, and grant proposals in Economics, Political Science, and related fields.
Fellow, *Econometric Society*: Elected 1995.
Fellow, *Center for Advanced Study in the Behavioral Sciences*, 1986-87.

RESEARCH PUBLICATIONS

3 books and over 70 articles on a wide range of subjects in economics, political science, management science, and finance

The CHAIRMAN. Professor Woods.

Mr. WOODS. Mr. Chairman, Congressman Fattah, and distinguished members of the committee. November 2000 was a vivid time in all of our lives, and in the heartland of America as well as here within the Beltway. The intense debate following the electoral surprise and crisis paralleled debates I have participated in as a human factor psychologist and researcher in industries such as nuclear power, aviation, and, most recently, health care.

The first step in that debate always seems to be assigning blame. Some people argued it was a voter error problem. Others commented on the antiquated technology such as punch cards. Many of the young people caught up in the debate were quite intrigued by these devices, thinking them only relics of their parents' ancient history.

My field of human factors studies the interaction of people and devices, people and computers, and how these systems sometimes fail to have both technological and human components.

What has our science learned from aviation and health care work that we can apply to election technology? First, the difficulties we witnessed are not simply voter error. Rather, they are system issues in the interaction between people and technology. And I want to point out that these interface issues apply just as much to the election official interacting with the equipment as well as to the voter interacting with the equipment.

Second, the difficulties we witness cannot be solved simply by replacing apparently antiquated equipment. Replacement systems can exhibit poor user/device interface that results in predictable risks of error.

Third, the good news. Many of these issues can be addressed by basic bread-and-butter usability, engineering and testing techniques, techniques that have been developed through our work with the Department of Defense and aviation and aerospace industries, and today have matured in the computer software industry, and are readily available, quick, and economical to apply.

Fourth, there are unique aspects to the voting context that create potentially difficult design decisions and tradeoffs that require careful consideration and longer-term investment of our energy and innovation skills.

Let's go back through these four points a little bit more. It is very important to recognize—and we constantly deal with this problem after a crisis like the November election—we very easily fall back into the blame game. Which is easier? A black eye for human intelligence or a black eye for technology? Instead, we have to look at the system and the interaction. The failures are in the failure design for effective interaction between people and technology.

Second, unfortunately, buying the vendor's latest model or bringing in computer interfaces, in and of itself, will not make issues and problems revealed by the Florida ballots and electoral controversies go away. The kinds of problems that were revealed can apply to the interaction of people and any kind of technology.

I also commented that we have a mature research base that is available, and a mature engineering base that is available to apply. Techniques for usability-testing the prototype designs have ma-

tured in the software industry and these can be brought to bear very economically.

Examples of the kinds of principles and techniques we bring to bear is the principle of good feedback. If you have to have effective device design for interaction, for usability, give people feedback so they can see the results of their actions, recognize problems, and correct them. The same principle applies to the interfaces with the election officials tabulating the vote; provide a visible audit trail.

With computer technology you can design electronic voting systems in many ways. You can even try to copy old paper or lever technology over inside the computer system. The change to computer technology brings potential benefits, but also new pitfalls. And this imposes a responsibility on the designers to think through how the functions you want to accomplish can break down, and how trouble can arise. This requires usability testing.

There is also the need in the long run for careful consideration of the new issues that arise. Balancing security and visibility feedback, providing wide access across a diverse and aging population, handling large numbers of issues and ballot choices in a timely fashion, supporting recovery for mistakes, and doing it all in a low cost, are formidable design challenges.

I want to point out that adopting new technology may reduce our overall average in accuracy or imprecision rate, but create the possibility of new forms of failure.

From past research we also find if vendors' claim for failure-proof designs merit skepticism, as the humorist Douglas Adam quipped, "The major difference between a thing that might go wrong and a thing that cannot possibly go wrong is when a thing that cannot possibly go wrong in fact goes wrong" it usually turns out to be impossible to get at or repair.

So part of usability design is to take into account the possibility for error and unanticipated situations. Computerized voting and tabulation systems must support our human ability to check and detect if new inaccuracies are creeping in. It is easy to rationalize away the need for action. Hyper-close elections are rare. My precinct didn't really have a highly publicized problem. It was only the usual error rate.

The Chicago Tribune, in a study, concluded that the error rate in Cook County in the last Presidential election had doubled to 6 percent. I and my colleagues in the human factors profession are shocked that we seem so willing to tolerate even that traditional 3 percent failure rate as a norm. And we ask, where in business or transportation or medicine would we tolerate such failure rates?

Voting is the centerpiece of democracy, and we need to establish systems to monitor for the early warning signs that inaccuracies or systematic errors are creeping into our voting system.

In closing, I would like to remind you that technology alone is not sufficient. Harnessing the system of people and technology to fulfill the ideals of the democratic process calls us all to make a commitment to excellence. Thank you.

The CHAIRMAN. Thank you.

[The statement of Mr. Woods follows:]

Testimony of

David Woods, Ph.D.

On behalf of the

AMERICAN PSYCHOLOGICAL ASSOCIATION

before the

UNITED STATES HOUSE OF REPRESENTATIVES

Committee on House Administration

on the subject of

Changes in the Election Process

May 24, 2001

The Honorable Bob Ney, Chairman

Good morning Mr. Chairman and members of the Committee. My name is Dave Woods and I'm here as a psychologist and professor of ergonomics at Ohio State University where I've made a career researching human performance in complex environments like aviation and medicine. I want to thank you for recognizing that basic principles related to human-technology interactions in those environments apply just as well to the deceptively mundane environment of the voting booth. This sort of research is often referred to as human factors - the study of how people interact with technology and with each other. As scientists, we are adept at researching, analyzing and mitigating sources of human error. And just as we have drastically reduced error rates in aviation, medicine, nuclear power plants, and maritime shipping, I believe we can contribute substantively to reducing error and improving the accuracy of voting behavior.

Partisan politics aside, the reported voting problems in Florida and elsewhere in the nation really deserve to be examined in a manner similar to accident investigations. For example, in Palm Beach it appears that a well-intentioned administrator altered the ballot design to accommodate the district's aging voter population. But the publication of the ballot design in local newspapers was an inadequate simulation of how voters would react to the ballot in the voting booth. Therefore, a laudable attempt to make the ballot easier for the elderly to read backfired with overwhelming consequences. Some people argued the problem was "dumb voters" and it was common to hear the refrain: 'They should have been able to follow the arrows' or 'I wouldn't have done that.'

However, previous studies in human performance would likely have anticipated such an outcome. The symmetry in the design of the butterfly ballot was recognized as problematic, and abandoned, decades ago in the evaluation of nuclear power plant control panels. Further, a small-scale high-fidelity simulation (called usability testing) would

have detected problems with the "user-friendliness" of the ballot design at a fraction of the cost of newspaper publication. Lastly, attempts to take corrective action on Election Day (when problems with the ballot were finally detected) revealed a second tier of human factors problems that further complicated the situation.

None of this is meant to cast blame on individuals; rather, it is meant to highlight the elements of a system that can contribute to human error. The best solutions in the other domains that I have mentioned have emerged from a marriage of engineering and behavioral science under the rubric of human factors. However, quick technological solutions without adequate input from human factors specialists have actually led to a worsening of the very problems they were assigned to address. For example, attempts to modernize air traffic control display terminals failed to adequately address human factors issues and resulted in the needless expenditure of hundreds of millions of dollars for retrofitting and enormous implementation delays. In medicine, attempts to reduce medication errors with bar-code technology have actually increased the number of errors when the systems have been too cumbersome to use.

We should be mindful of these examples as federal, state and local officials begin to review the cottage industry of new voting technologies emerging as a result of the 2000 election. Further, we can make no meaningful progress if we play the blame game pointing fingers after-the-fact only at the user or only at the design. Instead, we have to view the polling station as a system of people interacting with a device to accomplish their goal, in this case, registering their opinion about who should govern during the next term of office.

So the first point, from a human factors perspective, is to recognize that these difficulties point to basic principles used in the design of other devices to enhance their usability and accuracy that can be easily applied to voting technology as well. Termed "usability standards" they are already applied in the design of the software controlling computer games that our children play. Shouldn't we apply the same kinds of minimal standards to the development of the voting systems and technologies that support our election process?

A second point to remember is that fundamental inaccuracies in registering and tabulating votes have been present in our election system all along. However, it took the events in November, and an unusually close election, to change our threshold for acceptance of those acknowledged error rates. After the fact, we heard that there had been many smaller scale "dress rehearsals" for the Florida crisis, but the fact that these occurred only in local elections, or probably didn't make a critical difference to the outcome in a particular race, diminished their significance and went unappreciated.

Some want to regard the problems in the 2000 election as a set of unique local events that won't happen again. We hear this rationalization often when Human Factors professionals work within health care or aviation settings. It is more comfortable to focus on how "we" are different (our state, our technology, our voters). However, the success of high reliability activities like air travel reveals the need to set up mechanisms to learn before a crisis occurs. Aviation, and more recently medicine, have done this by establishing mechanisms to monitor the early warning signs of systems error analogous to those that are creeping into our voting system.

We can learn from the Florida crisis, and we can act on that new information because there is a mature research base on user-centered design. First, researchers on human-device and human-computer interaction have studied situations similar to the Florida ballot. We have worked out principles to prevent these kinds of problems in the

layout and design of devices, for example, in training military personnel as technicians and troubleshooters. Second, techniques for usability testing of prototype designs have matured in the software industry and can be applied to fit the requirements of organizations under budget pressure and in need of making quick decisions about where to invest limited resources to make the biggest impact. So a wealth of applied research is readily available to help federal, state, and local election officials make design and purchasing decisions that will avoid these kinds of election crises in the future.

But there is a third message I want to leave you with today. I don't want you to think about electoral reform as simply a case of replacing antiquated technology with modern technology. Unfortunately, simply buying the latest system or simply bringing in computer interfaces will not make all of the problems revealed by the Florida crisis go away. The kinds of problems we saw in Florida can apply to *any kind* of human-device interaction, whether that device is a mechanical device or a computerized device.

The good news is that results from human factors research point to two key elements necessary for any human-device interaction to work effectively. One critical element is the importance of providing feedback to the user so that they can see the results of their actions. Who does the machine think I voted for? Excellent examples of good feedback are evident in electronic commerce, look for example at how customers order something on Amazon.com. The customer receives feedback in several different forms and at several different times during the transaction to verify the accuracy and cost of the order. While copying this interface over into the voting booth is probably not appropriate, it illustrates the principles of good interface design—principles we can easily apply to the unique context of voting.

This same principle extends to the tabulation process as well – is there a visible audit trail? But feedback is essential not just for the voter but should apply to the entire set of election officials involved in the initial tally and any recount.

It's also important to note that people may not understand what they can do if they feel they have erred or mis-entered something in the voting booth. Would a voter fear that leaving the voting booth could invalidate their entire slate of votes if they had a difficulty or wanted to correct a mis-entry. How do voters get help to correct a mis-entry? Do poll-workers know how to help a voter recover from an error?

The last issue is an especially important aspect of the voting system and will become increasingly critical as Federal and state officials look to Florida's leadership in election reform. Interestingly, Florida just passed legislation mandating the use of optically scanned ballots for the 2002 election because of the problems associated with the punch card ballots. However, the average spoilage rate for punch-card ballots was actually better (3.93%) than the spoilage rate for optically scanned ballots that were not corrected for errors at the polling site (5.68%).

But optically scanned ballots were processed using two different systems. The more accurate of the two, referred to as "Precinct-Level" tabulation, was designed to allow voters an opportunity to correct any errors before leaving the polling station. The spoilage rate for ballots tabulated by this method was the lowest of the 5 voting technologies used in Florida (0.83%). While clearly an improvement, that spoilage rate meant that 17,172 votes were still tossed out and that leads one to wonder what was responsible for these uncorrected errors.

So as Florida, and other states that might adopt this technology, prepare for 2002 election officials will need to make a concerted effort to understand why thousands of votes were shot down by what probably appeared to be a bullet-proof technology. More generally, those responsible for making and implementing election reform policies should understand that no matter how sophisticated the technology, voting requires an interaction of human with machine, and a poor fit will inevitably result in errors.

We can apply principles of user-centered design to remedy this situation and create something analogous to a buyer's guide for the states. However, it will require some investment over the short time frame before the next election cycle to pull together the information most relevant to voting and tabulation processes. We can provide recommendations for minimum usability tests that voting systems should pass just as buyers guides often review a set of "essential" features for other electronic devices used in the workplace or home.

It is important to use the Florida ballot controversies as a wedge to go behind the publicity and identify all of the different places and paths where potential problems and inaccuracies can arise. Then we can use that information to learn, modify and continuously update our election system(s) to prevent crises like those we experienced in November from happening in the future.

Finally, I would like to close my remarks with one other specific issue highlighted in the 2000 election. As we upgrade our technology and change our voting systems, we most certainly will change the nature of a recount. I would submit to you that, as we change technology and adopt different technologies across different states and localities, we will have to accept a variety of recount strategies and set the boundaries for those recounts well in advance.

In closing, I'll just remind the Committee that "User-friendliness" happens by design, not by accident. Thus when voting-system options are being debated, it will be critical to include human-performance as well as technology expertise in the deliberations. Although readily available, it is frequently ignored. Thank you for your attention.

David Woods

David Woods (Ph.D., Purdue, 1979) is
~ Professor in the Institute for Ergonomics at the Ohio State University;
~ Associate Director of the Midwest Center for Inquiry on Patient Safety (GAPS Center) of the Veterans Health Administration;
~ Board of the National Patient Safety Foundation.

From his initial work following the Three Mile Island accident in nuclear power to his work on making pilots and computers team players in the cockpit to his role in today's national debates about patient safety, he has developed and advanced the foundations and practice of Human Factors -- the study of people and technology at work.

He studies how complex systems fail, how to make automated and intelligent systems team players, automation surprises, how people diagnose system anomalies, how distributed teams modify plans in progress, and data overload. His most recent projects examines these themes in space mission operations, air traffic management, and command and control.

He has helped stakeholders in aviation, space operations, nuclear power, critical care medicine, and health care use this research base to support expert human performance.

He was President and is Fellow of the Human Factors and Ergonomic Society as well as Fellow of the American Psychological Society, and the American Psychological Association. He has shared the Ely Award for best paper in the journal Human Factors (1994), a Laurels Award from Aviation Week and Space Technology (1995) for research on the human factors of highly automated cockpits, and five patents for computerized decision aids.

A multimedia overview of Cognitive Human Factors and his research perspective is available at http://csel.eng.ohio-state.edu/hf99/

The CHAIRMAN. Mr. Rivest.

STATEMENT OF RONALD L. RIVEST, VITERBI PROFESSOR OF COMPUTER SCIENCE, LABORATORY FOR COMPUTER SCIENCE, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CAMBRIDGE, MASSACHUSETTS

Mr. RIVEST. Chairman Ney, Mr. Hoyer, and distinguished members of the Committee on House Administration, I thank you for the opportunity to testify to your committee on the issue of security in voting technology. I have been involved in the mathematical aspects of security for the last 25 years. I lead the cryptography and information security within MIT's laboratory for computer science. I am a founder of RSA Data Security, a leading provider of security technology. Codes I have developed are used daily to secure millions of on-line Internet transactions.

For the past 5 years, I have investigated the security of electronic voting. My students have implemented an electronic voting system used for student elections at MIT. I am currently participating in the Caltech MIT voting project just described to you by Professor Palfrey. Our initial report will be out this summer. The opinions expressed here are my own.

I find voting intriguing. It is not only important for democratic society, but it is also technically challenging.

The challenge arises primarily from the need to remove voters' identities from their cast ballots, in order to prevent vote buying and the coercion of voters. This requirement for anonymity makes electronic voting different than electronic commerce or electronic banking, where well-labeled receipts and well-labeled audit trails are standard. This requirement for anonymity can also make fraud easier as the addition, deletion, or modification of an anonymous ballot is harder to detect.

In 1869, inspired by the potential benefits of electricity, Thomas Alva Edison was granted U.S. Patent 90646 for an electric vote recorder. Congress declined to use it because it reported votes too quickly. Today, inspired by the potential benefits of computing and Internet technology, inventors and election systems vendors are offering new technologies. We need to carefully assess what these new technologies can offer, to see if they really meet our needs and do so securely.

Given the short time available, I would like to offer some personal opinions on the security of existing prospective voting systems. I would be happy to expand further on any of these points in response to your questions.

Number one, we are not ready for Internet voting from home. I believe that voting equipment should be under the control of election officials. At least a decade of further research and development on the security of home computers is required before Internet voting from home should be contemplated.

Number two, however, I believe that we should use the Internet to post A lists of registered voters, B lists of actual voters, and C lists of actual ballots cast. Not being matched with the voters names, of course.

Number three, as far as getting the biggest bang for the buck as far as security goes, I believe we should (A) improve voter registra-

tion procedures and the computerization of voter list registration lists; and (B) eliminate absentee balloting except for cases of need. I am against voting by mail for convenience. I prefer having a national voting holiday or allowing voters to vote several weeks early at the town hall if need be. Voters who vote absentee are simply not guaranteed the same freedom from coercion and bribery that ordinary voters have.

Number four, I believe voting systems should have a physical audit trail. That audit trail should be directly created by the voter, or at least directly verifiable by the voter when he casts his vote. It need not be paper, but it should be immutable and archival. Many have proposed electronic systems fail this requirement. Electronic voting systems offer improved ease of use and lots of flexibility, but they do not intrinsically offer improved security. On the other hand, a physical audit trail is not a security panacea, although it is a big help.

Number five, we must ensure the highest degree of confidence that our elections are free of manipulation and fraud. The certification of voting systems should be an important part of this process.

However, it is difficult to certify complex software-based systems involving elaborate user interface and cryptographic functionality. Experts in computer security and cryptography need to be involved in the certification process. Requiring that all security-critical portions of the source code be "open source" can greatly help to establish confidence in such complex systems.

We are no more guaranteed protection against election fraud by buying flashy electronic equipment, than we are guaranteed protection against fire by buying a shiny new fire engine. Security demands depends on the entire system, not just the components, which need sound operational procedures managed by training personnel. These operational procedures, which themselves should be documented and certified, should primarily ensure that no single person or vendor is ever in a position to compromise the integrity of our democratic process.

Finally, I know that we are in the midst of a technological revolution that provides both an enduring and improving set of opportunities, and an increasing set of vulnerabilities. If there is a chance to improve things now, then our focus should not be on immediately spending money for new equipment but, rather, on improving the higher-order processes of voting system research, evolution certification, selection, financing, staffing, and oversight as well as on improving voter education.

I thank you for your attention.

The CHAIRMAN. Thank you very much.

[The statement of Mr. Rivest follows:]

Testimony of Professor Ronald L. Rivest
Viterbi Professor of Computer Science
Massachusetts Institute of Technology

Dear Chairman Ney and members of the Committee on House Administration:

I thank you for this opportunity to testify to your committee on issues of security in voting technology.

(I apologize for the brevity of these remarks, but I returned home from conferences in Europe only Monday night to discover your invitation for my testimony.)

I have been involved in the mathematical aspects of security for the last twenty-five years. Codes I have developed are used daily to secure millions of on-line Internet transactions.

For the past five years I have investigated the security of electronic voting. My students have implemented an electronic voting system used for student elections at MIT. I am currently participating in the CalTech/MIT Voting Technology Project; our initial report will be out this summer. The opinions expressed here are my own.

I find voting intriguing: it is not only important for our democratic society, but it is also technically challenging.

The challenge arises primarily from the need to remove voter's identities from their cast ballots, in order to prevent vote-buying and the coercion of voters. This requirement for anonymity makes electronic voting different than electronic commerce, where well-labelled receipts and well-labelled audit trails are standard. This requirement for anonymity can also make fraud easier, as the addition, deletion, or modification of anonymous ballots is harder to detect.

In 1869, inspired by the potential benefits of electricity, Thomas Alva Edison was granted U.S. patent 90,646 for an "Electric Vote-Recorder". Congress declined to use it, since it reported votes "too quickly" (!). Today, inspired by the potential benefits of computing and Internet technology, inventors and election system vendors are offering new voting technologies. We need to carefully assess what these new technologies can offer to see if they can really meet our needs.

Given the short time available, I would like to offer some personal opinions on the security of existing and prospective voting systems; I would be happy to expand further on any of these points in response to your questions.

(1) We are not ready for Internet voting from home.

-- I believe that voting equipment should be under the control of election officials. At least a decade of further research and development on the security of home computers is required before Internet voting from home should be contemplated.

(2) I believe that we should use the Internet to post:

(a) lists of registered voters
(b) list of actual voters
(c) list of actual ballots cast (not matched with voter's names, of course)

(3) As far as getting the biggest "bang for the buck" as far as security goes, I believe that we should

(a) Improve voter registration procedures and the computerization of voter registration lists
(b) Eliminate absentee balloting except for need.
-- I'm against voting by mail for convenience. I'd prefer having a national voting holiday and allowing voters to vote several weeks early at their town hall. Voters who vote absentee are not guaranteed the same freedom from coercion and bribery that ordinary voters have.

(4) I believe voting systems should have a physical audit trail. That audit trail should be directly created by the voter, or at least directly verifiable by the voter when he casts his vote.

-- Many proposed electronic voting systems fail this requirement. Electronic voting systems offer improved ease-of-use and flexibility. They do not intrinsically offer improved security. (On the other hand, a physical audit trail is not a security panacea, although it is a big help.)

(5) We must ensure the highest degree of confidence that our elections are free of manipulation and fraud. The certification of voting systems should be an important part of this process.

However, it is difficult to certify complex software-based systems involving elaborate user interfaces and cryptographic functionality. Experts in computer security and cryptography need to be involved in the certification process. Requiring that all security-critical portions of the source code be "open-source" can help to establish confidence in such complex systems.

> But we are no more guaranteed protection against election fraud by buying flashy electronic equipment than we are guaranteed protection against fire by buying a shiny new fire engine. We also need sound operational procedures managed by trained personnel. These operational procedures, which themselves should be documented and certified, should primarily ensure that no single person or vendor is ever in a position to compromise the integrity of our democratic process.

Finally, I note that we are in the midst of a technological revolution that provides both an enduring and improving set of opportunities and an increasing set of vulnerabilities. If there is a chance to improve things now, then our focus should not be on immediately spending money for new equipment, but rather on improving the higher-order processes of voting system evolution, certification, selection, financing, staffing, and oversight, as well as on improving voter education.

I thank you for your attention.

Ronald L. Rivest

Professor Rivest is the Viterbi Professor of Electrical Engineering and Computer Science in MIT's Department of Electrical Engineering and Computer Science. He is a member of MIT's Laboratory for Computer Science, a member of the lab's Theory of Computation Group and is a leader of its Cryptography and Information Security Group. He is also a founder of RSA Data Security. (RSA was bought by Security Dynamics; the combined company has been renamed to RSA Security.)

Professor Rivest has research interests in cryptography, computer and network security, and algorithms.

Professor Rivest is a Fellow of the Association for Computing Machinery and of the American Academy of Arts and Sciences, and is also a member of the National Academy of Engineering. Together with Adi Shamir and Len Adleman, he has been awarded the 2000 IEEE Koji Kobayashi Computers and Communications Award and the Secure Computing Lifetime Achievement Award.

Professor Rivest is an inventor of the RSA public-key cryptosystem. He has extensive experience in cryptographic design and cryptanalysis, and has published numerous papers in these areas. He has served a Director of the International Association for Cryptologic Research, the organizing body for the Eurocrypt and Crypto conferences, and as a Director of the Financial Cryptography Association.

He received a B.A. in Mathematics from Yale University in 1969, and a Ph.D. in Computer Science from Stanford University in 1974.

He has also worked extensively in the areas of computer algorithms, machine learning, and VLSI design

The CHAIRMAN. I appreciate the panel's input. I am going to go ahead and yield to Mr. Ehlers first.

Mr. EHLERS. Thank you, Mr. Chairman. I appreciate that, since I have to leave shortly.

I really appreciate the testimony we have heard, and it brings out a number of factors that have always struck me as very important. My background is both having served in local government where we deal directly with the election process, and also with being a scientist by training and being appalled at some of the things that I saw.

I think the very first step, of course, is good law. That was a very major problem in Florida. The law was not well written, well structured, it was not clear, and could not be clearly interpreted. I think that problem is being dealt with rather quickly by most legislatures throughout this land.

Secondly, we need good technology. I think we have done reasonably well in that in terms of the technology itself, ranging from the paper ballot up to the computers. What I find missing in that, however, is the next factor we need, and that is good human factors engineering. I think that has been a major problem with the newer election devices that have been developed and are on the market.

I also think something we don't pay enough attention to is good security, good privacy, and good integrity. We pay a huge amount of attention to that in our computer systems in commerce. Even in the House, when we put that system in, that is one thing that I insisted on very strongly. And I am very proud, as is Ronald Schweickhardt who sits behind me, a staff member involved in this, and a number of other members.

It is interesting to read in the paper about all the hackers breaking into the Pentagon, the Senate, the White House, but you have never read about them hacking into the House. I don't want to say that too loudly because then we will become the prime target.

I am very pleased. We put a lot of effort on security, and I believe we have succeeded, but you have to have precisely the same security in the voting booth that we installed here. And I don't see that at all in the electronic systems, and even many of the other systems are not as secure.

Just a quick comment on what was said earlier, I think it is important for everyone to vote at once, to the greatest extent possible. I am prejudiced on that because I run for office and my campaign is planned so that all the information is out there by Election Day. People vote 3 weeks ahead of time, they miss most of the information that I am providing. But also, absentee ballots lend themselves tremendously to abuse and fraud. The one thing we haven't mentioned here, I think the greatest opportunity for fraud, is in voter registration; and we need to pay much more attention to voter fraud there and ensuring that voting lists are good, that we purge them regularly; that when someone moves, they can't keep registration at their former address and so forth.

Now, given these facts and some suggestion of research grants, what would you recommend the Federal Government spend its money on for research grants if we should decide to go in that direction? Where would you concentrate the efforts in trying to get at these various problems I mentioned?

Mr. WOODS. One of the resources that is available we have already, through work with aerospace, the Department of Defense, the government has already built up expertise on these human factor engineering issues. For example, in the national laboratories, they have expert groups who provide advice on these interface design issues to many government agencies. We could bring those in to, in the short run, provide a great deal of guidance about how to evaluate potential new systems and how to implement them and train the kinds of election officials in operating these to achieve greater levels of success and avoid some of these difficulties that could be done very quickly. Some of these organizations could provide input to election officials in the form of a guidance document, probably on the order of months, and on the order of tens of thousands of dollars in investment for a short-run benefit.

Mr. EHLERS. But we have talked in here about educating the voters, training the poll workers and so forth. I really would like to see a system where that is not a factor. In other words, the human factors are so good that you don't need to educate voters.

For example, in voting I think you should show the final slate and have a Regis Philbin question at the end: Is this your final vote? And, if not, you can go back and change it. Poll workers, too, they are wonderful people, just the salt of the Earth, really trying to serve their country in a very difficult job, which they only do a couple of times a year for long hours and hardly any pay, but they only do it a couple of times a year. You can't train them every time. And again, I think we need a system that doesn't require much training for poll workers.

Let me ask a follow up question to that, and the others can comment on any of these issues. What is the Federal Government's appropriate role in this? We don't run the elections. We have always trusted local governments and States to handle that. How would we deal with the human factors issue? Are we going to recommend certain systems? Are we going to set Federal standards that systems have to meet in order to be used to elect Federal candidates? How do you see us playing a role in that?

Mr. PALFREY. I think the Federal Government could certainly play a role in setting standards for certification of processes. I don't think the Federal Government wants to insist on everything being exactly one way. I think, for example, the current testing procedures that are done to certify equipment is machine testing. It is basically machines testing machines. I think human testing is needed for the ballot interfaces and for the various designs that are proposed. Currently there is no human testing. I think that is one thing that a Federal agency could do is to oversee the testing of these machines and the development of appropriate standards.

Mr. WOODS. There are many kinds of guidance documents available to organizations that design computer devices for human use. For example, several organizations have just put out new guidance documents on access to computer and electronic systems for the disabled and the visually handicapped. These kinds of documents do not tie the hands of designers but, rather, try to be a positive resource, to say there are some of the effective techniques and ways that you can design your electronic interfaces, as in this case, to make access for the disabled more successful.

Mr. EHLERS. How do we deal with the security issue? You know, if we have the modern equipment of Tamany Hall, any college freshman can make some changes to the software on the computers. How do we really ensure the security of the hardware or the software?

Mr. RIVEST. That is a very complex question. I think continued monitoring of what is going on, making sure there is separation of function, taking apart voting equipment after it has been used to see if it has been tampered with, making sure the code is "open source," and looked at by lots of people. It is a multifaceted problem. Making sure the poll workers know what is appropriate to do and what is not, making sure the equipment doesn't support modes of operation that would allow a poll worker to reset the clock or whatever you can do through various kinds of tampering. We are dealing with computer systems now that are very much—voting systems that are computer systems and have all the complexity and security problems of computer systems. We need to keep the system simple as possible to minimize the complexity. And security often arises from simplicity. So, looking for simplicity in design is an important criterion here, too.

Mr. EHLERS. Do you think it would be reasonable after each election that all the systems are tested, that you run a quick program through them to make sure there——

Mr. RIVEST. It is reasonable to do some sampling, random sampling, look at some of them to see if there has been any tampering.

Mr. BAUM. Also, sir, you could apply statistics to the districts and find out where there are anomalies and test that equipment stronger, and you can harden the equipment that is being used. You can also move to internal memories on the computer systems that are unalterable so they can't be changed on Election Day. There are a number of technologies that you can apply here to this equipment to make them almost military grade in terms of hardness.

Mr. EHLERS. What I hear coming through, though, is that you see the Federal role as one of doing the research, setting the standards, and helping the States and localities to meet the standards.

Mr. BAUM. That is certainly what our survey shows would be acceptable by State and local governments.

Mr. EHLERS. Thank you very much. Thank you, Mr. Chairman.

The CHAIRMAN. Thank you, Mr. Ehlers. Mr. Hoyer.

Mr. HOYER. Thank you, Mr. Chairman. Gentlemen, I apologize for my lateness. I had another meeting at 11 o'clock, and took that as quickly as I could and got here.

Thank you, Mr. Chairman, for including my statement in the record. I won't repeat it.

Mr. Baum in the end of your prepared statement, you mention, and I quote, "the daunting fact that no single standard exists to certify voting technology." This is an opportunity for the Federal Government to provide guidance and promote innovation.

You have just been discussing that, obviously, in response to Mr. Ehlers' question. Can you describe specifically how the Gartner Group found—what it found when it looked at the voting machine certification process.

Mr. BAUM. Yes, sir. What we found was disarray. There is, of course, the NASED who will approve voting machines, and anyone can adopt NASED-approved machines. But that process, while well documented, is still open to a certain amount of interpretation.

For the States and local governments that do not accept NASED-approved machines, there quite often is no set standard. It is conceivable and I have seen instances where new technologies are being introduced, for the companies to call on local sales or local election officials. The response is, come back when you have been certified by someone, not necessarily who, but just someone.

That is where the difficulty comes in. There are over 3,000 touch points for election systems. One of the things that is very interesting, is we don't even have consensus on the number of counties there are in the United States currently. We went out and called the secretaries of state of each State and got the number of counties that they thought they had, and added them up and got 3,066. According to the Federal U.S. Census, there were 3,042. So there are some fundamental issues here that we really need to address. And the lack of standards, you simply cannot survive in a market where you have got a $20 million opportunity or $200 million opportunity, and you have to deal with 3,000 separate standards for equipment.

Mr. HOYER. Could I say this as an aside, not necessarily as a question? In the State of Maryland, which is a relatively simply organized State in that we have 23 counties and Baltimore City, could the discrepancy be that for many purposes Baltimore City is considered to be a county, NACo however would presume it to be a city?

Mr. BAUM. Right.

Mr. HOYER. So that might—I don't know how many other States have that same phenomenon—but that might count for that 20-plus discrepancy between the two.

Clearly, it would be useful from your standpoint, to have an agency at some level that looked to assist not in a mandatory way, but in an advisory way, to solve this chaos or disarray—I think you used the world "disarray," chaos may be a harsher word—but disarray that you confronted?

Mr. BAUM. Yes, sir. We do not necessarily believe it needs to be a separate organization than the FEC, but we do think that there needs to be a place where officials can go and where vendors can do to say these are the requirements that we recommend, these are the procedures that can bring you to those requirements, and these are the sources of information.

Mr. HOYER. I would say, as an aside, to all of you as you do your work, it is my view that the time has come when the election administration responsibilities at the Federal level and the monitoring responsibilities of finances in elections need to be separate, not because they are inherently contradictory to one another as the OEA currently exists in the FEC, but because there is so much immediate demand on the financial oversight, that electoral reform at the Federal level, as it has at the State and local levels, has taken a second or third share.

Professor Rivest—how do you pronounce that?

Mr. RIVEST. It is pronounced different ways within my own family.

Mr. HOYER. Well, I would like to pronounce it the way you pronounce it.

Mr. RIVEST. Rivest.

Mr. HOYER. You offer some very sobering insights regarding the fraud security of new voting technologies, specifically Internet voting. Let me say I also agree with the chairman and with yourself very strongly that voting is a communitarian process—George Will wrote a column on this some months ago—and that coming together in and of itself has a value, I think, above and beyond the process value.

You express confidence in using the Internet for improving voter registration, but please elaborate on how the Internet can improve registration. Obviously, as a number of you have referenced in your comments, that is a very key issue with which we need to deal if we are going to have voter confidence; that they come to the polls and they will be allowed to vote. That, coupled with a very good provisional voting process. But would you comment on that?

Mr. RIVEST. I would be very happy to comment on that, Mr. Hoyer. I think at the highest level, the voting system will be improved by a greater degree of transparency, having more information available to more people, more eyes looking at the process. Applying that to the voting registration process, if the voting registration lists are posted on the Internet in a way that anybody can look at, you will see fewer dead people on the rolls, you will see fewer people that are still on the rolls that have moved. You know, somebody will call up their official and say, did you know that so and so has left town? Things like this can happen.

So just the process of keeping the accuracy of the voter registration lists will be improved by having it open and public, as I believe it should be.

I think the process of registering to vote per se, is not something we should be attempting to do over the Internet. I think it should require an in-person visit. But once you are on the registration rolls, having your name listed as you are registered to vote in this county, I think that would be a help.

Mr. HOYER. Do you have any thought as to how long it would take to construct a statewide system in a State like California, which is—well, there are no States like California. That was a stupid thing to say. There are only a few Nations like California. But a State—let's say a smaller State, Florida, has just gone to mandating a system of central registration. I don't know what cost that they attributed to that. Maryland is going to a central registration system. I think that is going to be critical, because in an era of very mobile individuals and families, when you move from precinct to precinct, house to house, and you really don't—there is nothing that tells you this is a precinct line—that we need to have that kind of system.

What is technically—how long would it take to create such a system in a State like Maryland or Florida or Pennsylvania, and what would its cost presumably be? Anybody have a guess on that? Have you looked at it?

Mr. RIVEST. Let me just respond. Part of it is different States do it in different ways. I think it is Michigan that is combining it with the DMV database. If you have a single voter registration database and that is its only function, you might be able to do it in 2 or 3 years. And I don't know what the cost would be per voter. But if you are trying to organize your State's citizen records along more lines than one, so you are doing the DMV and the Social Security or whatever, everything else altogether with within the State, I think that could be 6 or 7 years and lots more money.

Mr. HOYER. Professor Rivest, one of the things, though, if you try to combine it, your transparency issue becomes more complicated, it seems to me, because there is information that voters clearly do not want and should not want transparent to the rest of us.

Mr. RIVEST. Yes.

Mr. HOYER. So that from my perspective, you are really going to have very limited use of a document that is totally transparent, and I agree with you it ought to be totally transparent, because I think that will protect against fraud and mistakes. I think my own view is that there are far more mistakes than there are actual intentional fraudulent acts.

Mr. BAUM. Sir, the National Voter Registration Act of 1993 pretty much requires a strong link with the Department of Motor Vehicles in each of the States, so that has to be investigated. Even so, there are commercial products available already. At its most simple level, a statewide voter registration system is simply a database.

Now, there are security issues that surround it, but they are all known and solvable. And when you are taking a look at a State with the population of New Mexico, or something like that, it is not even a large database, so these are—again, it is more of a political consideration than a technical consideration.

Mr. HOYER. Well, I am hoping that one of the things we do in legislation, that we are considering, is to have dollars available to assist States in the creation of a central database. In my view, in large part, the States will have to decide the individual problems and how they create that; that we can assist them in doing that to provide greater voter confidence when they go to the precinct, somebody will know in this computer age, when everybody gets on the Internet, can get access to gargantuan amounts of information, that they can get information that Joe Dokes has in fact registered to vote in this State.

So, Mr. Chairman, I have got other questions but I know that time keeps running. Do you have questions?

The CHAIRMAN. I have got questions.

Mr. HOYER. Why don't I yield to you?

The CHAIRMAN. And if you want more time. I want to ask a specific question, Mr. Palfrey. Are you aware of any research that has studied the voting patterns of persons who are dyslexic or, let's say, illiterate?

Mr. PALFREY. With respect to the voting technology?

The CHAIRMAN. And how to facilitate and help those individuals. Or is there technology that—for example, technology comes forth—is it helpful, not helpful?

Mr. PALFREY. There is some informal research. I don't think there has been very much that has systematically been done to

identify specific problems with technologies. Certainly, with respect to user interfaces, maybe Professor Woods can say more about this as far as dyslexic interfaces, but I think as far as handicapped considerations, use of audio, use of Braille and also overlays for the optical scanning equipment.

The CHAIRMAN. We know, if it is an issue of sight, I saw the equipment here. So we know you have the earpiece. If it is an issue of height, you can accommodate downwards. But if it is an issue of dyslexia or an issue of illiteracy—

Now, an easy answer is, we take somebody in the voting booth, a poll worker. For a lot of people, though, it is such a private item about voting. So I just wondered—again, for sight, there are certain devices, but what about dyslexia?

Mr. PALFREY. Well, there are examples——

Mr. HOYER. Can I make a comment, because I would like to hear—everything you mentioned, the hearing—that the audio transmission may not only solve the sight problem but may solve the inability—the dyslexic problem or another reading problem that might occur. That might solve, most of us wouldn't think of it in those terms, but it may do that as well. You might want to comment on it.

The CHAIRMAN. And touchtone screen. It was an interesting issue that we were discussing today.

Mr. PALFREY. Right. And that is a possibility in some foreign countries, where illiteracy is a more serious problem than it is here. In South America, for example, they actually have pictures of the candidates, or icons to represent different parties, for example, to assist voters who can't read.

The CHAIRMAN. Also, Professor Palfrey, in your study over a 20-year period, 60 percent of the counties have adopted new technologies of one sort or the other. Forty percent of the counties have been using the same technology basically, I would assume, for 20 years. Are there any similarities or common characteristics about counties that have been using the same technologies for a long period of time versus the ones that have switched to some new technology? Are there any outstanding——

Mr. PALFREY. Yes, there are two factors that seem to be important with that. The larger counties, populationwise, we have tended to switch to new technologies, largely to handle problems of bandwidth and just dealing with large numbers of voters. So, they are concerned about speed and cost. That actually was one of the reasons for the transition even earlier to punch card systems, but certainly transitions from paper ballots to optical scanning equipment was done for cost and speed considerations in larger counties. There is also a correlation, with sort of average income levels or the sort of county revenues controlling for size, that counties that don't have as much to spend, available to spend, have not been changing as fast.

The CHAIRMAN. Mr. Baum, I wanted to ask you a question. You had stressed, and I think made a couple of good points about, the fact of the different standard where somebody turns to an election official and they say, "as long as you are certified."

Mr. BAUM. Right.

The CHAIRMAN. Let me just throw something out here, because you mentioned the word "agency" a couple of times, as other people indicated. Let's assume you are not going to create an agency per se, as we would think an agency to be, because the downside of that, frankly, in the election process, is that it is not an environmental issue or a highway where you have a daily ongoing situation. So therefore, the thought of agency would tend to scare people across the board here, I think on both sides of the aisle, and a majority of both, only because a downside could be that there would be constant rules made by a rulemaking body that would make people eventually shiver about the agency saying whether you have an ID at the poll or not, versus, you know, the local governments and the Congress.

So let's assume we don't have a full-blown agency. But what would you—or could you speculate, on what you would want to see if we created some type of body that was an advisory type of body; who would be on that body, in your opinion?

Mr. BAUM. Well, first I would like to respectfully suggest that it is certainly more than a one-day project or a single-day project. The example I like to give most is that of a wedding. When you start planning a wedding, the events of the day actually become very much smaller in proportion to what it took you to get there. And running an election from an election board's point of view is very much like planning a wedding year after year after year.

The CHAIRMAN. I should clarify. I know it is year-round. I am just saying, if you had an agency, though, and you set up a full-blown agency, if it does have a daily function, I think we would be scared of the product after about a year. If you have an agency that creates a new staff daily, thinks of new rules to create on local people, I should tell you where I am coming from on that.

Mr. BAUM. So in that setting, then, I think that what you need is representative—I think what we are talking about here is really a governance board, not a new kind of committee, but people that are involved with the process. And that means that you have people from State and local and Federal elections; you have people that have other concerns, interest groups, people who come in that are proponents for those who have disabilities; making sure that people that come in, from the Majority and Minority parties, to ensure that ballots are fair in the way that they are set up, and people with other interests coming in—I was going to use the term "disinterested," but we are all voters, we should all be interested. Like my fellow panel members here; people that can come in and come together and build a consensus on these, including the vendors themselves.

The CHAIRMAN. Thank you.

I had a question of Professor Rivest. For the machines you are familiar with—because Mr. Swigert tells me he wouldn't let you bring a laptop in here. That is how good you are. So those voting systems which you are familiar with, how long would it take to break into them while in a polling place? That could change the results of an election, if that could be done? Is it a long time process?

Mr. RIVEST. I think it depends on who is doing it. I think if you have a voter who is just walking in to try to, you know, monkey with the equipment he is probably unlikely to have much effect. A

poll worker, similarly, has little background with the equipment and wouldn't know quite what to do except to operate it. A vendor's technician on-site might have intimate knowledge of how the machine works and might have a preprogrammed smart card to change a tally or something like that.

So I think it depends on knowledge of the equipment. It could be very quick if someone knowledgeable—changing electronic systems, you know, can be done quickly. If there is a card that is plugged in, as many machines have, that controls the operation of the machine. If the card can be changed you are changing the programming of the machine. If there is no audit trail, if that card was removed and replaced, you may have a successful hack.

The CHAIRMAN. Some observers have recommended an open source process, so software can be used to control voting systems that would be subject to impartial inspection that could lead to increased quality. What do you think about that idea?

Mr. RIVEST. I am in favor of it, basically. I think that this poll process is too important to be left wrapped in the cloaks of the vendors' claims of proprietary need. I think that having the software available for inspection by whomever will increase our confidence that the voting is being tabulated correctly.

It is not sufficient by itself, of course. You need to assure that the software that you have looked at is actually the software that is running in the machine and have procedures installed to ensure things like that. But having the software out for inspection I think will be to everyone's benefit.

Mr. CHAIRMAN. The last question I have is for Professor Woods.

We had the voting machines in here, and I found them of interest because that is the first time in my life I have not used a punch card. I went originally to the X's we used to do when I first voted down in Ohio in Belmont County. Then we went to the punch cards, because that is what we used. So this is the first time I ever actually touched some other type of device.

The one thing I would ask of the vendors is, don't help me, let me see if I can do that. I don't claim to have the ability of Mr. Ehlers on scientific knowledge at all our computers, but it was interesting just using the machines.

Now, I noticed an exhibit was there when, once you wanted to make your choice, you had to retouch to cancel out and then you touch back. But then there was another machine that you pushed the next name, it automatically canceled back. Because of what you do, dealing with human interface and ergonomics, is there any machine, when you talk about the touch screens or maybe a non-touch screen, that is a better type of machine or the machine of the day?

Mr. WOODS. It is difficult for us to recommend a particular technology or system. But the example you use is I think a very illustrative example where some of the principles we found apply. One is feedback. So either of those systems can confuse people depending on the degree to which they get clear feedback with respect to their actions.

So, for example, take the second case you have mentioned before, where you simply push the second candidate. Someone could get confused about what the impact of that is. Are they going to end up the equivalent on the punch card of having two holes punched?

If you have clear feedback—for example, when you press the second one, the first one starts to blink in a salient way and then goes dark—those kinds of systems are likely to work better.

The second aspect of my response, this is the sign of usability testing, is about that we have procedures for doing tests so we don't rely just on opinion or quick walk-up, a couple users trying it out. We have processes to do that that are very economical to generate the best kind of information to act on and get the best leverage when you have to make design decisions or purchasing choices. So by using that technology of user testing, technology that is used every day in the software industry for the products you and your family buy on the local scene, those kinds of tests can result in many of these kinds of questions and result in more easy to understand and use, especially for the diverse population that you pointed out is so critical to the voting application.

The CHAIRMAN. One final thought—I will see if Mr. Hoyer has some questions—basically indicated here and at least one of the testimonies that, you know, it is the human error. You know, we know that is part of it. But if it is just a human error factor, should we just keep punch cards and spend a lot of money? Well, if it is only human error, could we keep those punch cards and spend a lot of money to educate people, or should we go on to something else?

Mr. PALFREY. With respect to punch cards, I think we should go on to something else.

The CHAIRMAN. Your testimony did indicate, though, that it is human error. Well, if it is, do you just work with what you have?

Mr. PALFREY. One way I like to think about it is in terms of a technology being dominated. In other words, if you think about spending the effort to educate the voters, if you want to spend the same amount of effort educating voters using punch card systems or you are educating voters using an optical scanning system, what would the results be? And I think the results of one would be better than the other.

The CHAIRMAN. Is there anyone that would like to keep punch cards?

Mr. BAUM. I think punch card manufacturers would like to keep punch cards.

The CHAIRMAN. We know that.

Mr. WOODS. The success we have achieved in cockpits and other high criticality domains has come from dropping this red herring of human error. When we want to label a problem as human error, the scientific approach says you take that as a symptom of an underlying problem in the system and the interaction between people and technology. And there lies the grounds for improvement so that we can achieve what we all desire, in this case in the democratic process.

So, now, with respect to punch cards in particular, it violates a very old rule for designing interfaces between devices and people, all right? The punch card, you actually make a hole, all right? The absence of something, the hole is supposed to indicate the presence, the state that we are interested in, the vote.

If I had designed—when I started our designing nuclear power plant control rooms 20 years ago, if I had tried to code the critical

state stage of the nuclear reactor using that principle that is done in punch cards, I would not be here today. We have learned through bitter experience in aviation interfaces and energy systems that is not a good way to set up the interface.

The CHAIRMAN. You are making a good point. So I totally grasp it, it is not a good way to set it up to read that card, or it is not a good way to set up to have the human being, the voter, reacting that way of the punch?

Mr. WOODS. Both.

The CHAIRMAN. I understand, on the reading side of it, I believe, of the machine reading it—it is probably not the word—but why the voter?

Mr. WOODS. We say that in all these issues of did they punch through, was the card aligned, the basic rule of thumb is you want people to make a positive indication so that you have transparency and traceability, as my colleague to my right indicated earlier.

The CHAIRMAN. Do you have any questions? That is interesting.

Mr. HOYER. Well I think that—we pretty much have a consensus I think in the country at State, local and Federal levels that we want to get—rid ourselves of the punch card, save perhaps the manufacturers, as Mr. Baum put it. But it is interesting that systemically there is a reason for that as well. I was glad to hear that.

Let me ask Dr. Rivest, then I am going to go to some other quick questions. You have reservations about the Internet voting, and that is shared I think by a vast number of people, including myself. However, I would like your comments on whether it is worth testing in an area that we think does not work as well, and we need to make it work well and may be an area where we want to at least test this, and that is overseas voting and military voting. Could you comment on applications that may be perhaps more appropriate in that limited setting?

Mr. RIVEST. I would be happy to.

I think that the military application is a good one to look at. I think that you have the kinds of controls both over the environment and the networks that you may not have in other kinds of remote Internet voting, and you also have a very clear and important need for our soldiers to be able to vote, and also I am in favor of experimentation.

I think we need to plan to evolve our voting systems over the next 20, 30—you know, as technology improves, we are going to keep changing our minds as to what, as Professor Palfrey said, what the dominating technology is. But in order to learn what the dominating technology is, what the best voting systems are, we need to have experience with them.

So, for all of those reasons, I think that experimenting on a small basis at first, maybe expanding if the system seems to work well, with remote Internet voting for military purposes, I would be in favor of that. But it needs to be carefully controlled and looked at. The Internet is a very fragile and vulnerable entity, and it is vulnerable to attack by malicious organizations from outside our country. So we need to make sure that there is back-up systems in place should our soldiers not be able to use the Internet.

Mr. HOYER. Thank you.

Professor Palfrey, I was pleased to see in your statement that you support the five principles that Chairman Ney and I are essentially working around; and I take it from your statement that our focus should not be exclusively on the 72,000 precincts, or whatever number precinct we have, the 72,000 precincts, but on a broader array of the technology use in other technologies, used in other precincts, is that correct?

Mr. PALFREY. That is correct, yes.

Mr. HOYER. How expensive do you think we ought to be on this in terms of assistance to improve an election infrastructure?

Mr. PALFREY. Well, I think as far as coming up with a single number I am not sure that is quite the way that I think about it, partly because I view this as sort of an ongoing process. As far as approximately, I don't know if you are looking for approximate numbers.

Mr. HOYER. No, I was not looking for a number. I apologize if I implied that, obviously.

But the bill that I have introduced, along with a lot of other people, sought first, as Florida has done, to eliminate the punch card system. And then, as you know, it provides ongoing resources for technology replacement as well as a lot of other things in terms of education and technology development.

What I am wondering is, if we limited our first step to that, would you think that is an error, or do you think we ought to make sure that this can be applied to other technologies, i.e., lever machines initially? Obviously, we are talking about limited resources that we will come up with in the first traunch, if you will. That is what I am really getting at.

Mr. PALFREY. I think there are other technologies that have known problems besides punch card systems. Without identifying specific vendors, there are examples of full face DRE machines that have not been successful, that the administrators that use them would probably be happy to replace. I think centrally counted precinct scan equipment should be replaced by precinct counting. If you are looking for a quick fix of that, that is certainly a better technology having to do with the voter feedback and also the ability for errors to be detected before the vote is tallied.

Mr. HOYER. so in other words—and I hadn't thought about that—but clearly everybody believes that in order for a system to be as accurate as it can be you need precinct where-a-voter-is-still-present technology to let the voter know whether or not they have made mistakes.

Mr. PALFREY. Yes. I think we are at a stage now where there exists technologies to do that. We should take advantage of it.

Mr. HOYER. Okay. That is helpful.

Dr. Woods, you addressed three key factors of voting—user friendliness, voter feedback and balance the design. What is the best feedback tool to let voters verify whether they actually voted for the candidates that they want without compromising voter privacy?

Mr. WOODS. Well, you have hit the heart of the design problem from a human factor's perspective.

Normally, as Professor Rivest indicated, we don't have those simultaneous constraints to deal with. Obviously, the feedback has

to be something that can be terminated by the voter so that they get a display, they get feedback that says this is what the machine thinks you told it. Then, in registering their vote, the voter must have a confident feeling that that information has gone into the computer and the traceability back to them has gone away; and that requires careful design and testing with users, again meeting the challenge of the diverse kinds of populations we have in the voting. And that is the kind of usability testing that is standard in our profession and that we can carry out on a very rapid basis. But there is no way to give a global answer without going through that indurative testing process.

Mr. HOYER. Okay. Obviously, that, however, is going to be one of the key issues we need to deal with; and I say that perhaps not at our level. We are talking about a lot of things that, frankly, States and locals are going to make the decision—final decision on, perhaps with advice of counsel and best practices and best standards advice, but——

Mr. WOODS. This is where an independent technical group can come in and demonstrate. Often, we can show you some clearly undesirable ways to try to accomplish those goals, and we can point people in these kinds of guidance documents I have referred to to several different kinds of techniques that will work and how to do quick tests to verify that your particular choice as an election official or a State official will be successful.

Mr. HOYER. Thank you.

Dr. Woods, let me ask you about the DRE machines, because I want to know what extent the flaws in DRE machines are attributable to poor ballot design versus problems that are inherent in the technology itself or perhaps a combination of the two. I think Dr. Palfrey just made the observation that DRE machines themselves—some technology applications have not worked as well and administrators are not pleased with how well they have worked. Could you comment on the issue?

Mr. WOODS. I haven't looked directly and evaluated those interfaces. Ohio State did run a study 2 years before the recent controversy evaluating a variety of different voting systems and anticipated many of the punch card difficulties and identified a variety of other problems with the visual layout of the ballot design, ways that people could miss certain aspects of the ballot choices they had. For example people were able to—we had some issues where people—shorter people missed certain referenda, didn't even realize that they had those options available to vote on them. That is why there was no choice made on those issues facing the voter. So those layout issues can apply.

Mr. HOYER. Anybody else have any comment on that?

Mr. PALFREY. I think actually Mr. Ney identified one source of some of these problems when he mentioned the machines that he looked at and there was all sorts of variety of ways that lights popped on and went off and whatever. And if there isn't good, you know, clear instructions on the screen for what is going on, voters could easily get the wrong idea.

Mr. HOYER. Seems to me you need to take this technology and expose it to large focus groups and make a scientific analysis of the human error rate, user friendliness of the technology. I think that

is going to take a lot of—I imagine you folks are the perfect people probably to do that on contract for some group, perhaps the OEA, which would be able to give grants to carry out such testing. I mean, ultimately, a human being is going to use this, got to put a lot of human beings in the room and see what happens.

Mr. PALFREY. Not only sort of human testing, sort of human laboratory testing where you put them in a room and have them bang around it, and also field testing could be useful as well.

Mr. BAUM. In addition to in-field testing, we are not really talking about voter education here. That is an oxymoron. You don't go out and educate voters on the technology. They come in and use it.

Mr. Ney, you indicated that was your first time seeing that technology. For a majority of voters the first time they are going to see that technology is when they go in to vote on it. That is incorrect. They should have had a familiarity with it before. You put it out in the shopping malls, you put it out in the libraries, you put it out in the high schools and let them go out and play with it some. So by the time they go in and see it, it is not an intimidation of the equipment.

The CHAIRMAN. Especially for certain age years now. My children, if I buy a VCR today, they install it, my 12-year-old. It used to be my 17 year old when he was 12. If I need something done on the computer, they come over, and they help me. I am the problem. They aren't.

So I know you know the school age children through computers through school are not the—that they are not—that they don't need the education. They will have a much easier time. They don't fear things as I do. I am not a user of technology. I try and, you know, I do e-mail and things like that. So there is also age groups.

That is why you have got a great idea, the malls. If you have a mobile traveling unit that goes to senior centers, it is you know, open to the public. The schools are great, too. But school children are going to adapt quicker because they are used to computers.

Mr. BAUM. it depends. I think my kids would be very intimidated by a punch card machine——

The CHAIRMAN. Yeah, that is right.

Mr. BAUM [continuing]. And have a whole different experience with what the marked sensor cards are, too. The optical scan, you look at one of those, and you are taking a test.

Mr. WOODS. We refer to this problem as the walk-up interface problem, because people won't have practice. Even if it is you are voting in the same area, you only do it once a year. So it is always this kind of walk-up interface, and you have to remember again how to do it.

I would point you, without even the latest technology, to the L.A. Olympics in 1984. One major telecommunications company in the U.S. Human factors group was—volunteered to help design the information system—the electronic information system for the athletes, the participants in those games, how to deal with people with different languages and backgrounds and compute awareness. And they needed information about the times of their various practices and preliminary heats and also how to contact and schedule meetings with that tremendous opportunity to get to know people from around the world.

It was a tremendous success because they applied the science of human factors to those walk-up interfaces and experienced very few problems. People didn't think about it as a problem or a challenge, how to learn how to operate the device. They just walked up and found the information or communication to the people they wanted to contact.

The CHAIRMAN. I think Mr. Hoyer made a good point about focus groups. You have the scientific community that watches the group's interaction, you have your different type of people that are watching, but have you the people that participate in focus groups? I think that in fact, you know, would help a lot.

Mr. WOODS. Those usability tasks can be run.

Again, I would point out there are plenty of interfaces and potential for problems to arise when the election officials interact in the various stages of processing the votes. We shouldn't forget about those interfaces as well, because that is where we would inadvertently introduce large inaccuracies.

Mr. HOYER. Thank you.

Let me sort of ask a global question. If we could do only one thing this year, do you have any thought as to what that ought to be? In other words, the first step. I have mentioned some first steps personally, but do you have any views?

Mr. WOODS. Well, from my point of view, it would be very easy to put out a kind of initial guide to the human factors of voting technology that would give some examples, some basic principles and some testing focus group techniques, how to run the focus groups, to provide an initial resource to local election officials as they contemplate what decisions they should make now or put off as more information and options become available. And I think there are independent bodies, national laboratories such as Brookhaven National Lab or universities, who could respond quickly to provide that guidance.

Mr. HOYER. Any other Comment?

Mr. BAUM. I think if you were only going to do one thing—and that is my sincere hope that that is not the case—it would be to publish some information on how to live with what you have. I mean, yes, there are challenges in each one of these technologies. But with proper planning, with good processes in place and good training in place, we can certainly reduce the error rate of even the equipment that is there by handling it better.

Mr. RIVEST. I think I would respond by saying to create a organization whose mission is to assist the States, the local officials, by creating a fund, and organization to generate and distribute and share information about voting systems, supporting research, supporting focus groups on usability, supporting hacker attacks on systems to see what can be done. You know, publishing a source code, when that could be made available. An organization whose goal is to help the State officials know everything that needs to be known about these systems so they can choose well.

Mr. PALFREY. I would second that. Because I think one of the biggest problems is lack of information, okay? You have election administrators who are in a situation, whether the money is coming from the Federal Government or not, they are basically under pressure. They are going to have to replace some equipment. They don't

have good guidance for how to do it, how to implement it, what kind of pitfalls there are. And it goes to security, it goes to all these other different issues. I think you really do need an agency or an organization who is responsible for collecting and providing an information clearinghouse of that sort.

Mr. HOYER. As I say and as you know, we do have an organization, small and incorporated within the FEC, the OEA. But, I was stricken by the fact that all of the Secretaries of State that testified and all of the election administrators that testified were looking to the OEA for better information, better—best practices advice and counsel, better standards advice. And you have echoed that, and I hope we do that.

I want to say very quickly, I hope we don't do just one thing. I agree with that, and the question was, to that degree, rhetorical.

Last question I will ask, Mr. Chairman, and I have some others here but, if we might, I hope that our staffs can feel free to contact you from time to time and get the value of your expertise.

What would the best way for Congress to facilitate research and development of new voting technology, and how can Congress make it easier to develop and implement new technology? I think that is going to be, I hope, one of the aspects of what we will do. Because such a limited market, such a relatively—"sterile" is the wrong word but stable market, not a very volatile or vibrant market here, so the technology has not turned over as quickly as it otherwise might have. Florida has spurred that, and we will have a short window, in my opinion, to take advantage of that sort of awareness. So how can we best do that—that is, to spur our DT&E in this area?

Mr. BAUM. I would like to point out that, although the market for public elections may be set and stable, there are other kinds of elections where this technology applies. There are union elections, professional organization elections, and all kinds of places where these other factors are also a part. That allows the opportunity for the private sector and the public sector to cooperate here in building up standards that become then, generally accepted election standards. So that is one area of cooperation with the private sector where Congress can make a huge contribution. Also, as we have all stated before, coming up with standards that can be applied in these areas would make a significant contribution.

Mr. PALFREY. I think one of the barriers to innovation, is that election administrators have to be cautious when they make an acquisition of a replacement for whatever technology they had. And what has happened is that they just switch wholesale to a new technology.

I think one thing that would help innovation—and there are start-up companies that are out there trying to work on innovation in this area—is to provide some sort of funding for pilot testing, pilot experiments, and field testing so that you don't have to jump into it full force. You can try it out in a couple precincts, see how it is working, and monitor it. I think that is one thing that might help.

Mr. RIVEST. I think perhaps some guidance to either NSF or DARPA, or both, to support research in this area could be helpful. DARPA may seem strange, but in fact there is national security in-

volved with these elections. NSF has traditionally funded research in computer security and cryptography, for example. As my colleagues have pointed out, there are also businesses that need to be involved. I am not sure what the best way to encourage them to innovate is.

Mr. WOODS. Another aspect of the activity of the independent resource in that area, we need a mechanism for people to monitor potential or emerging sources of inaccuracy and problems. This is almost a classic advice that we give to almost every agency that has safety, for the potential for a crisis to arise. We don't want to react after the fact to a crisis, like Florida, and try to repair and intervene. High reliability organizations are out there testing and monitoring their systems to notice early warning signs or even dress rehearsals. Instead of rationalizing away the dress rehearsal of inaccuracies in this, our system, which we have been too tolerant of, we need these bodies to be out there saying, whoops, look at what we are starting to see as problems, sharing that information so people can change the technology, change the education, and change the procedures they are using to prevent crises from happening.

Mr. HOYER. Thank you very much to the panelists. You have been very helpful, I think, and very thoughtful. Hopefully, as I said earlier, we will be able to work with you so you can help us. Again, there's a much longer term—States and localities and whatever agency, whether it is the existing OEA within FEC or some other organizational structure like that, work with them to accomplish objectives which I think clearly all of us want to accomplish.

And they are not partisan in nature. Everybody wants to make sure that, not only does every American have the right to vote, but every American's vote is made easier to cast, more accurately, and counted correctly. And although this is not solely a technology problem, clearly it manifested itself in many ways as a technology problem, as well as a human behavior interface with technology problem.

Thank you very much; and thank you, Mr. Chairman.

The CHAIRMAN. We do appreciate your testimony today. You are an important component from the technology side.

Also one thing, I want to assure you too, and I feel very good about, the way we have proceeded and also about the ideas that Mr. Hoyer has been able to develop and we have been able to develop together and, you know, to reach some basic consensus among members when you start to talk about it.

I think the statement you made, Professor Woods, is what we are doing—you know, this isn't debating Florida, but Florida caused the debate. And I can barely remember anyone coming to me over a period of 20-some years, whatever office I have held, of saying, gee, this certain technology needs to be looked at or it needs work. It wasn't drawn out until you had some national view. And that is what the Presidential did.

So I think what we are doing is trying to work with the desires of the locals to do something about the existing systems that are out there, but also I think what we are doing, is we are not in the middle of the crisis right now, we are personally not letting this sit-

uation go. We are driving a piece of legislation. I think it is going to be good. But I think we are reacting the right way to look ahead.

So, I think your statements were well taken. It is the way to proceed on this, and I think that is what we are doing.

Mr. HOYER. Mr. Chairman, on a nonelectoral reform issue, if I might, I want to say to you and to Dr. Woods that—how highly resentful we in Maryland are that you have taken our president of the University of Maryland away. I don't know whether you have had an opportunity to get to know Brit Kirwan very well, but he is an extraordinary asset. He is a wonderful human being. Ohio State is very fortunate to have him. We miss him a lot in College Park.

I am on the board of regents of the university systems, and I was a graduate of the University of Maryland and worked with Brit very, very closely for all the time that he was at the university which, as you know, was over 2 decades. I trust that Ohio appreciates him as much as they should. You certainly compensated him better than we did; and he appreciates that, I know. But I hope you enjoy working with Brit. He is a terrific fellow.

The CHAIRMAN. We like him, and we in Ohio will not mention what Baltimore took from us in Cleveland a few years ago. We will just leave it at that.

On that note, I ask unanimous consent that witnesses be allowed to submit their statements for the record. Members have 7 legislative days to insert extraneous material into the record, and for those statements and materials to be entered into the appropriate place within the record. Without objection, so ordered.

I ask unanimous consent the staff be permitted to make technical and conforming changes on all matters considered, by the committee at today's hearing. Without objection, so ordered.

Having completed our business of the day for this hearing on election reform, the committee is hereby adjourned. Thank you.

[Whereupon, at 12:35 p.m., the committee was adjourned.]