New Mexico 2022 Election Audit Analysis

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Overview

The culmination of an election is the independent random audit of election results. An initial reading of the 2022 New Mexico general election's audit report looks benign, finding only a few handfuls of ballots that were read differently by tabulators vs. the hand count. Yet, a deeper inspection reveals that the purportedly random precinct selection process skipped over 281 adjacent precincts in Bernalillo County, meaning over 100,000 ballots could not trigger an audit of the voter's precinct, possibly revealing a door open to nefarious actors. This document analyzes the audit and its adherence to voluntary federal guidelines, concluding that guidelines should be taken more seriously.

Introduction

The green curve in Fig. 1 shows the purportedly random Bernalillo County precincts considered for the 2022 audit [1], sorted by position in the precinct list. The red curve is a recalculation of the correct precinct selections based on recorded dice rolls. The reader can see that the first 30 rolls are identical noisy lines of about the right slope, which is characteristic of a random distribution.

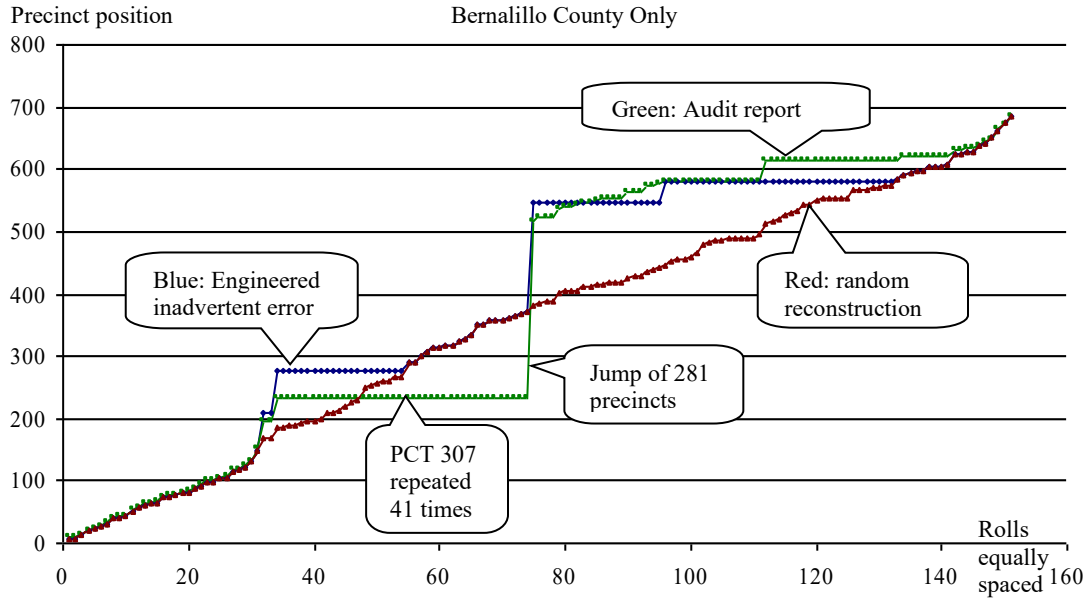


Fig. 1. One dot per dice roll that specified Bernalillo County. The height of each dot is the precinct position in the state's precinct list and the slope of curve is the spacing between selected precincts. In 2022, Bernalillo County had 687 precincts named "PCT N" with no gaps (although out of order in the government's files). The average number of registered voters was 556 and maximum was 1,130 and there were 152 rolls specifying Bernalillo County. Green curve from AGREED UPON PROCEDURES REPORT pdf file [1] table A-3, cut and pasted into Excel, all counties except Bernalillo deleted, rows sorted by precinct number, and plotted. See Appendix 1 for details [2].

Yet, the 34th to 74th selections of the green curve used by the audit are 41 repetitions of precinct 307 (PCT 307), creating a conspicuous horizontal line. The purportedly random precinct selection process not only favored some precincts but there is a jump in the

green curve in Fig. 1 indicating a range of 281 precincts that the random process did not select even once in 152 trials. Jumps are expected to occur naturally, yet the probability of such a large jump is computed to be 8.4 x 10^{-31} (see Appendices 1-4 for details). To change the outcome of an election requires hacks in many precincts at once, so auditing a modest percentage of precincts should be sufficient as long as the identity of non-audited precincts cannot be known by a nefarious actor in advance.

While the spreadsheet used for the supposedly public precinct selection is not available, some aspects of the computational process could be deduced. The blue curve was then created by setting up the spreadsheet in Appendix 5 in accordance with the audit report [1] and then changing four numbers similarly to accidental keystrokes in Excel.

The fact that there are similar erroneous rectangular corners in the same places shows the error in [1] could be the result of accidental keystrokes or an engineered hack disguised to look like accidental keystrokes. Yet, it is not possible to figure out whether the anomaly was accidental or deliberate because there is no audit log or chain of custody for the audit spreadsheet, leading to this document's conclusion that security processes applied to other mission critical software should be applied to election software.

Explanation of random precinct selection

New Mexico law requires precinct selection to be random although weighted by the number of registered voters in each precinct, yet the auditor weighted by the number of ballots cast in each precinct. To accommodate both cases, this document will use the term "people." See Appendix 1.

Fig. 2. New Mexico uses dice color order of Red-White-Blue, Black-Gray-Green-Purple, so the image shows 5,442,328.

Randomness in the 2022 audit came from rolls of seven dice of specific colors, as shown in Fig. 2, each with 10 sides labeled 0-9. Color indicates place value, so a dice roll yields a "raw" number 0-9,999,999. Normally, the raw number is multiplied by the factor N/10,000,000 to yield a random number in the range 0 to N–1, such as 0-11 in Fig. 3b; see Appendix 6 for details.

Fig. 3a-d are diagrams illustrating New Mexico's process for a hypothetical state with 12 people divided into 4 precincts named PCT 1 to PCT 4. Fig. 3b shows the people as a column of 12 🧍 symbols.

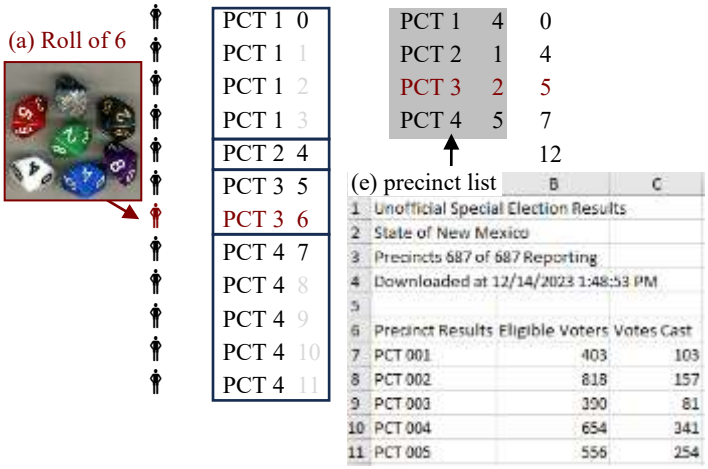


Fig. 3. (a) Roll, (b) hypothetical audit applied to a state with 12 people and 4 precincts (c) precinct table, (d) running total, (e) screenshot of the upper-left corner of a New Mexico precinct list [3].

Rolling the dice in Fig. 3a yields a number 0 to 11 that specifies one of these people at random. The figure shows an example roll of 6, in red. Each person corresponds to a row of the table containing the name of their precinct and the person's number within the state.

However, the process does not need a large table with one row per person because the people are never identified. In fact, government documents refer to the people as "UNNAMED" and the auditor's report includes a column labeled "row matched" that varies from 0 to the number of precincts in New Mexico. Based on this, the computation is shown in Fig. 3c, where each row contains the precinct name and the number of people in it. Fig. 3d shows the computer must keep a running total of the number of people in the precincts above it. A precinct is selected by finding the row where either (i) the running total equals the person's number or (ii) the person's number is in the gap between running total of a row and the row below it. This process provides the required weighting.

New Mexico voter turnout spreadsheets for each election are on the internet [3]. These spreadsheets have the structure described in the previous paragraph, although the table is much larger. The upper-left corner of a Bernalillo spreadsheet is shown in Fig. 3e.

The auditor's files covered 714,797 total votes, but the files currently on the internet were put online a week after the drawing and cover 714,754 total votes. The 43-vote difference is not consistent with the requirement for public precinct selection, although it is so small that it does not affect the results in this document.

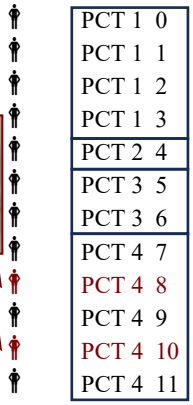
Reconstructing the number of people in a precinct

The audit report [1] reveals information about the number of people in each precinct. Say that two dice rolls select the people numbered 8 and 10, who are both registered in PCT 4, as shown in Fig. 4a-b. From Fig. 4b, we see that PCT 4 must be large enough to include both persons 8 and 10, meaning PCT 4 must have at least three people. As a mathematical expression, if A and B are the numbers of two people in the same precinct, ordered such that $A < B$, there must be at least $B-A+1$ people in that precinct.

Fig. 4c is a composite of screenshots of table A-3 in the 2022 New Mexico audit report.

(a) Roll 8 and 10

(b) UNNAMED person, precinct, and number:



(c) Screenshots of table A-3 in the audit report [1]:

NEW MEXICO SECRETARY OF STATE
2022 GENERAL ELECTION HELD ON NOVEMBER 8, 2022
RANDOM COUNTY/PRECINCT SELECTION

Aggregation	Roll Number Normalized	Row Matched	County	Precinct #
5442328	389,016	1,218	Lea	PRECINCT 040
0887873	63,465	234	Bernalillo	PCT 307
1818800	130,007	234	Bernalillo	PCT 307
7507883	536,661	1,687	Sandoval	PCT 032

Fig. 4. (a) Rolls, (b) hypothetical audit applied to a state with 12 people and 4 precincts (c) screenshots from the online auditor's report, compressed to show size of PCT 307.

Let us describe the structure of table A-3 first. The image of dice in Fig. 4a shows a roll of 5-4-4-2-3-2-8 using the color order in Fig. 2 and corresponds to the number 5,442,328, which is in the first row of the "aggregation" column in Fig. 4c (the reader can verify the screenshots by searching the online pdf [1] for 5442328). This value is multiplied by 714,797/10,000,000 to yield a person number in the range 0 to 714,796 – identifying an "UNNAMED" person in the 2022 election. In this case, multiplication yields 389,016 in the first row of the column labeled "roll number normalized." Screenshots from the report in Fig. 4c show that the UNNAMED person numbered 389,016 matched row 1,218 of the table (column "row matched") and that this row contained "Lea" County "precinct 040."

Similarly to the previous example selecting persons 8 and 10, Fig. 4c shows the 2022 audit selected persons 63,465 and 130,007 (the reader can similarly verify the screenshots by searching the online pdf [1] for these numbers). These numbers matched row 234 of the precinct table, which specifies Bernalillo County PCT 307 (red in Fig. 4c). If we apply the expression $B–A+1$ from the previous example with A = 63,465 and B = 130,007, we find that the precinct must contain at least 66,543 people. Since 500 people cast ballots in PCT 307, the audit adjusted the probability of PCT 307 based on a weighting factor that was about 120 times larger than it should have been.

While the spreadsheet used for the supposedly public precinct selection is not available, we can deduce to limited accuracy the precinct weighting factor and hence the number of people in a precinct (which ends up revealing an error). Appendix 7 computes $B–A+1$ for all precincts and sorts the results by size. Table 1 lists the precincts where the weighting factor is larger than the legal limit on precinct size (1,200), indicating an error. To avoid misunderstanding, the excessively large numbers are believed to result from erroneous nonrandom precinct selection rather than improper voting or unlawfully large precincts.

Table 1: Implied minimum number of ballots cast (all precincts are legally limited to 1,200 voters)

Precinct	People	Precinct	People
Bernalillo County PCT 307	66,543	Eddy County PRECINCT 33	4,374
Bernalillo County PCT 588	24,319	Santa Fe County PRECINCT 098	4,200
Bernalillo County PCT 380	18,633	Sandoval County PCT 091	3,635
Dona Ana County PRECINCT 007	6,914	Lea County PRECINCT 003	2,939
Bernalillo County PCT 620	6,611	Santa Fe County PRECINCT 131	2,473
Quay County PRECINCT 012	5,653	Luna County PRECINCT 006	2,334
San Juan County PRECINCT 121	4,825	Valencia County PRECINCT 11	2,044
Sandoval County PCT 123	4,414	Bernalillo County PCT 586	1,242

Sources of the nonrandomness and implications

In this section, we consider three types of nonrandomness that have different implications to elections. These types are:

1. an inadvertent error
2. an inadvertent error that technology can prevent, but the technology was not used
3. a deliberate error

Sources for the nonrandomness can be divided into categories, specifically (a) incorrect or counterfeit precinct voter turnout files similar to Table 1, (b) software that incorrectly

translates dice rolls into precincts, and (c) an Excel operator error, such as applying unsorted input data to the Excel MATCH function.

While category (c) is often inadvertent, this document will further analyze the situation to see if a bad actor could deliberately create an error, disguise it as an inadvertent error, and possibly use a "false flag" operation to direct blame to another party if caught. If this scenario is considered feasible, it may not make sense to consider the others.

The auditor states they used a spreadsheet [1], and we presume (without proof) that it was Excel, so we consider the Excel MATCH function – which is the straightforward way to create the "row matched" column in Fig. 4c. Fig. 5a is a screenshot of the MATCH help file from Microsoft. The red underlines (added) disclose an unchecked requirement for sorted input data. As explained in Appendix 5, not complying with this requirement causes the binary search algorithm in MATCH to search incorrectly. The error is similar to moving a handful of paper files from one place to another in a file drawer. From common experience we know that the files are still in the drawer but they will not be found by the standard method of searching file drawers. The next question is whether there are any unsorted spreadsheet rows under discussion. The answer is in the screenshot of Fig. 5b, showing the 449th row of [3] to have a lower precinct number than the 448th row – hence the file is not sorted from that point onward.

(a) MATCH help text from Microsoft:

Syntax

MATCH(lookup_value, lookup_array, [match_type])

Match_type	Behavior
1 or omitted	**MATCH** finds the largest value that is less than or equal to ***lookup_value***. The values in the ***lookup_array*** argument must be placed in ascending order, for example: ...-2, -1, 0, 1, 2, ..., A-Z, FALSE, TRUE.

(b) Out-of-order precinct table:

448	PCT 603	693	266
449	PCT 232	709	84

Fig. 5. (a) Excel MATCH function (red underlining added) includes a warning about unsorted arrays. (b) The MATCH function would be applied to a list of precincts and the 2022 list of precincts is sorted up to row 448, but PCT 603 is followed by PCT 232. Note the precinct table is the same file as shown in Fig. 3, but further down the spreadsheet.

Appendix 5 is a spreadsheet that creates the red curve in Fig. 1 by rerunning the precinct selection using recorded dice rolls, but also has the ability to prototype MATCH function errors, which are then drawn in real time as the blue curve. Inspection of Fig. 1 reveals that the undocumented nonrandomness moves precinct selections from someplace to PCT 307 and several other precincts. The fact that the probability for uninvolved precincts stays the same is evident because all three curves are on top of each other on the left and right ends. Thus, both the MATCH function error and the green curve in Fig. 1 would lead to rectangular "corners" raising the possibility that the first causes the second. In Appendix 5, each time a value of ***lookup_array*** is changed by hand, the blue curve acquires a rectangular corner, validating the discussion above to some extent.

Thus, we cannot rule out a staff person with a proper spreadsheet and a proper precinct file made a manual change, such as sorting the precinct table, causing the running totals in ***lookup_array*** to be in nonascending order. Irrespective of whether a staff person actually did so, this should be enough for a nefarious actor to engineer a MATCH error that would appear inadvertent.

This error could be detected by software that validates operator input, such as verifying that the input files are sorted. However, Excel does not check input for consistency.

Election security

The United States government's definition of critical infrastructure covers audits [4]:

> *IT infrastructure and systems used to manage elections (such as the counting, auditing, and displaying of election results, and the post-election reporting to certify and validate results).*

The New Mexico and Federal governments post "rumor vs. reality" web pages describing election security. New Mexico's position is that auditing is one of multiple defenses against nefarious actors creating inaccurate election results [5]:

> *Every election in New Mexico uses one-hundred percent paper ballots. Using all paper ballots in every election allows for auditing and verification of automated vote counting systems because there is always a paper trail. That means that even if by some means a nefarious actor was able to penetrate one of our systems, we always have a physical backup of paper ballots that can be referred to in order to achieve the accurate result.*"

The Election Assistance Commission (EAC), an independent agency of the United States government, created a Voluntary Voting Systems Guidelines (VVSG) document [8] with 326 pages of "best practices" for running elections. Appendix 9 analyzes the 2022 random audit anomalies as described above against five of the voluntary recommendations, identifying why following those recommendations could have prevented the error.

The Federal Cybersecurity Infrastructure and Security Agency's (CISA's) "rumor vs. reality" web page [6] tracks New Mexico's in many ways, but makes the following statement that does not seem to be included in New Mexico's position [6]:

> [*i*]*dentifying and mitigating vulnerabilities is an important security practice.*

So, this document identifies a security incident that cannot be categorized as inadvertent or deliberate because Excel does not check operator input and other inconsistencies with applicable (but voluntary) guidelines [8]. First steps to prevent recurrence could be to (a) test software before use or (b) base election software on a system that validates operator input, which would require using something other than a spreadsheet.

Conclusions

This document shows a purportedly random audit in the 2022 general election was not actually random, invalidating the state's argument that elections are accurate even in presence of nefarious actors. For the reader's convenience, Fig. 6 shows how a reader can verify the nonrandomness with nothing more than a web browser.

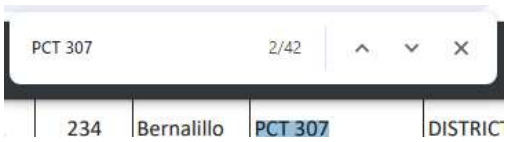


Fig 6. A simple process to validate nonrandomness. Open auditor's report [1] in a browser and search for "PCT 307" using the built in search function. The browser reports 42 matches, one in the table of precincts to be audited and 41 in rows documenting dice rolls.

When everything is working correctly, it is natural to see the EAC's voluntary guidelines [8] as optional. Although we do not have an indication that any race was called erroneously, the error may reduce public confidence. So, due to the error, making the voluntary guidelines into mandatory guidelines might look like a good idea.

Even though the guidelines were voluntary, we can conclude New Mexico and CISA make overstatements about election accuracy.

The New Mexico "rumor vs. reality" website [5] overstates the value of New Mexico's audits. This document provides evidence that a legally required random audit was nonrandom and actually a partial audit. New Mexico is not required to follow the voluntary federal requirements, but it is nonetheless an overstatement to claim that a partial audit ensures accuracy.

While the US government claims that identifying vulnerabilities is important [6], CISA does not include the mandatory reporting for elections that apply to security breaches on other types of critical infrastructure. CISA has world-class capabilities, but these capabilities are not applied to elections.

If the claims on the internet [5-6] are to become reality, the identifying entity should privately notify the entity responsible for the vulnerable systems, i.e. the state of New Mexico, allowing time for assessment and mitigation without tipping off nefarious actors. If there is no mitigation after a suitable interval, a possible next step would be to advocate for a mandatory version of something like VVSG [8].

References

[1] "STATE OF NEW MEXICO SECRETARY OF STATE AGREED UPON PROCEDURES REPORT." Accessed: December 24, 2023. [Online]. Available: go to https://www.sos.nm.gov/voting-and-elections/voter-information-portal-nmvote-org/election-audits-2/ then go to the line 2022 Post General Election… and click on open file on the right margin.

[2] Spreadsheet file name "NM2022Audit*.xls," a file intended to be available along side this document.

[3] "Voter turnout files Results last updated: 11/28/2023 1:11 PM MT." Accessed: December 2023 and January 2024. [Online]. Available: go to https://www.sos.nm.gov/voting-and-elections/election-results/ then click on 2022 or 2023, click on the first checkmark, click on STATEWIDE VOTER TURNOUT, click on EXPORT precinct level results for all counties and manually concatenate.

[4] "Election Security." Accessed: December 25, 2023. [Online]. Available https://www.cisa.gov/topics/election-security.

[5] "Rumor vs. Reality Fact checking misinformation about New Mexico's voting and elections" Accessed: December 24, 2023. [Online]. Available: https://www.sos.nm.gov/voting-and-elections/voter-information-portal-nmvote-org/rumor-vs-reality/.

[6] "Election Security Rumor vs. Reality." Accessed: December 25, 2023. [Online]. Available: go to https://www.cisa.gov/topics/election-security/rumor-vs-reality, expand post-election section.

[7] "Federal results." Accessed: January 10, 2024. [Online]. Available: go to https://www.sos.nm.gov/voting-and-elections/election-results/election-results-2022/, click on the first checkmark, click on "Federal," and click on "Export – precinct level."

[8] Election Assistance Commission. "Voluntary Voting System Guidelines VVSG 2.0.(2021)." *Election Assistance Commission: Washington, DC, USA (2023)*. Accessed: February 8, 2024. [Online]. Available https://www.eac.gov/sites/default/files/TestingCertification/Voluntary_Voting_System_Guidelines_Version_2_0.pdf.

Appendices 1-8

This document references a companion spreadsheet [2]. Appendices 1-8 each correspond to a tab or worksheet in accordance to the table below:

Tab/Appendix Name	**Description**
1. Overview	Descriptions of the worksheets or tabs
2. Audit Table A-3	Table A-3 from the auditors report
3. Voter Turnout	Voter turnout files combined into a single array for New Mexico
4. Jump Probability	The (low) probability of a jump over 42% of the precincts
5. Select	The selection process, with and without the erroneous behavior
6. Normalize	Analysis of the normalization formula used in the audit
7. Min Pct Size	The (erroneous) weighting factor and minimum precinct size
8. Sorted or Not	(Reserved)

Appendix 9

The 41 repetitions of PCT 307 and the 281-precinct jump could represent either failure of randomness or voter turnout files that (for example) claim over 66,536 ballots were cast in PCT 307.

Taking the options one at a time, section 9.4-B of the VVSG [8] requires a documentation of randomness, which could be the random precinct selection [8, p. 193]:

> *Voting systems that generate or rely on random or pseudo-random numbers for auditing purposes must document the method used to obtain the numbers and how the random numbers are used within the voting system.*

An alternative interpretation is that dice rolls in the range 0-9,999,999 were the source of randomness, which were converted to precincts by application logic – and there was an error is in the application logic. Section 3.1.1-D requires documentation of software, but it was not provided [8, p. 93]:

> *System overview documentation must include full identification of all software and firmware items, indicating items that were:*
>
> *1. written in-house including subcontracted;*
>
> *2. procured as COTS, unmodified; and*
>
> *3. procured as COTS and modified, including descriptions of the modifications to the software or firmware and to the default configuration options.*

The rhetorical question is whether somebody would write either form of documentation and fail to notice that it might overweight a precinct by 120 times. Even if the person writing the documentation failed to notice the vulnerability, the person would be a first point of contact in the even of an error.

The second option would be failure of the implantation. The audit report [1] mentioned a spreadsheet, but there are guidelines in section 2.1-A for programming languages based on features that reduce the likelihood of errors and security vulnerabilities. Spreadsheets

use a dependency graph for control, so a spreadsheet will not meet the requirements [8. p. 67]:

> *Application logic must be produced in a high-level programming language that has all of the following control constructs:*
>
> *1. sequence;*
>
> *2. loop with exit condition (for example, for, while, or do-loops);*
>
> *3. if/then/else conditional;*
>
> *4. case conditional; and*
>
> *5. block-structured exception handling (for example, try/throw/catch).*

The 41 repetitions of PCT 307 are consistent with correct application logic, but a voter turnout file reporting that 66,543 ballot cast in that precinct. This raises the question of whether the voter turnout files were corrupt or counterfeit. The relevant recommendation is [8, p. 79]:

> *2.5.1-D – Prevent tampering with data*
>
> *All voting devices must prevent access to or manipulation of configuration data, vote data, or audit records (for example, by physically tampering with the medium or mechanism containing the data, by other programs on the system, or by faulty code) except where this access is necessary to conduct the voting process.*

The two guidelines above were not followed by the organization when they chose a spreadsheet for implementation. Had they followed either of the two guidelines above, they might have spotted by reading the high-level programming codes – either the code for MATCH (or equivalent) or the code for checking input. Yet, by using a spreadsheet, the error could lurk in the expressions within in cells that are not ordinarily displayed or "cut-and-pasting" data in arrays that are not checked for data consistency.

The author's organization attempted to get the spreadsheet from which table A-3 in [1] was generated, but the New Mexico government did not honor the request. However, the guidelines [2] include provisions for inspecting an election system [8, p. 109]:

> 3.2-B – Minimum properties included in the setup inspection process
>
> Setup inspection process documentation must at a minimum include:
>
> 1. inspecting voting system software;
>
> 2. inspecting storage locations that hold election information that changes during an election;
>
> 3. inspecting other voting device properties; and
>
> 4. executing logic and accuracy testing related to readiness of use in an election.

Had the previous guideline been followed, the author of this document might have identified the error in time to be corrected before it became an issue affecting public confidence.