VoTeR Center

UConn Voting Technology Research Center

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Statistical Analysis of the Post Election Audit Data 2007 November Elections

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Version 0.2

Summary

The University of Connecticut Voting Technology Research (VoTeR) Center received the data gathered in the post-election audit performed in the State of Connecticut following the November 2007 election. The audits of the randomly selected 10% of the districts were conducted in November and December of 2007, and the returns were conveyed by the Office of the Secretary of the State (SOTS) to the VoTeR Center on January 8, 2008. The audit data received by the Center contains 958 records, where each record represents information about a given candidate. Specifically, each record contains the following significant information: date, district, machine seal number, office, candidate, machine counted total, undisputed hand counted total, questionable hand counted total, overall hand counted total, that is, the sum of undisputed and questionable ballots. This report contains several statistical analyses of the audit returns and recommendations. Among the 958 records received by the Center, 175 records (18.3%) were incomplete, unusable, or obviously incorrect. Another 111 records (11.6%) contained usable, but incomplete data, or minor arithmetic errors. Thus about 70% of the audit records were complete and contained no obvious errors. While some problematic records were clearly due to human error (e.g., in addition), the large number of incorrect and/or incomplete audit returns suggests that auditors found the instructions to be ambiguous or insufficiently specific. Thus one immediate recommendation is to revise and improve the instructions and the audit procedures, and to refine the definitions of the data to be reported. The statistical analysis in this report deals with the 783 records that are sufficiently complete to perform the analysis.

Version 0.1 of this report, issued on January 30, 2008, identified 44 records with discrepancies of 8 (eight) or more between the machine-counted totals and hand-counted audit returns, although in all such cases the discrepancies did not come close to affecting the outcome of the election. Subsequently, SOTS personnel performed a review of these returns, which in some cases required second hand counting of the ballots. As the result, the discrepancies were substantially reduced or eliminated. The results from the re-audit were communicated to the Center on March 20, 2008. This reconciliation focused on the differences between the machine-counted totals and hand-counted totals. The number of questionable ballots was not separately identified in 41 out of 44 revised records. Consequently this revised report has two parts. In the first part it deals with 742 records (739 from the original data plus 3 from the re-audit) for which we

repeat the analysis as done in the version 0.1 of the report. In the second part we present simplified analysis for the 41 remaining records from the re-audit.

Among the 742 records that form the basis for the first part of this report, 523 records (70.5%) show discrepancy of 0 or 1 votes between the machine counts and audit hand counts, and 703 records (94.7%) show discrepancy of 5 votes or lower. Here there are 39 records that show the discrepancy of more than 5 votes, where the single highest discrepancy is 8 (it was determined during the re-audit that in that district a number of ballots were mismarked). The average discrepancy here is -0.21%, and the average of the absolute value of discrepancies is 0.51% (1.3 votes), where the average count of votes is 259. Finally, we note that the average number of questionable votes per district is 4.98. Thus on the average reported discrepancy is less than 1/3 of the average number of reported questionable votes.

Among the 41 (revised) records that form the basis for the second part of this report, 20 records (48.8%) show discrepancy of 0 or 1 votes between the machine counts and audit hand counts, and 33 records (80.5%) show discrepancy of 5 votes or lower. There are 8 records with discrepancy is above 5, with the highest discrepancy being 10. The average discrepancy here is 0.11%, and the average of the absolute value of discrepancies is 0.61%, where the average count of votes is 601.

It is also noted that the 41 revised records (for which re-audit was done) in the second part of the report correspond to districts for which the average count is more than twice as compared to the average vote count in the first part of the report (601 votes vs. 259 votes). This naturally suggests that in larger districts the audit process is more prone to hand counting and recording errors.

This analysis was performed on request of the Office of the Secretary of the State.

1 Preface

The University of Connecticut Voting Technology Research (VoTeR) Center received the data gathered in the post-election audit performed in the State of Connecticut following the November 2007 election. The audits of the randomly selected 10% of the districts were conducted in November and December of 2007, and the returns were conveyed by the Office of the Secretary of the State to the VoTeR Center on January 8, 2008. For the definition of the audit see Connecticut Public Act 07-194 AN ACT CONCERNING THE INTEGRITY AND SECURITY OF THE VOTING PROCESS, approved July 5, 2007. For the instructions on conducting the audit, see Audit Procedures Optical Scan Voting Equipment, Office of the Secretary of the State, November 2007. The Center is currently working with the Office of the Secretary of the State in order to develop the criteria that will be used in the future elections audits (starting with November 2008) to identify audit returns that report certain discrepancies that will cause additional audits and/or examination of equipment to be requested. This report contains several statistical analyses of the audit returns and recommendations.

Version 0.1 of this report, issued on January 30, 2008, identified 44 records with discrepancies of 8 (eight) or more between the machine-counted totals and hand-counted audit returns, although in all such cases the discrepancies did not come close to affecting the outcome of the election. Subsequently, SOTS personnel performed a review of these returns. In some cases the issue was resolved by contacting the Registrars of Voters, while in other cases actual hand SOTS staff hand counted the ballots. As the result, the discrepancies were substantially reduced or eliminated. The results from the re-audit were communicated to the Center on March 20, 2008.

This report presents the revised analysis of the post election audit data.

This analysis was performed on request of the Office of the Secretary of the State.

2 Overview of the Analysis

This report contains several statistical analyses of the audit returns and recommendations. Among the 958 records received by the Center, 175 records (18.3%) were incomplete, unusable, or obviously incorrect. Another 111 records (11.6%) contained usable, but incomplete data, or minor arithmetic errors. Thus about 70% of the audit records were complete and contained no obvious errors. While some problematic records were clearly due to human error (e.g., in addition), this suggests that auditors found the audit instructions to be ambiguous or insufficiently specific. Thus one immediate recommendation is to revise and improve the instructions and the audit procedures, and to refine the definitions of the data to be reported.

This revised data supplied by the SOTS personnel focuses on the differences between the machine-counted totals and hand-counted totals. The number of questionable ballots was not separately identified in 41 out of 44 revised records. Consequently this revised report has two parts. In the first part it deals with 742 records (739 from the original data plus 3 from the re-audit) for which we repeat the analysis as done in the version 0.1 of the report. In the second part we present simplified analysis for the 41 remaining records from the re-audit.

Among the 742 records that form the basis for the first part of this report, 523 records (70.5%) show discrepancy of 0 or 1 votes between the machine counts and audit hand counts, and 703 records (94.7%) show discrepancy of 5 votes or lower. Here there are 39 records that show the discrepancy of more than 5 votes, where the single highest discrepancy is 8 (it was determined during the re-audit that in that district a number of ballots were mismarked). The average discrepancy here is -0.21%, and the average of the absolute value of discrepancies is 0.51% (1.3 votes), where the average count of votes is 259.

We also report that the average number of questionable votes per district is 4.98, while the average absolute discrepancy mentioned above is 1.3. Thus on the average reported discrepancy is less than 1/3 of the average number of reported questionable votes.

Among the 41 (revised) records that form the basis for the second part of this report, 20 records (48.8%) show discrepancy of 0 or 1 votes between the machine counts and audit hand counts, and 33 records (80.5%) show discrepancy of 5 votes or lower. There are 8 records with discrepancy is above 5, with the highest discrepancy being 10. The average discrepancy here is 0.11%, and the average of the absolute value of discrepancies is 0.61%, where the average count of votes is 601.

It is also noted that the 41 revised records (for which re-audit was done) in the second part of the report correspond to districts for which the average count is more than twice as compared to the average vote count in the first part of the report (601 votes vs. 259 votes). This naturally suggests that in larger districts the audit process is more prone to hand counting and recording errors.

The statistical analysis in this report deals with the 742 records that are sufficiently complete to perform the analysis. Among these records, 523 records (70.5%) show discrepancy of 0 or 1 votes between the machine counts and audit hand counts, and 703 records (94.7%) show discrepancy of 5 votes or lower there are just 39 records which have the discrepancy of more than 5 votes and the maximal discrepancy after the recounting was done is 8 and this is the case when the ballots were mismarked. The next maximal discrepancy is 7.

Note: on January 16, 2008, The Connecticut Citizen Election Audit Coalition published “Report and Feedback: November 2007 Connecticut Election Audit Observation.” That report is available online at www.CTElectionAudit.org. In presenting statistical data in our report, we use similar tiered presentation of the results to enable comparison. However, given the incomplete audit data, the subsets of the data presented in the respective reports differ. In particular, we present analysis of 783 records out of 958 records, while the Coalition report presents analysis of 912 records.

3 Introduction and Notation

Throughout this document we use the following notation:

- M is used to denote the machine counted ballots
- U is used to denote the number of undisputed hand counted ballots
- Q is used to denote the number of questionable hand counted ballots
- H is the sum of undisputed and questionable ballots, that is, $H = U + Q$
- D is the discrepancy between the hand counted total and machine total, that is, $D = H – M$
- $|D|$ is the absolute value of the discrepancy (the positive value of D)

Thus for a given candidate, we define discrepancy D as the difference between H (the sum of the undisputed ballots U and the questionable ballots Q) and M (the machine count).

If the discrepancy D is positive then we say that we observe a machine undercount relative to the hand count H, i.e., the machine counted fewer ballots in a certain race than the auditors.

If the discrepancy D is negative then we say that we observe a machine overcount relative to the hand count H, i.e., the machine counted more ballots in a certain race than the auditors.

Note that this presupposes that the hand count does not contain (human) errors. This is not necessarily so in reality. For example, in at least one case where a certain candidate is on the ballot under two different parties the hand counted ballots are not correctly assigned along part lines, resulting in large discrepancy D, although in actuality the discrepancy is considerably smaller. In general it is not possible to ascertain

whether the hand counted data contain errors, and so we assume that the hand counted data is reported correctly.

In the analysis below, unless indicated otherwise, we consider only the 742 records that we view as "clean", that is, the records that provide complete information at least about M and H.

4 Statistical Analysis

4.1 Absolute Value of Discrepancy

First we give the analysis considering the **absolute** number of discrepancies, |D|. We include discrepancies for all records for which both the machine count M and the total hand count H is given; here in some cases some of data is missing, such as values of U and Q. Over all 742 records, the average absolute discrepancy is 1.3, and the standard deviation is 1.7, suggesting that the occurrences of discrepancies are reasonably clustered in the vicinity of the average. Here on the average there are 259 hand counted ballots, and with the average absolute discrepancy of 1.3, the absolute discrepancy is about 0.5% with respect to the average hand counted ballots. Table 1 presents tiered view of the absolute discrepancies.

Table 1: Absolute value of discrepancy.

Description	Counts	% of Counts
Records with discrepancy |D| of 0	319	42.99%
Records with discrepancy |D| of 1-3	337	45.42%
Records with discrepancy |D| of 4-6	66	8.89%
Records with discrepancy |D| of 7-8	20	2.7%
Totals:	**742**	**100%**

Table 2 presents tiered view of the absolute discrepancies by the percentage of discrepancy. We note that the highest discrepancy here is a single case of 8 (eight) votes, and this was due to mismarked ballots (as reported by SOTS personnel following re-examination of ballots).

Table 2: By Percentage of Discrepancy

Description	Counts	% of Counts
Records with discrepancy less than 0.5%	442	59.57
Records with discrepancy 0.5% to 1%	114	15.36
Records with discrepancy 1% to 2%	102	13.75
Records with discrepancy 2% to 10%	63	8.49

Records with discrepancy over 10%	21	2.83
Totals:	**742**	**100%**

4.2 Undercount and Overcount Discrepancies

When considering negative discrepancies (overcounts) and positive discrepancies (undercounts) over the 742 records, the average discrepancy is –0.5, and the standard deviation is 2.12, again suggesting tight clustering of discrepancies about the average.

Table 3 presents discrepancies for the records that indicate overcounts.

Table 3: Records indicating overcounting: 269 records with negative values of discrepancy.

Description	Counts	% of Counts
Records with discrepancy D from -1 to –3	201	74.72
Records with discrepancy D from -4 to –6	56	20.82
Records with discrepancy D from -7 to –8	12	4.46
Totals:	**269**	**100**

Table 4 presents discrepancies for the records that indicate undercounts.

Table 4: Records indicating undercounting: 154 records with positive values of discrepancy.

Description	Counts	% of Counts
Records with Discrepancy D of 1-3	136	88.32
Records with Discrepancy D of 4-6	10	6.49
Records with Discrepancy D of 7-8	8	5.19
Totals:	**154**	**100**

4.3 Statistics for Questionable Ballot Counts

Table 5 presents statistics with respect to the questionable ballots per candidate.

Table 5: Questionable Ballot Counts.

Description	Counts	% of Counts
Records with questionable count Q of 0	326	43.94
Records with questionable count Q > 0 to 2% (or < 10 candidate votes)	223	30.05
Records with questionable count Q > 2% to 5%	89	11.99
Records with questionable count Q > 5% to 10%	58	7.82
Records with questionable count Q > 10%	45	6.07
Records with questionable count Q of –3	1	0.13
Totals:	**742**	**100%**

Although over 70% of the records indicate that the number of questionable ballots is under 2%, in about 15% of the records, the number of questionable ballots is over 5%, and in one case the number of questionable ballots is negative (this should never occur). It is clear that more guidance needs to be given to the auditors, and the definitions need to be more specific.

Finally, we note that the average number of questionable votes per district is 4.98, while the average absolute discrepancy is 1.3. Thus on the average reported discrepancy is less than 1/3 of the average number of reported questionable votes.

5 Assumption that Just the Right Number of Questionable Ballots were Counted

The analysis thus far was done by assuming that the machine in fact counts all questionable ballots. We next provide analysis where the number of questionable ballots is reduced so as to minimize undercounts and overcounts, thus assuming that not all questionable ballots are counted by the machine. This is done according to the following formulation.

- If $M > H$,
  then all questionable ballots are counted, thus $D = H - M$
- Else if $M < U$,
  then no questionable are counted, thus $D = U - M$
- Else if $U \leq M \leq H$,
  then exactly the right number of questionable ballots are counted, thus $D = 0$

The average discrepancy in this case is 0.99, and the standard deviation for discrepancy in this case is 1.66; again on average there are 259 ballots per record.

Table 6: Absolute value of discrepancy for the 742 records, where Q is adjusted where possible to reduce discrepancy.

Description	Counts	% of Counts
Records with absolute discrepancy |D| of 0	452	60.92
Records with absolute discrepancy |D| of 1-3	218	29.38
Records with absolute discrepancy |D| of 4-6	60	8.09
Records with absolute discrepancy |D| of 7-8	12	1.62
Totals:	742	100

Table 7 presents discrepancies for the records that indicate overcounts. Note of course that it is impossible to reduce overcounting by reducing the number of questionable counted votes, and so this table is the same as Table 3.

Table 7: Records indicating overcounting: 269 records with negative values of discrepancy.

Description	Counts	% of Counts
Records with discrepancy D from -1 to –3	201	74.72
Records with discrepancy D from -4 to –6	56	20.82
Records with discrepancy D from -7 to –8	12	4.46
Totals:	**269**	**100**

Table 8 presents discrepancies for the records that indicate undercounts. The total number of undercounts is reduced from 154 (Table 4) to 21 below.

Table 8: Records indicating undercounting: 21 records with positive values of discrepancy, where Q is adjusted where possible to reduce discrepancy.

Description	Counts	% of Counts
Records with Discrepancy D of 1-3	11	52.38
Records with Discrepancy D of 4-6	7	33.33
Records with Discrepancy D of 7-8	3	14.29
Totals:	**21**	**100**

6 Analysis of Corrected Audit Returns

Here we give a simplified analysis for the corrected data. As we pointed out earlier, SOTS personnel updated 44 records in a re-audit. Three of these records included explicit counts of unambiguous and questionable ballots, and they are incorporated in the above. The remaining 41 records reported only the total number of votes as the result of re-audit. These records do not include information on questionable and undisputed ballots.

In this section we give analysis for these remaining revised 41 records.

6.1 Absolute Discrepancy

Table 9 presents the absolute value of discrepancy between the total hand counted ballots and the machine count.

Table 9: Absolute value of discrepancy.

Description	Counts	% of Counts
Records with discrepancy |D| of 0	17	41.46%
Records with discrepancy |D| of 1-3	13	31.71%
Records with discrepancy |D| of 4-6	4	9.76%
Records with discrepancy |D| of 7-10	7	17.07%
Totals:	**41**	**100%**

Table 10 presents a tiered view of the absolute discrepancies by the percentage of discrepancy.

6.1.1 Table 10: By Percentage of Discrepancy

Description	Counts	% of Counts
Records with discrepancy less than 0.5%	41	100
Totals:	**41**	**100%**

The highest discrepancy among these 41 records is 10, however the results of Table 10 show that all the discrepancies are less than 0.5%.

6.2 Undercount and Overcount Discrepancies

When considering negative discrepancies (overcounts) and positive discrepancies (undercounts) over the 41 records, the average discrepancy is –2.2, and the standard deviation is 3.97.

Table 11 presents discrepancies for the records that indicate overcounts.

Table 11: Records indicating overcounting: 19 records with negative values of discrepancy.

Description	Counts	% of Counts
Records with discrepancy D from -1 to –3	9	47.37
Records with discrepancy D from -4 to –6	3	15.79
Records with discrepancy D from -7 to –10	7	36.84
Totals:	**19**	**100**

Table 12 presents discrepancies for the records that indicate undercounts.

Table 12: Records indicating undercounting: 5 records with positive values of discrepancy.

Description	Counts	% of Counts
Records with Discrepancy D of 1-2	4	80%
Records with Discrepancy D = 6	1	20%
Totals:	**5**	**100**

7 Discussion

We note that the quality of the audit returns and the meaning of the reported counts varied from district to district. It appears the auditors either misinterpreted what needs to be reported or did not follow the prescribed procedures. For example, whereas the data had to be reported in such a way that the number of hand counted ballots (H) is the sum of undisputed (U) and questionable (Q) ballots, these numbers did not match up on several audit returns. Moreover, there seems to be a lack of understanding on what needs to be reported for Questionable (Q) and Undisputed (U) ballots. Thus, some audit data is impossible to analyze. As a result in this report we presented the analysis of the data on 783 records out of 958. Our analysis was presented in two parts, where we separately analyzed audit returns that were revised based on a re-audit.

In more detail, among the 958 records received by the Center, 175 records (18.3%) were incomplete, unusable, or obviously incorrect. Another 111 records (11.6%) contained usable, but incomplete data, or minor arithmetic errors. Thus about 70% of the audit records were complete and contained no obvious errors.

We now present some additional observations.

- For **Durham** we see an overcounting discrepancy and there is a non-trivial discrepancy for each record of that district. We note that as the result of re-audit, the number of discrepancies for each record was reduced. On the average, the discrepancy was reduced on the average from 2.4% to 0.9%. However all discrepancies in this district are overcounting discrepancies. On the other hand, the relative discrepancies are not large.

- For **West Hartford** we observe that the number of Questionable ballots was filled out not by analyzing the ballot itself. It seems that the auditors just tried to match the number of hand counted and machine counted data. Thus, here we can observe even a negative number of Questionable ballots (such as -3).
- As we noted in our previous report, in **Plainfield** there were a number of overcounting cases, and most of these remained after re-audit. Here out of 14 records 9 have discrepancy, and out of these 6 are overcounts.
- In **Waterbury** we see that there are many cases when the number of Questionable ballots is 0, while there is a discrepancy for that record. This is the case with many records, suggesting that perhaps the auditors did not fill out the form correctly. In our previous report we mentioned that in Waterbury we could see the highest absolute discrepancies, which are 74 and -72. As we noted earlier these discrepancies were result of a human error. The recounting confirmed it and in both cases these discrepancies went down up to 1.
- In **Milford** and **Norwich** the auditors filled out only the number of ballots counted by the machine and number of hand counted ballots. There is no information about the number of Undisputed/Questionable ballots, thus analysis is impossible.
- "Large" vs. "small" districts: We note that the 41 revised records (for which re-audit was found to be needed and was done) correspond to districts for which the average count is more than twice as compared to the average vote count in the rest of the audit records (601 votes vs. 259 votes). This naturally suggests that in larger districts the audit process is more prone to hand counting and recording errors.
- Questionable ballots vs. the absolute discrepancy: When averaged over the 742 records considered in the first part of our analysis, we observe that the reported average number of questionable ballots per district (4.98) is more than 3 times the average absolute discrepancy (1.3) and more than 9 times the average discrepancy (0.5).

Finally, the following two developments are already in progress as the result of the current audit:

- Criteria need to be developed that will be used in future election audits to identify audit returns that either report certain discrepancies or lack in completeness that in turn will cause additional information gathering, audits, and/or examination of equipment.
- Audit procedures and definitions need to be substantially revised to make the audit returns more comprehensive and to make the job of the auditors easier by providing better instructions for how the data is to be collected and what data is to be collected. In particular, the current definition of questionable ballots needs to be refined and specialized to several types of questionable ballots. For example it makes sense to have separate categories for ballots that clearly show positive voter intent but possibly would not be counted by the machine, and ballots that show negative voter intent yet possibly could be counted by the machine.

[End]

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 staff of the Computer Science and Engineering department at the University Of Connecticut.

The work of the 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 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. It is worth pointing out that the VoTeR center is not involved in the State's policies for choosing a vendor to procure the voting technology, but limited to evaluating these technologies before deployment and use by the State. In this sense the VoTeR Center is a third party independent technical consulting resource for the State of Connecticut.

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