White Paper

New Practices for LCD-DRE's

An examination of Punchcard and Marksense voting systems election practices and recommendations for LCD-DRE voting systems.

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Introduction

The election industry has been gradually changing over the past ten years. Forces driving this gradual change include early voting, relaxation of absentee restrictions, expansion of computer technology, the recognition of the rights of disabled voters, and the recognition of the basic inadequacies of older voting systems. The 2000 presidential election in Florida brought the deficiencies of the present voting systems into harsh public scrutiny, and forced this gradual advance into a call for instant action.

Adaptation to these changes mandates a conversion to computer-based voting systems, which provide greater accuracy, flexibility, accessibility and cost effectiveness. However, most present state election laws covering election equipment testing, recount procedures, and records retention were developed around earlier election equipment, mainly punchcard and marksense systems. It simply does not make sense to blindly apply current laws and practices to these emerging technologically advanced systems. Step-by-step procedures meant to test and record paper based election systems may have no meaning when applied to computer-based voting systems. Such an approach would be detrimental to the election industry and negate the cost effectiveness and operational advantages of the new electronic methods.

There are four areas of current election practice that require examination:

- Logic and Accuracy Testing
- Recounts and Recount Procedures
- Election Records Retention
- Voting Equipment Acceptance Testing

While not part of the public voting process itself, these four areas are made part of every election in order to ensure public confidence and provide the basis for public scrutiny. The purpose of this paper is to discuss these areas from a technical perspective, review the differences in underlying technologies and understand what procedures and practices can be used to meet the intent of existing laws and practice.

Finally, this paper describes emerging electronic voting systems in a generic fashion and makes no attempt to define the functionality of any commercially available product or system. Adoption of any of the recommendations contained in this paper would be at the direction of the authorities responsible for voting system approval.

Background

In this paper it is assumed that the transition in election equipment contemplated by a state or county is from either a punchcard or marksense voting system to a **Liquid Crystal Display based Direct Recording Electronic (LCD-DRE)** voting system. The election industry has done an excellent job of defining laws and practices for support of punchcard and marksense voting systems and the testing, recount and records retention procedures are appropriate for these technologies. As we will see however, these same procedures are not appropriate for the new LCD-DRE voting systems.

Point of Technological Interest

A brief discussion of the technological difference between paper ballot systems and LCD-DRE systems is required before proceeding. From one engineering perspective, elections can be described as a process of information dissemination and collection. The critical element of this process is translating the voter's intent into election results. This information path requires that, at some point, the information be converted from one type to another. Precisely where in the information path the data is converted is fundamental to the procedural treatment of the system.

Any digital electronic device that interfaces to the real world possesses some capability to convert analog information into a digital form. The real world operates with analog data and must be interpreted while computer electronics operate on digital representation of analog data. In the case of voting systems, the technology used for conversion from analog to digital data can be a wheel and an enter button, a touchscreen or by detecting the presence of a mark or hole in a piece of paper. For a

LCD-DRE, the conversion takes place directly through voter interaction.

When the voter makes a selection on a LCD-DRE, it is instantly converted to digital data. The process used to handle the digital data from that point forward is easily verified and validated through software and system testing. Compare this to punchcard or marksense systems where direct voter interaction merely creates another form of analog data that is processed through a variety of paths before it is converted to digital data. The critical factor here is where in the process the analog to digital conversion takes place relative to voter interaction.

Punchcard and Marksense Voting Systems Overview

In order to understand the laws and practices that are currently used to support punchcard and marksense systems, an understanding of their technical characteristics is required.

Punchcard and marksense voting methods are most notably characterized by the paper ballot. Ballot data on election race titles, candidate names, race ordering and other information is gathered and assembled by election officials. This information, listed as different ballot styles, is then delivered to a third party printer, in an electronic or written format. When the printed ballots are returned to the election official, the ballots are proofed and verified. During the voting process, these paper ballots are either typically indelibly marked by hand, in the case of marksense ballots, or the voter records his or her selections by punching out a perforated hole on punchcards.

Punchcard and marksense tabulation is essentially a process in which positional information is mechanically or optically extracted from the ballot and given meaning by the computer code. Extraction of the positional information is an analog process and, as such, is subject to environmental factors (temperature, humidity, moving mechanical parts on the tabulation equipment), calibration issues and the condition of the ballots.

For a punchcard and marksense election, the input of election data, the ballot creation and the printing of ballots are part of a process separate from the tabulation of these ballots. The output of this ballot creation process is a hardcopy, printed ballot that is **analog** data. To initialize the tabulation, an operator must program this analog data into the format that is compatible with the digital requirements of punchcard or marksense tabulation equipment. The programming written for each election must synchronize the tabulation equipment with the ballot. An important point here is that **punchcard and marksense voting methods require operator intervention between the ballot generation and tabulation programming steps of the election cycle.**

The tabulation function of counting ballots is initialized by an operator who, using the printed ballot, programs the punchcard and marksense tabulation equipment for each different ballot styles (each style has a unique set of races and issues). Because of the operator involvement, the information transition between ballot generation and tabulation programming requires testing and verification of the accuracy and logical correctness for each and every election.

When punchcard and marksense tabulation code is written, the code must equate a position on the ballot with an option on the ballot. This tabulation code must be re-written for each election. To verify that each position is correctly identified and equated to the correct ballot option, each and every ballot position must be marked and read by the punchcard or marksense tabulation equipment. This reading is followed by an operator comparing the known marked or punched position with the results as reported by the punchcard or marksense tabulation equipment.

Given the analog nature of the paper ballots, the analog-to-digital conversion process is susceptible to environmental and calibration factors. Temperature and humidity can change the properties of the paper, thus affecting the mechanical feed of the ballots into the tabulation equipment. The detection threshold at which a marksense system identifies a valid mark can float and mechanisms in the punchcard readers can stick. Merely handling the ballots during processing can also affect the outcome. As such, the verification needs to be preformed both before and after tabulation of the ballots to validate that these factors did not cause any process inaccuracies.

For every new punchcard and marksense election, the tabulation program is created and entered into the tabulation equipment anew. Therefore, every new punchcard and marksense election is tabulated using new and different software code for each election. Punchcard and marksense tabulation code is considered dynamic, meaning that it changes with every election. The dynamic nature of punchcard and marksense tabulation computer code rightfully necessitates extensive testing and verification surrounding its use for an election. Testing and verification of punchcard and marksense tabulation code has been wrapped up in process called **Logic and Accuracy Testing, or LAT** and is a requirement of all punchcard and marksense elections. These requirements have been codified as administrative rules or statutory requirements in most states that permit the use of punchcard and marksense systems.

The LAT does not test the ability of the punchcard or marksense system to detect marks or holes in a ballot; it tests whether the holes or marks have the correct digital representation resulting from the analog-to-digital conversion process, system calibration and whether the sensing method is operating correctly. The ability of a punchcard or marksense system to convert analog to digital data is limited to a specifically configured election. The computer code used to detect marks or holes does not change, but for each election the punchcard or marksense system must be instructed as to what the positional marks or holes mean. This is why a punchcard or marksense system must be re-programmed for each election and why extensive Logic and Accuracy testing is required.

The development and implementation of this LAT process is well thought out and is appropriate for punchcard and marksense systems as with any system that is re-programmed. These processes yield the highest possible degree of assurance that the election results are logically correct and accurate, given the known environmental problems and potential inaccuracies of paper ballot tabulation.

Direct Recording Electronic Systems Overview

LCD-DRE systems generally provide a more efficient use of data entered into the system. Data is entered once into the system and any subsequent use of the data is provided from an electronic reading of this original data. This same data flows to the tabulation function generally without any alteration, modification or operator intervention. Unlike punchcard and marksense systems, the use of data in this manner creates an uninterrupted data flow that begins with entering the data into the ballot definition function that, in turn, supplies formatted ballot data information to a voting terminal.

The primary software elements of a modern LCD-DRE system include some form of ballot definition software, a separate piece of software that runs the voter terminal and a tabulation function. LCD-DRE systems are centered not on the hardware device, represented by the voter terminal but rather the database that stores the election data. Primary control for the voting system resides with the ballot definition software that is typically a database application that runs on a standard Personal Computer.

Database software applications consist of two components. The first is the database "engine" which is manufactured by a third party company specializing in database software (i.e. Oracle). The database engine stores information in tables and can implement "stored procedures" that assist in data manipulation at the database level, improving performance. The second part is executable software that performs a variety of programmed functions using the data stored in the database tables.

Election data is entered into the database using the ballot definition software and can include election management information but, at a minimum, includes the necessary information (i.e. race title, candidate name, etc.), as it is to appear on the ballot.

Typically, the executable software performs formatting, organization and control functions to produce the various ballot styles that collectively are referred to as **formatted ballot data**.

In the creation of formatted ballot data, the ballot definition software application typically allows for the identification of ballot logic for races and contests, such as straight party, vote for two, race order, etc. Furthermore, precinct and/or district information is added to distinguish voter eligibility. All of this ballot logic is carried with the formatted ballot data, rather than being programmed separately as in a punchcard or marksense system.

The ballot definition software typically includes a ballot generation process where the ballot data is retrieved from the database and formatted for use on the voter terminal. Some form of data transport/transfer is used to supply the formatted ballot data to the voter terminal where the ballots are displayed. The nature of this technology requires that the formatted ballot data first carry with it the necessary control information required for the ballot and then pass it to the voter terminal.

The ballot definition software also initializes the tabulation function and establishes the ballot logic. The database contains all the election data so the only process performed by the tabulation function is accumulating the information contained in the ballot images.

Logic and Accuracy Testing

As described above, the purpose of the Logic and Accuracy Test (LAT) is to ensure voter confidence and assure election officials that the voting system is accurately tabulating votes. On a marksense or punchcard system, an LAT is required to be performed prior to and following an election. The following discussion will show that, due to the different nature of LCD-DRE tabulation software (static versus dynamic) and the absence of environmental factors (temperature, humidity, analog processes, condition of the ballots) LAT designed around punchcard and marksense voting systems are not required to establish the accuracy of LCD-DRE systems.

Software can be considered as static or dynamic. For election systems, software that does not change from election to election is static while software that does change is dynamic. Further, software is executable code and should not be confused with data that is external to the executable software. External data is read, written or acted upon by the executable software. Executable software provides instructions to the system to control its function. External data is used as input, output or configuration information for the executable software. External data is secured by precise boundary conditions and the executable software is verified to operate within that bounded space. The outcome of executable software acting upon bounded external data is said to be **deterministic**, meaning that it has specific verifiable and testable outcomes when acting upon a set of data within a bounded space.

For a punchcard or marksense system, the executable software that performs the analog conversion of relating positional information to election parameters is dynamic. In contrast, all modern LCD-DRE executable software is static. The database **structure** is static while the content of the database is dynamic (external data). The executable software of the database application is static. The only dynamic component of a modern LCD-DRE should be external data. This means that software execution can be tested and verified as accurate within the bounded conditions of the external data. **The static executable nature of LCD-DRE software allows the logic and accuracy to be tested and verified, remote and independent of any election**.

Testing and verification that, in fact, the LCD-DRE static executable software is accurate and operates with in the logical confines of applicable election laws is built into certification processes. The primary function of the Independent Test Authority (ITA) is to provide independent verification and validation that the system software functions as required within the bounded space of its defined external data. State certifications can also require demonstrations of accuracy and correctness. Counties can further require testing that demonstrates proper functionality. But once the accuracy and logical correctness has been demonstrated, the performance of a particular revision of the software has been determined and will behave identically for all future uses.

Since the static executable software system behaves identically when acting on the bounded external data, testing to verify that the election system is ready for a specific election needs to be performed on the external data only.

LCD-DRE Analog-to-Digital Conversion

Previous discussions have focused on the analog-to-digital conversion process used for punchcard and marksense systems and how critical the function is as related to election information processing. It was the analog-to-digital conversion process that required conducting an LAT to verify the accuracy and correctness for punchcard and marksense. It was noted that for a LCD-DRE, the conversion occurs through direct voter interaction and that an LAT was not required to verify the conversion process. This will become apparent in the discussion below.

When a voter steps into a voting booth to a LCD-DRE, his or her ballot is presented electronically on the LCD. Whether the voter touches the desired selection or highlights it by turning a wheel and pressing a button, the LCD-DRE provides the voter feedback by responding with visual or audio indicator. Presentation of the indicator to the voter is the result of an analog-to-digital conversion. This means that every time a voter makes a selection, the voter is verifying the accuracy and correctness of the analog-to-digital process. Should the voter attempt to express his or her intent and LCD-DRE fails to register it, that fact is obvious to the voter.

The ballot displayed to the voter is presented using the formatted ballot data that contains all ballot logic necessary to trigger a response to the voter. The fact that the system responds correctly provides confirmation that the selection will be represented in the voter's ballot image. The processing and creation of the voter's ballot image is performed by static software and therefore the outcome is deterministic.

An exception to this static, deterministic process is if any component of the voter terminal requires calibration. In this case, the process is deterministic within an identified tolerance range. Whether the system operates within the tolerance or outside the range can be affected by temperature, humidity and any contaminants present. Systems that require calibration should be required to have the calibration checked immediately prior to the beginning of the voting process, immediately following and periodically throughout the day. While the system may drift out of calibration during operation, it will be readily apparent to the voter and support personnel.

LCD-DRE Election Readiness

Verification is required to assure that the dynamic external data to be used with the executable software resides within the boundaries required by the executable software. There is a difference between precision and accuracy. Precision can be high and the data completely inaccurate. A well-designed software system will restrict external data from being entered that does not reside within the bounded range required by the executable code – precision. This function typically takes the form of data-entry error checking or input data validation. If a system does not incorporate this functionality, manual verification is required and could be an extremely tedious task.

Given that a system has input data validation and the operator enters valid data, the second factor to consider is whether the entered data is correct – accuracy. This is a matter of guarding against inevitable human error. Misspellings, incorrect ordering and other factors all amount to allowable external data being improperly entered, thus rendering an incorrect election presentation.
From an engineering perspective, verification of election readiness for a LCD-DRE simply requires proofing the data entered into the database. The ballot definition software can produce reports, which allows ballot text and assigned ballot logic for races to be verified. This is sufficient to verify accuracy of the election for use by a deterministic system. However, given the historical procedures for paper-based systems and the need for public demonstration, a simple review of data stored in

ballot definition database is unlikely to be an acceptable “test”.

For marksense and punchcard systems, the LAT includes creating a test deck where ballot options are pre-selected on a set of ballots and these ballots are then run through the tabulation system. The results produced by the tabulation system are then compared to the results as accumulated manually from the test deck. In this test scenario, the analog record of the input data is compared to the converted digital data. The human error associated with this process is minimized and traceable given the tangible records of the input and output data.

Given the deterministic nature of the LCD-DRE system, the results of a test deck LAT applied to a LCD-DRE would merely be a measure of whether the votes were accurately entered by the operator. Any discrepancy between the LCD-DRE system tabulation and the manually accumulated results from the test deck could not be attributed to the system accuracy. Marking the ballots is an analog-to-analog information transfer, i.e. creating the test deck, and to perform a classic LAT on a LCD-DRE, an operator would be required to replicate the test deck selection on the LCD-DRE. As previously stated, the operator would be performing the analog-to-digital conversion process for which there is no resulting tangible record that the conversion was performed correctly. As the number of ballots in the test deck increases, the possibility for human error increases considerably. So in practice, the LAT would be re-run until the tabulated results match those described by the test deck, proving only that the votes were entered correctly.

Attempting to enforce the classical LAT using the test deck concept creates a tremendous, unnecessary burden on the LCD-DRE systems and its customers. Attempts to support this concept have been suggested by providing automated processes to replace the human operator because of the high probability of incorrect entry of votes – an automated LAT. To implement an automated LAT, software routines or functions are added to the system that allows votes to be cast without human interaction. As previously discussed, performance of an automated LAT proves nothing and merely gives the appearance of accuracy testing. Couple this with the fact that special software is required that is not part of normal voting process and has the potential to seriously undermine public confidence, suggests that automated LAT capability should be expressly forbidden in saleable systems.

There are, however, additional actions available that provide validation and assurance for officials that the system is operating correctly and is ready for an election. LCD-DRE systems have a “round trip” data path where election data is entered into the ballot definition software, formatted ballot data is generated, votes cast on voting terminals and the result fed into the tabulation function. The round trip process can be set-up using test or live data with the resulting reports from the tabulation function providing a second level of verification that the external data is correct. Although it’s the same data from the ballot definition database, the round trip reports will show the votes cast on the voting terminals and that the data path is exercised.

The preferred approach when casting votes is the **Single Option Audit (SOA)** where one selection is made for every unique option on the ballot(s). This test will validate that the data path for every option is functioning properly and registers through the system and is reported by the tabulation system. For the purpose of validating election readiness, the response of a LCD-DRE to input operates identically, so casting a single vote is the same as casting one million, the number of votes is irrelevant. By casting a single vote for each unique option, the process is manageable, traceable and minimizes the possibility of human error.

Should a greater number of votes be desired for readiness validation, a **Random Option Audit (ROA)** should be performed. Here, multiple ballots are cast with selection made in a random manner. Only the number of votes cast needs to be tracked and the tabulation results reviewed to verify that all selections received votes. The random entry of votes is provided by an operator(s) making selections at will and they should be instructed to vote all options.

When performing an SOA or ROA, only a sampling of voter terminals is required. The static nature of the voter terminal software guarantees that the voter terminals will all respond identically. This fact can be further substantiated if the LCD-DRE system provides a means to verify that the correct version of software is resident in the voter terminal immediately prior to use. There are several ways to accomplish version verification and the most robust approach is to re-calculate the resident software "footprint" and compare the result to a known value.

Recounts

Much confusion exists over what constitutes a recount when using a LCD-DRE system. As explained below, this confusion is due to attempts to apply the practices used for punchcard or marksense system recounts to LCD-DRE systems. Under present voting systems, recounts are undertaken when the results of an election come into question or are challenged. Ballots are fed through the tabulation system a second or even a third time and the results are compared to the original outcome. There are instances in which a manual count of a small percentage of votes is performed to verify that the tabulation system is properly accumulating the totals. Again, as described in greater detail below, these are appropriate procedures for punchcard and marksense voting systems but they do not sensibly translate to LCD-DREs.

Punchcard or marksense systems involve a two-step process for recording a voter's ballot. First, there is an analog-to-analog information transfer. The voter marks a ballot card, an analog process that yields analog information to be passed further along the system. The second step is the analog-to-digital conversion process of converting the analog ballot into its digital representation by the tabulation equipment. It may be argued that a punchcard or marksense ballot is machine readable, which is true, but it requires a mechanical or optical process to convert it to digital data. Because this conversion process is subject to the effects of analog error sources, such as environmental factors, this makes it an analog process.

A recount of a punchcard or marksense system involves repeating the analog-to-digital conversion process using the tabulation equipment. However, because the analog-to-digital conversion process on a LCD-DRE results directly from voter interaction with the voting terminal, the traditional notion of a "recount" would require the voters to vote again. This clearly is not the intent of an election recount. Rather, the intent is to verify the outcome of what may be a close election, thereby ensuring public confidence in the tabulation process. With LCD-DRE systems, the only process required is system verification, used to validate the performance of the voting system.

Most modern LCD-DRE systems redundantly store the voters' choice set as a singular record – the voters' ballot image. These ballot images are typically saved in multiple memory locations and are duplicate originals. The main intent of this practice is to provide system redundancy in the event that the primary source becomes unusable in some manner. There is typically a primary data path through which the election data flows and along this path, LCD-DREs save the **duplicate originals** of the voters' converted analog input, i.e. the voters' ballot image. A 'ballot image' is a block of digital data that represents the voters' choice set.

Application of the punchcard and marksense concept of recount may suggest that these additional copies of the voters' ballot image be used for a recount. But an election canvass generated from the redundantly saved ballot images in a LCD-DRE system is not a repeat of the analog-to-digital conversion – a "recount" – but is a verification that the voting system accurately processed the duplicate originals of the voters' ballot image – "system verification."

It is preferable that the duplicate originals travel different paths through the system. De-centralized functionality, along with a different physical method by which the duplicate originals are transported from the vote collection location to the tabulation location, raises the level of system security. Furthermore, best practices suggest that the duplicate originals be used for system verification for every election.

Election Records

Records relating to elections are vital facets of elections because they help protect the integrity of the process. Retention of voting records is required for federal elections under 42 U.S.C § 1974 and most states have adopted equal or greater retention periods. As with the other topics of this paper, record retention has been well-defined and intended for punchcard and marksense voting systems, but the application to modern LCD-DREs is strained and mismatched. While the type and content of election records remains constant, technology has evolved and so must the processes used to identify and retain this information.

Mr. Craig C. Donsanto, Director of the Election Crimes division of the U.S. Department of Justice, wrote the definitive publication on records retention. Mr. Donsanto's work appeared as an appendix to a Federal Election Commission publication titled "Election Document Retention in an Age of High Technology, published in 1994. The appendix, titled "Retention of Voting Records Under 42 U.S.C. § 1974" provided guidance and recommendations to election administrators in response to the emergence of electronic media in election tabulation. The primary technological advances covered in the paper were marksense ballot readers and retention of the dynamic software that was programmed into the (removable) Programmable Read Only Memory (PROM). Invariably, technology has evolved, specifically electronic storage media, and voting systems have followed. While the recommendations provided by Mr. Donsanto remain valid, the discussion below is intended follow his work to the next step of technological evolution.

42 U.S.C. § 1974 provides that any record created as part of an election must be retained for twenty-two months. One purpose served by the duplicate originals created by LCD-DREs is to provide redundant storage for the ballot image in the event the memory used in the primary data path becomes corrupt or destroyed. The fact that the duplicate originals are created requires them to be retained. As such, the preservation of these records requires discussion.

With a LCD-DRE system, two or three duplicate originals are created and saved when the voters cast their ballots. The physical location in which the duplicate originals are saved within the system varies among the currently manufactured systems but, ideally, the locations would be physically separate devices. At the end of an Election Day, one set of originals is made available to a central tabulation system for generating election results. The remaining originals reside with the LCD-DRE. Drawing a parallel with Mr. Donsanto's work, these remaining originals can be regarded as duplicate PROMs. The question presented is how to manage the originals in such a manner that their authenticity would be accepted by a court of law.

Without thought, it would seem that the simplest approach would be to leave the data intact in the memory device or DRE for twenty-two months. If the LCD-DRE can maintain data for only a single election, then the equipment must be taken out of service for twenty-two months. This is obviously impractical as there are generally more than four elections within this time period. Another option is for the equipment to maintain an on-going record for multiple elections. However, this places past election records in jeopardy of being over-written or destroyed through use in subsequent elections.

The optimal solution is to electronically transfer the records from the memory devices or LCD-DREs to a separate storage medium so that they can be properly archived and protected in the event it is required for future evidentiary purposes.

In order to effect the transfer of these original records and preserve their authenticity and validity as evidence, the treatment of the data must be able to withstand challenge in a court of law. Research establishes that transfer or copies of electronic files or memory are an acceptable form of records and will satisfy the federal requirement of twenty-two months, provided the process used to transfer or copy the data is validated and auditable. These archived records would likewise be readily admitted in any court of law.

It is important to note that these records are duplicate originals – not copies–and would therefore be subject to the same evidentiary rules governing the transfer of any piece of evidence. The proponent of the evidence must establish the validity of the transfer process and the unbroken chain of custody preceding its submission into evidence. This can be readily accomplished as explained below.

The process used to transfer or copy the file or memory range that includes cast ballot data and audit trail information must be tested and verified. The transfer function should include multiple steps and each step tested with evidence of test results maintained for process validation. A first step in the transfer process is to copy the cast ballot data and audit trail information from the source to the target storage medium. The transferred data should be an image of the source data and enough information should accompany the cast ballot data to uniquely identify the source.

The next step should be a verification process in which the image of the transferred data (Record Image) is compared to the source data. This process should require that the Record Image be exact, meaning that the verification process should be able to detect 1-bit errors. Evidence of test results that include 1-bit errors injected into the function should be maintained. The complete data transfer process should include entries into an audit log that include source information, size of the transferred data and results of the Record Image verification.

Acceptance Testing

The last topic of this paper relates to delivery of LCD-DRE voting system products to customers. Given the static nature of LCD-DRE system software, testing of system components amounts to a functional test of the products to verify their operation. A functional test simply exercises the mechanical and electrical elements of the product to verify that the product functions as required. Exercising the elements of a product may include producing a printout from a printer, turning wheels and pressing buttons and other operational aspects and then verifying the correct response. For touchscreen units, verifying that each switch on the touchscreen grid is responsive should be required. The acceptance test for a particular product should be defined by the manufacturer of the product and reviewed by the certifying board(s) and agreed to by the customer.

Pre-Election Functional Test

Prior to delivery of equipment to a polling location, a functional test should be performed to verify operation. The functional test exercises the mechanical and electrical elements identified by the acceptance test. Typically, the functional test is a sub-set of the acceptance test and the final test coverage should be determined with the customer.

Conclusion

The discussions set forth in this paper point to the inescapable conclusion that the current procedural infrastructure that has developed around punchcard and marksense voting systems cannot sensibly support emerging LCD-DRE systems. As technology pushes ever forward and the privilege of voting is made more accessible to an ever-increasing diverse population, the processes and rules surrounding elections must continue to evolve at the same pace. The recommendations espoused in this paper will allow this industry to keep pace with and support the currently emerging voting systems and will, in turn, become one more foundational block upon which the next technological advances will be built.

About the Author

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Mr. McClure has over fifteen years of combined experience in design, development and manufacture of products for the elections, aerospace, telecommunications and medical industries. Mr. McClure gained an introduction to the election industry as a consultant to United States Voting Machines where he managed a research and development effort to produce an electronic voting system. As a result of this experience, he founded Worldwide Election Systems which was acquired by Hart InterCivic in 1999. Mr. McClure is directly responsible for the development of eSlate• , Hart InterCivic's highly acclaimed Direct Record Electronic (DRE) voting solution.

Prior to founding Worldwide Election Systems in 1996, Mr. McClure served as a product line manager at Ohmeda Medical Systems, which designed and manufactured patient monitoring devices for the operating room and intensive care environments. He holds one patent and three pending applications. Mr. McClure holds a MS degree in Systems Management from the University of Denver with undergraduate degrees in Electrical Engineering and Physics.

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