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## Post-Election Audit of Memory Cards for the November 6, 2012 Connecticut Elections

June 23, 2014, Version 1.0

### Summary

The University of Connecticut Center for Voting Technology Research (VoTeR Center) performed post-election audit of the memory cards for the Accu-Vote Optical Scan (AV-OS) tabulators that were used in the November 6, 2012 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) the 10% of the districts that were randomly selected for the post-election hand-counted audit as well as any districts that were interested in participating in the audit were asked to send their cards for the post-election technological audit, and (b) any card was to be submitted if it appeared to be unusable. Given that the cards were submitted without consistent categorization of the reason, this report considers all unusable cards to fall into category (b).

The Center received 578 memory cards from 286 districts (as of March 15, 2013). This is the largest number of cards submitted since 2008. Among these cards, 375 (64.9%) fall into category (a). All of these 375 cards were correctly programmed. Out of 375 cards, 174 contain completed elections (the rest were not used in the elections). There remaining 203 cards (35.1% of all cards) were found to be unusable by the AV-OS, thus falling into category (b). Among those, 192 cards contained apparently random (or 'junk') data, 7 cards were unusable by AV-OS, but did not contain random data (this requires further investigation), 4 cards were formatted using AV-OS utility, however, they were not programmed. None of these cards are usable by the AV-OS for the purpose the election. Given that such cards were not selected randomly, we estimate that the percentage of unusable cards is between 6.7% and 17.7% in this audit, and this is consistent with prior audit results.

All cards in category (a) contained valid ballot data and the executable code on these cards was the expected code, with no extraneous data or code on the cards. Overall the audit found no cases where the behavior of the tabulators could have affected the integrity of the elections. The adherence to the election procedures by the districts had improved compared to prior years, especially in preparations for election. However the analysis the established procedures are not always followed and in several cases problems with tabulators were apparently encountered at the districts and were not reported to the SOTS Office. It would be helpful if any extra-procedural actions and technical problems 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.

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## 1 Preface

The University of Connecticut Center for Voting Technology Research (VoTeR Center) conducted post-election audit of the memory cards used in the Accu-Vote Optical Scan (AV-OS) tabulators in the November 6, 2012 presidential 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 post-election audit was performed on the set of 578 memory cards that were shipped to the VoTeR Center by the towns between December 5, 2012 and February 12, 2013. The cards are tested as they arrive. 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 and the Office followed up with the districts in the cases when memory cards raised questions.

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<sup>1 2</sup>. 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. For the compilation of the technological audit results for prior years please consult our prior reports<sup>3</sup>.

In this report, we present the objectives of the post-election audit and the audit results. 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 electromagnetic) 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.

This is a preliminary report. At this time we are still receiving memory cards for the audit. Additionally the SOTS Office follow up is still in progress with several districts in several cases where event logs on the memory cards raised questions (these cards are identified in this report). Once the follow up is complete and newly arrived cards are analyzed we will issue the final report.

## 2 Introduction

We start by briefly describing the electronic election system used in Connecticut. We then review the goals of the post-election 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

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<sup>1</sup> Pre-Election Audit of Memory Cards for the November 2007 Connecticut Elections. UConn VoTeR Center, Version 1.0, January 24, 2008. Available online at <http://voter.engr.uconn.edu/voter/Reports.html>.

<sup>2</sup> Automating Voting Terminal Event Log Analysis. UConn VoTeR Center, EVT09, Montréal, Québec, Canada, August 2009, available at <http://voter.engr.uconn.edu/voter/wp-content/uploads/evt09.pdf>.

<sup>3</sup>See “Reports” at <http://voter.engr.uconn.edu>; the audits prior to 2011 are also summarized in Technological Audits of Optical Scan Voting Systems: Summary for 2007 to 2010 Connecticut Elections, VoTeR Center, 2011, at <http://voter.engr.uconn.edu/voter/wp-content/uploads/VC-TechAudits-2007-2010c.pdf>

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, a 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. Recently, non-volatile cards (that do not require a battery) became available. These cards are undergoing testing, and a pilot deployment of such cards started 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 Post-Election Memory Card Audit

The VoTeR Center prepares for and implements memory card audits at the request of the SOTS.

The 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.

### 3 Summary of the Post-Election Audit Results

We now highlight post-election audit results for the cards that were received and analyzed by the Center. We received 578 memory cards. These cards correspond to 286 distinct districts in Connecticut.

Cards were submitted for two reasons per instructions from the Secretary of the State (SOTS) Office: (a) the 10% of the districts that were randomly selected for the post-election hand-counted audit as well as any districts that were interested in participating in the audit were asked to send their cards for the post-election technological audit, and (b) any card was to be submitted if it appeared to be unusable. Given 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 post-election audit are given in Section 4.

**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. We note that some correct cards were involved in card duplication; such correct cards are grouped together with the correct cards, but we note the number of cards that were involved in duplication.

Among the 578 cards received for the post-election audit, 375 (64.9%) were correct. That is, each of these cards contained correct election data for the specific districts. This category includes both 336 (58.1%) cards programmed according to the correct procedure (using GEMS), and also the 39 (6.8%) cards whose audit logs contain duplication events. All of these cards (including those that were involved in duplication) contained valid ballot data and the executable code on these cards was the expected code.

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

The audit identified two hundred and three (203) cards, or 35.1%, that were unusable by the tabulators. We estimate that for the post-election audit the percentage of unusable cards is between 6.7% and 17.7%, within the overall card population. This range is consistent with prior observations<sup>4</sup> and represents a high failure rate. This calculation is given in Section 4.3.1.

**Event log analysis.** The post-election technological audit includes the analysis of the event (or audit) logs 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

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<sup>4</sup> Technological Audits of Optical Scan Voting Systems: Summary for 2007 to 2010 Connecticut Elections, VoTeR Center, 2011, at <http://voter.engr.uconn.edu/voter/wp-content/uploads/VC-TechAudits-2007-2010c.pdf>

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 programming of the card using GEMS.
DOWNLOAD START	Recorded the start of data load during the programming 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.
COM ERROR	A communication error between the AV-OS unit and the GEMS system.

Table 1: Audit log action types

must precede the election. The report that documents our approach and the log analysis tool is available online <sup>5</sup>.

The rules implemented in the audit log checker do not cover all possible sequences, and the Center continues refining the rules as we are 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.

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

<sup>5</sup>T. Antonyan, S. Davtyan, S. Kentros, A. Kiayias, L. Michel, N. Nicolaou, A. Russell, and A. Shvartsman, "Automating Voting Terminal Event Log Analysis", <http://voter.engr.uconn.edu/voter/wp-content/uploads/evt09.pdf>, EVT09, Montréal, Canada, August 2009, [www.usenix.org/events/evtwote09/](http://www.usenix.org/events/evtwote09/).

AccuBasic bytecode analysis support will need to be updated to correspond with the new version.

## 4 Post-Election Audit Results: Additional Details

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

- 578 cards were received for the post-election audit
- 375 cards were correct (this includes 39 cards that were involved in duplication, and 4 cards with benign, explained byte differences between the baseline and the memory card data)
  - 174 cards were used in the elections
  - 157 cards were set to be used in the elections
  - 44 cards were not set to be used in the elections
- 203 cards were unusable (by AV-OS)
  - 192 cards contained apparently random data (‘junk’ data)
  - 7 cards were unusable (but the data is not random)
  - 4 cards were not programmed (formatted, but blank)

We note that all cards submitted for the post-election audit have an invalid initialization date: this date is 00/00/127. This is apparently due to the incorrect date on the AV-OS tabulator that was used to program the memory cards at LHS. As the result, we could not perform certain parts of the analysis pertaining to the timing sequences associated with the election timeline. We have already reported this in the pre-election audit report<sup>6</sup>. The SOTS personnel have already been in contact with LHS regarding this matter, and we make no further mention of this in the sequel.

**Note:** All times in this report are given in the 24 hour format as recorded by the tabulator (unless AM/PM is explicitly given). For example, 06:45 stands for 6:45 AM and 18:45 stands for 6:45 PM.

### 4.1 Overall Card State Analysis

Table 2 shows the frequency of various states observed on the 578 audited memory cards.

### 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.

In total there are 174 cards that were used in the election. 172 cards (98.9%) are in Election Closed state and have Non-Zero counters. This is the intended state for memory cards that had been used in the election.

Among 172 cards there are 2 cards that contain byte differences between the baseline and the memory card data. Manual examination showed that the difference is in the race area of the card.

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<sup>6</sup>Pre-Election Audit of Memory Cards for the November 6, 2012 Connecticut Elections, January 18, 2013, Version 1.0, Univ. of Conn Center for Voting Technology Research, <http://voter.engr.uconn.edu/voter/wp-content/uploads/VC-pre-audit-Nov-2012.pdf>.

All Cards (578)		
(a) Card Format	Number	% Total
Correct Cards	375	64.9%
Unusable (Junk) Data	192	33.2%
Unusable (Not Junk)	7	1.2%
Unusable (Not Programmed)	4	0.7%
<b>Totals:</b>	578	100%

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

Both cards pertain to the town of Wethersfield, and it appears that the label of the race “REP. IN CONGRESS” was revised to include a space after “REP.”. This also caused data to be shifted by one byte shift, resulting in other differences between the baseline and the memory card data. It is plausible that some of the cards for Wethersfield were programmed prior to the change in the race label, while the rest were programmed following the change. As a result, not all cards from Wethersfield contain these differences. According to the date, this change was made by LHS (October 10, 2012), however since all the cards have an incorrect initialization date, specifically, 00/00/127, it is impossible to conclude with certainty whether the cards with byte differences were programmed prior or after the change in the race label.

The audit found 2 cards (1.1%) to be in Results Print Aborted state with Non-Zero counters. The cards are expected to have non-zero counters after the election, however Results Print Aborted is an undesired state, indicating that poll workers either (1) shut the machine during the printing of the results, or (2) did not conclude properly the printing procedure (by pressing “No” when prompted to print another copy). Although this does not present an immediate integrity concern, provided that the the results report is printed, neither of the above is the intended procedure. According to election procedures, the results must eventually be printed and signed by the poll officials, but election officials either did not wait for the (final) printing to complete, and turned off the machine prematurely or did not follow the procedures for turning off the machine properly. It should be recommended that the poll workers must 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.

#### 4.2.1 Event Log Analysis: 174 Cards Used in the Election

Here we present the result of the event log analysis for the cards that were used in the election.

The event log analysis for the cards used in the election produced 546 notifications. All 174 cards (100%) used in the election, were flagged because their event logs did not match our sequence rules. Note that a single card may yield multiple notifications. Also recall that not all notifications mean that something went wrong — a notification simply means that the sequence of events in the event log did not match our (not-all-inclusive) rules. Such notifications are subsequently examined to determine their significance. We next present the details of the analysis.

**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.

Out-of-Bounds Dates	Cards Usable for the Election			
	# Warn.	% Warn.	# Cards	% Usable
Sequence: Initialization	174	31.9%	174	100%
Sequence: Test Election	38	7.0%	38	21.8%
Sequence: Prepare For Election	37	6.8%	37	21.3%
Sequence: Election	242	44.3%	141	81.0%

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

(a) **Initialization: 174 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 09/06/2012 and 10/23/2012. Our assumptions for the sequencing of events are based on the SOTS documentation <sup>7</sup>.

The initialization of all correct cards fell outside of our assumed period. This is apparently due to the fact that the AV-OS machine used for initializing these cards at LHS does not have its date/time set correctly. Instead, the date of initialization appears as 00/00/127 in the event log of all correct cards. We reiterate that it is important that all AV-OS tabulators have the date/time set correctly.

(b) **Test Elections: 38 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 <sup>8</sup>. For this election we expect this process to be completed between the dates 09/13/2012 and 10/28/2012.

Table 4 lists only those districts that show unexpected test dates due to AV-OS tabulator's incorrect date/time.

Card Name	Test Election	
	Date	Time
ANSONIA-DISTRICT_5-0001633	6/7/62	12:08
BLOOMFIELD-DISTRICT_2-0001547	00/00/127	31:63
EAST_HARTFORD-DISTRICT_7-0005377	12/20/60	17:42
GLASTONBURY-ABSENTEES-0002752	00/00/127	31:63

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

<sup>7</sup> 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](http://www.ct.gov/sots/lib/sots/legislativeservices/regulations/12_opscanusereg.pdf).

<sup>8</sup>Ibid.

Manual examination of those cards shows that both cards with test elections with 00/00/127 test date were most likely tested at LHS, since the test election was run immediately after the initialization was complete, and because the date/time of the machine used for initialization is incorrect.

ANSONIA-DISTRICT\_5-0001633 card deserves attention. Here the machine with an incorrect date/time was used at the district. The manual examination of the audit log of the card showed that the election was conducted using this card. The result is that neither Zero Totals Report nor the final Totals Report have correct dates. Strictly speaking, it may be the case that some election was held on the wrong date, although it is much more plausible that the clock was wrong. It is important that the tabulators used for elections have their date/time set correctly. SOTS Office follow up is in progress for this memory card.

EAST\_HARTFORD-DISTRICT\_7-0005377 card seems to have been tested at the district using a tabulator with an incorrectly set date/time. However, the audit log of this card shows that the election was run on 11/06/2012, which is the expected date. Hence, either the date/time on the tabulator was corrected before the election, or a different machine was used for the election. Either way this does not present a concern.

- (c) **Preparation for Election: 37 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 sequencing of events for the cards submitted for the post-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 only the districts that show preparation for elections on unexpected dates either due to the AV-OS tabulator's incorrect date/time setting or due to the card being prepared for election on the Election Day.

Card Name	Prepare for Election	
	Date	Time
ANSONIA-DISTRICT_5-0001633	6/7/62	12:12
BLOOMFIELD-ABSENTEES-0001565	11/6/12	19:39
DANBURY-WARD_4-109-0003538	11/6/12	7:15
DANBURY-WARD_7-110-0005474	11/6/12	7:58
DANBURY-WARD_7-138-0005473	11/6/12	14:57
EAST_HARTFORD-DISTRICT_7-0005377	11/6/12	6:43

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

ANSONIA-DISTRICT\_5-0001633 card was already discussed in the clause (b) of this section.

BLOOMFIELD-ABSENTEES-0001565 is an absentee card, and for the purposes of this audit we do not expect such cards to have sequencing constraints.

The cards DANBURY-WARD\_4-109-0003538, DANBURY-WARD\_7-110-0005474, and EAST\_HARTFORD-DISTRICT\_7-0005377 were prepared for election on the election day between 06:30 and 08:00 AM.

DANBURY-WARD\_7-138-0005473 was prepared for election at 14:57 on the election day. Responding to the SOTS Office followup, Danbury reported the following. They noticed a problem with the public counter and then could not feed the ender card through to get a count. So they just replaced the machine and refeed the ballots. They also had several problems with machines they just had serviced before the election.

The remaining 31 cards were prepared for election at least three days prior to the election. It is worth reiterating that according to the SOTS regulations<sup>9</sup> the cards should have been prepared for election no later than the *tenth* day before the election.

(d) **Election: 141 cards indicate minor deviations in the Election Day sequence timing.**

We expect the election to be held on the Election Day. According to the SOTS regulations<sup>10</sup> the zero totals report should be printed no earlier than 04:30 and the election should be closed no later than 20:01. Based on this, on the Election Day, we expect Zero Totals Report to be printed between 04:15 and 05:45, and the Ballot Count should end between 20:00 and 20:15.

The card ANSONIA-DISTRICT\_5-0001633 has an incorrect election date (6/24/62). As discussed above (including this card) the AV-OS tabulator should always be set to a correct date/time.

11 out of 141 cards printed Zero Totals Report prior to the election day. However, this should not be a cause of concern since Zero Totals Report was also printed on the election day for all of those cards. And in general if a card is set for election, the Zero Totals Report will be automatically printed every time the machine is turned on.

12 out of 141 cards either started or closed the election at unexpected times. This caused a follow up by the SOTS Office. Table 6 lists those districts (note that there may be more than one notification for each district in question). For completeness we present all notifications for those 12 cards.

SOTS Office follow up is in progress for several of these memory cards.

Card Name	Election Sequence		
	Action	Date	Time
CHESHIRE-DISTRICT_6-0003021	ZERO TOT REPORT	11/6/12	14:57
DANBURY-WARD_7-110-0005474	ZERO TOT REPORT	11/6/12	08:29
DANBURY-WARD_7-110-0005474	BAL COUNT END	11/6/12	21:19
DANBURY-WARD_7-138-0005473	ZERO TOT REPORT	11/6/12	15:52
DANBURY-WARD_7-138-0005473	BAL COUNT END	11/6/12	21:13
EASTON-DISTRICT_1-0004863	ZERO TOT REPORT	11/6/12	06:45
EASTON-DISTRICT_1-0004863	BAL COUNT END	11/6/12	22:52
FAIRFIELD-DISTRICT_1-0005287	ZERO TOT REPORT	11/6/12	05:48
FAIRFIELD-DISTRICT_1-0005287	BAL COUNT END	11/6/12	07:54
GLASTONBURY-DISTRICT_1-0005151	ZERO TOT REPORT	11/6/12	19:33
GLASTONBURY-DISTRICT_1-0005151	BAL COUNT END	11/6/12	20:23
GLASTONBURY-DISTRICT_1-0005152	ZERO TOT REPORT	11/6/12	20:31
GLASTONBURY-DISTRICT_1-0005152	BAL COUNT END	11/6/12	00:05
MILFORD-PRESIDENTIAL_ONLY-0003828	ZERO TOT REPORT	11/6/12	17:59
MILFORD-PRESIDENTIAL_ONLY-0003828	BAL COUNT END	11/6/12	21:02
NEW_MILFORD-DISTRICT_5-0001429	BAL COUNT END	11/6/12	19:07
NEW_MILFORD-DISTRICT_5-0001431	ZERO TOT REPORT	11/6/12	03:33
NEW_MILFORD-DISTRICT_5-0001431	BAL COUNT END	11/6/12	18:09
WATERFORD-DISTRICT_4-0001162	BAL COUNT END	11/6/12	18:58
WESTBROOK-DISTRICT_2-0002663	BAL COUNT END	11/6/12	19:04

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

Responding to the SOTS follow up, the towns provided the following information.

<sup>9</sup>Ibid.

<sup>10</sup>Ibid.

Cheshire had problems with the machines taking in cards so they just set up a new machines.

Danbury noticed a problem with the public counter and then could not feed the ender card through to get a count. So they just replaced the machine and refeed the ballots. They also had several problems with machines they just had serviced before the election.

Glastonbury had to shut down a machine because it would not feed ballots.

The remaining cards show minor deviations that fall into one of the following two categories: (a) It appears that the time on some AV-OS tabulators was off by one hour, possibly due to Daylight Saving Time (DST); (b) For some of the cards either the printing of the Zero Totals Report or the election closing time is slightly out of the expected time interval. For the former, most Zero Totals Report were printed prior to 06:00, and only in one case it was printed at 06:12. For the latter, in almost all of the cases the election was closed up to 4 minutes before 20:00 (8:00 PM). In some cases the election was closed after 20:15.

In one case, however, when the election was closed at 19:41 (FAIRFIELD-DISTRICT-3-0005290, for which Zero Totals Report was printed at 04:50). SOTS Office follow up is in progress for this memory card.

**Many Instances of Events.** 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 event 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 No.	Suggested Max.	Description
SESSION START	$\geq 3$	30	Tabulator is turned on (e.g., 3 times: for initialization, testing, and election)
POWER FAIL	0	10	Tabulator switches to backup battery as the result of a main power failure
AUDIT REPORT	0	5	Audit report is printed
COUNT RESTARTED	0	0	Tabulator is restarted while in election mode and counting is resumed
MEMORY CARD RESET	0	0	The card is reset to a pre-election state following/during an election
DUPLICATE	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) **15 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.

We manually examined the event logs of all duplicated cards and compared the initialization date of the card to the date of the duplication. We observed that all cards submitted for post-election audit have an invalid initialization date (recall that this invalid date is 00/00/127). As a result

Flagged Number of Instances	Cards Used in the Election			
	# Warn.	% Warn.	# Cards	% Usable
DUPLICATE (none allowed)	15	2.7%	15	8.6%
MEMORY CARD RESET (none allowed)	3	0.5%	3	1.7%
COUNT RESTARTED (none allowed)	8	1.5%	6	3.4%

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

we could not establish whether the cards were involved in duplication at LHS or at the districts. It is extremely important that both LHS and the districts set the AV-OS date/time correctly.

- (b) **3 cards contain event “MEMORY CARD RESET”**: This event indicates that the cards were prepared for election and then were reset to a pre-election state. These cards appear in Table 9.

Card Name	Observed
SUFFIELD-DISTRICT_1-0001601	1
SUFFIELD-DISTRICT_1-0002559	1
THOMASTON-DISTRICT_1-0004668	1

Table 9: Cards involved in memory card reset.

Examining the event log of SUFFIELD-DISTRICT\_1-0001601 card we find that the reset was recorded on 10/18/12. The card was then tested again on 10/23/12 and prepared for election.

For SUFFIELD-DISTRICT\_1-0002559 card we find that the card was tested and prepared for election on 10/18/12. It was then reset on 10/23/12, and subsequently tested and prepared for election on the same day.

For THOMASTON-DISTRICT\_1-0004668 card we find that the card was tested, prepared for election, and subsequently reset on 10/22/12. After resetting the card was subsequently tested and prepared for election on the same day.

Since in all three cases the memory card reset event appears prior to the election, and each 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.

- (c) **6 cards contain event “COUNT RESTARTED”**: This event is recorded when the tabulator is restarted while in election mode and the ballot counting is started. These cards appear in Table 10

Card Name	Observed
FAIRFIELD-DISTRICT_1-0005287	1
LITCHFIELD-DISTRICT_1-0001978	1
MILFORD-DISTRICT_018-0003826	2
NORTH_HAVEN-DISTRICT_2-0005999	1
SOUTHINGTON-DISTRICT_1-0002768	1
THOMASTON-DISTRICT_1-0004669	2

Table 10: Cards involved in count restart.

We manually examined the audit logs of all those cards and our findings are as follows.

FAIRFIELD-DISTRICT\_1-0005287 shows that the Zero Totals Report was printed at 05:48, then a Power Fail event is reported, after which the tabulator is restarted. As a result, the event log contains a Count Restarted event. Note that a few minutes after this the election was closed and the Totals Report was printed at 07:58. The card was not subsequently used.

SOTS Office follow up is in progress for this card.

LITCHFIELD-DISTRICT\_1-0001978 shows that the machine was restarted at 08:48, which resulted in the Count Restarted event to be reported in the event log. The election proceeded normally following this event and it was closed at 20:58.

MILFORD-DISTRICT\_018-0003826 shows two Count Restarted events in the log within a few minutes from each other. The machine was first restarted at 09:11, followed by a power fail at 09:13. After 5 minutes the machine was restarted again and at 09:18 the second Count Restarted event is recorded. The election proceeded normally after this and was closed at 20:08.

NORTH\_HAVEN-DISTRICT\_2-0005999 shows that the machine was restarted at 14:43, which resulted in the Count Restarted event to be reported in the event log. The election proceeded normally following this event and it was closed at 20:07.

SOUTHINGTON-DISTRICT\_1-0002768 shows that the machine was restarted at 09:04, which resulted in the Count Restarted event to be reported in the event log. The election proceeded normally following this event and it was closed at 21:13.

THOMASTON-DISTRICT\_1-0004669 shows that the machine was restarted twice: at 15:58 and at 19:45, which resulted in the Count Restarted events to be correspondingly reported in the event log. The election was closed at 20:09.

Restarting count does not interfere with the tabulation process, however it is important that the election officials record the reasons for restarting counting and bring to the attention of the SOTS Office any reliability issues.

**Miscellaneous Notifications.** Miscellaneous notifications are caused either by unexpected events appearing in some event log sequences, or when an event occurred beyond the scope of rules covered by the current audit log analysis. In the latter case additional events appear in the log, after all the rules are satisfied. Table 11 presents the frequency of such notifications and the cards for which the notifications were issued are listed in Table 12.

Sequence Inconsistencies	Cards Used in the Election			
	# Warn.	% Warn.	# Cards	% Usable
Action Missing	22	4.0%	9	5.2%
Action Exceeded Rules' Scope	6	1.1%	1	0.6%
Action Beyond Rules' End	1	0.2%	1	0.6%

Table 11: Post-Election Event Log Analysis Results - Sequence Inconsistencies

The (manual) examination of the event log did not reveal security issues. However we note the following deviation from the election procedures.

- For FAIRFIELD-DISTRICT\_1-0005287, LITCHFIELD-DISTRICT\_1-0001978, MILFORD-DISTRICT\_018-0003826, NORTH\_HAVEN-DISTRICT\_2-0005999, SOUTHINGTON-DISTRICT\_1-0002768 and THOMASTON-DISTRICT\_1-0004669 the tabulator was restarted during the election. As a result the BAL COUNT

Card Name	No. of Notifications
FAIRFIELD-DISTRICT_1-0005287	1
GLASTONBURY-ABSENTEES-0002752	1
LITCHFIELD-DISTRICT_1-0001978	1
MILFORD-DISTRICT_018-0003826	1
NAUGATUCK-DISTRICT_2-1-0003475	1
NORTH_HAVEN-DISTRICT_2-0005999	1
SOUTHINGTON-DISTRICT_1-0002768	1
SUFFIELD-DISTRICT_1-0001601	6
SUFFIELD-DISTRICT_1-0002559	6
THOMASTON-DISTRICT_1-0004668	8
THOMASTON-DISTRICT_1-0004669	2

Table 12: Cards involved in sequence inconsistencies.

START event is reported in the log when the ENDER CARD event is expected. For THOMASTON-DISTRICT\_1-0004669 the machine was restarted twice. This was discussed in more detail earlier in the report.

- For GLASTONBURY-ABSENTEES-0002752 the ENDER CARD was cast prior running a test election, which resulted in sequence inconsistencies.
- For NAUGATUCK-DISTRICT\_2-1-0003475 the TOTALS REPORT event was reported twice in the log. However, this appears to be the result of a known AV-OS firmware bug.
- For SUFFIELD-DISTRICT\_1-0001601, SUFFIELD-DISTRICT\_1-0002559 and THOMASTON-DISTRICT\_1-0004668 after preparing the cards for election they were reset and a test election was run on those cards when the election sequence was expected according to our current audit log analysis. MEM CARD RESET event was discussed in more detail in clause (b) above.

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

The VoTeR Center received 578 cards for the post-election audit. This number includes 174 cards used in the election, with the analysis results presented in the previous section. Here we present the audit results for the remaining 404 cards. A high level breakdown of the cards not used in the election is as follows.

- 404 cards were not used in the election.
- 201 cards were correct (this includes 24 cards that were involved in duplication)
  - 157 cards were set to be used in the elections
  - 44 cards were not set to be used in the elections
- 203 cards were unusable (by AV-OS)
  - 192 cards contained apparently random data (‘junk’ data)
  - 7 cards were unusable (but the data was not random)
  - 4 cards were not programmed (formatted, but blank)

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

Table 13 shows the frequency of various states observed on the 404 audited memory cards not used in the election.

Cards (404) Not Used in the Election		
(a) Card Format	Number	% Total
Correct Cards	201	49.8%
Unusable (Junk) Data	192	47.5%
Unusable (not Junk)	7	1.7%
Unusable (Not Programmed)	4	1.0%
Totals:	404	100%

Table 13: Memory card analysis summary: (a) Card Format.

**(a) Card Format:** Among the 404 cards not used in the election, 201 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 201 cards, 177 cards (43.8%) were programmed directly using GEMS and contained data matching the baseline; these cards involved no duplication. 24 cards (6.0%) were involved in duplication, otherwise they contained correct data, matching the baseline.

There are 2 cards that contain byte differences between the baseline and the data on the memory card. Manual examination showed that the difference is in the race area of the card. Both cards pertain to the town of Wethersfield, and it appears that the label of the race “REP. IN CONGRESS” was updated to include a space after “REP.”. This also caused a shift by one byte, resulting in other differences. It is plausible that some of the cards for Wethersfield were programmed prior to the change in the race label, while the rest were programmed following the change. As a result, not all cards from Wethersfield contain these differences. We identified the date on which the change was made, apparently by LHS (October 10, 2012), however since all cards have a wrong initialization date (recall that it is 00/00/127), it is impossible to conclude with certainty whether or not the cards with byte differences were programmed prior the change.

203 cards (50.2%) 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. 192 cards (47.5%) contained apparently random (‘junk’) data and are readily detected through pre-election testing by poll workers, thus they could not have been used in the election. 7 cards (1.7%) were unusable by the AV-OS. Similar to ‘junk’ cards they are readily detected through pre-election testing by poll workers, however these cards did not contain random data and these cards have been retained for a follow up evaluation. 4 cards (1.0%) were not programmed. Such cards contain no data about the election, and this is not an intended state of the card. It is possible that these cards were (inadvertently) reformatted after testing; else they may have arrived not programmed.

**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 6.7% and 17.7%. This estimate is made on the basis of the following calculation. We received cards from 286 districts out of the total 754 districts that participated in this election (this includes absentees), where there are four cards per district. The number of unusable cards in the audit is 203. Thus the minimum percentage is calculated as

$203/(754 \cdot 4) = 6.7\%$ , given that unusable card data does not contain district information. Performing similar calculation for the 286 participating districts, we obtain the maximum percentage as  $203/(286 \cdot 4) = 17.7\%$ . 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 201 cards (among the 578 audited cards) that were usable for the elections.

<b>Usable Cards (201) Not Used in the Election</b>		
	Number	% Total
<b>(b) Card Status Summary</b>		
Set for Election	157	78.1%
Not Set for Election	44	21.9%
Totals:	201	100%
<b>(c) Card &amp; Counter Status</b>		
Set For Elections, Zero Counters	146	72.6%
Set For Elections, Non-Zero Counters	11	5.5%
Not Set, Non-Zero Counters	42	20.9%
Not Set, Zero Counters	2	1.0%
Totals:	201	100%
<b>(d) Card Duplication (24)</b>		
Master Card	22	10.9%
Copy Card	2	1.0%
Totals:	24	100%

Table 14: 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.

**(b) 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.

157 cards (78.1%) were in Set For Election state. This is the appropriate status for cards intended to be used in the elections.

44 cards (21.9%) 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.

**(c) 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.

11 cards (5.5%) were found in Set For Election state and had Non Zero Counters. This is not the appropriate status. Manual examination of the event log of these cards showed that 10 out of 11 cards were used on the Election Day (November 6, 2012) and record that anywhere between 3 and 3720 ballots were cast. These cards necessitated a follow up from the SOTS Office. Below we provide more details for the cards in question.

- For ANSONIA-DISTRICT\_6-0001638 the machine was restarted at 10:56 and the last event recorded in the log is BAL COUNT START at 10:59. There were 326 ballots cast.  
SOTS Office follow up is in progress for this card.
- For BURLINGTON-DISTRICT\_5-0001592 the last event recorded in the log is POWER FAIL at 08:00. There are 158 ballots cast. Responding to the SOTS Office followup, Burlington explained that they could not feed the ender card into the machine and just replaced the machine and card. After which they refeed the ballots into the new machine.
- For CHESHIRE-ABSENTEES-0005045 the last event recorded in the log is BAL COUNT START at 15:34. Note that ZERO TOT REPORT was recorded at 14:26. There were 178 ballots cast.  
For CHESHIRE-DISTRICT\_4-0003015 the last event recorded in the event log is POWER FAIL at 09:44. There were 905 ballots cast.  
Responding to the SOTS Office followup, Cheshire reported that they had problems with the machines taking in cards so they just set up a new machines.
- For DANBURY-WARD\_2-138-0003524 the last event recorded in the event log is BAL COUNT START at 07:05. There were 18 ballots cast.  
For DANBURY-WARD\_7-110-0005476 the last event recorded in the event log is COUNT RESTARTED at 08:34. It was proceeded by two power failures and machine restarts. There were 3 ballots cast.  
For DANBURY-WARD\_7-138-0005470 the last event recorded in the event log is POWER FAIL at 09:42. There were 690 ballots cast.  
For DANBURY-WARD\_7-138-0005472 the last event recorded in the event log is POWER FAIL at 15:44. Note that this card pertains to the same district as the one above. The event log shows that ZERO TOT REPORT was recorded at 10:41, which is after the power failure event occurred for DANBURY-WARD\_7-138-0005470. There were 1882 ballots cast.  
Responding to the SOTS Office followup, Danbury reported the following. They noticed a problem with the public counter and then could not feed the ender card through to get a count. So they just replaced the machine and refeed the ballots. They also had several problems with machines they just had serviced before the election.
- For GLASTONBURY-DISTRICT\_1-000575 the last event recorded in the event log is POWER FAIL at 19:17. There were 3720 ballots cast.  
For GLASTONBURY-DISTRICT\_5-0002730 the last event recorded in the event log is BAL COUNT START at 05:55. There were 2595 ballots cast.  
Responding to the SOTS Office followup, Glastonbury reported that they had to shut down a machine because it wouldn't feed ballots.
- For the remaining one card (NEW\_BRITAIN-DISTRICT\_10-0003708) an election was run on 10/18/10 according to the event log. It is obvious that the date/time of the AV-OS tabulator was not set correctly. The last event recorded in the log is COUNT RESTARTED. There was only one ballot cast. Responding to the SOTS Office followup, New Britain reported that their machine was able to take only one ballot and then failed.

146 cards (72.6%) 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.

42 cards (20.9%) were 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.

2 cards (1.0%) were found to be in Not Set for Elections state with Zero Counters. This is similar to the 42 cards above. This situation would have been similarly detected and remedied if such cards were to be used on the election day. Manual examination of the event log of these cards showed that two test elections were run on both cards. However, the dates of the testing suggest that both cards were most likely tested at LHS rather than at the district.

Taking the above percentages together, it appears that almost all districts (5.5%+ 72.6%+ 20.9% = 99%) performed pre-election testing before submitting the cards for the audit.

**(d) Card Duplication:** The only authorized source of the card programming in Connecticut is the external contractor, LHS Associates. The cards are programmed using the GEMS system. Cards duplications are 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, and it masks the problem with card reliability. Additionally, it is impossible to determine with certainty who and why resorted to card duplication. Lastly, if the data on the card being duplicated is erroneous, the same error will be reproduced on the copy.

Among the usable cards not used in the election 24 cards were involved in duplication. 22 out of 24 cards are *master* cards used for duplication. 2 cards are *copy* cards produced by duplication.

We manually examined the event logs of all duplicated cards and compared the initialization date of the card against the date of the duplication. We observed that these cards (as well as all other usable cards) submitted for post-election audit have an invalid initialization date (recall that this date is 00/00/127). Thus we could not establish whether the cards were involved in duplication at LHS or at the districts. It is extremely important that both LHS and the districts set the AV-OS date/time correctly (as indicated earlier, SOTS Office has already contacted LHS regarding this).

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.

### 4.3.3 Event Log Analysis: 201 Cards Not Used in the Election

Here we present the result of the event log analysis for the usable cards that were not used in the election. All 201 cards (100%) were flagged because their event logs did not match our sequence rules. The main reason that all cards were flagged is that the initialization date is wrong (this was discussed earlier).

The event log analysis for the cards not used in the election produced 384 notifications. Recall that not all notifications mean that something went wrong — a notification simply means that the sequence of events in the event log did not match our (not-all-inclusive) rules, also note that a single card may yield multiple notifications. Such notifications are subsequently examined to determine their significance. We next present the details of the analysis.

**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 15.

Out-of-Bounds Dates	Cards Not Used in the Election			
	# Warn.	% Warn.	# Cards	% Usable
Sequence: Initialization	201	52.3%	201	100%
Sequence: Test Election	62	16.1%	62	30.8%
Sequence: Prepare For Election	58	15.1%	58	28.9%
Sequence: Election	16	4.2%	13	6.5%

Table 15: Post-Election event log Analysis Results - Out-of-Bounds Dates

(a) **Initialization: 201 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 09/06/2012 and 10/23/2012. Our assumptions for the sequencing of events are based on the SOTS documentation <sup>11</sup>.

The initialization date of all correct cards fell outside of the assumed period. This is apparently due to the fact that the AV-OS machine used for initializing these cards at LHS does not have its date/time set correctly. Instead, the date of initialization appears as 00/00/127 in the event log of all correct cards. We reiterate that it is important that all AV-OS tabulators have the date/time set correctly.

(Given the large number of cards involved we do not list them here individually.)

(b) **Test Elections: 62 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 expect Test Elections to be performed two weeks after the beginning of card Initialization and ten days before the election day <sup>12</sup>. For this election we expect this process to be completed between the dates 09/13/2012 and 10/28/2012.

Table 16 lists only the districts that show unexpected test dates due to AV-OS tabulator's incorrect date/time and the cards that were tested on the election day. The rest of the cards were tested at least two days prior to the election day.

Manual examination of the audit log of this cards show the following:

BLOOMFIELD-DISTRICT\_1-0001539 was tested at LHS just after it was initialized. And we already discussed the incorrect date/time of the machine used for initialization at LHS.

DANBURY-WARD\_7-138-0005472 was tested and prepared for election on the Election Day. Subsequently there was an attempt to use the card in the election. This card was discussed earlier in the report.

<sup>11</sup> 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](http://www.ct.gov/sots/lib/sots/legislativeservices/regulations/12_opscanusereg.pdf).

<sup>12</sup>Ibid.

Card Name	Test Election	
	Date	Time
BLOOMFIELD-DISTRICT_1-0001539	00/00/127	31:63
DANBURY-WARD_7-138-0005472	11/6/12	09:56
EAST_HARTFORD-DISTRICT_4-0003440	11/6/12	05:16
LITCHFIELD-DISTRICT_4-0001993	11/6/12	05:46
NEW_BRITAIN-DISTRICT_10-0003708	10/18/10	19:12

Table 16: Test Election dates outside of the assumed time window.

EAST\_HARTFORD-DISTRICT\_4-0003440 card shows that on the election day ZERO TOT REPORT was printed at 06:02 on 11/6/12 and BAL TEST START event was recorded. It is plausible that the election officials assumed that the card was prepared for election, but did not use it upon discovering that it is not prepared for election on the Election Day.

SOTS Office follow up is in progress for this card.

LITCHFIELD-DISTRICT\_4-0001993 card shows that TOTALS REPORT was printed on the Election Day at 05:46. The card was subsequently prepared for election and the last event recorded in the log is POWER FAIL at 07:36.

SOTS Office follow up is in progress for this card.

NEW\_BRITAIN-DISTRICT\_10-0003708 card was used on the AV-OS machine with incorrect date/time set, most likely at the district.

(c) **Preparation for Election: 58 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 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 17 lists only districts that show preparation for elections on the Election Day (these cards were already discussed earlier). The rest of the cards were prepared at least two days prior to the election day and should not be a cause for concern. However, according to the SOTS regulations<sup>13</sup> the cards should have been prepared for election no later than the tenth day before the election.

Card Name	Prepare for Election	
	Date	Time
DANBURY-WARD_7-138-0005472	11/6/12	10:02
LITCHFIELD-DISTRICT_4-0001993	11/6/12	05:48

Table 17: Prepare for Election dates outside of the assumed time window.

Both cards were already discussed in paragraph (b) above.

(d) **Election: 13 cards appeared to have a deviation from the expected sequence.**

We do not expect to see a card with an event that pertains to the Election Sequence for cards not used in the election. Only a test election should be run on a card prior to the election. This is a deviation from the procedures set by the SOTS Office. We note that 7 out of 13 cards were apparently used on the Election Day (or at least there was an attempt to use them). However, per our definition we consider the card as “Used in Election” only if the card appears

<sup>13</sup>Ibid.

in “Election Closed” or “Results Print Aborted” state and has non-zero counters. Earlier we already discussed all cards that were used on the election day but the election was not closed. Follow up by the SOTS Office will need to determine the cause of these irregularities.

For 5 cards out of the remaining 6 the Zero Totals Report was printed prior to the Election Day since the machine was restarted after the cards were prepared for election. This is not a security concern since for a card prepared for election Zero Totals Report is printed every time the machine is turned on. As a result, if the cards were used in the election the Zero Totals Report would have been printed on the election day.

The remaining card, NEW\_BRITAIN-DISTRICT\_10-0003708, has one ballot cast. Hence, if the card was used on the Election Day no Zero Totals report would have been printed and the memory card should have been reset. This is a concern because this card was not ready for running an election on the Election Day, more importantly, if it was used as is on the Election Day it would have resulted in an erroneous totals. This problem, however, would have been detected on the Election day because the Zero Totals report must be printed, signed, and preserved by the election officials. The SOTS followup in this case was reported earlier.

**Many Instances of Events.** 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 event 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 18.

Flagged Number of Instances	Cards Not Used in the Election			
	# Warn.	% Warn.	# Cards	% Usable
DUPLICATE (none allowed)	24	6.3%	24	11.9%
COUNT RESTARTED (none allowed)	8	2.1%	4	2.0%

Table 18: Post-Election Event log Analysis Results - Many Instances of Events

- (a) **24 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. We already discussed card duplication in Section 4.3.2.
- (b) **4 card contained event “COUNT RESTARTED”:** This event is recorded when the tabulator is restarted while in election mode and the ballot counting has started. The cards appear in Table 19.

Card Name	Observed
ANSONIA-DISTRICT.6-0001638	1
DANBURY-WARD_7-110-0005476	2
DANBURY-WARD_7-138-0005472	3
NEW_BRITAIN-DISTRICT_10-0003708	2

Table 19: Cards involved in count restart.

**Miscellaneous Notifications.** Notifications were issued for 8 cards that were caused either by unexpected events appearing in some event log sequences. The following cards contained such notifications:

Card Name	No. of Warnings
ANSONIA-DISTRICT_6-0001638	1
BLOOMFIELD-DISTRICT_2-0001544	7
CHESHIRE-ABSENTEES-0005045	1
DANBURY-WARD_7-138-0005472	2
GLASTONBURY-DISTRICT_5-0002730	1
MIDDLETOWN-DISTRICT_3-0003942	1
MIDDLETOWN-DISTRICT_7-0003958	1
NEW_BRITAIN-DISTRICT_10-0003708	1

Closer examination of the event logs on these cards show the following:

- For ANSONIA-DISTRICT\_6-0001638, CHESHIRE-ABSENTEES-0005045, DANBURY-WARD\_7-138-0005472 and NEW\_BRITAIN-DISTRICT\_10-0003708 BAL COUNT START event appears twice in Election sequence when ender card is expected. This was caused by the tabulator being restarted while in election mode. If the reason for this was some problem with the tabulator, the election officials should inform the SOTS Office.
- For BLOOMFIELD-DISTRICT\_2-0001544 DOWNLOAD END event is not recorded in the event log. This is a one-of-kind situation that probably occurred at LHS; otherwise the data on the card is correct.
- For GLASTONBURY-DISTRICT\_5-0002730, MIDDLETOWN-DISTRICT\_3-0003942 and MIDDLETOWN-DISTRICT\_7-0003958 the COM ERROR event was reported. This event indicates a communication error with an external system. This will be recorded in the audit log if one tries to program a memory card through direct mode from GEMS, and either a communication error occurs or the AV-OS tabulator is not connected to an external system. Also, the duplication event appears right after COM ERROR event for all three cards, suggesting that after direct mode failed, duplication was performed. Manual examination of the audit log of these cards suggests that the duplication was most likely done at LHS.

## 5 Addressing Memory Card Reliability

We estimated the overall percentage of the cards that are not usable in the election to be between 6.7% and 17.7%. 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, consistent with prior observations<sup>14</sup>, is 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.

<sup>14</sup> 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>.

New non-volatile (battery-less) memory card was recently developed by the vendor. Our preliminary analysis of this card confirmed that it is software-compatible with AV-OS systems deployed in Connecticut. However only a small sample of cards was available for testing.

A pilot deployment of the new cards in April, 2012 was done in the Town of Vernon using 12 of the new cards. The cards performed well, no failures were detected, and no such cards lost their data.

The Town of Wilton encountered problems using the new cards in preparation for the November 2012 elections. We have examined these cards as well as the tabulators used in Wilton and determined that the dimensions of the new cards are not 100% compatible with the original cards <sup>15</sup>, causing poor electrical contact with the J-40 connector in the tabulator; additionally the connector had at least one pin that was slightly bent. These issues were reported to the vendor and LHS.

## 6 Conclusions and Recommendations

We note that adherence to the established pre-election testing procedures has improved at the districts compared to prior years, particularly in preparation for elections. Overall the audits did not detect any cards whose data raised concerns about the integrity of tabulation. We make the following concluding remarks and recommendations.

- For this audit we received 578 cards (prior to March 15, 2013). This is the largest number of cards submitted since 2008. This is a substantial improvement. When a sufficiently large collection of cards is audited, the results meaningfully represent the overall State landscape and help identify technological and procedural problems that need to be solved.
- The SOTS Office should continue publicizing proper procedures and continue offering training. In particular, the Office should reinforce the need to prepare all cards for election prior to the election day and prior to the pre-election audit.
- There is a slight increase in the number of cards being duplicated. However, because of the incorrect time setting at LHS it is not possible to state with certainty whether the duplication occurs at LHS or at the districts. Any cases of duplication should be recorded in the moderators' logs and be brought to the attention of the SOTS Office with a documented explanation of why this is necessary.
- It is important for the districts to report any problems during pre-election testing (and any card problems) to the SOTS Office as soon as possible upon completion of the tests.
- 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 case of tabulator malfunction it is strongly recommended that the problematic tabulator is tested by the Center personnel (either at the district or in our laboratory).
- 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 in Connecticut. The use

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<sup>15</sup>Engineering Notes: Follow up on the problem encountered in the Town of Wilton using new non-volatile memory cards, Version 1.0, the University of Connecticut Center for Voting Technology Research, February 9, 2013.

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.

- The districts are encouraged to submit all malfunctioning cards to 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.)
- Lastly, it is important that the date and time of the AV-OS tabulators are set up correctly at LHS and at the districts. If this is not done correctly, the appearance may be created that the cards were not used consistently with the proper conduct of an election. The SOTS Office is addressing this issue with LHS.

This is a preliminary report. As of this writing, memory cards are continuing to arrive for the audit. The final report will be issued once the cards are analyzed and the SOTS follow up that is currently in progress concludes.

[End]