Background material for AAAS briefing

July 12, 2001

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 nearly completed with the initial phase of our project, which is a 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 at a press conference scheduled for July 16, 2001 at 12:00 Noon Eastern time (9:00 AM Pacific)**. It will held at two locations, the campuses of Caltech and MIT. For details contact our media offices. 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 will focus on design, and more detailed study and 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.

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

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, although they occur regularly in local elections. 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 as a supplement to these notes.

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 as many as 3 million registered voters failed to cast a vote because of registration problems. We should set standards for quality of data bases and fund efforts to clean the databases 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. Our final report next week will offer a proposal for a general modular architecture for voting systems.

- *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: (internet; 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. The small size 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.

Recommendations

We need to upgrade for "the present" (2004) without losing sight of what is further down the road. We propose a combination of immediate reforms and longer term recommendations.

· **The phasing out of punch-card voting systems and other dominated technologies**

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.

· **Federal assistance to States and localities that want to upgrade 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 federal government should not mandate a single solution.**

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 federal government should also provide funding for voter education, poll worker training, the development and administration of standards and certification, field testing, and research and development grants

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, including field pilot testing of new technologies.

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.

· Recognize that this is an on-going process

There is a need to maintain vigilance over 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.