
VoTeR Center

UConn Center for Voting Technology Research

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# Technological Audit of Memory Cards for the August 12, 2014 Connecticut Primary Elections

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**Summary**

The University of Connecticut Center for Voting Technology Research (VoTeR Center) performed a combined pre-election and post-election audit of the memory cards for the Accu-Vote Optical Scan (AV-OS) tabulators that were used in the August 12, 2014 elections. The cards were programmed by LHS Associates of Salem, New Hampshire, and shipped to Connecticut districts.

Cards were submitted for two reasons per instructions from the SOTS Office (a) one of the four cards per district was to be selected randomly and submitted directly for the purpose of the audit, and (b) any card was to be submitted if it appeared to be unusable. Given that cards in category (a) were to be randomly selected, while all cards in category (b) were supposed to be submitted, and that the cards were submitted without consistent categorization of the reason, this report considers all unusable cards to fall into category (b).

For the pre-election audit, the Center received 2 memory cards from 2 districts. For the post-election audit, the Center received 149 memory cards from 97 districts. Due to the small volume of cards received for pre-election audit, we group the two pre-election audit cards together with the cards received for post election audit, and present the combined audit results in this report.

For the combined audit, the Center received 151 memory cards from 97 districts. 45 of these cards were used on Election Day. Among 151 cards, 117 fall into category (a). All of these 117 cards were correct. There are 34 cards (22.5% of all cards) that were found to be unusable by the AV-OS, thus falling into category (b). In particular, 31 contained apparently random (or 'junk') data. Given that such cards were not selected randomly, we estimate that for post-election audit the percentage of unusable cards is between 1.2% and 8.8%; the high estimate is somewhat lower than in prior audits, but the overall the range is consistent with prior audits.

Cards that fell into category (a) contained valid ballot data and the expected executable code, with no extraneous data or code on the cards. Overall the audit found no evidence of the tabulators deviating from the expected behavior in ways that could have affected the integrity of the elections. The audit identified a few cases where the established procedures are not followed; it would be helpful if reasons for these actions were documented and communicated to the SOTS Office in future elections.

The audit was performed at the request of the Office of the Secretary of the State.

# Contents

# 1 Preface

The University of Connecticut Center for Voting Technology Research (VoTeR Center) conducted pre-election and post-election audit of the memory cards used in the Accu-Vote Optical Scan (AV-OS) tabulators in the August 12, 2014 primary elections in the State of Connecticut. The audit was performed at the request of the Office of the Secretary of the State of Connecticut.

The memory cards were programmed by LHS Associates of Salem, New Hampshire, and provided by LHS to the districts in Connecticut. The pre-election audit was performed on the set of 2 memory cards that were shipped to the VoTeR Center by the towns, where the cards should have been randomly chosen for pre-election testing. The cards are tested as they arrive. The first pre-election card arrived at the Center on July 30, 2014 and the last pre-election card arrived at the Center on August 5, 2014. The first post-election card arrived at the Center on August 28, 2014 and the last post-election card arrived at the Center on October 07, 2014.

If noteworthy irregularities that might affect integrity or security of ballot tabulation are detected, they are reported to the SOTS Office without delay. Preliminary results were reported to the SOTS Office during the audit.

The memory cards were subject to several integrity tests. A comprehensive overview of the procedures followed by the Center personnel in conducting such technological audits is presented in prior reports.[1,2] We do not repeat here the description of the engineering that was performed to enable the audit, including the log analysis, and the technical setup used in the tests. Results of the prior technological audit reports since 2007 can be found on the Center website.[3]

In this report, we present the objectives of the technological audit and the audit results. Given that only two memory cards were submitted for pre-election audit, we include the analysis of these cards in this report. The audit process included testing, comparison, and analysis of the data collected during the audit. The procedures followed in this audit include a strict chain of custody policy with regard to handling the cards, maintaining a log of all transactions and activities, and safekeeping (both physical and electro-magnetic) of the memory cards. This report is a high-level, non-technical presentation of the audit results and it omits technical details. We also note that we did not use any vendor documentation regarding the design and the internals of the AV-OS terminal.

We conclude the report with several observations based on what was learned during the audit process. We believe that technological audits are crucial in maintaining the integrity of the electoral process.

# 2 Introduction

We start by briefly describing the electronic election system used in Connecticut. We then review the goals of the technological memory card audit, and present a preview of the audit results.

## 2.1 Brief Description of the AV-OS

The State of Connecticut uses an election system that consists of two main components: the Accu-Vote Optical Scan voting terminal (AV-OS terminal) and the ballot design and central tabulation

[1] Audit and Analysis Reports, UConn Center for Voting Technology Research. Available online at http://voter.engr.uconn.edu/voter/Reports.html.

[2] L.D. Michel, A.A. Shvartsman, and N. Volgushev "A Systematic Approach to Analyzing Voting Terminal Event Logs", EVT/WOTE14, San Diego, CA, USA, August 2014, http://voter.engr.uconn.edu/voter/2014/12/a-systematic-approach-to-analyzing-voting-terminal-event-logs/.

[3] http://voter.engr.uconn.edu/voter/Reports.html.

system called GEMS (Global Election Management System). We point out the following characteristics of these components:

- The AV-OS systems currently in use in the state of Connecticut contain the firmware version 1.96.6. This model is equipped with an optical scanner, a paper-tape dot-matrix printer, an LCD display, a serial communication port, and telephone jacks leading to a built-in modem.
- The GEMS software is installed on a conventional PC (or a laptop). It includes a ballot design system and a tabulation system. Connecticut does not use GEMS for central aggregation of the election results.
- Once the election data is entered into the GEMS system, the specifications of the election are downloaded into a memory card via an AV-OS system connected to GEMS by a serial line cable.
- The memory cards are 40-pin, nominally 128KB cards. The memory card is installed into the 40-pin card slot of the AV-OS. Older (pre-2012) memory cards use an on-board battery to maintain the data on the card. Once the battery charge is depleted, the cards lose their data. This affects memory card reliability, and it is a source of ongoing concern. In 2012, non-volatile cards (that do not require a battery) became available. These cards have undergone preliminary testing, and a pilot deployment has been conducted in 2012.

For election deployment the system is secured within a ballot box so that no sensitive controls or connectors are exposed to the voter and unauthorized personnel. Each memory card contains executable code that is used for printing the reports. The code, called *bytecode*, is originally written in a proprietary programming language. The installation of the GEMS software on a PC system contains several databases that include the data and ballot layout corresponding to each district, as well as the bytecode for AV-OS.

See our report at URL http://voter.engr.uconn.edu/voter/Report-OS.html for additional details on this election system.

## 2.2 Goals of the Memory Card Audit

The VoTeR Center prepares for and implements memory card audits at the request of the SOTS. Here we present the goals of the pre-election and post-election technological audit. Note that since we are combining the pre-election and post-election audit report (due to the small volume of cards submitted for pre-election audit), this audit report focuses primarily on post-election goals.

### 2.2.1 Goals of the pre-election audit

The pre-election audit has three primary goals: (i) determine whether or not the memory cards are properly programmed for the specific district and specific election, (ii) determine whether or not proper pre-election procedures are followed by the election officials, and (iii) determine whether or not any technical failures occurred.

The memory cards contain the data and the ballot layout for the elections. The memory cards used in the AV-OS terminals also store the tally of the ballots cast and report the results of the election. In this sense the memory cards are the electronic analogue of a physical ballot box. The data, layout, and the functionality of the memory cards are loaded onto each memory card using the AV-OS terminal from the GEMS database. The election-specific GEMS database is also provided by LHS Associates prior to the election to be used as the baseline for the audit.

Prior to the election, each polling center receives four programmed memory cards from the external contractor, LHS Associates. According to the instructions from the SOTS Office, each district is supposed to perform pre-election tests of the four cards. After the testing is complete, they are asked to select randomly one memory card per district and send it to VoTeR Center for the pre-election technological audit. The procedure for random selection of memory cards applies to district-based tabulators and does not include central absentee ballot tabulation. (Sometimes the cards are submitted for the audit before the pre-election test, and sometimes after the pre-election test; this should be made consistent in the future). When the cards are submitted for the audit after they undergo pre-election testing and preparation for the election, such memory cards should be in "election mode" with all counters set to zero.

As the cards arrive from the districts at the Center, the contents of each card is examined to determine whether the data and code on the cards is correct for the given district and election, and whether the pre-election testing was performed and the cards are set for election. This is done by comparing the card contents to the known baseline data received from the external contractor, and by checking the status of the card and its audit log that should contain the timestamped events that correspond to the cards being programmed, tested, and set for election. The analysis of the card data is semi-automated, where the basic analysis is done automatically, and then any noteworthy issues cause additional manual analysis. Any discrepancies or deviations from the baseline are logged and analyzed. Specifically, the memory cards are audited for any deviations in the ballot data/layout, and any deviations in the bytecode (executable). Additionally the state of the counters and the content of the event logs are analyzed for consistency with the expected election procedures. The event logs contain significant events in the life of a card since the last time it was formatted, allowing for such an analysis to be performed.

This audit also includes the analysis of the cards that were submitted by the districts because the cards were unreadable/unusable per instructions from the SOTS Office.

### 2.2.2 Goals of the post-election audit

Post-election audit focuses on the memory cards that were used in the election. The audits have three primary goals: (i) determine whether or not the memory cards are still properly programmed after the election is closed for the specific district and specific election, (ii) determine whether or not proper pre-election procedures are followed by the election officials, and whether the usage of the cards is consistent with the proper conduct of the election, and (iii) determine whether or not any technical failures occurred. The post-election audit employs a procedure similar to the pre-election audit.

The selection of cards for the post-election technological audit differs from the pre-election audit as follows. The SOTS Office randomly selects 10% of the districts that are the subject of post-election hand-counted audit (this audit is not covered in this document). These districts are also asked to submit the cards that were used in the election for the post-election technological audit. Additionally, any district, in principle, is able (and encouraged) to submit their cards for the post-election audit.

As the cards arrive from the districts at the Center, the contents of the cards is examined to determine whether the data and code on the cards is correct for the given district and election, and whether the events recorded in the cards audit log correspond to a proper programming, preparation for the election, and conduct of the election. As before, this is done by comparing the card contents to the known baseline, by checking the status of the card, and by analyzing its event log.

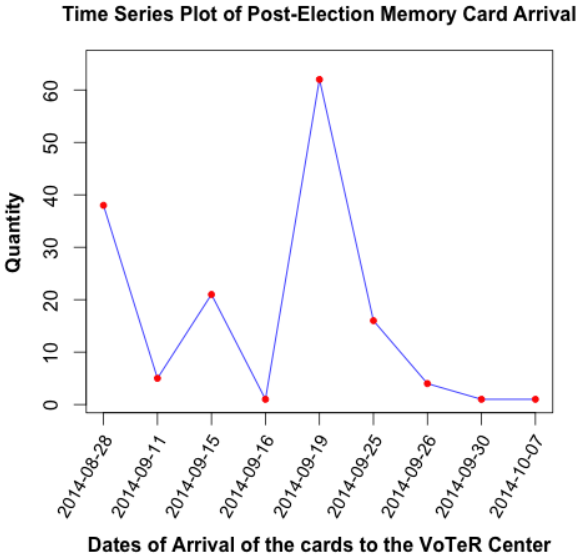


Figure 1: Arrival of the memory cards for post election audit

## 3 Summary of the Election Audit Results

We now highlight election audit results for the cards that were received and analyzed by the VoTeR Center.

For the pre-election audit we received 2 memory cards. These cards correspond to 2 distinct districts in Connecticut (for the purpose of this audit, the name 'district' denotes any polling or tabulation place for which specifically programmed memory cards are produced). For the pre-election audit, both memory cards were received prior to the Election Day: the first card was received on July 30, 2014 and the second card was received on August 05, 2014.

For the post-election audit we received 151 memory cards. These cards correspond to 97 distinct districts in Connecticut. Figure 1 graphs the arrival of these cards. The first post-election card arrived at the Center on August 28, 2014 and the last post-election card arrived at the Center on October 07, 2014.

Due to the small volume of cards received for pre-election audit (two cards), we group these cards together with the cards received for post-election audit and present the analysis results in one combined report.

Cards were submitted for two reasons per instructions from the Secretary of the State (SOTS) Office: (a) one of the four cards per district was to be selected randomly and submitted directly for the purpose of the audit, and (b) any card was to be submitted if it appeared to be unusable. Given that cards in category (a) were to be randomly selected, while all cards in category (b) were supposed to be submitted, and that the cards were submitted without consistent categorization of the reason, this report considers all unusable cards to fall into category (b). We note that the audits did not detect any cards whose data raised concerns about the integrity of tabulation.

Additional details concerning the election audit are given in Section 4 respectively.

**Category (a): Correctly Programmed Memory Cards.** For the purpose of this audit we consider a card to be *correct* if it contains the correct election data for the corresponding district, its bytecode is the expected bytecode, and it does not contain any unexplained or extraneous data

or code. Correct cards may include cards involved in duplication. Apart from reporting these cards as part of the total number of correct cards, we also report their number separately.

For the audit, among the 151 cards received, 117 (77.5%) were correct. That is, these cards contained correct election data. This category includes both 111 (73.5%) cards programmed according to the correct procedure, and also the 6 (4.0%) cards whose audit logs contain duplication events. Out of the 151 cards received, 3 cards were programmed for the wrong election. TRUMBULL-DISTRICT_2-0002837, and TRUMBULL-DISTRICT_4-0005722 were programmed for July 22, 2014 elections. BURLINGTON-DISTRICT_1-0001597 was programmed for November 05, 2013 elections.

**Category (b): Unusable Cards.** The SOTS Office instructed the districts to submit any cards that were found to be unusable by the tabulators to the VoTeR Center. Since these cards were not selected randomly for the audit, and these cards were not identified as the cards submitted in addition to the random audit, they appear in disproportionately high numbers.

The audit identified 34 cards, 22.5%, that were unusable by the tabulators. For the technological audits performed since 2007, on average about 9.0% of unusable cards were encountered in the election.

For this audit the percentage of unusable cards is estimated to be between 1.2% and 8.8%, within the overall card population. This is consistent with prior observations and represents a high failure rate. The estimation calculations are given in Section 4.3.1.

**Event log analysis.** All election audits include the analysis of the event (or audit) logs stored on the memory cards. AV-OS records in these event logs certain events that occur during the use of the tabulator. Table 1 presents the action types recorded by AV-OS in the event log along with a brief description. The event log has *action-time* entries and *date* entries. Most action-time entries contain the action name and the time of occurrence (no date). Some action-time entries, i.e., INITIALIZED and SESSION START also add the date.

The audit log is analyzed using a program developed for this purpose. The analysis examines the sequence of events reported in the audit log and checks that such sequences are consistent with the expectation of a properly conducted election. For example, one rule is that a zero counters report must precede the election. The report that documents our approach and the log analysis tool is available online.[4]

The rules implemented in the audit log checker do not cover all possible sequences, and the Center continues enriching the set of rules based on our experience with the election audits. For any sequence in the audit log that is not covered by the rules a notification is issued, and such audit logs are additionally examined manually. For the cases when the audit log is found to be consistent with a proper usage pattern we add rules to the audit log checker so that such audit logs are not flagged in the future.

Some results of the event log analysis are included in the presentation summary earlier in this section. Additional details of the event log analysis are presented in the next sections.

**Bytecode analysis for the readable cards.** The readable/usable cards include an executable program in the form of *bytecode* that is originally written in the proprietary AccuBasic language. The bytecode governs the printing of the reports. Incorrect bytecode may results in erroneous reporting of the election results.

[4] L.D. Michel, A.A. Shvartsman, and N. Volgushev "A Systematic Approach to Analyzing Voting Terminal Event Logs", EVT/WOTE14, San Diego, CA, USA, August 2014, http://voter.engr.uconn.edu/voter/2014/12/a-systematic-approach-to-analyzing-voting-terminal-event-logs/.

| Event Name | Event Description |
|---|---|
| AUDIT REPORT | Appears when an Audit Report is printed. |
| BAL COUNT END | After the ender card is inserted in an election, this action appears. |
| BAL COUNT START | Appears when the first ballot is cast in an election. |
| BAL TEST START | Records the beginning of a test election. |
| CLEAR COUNTERS | Appears when the counters are set to zero. |
| COUNT RESTARTED | Appears if the machine is reset during an election, after at least one ballot is cast. |
| DOWNLOAD END | Record the end of data load during the programing of the card using GEMS. |
| DOWNLOAD START | Recorded the start of data load during the programing of the card using GEMS. |
| DUPLICATE CARD | Appears when a card duplication takes place (in both the master card and the copy). |
| ENDER CARD | Records when an ender card is inserted, signifying the end of an election. |
| INITIALIZED | The 1st action in the Event Log; this action records date. |
| MEM CARD RESET | A memory card reset returns a card in 'not set' status, if it was set for election. |
| OVERRIDE | Records an override by a poll worker. Used for overvoted ballots in CT. |
| POWER FAIL | If the machine is unplugged or a power failure occurs, this action is recorded. |
| PREP FOR ELECT | Recorded when the card is set for election. |
| SESSION START | Date action. Appears every time you reset the machine. |
| TOTALS REPORT | Appears when a Totals Report is printed. |
| UNVOTED BAL TST | Appears when an unvoted ballot test is performed. |
| UPLOAD END | When an upload is completed, this action is recorded. |
| UPLOAD ERROR | Appears when an upload error is detected. |
| UPLOAD STARTED | Marks the beginning of an upload. |
| VOTED BAL TEST | Appears when an voted ballot test is performed. |
| ZERO TOT REPORT | Appears when a Zero Totals Report is printed. |

Table 1: Audit log action types

We have analyzed the bytecode that is loaded into each programmed memory card. Based on the analysis we conclude that the bytecode provided by LHS Associates for the elections is safe to use. The bytecode performs the expected reporting functions. Note that it is not possible to overwrite the contents of the card with the AccuBasic bytecode.

When, and if, a new version of GEMS and the AV-OS firmware will be used in Connecticut, the AccuBasic bytecode analysis support will need to be updated to correspond with the new version.

# 4 Election Audit Results: Additional Details

We now present additional details for the election audit. The high level breakdown of the received cards is as follows.

- 151 cards were received for the election audit. Of these cards, 2 were sent in for pre-election audit and 149 cards were sent in for post-election audit.
- 117 cards were correct (this includes 6 cards that were involved in duplication)
  - 45 cards were used in the elections
  - 57 cards were set to be used in the elections
  - 15 cards were not set to be used in the elections
- 34 cards were unusable (by AV-OS)
  - 31 cards contained apparently random data ('junk' data)
  - 3 cards were programmed for different elections

### 4.1 Overall Card State Analysis

Table 2 shows the frequency of various states observed on the 151 audited memory cards.

| All Cards (151) | | |
|---|---|---|
| **(a) Card Format** | Number | % Total |
| Correct Cards | 117 | 77.5 |
| Unusable (Junk Data) | 31 | 20.5 |
| Unusable (Not Junk) | 3 | 2.0 |
| Unusable (Not Programmed) | 0 | 0.0 |
| Unusable (Null) | 0 | 0.0 |
| Totals: | 151 | 100% |

Table 2: Memory card analysis summary for all cards received: (a) Card Format.

### 4.2 Analysis of Cards Used in the Election

We infer that a card has been used in an election if the following are true: (i) the card appears in an "Election Closed" or "Results Print Aborted" status, and (ii) has non-zero counters. Otherwise the card is considered not to have been used in the election. We start by summarizing the states of the audited cards, the we present detailed analysis of the event logs found on these cards.

- 45 cards were used in the election.
- 40 of the cards used in the election were in the Election Closed state and had Non-Zero counters. This is the intended state for memory cards that had been used in the election
- 5 of the cards used in the election were in the Results Print Aborted state with Non-Zero counters. The Results Print Aborted state is an undesired state. It indicates that poll workers either (1) shut down the machine during the printing of the results, or (2) did not conclude the printing procedure by pressing "No" when prompted to print another copy. Neither is the intended procedure. According to election procedures, the results report must be printed and signed by the poll officials and the machine must not be shut down until after all machine prompts have been answered. Poll workers should observe the prompt "Safe to Shut-Off the Machine", before turning off the AV-OS machines.
- No cards with uploaded results were found. This is the expected observation as Connecticut does not use uploading of results for central tabulation.
- No cards with audit report printed were found. This is the expected observation.

In the rest of this section we present the analysis of the 45 cards used in the election on the basis of automated and manual inspection of the event logs. Out of the 45 cards used in the election, 33 cards were flagged because their audit logs did not match our sequence rules.

The audit log analysis for the cards used in the election produced 72 notifications. Note that a single card may yield multiple notifications. Also recall that not all notifications necessarily mean that something went wrong — a notification simply means that the sequence of events in the audit log did not match our (not-all-inclusive) rules. We next present the details of the analysis.

#### 4.2.1 Out-Of-Bounds Dates.

This notification indicates that an event sequence in the log contains events that occurred outside of the expected chronological boundaries. For our analysis we dated the following chronological stages of an election: (a) Election Initialization, (b) Test Election, (c) Preparation for Election, and (d) Election.

The notification statistics for each stage appear in Table 3.

| | Cards Usable for the Election | | | |
|---|---|---|---|---|
| **Out-of-Bounds Dates** | # Warn. | % Warn. | # Cards | % Usable |
| Sequence: Initialization | 0 | 0.0 | 0 | 0.0 |
| Sequence: Test Election | 9 | 12.5 | 8 | 17.8 |
| Sequence: Prepare For Election | 10 | 13.9 | 10 | 22.2 |
| Sequence: Election | 38 | 52.8 | 27 | 60.0 |

Table 3: Post-Election Audit Log Analysis Results - Out-of-Bounds Dates

(a) **Initialization: 0 cards were initialized at unexpected times.**

(b) **Test Elections: 8 cards were tested at unexpected times.**
Test elections are performed after the cards are delivered to the districts. During this stage the districts test the usability of the memory cards they receive. Thus, we allow Test Elections to be performed two weeks after the beginning of card Initialization and ten days before the election day.[5] For this election we expect this process to be completed between the dates 6/26/2014 and 8/2/2014. Table 4 lists districts that show the unexpected test dates.

| | Test Election | |
|---|---|---|
| **Card Name** | **Date** | **Time** |
| BERLIN-DISTRICT_3-0006392 | 8/5/14 | 08:58 |
| BETHEL-DISTRICT_2-0002201 | 8/4/14 | 08:51 |
| COLUMBIA-DISTRICT_1-0001406 | 8/6/14 | 16:11 |
| ENFIELD-DISTRICT_158.159-0001786 | 8/4/14 | 10:47 |
| ENFIELD-DISTRICT_158.159-0001786 | 8/5/14 | 09:59 |
| MIDDLETOWN-DISTRICTS_11_&_12-0003975 | 8/5/14 | 11:28 |
| NORWALK-DISTRICT_142C-0006550 | 8/6/14 | 14:55 |
| STAFFORD-DISTRICT_2-0002439 | 8/5/14 | 10:10 |
| STAFFORD-DISTRICT_3-0006527 | 8/5/14 | 09:44 |
| TRUMBULL-DISTRICT_2-0002858 | 8/5/14 | 09:48 |
| WINDSOR_LOCKS-DISTRICT_2-0002827 | 8/7/14 | 11:30 |

Table 4: Test Election dates outside of the assumed time window.

Among these cards the test election was performed up to 5 days later than expected. This can be due to late card deliveries, or less-than-strict adherence to the established procedures (in the case of late dates).

(c) **Preparation for Election: 10 cards were prepared for elections at unexpected times.**
Cards should be prepared for elections after the testing is completed but before the election

[5] Ibid.

date. This is the expected state for the cards submitted for the pre-election audit. Since election preparation needs to be done immediately after the cards are tested, the date boundaries are the same as for the Test Election sequence. Table 5 lists districts that show preparation for elections on unexpected dates.

As the preparation dates are still prior to the election, this should not be a cause for concern. However, according to the SOTS regulations[6] the cards should have been prepared for election no later than the tenth day before the election.

| | Prepare for Election | |
|---|---|---|
| **Card Name** | **Date** | **Time** |
| BERLIN-DISTRICT_3-0006392 | 8/5/14 | 09:00 |
| BETHEL-DISTRICT_2-0002201 | 8/4/14 | 08:55 |
| COLUMBIA-DISTRICT_1-0001406 | 8/6/14 | 18:16 |
| ENFIELD-DISTRICT_158.159-0001786 | 8/5/14 | 10:03 |
| MIDDLETOWN-DISTRICTS_11_&_12-0003975 | 8/5/14 | 11:30 |
| NORWALK-DISTRICT_142C-0006550 | 8/6/14 | 14:56 |
| STAFFORD-DISTRICT_2-0002439 | 8/5/14 | 10:12 |
| STAFFORD-DISTRICT_3-0006527 | 8/5/14 | 09:56 |
| TRUMBULL-DISTRICT_2-0002858 | 8/5/14 | 09:52 |
| WINDSOR_LOCKS-DISTRICT_2-0002827 | 8/7/14 | 11:34 |

Table 5: Prepare for Election dates outside of the assumed time window.

As for test elections in the previous section, the preparation was performed up to 5 days later than expected. Again, this can be due to either early or late card deliveries, or less-than-strict adherence to the established procedures.

(d) **Election: 27 cards show deviations from the expected Election Day sequence.** We expect the election to be held on the election day. According to the SOTS regulations[7] the zero totals report should be printed no earlier than 04:15 and no later than 05:45; the election should be closed no earlier than 20:00 and no later than 20:15. We present the list of cards and events with out-of-range date information in Table 6. Manual examination of the logs resulted in the following observations.

- 3 out of 27 cards had printed zero total reports on the election day in the time window 03:34–4:14; printing zero total reports earlier on Election Day does not present a problem.
- 10 out of 27 cards had printed zero total reports on the election day in the time window 05:48–07:15; this is also a minor issue, although it is advisable to print zero total reports earlier to allow sufficient time for correcting problems, if any.
- For 3 out of 27 cards a zero totals report was printed prior to the Election Day. FAIRFIELD-DISTRICT_1-0005287 shows a complete election conducted on 07-29-14. No events are logged on the Election Day which prompts the assumption that the poll workers ran an election in place of a test election but did not use the card during the actual election. MIDDLETOWN-DISTRICTS_11_&_12-0003975 evidences a similar scenario. An election was conducted on 08-05-14. The card shows no events on the Election Day. It should be reiterated to poll workers that no election should be conducted in place of test elections as this potentially obfuscates the memory card event log and hinders the audit process.

[6] Ibid.
[7] Ibid.

| | Election Sequence | | |
|---|---|---|---|
| **Card Name** | **Event** | **Date** | **Time** |
| BERLIN-DISTRICT_3-0006392 | BALCOUNTEND | 8/12/14 | 18:54 |
| BETHEL-DISTRICT_2-0002201 | ZEROTOTREPORT | 8/12/14 | 04:07 |
| BETHEL-DISTRICT_2-0002201 | BALCOUNTEND | 8/12/14 | 18:45 |
| ENFIELD-DISTRICT_158.159-0001786 | ZEROTOTREPORT | 8/12/14 | 06:17 |
| ENFIELD-DISTRICT_158.159-0001786 | BALCOUNTEND | 8/12/14 | 19:59 |
| FAIRFIELD-DISTRICT_1-0005287 | ZEROTOTREPORT | 7/29/14 | 13:16 |
| FAIRFIELD-DISTRICT_1-0005287 | BALCOUNTEND | 7/29/14 | 13:33 |
| GREENWICH-DISTRICT_10-0002534 | BALCOUNTEND | 8/12/14 | 19:59 |
| GREENWICH-DISTRICT_6-0002517 | BALCOUNTEND | 8/12/14 | 19:57 |
| MIDDLETOWN-DISTRICTS_11_&_12-0003975 | ZEROTOTREPORT | 8/5/14 | 11:35 |
| MIDDLETOWN-DISTRICTS_11_&_12-0003975 | BALCOUNTEND | 8/5/14 | 02:19 |
| NEW_HAVEN-DISTRICT_16-0004309 | ZEROTOTREPORT | 8/12/14 | 06:14 |
| NEW_HAVEN-DISTRICT_16-0004309 | BALCOUNTEND | 8/12/14 | 19:57 |
| NEW_HAVEN-DISTRICT_20-2-0004324 | ZEROTOTREPORT | 8/12/14 | 06:31 |
| NEW_HAVEN-DISTRICT_20-2-0004324 | BALCOUNTEND | 8/12/14 | 19:57 |
| NEW_HAVEN-DISTRICT_24-0005854 | BALCOUNTEND | 8/12/14 | 19:59 |
| NEW_HAVEN-DISTRICT_25-0004346 | BALCOUNTEND | 8/12/14 | 19:58 |
| NEW_HAVEN-DISTRICT_27-1-0004376 | ZEROTOTREPORT | 8/12/14 | 07:15 |
| NEW_HAVEN-DISTRICT_27-1-0004376 | BALCOUNTEND | 8/12/14 | 19:59 |
| NORTH_HAVEN-DISTRICT_3-0001964 | BALCOUNTEND | 8/12/14 | 19:59 |
| NORWALK-DISTRICT_142C-0006550 | BALCOUNTEND | 8/12/14 | 19:50 |
| PROSPECT-DISTRICT_1-0004915 | ZEROTOTREPORT | 8/12/14 | 05:48 |
| SOUTHBURY-DISTRICT_3-0006335 | BALCOUNTEND | 8/12/14 | 18:59 |
| SOUTHINGTON-DISTRICT_2-0006293 | BALCOUNTEND | 8/12/14 | 19:55 |
| SOUTHINGTON-DISTRICT_7-0006300 | BALCOUNTEND | 8/12/14 | 19:58 |
| SOUTHINGTON-DISTRICT_8-0006301 | ZEROTOTREPORT | 8/12/14 | 06:03 |
| SOUTHINGTON-DISTRICT_8-0006301 | BALCOUNTEND | 8/12/14 | 19:58 |
| STAFFORD-DISTRICT_2-0002439 | ZEROTOTREPORT | 8/12/14 | 05:51 |
| STAFFORD-DISTRICT_3-0006527 | ZEROTOTREPORT | 8/5/14 | 09:59 |
| STAFFORD-DISTRICT_3-0006527 | BALCOUNTEND | 8/12/14 | 19:59 |
| TRUMBULL-DISTRICT_2-0002858 | BALCOUNTEND | 8/12/14 | 19:57 |
| TRUMBULL-DISTRICT_4-0002848 | ZEROTOTREPORT | 8/12/14 | 03:34 |
| TRUMBULL-DISTRICT_4-0002848 | BALCOUNTEND | 8/12/14 | 18:20 |
| WATERBURY-DISTRICT_71-2-0004130 | BALCOUNTEND | 8/12/14 | 18:53 |
| WATERBURY-DISTRICT_72-2-0004076 | ZEROTOTREPORT | 8/12/14 | 04:14 |
| WATERBURY-DISTRICT_72-2-0004076 | BALCOUNTEND | 8/12/14 | 18:54 |
| WATERBURY-DISTRICT_74-3-0004127 | BALCOUNTEND | 8/12/14 | 18:51 |
| WEST_HAVEN-DISTRICT_10-0006483 | ZEROTOTREPORT | 8/12/14 | 05:53 |
| WEST_HAVEN-DISTRICT_10-0006483 | BALCOUNTEND | 8/12/14 | 19:58 |
| WEST_HAVEN-DISTRICT_3-0006260 | ZEROTOTREPORT | 8/12/14 | 06:06 |
| WINDSOR_LOCKS-DISTRICT_2-0002827 | ZEROTOTREPORT | 8/12/14 | 06:08 |
| WINDSOR_LOCKS-DISTRICT_2-0002827 | BALCOUNTEND | 8/12/14 | 19:58 |

Table 6: Election date/time outside of the assumed time window.

STAFFORD-DISTRICT_3-0006527 contains a session start entry followed by a zero totals report entry on 08-05-14 which indicates that the machine was turned on before the Election Day. This is not a cause for concern since another zero totals report entry is logged on the Election Day, which is compliant with SOTS regulations.

- 16 of 27 cards closed the election on the Election Day and within the window 19:50–19:59. This should never happen. One possible explanation is that the clocks on the tabulators were not set exactly and are slightly behind the correct time.
- 7 of 27 cards closed the election before 19:00 on the Election Day. MIDDLETOWN-DISTRICTS_11_&_12-0003975 shows an election run concluded on 08-05-14. As previously mentioned, this card does not show events on the Election Day and as such does not cause concern for the integrity of the election. BERLIN-DISTRICT_3-0006392, BETHEL-DISTRICT_2-0002201, WATERBURY-DISTRICT_74-3-0004127, TRUMBULL-DISTRICT_4-0002848, WATERBURY-DISTRICT_71-2-0004130, WATERBURY-DISTRICT_72-2-0004076, and SOUTHBURY-DISTRICT_3-0006335 show elections closed between 18:24 and 18:58 on the Election day. This is over one hour before the expected time. A follow up is warranted for these districts to establish whether the clocks were off on the tabulators or whether the elections indeed were closed early.

### 4.2.2 Unexpected Number of Event Instances.

The event log analysis sets certain bounds on the number of events. Some of these bounds are ad hoc; for example: the analysis flags any card whose audit log contains more than 30 Session Start events. (These indicate that a tabulator was reset; such action does not interfere with ballot counting.) Other bounds are determined by the policies and procedural rules, such as that no card duplication events are allowed, thus one or more duplication events result in a notification.

Table 7 lists such events along with the expected number of appearances and suggested maximums. The statistics for all such notifications appear in Table 8.

| Event Name | Expected Number | Suggested Min. | Suggested Max. | Description |
|---|---|---|---|---|
| SESSION START | $\geq 3$ | 0 | 30 | Tabulator is turned on (e.g., 3 times: for initialization, testing, and election) |
| POWER FAIL | 0 | 0 | 10 | Tabulator switched to backup battery as the result of a main power failure |
| AUDIT REPORT | 0 | 0 | 5 | Audit report is printed |
| COUNT RESTARTED | 0 | 0 | 0 | Tabulator is restarted while in election mode and counting is resumed |
| MEMORY CARD RESET | 0 | 0 | 0 | The card is reset to a pre-election state following/during an election |
| DUPLICATE | 0 | 0 | 0 | The contents of the memory card are copied to another card |

Table 7: Events in an election timeline that may indicate a problem.

(a) **3 cards contain event "DUPLICATE":** This event indicates that the cards were produced not by the expected process (i.e., programmed from GEMS at LHS), but rather by duplication of another card.

The only authorized source of the card programming in Connecticut is the external contractor, LHS Associates. The cards are programmed using the GEMS system. Card duplications are

| | Cards Used in the Election | | | |
|---|---|---|---|---|
| **Flagged Number of Instances** | # Warn. | % Warn. | # Cards | % Usable |
| DUPLICATE (none allowed) | 3 | 4.2 | 3 | 6.7 |
| MEMORY CARD RESET (none allowed) | 1 | 1.4 | 1 | 2.2 |

Table 8: Event Log Analysis Results - Many Instances of Events

performed using the AV-OS voting tabulator; one can make a copy (duplicate) of a card on any other card by using the tabulator's duplication function. SOTS polices do not allow the districts to produce their own cards by means of card duplication.

Card duplication is a concern, as there is no guarantee that duplication faithfully reproduces cards. Duplicating cards masks the problem of card reliability. Additionally, it is impossible to determine with certainty who and why resorted to card duplication.

We manually examined the event logs of all 3 duplicated cards and compared the initialization date of the card against the date of the duplication. We established that one of the cards was most likely involved in duplication at LHS, since it was duplicated the same day that they were initialized. The other two (NEW HAVEN DISTRICT 20 and NEW HAVEN DISTRICT 27) were involved in duplication a week after they were initialized, which indicates that duplication occurred at their respective precincts. We recommend that it is reiterated to poll workers that cards must never be duplicated at the precincts.

(b) **1 card contains event "MEMORY CARD RESET":** This event indicates that the cards were prepared for election and then were reset to a pre-election state.

We manually examined the event log of the card that was reset. TRUMBULL-DISTRICT_2-0002858 was reset during the time-frame for testing elections after several test elections were conducted on it. The card was then used in the election.

Since the memory card reset event appears prior to the election, and the card is then tested and prepared for elections this does not present a security concern. However, the procedures established by the SOTS Office do not permit memory card reset and there should never be a need for it.

#### 4.2.3 Miscellaneous Notifications.

Miscellaneous notifications are caused either by incomplete elections, or events and election stages occurring outside of their expected context or in an invalid order.

No miscellaneous notifications were issued for the cards used in the election.

### 4.3 Analysis of Cards Not Used in the Election

The VoTeR Center received 151 cards for the post-election audit. This number includes 45 cards used in the election, with the result of analysis presented in the previous section. Here we present the audit results for the remaining 106 cards.

The high level breakdown of the cards not used in the election is as follows.

- 106 cards were not used in the election.
- 72 cards were usable

  - 72 were correct (this includes 3 cards that were involved in duplication)
  - 57 were set to be used in the elections
  - 15 were not set to be used in the elections

- 34 cards were unusable
  - 31 cards contained apparently random data ('junk' data)
  - 3 cards were programmed for different elections

#### 4.3.1 Overall Card State Analysis (Part a)

Table 9 shows the frequency of various states observed on the 106 audited memory cards not used in the election.

| **Cards (106) Not Used in the Election** | | |
|---|---|---|
| **(a) Card Format** | Number | % Total |
| Correct Cards | 72 | 67.9 |
| Unusable (Junk) Data | 31 | 29.2 |
| Unusable (not Junk) | 3 | 2.8 |
| Unusable (Not Programmed) | 0 | 0.0 |
| Unusable (Null) | 0 | 0.0 |
| Totals: | 106 | 100% |

Table 9: Memory card analysis summary: (a) Card Format.

Among the 106 cards not used in the election, 72 cards were readable by AV-OS and usable for elections. These cards were correctly formatted, and contained correct data and code for the specific districts for which they were prepared.

Among these 72 cards, 69 cards were programmed directly using GEMS. These involved no duplication. Out of the 69 cards, 69 cards matched the baseline, and 0 card had byte differences with the baseline. 3 cards were involved in duplication, otherwise they contained correct data, matching the baseline.

34 cards were unusable and did not contain data that can be used by the tabulators in the elections. Such cards do not present an immediate security concern.

31 cards contained apparently random ('junk') data and were readily detected through pre-election testing by poll workers, thus they could not have been used in the election.

3 cards (2.0% of all received cards) contained data referring to different elections than the one we audit. Manual examination of these cards showed that one card (BURLINGTON DISTRICT 1) was programmed for the November 5, 2013 Election and was not used in the Election, and two cards (TRUMBULL DISTRICT 2 and TRUMBULL DISTRICT 4) were programmed for the July 22, 2014 Election. The TRUMBULL DISTRICT 2's card had 516 ballots counted and the TRUMBULL DISTRICT 4's card had 863 ballot counted.

**Estimation of Unusable Cards Percentage.** Given that unusable (unreadable by AV-OS for the purpose of elections) cards were not selected randomly, we estimate that for post-election audit the percentage of unusable cards is between 1.2% and 8.8%. This estimate is made on the basis of the following calculation. We received cards from 97 districts out of the total 726 districts that participated in this election (this includes absentees), where there are 4 cards per district. The

number of unusable cards in the audit is 34. Thus the estimated minimum percentage is calculated as $34/(726 \cdot 4) = 1.2\%$, given that unusable card data does not contain district information. Performing similar calculation for the 97 participating districts, we obtain the estimated maximum percentage as $34/(97 \cdot 4) = 8.8\%$. This range is consistent with the results from prior audits.

### 4.3.2 Analysis of the Readable/Usable Cards Not Used in the Election

We now present the details of the audit for the 72 cards (among the 151 audited cards) that were not used in the elections (but could have been used if needed).

| **Usable Cards (72) Not Used in the Election** | | |
|---|---|---|
| | Number | % Total |
| **(b) Card Status Summary** | | |
| Not Set for Election | 15 | 20.8 |
| Set for Election | 57 | 79.2 |
| Totals: | 72 | 100% |
| **(c) Card & Counter Status** | | |
| Set For Elections, Zero Counters | 57 | 79.2 |
| Set For Elections, Non-Zero Counters | 0 | 0.0 |
| Not Set, Non-Zero Counters | 13 | 18.1 |
| Not Set, Zero Counters | 2 | 2.8 |
| Totals: | 72 | $\approx 100\%$ |
| **(d) Card Duplication (3)** | | |
| Master Card | 3 | 100% |
| Copy Card | 0 | 0% |
| Totals: | 3 | 100% |

Table 10: Summary of the analysis for memory cards not used in the election: (b) Card Status, (c) Card Record of Electoral Procedure, and (d) Card Duplication.

**Card Status Summary:** Here status refers to the current state of the memory card, for example, loaded with an election, set for election, running an election, closed election, and others.

57 cards were in Set For Election state. This is the appropriate status for cards intended to be used in the elections.

15 cards were in Not Set for Election state. This status would be appropriate prior to preparation for an election, but not prior to an election. This suggests that the corresponding districts sent these cards for the audit without first finalizing the preparation for the election. This is not a security concern, but an indication that not all districts follow the pre-election testing procedure.

**Card and Counter Status:** Here additional details are provided on the status of the counters on the usable cards. The expected state of the cards following the pre-election testing is Set for Elections with Zero Counters.

57 cards were found in Set For Election state and had Zero Counters. This is the appropriate status for cards intended to be used in the elections. One of these cards was submitted for pre-election audit, all the other cards were submitted for post-election audit.

13 were found in Not Set for Election state and had Non-Zero Counters. This is not an expected state prior to an election. This suggests that the cards were subjected to pre-election testing, but were not set for elections prior to their selection for the audit. This situation would have been detected and remedied if such cards were to be used on Election Day as the election cannot be conducted without putting the cards into election mode. One of these cards was submitted for pre-election audit, all the other cards were submitted for post-election audit.

2 cards were found to be in Not Set for Elections state with Zero Counters. This is similar to the 13 cards above. This situation would have been similarly detected and remedied if such cards were to be used on the election day. Manual examination showed that both cards are absentee cards from Middletown and for the purposes of this audit we do not expect such cards to adhere to the same sequencing constraints as non-absentee cards.

**Card Duplication:** Among the usable cards not used in the election 3 cards were involved in duplication. All of these cards (100%) were *master* cards used for duplication (meaning that the contents of such cards were copied to other cards).

### 4.3.3 Summary of the Event Log Analysis

There were 72 usable cards that were not used the election. Out of the 72 cards, 29 cards were flagged because their audit logs did not match our sequence rules.

The audit log analysis for the cards not used in the election produced 71 notifications. Note that a single card may yield multiple notifications. Also recall that not all notifications necessarily mean that something went wrong — a notification simply means that the sequence of events in the audit log did not match our (not-all-inclusive) rules. We next present the details of the analysis.

### 4.3.4 Out-Of-Bounds Dates.

This notification indicates that an event sequence in the log contains events that occurred outside of the expected chronological boundaries. For our analysis we dated the following chronological stages of an election: (a) Election Initialization, (b) Test Election, (c) Preparation for Election, and (d) Election.

The notification statistics for each stage appear in Table 11.

| | **Cards Not Used in the Election** | | | |
|---|---|---|---|---|
| **Out-of-Bounds Dates** | # Warn. | % Warn. | # Cards | % Usable |
| Sequence: Initialization | 4 | 5.6 | 4 | 5.6 |
| Sequence: Test Election | 19 | 26.8 | 13 | 18.1 |
| Sequence: Prepare For Election | 12 | 16.9 | 12 | 16.7 |
| Sequence: Election | 5 | 7.0 | 5 | 6.9 |

Table 11: Post-Election Audit Log Analysis Results – Out-of-Bounds Dates

(a) **Initialization: 4 cards were initialized at unexpected times.**
Card initialization is performed by LHS. We expect this process to start and complete no more than two months and no less than two weeks respectively before the election day. Thus, for these

elections we expected initialization to be performed between 6/12/2014 and 7/29/2014. Our assumptions for the sequencing of events are based on the SOTS documentation.[8]

4 cards fell outside of our assumed initialization period. The 4 cards are given in Table 12 for completeness.

| | Initialization | |
|---|---|---|
| **Card Name** | **Date** | **Time** |
| STAFFORD-DISTRICT_1-0002452 | 08-05-14 | 11:51 |
| STAFFORD-DISTRICT_1-0002453 | 08-05-14 | 11:53 |
| WESTPORT-ALL_DISTRICTS-0005451 | 07-31-14 | 09:50 |
| WESTPORT-ALL_DISTRICTS-0005453 | 07-31-14 | 09:51 |

Table 12: Initialization dates outside of our assumed time window.

(b) **Test Elections: 13 cards were tested at unexpected times.**
Test elections are performed after the cards are delivered to the districts. During this stage the districts test the usability of the memory cards they receive. Thus, we allow Test Elections to be performed two weeks after the beginning of card Initialization and ten days before the Election Day.[9] For this election we expect this process to be completed between the dates 6/26/2014 and 8/2/2014. Table 13 lists cards that show unexpected test dates.

(c) **Preparation for Election: 12 cards were prepared for elections at unexpected times.**
Cards should be prepared for elections after the testing is completed but before the election date. This is the expected state for the cards submitted for the pre-election audit. Since election preparation needs to be done immediately after the cards are tested, the date boundaries are the same as for the Test Election sequence. Table 14 lists districts that show preparation for elections on unexpected dates.

As the preparation dates are still prior to the election, this should not be a cause for concern. However, according to the SOTS regulations[10] the cards should have been prepared for election no later than the tenth day before the election.

The card WESTPORT-ALL_DISTRICTS-0001700 was prepared for election on the Election Day at 05:19. It should be reiterated to poll workers that the tabulators need to be prepared for the election before the Election Day to allow enough time to analyze and resolve potential malfunctions before the actual election takes place.

(d) **Election: 5 cards appeared to have some abnormalities in the Election sequence.**
We expect the election to be held on the election day. According to the SOTS regulations[11] the zero total report should be printed no earlier than 04:30 and the election should be closed no later than 20:01 on the Election Day.

Manual examination of these cards showed that after preparing the cards for election the machine was turned on and the zero total report was printed. For two of the cards it was printed a few

[8] For example, "Marksense Voting Tabulator", Section 9-242a-5, states that memory cards should be tested "as soon as ballots and ballot cards are available and not later than the tenth day before the election or primary". Hence, the testing of the cards must be completed no later than the tenth day before the election, and the initialization at least two weeks in advance. The document can be found at `http://www.ct.gov/sots/lib/sots/legislativeservices/regulations/12_opscanusereg.pdf`.

[9] Ibid.

[10] Ibid.

[11] Ibid.

| | Test Election | |
|---|---|---|
| **Card Name** | **Date** | **Time** |
| BROOKFIELD-DISTRICT_1-0005522 | 08-05-14 | 08:49 |
| BROOKFIELD-DISTRICT_2-0005526 | 08-05-14 | 08:42 |
| MIDDLETOWN-ABSENTEES-0003993 | 08-05-14 | 12:49 |
| MIDDLETOWN-ABSENTEES-0003993 | 08-12-14 | 08:37 |
| MIDDLETOWN-ABSENTEES-0003994 | 08-05-14 | 12:51 |
| MIDDLETOWN-ABSENTEES-0003994 | 08-05-14 | 12:52 |
| MIDDLETOWN-ABSENTEES-0003994 | 08-12-14 | 08:26 |
| MIDDLETOWN-ABSENTEES-0003994 | 08-12-14 | 08:38 |
| MIDDLETOWN-ABSENTEES-0003995 | 08-05-14 | 12:57 |
| MIDDLETOWN-DISTRICTS_11_&_12-0003976 | 08-05-14 | 11:40 |
| NORWALK-DISTRICT_142C-0004040 | 08-06-14 | 14:56 |
| STAFFORD-DISTRICT_1-0002452 | 08-05-14 | 13:17 |
| STAFFORD-DISTRICT_1-0002452 | 08-11-14 | 09:56 |
| STAFFORD-DISTRICT_1-0002453 | 08-05-14 | 13:18 |
| STAFFORD-DISTRICT_1-0002453 | 08-11-14 | 09:48 |
| STAMFORD-DISTRICT_16-0006133 | 08-06-14 | 10:42 |
| STAMFORD-DISTRICT_19-0006136 | 08-06-14 | 10:58 |
| STAMFORD-DISTRICT_8-0006125 | 08-06-14 | 11:01 |
| TRUMBULL-DISTRICT_2-0002862 | 08-05-14 | 09:24 |

Table 13: Test Election dates outside of the assumed time window.

| | Prepare for Election | |
|---|---|---|
| **Card Name** | **Date** | **Time** |
| BROOKFIELD-DISTRICT_1-0005522 | 08-05-14 | 08:52 |
| BROOKFIELD-DISTRICT_2-0005526 | 08-05-14 | 08:45 |
| MIDDLETOWN-ABSENTEES-0003995 | 08-05-14 | 12:59 |
| MIDDLETOWN-DISTRICTS_11_&_12-0003976 | 08-05-14 | 11:41 |
| NORWALK-DISTRICT_142C-0004040 | 08-06-14 | 14:59 |
| STAFFORD-DISTRICT_1-0002452 | 08-11-14 | 10:01 |
| STAFFORD-DISTRICT_1-0002453 | 08-11-14 | 09:53 |
| STAMFORD-DISTRICT_16-0006133 | 08-06-14 | 10:45 |
| STAMFORD-DISTRICT_19-0006136 | 08-06-14 | 11:02 |
| STAMFORD-DISTRICT_8-0006125 | 08-06-14 | 11:03 |
| TRUMBULL-DISTRICT_2-0002862 | 08-05-14 | 09:28 |
| WESTPORT-ALL_DISTRICTS-0001700 | 08-12-14 | 05:19 |

Table 14: Prepare for Election dates outside of the assumed time window.

days prior to the election day. This is not a security concern, since zero total report is printed every time the machine is turned on. For the remaining one card the zero total report was printed on the election day, however no ballots were cast, and hence this card was not considered as a card used in the election.

We present those cards in Table 15 for completeness.

| | Election Sequence | |
|---|---|---|
| **Card Name** | **Date** | **Time** |
| BROOKFIELD-ABSENTEES-0001577 | 07-28-14 | 10:09 |
| BROOKFIELD-DISTRICT_1-0005522 | 08-05-14 | 08:54 |
| BROOKFIELD-DISTRICT_2-0005526 | 08-05-14 | 08:46 |
| MIDDLETOWN-ABSENTEES-0003995 | 08-12-14 | 08:41 |
| WESTPORT-ALL_DISTRICTS-0005451 | 08-01-14 | 12:44 |

Table 15: Election date/time outside of the assumed time window.

### 4.3.5 Unexpected Number of Event Instances.

The event log analysis sets certain bounds on the number of events. Some of these bounds are ad hoc, for example, the analysis flags any card whose audit log contains more than 30 Session Start events (these indicate that a tabulator was reset; such action does not interfere with ballot counting.) Other bounds are determined by the policies and procedural rules, such as that no card duplication events are allowed, thus one or more duplication events result in a warning notification.

Table 7 lists such events along with the expected number of appearances and suggested maximums. The statistics for all such notifications appear in Table 16.

| | Cards Not Used in the Election | | | |
|---|---|---|---|---|
| **Flagged Number of Instances** | # Warn. | % Warn. | # Cards | % Usable |
| DUPLICATE (none allowed) | 3 | 4.2 | 3 | 4.2 |
| MEMORY CARD RESET (none allowed) | 2 | 2.8 | 1 | 2.2 |

Table 16: Audit Log Analysis Results - Unexpected Number of Events

(a) **3 cards contained event "DUPLICATE":** This event indicates that the cards were produced not by the expected process (i.e., programmed from GEMS), but rather by duplication of another card. These cards appear in Table 17.

We manually examined the audit logs of all duplicated cards not used in election and compared the initialization date of the card against the date of the duplication. We established that two cards (WALLINGFORD-DISTRICT_3-0001865 and WALLINGFORD-DISTRICT_6-0001880) were most likely involved in duplication at LHS, since they were duplicated the next day as they were initialized. The remaining one card (WALLINGFORD-DISTRICT_7-0001885) could have been involved in duplication in the district, since the duplication was done 7 days after the card was initialized. A follow up with the district is advisable.

Given the SOTS polices, the districts must not be producing their cards locally. If a district finds it necessary to duplicate cards, they need to make records of this activity and bring this to the attention of the SOTS Office.

(b) **2 cards contained event "MEMORY CARD RESET":** This event indicates that the cards were prepared for election and then were reset to a pre-election state.

We manually examined the event logs of the cards that were reset. TRUMBULL-DISTRICT_2-0002862 and WESTPORT-ALL_DISTRICTS-0005451 were both reset after an election run and prepared for an election again. In both cases these events took place before the actual election date in the time frame dedicated to testing elections. These cards do not contain event entries on election day and were not used in election, therefore these deviations raise no concern. It should however be emphasized that no elections should be run in place of test elections and that memory cards should not be reset by poll workers.

| Card Name | Observed |
|---|---|
| WALLINGFORD-DISTRICT_3-0001865 | 1 |
| WALLINGFORD-DISTRICT_6-0001880 | 1 |
| WALLINGFORD-DISTRICT_7-0001885 | 1 |

Table 17: Cards involved in duplication.

### 4.3.6 Miscellaneous Notifications.

Miscellaneous notifications are caused either by incomplete elections, or events and election stages occurring outside of their expected context or in an invalid order.

Table 19 presents the frequency of such notifications and the cards for which the notifications were issued are listed in Table 18.

| Card Name | Number of Warnings |
|---|---|
| BROOKFIELD-ABSENTEES-0001577 | 1 |
| BROOKFIELD-DISTRICT_1-0005522 | 1 |
| BROOKFIELD-DISTRICT_2-0005526 | 1 |
| DURHAM-REPUBLICAN-0002393 | 1 |
| FAIRFIELD-DEM._ABSENTEES-0005324 | 1 |
| GREENWICH-ABSENTEES_7-12-0002554 | 1 |
| LEBANON-DISTRICT_1-0001261 | 1 |
| MIDDLETOWN-ABSENTEES-0003993 | 1 |
| MIDDLETOWN-ABSENTEES-0003994 | 1 |
| MIDDLETOWN-ABSENTEES-0003995 | 1 |
| NEW_HAVEN-DISTRICT_15-1-0004304 | 1 |
| TRUMBULL-DISTRICT_2-0002862 | 1 |
| WALLINGFORD-DISTRICT_1-0001857 | 1 |
| WALLINGFORD-DISTRICT_3-0001865 | 1 |
| WALLINGFORD-DISTRICT_5-0005354 | 1 |
| WALLINGFORD-DISTRICT_6-0001880 | 1 |
| WALLINGFORD-DISTRICT_7-0001885 | 1 |
| WALLINGFORD-DISTRICT_9-0001891 | 1 |
| WESTPORT-ALL_DISTRICTS-0001693 | 1 |
| WESTPORT-ALL_DISTRICTS-0001697 | 1 |
| WESTPORT-ALL_DISTRICTS-0005451 | 1 |
| WESTPORT-ALL_DISTRICTS-0005451 | 1 |

Table 18: Cards involved in sequence inconsistencies.

| | Cards Not Used in the Election | | | |
|---|---|---|---|---|
| **Sequence Inconsistencies** | # Warn. | % Warn. | # Cards | % Usable |
| Unexpected Election Stage | 2 | 1.4% | 2 | 2.8% |
| Unfinished Election Process | 20 | 14.0% | 20 | 27.8% |

Table 19: Post-Election Audit Log Analysis Results – Sequence Inconsistencies

The manual examination of these audit logs of these cards revealed the following issues:

- The following cards show test election events, however they were not prepared for the election: DURHAM-REPUBLICAN-0002393, FAIRFIELD-DEM._ABSENTEES-0005324, GREENWICH-ABSENTEES_7-12-0002554, MIDDLETOWN-ABSENTEES-0003993, LEBANON-DISTRICT_1-0001261, MIDDLETOWN-ABSENTEES-0003994, NEW_HAVEN-DISTRICT_15-1-0004304, WALLINGFORD-DISTRICT_1-0001857, WALLINGFORD-DISTRICT_3-0001865, WALLINGFORD-DISTRICT_5-0005354, WALLINGFORD-DISTRICT_6-0001880, WALLINGFORD-DISTRICT_7-0001885, WALLINGFORD-DISTRICT_9-0001891, WESTPORT-ALL_DISTRICTS-0001693, WESTPORT-ALL_DISTRICTS-0001697. While this is not a security concern, it is against SOTS Office policies as all cards are supposed to be prepared for election before election day. Among these cards, LEBANON-DISTRICT_1-0001261 was received for pre-election audit.

- The following cards were prepared for election but no ballots were cast: BROOKFIELD-ABSENTEES-0001577, BROOKFIELD-DISTRICT_1-0005522, BROOKFIELD-DISTRICT_2-0005526, WESTPORT-ALL_DISTRICTS-0005451. This is not a security concern and consistent with the cards' state. These cards were not used in election and thus are assumed to be back-up cards.

- As discussed in Section 4.3.5, TRUMBULL-DISTRICT_2-0002862 and WESTPORT-ALL_DISTRICTS-0005451 were both reset after an election run and prepared for an election again. In both cases the reset occurred before the election date. This raises no security concern.

- Card MIDDLETOWN-ABSENTEES-0003995 contains a BAL COUNT START event on the Election Day, which indicates that ballots were cast in the election, however the card does not record evidence that the ender card was cast or that the election was properly concluded. It is likely that a different memory card or a different tabulator was used to conclude the election, however it is strongly recommended that such situations are reported to the SOTS Office so that the cards and/or tabulators are examined for possible malfunctions.

  Additionally, it is noted that the total ballots cast counter value is 2, all candidate vote counters and blank ballot counters are zero. This indicates that the two ballots cast were either invalid or unreadable by the tabulator. Given that this is a potential system malfunction, a technological audit of the tabulator might be warranted.

## 4.4 Memory Card Reliability

We estimated the overall percentage of the cards that are not usable in the election to be between 1.2% and 8.8% for the post-election audit (Section 4.3.1). None of these cards are readable by the tabulators, and as such they do not pose a security concern: such cards are detected as unformatted

cards by the tabulators and they cannot be used in the election. However, this high failure rate is consistent with prior observations[12] and it presents a reliability issue.

Our earlier investigation determined that the primary reason for memory card failures is depleted batteries. Once the battery's store of energy is depleted, the cards lose their data. The electrical properties of the batteries are such that the battery voltage output can decrease precipitously as the battery reaches the end of its service life. Therefore one cannot expect to rely on the low battery warning system built into the AV-OS. Battery depletion may happen within days after a card was programmed and tested. Thus even if a card is successfully programmed, it can fail before it is tested prior to an election, or at any time after it is successfully tested.

Card failures of this nature do not occur during the election. During the tabulation of ballots the optical scan tabulator supplies energy to the memory card, and the card's battery is not used.

# 5 Conclusions and Recommendations

1. One card submitted for post-election audit from Middletown for absentee ballots shows that two ballots were cast during the election, though no candidate vote counters or blank ballot counters were incremented. This might indicate a system malfunction of the tabulator and it is recommended that the specific tabulator is examined.

2. As expected, the current number of cards with unreadable data (junk data) continues to be high. We have determined that weak batteries are the primary cause of this. The vendor developed a new non-volatile, battery-less memory card, and our ongoing evaluation continues to confirm their software compatibility with the AV-OS machines used Connecticut. The use of the new card should eliminate the major cause of memory card failures, however at this time the dimensions of new cards are not 100% compatible with the original cards and this can cause problems as we have seen in the case of Wilton. Additionally, LHS needs to be encouraged to examine the J-40 connectors during routine maintenance and repair the connectors if any pins are bent or misaligned.

3. Three cards received for post election audit were programmed for the wrong elections. These cards were not usable for the election. This fact should have been identified during pre-election testing and the cards should have been submitted for pre-election audit.

4. We note that the number of cards submitted for pre-election audit was too low to obtain any meaningful statistics about the overall card population. A comprehensive pre-election audit helps minimize the number of potential system malfunctions on the Election Day and identify problematic memory cards.

5. The districts are encouraged to submit all malfunctioning cards to the VoTeR Center. All such cards need to be identified separately from the cards sent specifically for the audit. (This has been addressed in a recent newsletter from the SOTS Office.)

6. Several cards submitted for post-election audit show early election closings (up to an hour and a half before the official closing time). It is important that the root cause for these deviations is established. Once again, this underlines the importance of proper time and date setup on the AV-OS tabulators. Inaccurate time readings make it difficult to establish whether crucial election procedures were followed or not.

[12] See the summary of pre-election audits performed from 2007 to 2010 at `http://voter.engr.uconn.edu/voter/wp-content/uploads/VC-TechAudits-2007-2010c.pdf` and more recent reports at `http://voter.engr.uconn.edu/voter/reports/`.

7. It is important for the districts report to the SOTS Office any unexpected behavior of the tabulators that seem to necessitate a restart or a memory card reset. It would be helpful if moderators logs contained records of machine restarts, perceived causes, and reasoning for the restart or reset. In particular, whenever ballots are cast during an election on one tabulator, but the election is not concluded on said tabulator and another tabulator is used instead, the fact should be recorded in the moderator's log along with an explanation. In case of tabulator malfunction it is strongly recommended that the problematic tabulator is tested by the Center personnel (either at the district or in the Center laboratory).

8. The SOTS Office should continue publicizing proper procedures and offering training. In particular, the Office should: (a) reinforce the need to prepare all cards for election prior to the election day and prior to the pre-election audit, (b) reiterate the proper procedure for concluding an election, printing totals reports, and shutting off the tabulators, (c) stress that the cards should be tested using the test election procedure and not by running a live election and then discarding/zeroing it before the actual election.

9. Two cards used in the election and submitted for post election audit were involved in duplication at the precincts. Any cases of duplication should recorded in the moderators logs and be brought to the attention of the SOTS Office with a documented explanation of why this is necessary.

[End]