



Post-Election Audit of Memory Cards for the August 2008 Connecticut Primary Elections

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Summary

The UConn VoTeR Center performed a post-election audit of the memory cards for the Accu-Vote Optical Scan tabulators that were used in the August 2008 Connecticut Primary Elections. The cards were programmed by LHS Associates of Methuen, Massachusetts, and shipped to the towns in Connecticut. For the purpose of the post-election audit, the VoTeR Center received 297 memory cards from a number of districts after the elections. The audit was performed on 280 of these memory cards (among the 17 cards not included, 14 were from the February 2008 Connecticut Primary, two were from the March 2008 elections, and one card arrived damaged, preventing data analysis).

This document reports on the findings obtained during the audit. Among the 280 cards tested, 237 cards (84.6%) were found to have been properly programmed for election. These cards contained valid ballot data and the executable code on these cards was the expected code, with no extraneous data or code present. The remaining 43 cards, or 15.4%, were found to contain seemingly random data, or as we call it, “junk” data. Such cards are not accepted by the tabulators, and they could not have been used in the election. Nevertheless, this is a high percentage of faulty cards.

Among the 237 cards found to be properly formatted for elections, 153 cards, representing about 80% of the districts, were used for the actual election, while the remaining cards were not used (this is expected, given that under normal conditions, only one card is used per polling place). All cards were properly programmed and contained no unexpected code. Among the 153 cards actually used, 141 cards, or 92%, were in the “Election Closed” state with non-zeroed counters, which is the intended state. Additionally, 9 cards (5.9%) indicated that printing was aborted, which suggests that election officials turned off the machine before the printing of the election results was completed. 3 cards (2%) were in the ‘election closed’ state with zeroed counters.

Among the 84 cards that were not used in the elections, 83 cards, or 98.8% were in “Set for Election” state with zeroed counters, which is the intended state. The one remaining card was in “Not Set” state with non-zeroed counters. Although this is not the intended state for a card that was not used, before one could use this card, it would have to set for election, which would result in the card entering the “Set for Election’ state and the counters of the card zeroed.

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

1 Preface

The Voting Technology Research (VoTeR) Center at the University of Connecticut conducted pre-election audit and post-election audit of the memory cards that are used in the AccuVote Optical Scan (AV-OS) tabulators in the August 2008 Connecticut Primary Elections. The audits were performed on request of the Office of the Secretary of the State of the State of Connecticut.

The memory cards were originally programmed for the August 2008 election by LHS Associates of Methuen, Massachusetts, and provided by LHS to the districts in Connecticut. The pre-election audit was performed on a set of memory cards that shipped by LHS to the VoTeR Center at the University of Connecticut in Storrs. The results of the pre-election audit are documented in the previous report ¹

This document contains the results of the post-election audit of memory cards, discussion, and recommendations. This post-election audit was performed on the 297 cards from various districts that were made available to the VoTeR Center, following the instructions from, and with the assistance of, the Office of the Secretary of the State. We note that this set of available cards does not represent a randomly drawn sample.

The memory cards in both pre-election audit and post-election audit were subject to several integrity tests (an earlier report presents a comprehensive overview of the procedures followed by the VoTeR Center personnel in conducting such audits) ². We do not repeat here the description of the engineering that was performed to enable the audit and the technical setup used in the tests.

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 electro-magnetic) of the memory cards.

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

This report is a high-level, non-technical presentation of the audit results and it omits all technical details. We also note that we had no access to, and we did not use any vendor documentation regarding the design and the internals of the Accu-Vote Optical Scan terminal or the memory cards.

About the UConn VoTeR Center

Following our participation in the Connecticut Voting Technology Standards Board in 2005, the Voting Technology Research (VoTeR) Center was established in 2006 to advise state government in the use of voting technologies, to research, investigate and evaluate voting technology and voting equipment, and to develop and recommend safe use procedures for the computerized voting technology in elections. The personnel of the Center includes several faculty members, graduate students, and technical and administrative staff of the Computer Science and Engineering Department at the University Of Connecticut.

The work of VoTeR Center in the State of Connecticut is funded by the Office of the Connecticut Secretary of the State (SOTS), and we function in close contact with the SOTS Office personnel. We offer the State an independent, objective analysis of the voting technologies offered by several vendors, we advise the State on selecting and administering the voting equipment for its election

¹Pre-Election Audit of Memory Cards for the August 2008 Connecticut Primary Elections, UConn VoTeR Center, Version 0.3, October 7, 2008. Available online at <http://voter.engr.uconn.edu/voter/Reports.html>.

²Pre-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>.

needs, and we are not associated with any of the voting technology vendors. The evaluations of the voting technology are performed at the VoTeR Center Lab at the University of Connecticut. These include hands-on evaluations, exploration of possible attack vectors, physical integrity checks of the terminals and memory cards, and mitigation strategies. The VoTeR Center is not involved in establishing State's policies for procuring the voting technology, but limited to providing technical expertise on, and evaluating these technologies before deployment and during the use by the State. In this sense the VoTeR Center is a third party independent technical consulting resource for the State of Connecticut.

VoTeR Center personnel assisted the State in developing safe use procedures for the Optical Scan terminals. The procedures in place for the elections include strict physical custody policy, tamper-resistant protection of the equipment, and audits.

2 Introduction

We start by overviewing the AV-OS (AccuVote Optical Scan) based election system used in Connecticut, the goals of the post-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 AccuVote Optical Scan voting terminal (AV-OS terminal) and the ballot design and central tabulation system, GEMS, for Global Election Management System. See our reports at URL <http://voter.engr.uconn.edu/voter/Reports.html> for other information 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 contains the firmware version 1.96.6. It 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 the 40-pin 128KB Epson cards. The memory card is installed into to the 40-pin card slot (J40 connector) of the AV-OS. It is worth mentioning that Epson has discontinued this memory card some time ago, and reader/writers for this memory card are not readily available.

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 and the results. The code is written in a proprietary symbolic language. Such executable files are identified as *.abo (AccuBasic Object) bytecode. The installation of the GEMS software on the PC contains several databases as well as the bytecode for AV-OS. The databases are updated for each specific election to include the data and ballot layouts corresponding to the districts of the State of Connecticut.

2.2 Goals of the Post-Election Memory Card Audit

The VoTeR Center implements memory card audits as a part of its relationship with the Connecticut SOTS Office. The primary goal of the post-election audit was to perform an integrity check of the contents of the memory cards that were used in the elections. For the audit, with the assistance of the Office of the Secretary of the State, 297 cards were delivered to the VoTeR Center from various districts. We note that the set of cards does not represent a randomly drawn sample.

The memory cards used in the AV-OS terminals contain the data and the ballot layout for the elections. The memory cards 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 on memory cards are loaded from the GEMS database to the memory cards using the AV-OS terminal. The GEMS database to be used as the baseline for the election data was provided by LHS Associates prior to the election. Each district was given four identical memory cards containing the election information for that district. After the elections, many districts (about 80%) availed memory cards to the VoTeR Center for testing. The contents of the cards were then extracted and compared with the intended contents using the GEMS database as the reference. The audit process was automated to the extent possible. 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, bytecode, and the state of the counters. Additionally, the audit logs stored in memory cards were examined.

2.3 Preview of the Audit Results

A total of 297 cards were received and examined by the VoTeR Center. Among these 297 cards, 14 were from the February 2008 Connecticut Primary Elections, two were from the March 2008 elections, and one card arrived broken, making its analysis impossible. This report focuses on the 153 of these cards that actually were used in the August 2008 primary elections, and on the total of 280 cards pertaining to (i.e., used in, or prepared for) these elections.

Among all 280 cards pertaining to the August 2008 primary elections, 43 cards, or 15.4% were found to contain “junk” data, that is, they contained apparently random data. These cards are easily detected by the tabulators as such, and they could not have been used in the election.

From rest of the cards, 231 cards, or 82.6%, were found to have been properly programmed for election. These cards contained valid ballot data and the executable code on these cards was the expected code, with no extraneous data or code. Additional 6 cards, or 2.1%, contained a few bytes of noise (or “specks” as we call them) that apparently do not interfere with proper usage; these cards otherwise were properly programmed.

About 54.6% of the cards (153 cards) were used in the Elections. 29.6% of the cards were in “Set for Election” mode, this is the intended state for cards that were programmed for elections, but not used in the elections. One card, or 0.4%, was in the state “Not Set for Election”. This card was programmed for elections, but was not used in the election (thus serving as backup). The SOTS procedure calls for all cards to be tested by the districts and to be set for elections, even if they are not ultimately needed for the election.

Among the 153 cards used in the elections, 88.9% (136 cards) were properly programed, contained no unexpected code, and were in the state consistent with proper usage. 3.3% of the cards (5 cards) contained a few bytes of noise (or “specks”) that apparently do not interfere with proper usage; these cards otherwise were properly programmed. 5.9% of the cards (9 cards) were in the “Result Print Aborted” state. This is an undesired condition, although, provided results were in fact printed, this does not present a problem.

3 Audit Results

We now present the results of the post-election audit in greater detail. For the August 2008 Primary elections we received and examined 297 cards. Among these, one card arrived broken and 16 were from previous elections. Among the remaining 280 cards, 153 were used in the actual elections, while 83 in effect served as backup cards, and 43 contained “junk” data. Thus this report deals with total of 280 cards that pertain to the August 2008 Primary Elections. Moreover, we especially concentrate on the 153 cards that were actually used in the elections.

3.1 Memory Card Data Audit Results: 153 Cards Used in the Election

Table 1 shows the frequency of various states observed on the audited memory cards for the 153 cards used in the election. The data is presented in two parts:

(a) **Card Format:** About 96.7% of the cards were properly formatted and contained good data. The rest 3.3% of cards were properly formatted and contained good data, but also included a few “specks” in the (apparently) unused part of the card, that is a few isolated bytes with unexpected values. The specks are not detected by AV-OS, and it does not appear that they interfere with normal AV-OS operation.

(b) **Card and Counter Status:** About 92.1% of the cards were in Election Closed state and had non-Zero counters. This is the intended state for memory cards that were used in the election. 5.9% of the cards were in Results Print Aborted state with non-Zero counters. “Results Print Aborted” is an undesired state, possibly indicating that poll workers shut the machine during the printing of the results (perhaps unintentional printing).

Three cards (2%) were found in Election Closed state with Zero counters. This is not a problem, provided that no votes were cast in a district, or if a second tabulator was activated in a district but not actually used.

Finally one card that was in Election Closed state and had Zeroed counters, had uploaded results and an audit report was printed. Both those events happened before the elections started. We do not expect to encounter those events in any cards.

	Cards Used in the Election	
	Number	% Total
(a) Card Format		
Good Data, Clean Card	147	96.7%
Good Data, Some “Specks”	5	3.3%
Totals:	153	100%
(b) Card & Counter Status		
Election Closed, Non-Zero Counters	141	92.1%
Election Closed, Zero Counters	3	2.0%
Results Print aborted, Non-Zero Counters	9	5.9%
Totals:	153	100%

Table 1: Analysis summary for cards used in the election: (a) card format, (b) card & counter status.

3.2 Memory Card Data Audit Results: All 280 Cards

Table 2 shows the frequency of various states observed on the audited memory cards for all 280 cards examined, including the 153 cards that were used in the election. The data is presented in three parts:

- (a) **Card Format:** About 82.5% of the cards were properly formatted and contained good data. Another 2.1% of cards were properly formatted and contained good data, but also included a few “specks”, that is a few isolated bytes with unexpected values. The specks are not detected by AV-OS, and it does not appear that they interfere with normal AV-OS operation.

The remaining 15.4% of cards contained “junk” data, that is the card format is unrecognizable and appears to contain arbitrary noise. Such cards are not readable by AV-OS and they are readily detected through pre-election testing by poll workers, thus they could not have been used in the election.

A follow up effort is in progress to determine the cause of this. We are considering the possibilities that the cards may be damaged in shipping, and that junk data may be caused because the cards are not designed to be inserted into a running system. Future reports will document our findings.

In the rest of the analysis the percentages are computed for the 237 cards (84.6%) that were properly formatted and contained good data, i.e., the cards that did not contain junk data.

- (b) **Card Status:** This refers to the current state of the memory card, such as blank (not programmed), loaded with an election, set for election, running an election, or closed election, and others.

No blank/unprogrammed but properly formatted cards were found.

The majority of the cards, about 60.8% were in Election Closed state, which is the desired memory card state for cards that were used in the elections. One card with uploaded results and with audit report printed was found (this is not the expected results).

3.8% of the cards were found to be in the Results Print Aborted state, suggesting that the printing of the results, after the election was closed, was interrupted by turning-off the AV-OS machine, before the printing was completed. This is not the intended procedure. It is recommended that the poll workers must allow the printing of results to complete, before turning off the AV-OS machines, indeed this is the intended procedure.

35% of the cards were in Set For Election state. Such cards, were not used in the election. They were the spare cards (normally more than one programmed card is provided, but only one is used). This is the intended state for such cards.

One card, or 0.4%, was in Not Set state and thus it was not used in the election. This is not the intended state. Still if it was to be used in the election, it should first be “Set for election”, which would result in the counters of the card being set to zero, and the state changing to “Set For Election”.

- (c) **Card and Counter Status:** 35% of the cards were Set For Election state and had Zero counters. This is the intended state, for memory cards that were not used in the elections.

58% of the cards were in Election Closed state and had non-Zero counters. This is the intended state for memory cards that had been used in the election.

Three cards (1.2%) was found in Election Closed state with Zero counters. This is unexpected, unless it is really the case that nobody voted in that dsitric. See next section for more details.

3.8% of the cards were in Results Print aborted state, with non-Zero counters. (This was discussed above.)

0.4% of the cards were in Not Set state with non-Zero counters. This is not the expected state, this is discussed above (it is not a problematic case).

These observations indicate that poll workers follow strictly the procedures for pre-election testing (as compared to our previous reports), but there is still some confusion on post-election procedures and reporting.

The junk card rate is the highest rate we have encountered, and it is a continued source of concern from the quality perspective (junk cards cannot be used in any election).

	All Cards	
	Number	% Total
(a) Card Format		
Good Data, Clean Card	231	82.5%
Good Data, Some "Specks"	6	2.1%
Unusable Cards, "Junk Data"	43	15.4%
Totals:	280	100%
(b) Card Status		
Not Programmed (Blank)	0	0.0%
Not Set for Election	1	0.4%
Set for Election	83	35.0%
Results Print Aborted	9	3.8%
Election Closed	144	60.8%
Totals:	237	100%
(c) Card & Counter Status		
Not Set for Election, Non-Zero Counters	1	0.4%
Set for Election, Zero Counters	83	35.0%
Results Print aborted, Non-Zero Counters	9	3.8%
Election Closed, Non-Zero Counters	141	59.5%
Election Closed, Zero Counters	3	1.3%
Totals:	237	100%

Table 2: Memory card analysis summary for all cards: (a) card format, (b) card status, (c) card & counter status.

3.3 Cards in Closed State with Zeroed Counters

Here we provide additional information on the three cards with zeroed counters and election closed status that were not in one of the expected states. The three cards are:

WATERBURY, ABSENTEES with S/N 75739,
 SHELTON, DISTRICT 3 with S/N 79377, and
 SHELTON, DISTRICT 5 with S/N 79847.

After examining the log contained on the memory card for the WATERBURY, ABSENTEES card, we conjecture that no ballots were passed through this card during the election.

For SHELTON, DISTRICT 3, we also have a card with S/N 81480. This card is in election closed status with 39 ballots cast. From this we conclude that the later card was the card used in the

election and thus the card with S/N 79377 served in effect as a back-up card. By examining the log of the card, we conclude that the card was in the tabulator that was “set for election” and operated during the election day. At the end of the election an ender card was used to close the election on the machine. Thus two tabulators were turned on on the election day. On the other hand the procedures require that the second tabulator is put into service only if there is a problem with the first one. Thus poll workers in this case did not follow the established procedures.

For SHELTON, DISTRICT 5 we do not have another card. We present below the part of the log we extracted from the card that shows the events for the election day (middle column is the event code):

```
05:34  7      SESSION START
08-12-08
05:35  21     UPLOAD STARTED
05:36  7      SESSION START
08-12-08
05:37  25     AUDIT REPORT
05:37  3      PREP FOR ELECT
05:37  13     CLEAR COUNTERS
05:38  7      SESSION START
08-12-08
19:25  23     ZERO TOT REPORT
19:25  20     ENDER CARD
19:25  17     BAL COUNT START
19:25  4      BAL COUNT END
19:28  24     TOTALS REPORT
```

Here the events `UPLOAD STARTED` and `AUDIT REPORT` are unexpected. It is also not clear why the machine that was prepared for election and restarted at 5:38am did not have its Zero Totals report printed until 19:25 (7:25pm). We assume that this card was not used in the election, thus it could have affected the election results.

3.4 Bytecode Analysis Result

We have analyzed the Accu-Basic 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 Accu-Basic bytecode.

4 Discussion and Additional Recommendations

Having performed and completed both the pre-election and post-election audits, we believe that technological audits of voting equipment, and specifically memory card audits, are important in providing valuable and timely information and monitoring necessary to ensure the integrity of our electoral system. This section contains the conclusions we draw from the audit process, and some recommendations on safe-use procedures.

1. Absence of ballot data or bytecode corruption.

During the data analysis we have not noticed any corruption of the ballot data or the bytecode in the readable cards. The ballot layout of the audit cards were identical to the ballot layout of the corresponding baseline data.

2. There were too many cards with “junk data”

By saying that the card contains “junk data” we understand that the card contains arbitrary data and it does not contain proper programming. When one puts the card containing the “junk” data into the AV-OS terminal it issues a prompt requesting to format the card. Among the audited cards we detected 15.4% of the cards containing junk data. This percentage is very high and this issue has to be resolved. This is the highest junk data percentage we have ever received, and a 15.4% of malfunction on electronic equipment is unacceptable.

A follow on effort is in progress to investigate possible causes for cards to have junk data. Future reports will document our findings.

3. Election closed, but the print of results aborted.

This means that the cards were used in the election, they show non-zero counters, but the printing of the election results was aborted. Either there was a malfunction, or the poll workers turned off the machine before it finished all printing (probably as soon as the results were printed they turned the machines off). It is important to ensure in the future that all reports are properly and completely printed following an election before the machines are shut down.

We note however that the number of such cards was smaller then in February, specifically, we had 5.9% of such cards in August 2008 vs. 7.3% in February 2008

4. One card had non-zero counters and was not set for election.

In past audits we encountered substantial quantities of cards with this state. Thus we have observed a noteworthy improvement from the previous audits, indicating that in this area pre-election procedures are being applied diligently at the districts.

(We reiterate here all cards should be in “election mode” prior to an election and there should not be any non-zero counters.)

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