



## Pre-Election Audit of Memory Cards for the August 10, 2010 Primary Elections

October 26, 2010, Version 1.1

### Summary

The University of Connecticut Center for Voting Technology Research (VoTeR Center) performed a pre-election audit of the memory cards for the Accu-Vote Optical Scan tabulators that were to be used in the August 10, 2010 elections. The cards were programmed by LHS Associates of Methuen, Massachusetts, and shipped to Connecticut districts for use in the elections. The VoTeR Center received in total 226 memory cards from 218 districts for this audit. The cards were received during the period from August 6, 2010 to August 17, 2010. This document reports on the findings obtained during the audit.

Among these 226 cards, 192 (85%) were correctly programmed for elections. These cards contained valid ballot data and the executable code on these cards was the expected code, with no extraneous data or code on the cards. Concerning the remaining cards, 34 (15% of the total number of cards) were found to be unusable by the AV-OS. In particular, these cards contained ‘junk’ (i.e., apparently random) data. These cards were unreadable, according to the tabulators and could not have been used in an election. (We report on the causes of such card failures separately.)

Among the usable cards, 16 (7% of the total number of cards) were involved in card duplication; this is not permitted according to the SOTS rules. There are 45 cards that, although not presenting an immediate security concern, had audit log entries showing unexpected procedural event sequences. We note that the adherence to the election procedures by the districts is improving, however the analysis indicates that the established procedures are not always followed; it would be helpful if reasons for these extra-procedural 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.

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## 1 Preface

The University of Connecticut Center for Voting Technology Research (VoTeR Center) conducted a pre-election audit of the memory cards used in the Accu-Vote Optical Scan (AV-OS) tabulators in the August 10, 2010 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 Methuen, Massachusetts, and provided by LHS to the districts in Connecticut. The audit was performed on a set of memory cards that were delivered to the VoTeR Center from the towns, where the cards should have been randomly chosen for pre-election testing. The cards are tested as they arrive. The majority of the pre-election cards arrived at the Center during August, 2010. If noteworthy irregularities that might affect integrity or security are detected, they are reported to the SOTS office without delay.

The memory cards were subject to several integrity tests. A comprehensive overview of the procedures followed by the VoTeR Center personnel in conducting such audits is presented in prior reports<sup>1</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.

In this report, we present the objectives of the pre-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 electro-magnetic) of the memory cards.

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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>. 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>.

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

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.

## 2 Introduction

We start by surveying the AV-OS based election system used in Connecticut, the goals of the pre-election memory card audit, and a preview of the audit results.

### 2.1 Brief Description of the AV-OS

The AV-OS election system consists of two components: the Accu-Vote Optical Scan voting terminal (AV-OS terminal) and the ballot design and central tabulation system, GEMS, for Global Election Management System. See our report at URL <http://voter.engr.uconn.edu/voter/Report-OS.html> for details on this election 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.
- 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. In the State of Connecticut, GEMS is not used for central tabulation of election results.
- The memory cards are 40-pin, nominally 128KB cards. The memory card is installed into the 40-pin card slot of the AV-OS. It is worth mentioning that recent (summer 2009) instances of this card were manufactured by Smart Modular Technologies for Premier Election Systems, Inc., and that commercial-off-the-shelf readers and writers for this card have not been found.

For election deployment the system is secured within a ballot box so that no sensitive controls or connectors are exposed to the voter. Each memory card contains executable code that is used for printing the reports. The code, called *bytecode*, is written in a proprietary symbolic language. Such executable files are identified by means of the suffix *.abo* (AccuBasic Object). The installation of the GEMS software on the PC contains several databases that include the data and ballot layout corresponding to each district, as well as the bytecode for AV-OS.

### 2.2 Goals of the Pre-Election Memory Card Audit

The VoTeR Center prepares for and implements memory card audits at the request of the SOTS. The primary goals of the pre-election audit is to perform integrity checks on the contents of the memory cards and to obtain quantitative measures of the integrity of the contents of the memory cards.

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 GEMS database to be used as the baseline for the election data was provided by LHS Associates prior to the election.

For the pre-election the VoTeR Center examined 226 cards. These cards correspond to 218 distinct districts in Connecticut. These memory cards were delivered to the Center by the towns, where the cards should be randomly chosen for pre-election testing.

The contents of the cards were then extracted and compared with the intended contents using the GEMS database as the reference; this portion of the audit process is semi-automated. Any discrepancies or deviations from the baseline were then logged and analyzed. Specifically, the memory cards were audited for any deviations in the ballot data/layout, any deviations in the bytecode, the state of the counters and the content of the audit logs. These audit logs contain significant events in the life of a card since the last time it was formatted.

## 2.3 Overview of the Audit Results

We now highlight certain audit results for the 226 cards that were received and analyzed by the VoTeR Center. A more detailed survey in the next section.

For the purpose of this audit we consider a card to be *usable* when 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 usable cards were involved in card duplication, and we group them with the rest of usable cards, but we note the number of cards that were involved in duplication.

### 2.3.1 Usable for Election

Among the 226 cards received, 192 (85%) were found to have been usable for election. Usable cards are those containing correct election data. This category includes both 176 (78%) cards programmed according to the correct procedure, and also the 16 (7%) 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.

### 2.3.2 Unusable Cards

The audit identified thirty four (34) cards, 15%, that were unreadable by the tabulators. This failure percentage is disappointingly high and is consistent with that of recent elections, as shown in more detail later in this report.

We have determined that weak batteries are the primary cause of the unreadability of cards by the tabulator. As described in more detail in a separate report<sup>2</sup>, steps that maintain card data without reliance on the battery warning indication are recommended. We recommended that the batteries in the cards are replaced before each election. The state has followed this recommendation and is replacing all batteries for the November 2nd, 2010 election. The results for the upcoming election will be analyzed and we anticipate that this issue will be substantially resolved.

## 3 Audit Results

We now present the results of the pre-election audit in more detail. For the August 10, 2010 elections we received and examined 226 cards. These cards were programmed by LHS, (and reprogrammed, in

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<sup>2</sup>“Determining the Causes of AccuVote Optical Scan Voting Terminal Memory Card Failures”, 2010 Electronic Voting Technology Workshop/Workshop on Trustworthy Elections, EVT/WOTE’10, Washington, DC, August 2010, <[www.usenix.org/event/evtwote10/](http://www.usenix.org/event/evtwote10/)>.

the case of those cards that were the result of duplication). The cards were shipped by the districts to the VoTeR Center for the purposes of the pre-election audit. The high level breakdown of the received cards is as follows:

- 226 were received for the pre-election audit
- 192 (85%) were usable, correctly programmed for elections
- 118 were set to be used in the elections
- 68 were not set to be used in the elections
- 34 cards were unreadable, that is, they contained no valid data, but apparently random data
- 16 cards were prepared by duplication

### 3.1 Card State Analysis

Table 1 shows the frequency of various states observed on the 226 audited memory cards, and for the 192 usable cards. The data is presented in three parts, dealing with: (a) card format ad data, (b) election status data, and (c) counter contents.

	Number	% Total
<b>(a) Card Format (All Cards - 226)</b>		
Good Data, Clean Card	176	78%
Good Data, Duplicated Card	16	7%
Unusable (Junk) Data	34	15%
Totals:	226	100%
<b>(b) Card Status (Usable Cards - 192)</b>		
Not Set for Election	68	36%
Set for Election	118	61%
Election Closed	5	2%
Results Print Aborted	1	0.4%
Totals:	192	100%
<b>(c) Card &amp; Counter Status (Usable Cards - 192)</b>		
Set For Elections, Zero Counters	118	61%
Election Closed, Non-Zero Counters	5	2%
Results Print Aborted, Zero Counters	1	0%
Not Set, Non-Zero Counters	57	30%
Not Set, Zero Counters	11	6%
Totals:	192	100%

Table 1: Memory card analysis summary: (a) Card Format, (b) Card Status, and (c) Card Record of Electoral Procedure.

- (a) **Card Format:** Among the 226 audited cards, 192 cards contained data correct in format and content, and were usable for elections. (The remaining, unusable, cards contained junk data and were unreadable by the tabulators.)

176 cards (78%) were properly formatted and contained data matching the baseline. These involved no duplication.

16 cards (7%) were duplicated and contained data matching the baseline.

34 cards (15%) did not contain data that can be read by the tabulators. All these cards 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.

- (b) **Card Election Status:** 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.

118 cards (61%) were in Set For Election state. This is the appropriate status for cards intended to be used in the elections.

Five cards (2%) were in Election Closed status. This status would be appropriate at the end of an election, but not prior to an election. It is possible that instead of running a test election, poll workers ran an election to test the tabulator.

68 cards (36%) were in Not Set for Election state. This status would be appropriate prior to preparation for an election, but not prior to an election.

One card (0.4%) was found to be in the Results Print Aborted state. This state indicates that actual elections ran during the pre-election procedures; it is an inappropriate status for the pre-election timeframe.

- (c) **Card & 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.

All of the 118 cards (61%) were that were found in Set For Election state had Zero Counters. This is the appropriate status for cards intended to be used in the elections.

Five cards (2%) were in Election Closed status and had Non-Zero counters. This indicates that instead running a test election and preparing cards for election, poll workers tested the tabulators by running an election (using test ballots) and left the card in that state. This situation would be have been detected if such cards were to be used on the election day. The same applies to one card that was found to be in Results Print Aborted state.

57 cards (30%) were in Not Set for Election state and had Non-Zero Counters. This is not an expected state prior to an election. 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.

11 cards (6%) were found to be in Not Set for Elections state with Zero Counters. This is similar to the 57 cards above. This situation would have been similarly detected and remedied if such cards were to be used on the election day.

### 3.2 Audit Log Analysis Results

Here we present the result of the audit log analysis for all the usable cards.

AV-OS records on the memory card certain events that occur during the use of the tabulator. Table 2 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.

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 the insertion of 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 2: Audit log action types

The audit log analysis implemented by the VoTeR Center 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 is available online <sup>3</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 warning 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.

Out of the 192 usable<sup>4</sup> cards, 45 (24%) cards were flagged because their audit logs did not match our sequence rules.

The audit log analysis produced 156 warnings; they appear in Table 3. Note that a single card may yield multiple warnings. Also recall that not all warnings necessarily mean that something went wrong – a warning simply means that the sequence of events in the audit log did not match our (not-all-inclusive) rules. Below we detail the warnings.

<sup>3</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/).

<sup>4</sup>Usable cards are those that contain correct programming for the current election. Usable cards exclude those containing data unreadable by the tabulators, unprogrammed cards, and cards programmed for different elections.

	Cards Usable for the Election			
	# Warn.	% Warn.	# Cards	% Usable
<b>(a) Out-of-Bounds Dates</b>				
Sequence: Initialization	18	12%	18	9%
Sequence: Test Election	1	under 1%	1	under 1%
Sequence: Prepare For Election	1	under 1%	1	under 1%
<b>(b) Flagged Number of Instances</b>				
SESSION START (allowed 10)	5	3%	5	2.6%
DUPLICATE (none allowed)	16	10%	16	8%
MEMORY CARD RESET (none allowed)	3	2%	3	1.5%
<b>(c) Sequence Inconsistencies</b>				
Action Missing	2	1%	2	1%
Action Beyond Rules' End	110	70.5%	10	5%

Table 3: Audit Log Analysis Results - Cards Usable in the Election

### 3.2.1 Out-Of-Bounds Dates

This warning 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 Elections, and (c) Preparation for Elections.

#### (a) Initialization: 18 cards contained unexpected initialization 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 6/10/2010 and 7/28/2010. Several cards fell outside of our assumed initialization period, but all were initialized prior to Election Day, so this is not a security issue.

The cards that appeared to have initialization dates that differed from our assumption (sorted by district name) are given in Table 4 for completeness.

All listed cards show initialization prior to the election day; this is expected. Most of these cards were initialized more than a week prior to the elections. It is possible that some cards needed to be reinitialized and that some districts requested additional cards close to the election day. Given that our 2-week cut-off for initialization is arbitrary, these cards do not raise concerns.

#### (b) Test Elections: one card was 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 four days before the election day. For this election we expect this process to be completed between the dates 06/24/2010 and 08/06/2010. The following shows unexpected test date:

Card Name	Test Election Date
HARTFORD-DISTRICT_18-0005701	8/16/10 13:20

Card Name	Initialization Date
BETHEL-DISTRICT_5-0005278	8/2/10 07:33
BRISTOL-DISTRICT_77-1-0005290	8/2/10 14:11
BRISTOL-DISTRICT_78-2-0005291	8/2/10 14:12
DARIEN-DISTRICT_1-0003756	7/29/10 10:58
DARIEN-DISTRICT_2-0003777	7/29/10 10:58
DARIEN-DISTRICT_3-0005265	7/29/10 10:54
DARIEN-DISTRICT_4-0003765	7/29/10 10:59
DARIEN-DISTRICT_5-0005266	7/29/10 10:56
DARIEN-DISTRICT_6-0003770	7/29/10 11:00
ENFIELD-ABSENTEE-0001796	8/3/10 10:21
ESSEX-DISTRICT_1-0004474	8/2/10 10:20
GREENWICH-DISTRICT_1-0002471	8/2/10 12:24
GREENWICH-DISTRICT_6-0002483	8/2/10 12:24
GREENWICH-DISTRICT_7-0002501	8/2/10 12:25
GREENWICH-DISTRICT_9-0002503	8/2/10 12:26
NEWTOWN-DISTRICT_3-1-0005644	8/5/10 13:59
WESTON-DISTRICT_1-0002936	8/4/10 13:33
WINDSOR-DISTRICT_1-0002229	8/2/10 10:33

Table 4: Initialization dates outside of our assumed time window.

This card shows test date after the election date. The card was sent to the VoTeR Center as a pre-election card and it was received by on 8/20/2010. One possible explanation is that the clock on the tabulator was set incorrectly.

- (c) **Preparation for Election: one card was prepared for elections at unexpected times.** Elections should be prepared after the testing is completed but before the date of the actual election. 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. The following shows preparation for elections on unexpected dates.

Card Name	Preparation Date
BETHLEHEM-DISTRICT_1-0001138	8/7/10 9:10

The audit log for this card shows testing at least four days before the elections, but preparation for elections at a later date. As the preparation date is still prior to the election, this should not be a cause for concern.

### 3.2.2 Many Instances of Events

The automated log analysis sets certain bounds on the number of events that can occur. Some of these bounds are *ad hoc*, for example, the analysis flags any card whose audit log contains more than 10 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.

- (a) **5 cards contained more than 10 “SESSION START”:** This event is recorded in the audit log whenever a machine is turned-on. The cards that contained unexpected number of “SESSION START” events are:

Card Name	Number of Instances
BARKHAMSTED-REPUBLICAN_BALLOTS-0001145	Observed: 12 Expected: 10
FARMINGTON-DISTRICT_5,6-0005168	Observed: 14 Expected: 10
HAMPTON-DISTRICT_1-0003422	Observed: 11 Expected: 10
SOUTH_WINDSOR-ABSENTEE-0003853	Observed: 11 Expected: 10
TRUMBULL-DISTRICT_6-0002852	Observed: 12 Expected: 10

All of these cards contained fewer than 14 session starts (thus, they did not deviate significantly from our ad hoc threshold). Audit log examination showed that some tabulators were powered off and on multiple times in very close intervals (BARKHAMSTED-REPUBLICAN\_BALLOTS-0001145, SOUTH\_WINDSOR-ABSENTEE-0003853, TRUMBULL-DISTRICT\_6-0002852). This may have been a part of the testing. FARMINGTON-DISTRICT\_5,6-0005168 and HAMPTON-DISTRICT\_1-0003422 were turned on to run extra tests and elections.

Finally, TRUMBULL-DISTRICT\_6-0002852 was also turned on to perform card duplication.

While these numbers of such events do not present a concern, if a district experiences a difficulty that requires them to turn the tabulator on numerous times, then it is advisable that this is brought to the attention of the SOTS Office.

- (b) **16 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 are the following:

Card Name	Number of Instances
BRISTOL-DISTRICT_77-2-0003366	Observed: 1 Expected: 0
BRISTOL-DISTRICT_77-3-0003390	Observed: 1 Expected: 0
DARIEN-DISTRICT_1-0003756	Observed: 1 Expected: 0
DARIEN-DISTRICT_5-0005266	Observed: 1 Expected: 0
DURHAM-DEMOCRATIC_BALLOTS-0002391	Observed: 1 Expected: 0
HARTFORD-DISTRICT_14-0003208	Observed: 3 Expected: 0
HARTFORD-DISTRICT_15-0003212	Observed: 1 Expected: 0
HARTFORD-DISTRICT_21-0003235	Observed: 2 Expected: 0
HARTFORD-DISTRICT_22-0003239	Observed: 3 Expected: 0
HARTFORD-DISTRICT_5-0003170	Observed: 2 Expected: 0
HARTFORD-DISTRICT_6-0003176	Observed: 1 Expected: 0
NEWINGTON-DISTRICT_1-0002402	Observed: 1 Expected: 0
NEWTOWN-DISTRICT_1-0005660	Observed: 1 Expected: 0
SOUTH_WINDSOR-DISTRICT_4-0003845	Observed: 1 Expected: 0
TRUMBULL-DISTRICT_6-0002852	Observed: 3 Expected: 0
WALLINGFORD-DISTRICT_2-0001864	Observed: 1 Expected: 0

There should be no reason to duplicate the cards. One possibility is that duplication was performed when cards were reported unreadable by the tabulator. It is strongly recommended that duplication not be performed at districts and that all inadequately performing cards be reported to the SOTS Office as soon as they are discovered. In the event someone decides it is necessary to duplicate a card, that person should document the reason and circumstances and should ensure this information is supplied to the SOTS Office.

- (c) **3 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. This warning was reported for the following cards:

Card Name	Number of Instances
BRISTOL-DISTRICT_77-3-0003390	Observed: 1 Expected: 0
MONROE-DISTRICT_4-0004798	Observed: 1 Expected: 0
NEWTOWN-DISTRICT_1-0005660	Observed: 1 Expected: 0

Closer examination of the audit log of these cards revealed that the operators ran actual elections to test the machines, instead of using the built-in testing functionality. Since all memory reset instances were recorded before the election date, none of these raise concerns.

### 3.2.3 Miscellaneous Warnings

Here we report the warnings issued for 12 cards that were caused by unexpected events appearing in some audit 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. The following cards contained such warnings:

Card Name	Number of Warnings
BRANFORD-ABSENTEES-0002304	Observed: 1
BRISTOL-DISTRICT_77-2-0003366	Observed: 1
BRISTOL-DISTRICT_77-3-0003390	Observed: 12
CANTON-DISTRICT_1-0002561	Observed: 6
FARMINGTON-DISTRICT_5,6-0005168	Observed: 6
LEDYARD-DISTRICT_1-0002015	Observed: 8
LISBON-DISTRICT_1-0004785	Observed: 1
MONROE-DISTRICT_4-0004798	Observed: 58
NEW_FAIRFIELD-DISTRICT_108-0004531	Observed: 6
NEWTOWN-DISTRICT_1-0005660	Observed: 7
SOUTH_WINDSOR-ABSENTEE-0003853	Observed: 5
TRUMBULL-ABSENTEES-0002873	Observed: 1

The (manual) examination of these audit logs did not reveal security issues. However deviations from the election procedures are noted.

- Some cards appear to contain actual elections before the election day (BRISTOL-DISTRICT\_77-3-0003390, LEDYARD-DISTRICT\_1-0002015, SOUTH\_WINDSOR-ABSENTEE-0003853). This normally indicates that a district used election mode in place of testing mode for pre-election testing the cards. (We note that the frequency of such cases is lower than in previous elections.)
- On some cards the ZERO TOTAL REPORT was reported/printed before the election day: BRISTOL-DISTRICT\_77-2-0003366, LISBON-DISTRICT\_1-0004785. This is not an issue, provided such reports are also printed on the election day.
- MONROE-DISTRICT\_4-0004798 and NEWTOWN-DISTRICT\_1-0005660 were prepared for election and then reset. After the reset a test election was reported on both cards. We note that the Monroe testing appeared to contain multiple override events, possibly indicating that the district had difficulties with some ballots during testing. If this is the case, it is recommended that any such district informs the SOTS Office of such difficulties.
- The cards CANTON-DISTRICT\_1-0002561, FARMINGTON-DISTRICT\_5,6-0005168, and NEW\_FAIRFIELD-DISTRICT\_108-0004531 apparently have been intended for the post-election audit (and not pre-election audit). All of these cards contained election runs during the election day.

- Finally BRANFORD-ABSENTEES-0002304, and TRUMBULL-ABSENTEES-0002873 terminated one of their tests without casting any ballots. This may be considered an acceptable form of supplemental pre-election testing, and we will not flag such audit logs in the future.

### 3.3 Bytecode Analysis Result for the Readable Cards

We have analyzed the AccuBasic 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.

### 3.4 The Occurrence of Cards with Unreadable ('Junk') Data

The audit identified thirty four (34) cards, or 15%, that did not contain any meaningful data. Such cards contained apparently random data (a.k.a. 'junk' data), and these cards are not readable by the tabulators. Cards unreadable by the tabulators are unusable and they present a reliability problem, but 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. Below is the collected historical data on the occurrence of such unreadable cards.

Audit	Election	% of Unreadable Cards
Pre-election	August 2010 primary	15%
Post-election	November 2009 election	12%
Pre-election	November 2009 election	9%
Post-election	August 2008 primary	5%
Pre-election	August 2008 primary	15%
Post-election	February 2008 primary	5%
Post-election	November 2007 election	8%
Pre-election	November 2007 election	4%

Table 5: Historical occurrence of cards unreadable by tabulators

This is a high percentage of faulty/unusable cards.

The VoTeR Center performed an investigation to determine the cause of occurrence of unreadable cards, and reached the conclusion that the primary reason for this 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.

If a card fails, e.g., its data becomes 'junk', due to battery depletion, such a card can be restored to usefulness by changing the battery. Given the frequent occurrence of cards that lose their data, it is recommended that all batteries be replaced with suitable long-life batteries before each election. The state has followed this recommendation and is replacing all batteries for the November 2nd, 2010 election. We predict that the percentage of cards that lose their data will be greatly reduced as the result.

We have documented our detailed findings in a separate report, cited earlier herein.

### 3.5 Additional Observations and Details

Here we give additional information obtained from the audit analysis.

- Preparation for elections: Among the cards submitted for pre-election audit there are still many cards (about 36%) that are not set for election. All cards need to undergo pre-election testing and be set for election by election day.

It is possible that test elections were performed, however, the cards were not set for election by the districts. In any case, this indicates that pre-election procedures were not followed. All cards should have “Set for Election” state with zero counters going into election.

- Card duplication: The SOTS Office instructed the municipalities not to duplicate cards. If there is any perceived reason for cards to be duplicated, the SOTS Office must be promptly informed. Duplicating cards creates cards that have not been directly produced from the election database (GEMS at LHS), and should not be allowed to be used in the elections until proper procedures are developed. It is recommended that the SOTS Office continue offering training through ROVAC to reinforce that stated no-duplication policy.

The audit indicates that there is still a large percentage of cards (27%, or 62 cards) that are not found in the expected state. While it may be the case that the instructions to poll workers were unclear, it might also be that a poll worker has a reason for not following instructions; in this latter event, for the purpose of improvement in the support by the electronic component of the election process, it would be helpful if the poll workers would document why these steps were taken counter to the expected procedures.

## 4 Recommendations

The current number of cards with unreadable data (junk data), approximately 10%, is high. We have determined that weak batteries are the primary cause of this. A report cited herein has explained this and provides technical detail. Our recommendation is that the batteries in all cards are replaced prior to programming the cards for the next election. The state has followed this recommendation and is replacing all batteries for the November 2nd, 2010 election.

It appears from the available data that established pre-election testing procedures are not consistently followed. We recommend:

- It might be helpful if the SOTS Office would re-issue procedures and offer training. In particular, to reinforce the need to prepare all cards for election prior to the election day.
- It is important to reiterate that cards must never be duplicated by individuals local to the election. It would be helpful if such individuals desiring to duplicate cards would note their reasoning in the moderators’ logs.
- It is important for the individuals local to the election to report pre-election testing results (and any card problems) to the SOTS Office as soon as possible upon completion of tests.
- It is important for the individuals local to the election to report any unexpected behavior of machines that seemed to necessitate a restart or a memory card reset to the SOTS Office. It would be helpful if moderators’ logs contained records of machine restarts, perceived causes, and reasoning for the restart or reset.

- It is important that cards sent for audit should be selected at random. When a sufficiently large collection of cards is selected randomly for audit, the results of the audit represent well the whole set of cards. Should the selection not be at random, for example, by avoiding sending duplicated cards in for audit, the results are less representative. Therefore training should make clear that random selection is appropriate.

[End]