Expert and Peer Security Reviews of Elections Ballot Tracking and Accountability Business Case

A Report to the Metropolitan King County Council

From
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Scope of Work

In 2006, the King County Council adopted an ordinance authorizing all vote-by-mail elections in King County, and setting the time for the transition as 2007 or 2008, after certain conditions had been met, including the ability of voters to track their ballots[1]. An additional condition imposed upon the transition was for Council review and approval of a business case for purchase of elections equipment and software to assist in the transition to vote-by-mail.[2]

In April 2007, the Executive transmitted to Council a Ballot Tabulation Upgrade Business Case.[3] And in May 2007, the Executive transmitted to Council a Ballot Tracking and Accountability Business Case.[4] In summary, to facilitate the transition to all-mail voting, the Executive has proposed in these two business cases to purchase equipment and software for the following three election functions:

1. High-speed ballot tabulation, to handle the larger number of paper ballots that are expected with all-mail voting. (Ballot Tabulation Upgrade Business Case.)

2. Mail ballot tracking, so that voters will be able to track their ballots to confirm that they were received (and possibly, that they were counted). (Ballot Tracking and Accountability Business Case.)

3. Signature verification, to facilitate the process by which signatures on ballot envelopes are compared with signatures on file to verify that each incoming ballot was submitted by a qualified voter. (Ballot Tracking and Accountability Business Case.)

In April 2007, because election security is a high priority, the Council voted to have citizen, expert and peer security reviews of these two business cases.[5] The scope of work for the citizen review was to: (1) review the two business cases for purchase of new election equipment and software from a security perspective; and (2) solicit input from citizens on election security concerns. The citizen review was conducted by the Citizens' Election Oversight Committee (CEOC) and presented to the Committee of the Whole on July 16, 2007.

The scope of work for these expert and peer reviews was to review the business cases to determine whether the business cases conform to applicable best practices regarding election security including the recommendations contained in the report entitled "The Machinery of Democracy: Protecting Elections in an Electronic World." The reviews shall:

- Assess the analysis and recommendations contained in the business cases and compare the recommendations with any alternative courses of action that should be considered;

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1 Ordinance 15523.
2 Ordinance 15623.
3 Proposed Motion 2007-0240.
4 Proposed Motion 2007-0328.
5 Motion 12493.

- Identify the respects, if any, in which the business cases deviate from applicable best practices regarding election security and the recommendations contained in the report entitled "The Machinery of Democracy: Protecting Elections in an Electronic World;" and

- Recommend changes to the business cases, including, if appropriate, recommendation of different equipment and software for purchase, that would bring King County Elections into compliance with applicable best practices and the recommendations contained in the report entitled "The Machinery of Democracy: Protecting Elections in an Electronic World."

Council selected Lazarus Technology Mentoring, Inc. (LTM), an independent elections security firm, to complete this scope of work. (Qualifications of the Lazarus Technology Mentoring, Inc. team of Douglas W. Jones and Eric Lazarus may be found in Appendix One of this report.)

The peer security review of the Ballot Tracking and Accountability Business Case was facilitated by Douglas W. Jones and Eric Lazarus of Lazarus Technology Mentoring, Inc. The peer review was convened by DeForest "Buster" Soaries and consisted of nine elections experts from Florida, Illinois, California, Texas and Maryland. Peers included elections officials who use very similar technology as King County and administer elections in very large counties. A list of peer review names and titles may be found on page eleven of this report.

This report presents our expert and peer security reviews of the Ballot Tracking and Accountability Business Case. Separate reports present our expert and peer security reviews of the Ballot Tabulation Upgrade Business Case.

The Executive Recommendation in the Business Case

The Executive recommends in the Ballot Tracking and Accountability Business Case the following:

1. Melding of Pitney Bowes and VoteHere Technology for ballot tracking.

2. Work with Pitney Bowes to do a research and development project to support Automatic Signature Recognition (ASR) for deployment in the future.

3. Acquire mail-sorting machines.

4. Acquire software for sorting inbound ballots and integrate software with the voter registration system.

Findings and Recommendations

Expert Security Review Findings and Recommendations

Following are our expert security review findings and recommendations:

Overall Ballot Tracking Recommendation

- Recommendation One: In 2008, consider keeping the current ballot tracking system in place with only modest changes being made. The current voter registration and election management system (DIMS) can produce reports which could be made available to the public via a web interface, to allow individual voters to check that their ballots were received and accepted for tabulation (verified).

- After 2008, substantial upgrades to the ballot tracking system could be made.

Automatic Signature Verification

- **Finding One:** Until significant breakthroughs occur in computer handwriting recognition, attempts to speed the verification process by showing humans fewer of the signatures is likely to result in reduced election accuracy.
- **Finding Two:** Automatic Signature Verification may decrease elections security.
- **Finding Three:** The automatic signature verification software is very complex and particularly hard to inspect.
- **Recommendation One:** If the Council's primary goal is election accuracy, then we do not recommend implementing Automatic Signature Verification at this time. If the Council's primary goals are to reduce election costs and to improve the timeliness of reporting election results, then we recommend that the Council set explicit performance standards for election accuracy, cost and timeliness.

Both-on-Screen Signature Verification

- **Recommendation One:** Examine how the current signature verification process could be improved and measured before adopting an automated signature verification process. Once the desired improvements are determined, automation of the process might be considered.
- **Recommendation Two:** Eight best practices for current signature verification process should be considered (see page nine).

On-Site Sorting

- **Recommendation One:** For 2008, given the short time available, the county should consider keeping an outside vendor for sorting of ballots.
- **Recommendation Two:** The County should consider upgrading transparency by allowing election observers to watch the processes performed at the vendor's ballot sorting site.
- **Recommendation Three:** Long term the county should consider, sorting incoming mail ballots in-house.
- **Recommendation Four**: Consider conducting a broadly distributed request for proposal (RFP) process for on-site mail sorting.

VoteHere Technology

- **Finding One**: King County Elections is committed to not putting any unique identifiers on vote-by-mail ballots; however, a large part of VoteHere's Mail-in Ballot Tracking (MiBT) software is based on having unique identifier on each ballot.
- **Recommendation One:** Consider generating reports from data captured in the current voter registration system (DIMS) rather than from VoteHere's MiBT technology.

Peer Security Review Key Findings and Recommendations

Following are the peer security review findings and recommendations:

Overall Recommendations

- Melding of Pitney Bowes and VoteHere technology and Automatic Signature Recognition is both unlikely to be financially prudent and are likely to be the source of administrative challenges.
- Having King County sort ballots in-house is a conceptually good idea, but there is risk of not enough time to test the new sorting equipment and software before the presidential year election.
- We recommend considering implementing new ballot tracking equipment or changes to signature verification after the 2008 election cycle. Taking delivery of new equipment in early to mid 2009 would be more risk-adverse, in that it will allow the County to implement changes in the much lower risk environment of a non-Presidential year, without all the accompanying stressors to the system..

Melding of Pitney Bowes and VoteHere Technology

- **Finding One:** King County Elections is committed to not putting any unique identifiers on vote-by-mail ballots at this time; however, a large part of VoteHere's MiBT technology is based on having unique identifier on each ballot.
- **Recommendation One:** It is not appropriate to place unique identifiers on actual ballots.
- **Recommendation Two:** If the additional desired reports based upon data from returned ballot envelopes can be performed by Pitney Bowes or by in-house programmers, that would seem an attractive alternative.

Automatic Signature Verification

- **Finding One:** Nationally, best practice for signature verification currently requires a well-trained human signature verifier examining the ballot envelope and the signature or signatures on file.
- **Finding Two:** It may well be acceptable to have, as the Executive's proposal suggests, side-by-side, on screen comparisons of the on-file signature and the signature scanned from the envelope.
- **Finding Three:** The state of the art, however, is not adequately developed such that computerized automatic signature analysis is as accurate or reliable as well-trained humans.
- **Recommendation One**: King County should consider maintaining the best practice of human verification signature verification.

Mail Sorting Machines

- **Finding One:** Having sorting facilities within King County premises should provide an opportunity for enhanced security.
- **Finding Two:** The current sorting vendor has served the county for ten years and has developed a certain amount of expertise which would be lost just prior to a high volume presidential election.
- **Recommendation One:** The sorting capabilities as done in previous elections should work acceptably well for the upcoming election with the lowest risk of the options reviewed and available.
- **Recommendation Two:** The installation of new systems should be done deliberately with carefully planned implementation steps after the Presidential election year.

Ballot Sorting Software

- **Recommendation One**: The first several uses of the integrated ballot sorting software and voter registration system should be completed during low-volume, low-risk countywide elections.

Expert Security Review

Approach

There are many complexities underlying the Ballot Tracking and Accountability Business Case, rather than considering the business case as one unit, we found it more helpful to break down the considerations into component decisions, each of which can be considered individually rather than as one big "take-it-or-leave-it" decision.

Automatic Signature Verification

Should King County automate the signature verification process?

Currently King County Elections spends considerable resources verifying ballot signatures. A county employee verifies ballot signatures by comparing a voter's signature stored in the voter registration system with the voter's signature on the physical ballot envelope. The Executive is proposing to do research and development toward use using computers (i.e., Automatic Signature Verification) rather than depending solely on county employees to verify ballot signatures in order to reduce election costs and to improve the timeliness of reporting election results.

We are concerned that Automatic Signature Verification may decrease elections security.

Automatic Signature Verification requires very complex software which makes it difficult to inspect for errors in the computer code or security flaws. In addition, there is the possibility that the Automatic Signature Verification software could be programmed or configured to reject more signatures or apply higher standards in select areas. It should be noted that there must be adequate follow-up procedures in place to reconcile signatures that are not verified.

Our view is that, until significant breakthroughs occur in computer handwriting recognition, using computers rather than county employees to verify ballot signatures will result in reduced election accuracy. If the Council's primary goal is election accuracy, then we do not recommend implementing Automatic Signature Verification at this time. If the Council's primary goals are to reduce election costs and to improve the timeliness of reporting election results, then we recommend that the Council set explicit performance standards for election accuracy, cost and timeliness. These standards are important to establish since the level of accuracy would be reduced in order to increase timeliness and cost savings.

Both-on-Screen Signature Verification

Should King County move to signature verification of mail ballots where both signatures are on the computer screen?

As mentioned above, currently, a county employee verifies ballot signatures by comparing a voter's signature stored in the voter registration system with the voter's signature on the physical ballot envelope. The Executive's proposal is to have a county employee verify both ballot signatures on a computer screen. In this proposal, the

county would purchase ballot-sorting machines with cameras configured to take pictures of the signatures on the ballot envelopes. These pictures would be scanned into a computer and would be displayed on a computer screen along with the voter's original signature stored in the voter registration system.

We recommend examining how the current signature verification process could be improved and measured before computerizing the signature verification process. Once the desired improvements are determined, computer support for the process might be considered.

The following best practices for accuracy of signature verification should be considered:

1. There should be robust training of signature verification employees;
2. Signature verification employees should be selected on the basis of their ability to verify signatures accurately;
3. Resolution and quality of images should be high enough to ensure accuracy;
4. Signature verification employees should be supervised by a forensic document examiner;
5. The signature verification process should be "salted" with known good and bad pairs to ensure that the quality of work can be monitored all day long;
6. Signatures should be verified with the specimen above or below the questioned signature rather than side-by-side because the human eye performs that task better;
7. Collect, maintain and compare multiple signatures for each voter. This would enable the verifier to see the natural variation of the writer's signature; and
8. Collect, maintain and compare information besides signatures, such as, how a voter wrote their address or other writing samples.

On-Site Sorting

Should King County purchase its own sorting equipment, use an outside vendor as it has been doing most recently or lease equipment as needed as was done in the past?

A major advantage of using sorting equipment located within the election office premises is that this requires less transportation of ballots. Every time a ballot is transported off premises, opportunities are created for accidental error or intentional mischief. Processing ballots on premises not controlled by the election office also limits the ability of election observers to see that all aspects of ballot processing are conducted correctly.

The major disadvantage of owning sorting equipment is the expense.

For 2008, we recommend, given the short time available, that the county consider keeping an outside vendor for sorting both incoming and outgoing mail ballots. The county should also consider upgrading transparency by allowing election observers to watch the processes preformed at the outside vendor's site. In the long term, the county should consider buying outright or leasing equipment during election season and sorting incoming mail ballots in-house.

RFP for Sorting Equipment

We recommend that once the Council has determined that having on-site mail sorting capability is desired, a comprehensive, broadly distributed request-for-proposal (RFP) should be considered. It is relevant to recognize that, unlike voting-specific equipment, mail-sorting technology is highly evolved and common and the needs of even a county as big as King County are not challenging relative to what others who process mail do every day.

In addition, mail-sorting equipment is not considered election-specific technology, and, therefore, certifications are not required by either the state or federal government. This means that a well-constructed, broadly distributed RFP is likely to get many responses and the county may be able to get more functionality for considerably less investment than from the Executive's recommendation in the business case.

VoteHere Technology

Consider generating reports from data captured in the current voter registration system (DIMS) rather than from VoteHere's Mail-in Ballot Tracking (MiBT) technology for the following reasons.

First, King County Elections is committed to not putting any unique identifiers on vote-by-mail ballots at this time; however, a large part of VoteHere's MiBT technology is based on having a unique identifier on each ballot.

Second, generating reports from the current voter registration system would be less expensive than purchasing new technology. We estimate the cost to be in the range of $500 to $25,000 and to take one or two people less than a month to complete the work.

And, third, it would be less complex to generate reports from data from the current voter registration system than by adding an additional software vendor.

Conclusion

In 2008, consider keeping the current ballot tracking system in place with only modest changes being made, such as generating reports from data captured in the current voter registration. Maintaining the current ballot tracking system reduces the risk of an election breakdown during a high-volume presidential election. After 2008, substantial upgrades to the ballot tracking system could be made.

Peer Security Review

Approach

We facilitated a peer security review of the Ballot Tracking and Accountability Business Case. The peer review was convened by DeForest "Buster" Soaries, the first Chairperson of the US Election Assistance Commission (EAC) and panel members were:

Ion Sancho, CERA
Supervisor of Elections,
Supervisor of Elections Office, Leon County, Florida

Peter McLennon
Policy Analyst
Cook County Elections Office, Illinois

Thomas "TJ" James
Election Systems Manager,
Supervisor of Elections Office, Leon County, Florida

Nicholas Martinez
Demographic/GIS Manager
Supervisor of Elections Office, Leon County, Florida

Cynthia S. Kelley, CERA
Administrative Coordinator
Supervisor of Elections Office, Leon County, Florida

Pamela A. Woodside, PMP
former Chief Information Officer, Maryland State Board of Elections

Bruce Sherbet
Administrator
Dallas County Elections

Freddie Oakley
Clerk/Recorder
Yolo County Elections, CA

Tom Stanionis
Technology Director
Yolo County Elections, CA

Melding of Pitney Bowes and VoteHere Technology

While the goal of improved tracking of ballots is laudable, it is generally more attractive to employ fewer vendors for a given application and to use solutions that have worked well for other counties in the past thus avoiding challenging integrations of complicated technology.

The primary value provided by VoteHere's MiBT system involves having unique identifiers on ballots. However, this panel does not believe it is appropriate to place unique identifiers on the actual ballots (as opposed to ballot envelopes), because it is very hard to demonstrate to a voter or observer that such an identifier is not being used to violate voter privacy. The King County Council recently passed legislation to protect the secrecy of the ballot by requiring that no unique identifiers be placed on ballots if such identifiers "could allow an individual voter to be identified with a particular ballot." This is, in the minds of this panel, a very prudent and timely decision.

The other principal benefit provided by the VoteHere MiBT system, is the ability to generate reports for voters to know if their ballot has been received. If the additional desired reports based upon data from returned ballot envelopes can be performed by Pitney Bowes or by in-house programmers, then this approach would be an attractive alternative to purchasing the VoteHere MiBT system.

Automatic Signature Recognition

Accuracy of elections should be the highest priority. Nationally, best practice for signature verification currently requires a well-trained human signature verifier examining the ballot envelope and the specimen signature on file. It may well be acceptable to have, as the Executive's proposal recommends, on screen comparisons of the on-file signature and the signature scanned from the envelope.

The state of the art, however, is not adequately developed such that computerized automatic signature analysis is as accurate or reliable as well-trained humans. The result of errors in machine verification may well be both bad ballots being counted and good ballots being excluded and, thus, the accepted best practice nationally is human verifiers, not machine (automatic) signature verification. King County should consider maintaining the best practice of human verification signature verification for the near term at least.

Mail Sorting Machines

Pitney Bowes has a superb reputation in the world of mail processing, and upgrading the capabilities of King County elections is clearly something that needs to happen periodically. Having sorting facilities on King County premises should provide an opportunity for enhanced security. Less movement of ballots is a good thing.

However, moving to acquire, implement, test and train staff in time for the 2008 election cycle may not be the best strategy. The current sorting vendor has served the county for ten years and has developed a certain amount of expertise and familiarity with King County which would be lost just prior to a high volume presidential year. The sorting capabilities used in previous elections should work acceptably well for the upcoming

election, with the lowest risk of the options available. The installation of new mail processing systems should be done deliberately with carefully planned implementation steps, after the presidential election year.

Ballot Sorting Software

To make use of the new sorting machines and software, integration with the voter registration system will be required. Since King County uses a vendor for its voter registration system, it will be dependent on the vendor (i.e., Diebold) to make the necessary changes to support system integration. This integration creates some risk, especially if it cannot be completed and adequately tested before the 2008 election. An adequate test would include a live experimentation during a low-volume, low risk countywide election.

Relevant Best Practices

Should this business case move forward as recommended by the Executive, there are a number of best practices that we panel members would like to highlight:

Testing

If automatic signature verification is being considered for deployment, King County should test it with large batches of ballots, similar to what could be expected on one or two days in a high-volume election, and compare the results with what well-trained election workers can do. Proper testing can only be done in a "live" situation as would occur in a low risk countywide election. A best practice is to start small with a local Spring election within a special purpose district, and then increase the test environment to a countywide "mock" election. A test plan needs to be developed that identifies what is being tested (e.g., functionalities, volume of transactions, number of known "failures") and the expected outcomes of the test.

Testing should include a stress test (number of operators and speed) and a volume test. The test ballots should be augmented with known false, simulated signatures of various quality levels of signatures. Comparisons should be made with various levels of signature verification skill, including forensic document examiners.

We suggest that Council representatives see the new automatic signature verification technology demonstrated in-house on King County premises before its approval and acquisition. This demonstration could show both that the product will do what it is marketed as accomplishing, and that the product is not undeveloped, concept-only software.

Auditing

There are several sorts of auditing that are part of best practice:

- **Tabulation** – Election officials need to statistically sample committed batches of envelopes prior to opening ballots to ensure that the machine counts are

accurate. See the "Machinery of Democracy" study for why and how to perform such audits.[6]

- **Signature verification** – Statistically sample accepted and rejected signatures by looking at the paper records (i.e., the ballot envelopes and the voter registration cards) to ensure that the adjudication program is presenting the election worker with signatures that look like what is in the paper files. In addition, sampling will verify that workers are making the correct analysis and that the software captures the worker's intent properly.
- **Workflow** – At each workstation prior to feeding the ballots through, perform a physical count of the ballots in each batch to ensure that ballots are not added or missing from the batch. This should be done at least on a sampling of the batches and ballots.
- **Ballot Adjudication** – Many ballots do not scan correctly without corrective action. For example, voters draw an "X" where they should fill in an oval, a ballot might be too mutilated to be read or they might vote for two presidential candidates. Electronic adjudication attempts to rescue those votes but it provides an additional area for errors and attacks to take place. Adjudications must be done by at least two people, a Democrat and a Republican, per ballot and must be randomly sampled and examined by someone else to ensure that, for example, software problems are not causing adjudicators to make wrong adjustments and that their adjustments are being captured accurately.
- **Sorting Machine Function** – Sorting machines can fail. It is important to sample to ensure that poor functioning of sorting machines is detected rapidly. This sampling compares the number of ballots reported by the sorting machine with the actual number of ballots.
- **Transparency** – These audits should be public. Observers should participate in and see the results of all of these processes in real time.

Tracking Concepts

The "Intelligent Mail Barcode" is a set of services of the U.S. Post Office (USPS) used by bulk mailers. It employs machine-readable barcodes on envelopes, to uniquely identify each piece. The USPS says that it "...enables large [volume] mailers to follow the progress of their mail through the many stages of processing all the way to delivery." Mail piece scanning within the USPS provides another set of data that permits King County staff to generate more robust reports for tracking. This enables King County staff and voters another glimpse into the movement of the ballot.

If unique identifiers are placed on both the outgoing and incoming envelopes, perhaps using nested and window envelopes, King County could make use of this valuable USPS service. The Executive's plan considers the possibility of USPS tracking the outgoing mail but not the incoming mail returned to King County elections as individual pieces. However, we recommend using USPS tracking of both outgoing and incoming mail for several reasons:

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[6] "The Machinery of Democracy: Protecting Elections in an Electronic World" (2006) by the Brennan Center Task Force on Voting System Security. Known as the "Brennan Report."

- The data collected can be used to accurately assess the amount of lost and mis-delivered incoming ballots.
- The data collected can be used to persuade the USPS to address problems in its lower-quality distribution facilities

Conclusion

It is not considered a best election administration practice to make major changes in presidential election years; especially 2008 with no Presidential incumbent and a likelihood of extremely high voter turn out.

King County has already committed to two high risk and significant changes for the 2008 election cycle: (1) the movement of all of the election offices, facilities, and warehousing to a new location; and (2) the change in business practices to all vote by mail. We recommend considering implementing new ballot tracking equipment or changes to signature verification after the 2008 election cycle.

We conclude that melding of Pitney Bowes and VoteHere technology for ballot tracking and working with Pitney Bowes to do a research and development project to support Automatic Signature Recognition for deployment in the future are unlikely to be financially prudent and are likely to be the source of administrative problems.

It may well be right for King County to have its own mail sorting capabilities which can be considered as a part of a plan for an equipment change to occur after the 2008 elections.

Appendix One: Lazarus Technology Mentoring, Inc. Qualifications

Our LTM team, comprised of Eric Lazarus and Douglas W. Jones.

Eric Lazarus

Eric Lazarus is a Computer System Architect and expert in many technology disciplines. He is a researcher in the area of threats and risk evaluation and mitigation in general with a focus on voting security. He was the Principle Investigator on the Brennan Center for Justice study of voting system security and the initiator of the work on voting technology performed there. His methodology has become the standard for review of voting system vulnerabilities in the context of real elections.

Eric Lazarus was the Principle Investigator of the Brennan Center Report and the developer of the methodology underlying it. That study pioneered the methodical analysis of threats to voting systems and the power of countermeasures to address them. Eric is a co-author of a book based on the study from Academy Chicago Publishers.

Eric is a co-Principle Investigator of a project to develop a repeatable, and software supported, method for rational allocation of security-related resources. The methodology is currently envisioned to involve such elements as (a) the representation of threats as attack trees, (b) the annotation of attack-tree nodes with attack costing information (c) the annotation of costs to represent effects of countermeasures (d) the analysis of attack costs against countermeasures (e) the use of probabilistic mathematical methods to capture likely values for costing of attack difficulty. Funded by the National Science Foundation (NSF.) Result: The development of a unique threat-analysis application, AttackDog, employed at the National Institute for Standards and Technology and Technology (NIST) by the team who write voting system standards. We believe that AttackDog is the only fully featured threat analysis system that has even been applied to the problem of securing elections. It is almost definitely the only one designed specifically for the needs of election threat analysis. It is appropriate for use in modeling threats at the county level as well as to analyze voting system standards and practice more broadly.

Douglas W. Jones

Douglas Jones is an associate professor of computer science at the University of Iowa. He was one of the most productive members of the team that developed the Brennan report. He helped lead the NIST workshop that was a key element of the research process.

Doug Jones served on the Iowa Board of Examiners for Voting Machines and Electronic Voting Systems from 1994 to 2004, and chaired the board for 3 terms. This Board examines all voting systems offered for sale in the state of Iowa to determine if they meet the requirements of Iowa law. Jones was invited to testify before the United States Commission on Civil Rights on evaluating voting technology for their January 11, 2001 hearings in Tallahassee Florida. He was invited to testify before the House

Science Committee on problems with voting systems and the applicable standards for their May 22, 2001 hearings. He also was invited to testify before the Federal Election Commission on voting system standards for their April 17, 2002 hearings.

Jones wrote Chapter 1 of Secure Electronic Voting, edited by Dimitris Gritzalis and published by Kluwer Academic Publishers in 2002.In the summer of 2004, he consulted with Miami-Dade County to assess problems with their touch-screen electronic voting system and to assess their pre-election testing of their touch screen and optical scan voting systems. His paper, Auditing Elections, was published in the Communications of the Association for Computing Machinery in October 2004.

Doug Jones is one of the ten principle investigators in A Center for Correct, Usable, Reliable, Auditable, and Transparent Elections (ACCURATE), a multi-institutional center awarded a 5-year research grant by the National Science Foundation starting in October 2005. He has special expertise in the evaluation of optical scanners, the core of nearly all modern vote-by-mail systems.