New Hampshire
SB 43 Forensic Audit Report

Harri Hursti, Mark Lindeman, Philip B. Stark

July 2021

Executive Summary

This forensic audit addressed the unusual numerical disparity between the originally reported results for the November 2020 contest for New Hampshire State Representative in Rockingham County District 7 (the town of Windham) and the official hand recount results for that contest. The recount did not change the outcome of the election. (Official hand recounts are common in New Hampshire. For instance, there were 16 recounts requested and conducted following the 2020 General Election, and 7 following the 2020 State Primary. New Hampshire's elections are administered by 320 towns and wards,[1] of which 197 use voting machines[2] and 123 count their votes by hand.)

This audit found the primary root cause of the discrepancy to be folds through vote targets on some absentee ballots, largely resulting from using a machine to fold absentee ballots. That folding machine, leased by the town for other purposes, did not fold ballots along the score lines between vote targets, where the ballots were designed to be folded. Instead, it often folded ballots through vote targets in the State Representative contest, which the scanners interpreted as vote attempts a substantial fraction of the time: we estimate that about 44 percent of folds through targets were interpreted as marked ovals in November, and experiments conducted during the audit exhibited rates of about 20 percent to more than 72 percent. The problem may have been exacerbated by inadequate maintenance that allowed a build-up of white powder inside the scanners, obstructing the lenses. Folds through vote targets also affected the gubernatorial contest, but less frequently. We also found, as is generally the case in recounts, that the hand count was able to ascertain voter intent in some instances where voters marked ballots incorrectly, leading the scanners to misread valid votes as undervotes or overvotes. No malware was found on any of the tabulators. Forensic examination of a random sample of paper ballots revealed nothing anomalous about the paper, printing, or marking.

The folding machine problem notwithstanding, for the most part our audit found the Windham election to have been well run under challenging circumstances, and we confirmed the number of ballots cast to within two ballots. Inevitably, close scrutiny of election procedures identified some errors and concerns that may inspire procedural improvements in Windham and elsewhere in New Hampshire.

---

[1] https://sos.nh.gov/media/c30apdn2/towns-and-wards-as-districted-for-election-purposes2015.pdf
[2] https://sos.nh.gov/media/wmzh1ob1/voting-machines-may-2020.pdf

Scope

Authorized scope and background

The New Hampshire legislature mandated this audit via SB 43[3], in reaction to an unusual disparity between the originally reported results of the State Representative, Rockingham County District 7 contest and the results of a state recount. Rockingham County District 7 is coterminous with the town of Windham, which elects four members to the state's House of Representatives. Briefly, the original results and the state recount agreed that Republican candidates had won Windham's four seats. However, in the recount, each of the Republican candidates gained just under 300 votes; the Democratic candidate who had requested the recount, Kristi St. Laurent, lost 99 votes. Fundamentally, the audit aimed to find the root causes of these discrepancies and to determine which count, if either, was correct.

Accordingly, the scope of this forensic audit does not include a comprehensive security review of the system, which would require additional information and resources, including access to the source code. As part of the machine audit, we verified the integrity of the election equipment and inspected the software and configuration for anomalies and irregularities; we did not assess the underlying security properties of the software and hardware, Windham's procedures for machine and ballot custody (beyond reviewing the documents provided to us), the accuracy of eligibility determinations, and similar matters.

In April, 2021, the New Hampshire legislature enacted SB 43, which requires:

> 2:1 Purpose. Notwithstanding any provisions of law to the contrary, this act authorizes and directs an audit of the ballot counting machines and their memory cards and the hand tabulations of ballots regarding the general election on November 3, 2020 in Windham, New Hampshire of Rockingham County district 7 house of representatives for the purpose of determining the accuracy of the ballot counting devices, the process of hand tallying, and the process of vote tabulation and certification of races.
>
> …
>
> 2:3 Audit Process.
>
> I. The audit process shall be determined by the forensic election audit team formed pursuant to section 2, such that there is a determination as to whether the machine counting devices and memory cards functioned properly on November 3, 2020, and whether the number of ballots tallied by hand in Windham and those tallied by hand by the secretary of state during the recount on November 12, 2020 were the same as the number of ballots cast.

---

3 http://www.gencourt.state.nh.us/bill_status/billText.aspx?sy=2021&id=396&txtFormat=pdf&v=current

II. At a minimum the audit process referenced in paragraph 1 shall include the following:

(a) All ballots shall be run through all the ballot counting machines used by the town of Windham on November 3, 2020.

(b) Determine the total ballots cast, the total ballots counted, and total ballots received from the secretary of state.

(c) A hand tallying of all ballots cast in Windham in the Rockingham County district 7 State Representative race, the race for governor, and the race for United States senator.

…

2:4 Forensic Election Audit Team; Report Required. Within 45 days of the conclusion of the audit, the forensic election audit team shall produce a report which shall include, but not be limited to, a finding as to whether the ballot counting machines and memory cards accurately counted the ballots subject to the audit, whether hand tabulation procedures followed by the town of Windham at the general election and hand tabulation procedures followed by the secretary of state at the recount may have contributed to variances reported at the recount done for the Rockingham County district 7 house of representatives race in Windham, and recommendations as to what improvements to the machine processing and tabulation processes might be considered in the future. The report shall be provided to the secretary of state, the town of Windham, and the ballot law commission. The report shall be made available to the public forthwith.

We performed these duties in the order the law specified. However, this report addresses them in a different order to emphasize that the trustworthiness of an election outcome starts with the trustworthiness of the paper trail.

Number of ballots cast

To check the number of ballots cast, we performed ballot accounting and pollbook reconciliation, along with a check of all chain-of-custody information we are aware of. The primary documentation includes:

- Voter checklist (paper pollbook) listing registered voters who checked in and those who did not
- AccuVote report tapes
- Election night hand count documentation
- Moderator worksheet and reported ballot and vote totals
- Ballot reconciliation documents, further detailed below

We also checked supporting physical evidence, including spoiled, rejected, and unused ballots and absentee affidavit requests and envelopes.

The officially reported number of ballots cast was 10,006. Other sources were consistent with that figure, with small discrepancies detailed below.

Number of ballots received; hand tally of votes

All election material containers received from the Secretary of State were opened. Each cast ballot found therein was assigned to a *scan batch*; assigned a unique ballot ID number; and ultimately tallied by five-person teams. The process created a redundant record of every cast ballot in the audit and the votes found thereupon in the three audited contests.

This process enumerated 10,004 ballots. The cause of the two-ballot difference between the original (10,006) and audit (10,004) totals has not been determined. The state recount procedures did not provide a total ballot count. The hand count totals for the State Representative contest were close to the recount totals but far from the election night official totals. The hand count totals for governor and U.S. senator were similar to the official totals, but the hand count found more valid votes, particularly in the governor's contest.

Retabulation by all AccuVote machines

All ballots that the AccuVote machines could read were scanned into each of the four machines, grouped by scan batch. A total of 9,926 ballots were scanned, equal to the total number of ballots reported by the four tabulator tapes from election night. As discussed below, the audit machine totals for most contests were similar to those from election night. For the State Representative contest, the candidate totals varied across machines, and generally were between the election night totals and (both sets of) hand count totals.

The following elements of the audit design were not required by SB43. We undertook them to address hypotheses about the AccuVotes' causal role in the discrepancies – including the possibility of malicious tampering – and to address certain other expressed concerns about the election.

Forensic electronic investigation of memory cards and machines

After all scannable ballots had been rescanned , the AccuVotes' removable memory cards were digitally copied, as was the program data on each machine. After the machine count was completed, the voting equipment was forensically examined:

1) We verified that the telephone modems had been removed and that all cables connecting to the external ports had been cut or removed.
2) EPROM chips were removed from the motherboard and forensic images of the contents were made; those were compared with a forensic image of the contents of the EPROM from a reference machine from the Secretary of State.
3) A forensic image was produced of the contents of each memory card.

4) Programming data on the EPROMs were verified to be identical in all machines used in Windham and also identical to the EPROMs from the reference machine (not used in elections) provided by the Secretary of State's office.
5) The programming on the EPROMs was reviewed using a reverse engineering tool, Ghidra, to scan for code that might contain a hypothetical malicious "algorithm" or malware implant.
6) Election integrity segments of the memory cards were confirmed to contain identical ballot data, contest data, and candidate data (including the locations of vote targets on the ballots).
7) Expected and unexpected differences between the contents of the memory cards were identified and examined.

We also physically examined the machines to check their condition, and reviewed the activity logs that record when machines, memory cards, and canvas storage bags were opened and resealed.

Ballot paper forensics

Ballots were forensically reviewed (using a microscope, micrometer, and UV light) to determine whether:

1) Ballots were genuine printed ballots (not laser printed, photocopied, etc.)
2) Ballot paper type and quality were as expected including thickness from 3 parts of the paper and UV luminance
3) Ballots were handmarked
4) The fold (if any) was manual or machine-made

Ballots for the audit were selected by 3 means:

1) Hand-count teams were asked to flag any ballot which was determined to be suspicious for any reason. Every ballot was examined by a team of 5 people and no ballots were flagged as suspicious.
2) A box of ballots was randomly selected by a series of coin tosses, and ballots were randomly selected from that box.
3) To address claims in social media that the selection of the random box was rigged, we asked the audience to select a box of their choice for audit. The audience unanimously picked an additional box for examination.

Conduct of the audit

As required by SB43, the audit was directed by a three-person "forensic election audit team," the authors of this report. Harri Hursti was the designee of the Secretary of State and Attorney General. Mark Lindeman was the designee of the Town of Windham. Hursti and Lindeman jointly selected Philip B. Stark as the third member of the team.

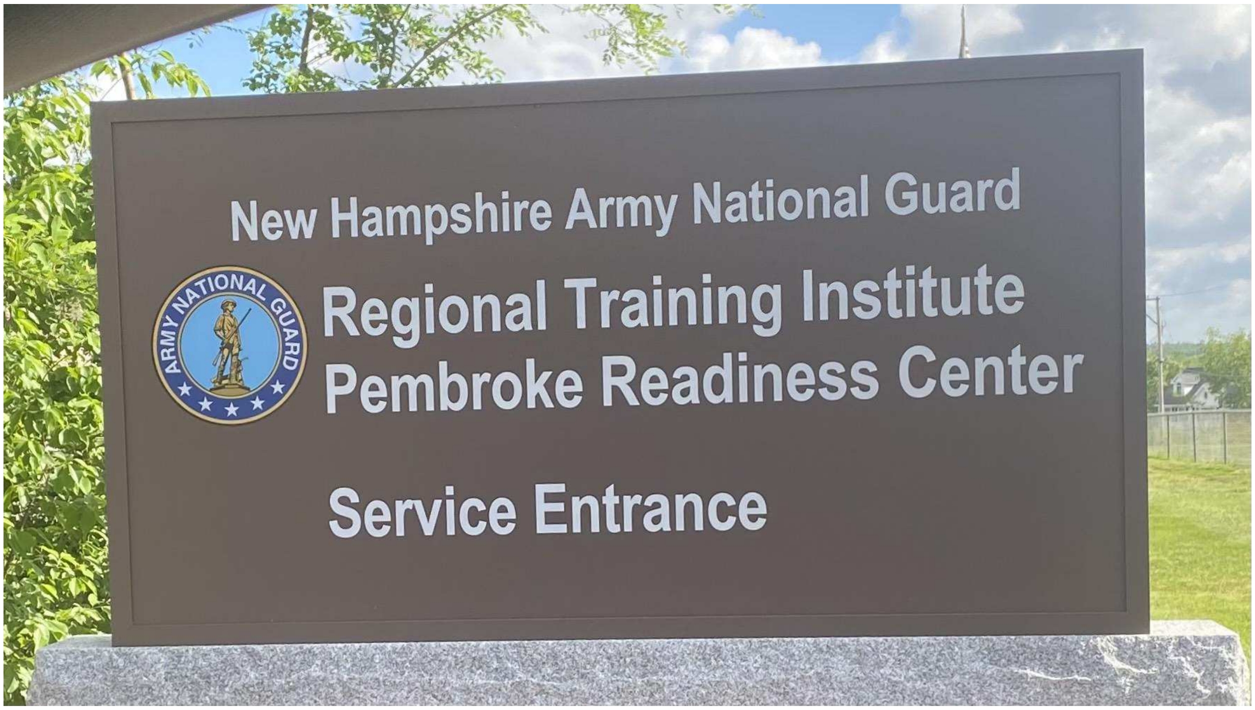
The in-person audit was conducted at the Edward Cross Training Complex, a National Guard facility in Pembroke, NH, just outside Concord. This facility was selected because it was convenient, readily secured, and provided a suitably large room to accommodate audit workers and observers safely. The site was under continuous (24/7) observation by state police officers throughout the time that election materials and voting equipment were on-site.

Most of the physical work of the audit – including the handling, retabulation, and hand-tallying of the cast ballots – was done by volunteers who are sworn election officials in New Hampshire cities and towns. (No officials from Windham were allowed to participate in the audit.) This audit would not have been feasible without the generosity and professionalism of these public servants, whose names are listed in Appendices A and B.

Representatives from the offices of the Secretary of State and Department of Justice were greatly helpful before and throughout the audit. Secretary of State Bill Gardner, Deputy Secretary of State Dave Scanlan, and Senior Elections Specialist Anthony Stevens all patiently answered our questions about ballot printing, recount procedures, and other topics. Associate Attorney General Anne Edwards, Assistant Attorney General Nicholas Chong Yen, Paralegal Jill Tekin, Director of Communications Kate Giaquinto, and Chief Investigator Richard Tracy provided indispensable logistical support.

We also thank the staff of the two companies that provided the livestream, Events United and Edify Multimedia Group; the state police officers who provided security throughout the audit; and the New Hampshire National Guard for the use of their facility. We also received remote assistance from CropScan Inc. in restoring their device to working order. Thanks also to Chrissa LaPorte for invaluable research assistance.

Transparency and security efforts



Sign at the entrance to the Edward Cross Training Complex

One of the main design drivers of the audit process was transparency both for in-person observers and for people monitoring the livestream. We also emphasized security of the ballots, other election materials, and voting machines. Here we detail some transparency and security measures.

1) Preparation and wind-down days

a) Transport of voting machines from Windham to the location was recorded.
b) Transport of ballots from Archives to the location was recorded.
c) Signing of all chain-of-custody documents was recorded and done in the presence of the public observers.
d) Transport of voting machines from the location back to Windham was recorded.
e) Transport of ballots from location back to the Archives was recorded.
f) Transports were guarded by local on-duty law enforcement.

Audit was conducted in a stand-alone building located inside a military compound. The building was surrounded by an easy-to-monitor perimeter.

2) Location, premises, chain of custody, and security transparency

a) The audit was conducted in a Regional Training Institute building located inside the New Hampshire Army National Guard Pembroke Readiness Center.
b) Additional security support on the base gate and outside of the building was provided by New Hampshire State Police. The building perimeter was protected in person 24/7 by state troopers.
c) Inside the building, additional security was provided by New Hampshire Department of Justice investigators.
d) Building access control and monitoring systems were provided by the New Hampshire Army National Guard and programmed to permit access to the building by a limited number of access cards. All use of the access cards was logged by the National Guard.
e) Security-sensitive materials, such as spare seals, were removed from the room each night and given to the State Trooper on duty for overnight safekeeping. The State Trooper on duty did not have an access card to enter the building, but had a complete view into the working room through large windows.
f) A livestream of the room, with audio, was broadcast 24/7.[4] Multiple physical clocks were positioned strategically in the room and visible in the livestreams.
g) Security seals of voting equipment were publicly inspected multiple times during the audit; the inspections were livestreamed.
h) Material under chain-of-custody was placed closest to the windows, allowing those outside of the room a clear view. In particular, the State Trooper on duty

[4] The livestream was interrupted several times as a result of technical difficulties. The largest gap occurred late on May 12, when an attempt to remotely refresh the feed as required by the streaming software failed, requiring a manual reboot of the system. The vendor was not permitted to enter the room without a representative of the Department of Justice. It took over an hour to resolve the problem. During this interruption, the room and its contents were secure, monitored continuously by the State Trooper on duty, who testified that no one entered or left the building. Reviews of the card key access logs also confirmed that no one accessed the building during those intervals. To our knowledge, no in-person or remote observer claimed that any box had been moved overnight.

for overnight watch had an unobscured view of the stored ballots and voting equipment.

i) Inventory of ballots, boxes, and other election related material was publicly inspected daily and livestreamed.

A panoramic view of the room taken from the far corner of the observation area during the hand recount phase of the audit. Screens on the perimeter tables were providing a close-up view of the documents on the hand count tables.

Cameras were readjusted to provide views from all angles, including over-the-shoulder in high detail and zoomed in as needed during the machine hardware audit.

3) Accessibility

a) Due to the ongoing Coronavirus pandemic, the number of in-person observers was limited and seats were socially distanced.

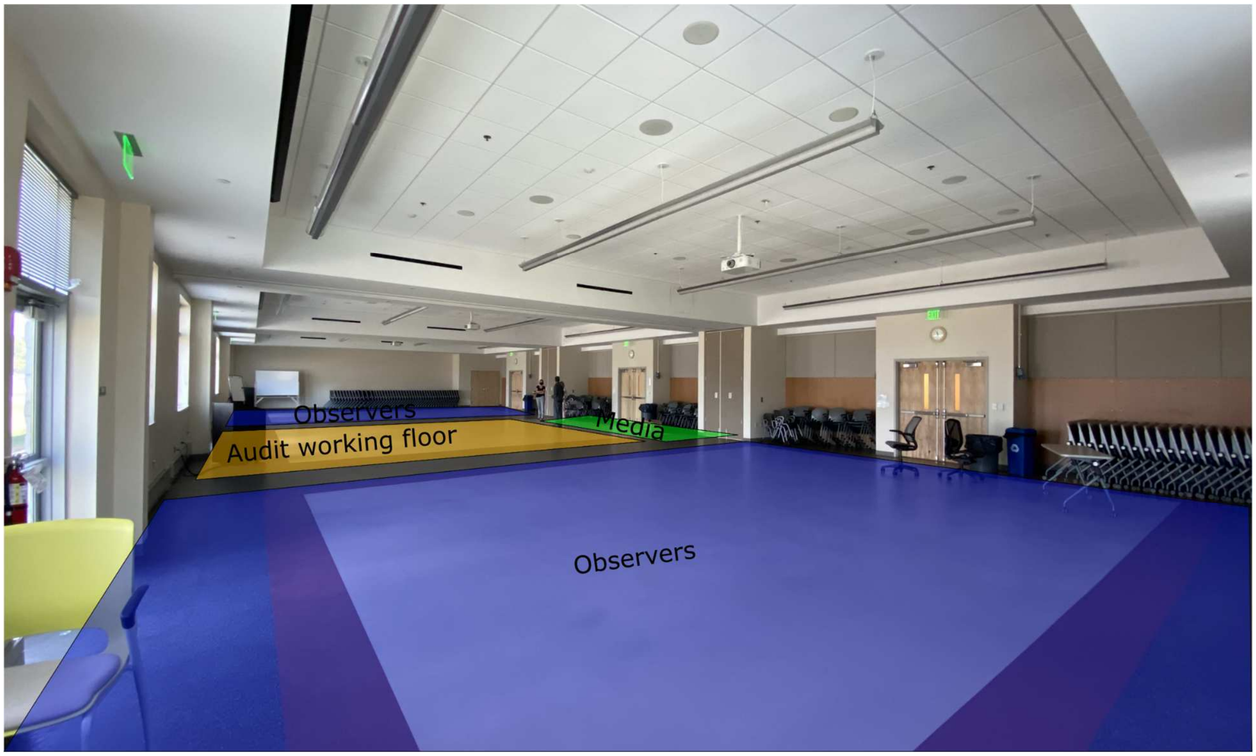
b) Half the observer spots were allocated to the Town of Windham to appoint; the other half were allocated to New Hampshire voters, by application.

c) A separate area was designated for members of media to cover the event.
d) Monitors and Observers were encouraged to bring personal cameras and were allowed to take photographs and stream video freely.
e) Items of interest were brought to the observers for them to take close-up pictures.
f) Official video recordings were done in Full-HD resolution and the composite livestream was broadcast in Full-HD.
g) Camera feeds were projected to the in-person audience on 3 large projector screens and 2 large flat screen projectors.
h) During the hand count, each ballot and the tally sheets were placed under overhead document cameras and broadcast to multiple screens on each hand count tables, allowing in-person observers and the livestream audience to see each ballot being tallied and hear how each vote was called.
i) The audience was able to submit questions, which were answered at least 3 times a day (many questions were answered immediately):
    i) Start of the day
    ii) Lunch break
    iii) Wrap-up of the day
j) When it was impossible to bring items of interest to the perimeter of the secure audit area to allow monitors and members of media to take close-up pictures, we offered to take their cameras into the secure audit area and take pictures of their liking with their equipment.

4) Process presentations and daily briefs

a) Before the audit started, the complete upcoming multi-phase process was outlined, and explained in detail to the observers and the livestream.
b) Presentations included:
    i) Sharing floor plans and workflow for all phases of the audit
    ii) Discussing considerations, choices, and rationales, for the process decisions (e.g., order of operations, roles, and camera locations)
c) At the start of each day:
    i) A recap the activities of the previous day and reminder of the overall structure of the process was presented.
    ii) The current phase was explained.
    iii) A detailed explanation of all activities planned for the day and detailed description of each sub-process to be observed were presented.
    iv) An estimated timeline for the rest of the audit process was given.
    v) Any changes were announced.
    vi) Time was allocated for Q&A.
d) For observability and clarity, only one kind of activity took place in the working area at any given time. Each time the types of activity changed, an announcement was made to inform observers and monitors.
e) When any exceptional event occurred, such as a mechanical malfunction, the event was announced, and the livestream was adjusted to cover the event.

f) Each day we asked the election official volunteers to state their political affiliation (Republican Party, Democratic Party or Unaffiliated). We also reminded the audience that all volunteers are sworn, non-partisan election officials.



Panoramic picture of the audit venue. The two blue areas and the yellow area are all roughly equal in size. The media area consisted of one long table for members of the media to set up their equipment. The small empty space beyond the media area was for AV equipment for the official recording and livestream.

5) Floor plan

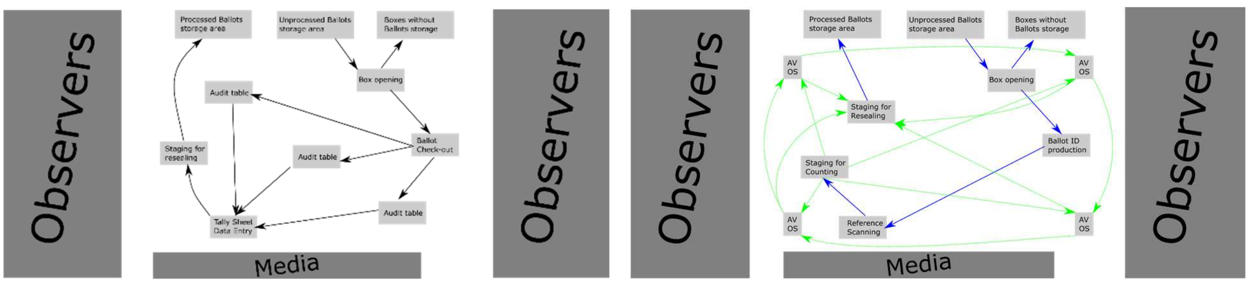
The layout was designed to keep materials safe, to allow the audit to be conducted efficiently, and to maximize the observability of all audit processes:

a) We allowed observers to be as close to activities as possible and to capture footage with their own devices.
b) We used large display screens and monitors to provide additional visibility.
c) We situated the audit working area between the observation areas, to allow as many observers as possible to be close to the action.
   i) Activities were planned to give both sides of the observation area comparable close-up views of the activities.
   ii) All items of special interest, such as result tapes and audit report tapes, were rotated to both sides of the observation area for picture-taking.
d) The media area was on a third side of the working area. To maximize visibility of materials under chain of custody, those were placed next to the wall on the

opposite side of the media space. This provided the best overall visibility of all activities for members of the press.

e) We reorganized the floor plan for each phase of the audit to maximize the observability of the operations by bringing the activities closest to the observer and media areas and ensuring unobstructed camera views for the official recording and livestream.

f) All material under chain of custody was stored away from activity areas, allowing unobscured views of the materials from everywhere in the room. Sealed boxes of voted ballots were stored on a single table.



Workflow schematics for the machine count (left) and hand count (right)

6) Workflow, key design parameters

a) Only one type of activity took place in the working area at any given time, prioritizing clarity and observability over speed or efficiency.
   i) This allowed the four official video cameras to capture all the activities in the room.
   ii) It increased the predictability of processes and made it easier to have all materials under control during the lunch break and at the end of each day.
   iii) It allowed the activities to be organized in a way that kept the most important action as close as possible to the observers.

b) We managed inventory and flow control over the materials subject to chain of custody to make those materials as easy as possible for the audience to track visually.
   i) Only a limited number of ballots were at any given time unsealed out of the boxes.
   ii) Only a limited number of ballots were on the processing tables at any time.
   iii) Only workers who were clearly identifiable (wearing bright yellow vests) were allowed to move ballots from one station to another.

c) When activities changed, there was a clear demarcation.
   i) The current activity was finalized.
   ii) The transition was announced.
   iii) The floor plan was set up for the next activity.
   iv) Details of the next workflow were (re)announced.
   v) Instructions were given to the volunteers as needed.
   vi) The next workflow began.

d) Movement of sensitive materials under chain-of-custody was minimized.
   i) To-be-processed and already processed materials were kept physically separate.
   ii) Voted ballots and other voting materials material were kept physically separate (on different tables).

7) Audit working area security

a) Only the auditors, volunteer sworn New Hampshire election officials, videographers, law enforcement, and staff of the Attorney General's office were permitted to be in the audit working area.
b) Aside from ballot paper forensics and machine forensics conducted in the final days of the audit (after the electronic retabulation and the hand tally), only volunteer sworn New Hampshire election officials operated voting machines or handled voted ballots.
c) Ballots were always kept sealed and under surveillance when unattended.
d) Only designated "runners" with brightly colored vests were allowed to carry ballots from station to station.
e) No pens with blue or black ink were allowed in the audit space.
f) No personal articles were allowed near the counting tables.
g) No food or drink was allowed at the counting tables.
h) No opaque garbage cans or garbage bags were allowed in the working area.

8) Livestreaming

a) Livestreaming was done using 4 Full-HD recording cameras, producing a Full-HD composite broadcast picture with composite sound.
   i) All work tables had microphones to capture discussions.
   ii) Some of the cameras were remote-controlled allowing quick adjustment of camera angle and zoom to capture activities of interest without interrupting the audit or the stream.
b) All cameras were movable to allow flexible capture of all activities.
c) Audio:
   i) All work tables had microphones to capture conversations.
   ii) Portable microphones were used to capture audio away from the working tables, including periodic announcements.
d) All raw recorded video footage is available[5] online.
e) We encouraged observers and members of the media to broadcast their own streams, so many redundant and complementary streams were broadcast.
f) During the hand count, two video monitors were placed side by side at each counting table. Document cameras displayed each ballot on one monitor and one of the two tally sheets on the other. Three of the four livestream channels focused on these monitors, allowing remote observers to follow the audit in real time. When a tally sheet was completed, it and the second tally sheet were displayed on

[5] https://sadojauditlogs.z13.web.core.windows.net/

camera for the public to confirm that the two matched, before the data was publicly keyed into the tally spreadsheet.

g) The audit team had no role in selecting or contracting the recording and streaming services vendors. The audit team never had possession or control over the recordings.

9) Timely posting of audit documents and other evidence

a) Documents created in the audit process were published online[6] daily and in as timely and orderly fashion as possible.
   i) Documents were posted on the Department of Justice website for the audit on 13 of the audit days.
   ii) There were 9 general posts and 60 separate daily posts.
   iii) Each post contained from one to over a hundred individual documents.

b) Upon request from the observers, pictures and other material were published essentially immediately.

10) Live documents online

a) During hand count, observers could witness the (redundant) data entry from the paper tally sheets into an online spreadsheet in real time[7] to confirm that the data were entered accurately from both tally sheets for each tally batch.

b) During the forensic audit of the paper ballots, monitors could witness the data entry of the results into a separate tab of the online spreadsheet.

[6] https://www.doj.nh.gov/sb43/index.htm

[7] https://docs.google.com/spreadsheets/d/1vPE7prlV3ECLbhqAfuXshTF1u0SX6TDHb5L9mRAflc8/edit#gid=545963302

Workflow and order of operations

1) The first day of the audit was used to set up the venue and the recording, projecting, and broadcasting technology.

2) We provided introductory comments and presented the audit process to the in-person and livestream audience, followed by an extensive pre-audit question & answer session.

3) We received the materials needed for the audit (their transport to the audit site was video recorded) and signed the chain-of-custody documents for the materials:
   a) election material containers (ballots and other documentation) from the State Archives
   b) AccuVote scanners and ballot boxes from the town of Windham

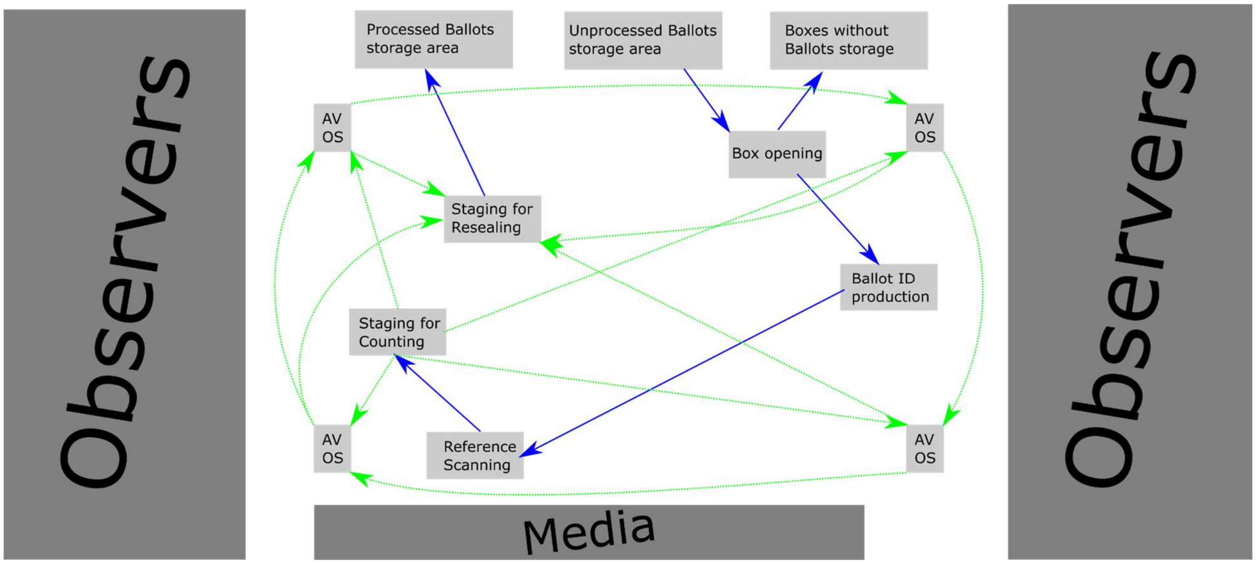
4) We displayed each box or container on the livestream, showing all sides of each item.

5) We verified that the ballot boxes for the voting machines were empty.

6) We checked seals on all voting machines and reconciled the seal numbers against the chain-of-custody logs, including seals on
   a) memory cards
   b) ports
   c) cases
   d) canvas storage bags (one per machine)

7) Volunteers (sworn NH election officials) printed Audit Log tapes for each voting machine.

8) Volunteers prepared for the machine recount:
   a) Reset the mode of each memory card from Post-Election to Pre-Election
   b) Set the dates on the AccuVote machines to election night to simulate the actual election as accurately as possible
   c) Zeroed the vote counters, per NH procedure
   d) Printed "zero tapes" per NH procedure, to confirm the counters had been reset



Ballot flow in the room during the machine recount process. To facilitate observability, the ballot movements shown in blue arrows and green arrows alternated and never happened at the same time.

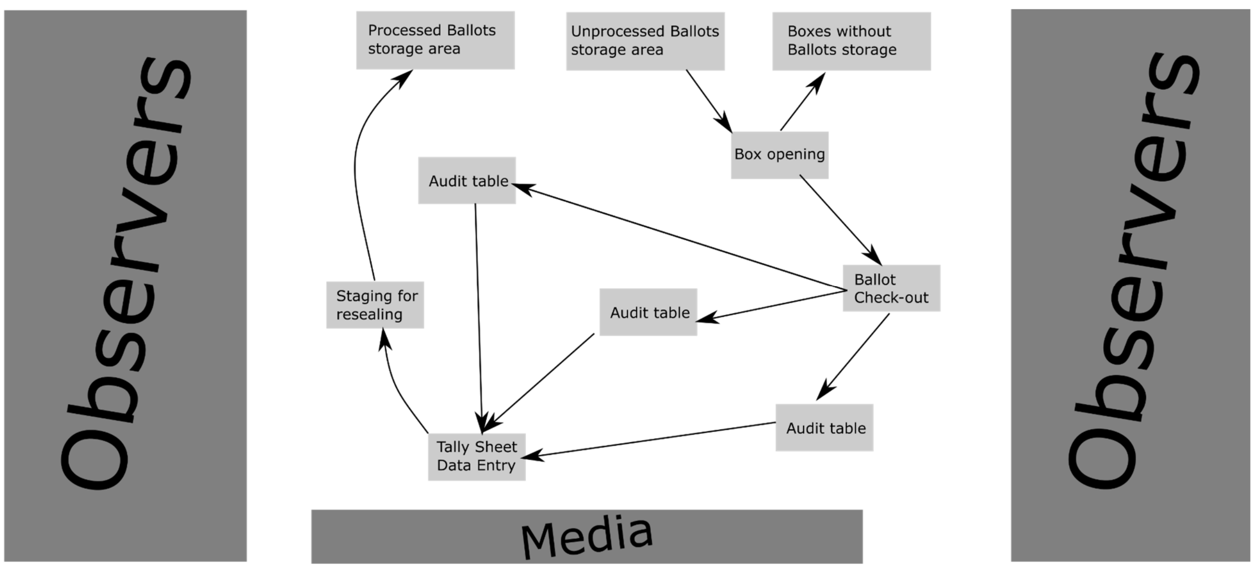
9) Locating all cast ballots:
   a) Volunteers opened each election material container and determined its contents: cast ballots, other election materials, or a combination.
   b) Cast ballots immediately proceeded to the next step.
   c) Other election materials were reboxed for further scrutiny at a later step. (One box contained a combination of cast ballots and other election materials, so a new box was created for the other election materials at this step.)

10) Creating scan batches and adding ballot IDs:
   a) Volunteers divided the ballots in each box into one or more "scan batches." Each scan batch had an orange scan batch cover sheet. (Most scan batches contained between 150 and 300 ballots.)
   b) On the bottom of the back of each ballot, volunteers wrote a unique ballot ID number in red ink. Bates stamps designated for this purpose broke down, so most ballot IDs were hand-written by the volunteers.

11) Reference scans:
   a) Using one of two commercial scanners, volunteers created a 600 or 300 dpi 24 bpp color scan of every ballot in each scan batch.
   b) Images were stored with lossless compression as Portable Network Graphics (PNG) format files.

12) AccuVote tabulation:
   a) Two-person teams (one team per AccuVote scanner) fed each scan batch through each of the AccuVotes.
   b) After each scan batch had been fed through all four AccuVotes, it was reboxed (with its cover sheet) to await the hand tally.
   c) After all readable ballots are scanned through all four machines:
      i) Volunteers printed the Results Tapes in short and long format.
      ii) Volunteers printed Audit Log tapes.
      iii) Those tapes were immediately presented to the public observers to inspect and photograph. Tapes were also slowly scrolled into the livestream.

13) After scanning, the batches were moved to the staging station for re-boxing and resealing for storage until they were hand-tallied.



Ballot flow in the room during the hand count process.

14) Hand-tallying of cast ballots:
   a) There were three 5-person tally teams, each comprised of a multi-partisan mix of sworn New Hampshire election officials:
      i) a caller who read the ballot IDs and votes
      ii) a checker who confirmed the caller
      iii) two talliers who independently recorded the ballot IDs and votes on tally sheets that have room for up to 25 ballots
      iv) a flagger who noted anything special about a ballot, including
         (1) whether it was marked in a manner the AccuVote was likely to misread because of faulty marks, ink color, voter intent rules for hand counts, folds through vote targets, or other reasons

(2) if any team member found the ballot suspicious for any reason, for instance, if the marks appeared to have been printed by machine or the paper did not appear to be proper ballot stock

(Detailed instructions for this process are in Appendix D.)

b) Each tally team processed one scan batch at a time. Designated runners would open sealed boxes of ballots and deliver a scan batch to a tally table.

c) Ballots were tabulated in "tally batches" of up to 25 ballots (the limit of a tally sheet; see Appendix D for a sample tally sheet).

i) When each pair of tally sheets was completed, the talliers independently reckoned and compared their column totals. Any discrepancies were checked against the ballots before proceeding.

ii) When the totals agreed, the sheets were displayed side by side on camera.

iii) A designated runner then took the completed tally sheets and flagger log sheet(s) to the data entry table.

d) After each scan batch was tallied, a designated runner would deliver the tabulated ballots and cover sheet to a separate staging station to be reboxed and resealed.

15) Hand count data entry and documentation:

a) The two-person data entry team independently entered each tally sheet on a separate tab of a Google Sheet.

i) Each data entry volunteer had an individual login, to ensure that the provenance of any entry in the sheet could be traced. (The volunteers were instructed to change the randomly generated initial password to a private password.)

ii) The public could watch the data entry in real time to confirm that the entries matched the previously displayed tally sheet and that the entries for the two tally sheets agreed.

iii) A third tab in the Google Sheet compared the data in the two tabs to help locate keying errors.[8]

b) Tally sheets, flagger logs, and scan batch cover sheets were scanned and published each night on the Department of Justice webpage that hosted the livestream.

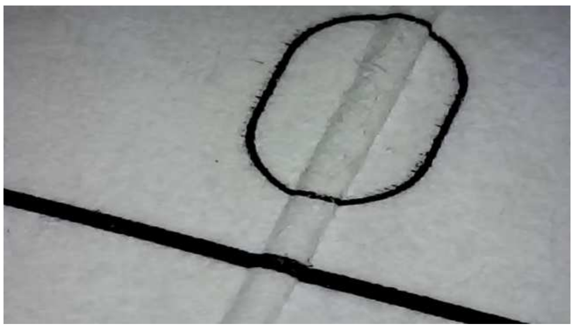
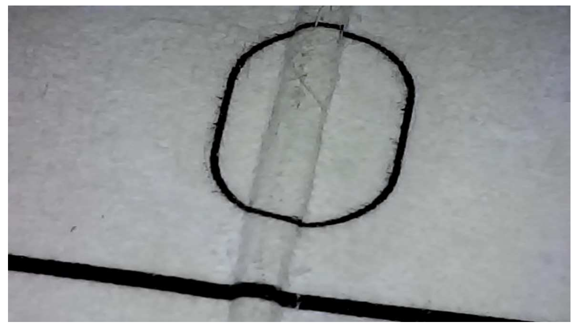
---

[8] The data entry spreadsheet can be found at https://docs.google.com/spreadsheets/d/1vPE7prlV3ECLbhqAfuXshTF1u0SX6TDHb5L9mRAflc8/. A fourth tab in this spreadsheet was created to report the ballot inspection described below.

Due to a problem in Google Sheets, the comparison tab sometimes displays apparent differences, highlighted in red, between values that are in fact are equal.

16) Using computer vision algorithms, we processed the reference images to superpose all ballot images into one composite image per ballot side. The composite image of the front side showed a high concentration of folds through St. Laurent's vote target.

17) Based on findings from earlier stages of the audit,[9] we created four test decks to investigate the impact of folds on scanner counts, as well as whether contests without folds through vote targets would be tabulated accurately. Volunteer New Hampshire election officials operated the AccuVotes for these experiments.

Microscopic photos of an unused absentee ballot folded in November, 2020 (left) and an unused absentee ballot folded during the audit using the folding machine (right).

18) Physical analysis of selected cast ballots:

   a) Randomly selected ballots were scrutinized using a microscope, micrometer, and ultraviolet light (by request).
   b) The inspection evaluated whether the ballots were genuine ballot paper, printed in a print shop, and hand-marked; no anomalies were found.

19) Volunteers reopened the boxes containing other election materials (other than cast ballots) to

   a) double-check for cast ballots
   b) count other categories of ballots
   c) count absentee affidavit envelopes

20) AccuVote inspection and forensic audit of digital artifacts:

   a) Each AccuVote scanner was opened and inspected.
   b) All memory cards were removed and imaged (digitally copied).
   c) All EPROM chips were imaged, along with the EPROM from a reference machine provided by the secretary of state's office.

---

[9] This evidence included the hand tally results; comparisons of the machine recount results with both the original results and the hand tally results; the composite image and tally team reports of many folds through St. Laurent's vote targets, as documented in the flagger logs.

d) A fiber optic microscope was used to inspect the inside of the readers for dust.

21) At this juncture, the audit team released the election materials and voting equipment, again signing chain-of-custody forms. The remaining steps, begun during the in-person audit, were completed later.

22) Ballot and voter reconciliation:

a) The digital copy of the voter checklist (paper pollbook) was closely reviewed to obtain an independent count of voters marked as having voted, in person or by absentee ballot.
b) Other digital documentation, such as the twelve election-day ballot clerks' worksheets on ballots received and ballots remaining, was closely reviewed, as were the scan batch cover sheets, the counts obtained in the review of other election materials, and other audit records,

23) The tally flagger logs were closely reviewed for additional evidence on possible causes of discrepancies between the election night results and the audit hand counts.

24) The reference images were processed using computer vision algorithms to identify ballots with folds through vote targets and count those likely to add or subtract votes from the State Representative and gubernatorial contests.

25) A decommissioned voting machine from Vermont was used to thoroughly disassemble the scanner unit and to understand a suitable cleaning strategy for the scanner read-head lenses.

Machine count preparations

After taking custody of the cast ballots, other election materials, voting machines and their ballot boxes, we carefully inspected the machine seals and chain-of-custody documentation, then prepared the machines for use in the audit. Here we describe the AccuVote scanners, the seal and documentation review, and preparations, including our decision to "zero out" the memory cards and not to copy data from the cards and machines before starting the machine count.

Hardware overview

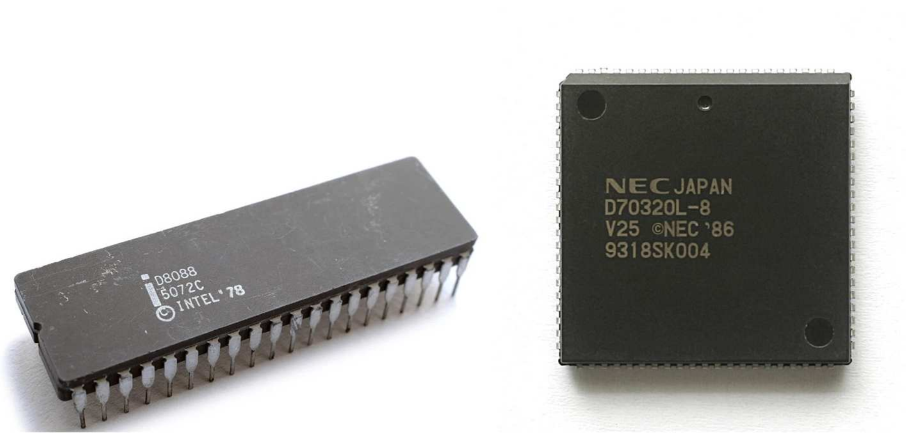
AccuVote is a common brand name for a family of voting terminal products. New Hampshire uses AccuVote-OS PC (Optical Scan Precinct Count) systems statewide in jurisdictions that use voting machines. For brevity, we often write just "AccuVote."

An AccuVote-OS attached to its large plastic ballot box

An AccuVote-OS with its cover opened. Notice the line of white powder on the metal box near the center of the picture. (See the discussion of cleaning the scanner beginning on page 96.)

The AccuVote-OS is very old technology. This machine was originally developed in 1986 and first introduced to the market in 1989. It is believed to have been used for the first time in U.S. general elections in Minnesota in 1990. This system has been marketed and maintained under many brand names over the years, but it has very little technology in common with other systems sold and marketed under those brands. The steps NH has taken to regulate how the system is operated further decrease the commonalities with other jurisdictions who have or still use this device.

The CPU of the system is an NEC V25[10], the microcontroller version of the NEC V20 processor. A microcontroller (MCU[11] for microcontroller unit) is a small computer on a single integrated circuit chip. In modern terminology, a microcontroller is similar to, but less sophisticated than, a system on a chip (SoC). Microcontrollers allow simplification of motherboard design while reducing size by integrating into a single package functions that otherwise would have required additional physical chips.

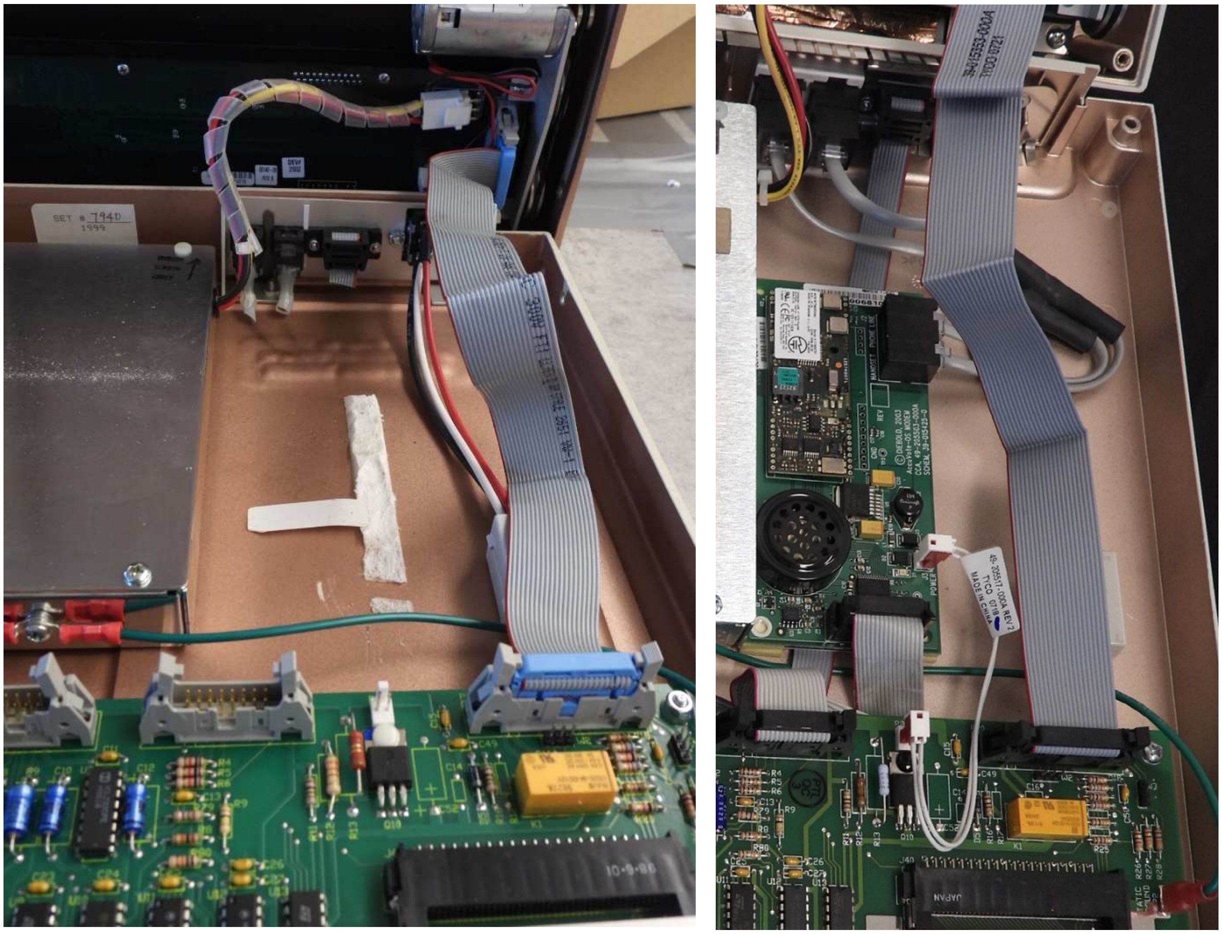


The Intel 8088 processor (left) and the NEC V25 processor (right)

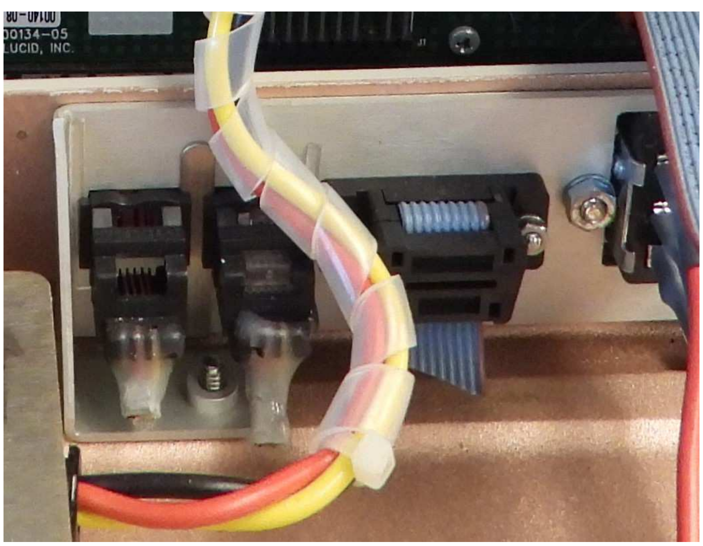
The V20 was a processor made by NEC that was a reverse-engineered, pin-compatible version of the Intel 8088 with an instruction set compatible with the Intel 80186. Intel 8088 was the processor of the original IBM Personal Computer model 5150, the first generation of PC computers introduced in 1981. The AccuVote-OS is a custom design single-purpose computer; it is not PC-compatible and does not share designs with PC hardware. For example, it does not have a PC BIOS. The V25 has a 16-bit internal architecture and 8-bit external data bus with 20-bit address bus, making the theoretical maximum addressable memory merely 1 Megabyte. The AccuVote-OS motherboard accommodates even less memory: it has two RAM chips with 128Kbytes each. The V20 was introduced in 1982 and launched in 1984. The V25 was officially phased out in early 2003.

[10] https://www.cpu-world.com/CPUs/V25/index.html

[11] https://www.electronics-notes.com/articles/digital-embedded-processing/embedded-systems/what-is-embedded-microcontroller-mcu.php



The modem circuit board has been physically removed from the devices used in New Hampshire



All cables to external connectors have been removed

This device does not have a hard drive or any other internal rewritable persistent storage. It does not have a filesystem and it does not have a general-purpose operating system. The design predates modern network technologies. It has no ability to communicate via Internet Protocol, Ethernet, or wireless networking. In the absence of a NIC, many electronic identifiers of physical devices like MAC addresses that are common today are not present in this machine, because it was designed before those technologies were widely adopted. The AccuVote-OS has a copper-wire telephone system modem and RS-232 serial ports, but those ports have been physically disabled in New Hampshire voting machines by cutting the cables and removing the modem board.

In this device, the software is installed on socketed 64 Kbytes and 128 Kbytes EPROM microchips, and the total space used is about 143 Kbytes. EPROM stands for Erasable Programmable Read-Only Memory. It is a type of programmable read-only memory (programmable ROM) that can be erased and reused. This type of chip has to be physically removed from the circuit board, placed into a separate erasing device and completely erased before it can be reprogrammed using a separate programmer device. Erasing the chip is done by shining an intense ultraviolet light through a window on the chip, through which the silicon chip is visible. The erasing window must be kept covered with an opaque label to prevent accidental partial or erratic erasure by the UV by sunlight or camera flashes. Therefore, the window is always covered by a sticker as seen in the circuit board picture on page 30. The voting machine is physically incapable of altering the programming on the chip on its own: reprogramming can only be done with a separate device.

The top and bottom of an AccuVote memory card connecting into a J40 connector

The only storage device the system has is an Epson-manufactured battery-refreshed SRAM card. Like everything else in the device, the memory card does not have a filesystem in a traditional sense. The memory card can hold up to 128 Kbytes and connects to the voting machine with a 40-pin card-edge J40 connector. The original manufacturer stopped making this card in 1998. A replacement technology became available around 2012. The memory card capacities are 32 Kbytes, 64 Kbytes, or 128 Kbytes.

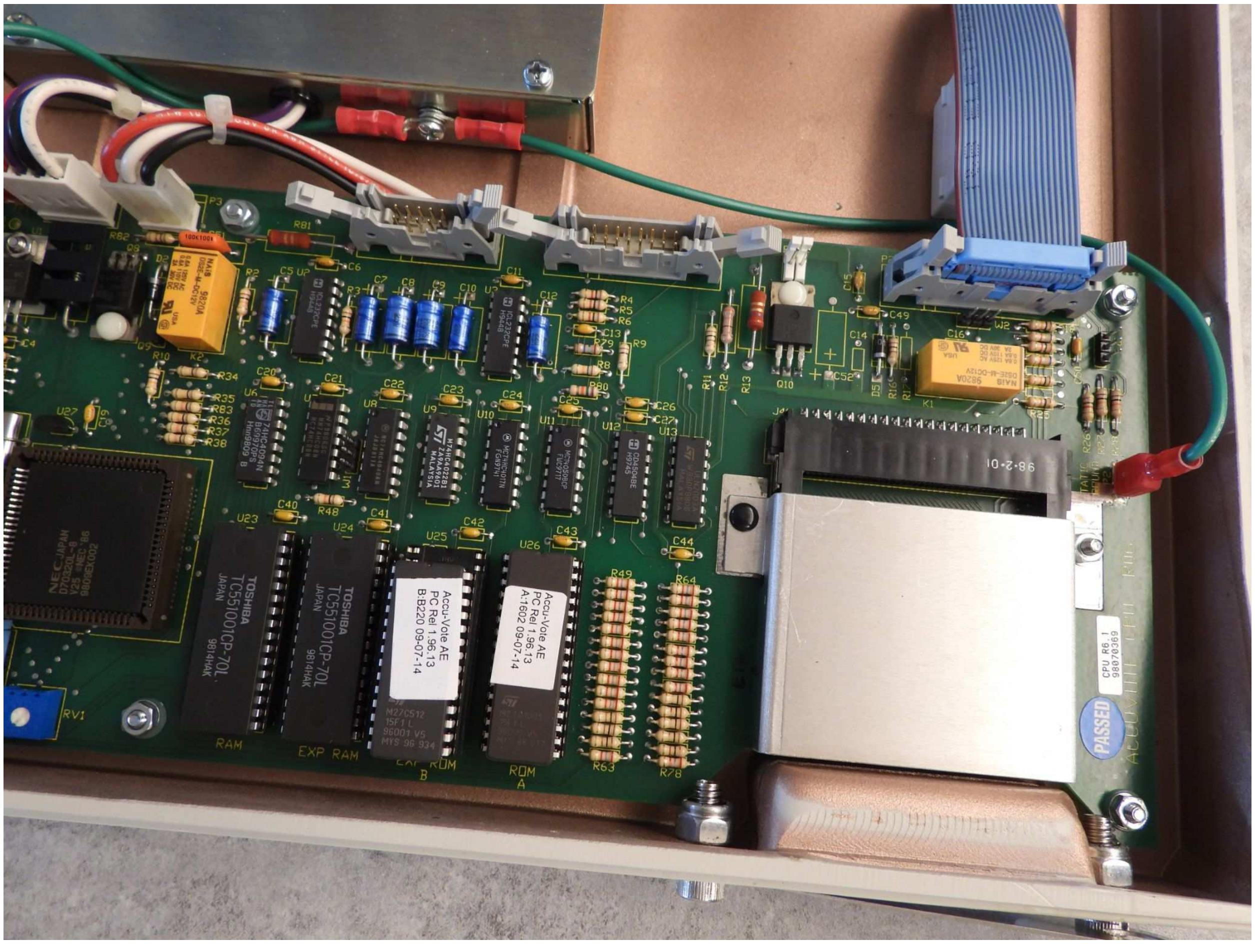
The source code of this device has been part of at least three independent studies. The code when it was last reviewed in an independent study, which comprises more than 20,000 lines of code, is written in C and Assembler. One module of the software that has received particular scrutiny and led to the discovery of vulnerabilities is the AccuBasic interpreter. It was originally created in 1996 to facilitate flexible election night reporting.

With only 256 Kbytes of RAM, the device cannot store or process digital images of ballots. Scanners of this type are called Optical Mark Recognition (OMR)[12] Scanners. The main CPU is primarily used to control the peripheral devices, analyze ballot data, update memory card totals, and print reports. Information gathered by the ballot reader is transferred to the CPU by means of a high-speed serial input connection. The scanner head controllers do not understand ("parse") the ballot; they transfer eight bits at a time for a total of ten bytes of data per scan line of both sides combined. From that very limited amount of data, the election software identifies which vote targets on the ballot contain voter marks. In this design, the voting targets are located as cross-sections of the timing marks on the sides of the paper ballot. If the timing marks are off, the voting machine will identify an incorrect location on the paper as the voting target.

This type of voting machine does not use white light to illuminate the paper. The scanning of each timing mark and voting mark position uses red-orange light-emitting diodes and silicon photodiodes in a special configuration which monitors the diffuse reflectance of the ballot surface. The red-orange emitters are Aluminum Indium Gallium Phosphide (AlInGaP) and have a peak wavelength of 621 nanometers. In a sense this design is intentionally color-blind. Red-orange is invisible and black is black, and all other colors are seen as shades of gray on a red-black scale. This is very similar to looking at objects under sodium-vapor fog light: all you can see is shades of gray in yellow.

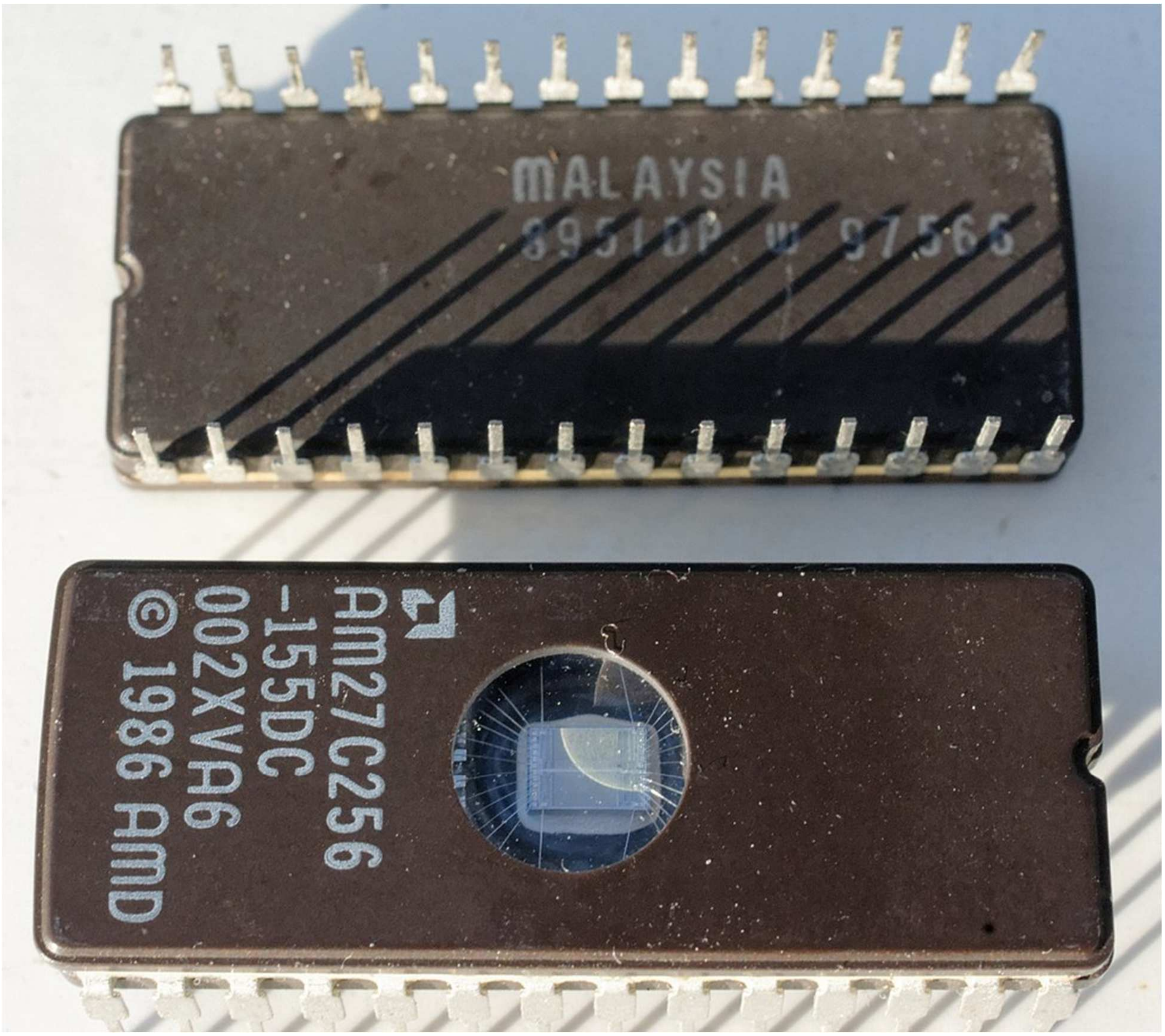
Many vulnerabilities in Diebold legacy voting systems, including the AccuVote-OS, are related to the election management software called GEMS. New Hampshire does not use GEMS for election results reporting. Election programming for New Hampshire is done by a third-party service company, LHS Associates, located in Salem, NH.

12 https://en.wikipedia.org/wiki/Optical_mark_recognition



AccuVote-OS circuit board with socketed EPROM chips containing election software (labeled with white stickers)

The photo above shows the AccuVote circuit board. The labeled chips are ST M27C512 and ST M27C1001. Software upgrades to this machine are installed by physically removing and replacing the chip; the chip is socketed to facilitate that. The chip inside a socket is a SmartWatch CMOS real time clock with an NVRAM controller circuit and an embedded lithium energy source – placing the chip in a socket was a common design at the time this board was designed. RAM chips are on the left and the square chip in the far left is the MCU.



EPROM memory chip without the sticker to protect the data on the chip from UV radiation

Machine chain of custody and supporting documentation

Ordinarily, all four AccuVote machines are in the custody of the town clerk. Whenever a numbered seal is removed or a new numbered seal installed, the change is logged in the "Electronic Ballot Counting Device Activity Log." Similar logs are kept for the memory cards. (Digital copies of the machine and canvas bag log pages from 2020 appear in the Right To Know folder supplied by the Town of Windham and available at https://1drv.ms/u/s!AkHTB_k5VsaxhWrgSV8JsZRcc5by?e=H5iNsC.) The audit team and volunteers reviewed the *complete* logs. In general, and except as detailed here, these documents were in good order and indicated that the machines were properly secured and supervised.

Each activity log entry has three rows, as shown in the example below from Machine 1. This example is characteristic in showing two signatures – either on the first two lines, or on the two witness lines. The log instructions, given at the bottom of each log page, state that each time a seal is installed or removed, "the person responsible for the process" must "sign in the presence of two witnesses who also shall sign the log." This instruction is consistent with the language of New Hampshire RSA 656:42 that "No person shall break a counting device seal without the presence of 2 witnesses," both of whose signatures are required. Our conversations with local election officials indicated that it is common for just two people to sign the logs. In effect, the person responsible for the process often serves as one of the witnesses. This widespread procedural shortcut, in itself, does not constitute a security failure. It is common around the country for two people, not three, to verify and document seal numbers. It likewise is common – not only in election administration – for some detailed statutory requirements to be broadly interpreted by the local officials who must implement them. Nevertheless, this divergence suggests that a broader review of New Hampshire election statute and common practice could identify ways to improve both.

	Check One ✓		Tape Seal				
Date	Installed	Removed	Number			Reason	Signature
2.8.19		V	001260754			LHS mat	[illegible]
			Location – Circle One			Witness #1	[illegible]
			Front	Rear	Ports	Witness #2	

An activity log entry from Machine 1; note that only two signatures are provided

Several binders of seal logs contained pages for different machines. It is thought that this commingling of records occurred while fulfilling an open records request: the pages were removed and scanned, then returned to the wrong binders after scanning. During the audit, volunteer sworn New Hampshire election officials restored the pages to the correct binders.

The "school" machine logs were substantially incomplete, suggesting that many log pages had been misplaced. For the memory card, all records between October 25, 2010 and May 7, 2020 (inclusive) were missing. For the counting device, all dates before May 7, 2020 were missing. For the canvas bag, only entries between October 31, 2016 and April 20, 2017, and entries on or after February 11, 2020 were in the binder. (As detailed below, forensic examination of the memory card and EPROM program chips from this and the other voting machines found no sign of tampering.)

The log record of the port seal on one machine could not be found. In addition, some communication port seals were not firmly affixed. These lapses do not raise security concerns because under New Hampshire law, the communication ports are disabled by cutting the cable internally. That was verified later when the machines were opened for forensic inspection: the cables were either cut or removed entirely on all four machines, as shown in the livestream.

Deciding on a sequence of machine operations

We were required to obtain complete counts by feeding all cast ballots through all four AccuVotes. Also, we were committed to forensically inspect the data on the memory cards and EPROM chips, which we therefore had to copy. We had to choose among several options for completing these steps. Here we explain the options, and how known vulnerabilities of the AccuVote and other considerations informed our choice to “zero out” the memory cards before the machine count, and to copy the data after the machine count.

Known vulnerabilities of the AccuVote

Known software (“hacking”) vulnerabilities of the AccuVote system rely on two mechanisms:

1) Pre-setting the vote counters (non-persistent attack)
2) Malicious AccuVote programs (persistent attack)

The original AccuVote software neglected to clear the counters before an election started, allowing “digital stuffing” of the ballot box. Before the software was improved, the recommended mitigation strategy was to manually clear the counters before election. It was shown in the original Hursti Hack[13] that if digital stuffing of the ballot box is done, the voting machine will erase all evidence from the counters in the course of the normal counting operations.

Diebold and its successor company, Premier Election Solutions, reacted to security vulnerability reports and produced multiple new software versions that claimed to address the vulnerabilities that had been found. Some of the early modified versions were tested; the tests found that the fixes were improvements but did not fully protect against attacks. Many jurisdictions never deployed any of the upgraded versions, but New Hampshire did. The version used in New Hampshire, and immediate predecessor versions, have never undergone independent security reviews, so it is unknown whether the vulnerabilities have been effectively addressed.

AccuBasic, the programming language for AccuVotes, is designed to be unable to change the contents of the memory card. Some of the vulnerabilities discovered and disclosed in “Security Analysis of the Diebold AccuBasic Interpreter,”[14] if properly exploited, have the potential to allow arbitrary code execution, which could allow malware to modify the contents of the memory card. That report was published in 2006, and the vendor has since claimed to have fixed these security vulnerabilities.

---

[13] https://www.blackboxvoting.org/BBVreport.pdf
[14] https://people.eecs.berkeley.edu/~daw/papers/accubasic.pdf

Assuming for purposes of security analysis that those fixes were ineffective, the attack vector to start the malware would be execution of the AccuBasic program. That execution happens when the Zero Tape is printed and when the Results Tape is printed.

It has been previously falsely theorized that parallel testing would be an effective way to test voting machines. More modern machine designs have many cues that malware could use to detect that the machine is being tested. Very old designs like AccuVote have fewer cues that malware could exploit.

Machine dates

It has been publicly claimed that the hypothetical malware "algorithm" that might have tampered with vote counts in Windham would only activate on Election Day. To alleviate that concern and to recreate Election Day as accurately as possible, we instructed the volunteer NH election officials to roll back the real-time clock to that date, November 3, 2020.

Because the machine count took place over two days, some people speculated that hypothetical malware might not execute due to the purportedly anomalous timeline. This concern is farfetched. In New Hampshire and elsewhere, tabulation is not always completed on Election Day. For example, Londonderry's Precinct 65 results tape indicates that they closed the election on November 4th, 2020 (the day after Election Day) – parallel to the timeline in our retabulation. It is far from obvious why malware would be programmed to check the election close date.

Options for sequence of operations

In normal operations across the United States, a machine recount would involve programming new memory cards specifically for the recount. In New Hampshire, the voting machines were preserved after Election Day, and the lawmakers who drafted SB43 intended the machine recount to be done in the pristine preserved state of the machines. As New Hampshire's procedures clear the counters before the election, they eliminate the possibility of a non-persistent attack (pre-setting the vote counters), provided physical security of the memory card is maintained.

To meet the lawmakers' intention to use the units in pristine condition, and given that in New Hampshire the communication port connectors of the machines were permanently disabled, we only had three options to re-enact the November 2020 election day as authentically as possible.

1) We could reset the operational mode of the card from Post-Election to back to Pre-Election, and zero the card counters. This would allow us to run the election with the cards in place without breaking the seals or removing the cards from the voting machines.
    - Pros: The cards are used in their preserved state, with only the counter reset. This approach eliminates the possibility that the cards have been modified and tampered with, because it does not involve physical access to the cards.

    - Cons: The Election Day vote counters will be lost in digital form. However, both the election counters and global counters would be preserved on paper, as we would start the proceedings by printing out the Audit Log of the machines. As the “Hursti Hack” attack published in 2005 demonstrates, the machine during its normal Election Day operation would have already effectively overwritten all artifacts from this memory area even if the New Hampshire procedure to clear the counters had failed.
2) We could use a CropScan device, described later, to create digital images (copies) of each card before returning the card to Pre-Election mode and clearing the counters.
    - Pros: A digital copy of the Election Day counters would be captured.
    - Cons: Election machine seals would need to be broken and cards would need to be removed from the voting machines, granting physical access to the cards. The CropScan device would be needed to be used for imaging. From the perspective of an observer, this requires trusting a new, unfamiliar device. This would open a legitimate concern that the public has no way of knowing what the device is actually doing to the cards. In particular, it could be claimed that the device had been used to "unhack" the cards to hide evidence of malware.
3) We could use the voting machine to make a copy of the cards before returning the card to Pre-Election mode and clearing the counters.
    - Pros: This approach does not involve trusting a new, unfamiliar device. It would preserve the Election Day vote counters in a backup card to be read later with a CropScan device.
    - Cons: Election machine seals would need to be broken and memory cards would need to be removed from the voting machines. Trust in the veracity of the copies would also require trusting the voting machines. Since the purpose of the audit is to determine whether the machines were trustworthy, it would be illogical to trust that a machine would make a verbatim copy of the card.

It is an unfortunate and well-known security property of the AccuVote design that any physical access to the card creates hard-to-mitigate security risks. To preserve as much of the original state as possible and to justify public trust, Option 1 was chosen: the forensic images of the memory cards were made after the machine count.

Forensically, New Hampshire’s security-enhancing procedure to clear the counters protects the integrity of the election process and negates any advantage of imaging the cards to preserve the counters. The only feasible attack path here is persistent malware, which would be preserved by the process we followed. The subsequent audit of the contents of the memory cards did not find malware on the memory cards.

Machine count

Timeline and ballot handling

The sheer number of ballots to be tabulated on all four AccuVote machines dictated that the retabulation had to take place over more than one day: even if tabulation could take place nonstop at a sustained rate of 5 seconds per ballot (unrealistically optimistic), it would take about 14 hours to feed all the ballots through a single machine. Because there were some new volunteers each day, part of the first hour of each day was devoted to training the volunteers for the day's activities and explaining to the observers and livestream what would take place and what to look for. Time also needed to be reserved to re-seal all materials at the end of each workday.

To keep the ballots as secure as possible, we tried to minimize the number of boxes of ballots open at any given time.

As mentioned above, the cast ballots were divided into scan batches. Each scan batch had an ID incorporating the box of ballots it came from; its "part" within that box; and its ballot ID prefix ("stamp"). For instance, scan batch 13/C/9 contains ballots from box 13; is "Part C" or the third scan batch from that box; and has ballot ID numbers that begin with 9-. (This scan batch comprises ballots 9-1 through 9-150.)[15]

Ballot IDs were added in red ink to the back of each ballot, in a blank area. We initially intended to use Bates stamps, numbered 1 through 4, specially modified to use red ink, to imprint a unique number to each ballot. For instance, the first ballot from Bates stamp 1 is numbered 010001. It soon became apparent that the Bates stamps were too fragile to be used for this purpose, so volunteers handwrote sequential ballot IDs using red pens and arbitrary "stamp" numbers (prefixes). The cover sheet for each scan batch shows the ballot ID range, referred to as the first and last "Bates #s," although most were handwritten rather than stamped.

Once ballot IDs had been added, the ballots in each scan batch were fed through one of two commercial scanners, obtaining 300dpi, 24-bit color reference images of both sides of the ballots. These images were intended primarily to preserve evidence, hedging against possible damage of ballots as they were fed through all four AccuVote scanners, and to provide an indirect means to "examine" ballots, in addition to direct physical inspection. Digital images cannot substitute for physical inspection of voted ballots, but offer a valuable supplement. Once these reference scans of each scan batch were complete, the scan batch was ready to be scanned by AccuVote scanners.

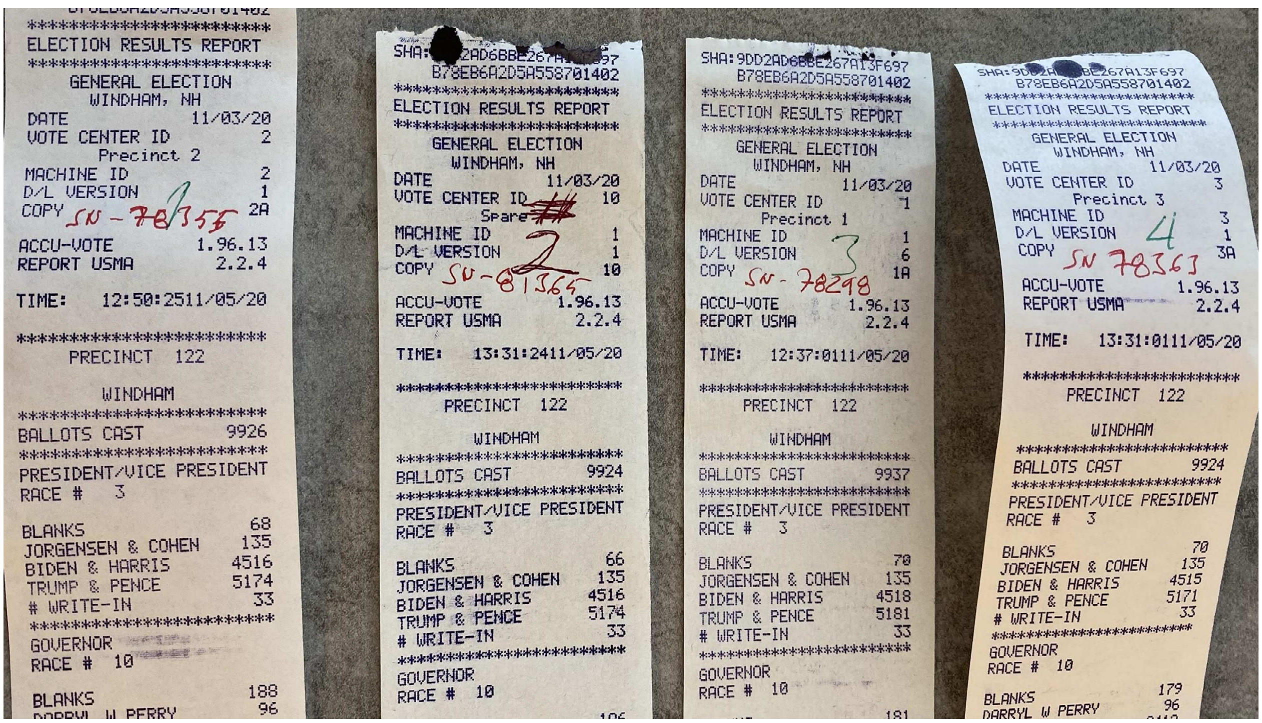
[15] A few hand-counted batches have idiosyncratic part IDs. Scan batch 20/A1/34 consists of a single ballot, originally from 20/A/34, that the AccuVotes failed to scan; similarly, scan batch 20/C1/32 contains a single ballot from 20/C/32. The final ballots from box 20 were split into batches 20/F1/35 (the "fronts" of three UOCAVA ballots) and 20/F2/35 (the "backs" of two UOCAVA ballots).

The scan batch cover sheets recorded the scan batch ID, the ballot ID range, who completed each processing step (numbering, reference scanning, and scanning by each of the four AccuVote machines), and when each step was completed. For the AccuVotes, the cover sheets further record the counter number (cumulative number of ballots counted) before and after each batch was fed through the AccuVote, an important check on the process.

A total of 78 ballots did not feed through the AccuVote scanners, although we did obtain reference image scans for these ballots. These ballots are variously assigned among eight scan batches (most of them very small) for accounting purposes.

Only sworn New Hampshire election officials (volunteers from both parties and Independents) handled ballots and operated the voting machines, including opening the storage bags and checking seals, resetting the date to November 3, running zero tapes, setting the machines up for tabulation, running ballots through the machines, emptying ballot boxes, dealing with jams and other malfunctions, closing out the tabulation, and running the Totals Reports (short and long versions). The entire process was livestreamed.

AccuVote scanning logistics



The tops of the four Result Report tapes from the audit retabulation. Complete images are at https://www.doj.nh.gov/sb43/documents/20210514-machine-count-poll-tapes.pdf.

New Hampshire's AccuVote scanners are programmed and serviced by LHS Associates. We requested that a representative from LHS be onsite throughout the machine count. Jeff Silvestro, the president of LHS, attended on these days and was available to answer our questions. He never left the observer area and never had access to the scanners.

On Election Day the four AccuVote machines were known as machines 1, 2, 3, and 4. Machine 4 also is known as the "school machine" or "spare machine," because it belongs to the school district, not the town, although it is used in federal elections. Because the machine log books were disorganized (as described above), we were not confident of accurately matching machines to these IDs, so we labeled the machines with arbitrary new ID numbers 1 through 4. These labels appear in the scan batch cover sheets.[16] However, the report tapes correspond to the original IDs: machines 1 through 3 appear as "Precinct 1," "Precinct 2," and "Precinct 3," respectively, while machine 4 appears as "Spare."[17] To minimize confusion, we here refer to the physical arrangement of scanners as A through D.

We considered having scan batches circulate clockwise through the four tabulators: storage to A to B to C to D, then back to storage. That would have meant that several machines were idle until batches had passed through the other machines. Because tabulation was already going to take several days, we decided to move the ballots from machine to machine in both directions, to reduce idle time: half the batches would go from A to B to C to D, and the other half would go from D to C to B to A. We quickly discovered that still left machines idle unnecessarily: the election officials operating the machines did not all work at the same speed and some batches were more time-consuming to scan than others, either because they contained more ballots or because the scanners rejected the ballots in some orientations, requiring the ballots to be reinserted several times.

Therefore, the plan was modified so that a runner would bring a scan batch to any idle machine. The scan batch cover sheets tracked which machines had tabulated each batch, to ensure that each batch was tabulated exactly once by each machine. The cover sheets also recorded the number of ballots each tabulator had counted before and after tabulating that batch, as a crosscheck.

Those crosschecks revealed that 11 ballots from one batch had gotten caught in the "chute" of one of the ballot boxes and were subsequently knocked loose by the next batch processed through that machine, joining that batch, which was then tabulated by a machine (the original machine 1) that had already tabulated those 11 ballots. Because the ballots were individually numbered, it was simple to find those 11 and to correct the machine totals to reflect each scanned ballot once and only once.33

In four other cases, single ballots from a scan batch were not recorded as having been counted. Unlike the previous case, it was not possible to isolate those ballots and reliably correct the totals. Thus, our totals report 9,926 ballots scanned on machines 1 (as adjusted) and machine 2, but 9,924 ballots scanned on machines 3 and 4. In addition to those, there were 78 hand-counted ballots that could not be scanned by AccuVotes, as mentioned previously.

[16] Audit machines 1 through 4 are, in order, election day machines 2, 4, 1, and 3.
[17] Machine 1 is not only "Precinct 1" but also "VOTE CENTER ID 1" and "MACHINE ID 1," and likewise for machines 2 and 3. Machine 4, besides "Spare," is listed as "VOTE CENTER ID 10" (!) and, confusingly, "MACHINE ID 1."

There were a few paper jams during the tabulation, which were cleared using standard NH procedures. Those procedures include noting whether the AccuVote screen indicated that the jammed ballot had or had not been tabulated.

A bearing in one machine's paper feed path froze on the second day of the retabulation (11/4 according to the machine's internal clock). The NH election officials operating the machine had experienced this a number of times in real elections, and knew the procedure for reseating the bearings, confirmed by the LHS representative:

- Note the value displayed in the ballot counter on the machine.
- Turn off the machine.
- Push an "ender card"[18] through the paper path backwards (back to front).
- Turn the machine back on.
- Note the value displayed in the counter, to ensure it did not change.

From the perspective of the machine's electronics, all that happens during this procedure is that the power goes off and back on, an event the machines are designed to cope with in case there is a power failure or a machine is accidentally unplugged during an election. The machine "notices" this power interruption and creates log entries for that machine like these:

38 SESSION START DATE: 11/4/20	11:41	This line is generated when the system is powered back on.
39 COUNT RESTARTED	11:41	This line is generated when the system determines that it was already in the election mode when it was powered on and the first ballot was entered. The only way to avoid generating this log entry would have been entering the Ender Card to close the election.
40 BAL COUNT START	11:41	This line is generated when ballot counting operations resume.

The audit logs show that both the "School machine" (Line item 21) and "Precinct 2" (Line item 22) were restarted on Election Day in 2020. Thus, a restart during the retabulation was not unusual.

Those messages do not mean that the count started from scratch, just that the power came back on and a ballot to be counted was inserted. The machine does not allow resetting the memory card while it is in Election Mode. (Resetting the counters would create a CLEAR COUNTERS log entry, as shown below.)

The AccuVote system has a function to erase the contents of the memory card; after that operation, the voting machine is unable to run any election-related operations with that

[18] An ender card is a stiff ballot-shaped card with markings that instruct the voting machine that tabulation is complete.

memory card until the card is configured with data for a new election. This is because the erase function removes all content from the card, including ballot definition, audit logs, and the reporting program: the system is unable to interpret ballots and produce counts or other outputs with an erased card.

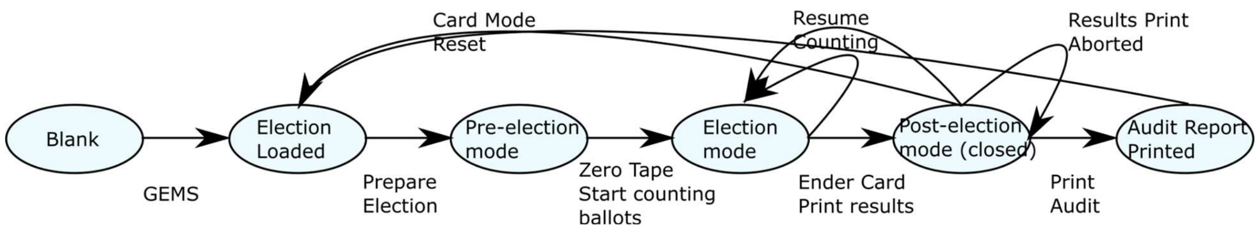
Explanation of the machine transaction logs

Here is a list of the most common Log Entries. The list is not comprehensive and the items outside of this list are mainly non-election related technical errors.

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. The most common reason for resetting is a loss of power.
DOWNLOAD END	Record the end of data load during the programming of the card using GEMS. (In New Hampshire, LHS Associates does the programming.)
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.
INCORRECT PIN	Supervisor PIN code invalid.
INITIALIZED	The 1st action in the Event Log; this action records the date.
MEM CARD RESET	A memory card reset returns a card in 'STAT_DOWNLOADED' status, pre-election mode.
OVERRIDE	Records an override by a poll worker. Used to force overvoted ballots to be accepted.
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.
SUPERVISE MODE	Appears every time the Supervisor PIN code is accepted.
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 a voted ballot test is performed.
ZERO TOT REPORT	Appears when a Zero Totals Report is printed.

Diagram of the election modes

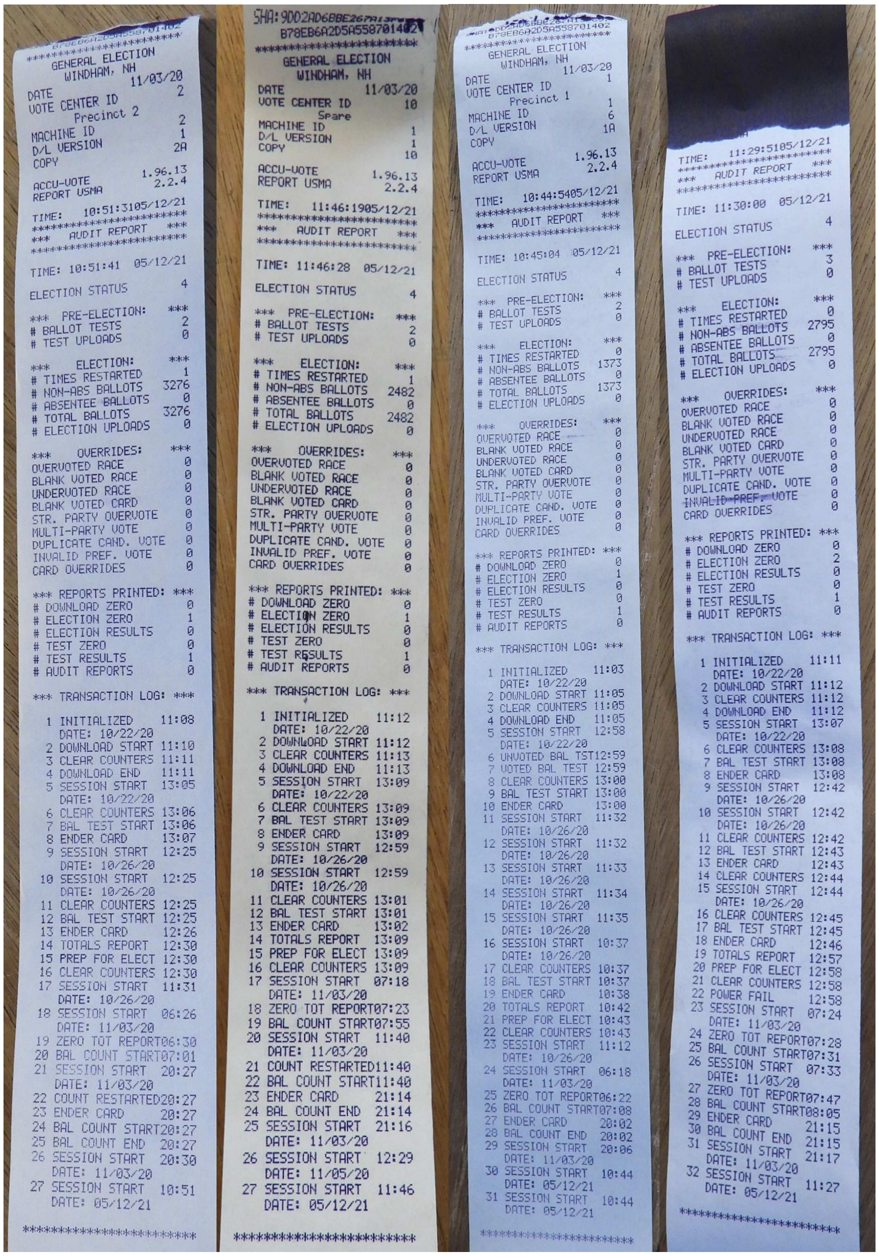


STAT_UNUSED	/* Empty formatted memory card.*/
STAT_DOWNLOADED	/* Downloaded memory card – pre-election mode.*/
STAT_ELECTION	/* Election counting mode.*/
STAT_ELECTION_DONE	/* Ender card fed, printing totals report.*/
STAT_DONE	/* Post-election mode -ready for upload.*/
STAT_UPLOADED	/* Upload done, ready for audit.*/
STAT_AUDIT_DONE	/* Final audit report printed.*/

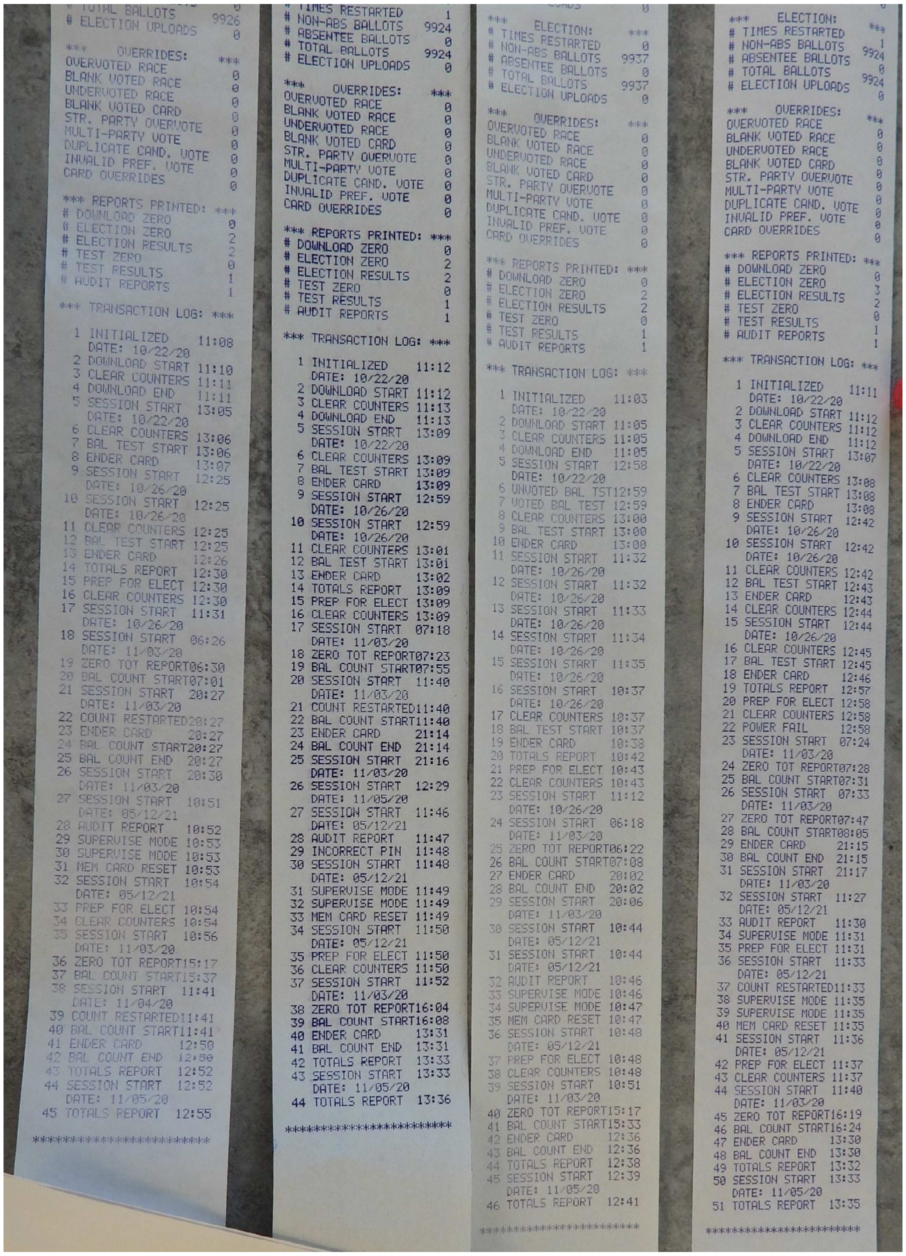
In New Hampshire, the memory cards were in STAT_DONE mode when the audit started, as in New Hampshire audit report printing is not part of the precinct end-of-election procedures. This is natural, because in New Hampshire, results are never uploaded to a GEMS server – instead, the results are manually copied from the Totals Reports – and the Audit Report has been intended to be printed after uploading the results.

We started the audit by completing the cycle by printing the Audit Reports. (Printing Audit Reports increases the global counter and generates an audit log entry. Subsequently resetting the card mode increases another global counter and generates another audit log entry.) These Audit Reports document that the machines were preserved on November 3rd. When the machine count was completed, new audit logs were printed after the machine count Results Tapes were printed.[19] Those logs document the operations undertaken during the forensic audit, appended to the previous logs. This comparison validates the integrity of the memory cards and logs.

[19] https://www.doj.nh.gov/sb43/documents/20210514-machine-count-poll-tapes.pdf



The audit tapes printed before the machine count started



The audit tapes printed after the machine count was completed

Narration of the machine transaction log

Here is a narration of the machine transaction log for the leftmost tape, which is for the machine that was turned off and back on during the retabulation. The others are identical except for line numbering and the two log entries that power cycling generates.

27 SESSION START	10:51	The machine was turned on
DATE: 5/12/21		Date the machine was turned on
28 AUDIT REPORT	10:52	Print an audit report, which is this log
29 SUPERVISE MODE	10:53	Enter supervisor mode for mode reset
30 SUPERVISE MODE	10:53	Enter supervisor mode for mode reset
		(In the new software version workflow used in NH, the Voting machine is verifying the password twice in a row. As each successful verifying the password triggers this line, the line appears twice in a row)
31 MEM CARD RESET	10:53	Enter pre-election mode with a display prompt to the operator: “Reset Card to Pre-Election?”. After completion of this command, the voting machine prompts the operator to remove the memory card. Alternatively, if the memory card is sealed in, the operator can switch the power off.
32 SESSION START	10:54	Date the audit session started.
DATE: 5/12/21		Early in this process (before line 35), the system clock was reset to November 3rd, 2020. The system does not generate a log entry for that.
33 PREP FOR ELEC		10:54 Prepare for Election: changes the mode of the card from Pre-Election mode to start the Election mode next time when the machine is powered on.
34 CLEAR COUNTERS		10:54 NH security measure as recommended by Hursti (After this the machine is powered off to wait for Election Day)
35 SESSION START	10:56	Start a new election: enter election mode
DATE: 11/3/20		Date the session started (This corresponds to when the machine would normally be powered on before the polls open on Election Day.)
36 ZERO TOT REPORT	15:17	A zero tape is automatically printed when the system is powered on to show the counters are empty
37 BAL COUNT STARTS	15:37	Start tabulating ballots

38 SESSION START	11:41	Log entry showing power was turned off & back on
DATE: 11/4/20		Date the power went off and on (to reset ball bearings)
39 COUNT RESTARTED		11:41 Machine is ready to continue tabulating
40 BAL COUNT START	11:41	Machine is tabulating
41 ENDER CARD	12:50	The “Ender Card” was inserted (on 11/5) to end tabulation and calculate the results
42 BAL COUNT END	12:50	The ender card signalled the end of the election
43 TOTALS REPORT	12:52	Print contest totals report, short version
44 SESSION START	12:52	When the report printing has completed, the machine resets itself to Post-Election Mode
DATE: 11/5/20		Date the ender card was inserted, ballot count ended, and totals were printed
45 TOTALS REPORT	12:55	Print the totals report, long version

The memory cards are not “cleared” (in the sense of erasing them) as part of logic and accuracy testing, nor before running an election. Only the counters that register ballot counts and various vote totals are cleared (set to zero). Global counters, such as how many reports have been printed, are left unchanged. The memory cards have the names of the contests, the candidates, the voting rules for each contest (e.g., vote for 4 versus vote for 1), the locations of the vote targets for each candidate (e.g., a mark at the intersection of the 22th row and the 15th column is a vote for candidate X), and the vote counters. Election-specific information is programmed into the memory card by LHS (the contractor for much of New England) using the election management system software GEMS. If the memory card is erased, the voting machine is incapable of tabulating ballots until it has been reprogrammed (by LHS, in the case of New Hampshire). The tabulator is useless until a memory card with election-specific information is inserted into it.

The cards are reprogrammed between elections to configure them with appropriate information for the next election (including contests, candidates, voting rules, and vote target locations). The reprogramming sequence starts by formatting the memory card. Logic and accuracy testing is then done with ballots for the upcoming election, counters are reset to zero, and a zero tape is printed.

Hand count

The hand count was the most time-consuming portion of the audit: it began on the afternoon of Friday, May 14 and continued through Friday, May 21. The procedures have been concisely summarized above; detailed instructions can be found in Appendix D. Here we foreground some central design considerations.

Individual ballot data

New Hampshire's Election Procedure Manual describes two broad variants of hand count, the hashmark method and the sort-and-stack method. These methods are similar in that they obtain vote counts for sets of ballots, but in general provide no way to determine how a specific ballot was interpreted. The recount of the State Representative contest in Windham used a combination of sort-and-stack, for "straight-Republican" and "straight-Democratic" ballots, and the hashmark method for other ballots.

These conventional methods were far too coarse for our purposes. We wanted to ensure that every ballot was accounted for throughout the hand count. We also wanted to capture both vote data and, if relevant, other qualitative information for each ballot. These considerations led us to assign individual ballot IDs to each ballot; to tally each ballot separately by ballot ID; and to maintain flagger logs with further information on ballots with unusual features.

Cross-checks

To minimize possible errors, most operations were checked by two people. On each audit team, the caller and the checker independently interpreted votes on ballots they could consult with other people at the table if warranted. The two talliers independently completed their tally sheets and computed the totals before comparing their results. At the data entry table, two people independently entered the tally sheet totals on separate tabs; their entries were automatically compared on a third tab.

These cross-checks worked well throughout the hand count. The election official volunteers who conducted the hand count seemed to appreciate the process of checking each other's work and recording results in detail. We observed errors being corrected in real time, both for individual ballots as they were initially tallied and for tally sheet totals. We were able to reconcile tally sheets with scan batch cover sheets, and to compare tally sheet and flagger log entries with the corresponding reference images.

Observability

The transparency elements of the hand count are described earlier in the report, beginning on page 10. We put considerable effort into allowing both in-person and remote observers to observe details of the process. Every ballot and every tally sheet was shown on camera, displayed on large screens (and, on most days, also on table-level monitors) for in-person observers, and recorded in full HD video for the livestream archive. In at least one case, an observer in the room commented – and the tally team agreed – that a ballot should be recorded in the flagger log because of a hesitation mark that could confuse the scanners.

Summary of hand count and machine retabulation results

Here we first present the hand count and retabulation vote counts for the three contests under audit and briefly discuss other counts. Subsequently, we discuss the evidence in the tally flagger logs about possible sources of discrepancies between hand counts and machine counts.

Vote totals by contest

The results below are reported using the original election night Windham machine IDs, which are consistent with the report tapes.

State Representative, Rockingham District 7

	Hand count			Machine count*				
				2020	2021			
candidate	2020	2021	diff		1	2	3	4
St. Laurent	4357	4355	-2	4456	4355	4349	4352	4367
Azibert	2808	2808	0	2787	2804	2805	2802	2800
Roman	3443	3442	-1	3415	3434	3436	3432	3432
Singureanu	2782	2782	0	2764	2777	2778	2776	2776
Soti	4777	4776	-1	4480	4742	4744	4727	4700
Griffin	5591	5591	0	5292	5558	5557	5540	5516
Lynn	5089	5089	0	4786	5055	5055	5037	5011
McMahon	5554	5554	0	5256	5520	5520	5502	5477
write in	n/a	34		41	41	41	41	41

* Machine-count results include 80 (for 2020) or 78 (for 2021) ballots that had to be hand counted. The 2021 results for machine 1 are adjusted for 11 ballots that went through the machine twice.

Two broad findings stand out here. First, the audit hand count results are very close to the recount results. Second, the audit machine count results are closer to the hand count results than the original election night totals were – but they still vary noticeably from the hand count totals and from each other. In light of our fold analysis presented below, we believe that storing the ballots flat for over six months between Election Day and the audit softened, but did not eliminate, the fold lines.

U.S. Senate

candidate	Hand count 2021	Machine count*				
		2020	2021			
			1	2	3	4
O'Donnell	169	168	167	167	168	168
Shaheen	4747	4738	4740	4738	4739	4740
Messner	4886	4876	4875	4874	4874	4876
Writein	7	7	7	7	7	7

* Machine-count results include ~80 ballots that had to be hand counted; 2021 machine-count results are adjusted for 11 ballots that went through the Town of Windham's machine 1 twice.

In the U.S. Senate contest, all the machine counts are closely similar. The audit hand count finds a small number of additional votes for all three named candidates – 20 in all, compared to the election night totals. This increase of about 0.2% is in the expected range for hand-marked ballots, because voters generally mark some ballots in ways that prevent the machines from counting them correctly. (We show examples below.)

Governor

candidate	Hand count 2021	Machine count*				
		2020	2021			
			1	2	3	4
Perry	97	98	97	96	96	98
Feltes	2448	2403	2433	2433	2434	2430
Sununu	7289	7241	7264	7256	7264	7256
Writein	7	6	6	6	6	9

* Machine-count results include ~80 ballots that had to be hand counted; 2021 machine-count results are adjusted for 11 ballots that went through the Town of Windham's machine 1 twice.

The results for governor partly resemble the results for U.S. Senate: in the hand count, the two leading candidates gain a roughly equal number of votes over the election night totals. However, the increase is considerably larger (93 votes, approaching 1% of all votes cast).

Also, the audit machine counts are not entirely consistent with each other or with the election night totals. Although these differences are not large (and their effect on the margin is very small), they suggest that some issue beyond mismarked ballots is affecting the totals.

President

Although the presidential contest was not hand-counted as part of the audit, we present the audit machine-count results for their intrinsic interest.

candidate	Machine count*				
	2020	2021			
		1	2	3	4
Jorgensen/Cohen	137	137	137	137	137
Biden/Harris	4567	4568	4567	4566	4567
Trump/Pence	5196	5194	5197	5194	5197
Writein	36	35	35	35	35

* Machine-count results include ~80 ballots that had to be hand counted; for 2021, the hand count is based on the reference images; 2021 machine-count results are adjusted for 11 ballots that went through the Town of Windham's machine 1 twice.

As in the U.S. Senate contest, the audit machine-count totals are very close to each other and to the election night results.

Some people have expressed concern that on election night, machine 2 had a higher rate of Biden votes than the other machines. Biden's machine 2 vote total equaled 55.6% of all ballots cast on the machine, compared with 40.3%-40.8% on the other three machines. Similarly, in the U.S. Senate contest, Jeanne Shaheen's vote total on machine 2 was 56.6% of all ballots, compared with 41.8%-43.7% on the other three machines. Some shift towards Democratic candidates is to be expected, because the vast majority of absentee ballots were counted on machine 2, and absentee ballots were expected to have a higher percentage of Democratic votes than ballots cast in person. The close similarity of all audit machine-count totals in these two contests suggests that indeed, the vote share differences on election day were due to the use of machine 2 to count most absentee ballots, rather than any difference among the machines or their programming.

Other contests

For the remaining contests on the ballot, we find – as with U.S. Senate and president – that the audit machine count totals are very close to each other and to the election night results.

Flagger log evidence

Tally teams, especially the flaggers, were instructed to watch for any sort of anomaly that might create a difference between machine count and hand count results. (In New Hampshire, hand counts attempt to determine voter intent.) These anomalies might include:

- Ballots marked lightly or in non-black ink – especially red ink, which is effectively invisible to the machines
- Ballots that are misprinted or damaged in ways that might affect the machines
- Vote attempts that mostly or entirely miss the vote targets
- Hesitation marks, not intended as votes, that might nonetheless be counted
- "Belt-and-suspenders" votes, where a voter marks a named candidate's vote target and *also* votes for that candidate as a write-in candidate (machines typically read these as overvotes, whereas they are valid votes under hand count rules)

It quickly became apparent that a particular kind of damage – folds passing through Kristi St. Laurent's vote target – might be remarkably common. Beginning on the second day (first full day) of the hand count, loggers were specifically instructed to look for folds passing through *any* vote target. Scans of all flagger logs are available via the Department of Justice's SB43 website. The direct URLs are as follows:

https://www.doj.nh.gov/sb43/documents/20210514-tally-flagger-log.pdf
https://www.doj.nh.gov/sb43/documents/20210517-tally-flagger-log.pdf
https://www.doj.nh.gov/sb43/documents/20210518-tally-flagger-log.pdf
https://www.doj.nh.gov/sb43/documents/20210519-tally-flagger-log.pdf
https://www.doj.nh.gov/sb43/documents/20210520-tally-flagger-log.pdf
https://www.doj.nh.gov/sb43/documents/20210521-tally-flagger-log.pdf

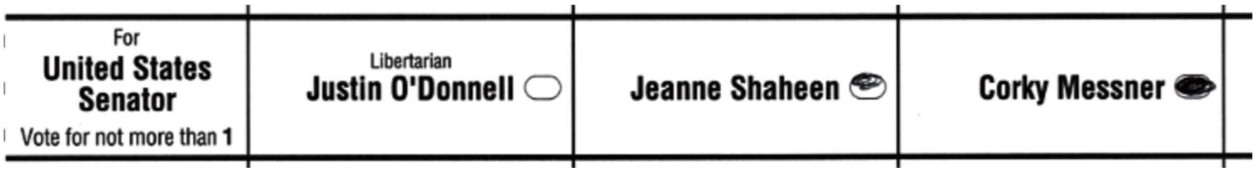
We found 2,019 ballot-specific entries in the flagger logs, over 100 of which annotate tally sheet corrections. By far the most common kind of entry reported a fold through one or more vote targets. There were over 1,600 such entries! Many of these entries are ambiguously recorded, for instance, referring to "fold through marked oval" (i.e., a vote target) but not specifying which one. Over 1,300 of these entries – possibly hundreds more – appear to refer to St. Laurent's oval; 19 refer to Julius Soti's oval. At least 131 entries refer to one or more ovals in the governor's contest. (Later we discuss how we used the reference scans to independently assess these folds.)

A variety of other, less common issues were recorded:

- At least 113 ballots were recorded as having been marked with something other than a black pen. Most (101) of these were marked in blue ink, 2 in purple ink, and 10 in pencil. At least 3 other ballots were recorded as having "light" markings that might not be read.
- At least 80 ballots were recorded as using checkmarks or X marks or otherwise failing to completely fill the ovals. Based on our review of the reference images, we

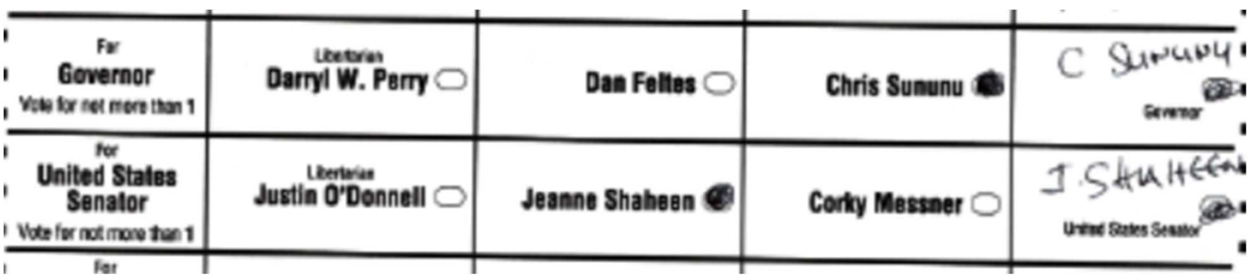
believe that many of these would very likely be read correctly by the machines, but some would not be.

- At least 50 ballots were recorded as having bleed-through, which should not affect the counts because no oval on the back of the ballot was aligned with an oval on the front.
- At least four ballots were recorded as having hesitation marks that might be interpreted as vote attempts. (The tally team interpreted the example below as a valid vote for Messner, but an AccuVote machine likely would not.)



A ballot with an apparent hesitation mark for Shaheen

- At least three ballots were recorded as having belt-and-suspenders overvotes. A partial example appears below (the entire ballot is marked similarly). These would almost certainly be treated as valid votes in hand counts, but as overvotes by the AccuVotes.



Belt-and-suspenders overvotes: voting for candidates twice

- Three ballots were recorded as having been torn at the top fold and retaped – one correctly, two "back-to-front." (Our analysis of reference images also found two, and only two, ballots taped back-to-front.) We conjecture that these ballots may have been hand-counted on election night, but became intermingled with other ballots during the recount. During the audit, they seem to have passed through the AccuVote machines without difficulty.[20] According to assistant moderator Betty Dunn, a "very few taped ballots, maybe one or two" were hand-counted on election night. Additionally, election worker Galen Stearns explained that while processing absentee ballots on election day, he taped perhaps 7 to 10 ballots and fed them through the scanners. It would seem that Mr. Stearns did his work so carefully that

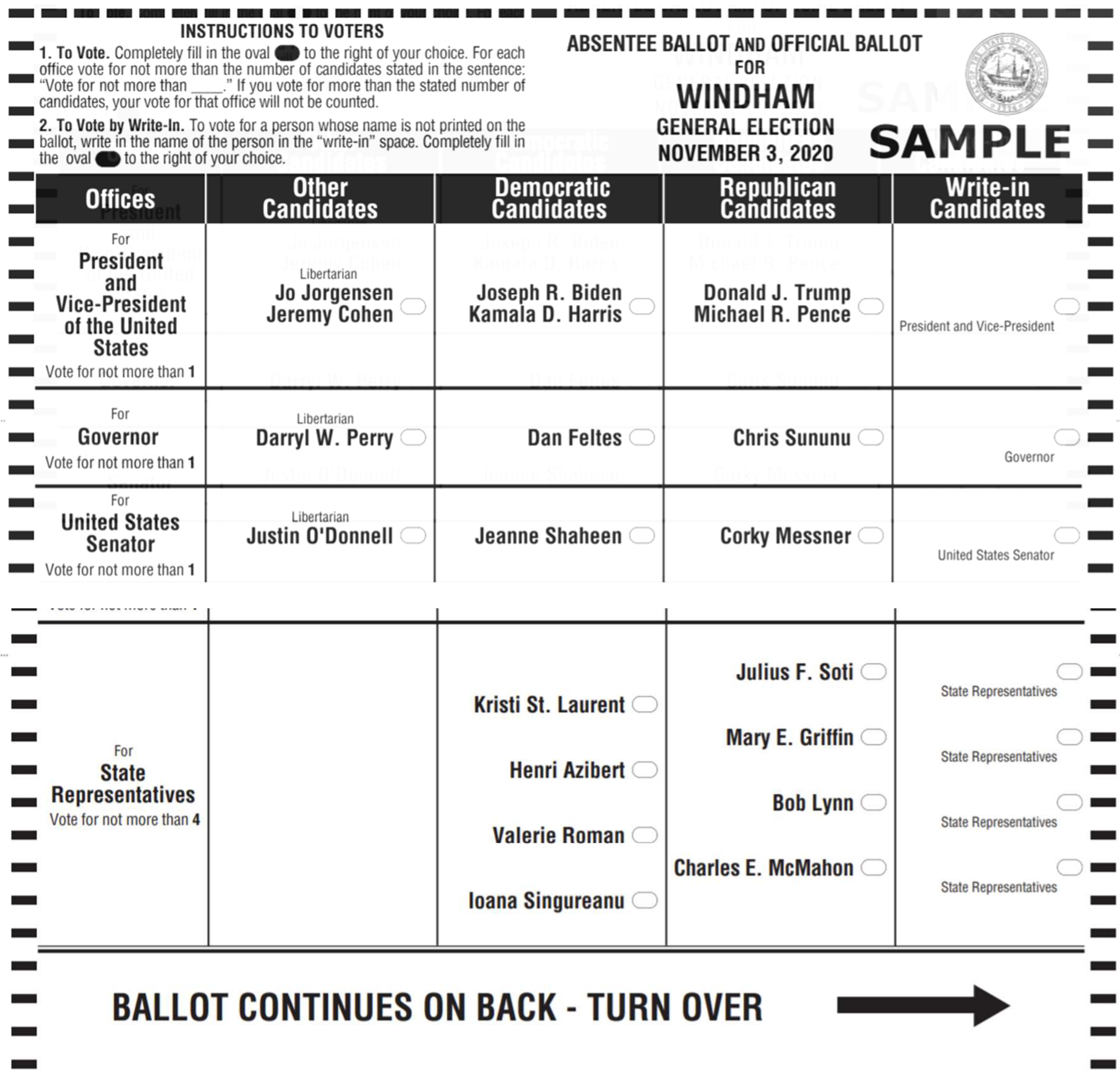
[20] For the mis-taped ballots, because the AccuVote uses the timing marks at the bottom of each ballot to determine ballot orientation, we expect that most contests would be counted correctly, but the contests above the fold – president, sheriff, county attorney, and county treasurer – would not be.

only one of these ballots was even entered in the flagger log. The reference image for this ballot, 3-534, closely resembles images from folded but intact ballots.

Some of the nonstandard marks mentioned above likely account for the small differences between the election night vote counts for U.S. Senator and the audit hand count results, and may have had similar effects (on the order of 20 or so votes) in other contests. Nothing in our review of the flagger logs or reference images – or our conversations with the volunteers who conducted the hand count – indicated that marking issues *substantially* contributed to the large discrepancies that motivated the audit. Rather, several lines of evidence suggested that folds through vote targets were a likely primary explanation of the discrepancies between hand and machine counts in the State Representative contest, as well as the smaller discrepancies found in the governor contest.

Folds through vote targets

The following images are part of a Windham sample ballot. (The complete image is available at https://www.doj.nh.gov/sb43/documents/windham-sample-ballot.pdf.) The thin horizontal lines at the edges of the ballot – above the vote targets for governor, and above the first vote targets for State Representative – show where ballots intended for absentee voting are scored, that is, deeply indented to facilitate proper folding. The scores are placed between timing marks to avoid affecting vote targets.



INSTRUCTIONS TO VOTERS

1. To Vote. Completely fill in the oval to the right of your choice. For each office vote for not more than the number of candidates stated in the sentence: "Vote for not more than ____." If you vote for more than the stated number of candidates, your vote for that office will not be counted.

2. To Vote by Write-In. To vote for a person whose name is not printed on the ballot, write in the name of the person in the "write-in" space. Completely fill in the oval to the right of your choice.

ABSENTEE BALLOT AND OFFICIAL BALLOT
FOR
WINDHAM
GENERAL ELECTION
NOVEMBER 3, 2020

SAMPLE

Offices	Other Candidates	Democratic Candidates	Republican Candidates	Write-in Candidates
For **President and Vice-President of the United States** Vote for not more than 1	Libertarian **Jo Jorgensen Jeremy Cohen**	**Joseph R. Biden Kamala D. Harris**	**Donald J. Trump Michael R. Pence**	President and Vice-President
For **Governor** Vote for not more than 1	Libertarian **Darryl W. Perry**	**Dan Feltes**	**Chris Sununu**	Governor
For **United States Senator** Vote for not more than 1	Libertarian **Justin O'Donnell**	**Jeanne Shaheen**	**Corky Messner**	United States Senator
For **State Representatives** Vote for not more than 4		**Kristi St. Laurent** **Henri Azibert** **Valerie Roman** **Ioana Singureanu**	**Julius F. Soti** **Mary E. Griffin** **Bob Lynn** **Charles E. McMahon**	State Representatives State Representatives State Representatives State Representatives

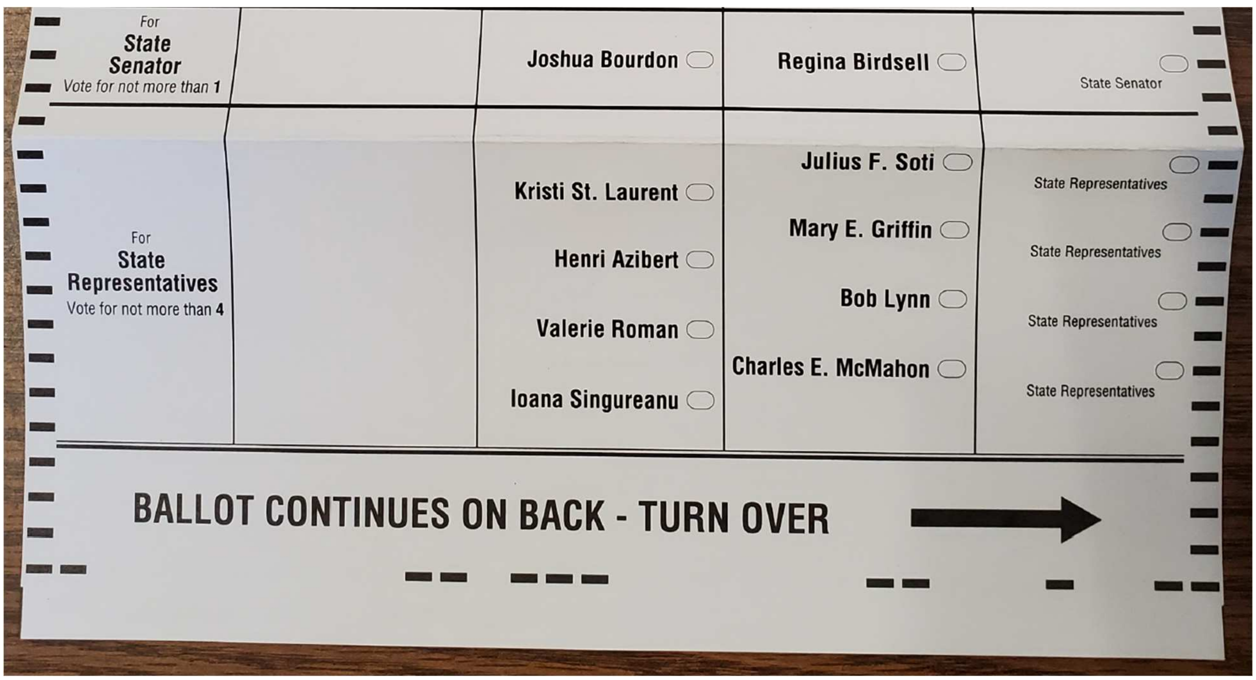
BALLOT CONTINUES ON BACK - TURN OVER

Part of a Windham sample ballot, including the audited contests and score locations

Note that in the vote-for-one contests, all the voting targets are vertically aligned. However, in the State Representative contest, the targets for Democratic candidates are intentionally aligned below the targets for Republican (and write-in) candidates. This alignment is mandated to indicate that the Democratic and Republican candidates are not competing in pairs – voters are free to vote for any combination of Democratic, Republican, and write-in candidates, as long as they do not vote for more than four.

Note also, at the top of the first image above, the language “ABSENTEE BALLOT AND OFFICIAL BALLOT.” In most New Hampshire elections, ballots would be marked either “OFFICIAL BALLOT” (for ballots to be voted in person on election day) or “ABSENTEE BALLOT.” In 2020, due to the difficulty of predicting how many people would request absentee ballots, the state opted to use a single template for both kinds of ballots. Ballots intended for absentee voting would be scored for folding, but it would be possible to use scored ballots on election day.

The image below shows part of the front of an actual unmarked, folded Windham ballot. (The complete image is available at https://www.doj.nh.gov/sb43/documents/unmarked-folded-windham-ballot.pdf.) This ballot has been correctly folded at the score mark.

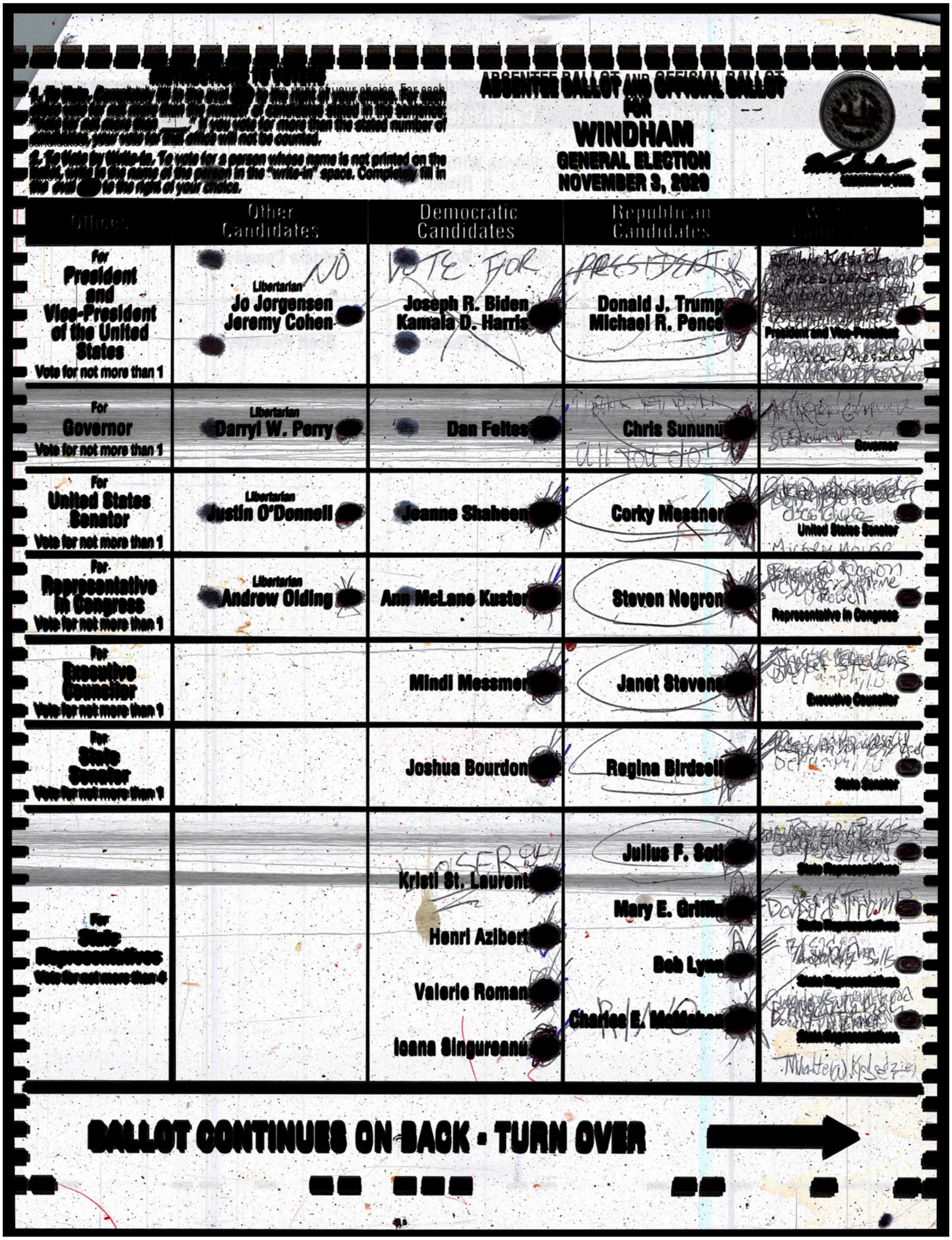


An actual unmarked Windham ballot, correctly folded at the score mark

Superposition of reference scans

The audit revealed that many ballots were not correctly folded so as to avoid vote targets, and that folds through Kristi St. Laurent's vote target were especially common. One way to visualize what we observed is to superpose the reference scans so that all fold lines can be seen simultaneously.

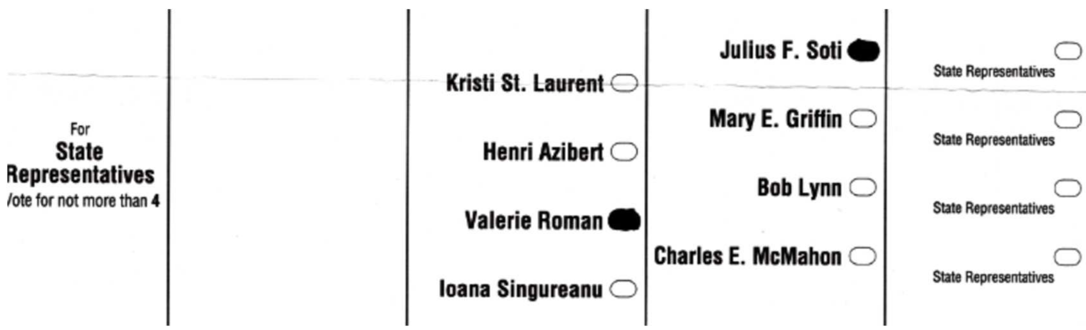
The image below shows that, in practice, the top fold line might appear almost anywhere in the "governor" portion of the ballot – not just above all the vote targets, as intended – and that many lines went directly through several or all vote targets. If a machine interpreted some of those folds as vote attempts, it could regard a valid vote as an overvote. Even more alarming is the concentration of folds through St. Laurent's target. The band of folds through St. Laurent's target is wider at the edges than in the center (where her target is), suggesting that those folds often sloped up or down, but went through her target regardless. The image also attests to folds that passed through Soti's target and/or the write-in target next to Soti's.



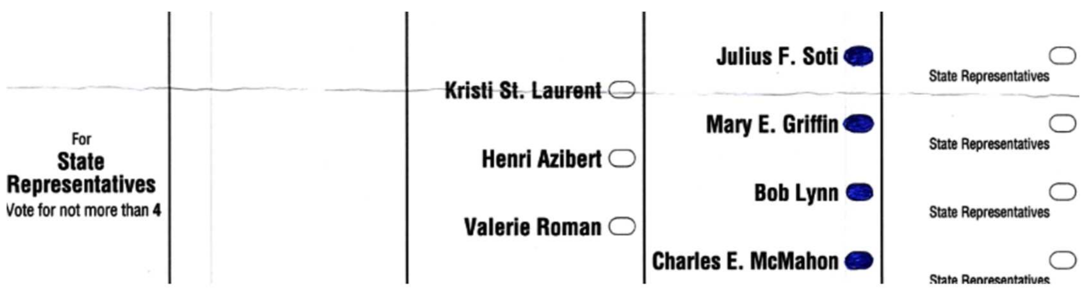
Superposition of reference scans; note the many folds through St. Laurent's target

Qualitatively, these folds could account for the observed discrepancies in the State Representative contest, by both adding votes for St. Laurent and, more often, subtracting votes for her Republican opponents. For instance (see also “Exemplar Folds” below starting on page 65):

- Consider a ballot marked only for Soti and Roman, but with a fold through St. Laurent’s target. If the machine read all three of these as vote attempts, St. Laurent would gain a vote in the machine count. The image below is from just such a ballot, ballot ID 3-272 (although we cannot know how the machines read this ballot).



- Consider a ballot marked for all four Republicans, but with a fold through St. Laurent’s target. If the machine read all *five* of these as vote attempts, it would reject them as overvotes, and each of the Republicans would lose a vote in the machine count. The example below is from ballot ID 7-364.



The fold hypothesis also could explain why the reported rate of “blank” votes (overvotes and undervotes) in the State Representative contest was highest on machine 2, which tabulated at least 90% of the absentee ballots.

	Machine 1	Machine 2	Machine 3	Machine 4
overvote/undervote rate in State Rep contest machine count, 2020	14.5%	***19.3%***	15.5%	16.0%

Finally, the fold hypothesis is consistent with the fact that the machine-count vote totals in the audit were between the original machine totals and the 2020 and 2021 hand-count totals for the State Representative contest, and that Feltes and Sununu picked up votes in the machine retabulation. The voted ballots had been stored under the weight of other ballots for 6 months between November, 2020, and May, 2021. It is reasonable that this storage period flattened the folds to some extent and thereby reduced their impact on machine tabulation accuracy. Changes to the machine-count totals for contests with no vote targets hit by folds (e.g., the Presidential contest) were small in comparison.

Investigating and testing the fold hypothesis

Although this line of reasoning made it plausible that folds could largely account for the discrepancies in the State Representative contest, as well as the difference between hand count and machine count results in the governor contest, we were left with several tasks after the hand count:

1. Account for why there were so many folds, especially unexpectedly through St. Laurent's vote target – well below the expected and intended fold location.
2. Experimentally verify that folds through vote targets could cause overvotes and extra votes on the AccuVote machines.
3. Use the reference images to verify that there were enough ballots folded through the vote targets to account for the discrepancies.[21]

Determining how absentee ballots were folded

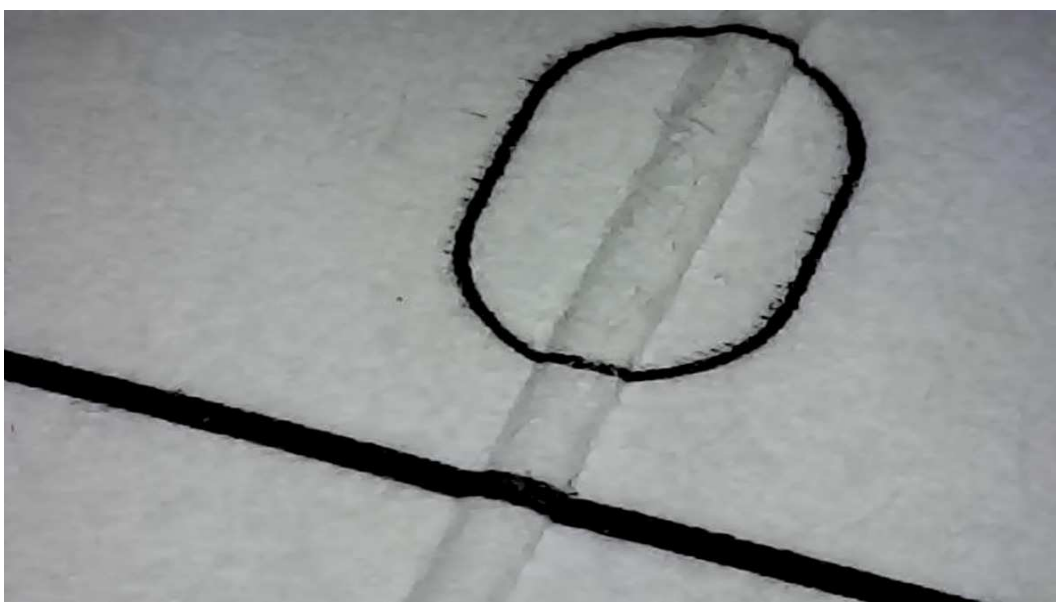
Town clerk Nicole Bottai explained that many of the absentee ballots had been folded using an automatic folding machine, the Neopost DS-35,[22] when the election workers were struggling to keep up with the demand for thousands of absentee ballots. The DS-35, which had been leased to handle motor vehicle renewal forms, can rapidly "C-fold" documents such as Windham's ballots. The staff then "ironed" the ballots, typically with a coin or a scissors handle, to further flatten them.

[21] Even if we had completed the flagger log analysis at this time, we would have been uneasy relying upon it entirely. Most folds were not visually conspicuous, so perfect reporting was implausible. Contrariwise, election officials might notice a fold that was "invisible" to the reference scanner and, most likely, the AccuVotes.

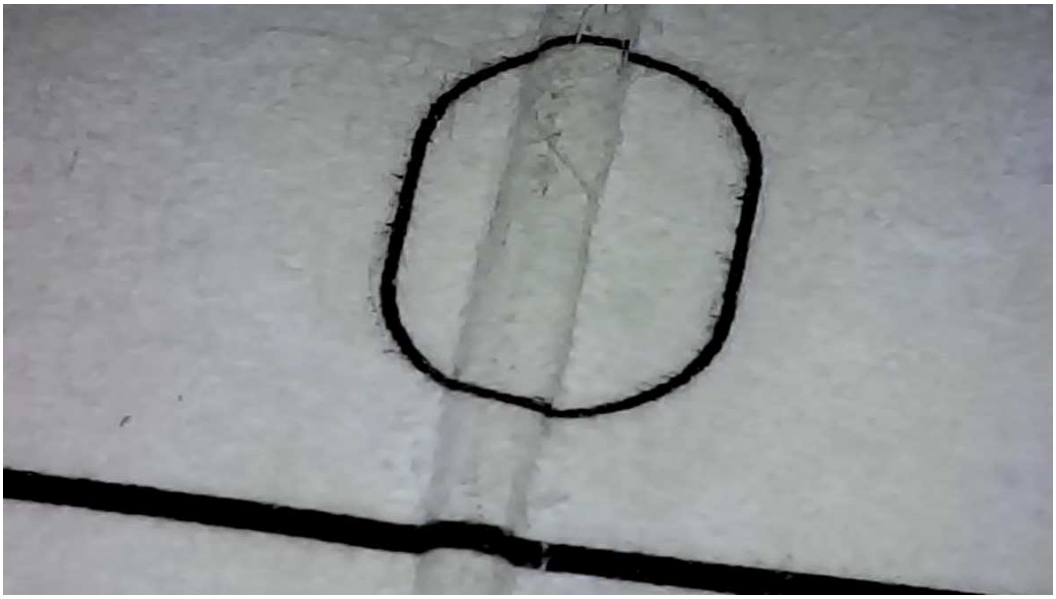
[22] https://kb.neopost.com/~/media/kb_neopost_com/products/document+systems/ds-35/standalone+media/operations/user+guide/ds-35+user+guide.pdf

A Neopost DS-35 folding machine

Bottai brought the folding machine to the audit site, and we were able to use unvoted absentee (scored) ballots to determine how the machine was used. We microscopically compared ballots we ran through the DS-35 and "ironed" to previously folded absentee ballots to confirm that our test ballots closely resembled the ones used in the election. We found that the machine-folded ballots consistently had folds through St. Laurent's target. The upper fold was consistently located just below the dividing line between President and Governor, well above the score line but not affecting any vote targets.

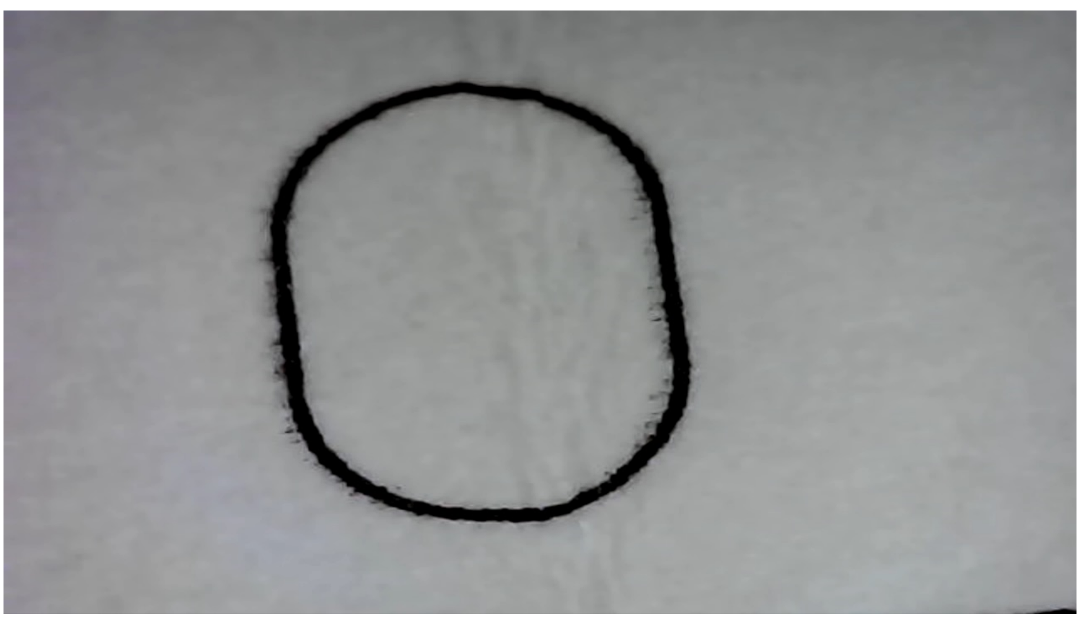


Microscopic photo of an unused absentee ballot folded in November 2020. The fold goes through Kristi St. Laurent's vote target.



Microscopic photo of unused absentee ballot folded during the audit using the folding machine. The fold goes through Kristi St. Laurent's vote target.

Both reference scans and microscopic examination of the folds reveal that the direction of the folding (up or down) creates asymmetric damage to the ballot paper. When the paper is folded in the opposite direction, the bump forms on the back side of the ballot and folding on the front side is barely visible. The direction depends upon the orientation in which the ballot has been inserted into the feeder of the folding machine.



Microscopic photo of paper folded with the folding machine in the opposite direction.

We have been made aware that the Secretary of State did conduct a ballot folding test to determine whether folding in an incorrect location could affect the accuracy of the voting machine. They did not find an impact, but their test comprised only a few ballots and it is unclear how they folded the ballots and whether they tested folds in both directions.

Test decks and mock elections

Having accounted for why so many ballots were folded through St. Laurent's vote target, we were now able to test experimentally whether those folds could account for the discrepancies observed in the election night counts, using test decks of unvoted ballots. Although the flagger logs identify over 1,300 ballots (quite possibly over 1,400) that apparently contain folds through St. Laurent's target, many of those ballots were voted for St. Laurent, so the fold would not affect the count. Among the remaining ballots, could the miscount rate be high enough to account for the observed discrepancies?

Our experiment involved four test decks of 75 absentee (scored) ballots apiece. Two of these decks were never folded. We folded and "ironed" the other two test decks to match the folds from November, as described in the previous section. We captured reference scans of these test decks, which are published on the SB43 webpage under Saturday, May 22. These reference scans consistently show visible fold lines, increasing our confidence that we can reasonably examine the reference scans of voted ballots to locate similar folds.

In the first pair (folded/unfolded) of test decks, all 75 ballots in each deck were voted for all four Republicans in the State Representative contest. (In other contests, 50 ballots were marked straight party Republican, and 25 ballots were marked straight party Democratic.) In the second pair of test decks, just one candidate (either Democratic or Republican) was marked for State Representative. Thus, the first pair tested whether the folds could subtract votes from Republicans, and the second pair tested whether the folds could add votes to St. Laurent.

We used two groups of volunteers, 3 persons in each group, to mark the test ballots. These volunteers are listed in Appendix C.

Two machines were tested: the "school" machine, which was least accurate in the full tabulation, and "machine 2," which was used to tabulate the majority of absentee ballots on election day.

The ballots were scanned in all four orientations: head first, face up; head first, face down; foot first, face up; and foot first, face down. (According to Nicole Bottai, absentee ballots generally were inserted head first, face down – but reoriented if the scanner rejected the ballot.)

All ballots that had never been folded were tabulated accurately, on both machines and in all orientations. All contests on folded ballots except those with folds through vote targets were tabulated accurately in all orientations. The State Representative contest was not tabulated accurately when there were folds through St. Laurent's vote target. Accuracy depended on the orientation and on the machine. The school machine was less accurate than machine 2 in every case.

In the first folded test deck (voted straight Republican in the State Representative contest), the folds produced between 27 and 54 overvotes, depending on the machine and the ballot orientation. As further described later in the report (page 96), one machine was subsequently cleaned using compressed gas, then used to retabulate the deck; cleaning reduced the number of overvotes from 54 to 35 in the "head first, face up" orientation. On machine 2 – the machine actually used to process most absentee ballots – the head first, face down orientation most often used on election day produced 46 overvotes, a rate of about 61%.

In the second folded test deck (voted for just one State Representative contest), the folds produced between 15 and 43 spurious votes for St. Laurent, depending on machine and orientation. On machine 2, the head first, face down orientation produced 24 spurious St. Laurent votes.

These strikingly high miscount rates suggest that folds could indeed account for the large discrepancies in the State Representative contest.

Machine	head first face up	head first face down	foot first face up	foot first face down
2 (78355)	27	46	46	27
"school" (81365)	54	54	52	41
"school" after cleaning w/ compressed gas	35	N/A	N/A	N/A

Number of erroneous overvotes on 75 ballots folded through Kristi St. Laurent's otherwise unmarked vote target when the State Representative contest was fully voted for all four Republican candidates. See footnote for documentation.[23]

[23] Poll (result) tapes are available at https://www.doj.nh.gov/sb43/documents/test-deck-poll-tapes.pdf. Test deck is available at https://www.doj.nh.gov/sb43/documents/test-election-1-folded.pdf. Test deck with no folds is available at https://www.doj.nh.gov/sb43/documents/test-election-1-unfolded.pdf.

Machine	head first face up	head first face down	foot first face up	foot first face down
2 (78355)	25	24	27	15
"school" (81365)	43	32	37	24

Number of erroneous votes for St. Laurent on 75 ballots folded through Kristi St. Laurent's otherwise unmarked vote target when only one candidate in that contest was selected. See footnote for documentation.[24]

The difference between the two sets of experimental results for folded ballots is most likely due to differences in how the ballots were ironed, or some other difference between test decks – not to the difference between overvotes and erroneous votes. The AccuVote evaluates each vote target independently of all other vote targets, so whether an AccuVote "sees" a vote attempt for St. Laurent should not depend on the presence or absence of votes for other candidates in the contest. The two test decks do differ observably: The reference scans from the test decks show over a dozen ballots in the second test deck with light folds, compared with only two or three in the first deck.[25] Thus, it seems likely that the miscount rates in the second deck are diluted. That said, our test procedure was not designed to closely estimate the likely error rate for absentee ballots counted on Election Day. We could not hope to reconstruct exactly how the Windham ballots were ironed (although the microscopic comparison indicates that we are not far off), nor the effects of being mailed, flattened during voting, refolded, mailed again, opened, and perhaps manually flattened before being scanned.

As we discuss next, our examination of ballots cast in the actual election indicates that folds through St. Laurent's target in the two conditions (possible overvotes or possible spurious St. Laurent vote) were about equally likely to be miscounted. The agreement between those two rates is additional support for the fold hypothesis.

Number of folds through unmarked vote targets

We used computer vision algorithms to detect folds through unmarked vote targets in the Governor and State Representative contests using the reference scans, and to cross-reference these folds with apparent votes for the State Representative and gubernatorial candidates.

---

[24] Poll tapes available at https://www.doj.nh.gov/sb43/documents/test-deck-poll-tapes.pdf. Test deck available at https://www.doj.nh.gov/sb43/documents/test-election-2-folded.pdf. Test deck with no folds available at https://www.doj.nh.gov/sb43/documents/test-election-2-unfolded.pdf.

[25] See pages 35, 97, and arguably 87 in the first deck; see pages 1, 37, 49, 69, 77, 79, 95, 97, 99, 113, 115, 117, 121, and arguably 85 and 123 in the second deck. These reference images may not be directly comparable to the images from voted ballots, because they were captured with a different scanner.

Any method for detecting folds has the possibility of false positives (claiming there is a fold when there is not) and false negatives (not noticing a fold). To ensure that our results were conservative, we manually reviewed *every* image the algorithms identified as having a fold to confirm that it indeed had a fold that intersected an otherwise unmarked vote target.[26]

Through this analysis, we identified and verified at least 599 ballots with folds through St. Laurent that could convert straight-Republican votes to overvotes, as well as 3 ballots with folds through *Soti's* vote target that could convert straight-Democratic votes to overvotes. We similarly found at least 255 ballots with folds through St. Laurent that might provide spurious St. Laurent votes (because the contest was undervoted and St. Laurent's vote target was otherwise unmarked), and 2 ballots with folds through Soti that might add to his vote total. In the Governor contest, we found 225 ballots with folds through one or more targets that might convert valid votes to overvotes, of which 132 would have subtracted from Sununu's tally and 93 would have subtracted from Feltes's tally.[27] Although it is possible that some of the Soti and Governor folds were caused by the folding machine, we suspect (based on inspecting the images) that many were caused by *manual* folds slightly below where the ballots were scored, deepened by "ironing" as with the machine folds.[28]

These counts dovetail reasonably well with the observed discrepancies and the experimental results. First, consider that the three Democratic candidates other than St. Laurent, who should have been *almost* unaffected by folds, gained 22 votes apiece in the recount over the election night returns. Presumably (and typically in hand counts) Republican candidates for State Representative also would have gained some votes in the recount even without the folds. If we assume that the Republican candidates gained about 275 votes apiece due to folds and around 22 to 24 votes apiece due to voter intent issues, the required fold miscount rate is about 275 / 599 = 46%. Similarly, if we assume that in the recount, St. Laurent lost about 120 phantom votes attributable to folds, partly offset by about 21 votes gained due to voter intent issues, the required fold miscount rate is 120 / 255 = 47%. (The miscount rate in the governor's contest looks similar, perhaps on the order of 100 / 225 = 44%.) In the mock election results for machine 2, in the head first/face down orientation that was most common on Election Day, the observed fold miscount rates were 61% in test deck 1 and 32% in test deck 2, about 44% on average. All three of our estimates for actual voted ballots here are thus near the average of our two experimental results. Put another way, our mock election results indicate that folding-machine folds can

---

[26] We also manually reviewed a random sample of 300 images the software classified as not having a fold through any vote target; that manual review found one ballot with a fold through the gubernatorial contest. The ballot was voted for Feltes. Based on finding 1 false negative in a random sample of 300 ballots, a 95% upper confidence bound for the number of ballots with folds through vote targets that the software did not identify is 116 (among the 10,004 ballots).

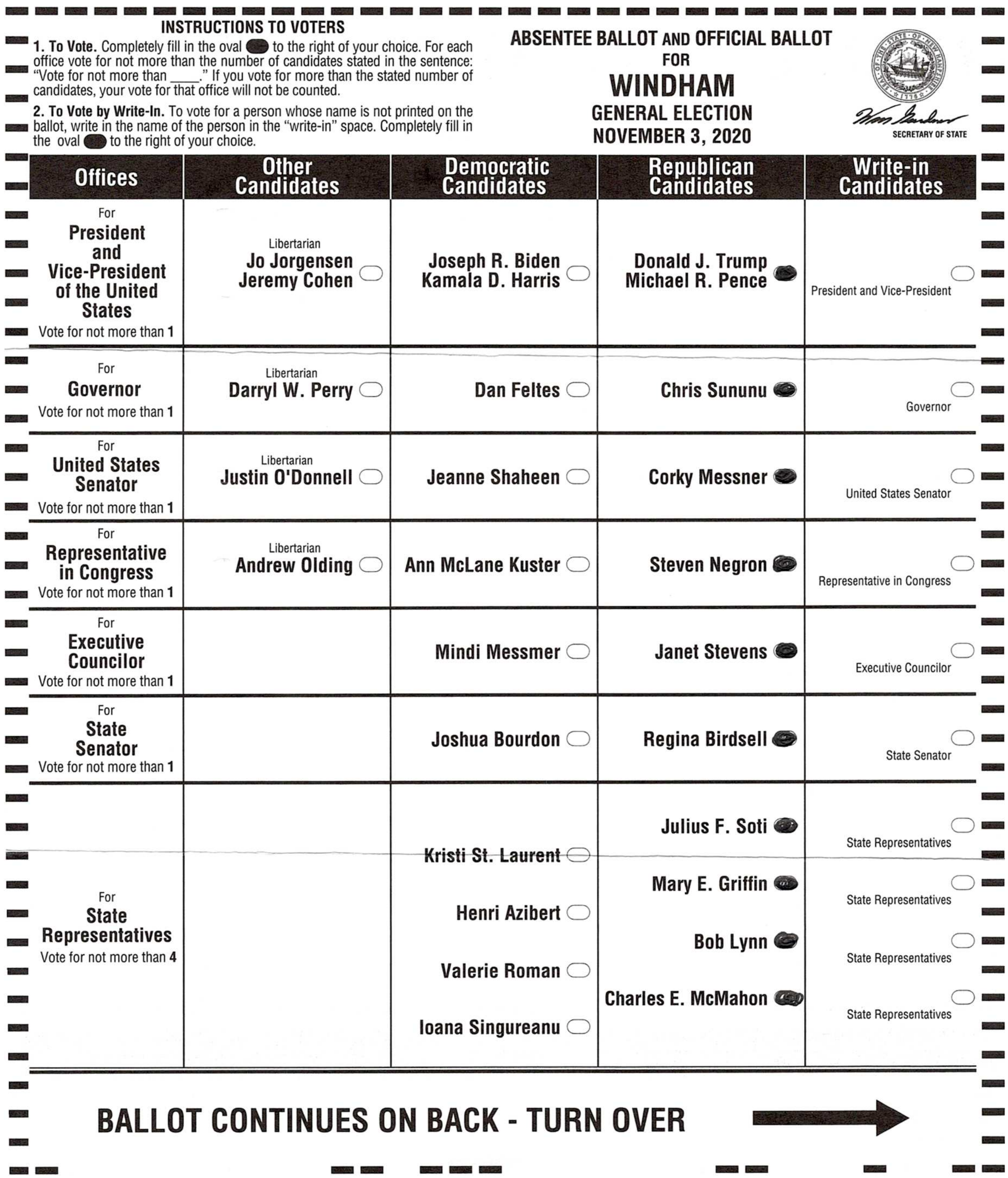
[27] These figures represent about 2% of Sununu's total and about 4% of Feltes's total, respectively.

[28] Simply putting the ballots in the folding machine head first should not have this effect: in that scenario, the folds should be about two timing marks above the vote targets for Governor.

substantially account for the observed discrepancies between machine and hand counts – and under other circumstances could have caused more (or fewer) miscounted ballots.

Exemplar folds

Here we reproduce reference images of voted ballots with folds that we conclude were likely to be miscounted by the AccuVotes.



INSTRUCTIONS TO VOTERS

1. To Vote. Completely fill in the oval to the right of your choice. For each office vote for not more than the number of candidates stated in the sentence: "Vote for not more than ____." If you vote for more than the stated number of candidates, your vote for that office will not be counted.

2. To Vote by Write-In. To vote for a person whose name is not printed on the ballot, write in the name of the person in the "write-in" space. Completely fill in the oval to the right of your choice.

ABSENTEE BALLOT AND OFFICIAL BALLOT
FOR
WINDHAM
GENERAL ELECTION
NOVEMBER 3, 2020

SECRETARY OF STATE

Offices	Other Candidates	Democratic Candidates	Republican Candidates	Write-in Candidates
For **President and Vice-President of the United States** Vote for not more than **1**	Libertarian **Jo Jorgensen Jeremy Cohen**	**Joseph R. Biden Kamala D. Harris**	**Donald J. Trump Michael R. Pence**	President and Vice-President
For **Governor** Vote for not more than **1**	Libertarian **Darryl W. Perry**	**Dan Feltes**	**Chris Sununu**	Governor
For **United States Senator** Vote for not more than **1**	Libertarian **Justin O'Donnell**	**Jeanne Shaheen**	**Corky Messner**	United States Senator
For **Representative in Congress** Vote for not more than **1**	Libertarian **Andrew Olding**	**Ann McLane Kuster**	**Steven Negron**	Representative in Congress
For **Executive Councilor** Vote for not more than **1**		**Mindi Messmer**	**Janet Stevens**	Executive Councilor
For **State Senator** Vote for not more than **1**		**Joshua Bourdon**	**Regina Birdsell**	State Senator
For **State Representatives** Vote for not more than **4**		**Kristi St. Laurent** **Henri Azibert** **Valerie Roman** **Ioana Singureanu**	**Julius F. Soti** **Mary E. Griffin** **Bob Lynn** **Charles E. McMahon**	State Representatives State Representatives State Representatives State Representatives

BALLOT CONTINUES ON BACK - TURN OVER

A ballot with a fold likely to create an overvote in the State Representative contest, subtracting votes from the 4 Republican candidates (compared to a hand count)

INSTRUCTIONS TO VOTERS

1. To Vote. Completely fill in the oval to the right of your choice. For each office vote for not more than the number of candidates stated in the sentence: "Vote for not more than ____." If you vote for more than the stated number of candidates, your vote for that office will not be counted.

2. To Vote by Write-In. To vote for a person whose name is not printed on the ballot, write in the name of the person in the "write-in" space. Completely fill in the oval to the right of your choice.

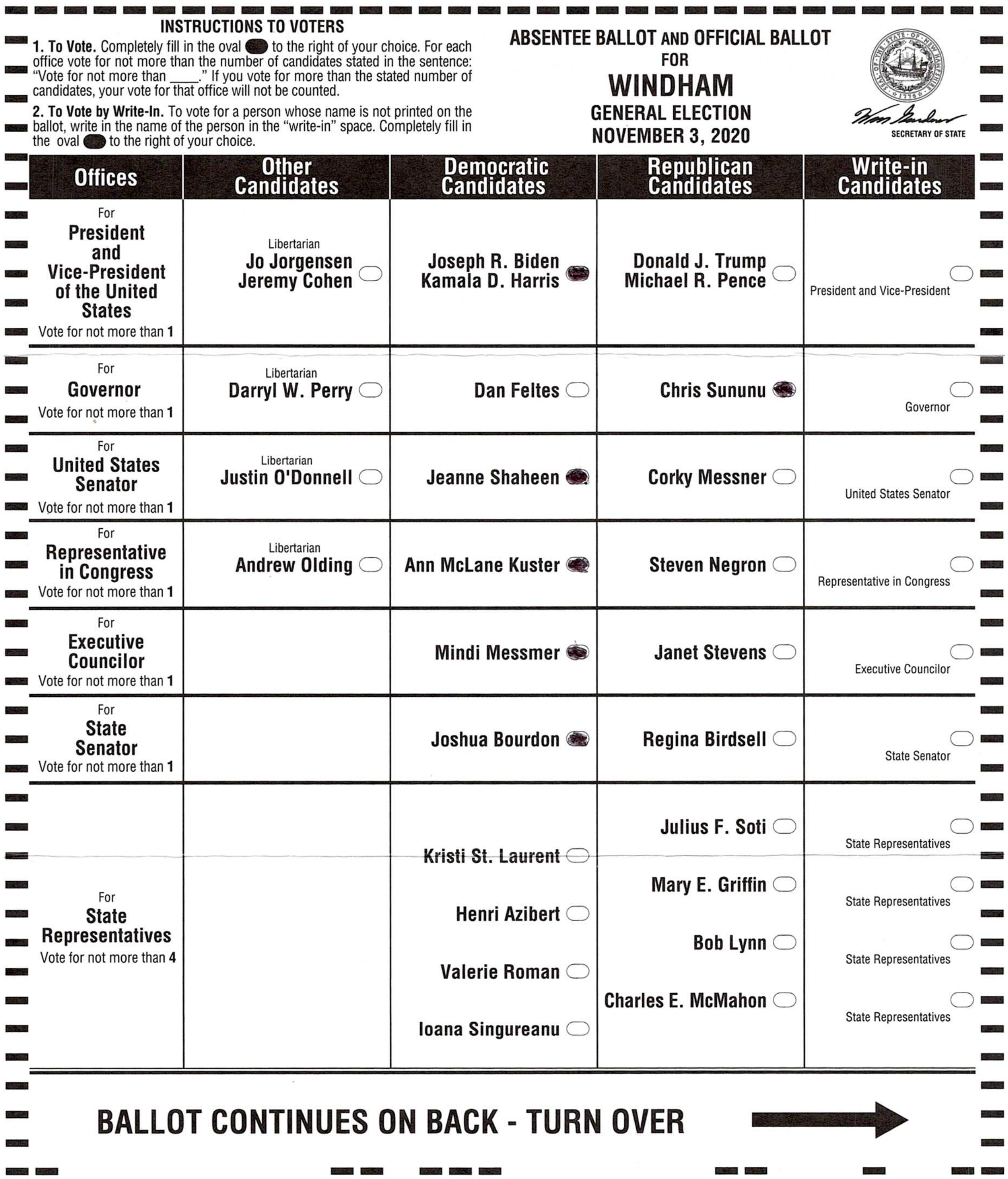
ABSENTEE BALLOT AND OFFICIAL BALLOT
FOR
WINDHAM
GENERAL ELECTION
NOVEMBER 3, 2020

SECRETARY OF STATE

Offices	Other Candidates	Democratic Candidates	Republican Candidates	Write-in Candidates
For **President and Vice-President of the United States** Vote for not more than **1**	Libertarian **Jo Jorgensen Jeremy Cohen**	**Joseph R. Biden Kamala D. Harris**	**Donald J. Trump Michael R. Pence**	President and Vice-President
For **Governor** Vote for not more than **1**	Libertarian **Darryl W. Perry**	**Dan Feltes**	**Chris Sununu**	Governor
For **United States Senator** Vote for not more than **1**	Libertarian **Justin O'Donnell**	**Jeanne Shaheen**	**Corky Messner**	United States Senator
For **Representative in Congress** Vote for not more than **1**	Libertarian **Andrew Olding**	**Ann McLane Kuster**	**Steven Negron**	Representative in Congress
For **Executive Councilor** Vote for not more than **1**		**Mindi Messmer**	**Janet Stevens**	Executive Councilor
For **State Senator** Vote for not more than **1**		**Joshua Bourdon**	**Regina Birdsell**	State Senator
For **State Representatives** Vote for not more than **4**		**Kristi St. Laurent** **Henri Azibert** **Valerie Roman** **Ioana Singureanu**	**Julius F. Soti** **Mary E. Griffin** **Bob Lynn** **Charles E. McMahon**	State Representatives State Representatives State Representatives State Representatives

BALLOT CONTINUES ON BACK - TURN OVER

A ballot with a fold likely to create an overvote in the State Representative contest, subtracting votes from the 4 Democratic candidates (compared to a hand count)



INSTRUCTIONS TO VOTERS

1. To Vote. Completely fill in the oval ⬬ to the right of your choice. For each office vote for not more than the number of candidates stated in the sentence: "Vote for not more than ____." If you vote for more than the stated number of candidates, your vote for that office will not be counted.

2. To Vote by Write-In. To vote for a person whose name is not printed on the ballot, write in the name of the person in the "write-in" space. Completely fill in the oval ⬬ to the right of your choice.

ABSENTEE BALLOT AND OFFICIAL BALLOT
FOR
WINDHAM
GENERAL ELECTION
NOVEMBER 3, 2020

SECRETARY OF STATE

Offices	Other Candidates	Democratic Candidates	Republican Candidates	Write-in Candidates
For **President and Vice-President of the United States** Vote for not more than **1**	Libertarian **Jo Jorgensen Jeremy Cohen**	**Joseph R. Biden Kamala D. Harris**	**Donald J. Trump Michael R. Pence**	President and Vice-President
For **Governor** Vote for not more than **1**	Libertarian **Darryl W. Perry**	**Dan Feltes**	**Chris Sununu**	Governor
For **United States Senator** Vote for not more than **1**	Libertarian **Justin O'Donnell**	**Jeanne Shaheen**	**Corky Messner**	United States Senator
For **Representative in Congress** Vote for not more than **1**	Libertarian **Andrew Olding**	**Ann McLane Kuster**	**Steven Negron**	Representative in Congress
For **Executive Councilor** Vote for not more than **1**		**Mindi Messmer**	**Janet Stevens**	Executive Councilor
For **State Senator** Vote for not more than **1**		**Joshua Bourdon**	**Regina Birdsell**	State Senator
For **State Representatives** Vote for not more than **4**		**Kristi St. Laurent** **Henri Azibert** **Valerie Roman** **Ioana Singureanu**	**Julius F. Soti** **Mary E. Griffin** **Bob Lynn** **Charles E. McMahon**	State Representatives State Representatives State Representatives State Representatives

BALLOT CONTINUES ON BACK - TURN OVER

A ballot with a fold likely to create a phantom vote for St. Laurent

INSTRUCTIONS TO VOTERS

1. To Vote. Completely fill in the oval ⬬ to the right of your choice. For each office vote for not more than the number of candidates stated in the sentence: "Vote for not more than ____." If you vote for more than the stated number of candidates, your vote for that office will not be counted.

2. To Vote by Write-In. To vote for a person whose name is not printed on the ballot, write in the name of the person in the "write-in" space. Completely fill in the oval ⬬ to the right of your choice.

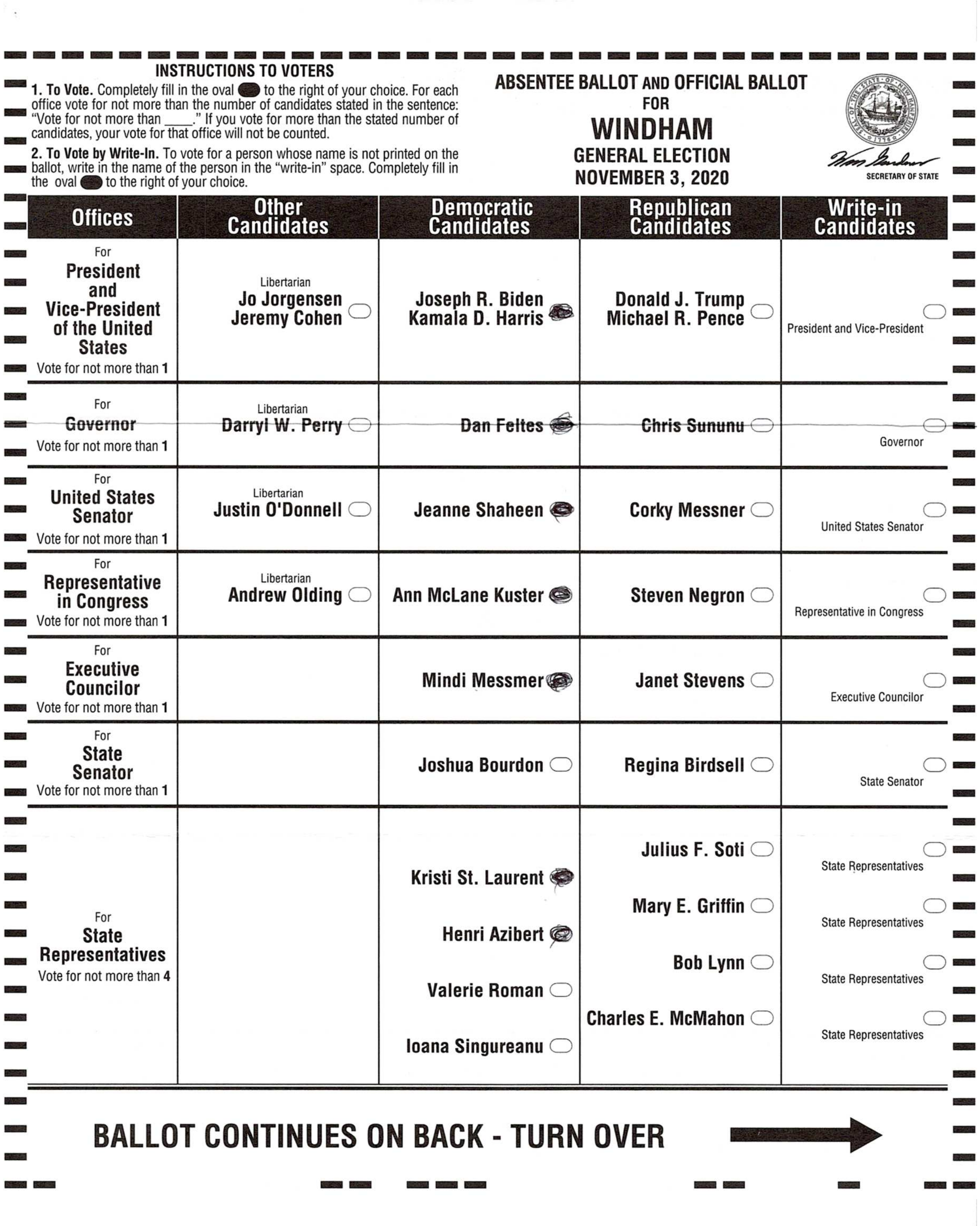
ABSENTEE BALLOT AND OFFICIAL BALLOT
FOR
WINDHAM
GENERAL ELECTION
NOVEMBER 3, 2020

SECRETARY OF STATE

Offices	Other Candidates	Democratic Candidates	Republican Candidates	Write-in Candidates
For **President and Vice-President of the United States** Vote for not more than **1**	Libertarian **Jo Jorgensen Jeremy Cohen**	**Joseph R. Biden Kamala D. Harris**	**Donald J. Trump Michael R. Pence**	President and Vice-President
For **Governor** Vote for not more than **1**	Libertarian **Darryl W. Perry**	**Dan Feltes**	**Chris Sununu**	Governor
For **United States Senator** Vote for not more than **1**	Libertarian **Justin O'Donnell**	**Jeanne Shaheen**	**Corky Messner**	United States Senator
For **Representative in Congress** Vote for not more than **1**	Libertarian **Andrew Olding**	**Ann McLane Kuster**	**Steven Negron**	Representative in Congress
For **Executive Councilor** Vote for not more than **1**		**Mindi Messmer**	**Janet Stevens**	Executive Councilor
For **State Senator** Vote for not more than **1**		**Joshua Bourdon**	**Regina Birdsell**	State Senator
For **State Representatives** Vote for not more than **4**		**Kristi St. Laurent** **Henri Azibert** **Valerie Roman** **Ioana Singureanu**	**Julius F. Soti** **Mary E. Griffin** **Bob Lynn** **Charles E. McMahon**	State Representatives State Representatives State Representatives State Representatives

BALLOT CONTINUES ON BACK - TURN OVER

A ballot with a fold likely to create a phantom vote for Soti



INSTRUCTIONS TO VOTERS

1. To Vote. Completely fill in the oval to the right of your choice. For each office vote for not more than the number of candidates stated in the sentence: "Vote for not more than ____." If you vote for more than the stated number of candidates, your vote for that office will not be counted.

2. To Vote by Write-In. To vote for a person whose name is not printed on the ballot, write in the name of the person in the "write-in" space. Completely fill in the oval to the right of your choice.

ABSENTEE BALLOT AND OFFICIAL BALLOT
FOR
WINDHAM
GENERAL ELECTION
NOVEMBER 3, 2020

SECRETARY OF STATE

Offices	Other Candidates	Democratic Candidates	Republican Candidates	Write-in Candidates
For **President and Vice-President of the United States** Vote for not more than **1**	Libertarian **Jo Jorgensen Jeremy Cohen**	**Joseph R. Biden Kamala D. Harris**	**Donald J. Trump Michael R. Pence**	President and Vice-President
For **Governor** Vote for not more than **1**	Libertarian **Darryl W. Perry**	**Dan Feltes**	**Chris Sununu**	Governor
For **United States Senator** Vote for not more than **1**	Libertarian **Justin O'Donnell**	**Jeanne Shaheen**	**Corky Messner**	United States Senator
For **Representative in Congress** Vote for not more than **1**	Libertarian **Andrew Olding**	**Ann McLane Kuster**	**Steven Negron**	Representative in Congress
For **Executive Councilor** Vote for not more than **1**		**Mindi Messmer**	**Janet Stevens**	Executive Councilor
For **State Senator** Vote for not more than **1**		**Joshua Bourdon**	**Regina Birdsell**	State Senator
For **State Representatives** Vote for not more than **4**		**Kristi St. Laurent** **Henri Azibert** **Valerie Roman** **Ioana Singureanu**	**Julius F. Soti** **Mary E. Griffin** **Bob Lynn** **Charles E. McMahon**	State Representatives State Representatives State Representatives State Representatives

BALLOT CONTINUES ON BACK - TURN OVER

A ballot with a fold likely to create an overvote in the Governor's race, costing Feltes a vote

Ballot and voter reconciliation

The language of SB43 charged us with determining "whether the number of ballots tallied by hand in Windham and those tallied by hand by the secretary of state during the recount on November 12, 2020 were the same as the number of ballots cast," and also with establishing "the total ballots cast, the total ballots counted, and total ballots received from the secretary of state." This text is somewhat confusing, but we conservatively constructed it to require the most thorough possible accounting of (at least) cast ballots throughout the process.

Various findings below rely upon digital documents provided by the town of Windham pursuant to a Right-To-Know request.[29] Especially important are the following:

Moderator's worksheet (Attachment A)
End of night tally (Attachment B)
End of night hand count (Attachment H)
Ballot clerk book summary (Attachment I)
Ballot control (Attachment J)
End of night check-in tally (Attachment K)
Marked checklist (paper pollbook) (Attachment L)

Also useful for reference are the recount results (Attachment E).

Election night (November 3) results

The moderator's worksheet (Att. A) and the official results from election night (Att. B) agree that 10,006 ballots were cast and counted – 9,926 counted by the AccuVote scanners, and 80 counted by hand.

Ballots tallied during the recount

Regrettably, the recount procedures followed on November 12, 2020, did not track the number of *ballots* counted, nor did it count "blank votes" (undervotes or overvotes observed on the ballots). Instead, only *votes* for each candidate named on the ballots were tallied and counted. This approach provides no basis for assurance that the number of ballots recounted equals the number of ballots originally counted. Indeed, some observers strongly suspected that some ballots had been counted more than once. If either total ballots or blank votes had been tracked, it would have been clearer – as we believe in retrospect – that the recount did include approximately or exactly 10,006 ballots but that the number of blank votes was substantially smaller than reported on election night.

[29] These are available at https://1drv.ms/u/s!AkHTB_k5VsaxhWrgSV8JsZRcc5by.

Election material custody

This section briefly summarizes the chain of custody for cast ballots and other election materials.

Under New Hampshire state law, all ballots (voted or not), absentee ballot applications and affidavit envelopes, and certain other materials are to be retained by city or town clerks for at least 22 months after a federal or state election, unless requested by the Secretary of State. The ballots and other materials were indeed requested by the Secretary of State for the recount of the State Representative contest, conducted on November 12. Additional materials were requested for a Ballot Law Commission hearing on November 23.

Accordingly, the custody logs from November 2020 show two separate transfers of election materials from Windham to the state.

According to the November custody logs,[30] on November 10, town clerk Nicole Bottai signed over a total of 24 boxes, bearing bar codes 159590 through 159613, to Peter "Hoppy" Falzone, a clerk at the secretary of state's office. (A 25th box, 159614, does not appear in these logs, but presumably was signed over at the same time. As noted below, the audit found that this box contained absentee ballot envelopes and other non-ballot materials.) Falzone in turn signed them over to Justin Ober of the state Division of Archives and Records Management ("state archives"). According to Falzone's log entries, 12 of the boxes contained cast ballots, one contained uncast ballots, and the other 11 contained absentee affidavit envelopes.

On November 20, assistant moderator Elizabeth Dunn submitted an additional box of "rejected absentees" with bar code 159782, signed for by state archivist Brian Nelson Burford. This log page indicates that this box was "opened at [the] Ballot Law Commission hearing 11-23-2020" and the "contents examined by [the] Commissioners" before being resealed by Burford and another state employee. The recount itself did not generate additional custody paperwork. As explained to us by Deputy Secretary of State Dave Scanlan, state archivist Brian Nelson Burford was responsible for transferring the cast ballots from a sealed vault to the recount room. Ballots were removed from the storage boxes, then returned to the boxes as they were counted. At the end of the recount, all boxes were resealed with security tape, and Burford returned them to the vault.

The custody logs[31] from May 11, 2021, at the beginning of the audit, show a total of 27 containers (26 boxes and one envelope) released by Ober or (in the case of the rejected absentee ballots) Burford to Hoppy Falzone, and subsequently from Falzone to Mark Lindeman of the audit team. In addition to the 25 boxes originally transferred to the state, these containers include a box with bar code 159614 and a yellow "envelope of challenged

---

[30] These are available at https://www.doj.nh.gov/sb43/documents/20210520-windham-sos-chain-of-custody.pdf.
[31] These are available at https://www.doj.nh.gov/sb43/documents/20210519-windham-ballot-chain-of-custody.pdf.

ballots at recounts [sic].” These containers are further identified by numbered yellow “sticky notes” attached with tape, numbers 1 through 27. (These numbers were added shortly before the boxes were transferred to the audit team, and their order does not correspond to the bar codes. In particular, the additional box is #2; the envelope is #4.) One box containing absentee documents was damaged, apparently due to having weight stacked on it, and was not well sealed. The remaining containers, including all containers with voted ballots, appeared well sealed and in good condition.

As the sworn volunteers opened and inventoried the containers during the audit, they recorded the box numbers and contents in the election material container manifest. This manifest[32] clarifies that the additional box (#2, bar code 159614) contained absentee ballot envelopes. An additional box, labeled #28, was also created at this time; it contained 43 spoiled ballots from box #13.

During the audit, the two challenged ballots were removed from envelope #4 and it was destroyed. All the cast ballots ultimately were stored in new boxes; the twelve empty boxes that originally contained cast ballots also were returned to state custody.

Ballot accounting during the audit

As explained above, every cast ballot found during the audit was assigned to a *scan batch* and given a *ballot ID*. The AccuVote counter numbers and ballot ID ranges recorded on the scan batch cover sheets give us multiple lines of confirmation that 9,926 ballots were fed through the AccuVote scanners during the audit. The scan batch cover sheets and tally sheets confirm that these 9,926 ballots, plus an additional 78 ballots that could not be fed through the AccuVotes, were hand-counted during the audit.

The ballot ID numbers were intended to be unique and consecutive within “stamp” (prefix) number. Because most IDs were handwritten, a few discrepancies were discovered during the hand count and/or when we reviewed the scan batch cover sheets and reference images.[33] We also found one obvious mistake in recording counter numbers on a scan batch cover sheet. We confirmed that with these adjustments, the ballot IDs, scan batch cover sheets, and tally sheets consistently documented the same set of ballots. The documentation supports the conclusion that every ballot assigned to a scan batch was manually tallied during the audit.

---

[32] The election material manifest is available at https://www.doj.nh.gov/sb43/documents/election-material-container-manifest.pdf.

[33] Ballot IDs 3-369, 3-373, 13-169, 13-265, 14-322, and 17-93 were assigned twice each. (For instance, the two 13-265s are identified as “13-265A” and “13-265B” on tally sheet T-1111.) Also, ballot IDs 3-854, 8-588 and 14-217 were never used, and ballot IDs 3-307 through 3-366 and 3-450 through 3-499 were never used.

Kinds of ballots

New Hampshire ballots come in several different kinds, which can complicate ballot accounting. Here, for reference in the following exposition, we summarize the kinds of ballots encountered during the audit:

- **Standard ballots (including most absentee ballots):** As explained above, in 2020, instead of printing separate election day and absentee ballots, the Secretary of State's office decided to print ballots that could be used for either purpose. Some ballots were scored for convenience in folding if they were used as absentee ballots. However, prescored ballots still could be used on election day, and unscored ballots still could be folded and used as absentee ballots.

  The standard Windham ballots for November 2020 were printed duplex (front and back) on letter-size cardstock. Ballots could have been printed on one side of larger stock, but that would have entailed more folds in absentee ballots.

- **UOCAVA ballots:** Under the federal Uniformed and Overseas Citizens Absentee Voting Act (UOCAVA) and related federal and state statutes, New Hampshire military and overseas voters may receive their ballots by mail, email, or fax. These ballots must be hand-counted. Although their formatting is similar to that of standard ballots, they do not have timing marks (required for the AccuVote scanners to count ballots). Sometimes, UOCAVA voters print their ballots on a single piece of paper, as with a standard ballot. Often, they print the front and back on separate pieces of paper.

- **Federal Office Only (FOO) ballots**: Certain overseas voters who are not New Hampshire residents are eligible to vote in New Hampshire for federal offices only. Each Federal Office Only (FOO) ballot occupies just one side of a sheet.

- **Accessible Electronic Absentee Ballots**: Beginning in 2020, New Hampshire voters with print disabilities were allowed to cast Accessible Electronic Absentee Ballots. These voters enter their vote selections using an online interface, then print their ballots and submit them by mail or by delivery. Windham's accessible ballots were printed on two pages, formatted differently than the standard ballots. (The state representative contest appeared on page 2.)

  These ballots should not be confused with ballots cast on election day using the one4all accessible voting system. The one4all system prints voters' selections onto standard ballots, which then are scanned as if they had been hand-marked.[34]

UOCAVA, FOO, and accessible ballots all were hand-counted on election day, because their formats differ from the standard ballot format. Other ballots that could not be fed through

[34] A fuller description is at https://sos.nh.gov/media/lpyfaisw/2020-one4all-booklet-general-election.pdf.

the scanners (presumably because the ballots were damaged) also were hand-counted. It appears that Windham submitted all hand-count ballots to the state in one box (barcode number 159608, log entry "80 UOCAVA, hand count"). However, these ballots were not counted separately during the recount. In the audit, most of the hand count ballots were found in the original box, also known as box #14. Additional UOCAVA ballots were found in box #20, along with standard ballots. While UOCAVA, FOO, and accessible ballots all can be identified by their formats, other ballots hand-counted on election night cannot be authoritatively identified.

In the audit, each ballot sheet received a unique identification number. Thus, UOCAVA and accessible ballots printed on two pieces of paper were assigned two ballot IDs. All these unique ballot sheets are recorded on the tally sheets. However, the *totals* on the tally sheets exclude ballot sheets that did not contain at least one of the three contests hand-counted in the audit. The audit found 27 UOCAVA ballots printed on two sheets apiece; the 27 "backs" are not included in the tally sheet totals (see tally sheets T-2147 and T-2150).

Cast ballot and voter reconciliation: election night and contemporaneous data

The official moderator's worksheet from election night (Attachment A) reports a total of 10,006 ballots cast, comprising 6,977 ballots cast by election day voters; 2,949 absentee ballots cast; 21 Federal Office Only and State Write-In Absentee Ballots; and 59 "other full (UOCAVA) Absentee Ballots." The vote counts, summarized in Attachment B and supported by the machine report tapes (Attachment C) and election night hand count tally sheet (Attachment H), similarly show 9,926 machine-counted ballots and 80 hand-counted ballots. The hand count tally sheet is annotated: "49 UOCAVA; 21 Federal Office Only ballots; 10 misread (machine couldn't count)." Thus, these totals appear to agree, with the caveat that the moderator's worksheet may report as full UOCAVA ballots some non-UOCAVA ballots that were not machine-readable. The evidence credibly supports (but does not prove) that 10,006 votes were cast.

The moderator worksheet further reports a total of 10,009 voters marked as having voted on the official checklist. The origin of this figure is not clear. Our review of the ballot clerk book summary (Attachment I) indicates 10,016 voters checked in, including 3,030 absentee voters. However, as we explain next, we do not believe those totals to be entirely accurate.

We manually reviewed the digital copy of the official checklist (Attachment L), which comprises 822 printed pages plus 722 backs of pages, some of which contain handwritten notes on additional voters or corrections. This laborious review cannot be guaranteed to be error-free, but we did carefully check all discrepancies against ballot clerk totals. We found 9,988 voters checked in, including 6,960 in-person voters and 3,028 absentee voters. Thus, whereas the ballot clerk book summary implies ten more checked-off voters than votes, the checklist (according to our review) implies there were eighteen more votes than checked-off voters.

Note that the count for absentee voters is very close to the 3,029 reported on the moderator's worksheet (as well as the 3,030 reported in the ballot clerk book summary). Almost the entire discrepancy is attributable to in-person election-day voters. Although we cannot further trace this discrepancy, one plausible explanation is that ballot clerks simply failed to check in (or to legibly check in) approximately one out of every 400 election day voters.

Cast ballot reconciliation: election night vs. audit

The audit tally sheets report a total of 10,006 ballots counted. However, upon closer inspection, only 10,004 unique ballots are recorded. This difference is attributable to two Accessible Electronic Absentee Ballots reported on tally sheet T-2146. Each ballot is reported on two separate rows: one for the governor and U.S. Senate contests (which appear on the first sheet) and one for the state representative contest (which appears on the second sheet).

A close reconciliation of the audit's scan batch cover sheets supports the conclusion that the AccuVote scanners counted 9,926 ballots during the audit. This total, 9,926, appears only on audit machine #1 (election night machine #2). Audit machines #2 and #4 scanned 9,924 ballots apiece, and the two unscanned ballots for each machine can be isolated to specific scan batches. Audit machine #3 scanned 9,937 ballots, including 11 ballots that were scanned twice – once with the correct scan batch, 18/F/19, and once with scan batch 16/C/17.

The scan batch cover sheets show a total of 107 ballot sheets in eight scan batches that were never fed through the AccuVote scanners. As explained above, 27 of those sheets are "backs" of UOCAVA ballots and 2 are second pages of accessible ballots, so the audit counted 78 unscanned ballots not included in the AccuVote totals. This is two ballots fewer than the 80 reported election night hand-count ballots. Comparing the election night hand-count results with the audit hand-count totals, the election night totals include two more votes for Sununu, one each for Shaheen and Messner,[35] and a scattering of seven votes for various state representative candidates (two for Griffin, and one each for St. Laurent, Roman, Soti, Lynn, and McMahon). We cannot know whether these small differences are fully accounted for by two ballots that were hand-counted on election night and scanned during the audit, or have a more complicated explanation.

---

[35] The tally sheet spreadsheets report a total of 26 votes for Messner, whereas the election night hand count total was 28. However, upon inspection of the audit reference images, ballot 18-0020 in tally batch T-2144, a Federal Office Only ballot, was tallied as an undervote for U.S. Senate but appears to be unambiguously marked for Messner. We interpret this as an error in the audit, likely facilitated by the unfamiliarity of the FOO ballot format and by fatigue on the last day of the hand count.

The audit confirms 21 Federal Office Only ballots[36] and 49 regular full UOCAVA ballots.[37] The eight (not ten) additional unscanned ballots in the audit were as follows: the two Accessible Electronic Absentee Ballots[38]; four standard ballots (apparently regular absentee, or possibly UOCAVA delivered by mail) that were stored in box #14 along with unscannable UOCAVA ballots; and two unscannable standard ballots, IDs 32-34 and 34-35, that were found in box #20.

The evidence does not allow us to resolve the discrepancy between the 10,006 cast ballots recorded on election day and the 10,004 cast ballots found in the audit.[39] Although the recount did not count the number of cast ballots or record the number of "blank" votes for state representative, the audit hand count found two fewer votes for St. Laurent, one fewer for Roman, and one fewer for Soti. This difference suggests the possibility that two ballots counted during the recount somehow were excluded from the audit.

Absentee ballot processing

To contextualize what follows, we briefly explain absentee ballot processing. To cast a standard absentee ballot in New Hampshire, the voter places the marked ballot in an affidavit envelope; seals the affidavit envelope (sometimes called the "inner envelope") and fills out the affidavit, including a signature; places the affidavit envelope in a larger mailing envelope (the "outer envelope"), seals it, and either mails or hand-delivers it.

In past years, New Hampshire absentee ballots have been processed at polling places entirely on election day: the outer envelopes would not be opened until then. A special law for the 2020 elections allowed partial processing of absentee ballots before election day; in Windham, this partial processing occurred on the Friday preceding election day. Partial processing is announced in advance so that party challengers and voters can attend and challenge the validity of ballots they believe not to be legally voted. In partial processing, election officials open the outer envelope, examine the affidavit envelope to confirm that it is "properly executed," and provide an opportunity to challenge the ballot for cause. If a ballot is accepted, the voter's name is marked with yellow highlighter in the checklist and

---

[36] These have ballot IDs 18-1 through 18-21, and are recorded in tally batch T-2144. All were found in box #14.

[37] These are as follows: (a) 18 full ballots, IDs 18-26 through 18-47 *except* 18-33 through 18-35 and 18-42; T-2143 and T-2145. (b) 4 full ballots, IDs 35-222 through 35-225, T-2149. (c) 24 fronts, IDs 19-1 through 19-24, T-2142. (d) 25 backs, IDs 20-1 through 20-25, T-2147. (e) 3 fronts, IDs 35-226 through 35-228, T-2148. (f) 2 backs, IDs 35-229 and 35-230, T-2150. Most of these were found in box #14; those with ballot IDs between 35-222 and 35-230 were found in box #20.

[38] These had ballot IDs 18-22 through 18-25, two IDs apiece, and were found in box #20.

[39] We have already explained why the discrepancy cannot be attributed to the Accessible Electronic Absentee Ballots. It also cannot be attributed to the two ballots that were challenged during the recount and set aside in envelope #4: those became ballots 1-1 and 1-2 (scan batch 4-A-1), reported on tally sheet T-1100.

the affidavit envelope is set aside to be opened and counted on election day. Under no circumstances is the affidavit envelope to be opened before election day.

On election day, the absentee ballots that arrived after partial processing were reviewed in much the same way as in partial processing – again, subject to challenge by party challengers or voters.

Five or so election officials worked to record and tabulate accepted absentee ballots on election day. According to election official Galen Stearns, officials first would take a set of affidavit envelopes to a ballot clerk and read off the names. Ballot clerks updated the checklist for each voter by adding an "AV" (Absentee Voter) notation in red ink; placing a check next to the voter's name; and crossing out the voter's last name. Then the official would open the affidavit envelopes, remove the voted ballots, flatten the ballots if necessary, and give them to another official to cast by feeding the ballots into the scanner. Several different officials were responsible for feeding accepted ballots into the scanner. According to Nicole Bottai, almost all absentee ballots were scanned on machine #2; occasionally, machine #1 was used.

Overseas (UOCAVA) ballots were handled similarly, except that voters did not return these ballots in standard affidavit envelopes. Indeed, many UOCAVA ballots were delivered to voters by email, so voters would return them in whatever envelopes they could, along with a signed affidavit, here called an UOCAVA oath.

Consistent with federal law, the New Hampshire election procedure manual directs:

> The moderator should save all spoiled and uncast ballots, the rejected (unopened) absentee ballot envelopes, any challenged (opened or unopened) absentee ballot envelopes and keep them with all the ballots cast at the election. Retain and preserve these materials in accordance with the laws governing the retention, preservation and destruction of ballots. RSA 659:101; RSA 33 A:3-a. See the Retention Chart at page 382. In the event of a recount, send the opened (empty) absentee ballot envelopes to the Secretary of State along with the ballots.

The retention chart clarifies that the city or town clerk retains these documents.

Review of election materials other than cast ballots

After the audit hand count, every container identified as containing materials other than cast ballots was reopened and inspected by hand. This was done to ensure that no cast ballots had been intermingled with these materials, and also to provide an additional point of comparison for absentee ballot documentation. In particular, the audit team directed the election official volunteers to hand-count the absentee affidavit envelopes (sometimes called "inner envelopes").

As expected, this review did not find any additional cast ballots that had been counted on election day. However, three voted ballots were found in opened affidavit envelopes. Under

New Hampshire election procedures, absentee ballots that are challenged and rejected are retained in their *unopened* affidavit envelopes. (A total of 71 rejected ballots were found in box #1.) We therefore tentatively conclude that these ballots were accepted but never recorded, cast, or counted. This is an unfortunate procedural failure.

The volunteers reported counting 2,936 absentee affidavit envelopes and at least 52 UOCAVA oaths.[40] Because we did not explicitly direct the election officials to count UOCAVA oaths, some may have gone uncounted. Given that all absentee ballot processing is done in public, we consider it unlikely that any ballots were cast without valid affidavits. We believe the discrepancy between affidavits/oaths and cast absentee ballots most likely is attributable to small errors during the audit, although we cannot rule out that some documents may have been misplaced.

The review found a total of 1,215 unmarked ballots, some of which were subsequently used in test decks. It also found 71 rejected absentee ballots, 43 spoiled ballots, and the 3 uncounted ballots, for a total of 1,332 uncast ballots. Combined with the 9,926 ballots that were retabulated during the audit and the 6 hand-counted ballots that were standard printed ballots,[41] the audit process accounted for 11,264 printed ballots. The state reported sending a total of 11,279 ballots to Windham.[42] Deputy secretary of state Dave Scanlan explained that this count should be considered approximate, because the ballots initially sent to each city and town are estimated by size, not counted individually. The similarity of these totals, allowing for the fact that some voters who were sent absentee ballots did not return them, suggests that ballots were well controlled.

Machine and memory card forensics

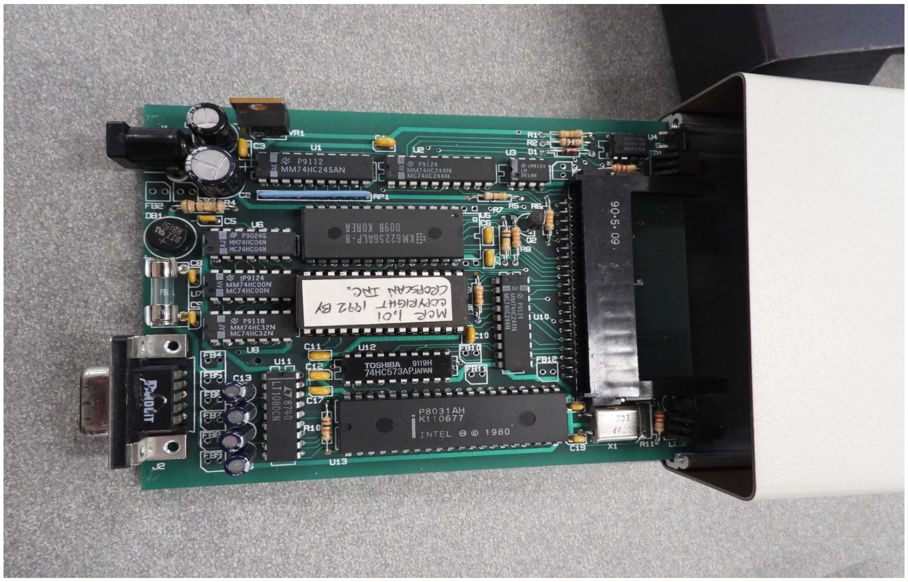
As explained above, in AccuVote systems, election-specific information is stored on memory cards, and the operating program is stored on EPROM chips. We copied and scrutinized data from these cards and chips, and also explored other aspects of the hardware.

Device used to read the memory cards

Memory cards were imaged using the CropScan Model 92 Data Logger Controller (DLC)[43] designed for the Multispectral Radiometer. A custom application developed for CropScan DLC is required to capture forensic images from the memory cards using the MSR BASIC interpreter. The DLC is an old single purpose system designed to process radiological data stored on the memory cards.

---

[40] The manifest for box #15 ambiguously refers to one "UOCAVA application."
[41] As detailed above, most hand-counted ballots were voter-printed UOCAVA ballots, Federal Office Only ballots, or machine-printed accessible ballots.
[42] This figure (10,500 ballots initially sent plus 779 overrun ballots) is documented at https://www.doj.nh.gov/sb43/documents/2020-overrun-ballots-sent-to-towns.pdf.
[43] https://manualzz.com/doc/6894884/user-s-manual-cropscan–inc .



The circuit board of the CropScan DLC

Device used to read the EPROMs

EPROM chips were read using the commercial off-the-shelf XGECU XGPRO TL866II+ PRO USB[44] Universal Programmer. It is one of the most widely used devices of its class, supporting over 15,000 different types of memory chips.

The XGECU device used to read the EPROM chips

[44] http://www.xgecu.com/en/TL866_main.html

Hash values of the memory card and EPROM data

We began by computing hash values from the two EPROM chips ("1001" and "512") in each AccuVote machine (including the reference machine provided by the Secretary of State's office) and from the Windham memory cards. The first table here reports the EPROM hashes. Filenames for EPROM data from the four Windham machines begin with "M#####" (the five-digit serial number); the reference machine is designated "MSOS." The second table reports the memory card hashes (designated by "Mcard_" plus the machine serial number). Note that two copies of the 1001 chip in machine #81365 were made.

```
Algorithm    Hash                                                                Path
-----        --                                                                  --
SHA256       FD402AC60F2ABC52A06CEBD2BDE047FC151B8D56A13335D50BC20E898E3A981A    M78298-C-1001.BIN
SHA256       DFC91DFECE21A8FB350EDEB83FCF536BC03814244458E934ADE2B889B418E2CD    M78298-C-512.BIN
SHA256       FD402AC60F2ABC52A06CEBD2BDE047FC151B8D56A13335D50BC20E898E3A981A    M78355-C-1001.BIN
SHA256       DFC91DFECE21A8FB350EDEB83FCF536BC03814244458E934ADE2B889B418E2CD    M78355-C-512.BIN
SHA256       FD402AC60F2ABC52A06CEBD2BDE047FC151B8D56A13335D50BC20E898E3A981A    M78363-C-1001.BIN
SHA256       DFC91DFECE21A8FB350EDEB83FCF536BC03814244458E934ADE2B889B418E2CD    M78363-C-512.BIN
SHA256       FD402AC60F2ABC52A06CEBD2BDE047FC151B8D56A13335D50BC20E898E3A981A    M81365-C-1001-2.BIN
SHA256       FD402AC60F2ABC52A06CEBD2BDE047FC151B8D56A13335D50BC20E898E3A981A    M81365-C-1001.BIN
SHA256       DFC91DFECE21A8FB350EDEB83FCF536BC03814244458E934ADE2B889B418E2CD    M81365-C-512.BIN
SHA256       FD402AC60F2ABC52A06CEBD2BDE047FC151B8D56A13335D50BC20E898E3A981A    MSOS-C-1001.BIN
SHA256       DFC91DFECE21A8FB350EDEB83FCF536BC03814244458E934ADE2B889B418E2CD    MSOS-C-512.BIN
```

```
Algorithm    Hash                                                                Path
-----        --                                                                  --
SHA256       9FB1D440969B86B55701E9475E436F622203AB7528843265DCB7A82F0D65FDA6    Mcard_78298
SHA256       1486D5432EC61E69333BBD92BC40DB74A35838DFBC8D6A9C6CB8232093E35FE4    Mcard_78355
SHA256       C2FE22C022E15533FAA850B4B29CDC9F03D3E7F6D2521CB5DC1ECC32F59E098B    Mcard_78363
SHA256       A7174FF5A743F63442958B80AEFB7CC8D8D593E7AE01EB1D6CF0693242EAB4F4    Mcard_81365
```

SHA is an abbreviation for Secure Hash Algorithm.[45] The Secure Hash Algorithms are a family of cryptographic hash functions published by the National Institute of Standards and Technology (NIST) as a U.S. Federal Information Processing Standard (FIPS). A cryptographic hash function is a mathematical algorithm that maps any size data to a small, fixed-size fingerprint called a digest. It is a one-way function, that is, a function that is practically infeasible or impossible to invert to find the original data. It is also collision resistant: it is practically infeasible to find two inputs that produce exactly the same output. This property makes SHA useful for fingerprinting digital data. SHAs exhibit the avalanche effect,[46] where changing even one bit of the input causes a large change in the output.

Publishing hash values of evidence before analysis is a best practice to ensure authenticity and digital chain of custody against evidence tampering. Hash values were shown in the live stream immediately after the evidence was obtained. Digital evidence without proof of authenticity has little or no value.

As seen from the hashes, programming on the chips on all machines was identical: all

45 https://csrc.nist.gov/projects/hash-functions

46 https://en.wikipedia.org/wiki/Avalanche_effect

"1001" values are identical, as are all "512" values. The memory cards contain different data and therefore have different hash values.

Analysis of the EPROM content

The EPROM chips are ST M27C512[47] and STM27C1001,[48] which provide a total of 192 Kilobytes of storage space. However, 49 Kilobytes of the space is not used, and therefore the combined size of the microkernel, AccuBasic interpreter and voting application is about 143 Kilobytes. Out of that, about 19 Kilobytes is human readable text, leaving approximately 124 Kilobytes for executable code and resident fixed configuration. Empty space is located in the later half of the M27C1001 chip from 0x13B70 to 0x1FFEF (in chip's address space, not in CPU's space). Bytes starting from 0x1FFF0 are in use.

The NEC V25 processor is reverse engineered from the Intel 8088, which inherited from the Intel 8086 a hardwired reset vector.[49] In computing, the reset vector is the default location a central processing unit will look at for the first instruction to execute after a power-on or reset. The reset vector is a pointer or address where the CPU should always begin as soon as it is able to execute instructions. The address is in a section of non-volatile memory initialized to contain instructions to start the operation of the CPU, the first step in the process of booting the system containing the CPU.

Reset vector mechanics are CPU model-specific even within the Intel family of CPUs. The reset vector for the V25 processor is at physical address FFFF0h in the CPU's addressable space (16 bytes below 1 MB). The value of the CS register at reset is FFFFh and the value of the IP register at reset is 0000h to form the segmented address FFFFh:0000h, which maps to physical address FFFF0h due to the way x86 memory segmentation was designed. The V25 CPU does not have separate reset vectors for power-on reset, for watchdog reset, for externally initiated reset, and for software-initiated reset: all starts are treated the same way. Here "x86 memory segmentation" refers to the implementation of memory segmentation in the Intel x86[50] computer instruction set architecture. Segmentation was introduced on the Intel 8086 in 1978 as a way to allow programs to address more than 64 KB (65,536 bytes) of memory in what used to be the only operational mode, since renamed to be called "real mode[51]" which is 16-bit x86-16 instructions only. V25 uses an 8-bit data bus, 16-bit instructions and 20-bit addressing. The x86-64 architecture, introduced in 2003, has largely dropped support for segmentation in 64-bit mode and therefore modern programmers are often no longer familiar with this concept.

---

[47] https://www.alldatasheet.com/datasheet-pdf/pdf/104409/STMICROELECTRONICS/M27C512.html
[48] https://www.alldatasheet.com/datasheet-pdf/pdf/22814/STMICROELECTRONICS/M27C1001.html
[49] https://www.sciencedirect.com/topics/engineering/reset-vector
[50] https://en.wikipedia.org/wiki/X86
[51] https://en.wikipedia.org/wiki/Real_mode

Due in part to the limitations of the hardware and the choices of the designers, AV-OS software is logically strongly segmented and includes code to facilitate interactions among the segments.

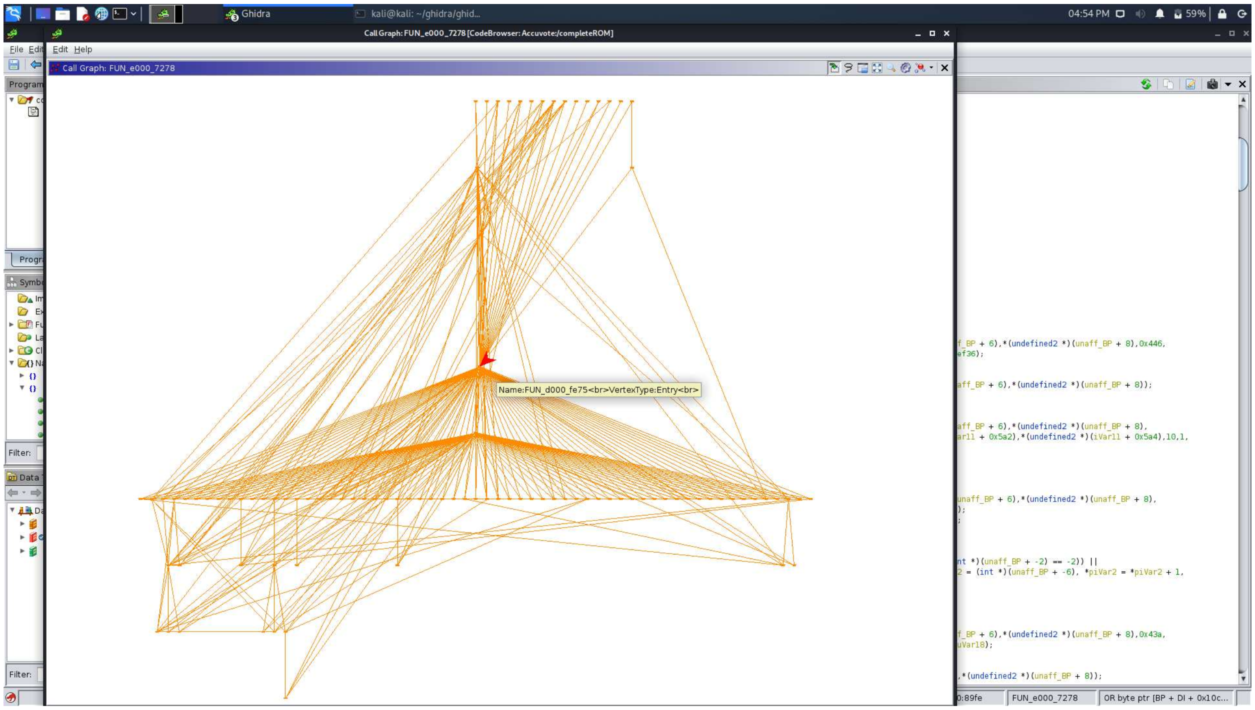
From previous studies we know that the AccuBasic interpreter in the AV-OS is written in C. The last version of the AV-OS interpreter studied in an independent study contained fewer than 2000 lines of C code (not counting blank lines, comments, or global declarations).

Our software analysis initially used IDA Pro and Ghidra[52] 10.0, but IDA Pro was soon abandoned. Ghidra is a free and open source reverse engineering tool developed by the National Security Agency[53] (NSA) of the United States. The scope of the Windham audit and the time available did not permit full reverse engineering of the code. We concentrated on mapping the functions as block flows, code flows, and call flows. While we decompiled the whole codebase, inspection concentrated on areas of code with constructs known to be potentially problematic or that had unusual properties.

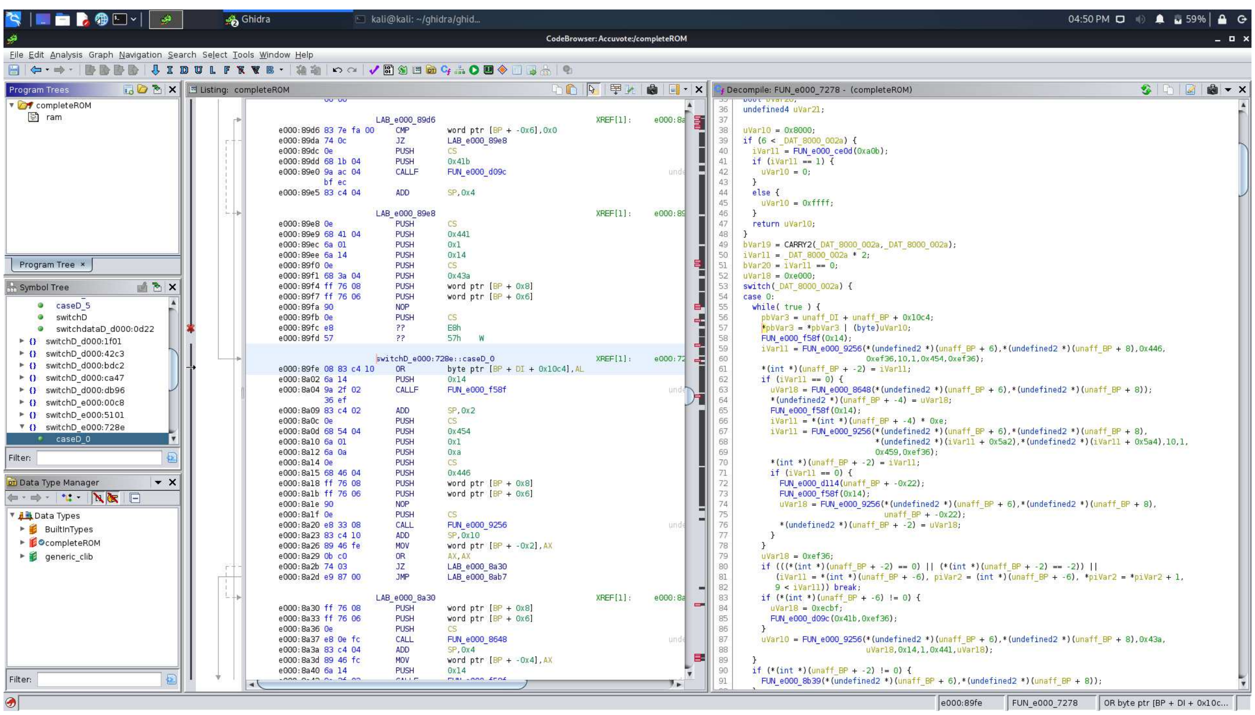
Exceptionally large case-clauses are generally red flags, but not in this case, as the code is known to have a built-in token code interpreter. At the time the AV-OS was created it was customary, albeit unsophisticated, to base such interpreters on nested and cascading case-clauses. Even though large case-clauses were expected, because they are known to be a time-honored means of code obfuscation – and therefore could be useful to build and conceal a hypothetical malicious "algorithm" – the majority of time was spent examining them. This review is labor-intensive because the compiled code is stripped of symbols: variable, function, and procedure names are missing..

Nothing suspicious was found.

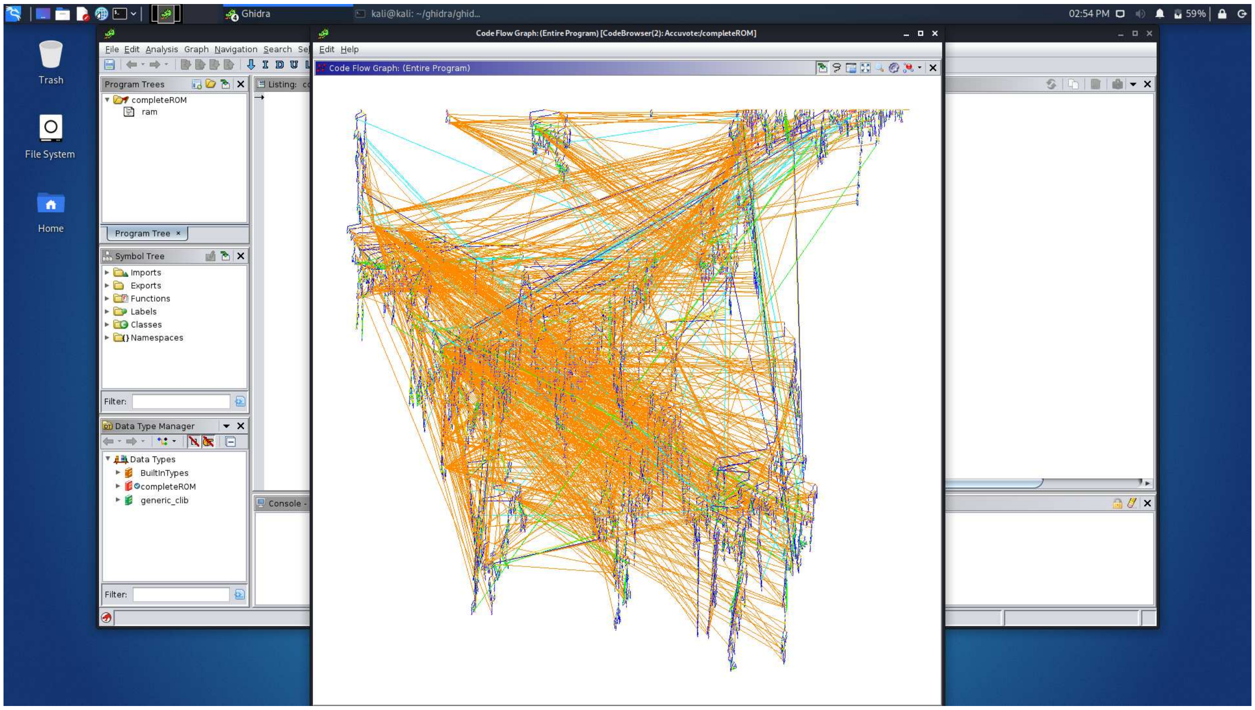
[52] https://ghidra-sre.org/
[53] https://www.nsa.gov/



Call graph map showing the nested / cascading case-clause structure



Raw binaries are translated into assembler code and further de-compiled into pseudo-C code and analyzed side-by-side to detect suspicious code



Code flow of entire software on EPROMs

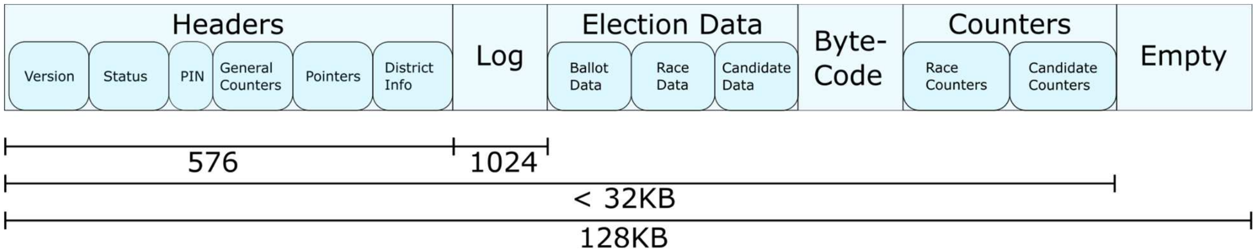
Analysis of the memory card contents

The AV-OS system uses a removable memory card as a key part of its architecture. The memory card is the only rewritable persistent storage available to the system, and contains several kinds of information in very condensed form:

1) the election description (a small database describing the races, candidates, parties, propositions, and ballot layout for the current election)
2) counters for every candidate and proposition on the ballot that store a count of the number of votes for that candidate, along with various summary counters;
3) byte-coded token object programs (.abo files), which are provided as a part of GEMS system and created by the software vendor
4) the internal electronic audit log
5) an election mode field indicating whether the system containing the card is currently in test, pre-election, election, or post-election mode
6) a large number of other variables including strings, flags (for selecting options), various event counters, and other data describing the state of the election

The entire election-specific state of the voting machine (the part that is retained between voting transactions) is stored on the memory card.

General structure of the memory card



Headers

The header of the card contains information about the organization of the contents of the card and main description of the election. The headers are all of a fixed length, 576 bytes. This segment includes

1) Memory card header:
    a) Firmware version.
    b) Card size.
    c) Election status, indicating the current operational mode of the card
    d) Counting mode (absentee or normal)
    e) Master card PIN number encoding
    f) General global counters, including the total ballots cast and total elections run
    g) Pointers to data segments on the memory card as a memory card heap.
2) Election header (District Info):
    a) Voting center name and number
    b) Download version number
    c) Obfuscated supervisor PIN
    d) Election title and date
    e) Election type
    f) Party code table
    g) Election configuration flags
    h) Data checksums

Log

This segment of the memory card is a fixed-size ``circular'' buffer in which the firmware logs certain actions and the time they were performed. When the maximum number of entries has been reached, any log additions overwrite entries in an earliest-first fashion.

Election data

The election data segment has a variable length and can be classified into three subsections:

1) Ballot Data: This section contains information about the ballot layout used in the current district for the current election.

2) Race Data: This section contains information about the offices in the current election. Key parts of this data include:
    a) Office ID
    b) Name of the office
    c) Number of candidates for the office.
3) Candidate Data: This section of the memory maintains information about the candidates. For each candidate it includes:
    a) Office ID the candidate belongs to
    b) Candidate ID
    c) Candidate name
    d) Location of the candidate on the ballot sheet.

Bytecode

This section of the card contains the tokenized bytecode. The AccuBasic (AB) bytecode in the programmed memory cards is responsible for the reporting procedures associated with an election. The code is written in a proprietary symbolic language; though the language explicitly lacks the ability to write to the memory card, it supports traditional control flow, arithmetic, reading and writing local variables, and procedure calls. AccuBasic programs are compiled to produce bytecode (externally) stored in .abo files in the EMS system, but on the memory card the code resides as a stored blob. The bytecode provided by LHS Associates for this election was manually analyzed to verify that no extraneous (or malicious) functionality was present. This analysis was performed in part with the help of experiments conducted using publicly available AccuBasic compilers, but those are older than the version of the election software used in NH. A compiler version matching the New Hampshire software version is not publicly available.

The AccuBasic token code on the memory cards is 7167 bytes, and identical on all memory cards. In previous research, the AccuBasic interpreter has been identified as a source of most of the known vulnerabilities. AccuBasic programs are used to drive reporting functions, and therefore any hypothetical malware using AccuBasic as an initialization vector can only start when reporting functions are used – i.e., when Zero Tapes or Election Results tapes are printed.

As the memory card is the only rewritable storage on the device, hypothetical malware would have to use the memory card to store parameters and programming. The memory card does not have a file system in a traditional sense. The closest resemblance in modern terminology would be hardware storage used as a block device. We inspected the contents of all memory cards and found nothing stored out of the bounds of expected election data blocks. The AccuBasic token code started from offset 0x112F on the memory cards used in Windham. This address is not consistent among all cities and towns, as the bytecode is stored after the ballot definition segment, which is variable-length.

Election counters

The election counters are located below the bytecode on the memory card as illustrated in the schematic. This is where all the election results and statistics are stored. This section can be divided into two broad subsections:

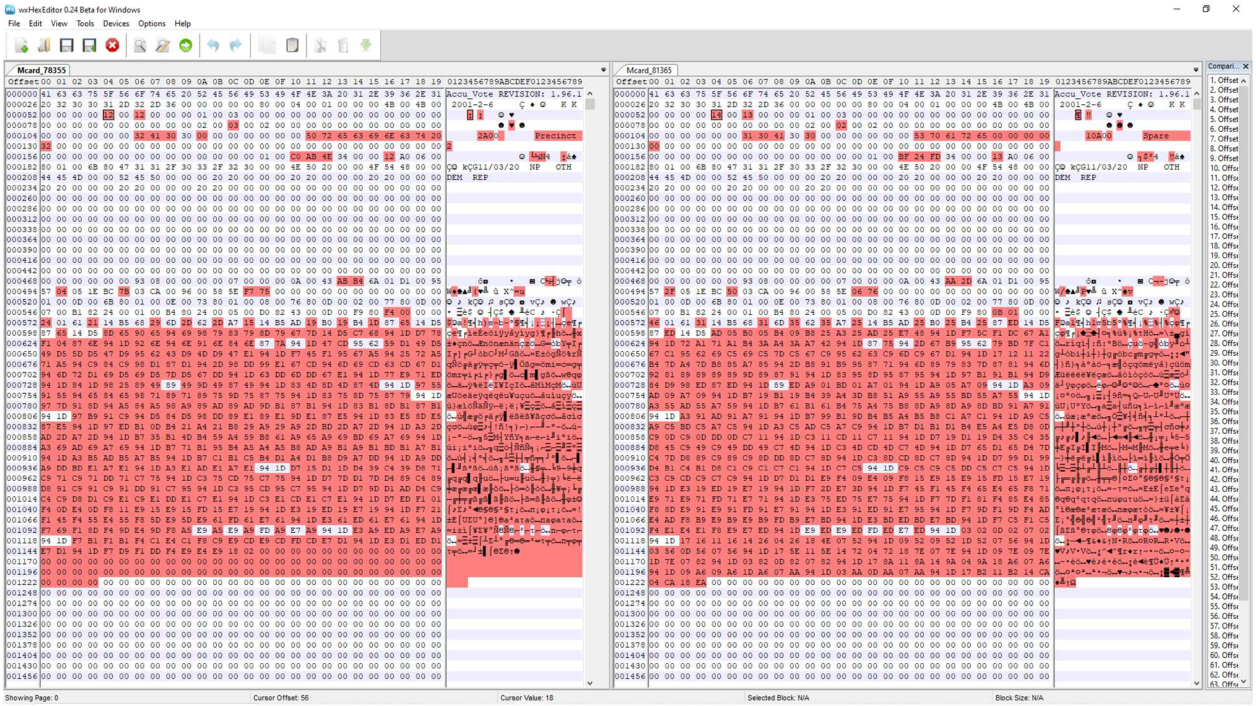
1) Race Counters:
   Statistics and counters for each office are kept in this section of the card.
2) Candidate Counters:
   This section contains the counters for each individual candidate.

Differences in bytes between the cards

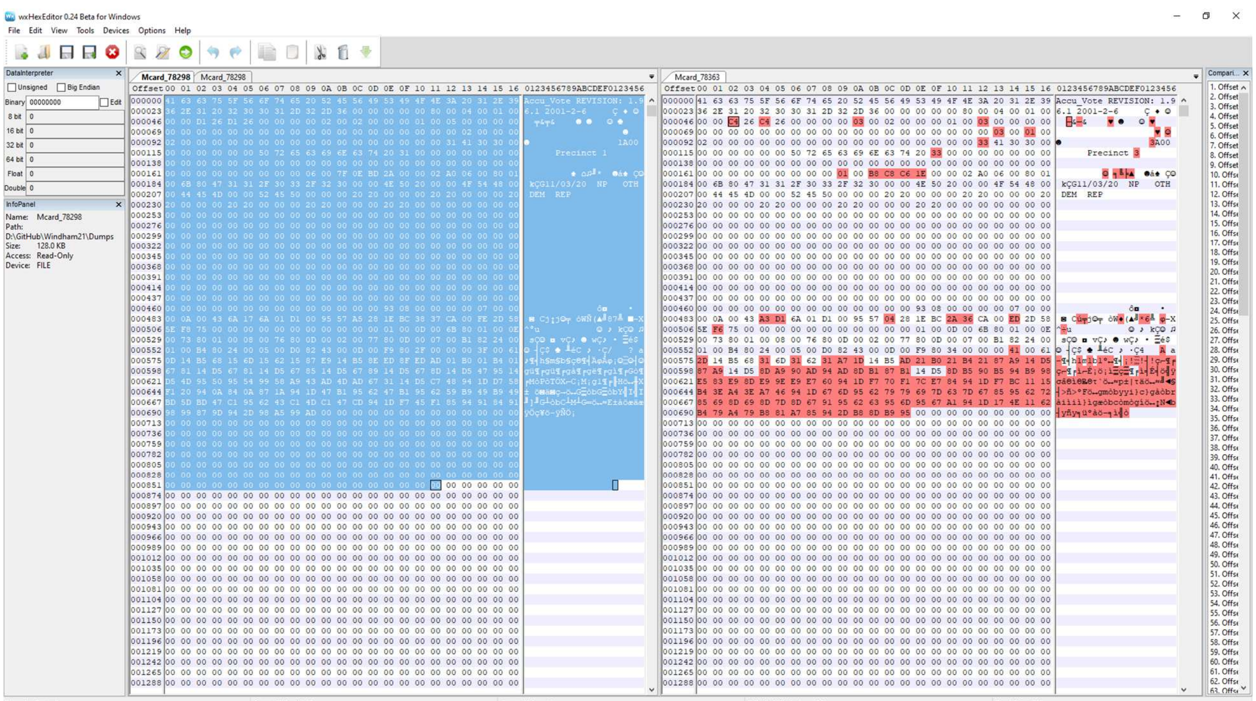
	78298	78355	78363	81365
78298		896	282	985
78355	896		893	675
78363	282	893		977
81365	985	675	977	

All differences between the cards were in areas where differences are expected. All three cards 78298, 78355 and 78363 were named after "precincts," corresponding to machines 1 through 3. Card 81365 was named "Spare," referring to the school machine (machine 4). The main source for the differing bytes count between the cards was the log segment, as expected. On cards 78298 and 76363, the log segment after the used area was zero as expected. However, two of the cards 78355 and 81365 seem to have about 500 bytes of unexplained garble. The Voting Technology Research Center and Computer Science and Engineering Department at the University of Connecticut study, "Pre-Election Testing and Post-Election Audit of Optical Scan Voting Terminal Memory Cards,"[54] also found junk data or data "specks" in the memory cards they examined.

[54] https://www.usenix.org/legacy/event/evt08/tech/full_papers/davtyan/davtyan.pdf



Comparison of the cards, showing the log segment differences



Comparison of the cards with clean end of the log segment

The global counters on the card did not explain when or why the junk bytes were at the end of the log segment. Also, card header fields “D/L VERSION” and “COPY” have curious values in New Hampshire and most likely reflect internal processes of LHS to produce election media for NH jurisdictions. These fields are used for inventory control, but in Windham those fields are not helpful for that purpose.

Without access to the source code it is not possible to tell whether the bytes have log entry meaning. However, the repetitive nature of byte patterns suggests that these are garbled log entries.

To double-check that the data has no execution properties, we loaded the unexplained segment in Ghidra for reverse engineering to see if any of the bytes would translate to meaningful opcodes for the CPU instruction set. It became very clear that regardless of the offset of the analysis, the next invalid instruction was always within less than half a dozen opcodes and there were no obvious function structures of program flow constructs, especially Return Statements.[55] These findings suggest that these byte ranges could not be used as gadgets for advanced exploitation techniques like Return-Oriented Programming.[56]

As the log overwrites data on the segment when it expands, this would be a volatile storage for anything of value. For this reason, if an attacker wanted to use this segment as a storage, the sensible way would be to utilize the end of the segment, to minimize the risk of discovery of the exploit by accidental overwriting. We observe the junk bytes to be right after the active log; therefore, they are continually overwritten as the log expands.

Finally, our examination of the memory cards revealed no incorrect ballot, race, or candidate data, or bytecode.

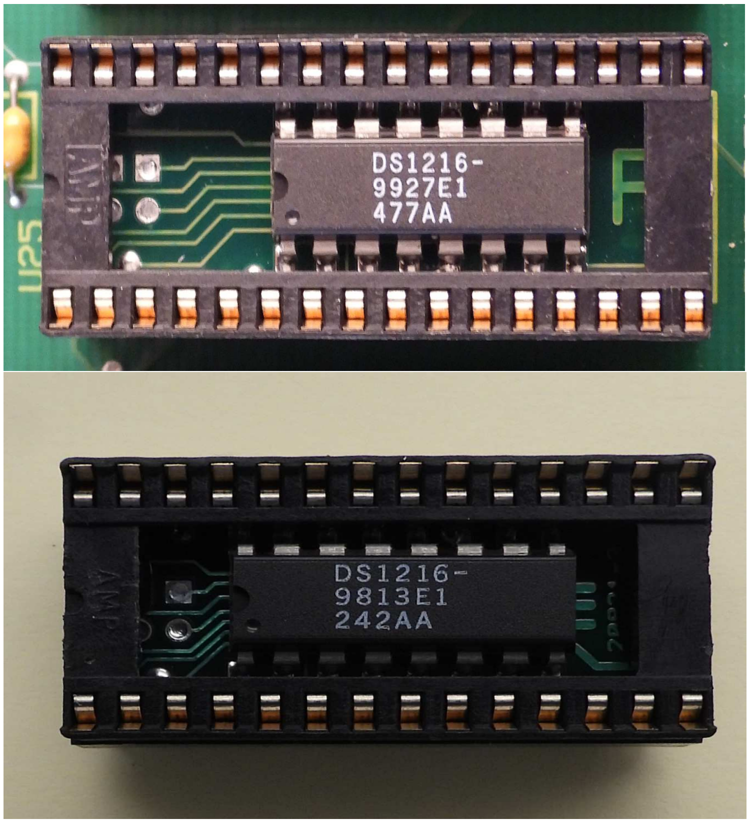
Hardware Inspection

Real-Time Clock Chip

During the hardware audit, it was discovered that units used in New Hampshire have two different Real-Time Clock Chips with physically different connectors to the main circuit board. Consulting the datasheet[57] revealed that this change between units does not affect the operations of the unit.

---

55 https://en.wikipedia.org/wiki/Return_statement
56 https://en.wikipedia.org/wiki/Return-oriented_programming
57 https://pdfserv.maximintegrated.com/en/ds/DS1216-DS1216H.pdf



The two kinds of Real Time Clock Chips

Optical Mark Recognition (OMR) scanner unit

Version identification markings on the circuit boards of the Optical Mark Recognition scanner unit

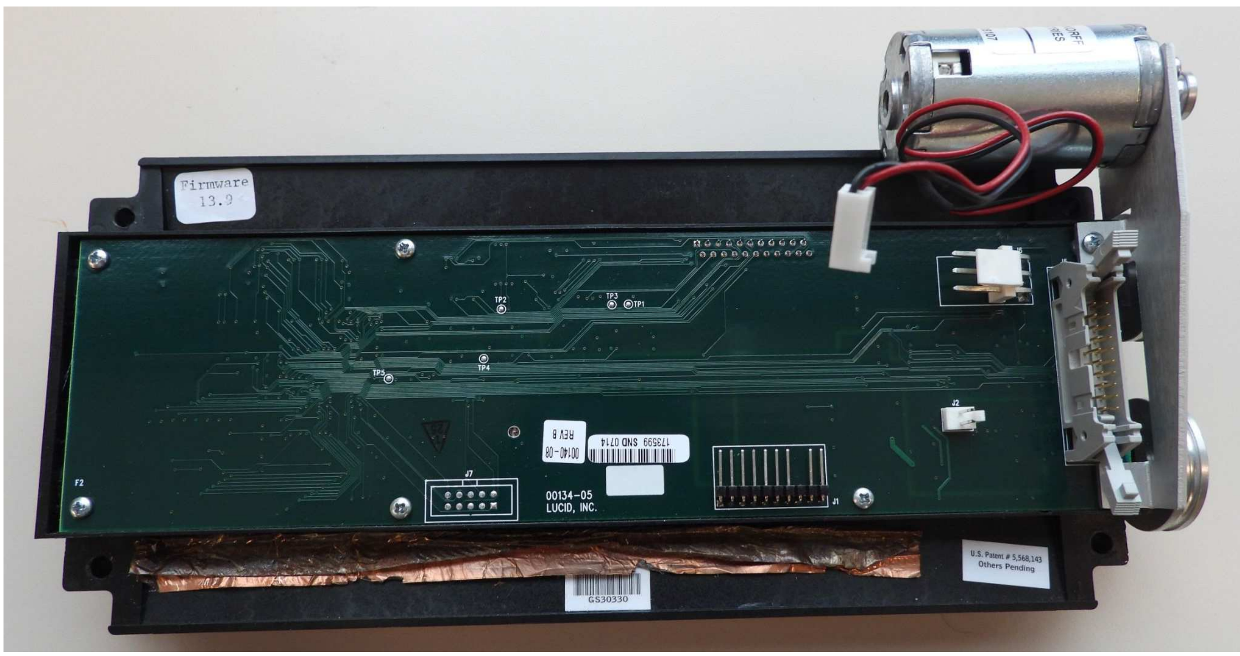
Hardware inspection revealed that different units had different versions of the scanner hardware unit. Lucid Inc., based in Rochester, New York, is the original designer of the AV-OS scanner unit. Lucid patented the AccuVote reader[58], a system for reading and recording pencil or ink marks made on paper, in 1994. Lucid sold its AccuVote-OS optical vote-

[58] https://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO1&Sect2=HITOFF&d=PALL&p=1&u=%2Fnetahtml%2FPTO%2Fsrchnum.htm&r=1&f=G&l=50&s1=5568143.PN.&OS=PN/5568143&RS=PN/5568143

scanner business to Diebold Election Systems, previously known as Global Election Systems, Inc., in 2002.

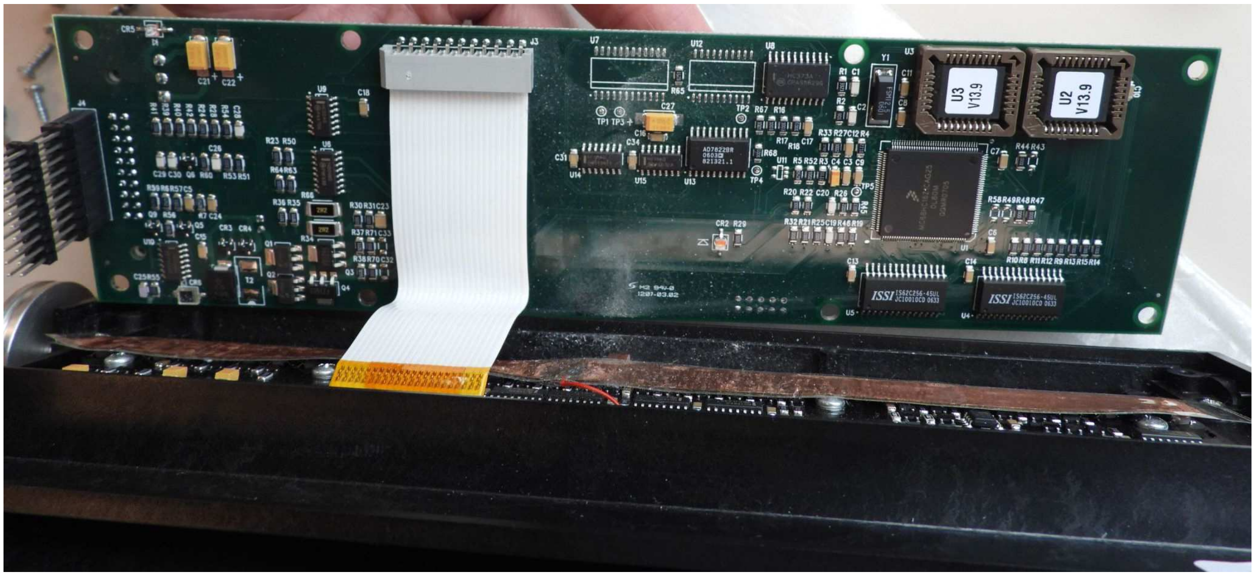
While the hardware units differ, there is reason to believe that they are running the same internal firmware, version 13.9. The scanner unit is a stand-alone generic optical mark recognition (OMR) component that does not understand the ballot itself; it only follows the landmarks and sends to the election software values of every cross section of the landmarks (timing marks) whether the position signifies a vote in the current election or not.

The scanner unit is mounted with screws into the casing of the voting machine. Opening the scanner unit requires extensive disassembly.



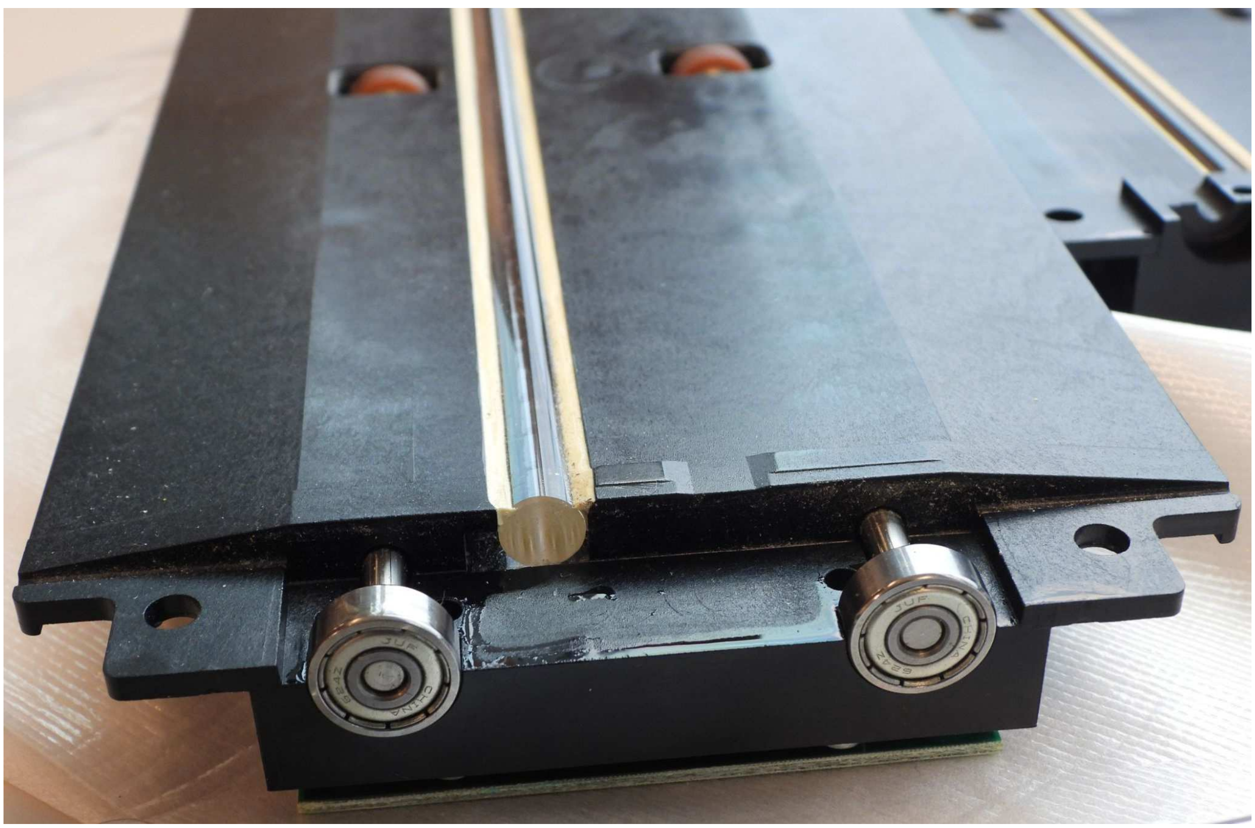
The scanner unit, removed from its casing

Removing the scanner unit from the casing and opening it to see the condition of the read heads took about 30 minutes. We disassembled a decommissioned unit previously used in Vermont, identical to the New Hampshire units. Upen disassembly we encountered white powder further inside the scanner unit on the surfaces, but far less than we found in the New Hampshire scanners, as discussed below.



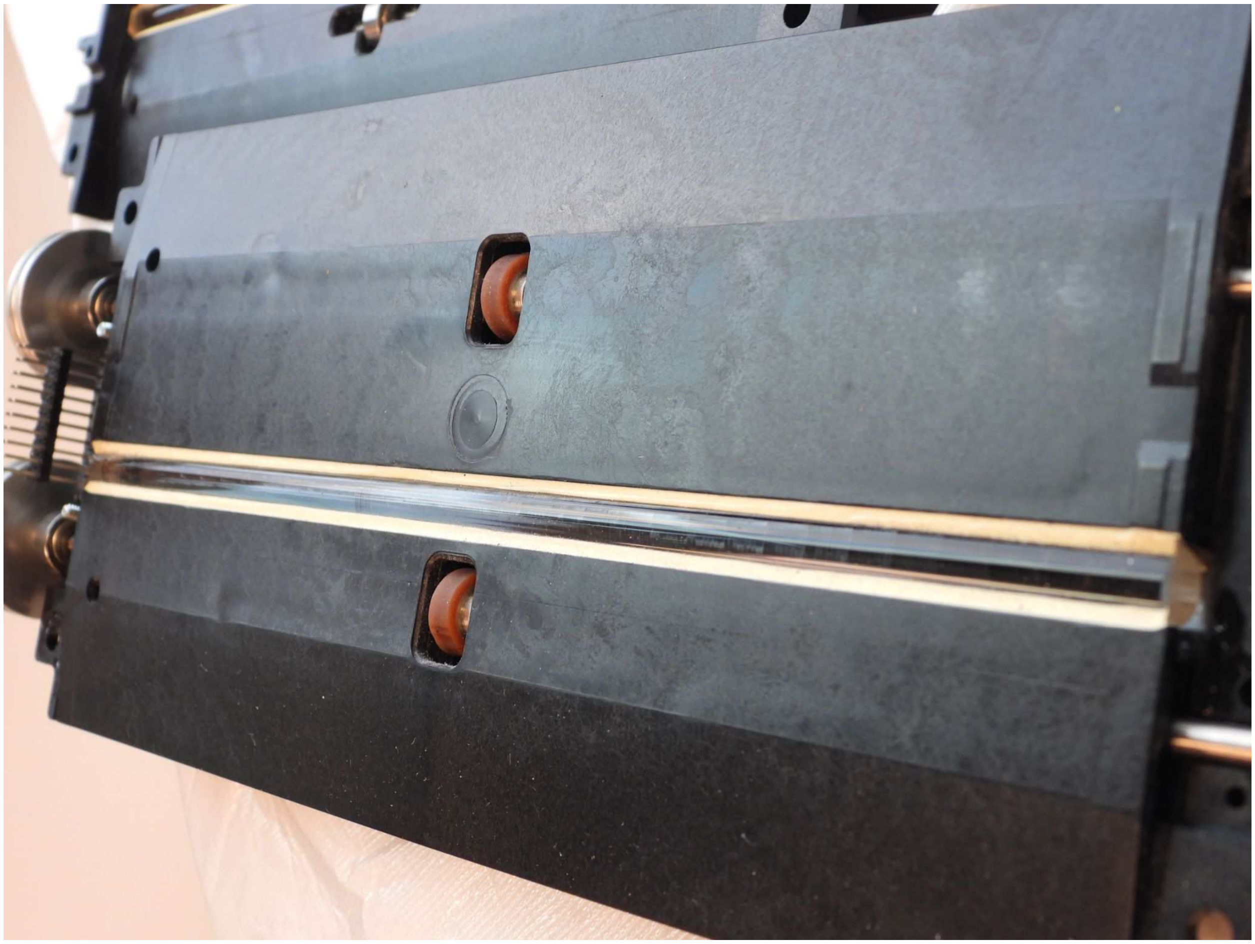
Inner view of the scanner unit, showing white powder on circuit board and support frame

The light emitters and the sensors are located underneath a cylindrical lens.



Inner view of the scanner unit, showing the lens and rollers

With this understanding of the scanner design, it is clear how the scanner can be cleaned without any disassembly. Simply taping a microfiber cleaning cloth to paper with similar strength as the ballot and dragging it through the machine backwards when the machine is switched off - the same procedure used to reset misaligned ball bearings - should clean any buildup of powder from the scanner lens.



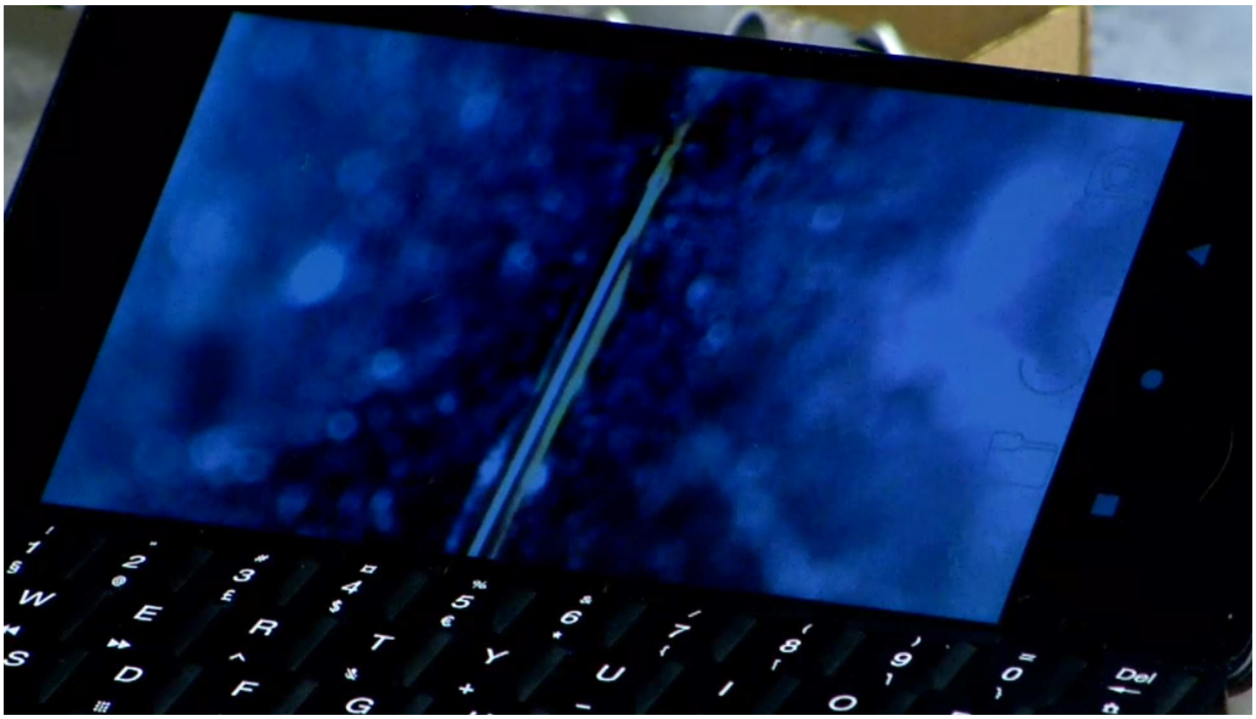
Another view of the lens and rollers

Maintenance and calibration

While the AccuVote-OS system uses “calibration sheets” in diagnostics to test accuracy, the device self-calibrates for each ballot separately. Each voting channel establishes a reflectance reference level during the first ¼” of ballot travel under each side of the sensor. A reference level is stored for each voting channel. As the ballot is scanned, the reflectance is measured and compared to a threshold percentage of the reference level. Areas of the ballot with reflectance below the threshold are reported as a logical “high” in the data sequence.

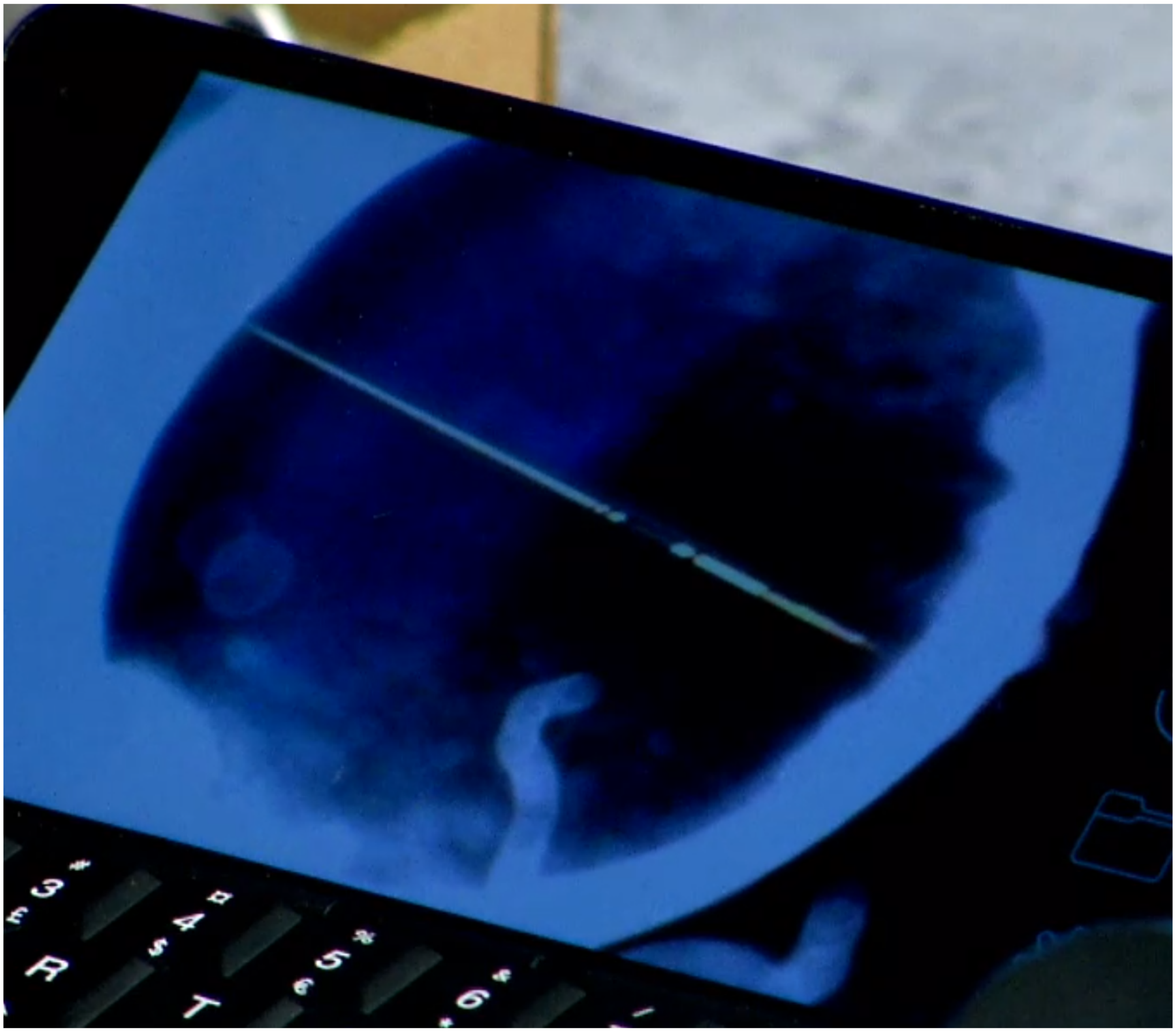
Because of this mechanism, the machine can compensate for powder and dust that affects the ballot evenly. However, it cannot adjust for dynamic changes along the length of the ballot, such as varying distance between the ballot and the light emitter and sensor, which may occur when ballots have folds. The main function of the calibration ballot is to test how timing marks are read, that a 1/32" wide black line through the vote target area registers as a vote, and that a roughly 3.6% relative darkness oval registers as empty.

As it was not possible to disassemble the scanner unit in the New Hampshire devices, we used an endoscope to view the scanner read head area. We immediately saw massive buildup of a white powdery substance on black surfaces. As we explain in the discussion of ballot printing (page 101), this powder is an artifact of the printing process.



Endoscopic image of the scanner read head area (displayed on laptop)

One of the scanners – the school machine (machine 4) – caused our endoscope lens to become overwhelmed with powder and small fibers.



The dirty lens

Cleaning and impact on scanner accuracy

After this happened, we attempted to clean the machine with two short blasts of compressed air. The effect was dramatic: A large amount of white powder and fiber blew out. The center of the assembly has the rollers that move the paper, as shown above; the rollers reduce the airflow in the center of the paper trail, limiting the effectiveness of this approach to cleaning the reader.

Cleaning the machine with compressed gas [image captured from the livestream]

White powder blown out the back of the scanner by cleaning [image from livestream]

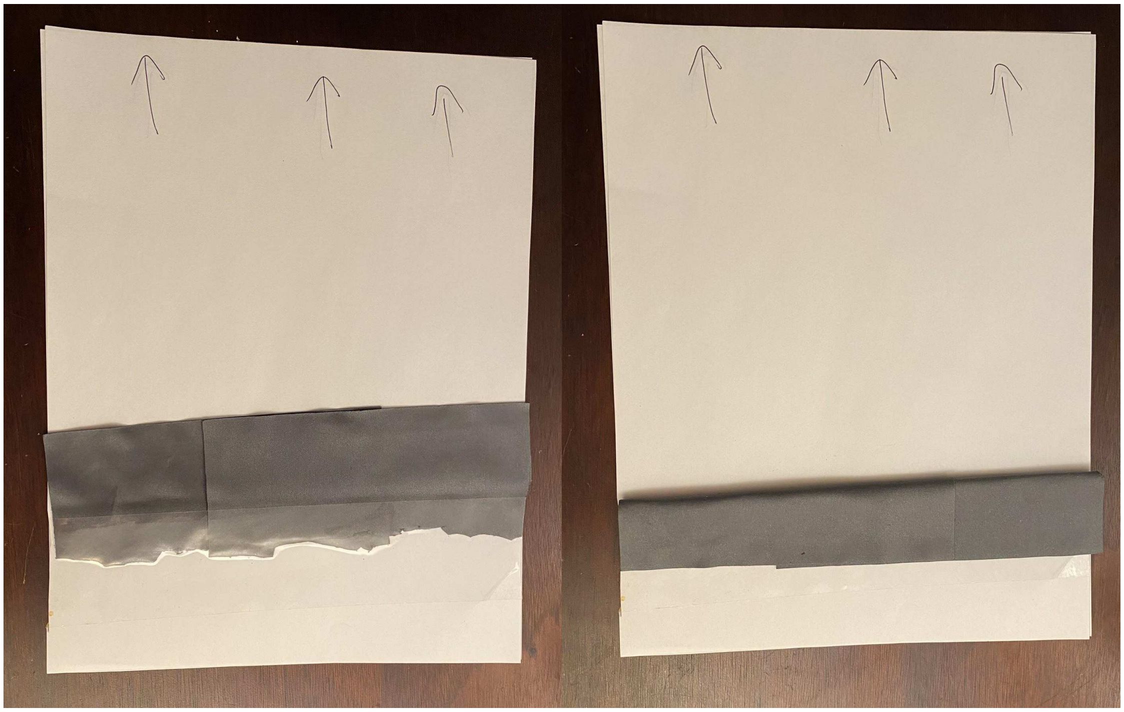
Close-up of white powder expelled by cleaning [image from livestream]

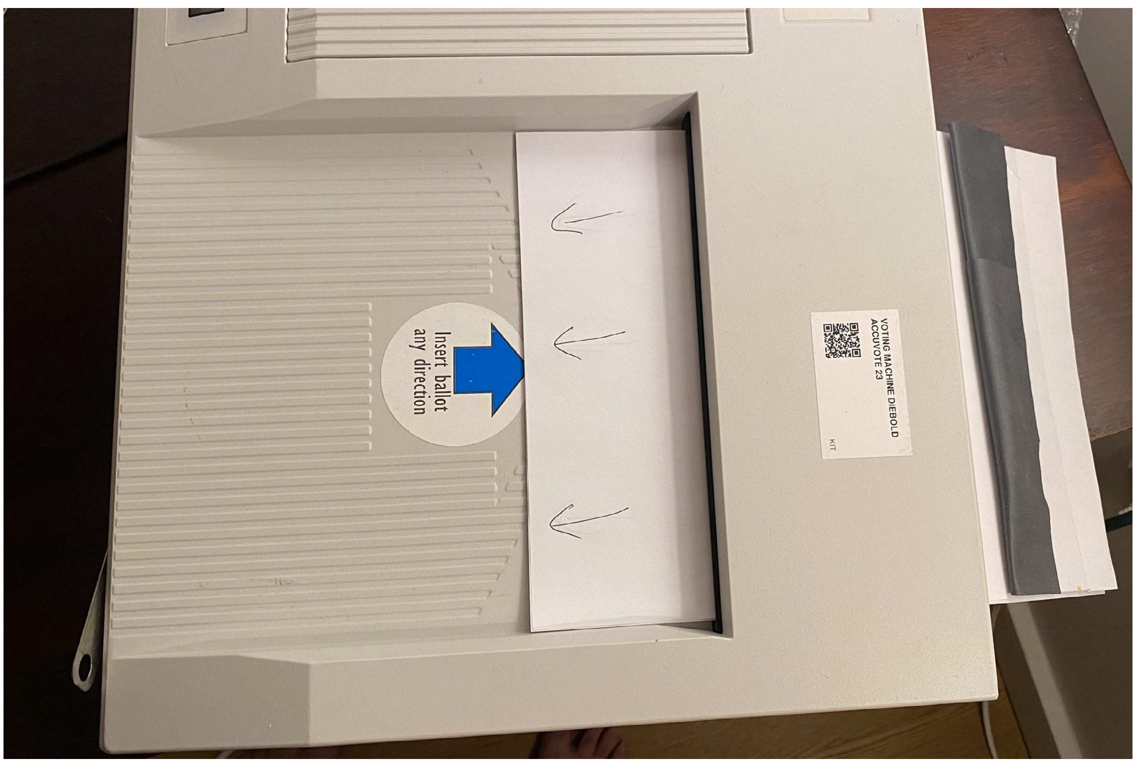
To test how cleaning the school machine affects tabulation accuracy, we rescanned the test deck of folded ballots that was marked straight-party Republican in the State Representative contest, in the face up, head first orientation. Prior to cleaning, this orientation produced 54 overvotes (reported as 216 blank votes) for 75 ballots. After cleaning, it produced only 35 overvotes (140 blank votes), about a 35% improvement.

Tabulation results on folded ballots before and after cleaning the reader with compressed gas

A better way to clean the scanner lens

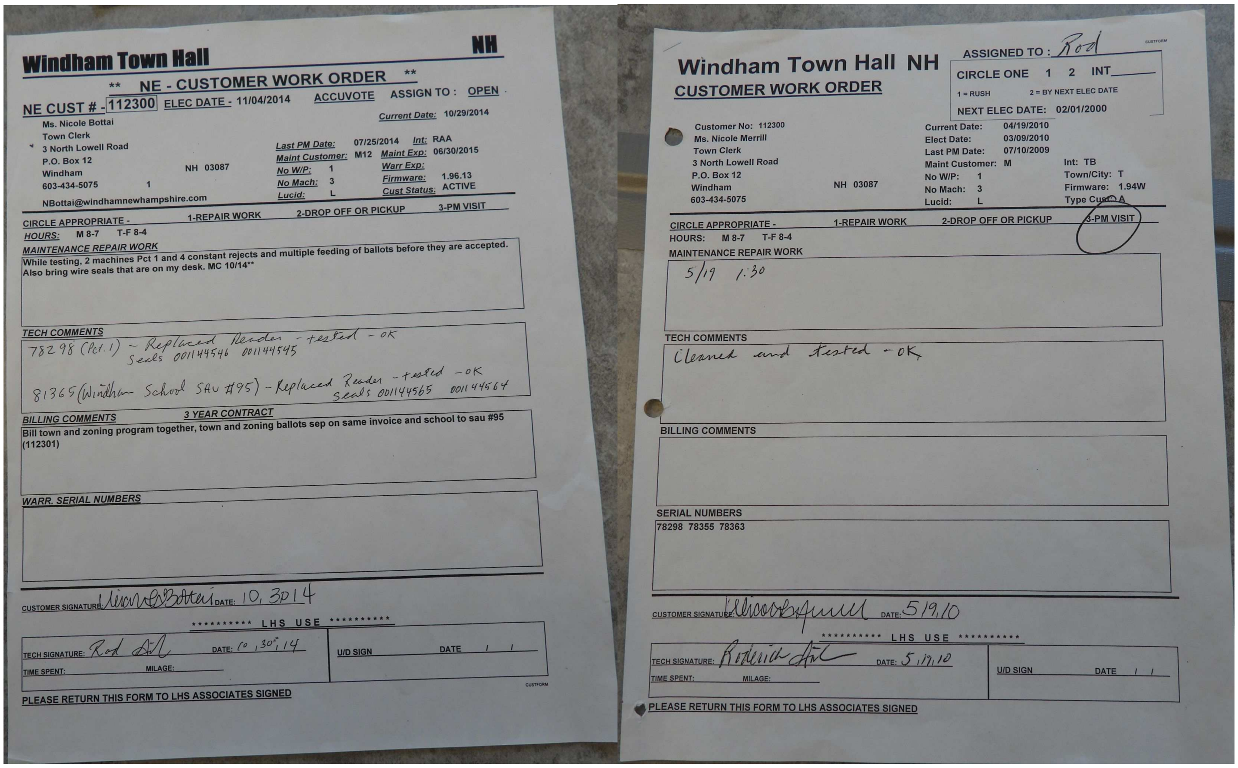
However, compressed air does not fully clean the lens. We found that an effective way to quickly clean the lens is to take lens cleaning microfiber cloth and tape it at one edge to ballot paper or paper of a similar weight. Fold the cloth over the tape. Then, using the same technique used to reset misaligned ball bearings, pull the paper through the voting machine from back to front (opposite the direction ballots normally feed) while the voting machine is off.





Using a lens cleaning cloth taped to heavy paper to clean the scanner lens

Review of work orders found no evidence that cleaning of the scanners is part of the routine maintenance.



Windham Town Hall NH

** NE - CUSTOMER WORK ORDER **

NE CUST # - 112300 ELEC DATE - 11/04/2014 ACCUVOTE ASSIGN TO : OPEN

Current Date: 10/29/2014

Ms. Nicole Bottai
Town Clerk
3 North Lowell Road
P.O. Box 12
Windham NH 03087
603-434-5075 1
NBottai@windhamnewhampshire.com

Last PM Date: 07/25/2014 Int: RAA
Maint Customer: M12 Maint Exp: 06/30/2015
No W/P: 1 Warr Exp:
No Mach: 3 Firmware: 1.96.13
Lucid: L Cust Status: ACTIVE

CIRCLE APPROPRIATE - 1-REPAIR WORK 2-DROP OFF OR PICKUP 3-PM VISIT

HOURS: M 8-7 T-F 8-4

MAINTENANCE REPAIR WORK

While testing, 2 machines Pct 1 and 4 constant rejects and multiple feeding of ballots before they are accepted.
Also bring wire seals that are on my desk. MC 10/14**

TECH COMMENTS

78298 (Pct. 1) – Replaced Reader – tested – OK
Seals 001144546 001144545
81365 (Windham School SAU #95) – Replaced Reader – tested – OK
Seals 001144565 001144564

BILLING COMMENTS 3 YEAR CONTRACT

Bill town and zoning program together, town and zoning ballots sep on same invoice and school to sau #95
(112301)

WARR. SERIAL NUMBERS

CUSTOMER SIGNATURE: DATE: 10, 2014

********** LHS USE **********

TECH SIGNATURE: Rod DATE: 10, 30, 14

TIME SPENT: MILAGE:

U/D SIGN DATE / /

CUSTFORM

PLEASE RETURN THIS FORM TO LHS ASSOCIATES SIGNED

Windham Town Hall NH

CUSTOMER WORK ORDER

ASSIGNED TO : Rod

CIRCLE ONE 1 2 INT

1 = RUSH 2 = BY NEXT ELEC DATE

NEXT ELEC DATE: 02/01/2000

CUSTFORM

Customer No: 112300
Ms. Nicole Merrill
Town Clerk
3 North Lowell Road
P.O. Box 12
Windham NH 03087
603-434-5075

Current Date: 04/19/2010
Elect Date: 03/09/2010
Last PM Date: 07/10/2009
Maint Customer: M Int: TB
No W/P: 1 Town/City: T
No Mach: 3 Firmware: 1.94W
Lucid: L Type Cust: A

CIRCLE APPROPRIATE - 1-REPAIR WORK 2-DROP OFF OR PICKUP 3-PM VISIT

HOURS: M 8-7 T-F 8-4

MAINTENANCE REPAIR WORK

5/19 1:30

TECH COMMENTS

Cleaned and tested – OK

BILLING COMMENTS

SERIAL NUMBERS

78298 78355 78363

CUSTOMER SIGNATURE: DATE: 5/19/10

********** LHS USE **********

TECH SIGNATURE: Roderick DATE: 5/19/10

TIME SPENT: MILAGE:

U/D SIGN DATE / /

PLEASE RETURN THIS FORM TO LHS ASSOCIATES SIGNED

Two scanner work orders, from 2010 and 2014

Inspection for hardware implants

In our inspection of the devices, no hardware implants or suspicious alterations were found. Thorough inspection for hardware implants would require a complete disassembly of the device and often destructive testing which are not in the scope of SB43.

Ballot printing and forensic paper audit

Ballots are produced centrally by the Evans Printing Company in New Hampshire, following the NH Ballot Specification Guide.[59] The paper used is 90# Springhill Index[60] by International Paper, 163 g/m^2 (90lb) index. The paper is very porous to take both print ink and pen ink well into the fabric. The paper has a pre-printing thickness (caliber) 0.0076 inch with acceptable variation +/-0.0005 inch; smooth finish; it has 97% opacity and 92GE brightness. The paper has good ink holdout, snap and resistance, and exceptional die-cutting, scoring and folding characteristics. A side effect of porosity is that the paper density varies greatly after processing, as witnessed in the forensic paper audit. The porosity of the paper prevents voting machines from getting polluted by ink chips falling off from the ballots. This has been an issue in jurisdictions outside New Hampshire.

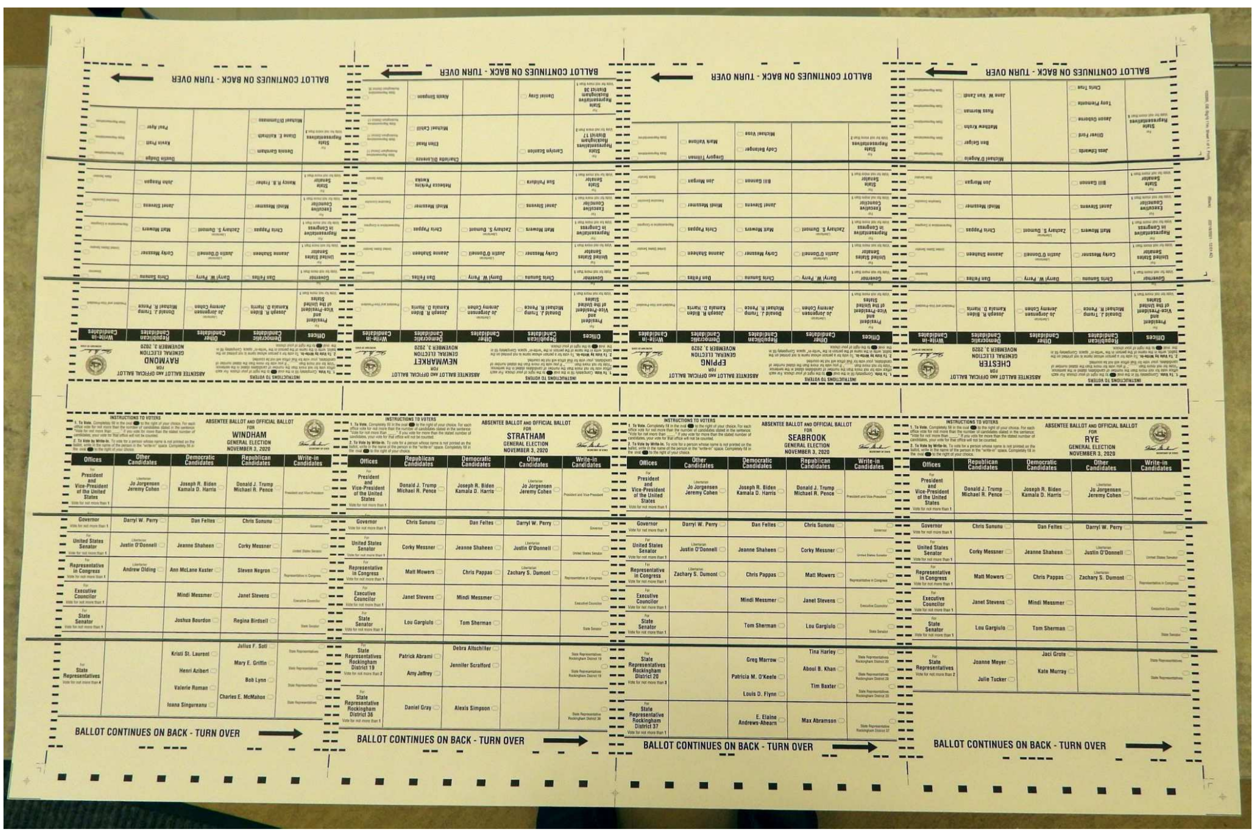
Ballot printing equipment at the Evans Printing Company

Ballots are printed using a Heidelberg Speedmaster offset printing machine. As shown below, a single printed sheet has 8 ballots from various jurisdictions, which are separated

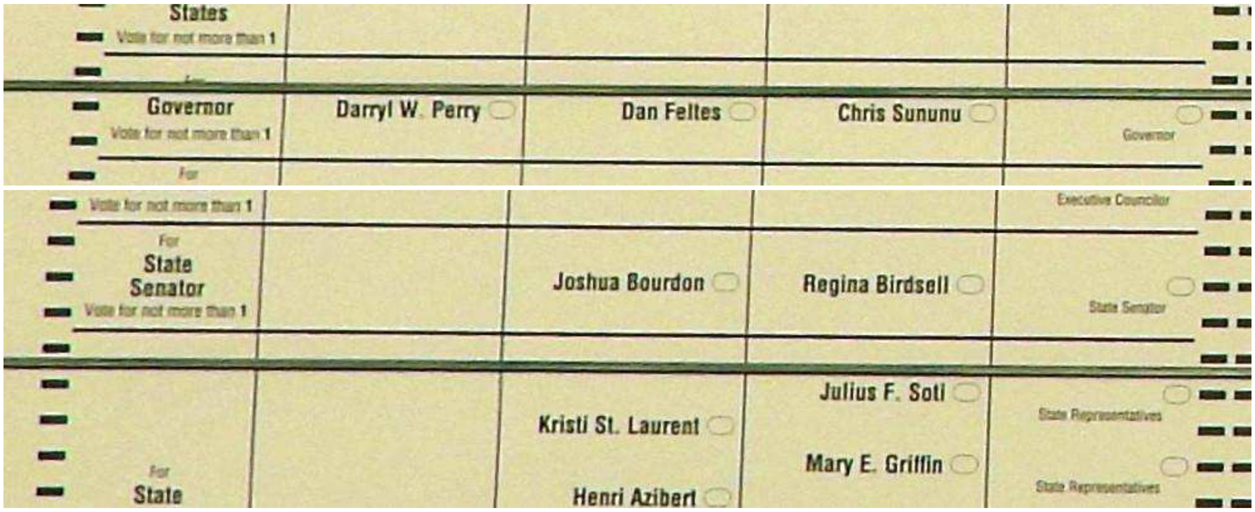
[59] https://aws.state.ak.us/OnlinePublicNotices/Notices/Attachment.aspx?id=93893
[60] https://www.internationalpaper.com/products/na/papers/commercial-printing-papers/springhill-uncoated-bristols/product-detail/springhill-index

using an Industrial Guillotine Paper Cutter. A separate smaller Heidelberg printing machine is used without ink to score the absentee ballots. Scoring is done by gluing a Litho-Score scoring accessory into a printed ballot and then installing that into an offset print drum. The Litho-Score's round scoring edge helps avoid cracking the ballot paper. The scoring is intended to ensure that the ballots are folded in the correct places, always between timing marks.

A Litho-Score in its packaging



A proof sheet containing ballots for Windham and seven other towns



Close-up showing the correct placement of fold scores in "safe zones" between timing marks

In offset printing, the ink is not fully dry when the ballot exits the printing machine. This can cause sheets to stick together. To prevent that, anti-set-off spray powder,[61] commonly called offset powder, is used to make an air gap between printed sheets of paper. This enables the ink to dry naturally and therefore avoid the unwanted transfer of ink from one printed sheet to another. Residual powder will remain on the printed paper. In fact, the scoring run on the paper through the secondary press machine removes some powder, and therefore the in-person voting ballots have more residual powder than absentee ballots.

[61] https://en.wikipedia.org/wiki/Anti-set-off_spray_powder

Application of Varn anti-set-off (offset) powder[62]

The diameter of the powder used is keyed to the density (g/m^2) of the stock (paper or board) being printed. For 150 g/m^2 paper the ideal anti-set-off spray powder would be 15 µm in diameter, for 200 g/m^2, 20 µm. The diameter of the particles is sufficiently small to cause scattering of light and diffraction. Diffraction is the spreading of light around the contour of a particle beyond the limits of its geometrical shadow with a small deviation from linear propagation. Diffraction is independent of the refractive index of the particles. The voting machine illuminates the ballot with highly monochromatic light. This exacerbates the effect of diffraction. The combination of these phenomena seems to contribute to increasing the error rate of the voting machine when incorrectly folded paper is processed with the voting machine excessively polluted by offset powder.

Ballots in New Hampshire are designed with ballot rotation. Ballot rotation is a practice where the order of parties from left to right (or top to bottom within a contest)[63] is

---

[62] https://www.flintgrp.com/media/2006/prc_speciality_ti_antiset-offpowder_e.pdf
[63] https://sos.nh.gov/media/itximdgm/generic-column-rotation-three-columns.pdf

different from one jurisdiction or ward to another, placing every party equally often into each position[64] on the ballot. Also, in races present in multiple jurisdictions and with more than one candidate per party, candidate names are rotated vertically, placing every candidate equally into each position[65] from top to bottom. Ballot rotation is evident in the proof sheet of 8 ballots from different towns, displayed above. (Because Windham comprises just one ward, its ballots all have the same party order.)

Forensic paper audit

As described in the workflow section above, a total of 35 ballots randomly sampled from a randomly selected box were inspected to measure their thickness, check for UV reactivity, and check whether they were professionally printed (presumably by Evans Printing Company) and hand-marked. No anomalies were found. By request, on the following audit day (Monday, May 24), an additional box was selected by audience members, and an additional 52 ballots were randomly selected and found to be professionally printed and hand-marked. These results dovetail with other ballot reconciliation results described above.

[64] https://sos.nh.gov/media/b3ynpn3v/column-rotation-2020.pdf
[65] https://sos.nh.gov/media/yibfopve/2020-2022-order-of-names-on-ballots-pursuant-to-rsa-656.pdf

Overall findings

Fundamentally, the large discrepancy between election night totals and both hand counts in the State Representative contest in Windham can be attributed to unforeseen consequences and misfortune. Harried election officials borrowed a folding machine to send out thousands of absentee ballots more quickly, and votes on roughly 400 ballots were miscounted as a result. We have no reason to believe that the folding machine was adjusted to achieve this result; the machine documentation does not even describe *how* to adjust the fold location. The 402-page New Hampshire Election Procedure Manual offers no guidance on how to fold (or not to fold) absentee ballots. We do not believe town officials could reasonably be expected to have anticipated this problem.

Even this near-perfect storm was not enough to alter the reported outcome in the State Representative contest (although under different circumstances, it might have). All counts agree that Republicans swept Windham's four seats in the state house of representatives. Nevertheless, the error – along with the smaller discrepancies in the landslide Governor's contest – expose some vulnerabilities that warrant further attention.

We found no basis to believe that the miscounts found in Windham indicate a pattern of partisan bias or a failed election. For most contests, a problem that converts valid votes to overvotes on scanned absentee ballots would be expected to harm Democrats more than Republicans. For multiple-vote contests such as the State Representative contest in Windham, consistently located folds could help or hurt either Democratic or Republican candidates. (In Windham, Democratic candidates were placed in the center of the ballot – but the party columns are rotated across cities/towns and wards, so Republican candidates are equally likely to appear in the center.)

We were able to review AccuVote report tapes from two towns (Amherst and Rye) that counted most or all absentee ballots on one machine. These tapes, unlike the ones from Windham, did not show higher blank vote rates on the absentee-ballot machines.[66] Recounts in nine other State Representative contests using AccuVote tabulators throughout the state did not reveal similar discrepancies. Thus, it appears that the statewide impact of folds in 2020 was marginal. It is not impossible that folds affected the outcome of some contest in the 400-seat New Hampshire House of Representatives, but we can conclude that Windham was not the tip of a massive miscount iceberg. Nonetheless, people's votes must be counted accurately, so procedural reforms are warranted.

The audit also revealed other small discrepancies and irregularities. Some of these cannot be confidently attributed. For instance, it is unclear what accounts for the two-vote difference between the election night cast ballot count and the audit result. Others are more straightforward. The three voted (and presumably accepted) ballots in open affidavit envelopes point to small but distinct procedural errors on election day. Nobody should be surprised or appalled that this close review of the election in Windham – as our close review of audit documentation found some clear errors in the audit itself, such as

[66] We could not review *all* such report tapes statewide: many are sealed among cast ballots.

redundant ballot IDs. People conduct elections, and people make mistakes. Discovering these mistakes provides an opportunity to improve procedures in future elections.

Recommendations

A full assessment of possible policy and procedural changes would be beyond the scope of the audit.

- Consider not folding ballots at all. Miscounts aside, folded ballots are liable to misfeed, complicating ballot processing on election day. Sending out ballots flat, in larger envelopes, could be a worthwhile investment. We recognize plausible arguments against this approach. The mailing expense per ballot would be substantially higher; unfolded ballots may be more vulnerable to damage in transit; and this approach might compel the use of two-sided ballots where larger one-sided ballots might be easier for voters to mark. We believe this approach deserves careful consideration.
- Clearly instruct election officials to fold absentee ballots along the score lines and to double-check the location of the folds. This instruction is important even for hand-folded ballots.
- Check the fold location when opening absentee ballots. Set aside ballots with folds through vote targets to be counted by hand. Ballots marked in pencil or colored ink that might not be counted also should be set aside for hand-counting.
- Add process controls to ensure that all accepted absentee ballots are counted. If feasible, dedicate one scanner exclusively to absentee ballots, to provide an easy check on how many have been counted. Check the affidavit envelopes for ballots that have been overlooked.
- Enable overvote notification on the AccuVotes. New Hampshire has argued that its wide use of hand-counted paper ballots and mail ballots exempts it from the Help America Vote Act's requirement for voting systems to notify voters who cast overvoted ballots. In 2018, the state's Committee on Election Law opposed overvote notification legislation on the grounds that it would "compromise the secrecy of the ballot."[67] Overvote notification alone would not have prevented the problem in Windham: almost certainly, a full hand count would have been necessary to establish the winners. But the problem would have been identified quickly.
- Improve machine maintenance. In our experiments, the miscount rate on the school machine (machine 4) was reduced by 35% after it was cleaned with compressed gas. We have no evidence on the effects of inadequate maintenance in more routine circumstances, but voters should not have to entrust their ballots to poorly maintained machines.
- Conduct routine risk-limiting audits of all election results. If tabulation errors (regardless of their cause) alter outcomes, a risk-limiting audit has a large, known chance of catching and correcting the problem before the result becomes final. To

[67] http://gencourt.state.nh.us/SofS_Archives/2018/house/HB1486H.pdf

conduct routine risk-limiting audits efficiently will require changes to New Hampshire’s voting technology.

- Keep ballots from different scanners or counting methods separate, on election day and thereafter. Increasing the points of comparison for subsequent hand counts (whether routine audits, recounts, or otherwise) can simplify the task of isolating discrepancies and tracing their causes.
- During recounts, track ballots, write-in votes, undervotes, and overvotes. More detailed accounting is useful to confirm that all ballots have been included in the recount, and to correct errors if they occur.

Appendix A: Hand tabulation teams

Day 1, 5/14

- Table 1: Colleen McCormack, Louise Gosselin, Nicole E. Hoyt, Barbara Holland Cooper, Jean Lightfoot
- Table 2: Pete Basiliere, Roger Gosselin, Kathleen McDonald, Lynn Christensen, Fran L'Heureux
- Table 3: Barbara Chagnon, Jonathan Kipp, Daniel Healey, Ruth Millet, Don Riley

Day 2, 5/17

- Table 1: Colleen McCormack, Louise Gosselin, Kathleen Seigars, Virginia O'Brien Irwin, Barbara Holland Cooper
- Table 2: Peter Imse, Judith Knapp, Jennifer McDaniel, Chester Bowles, Howard Roundy
- Table 3: Daniel Healey, Bill Cote, Don Riley, Judy Strakalaitis, Pete Basiliere

Day 3, 5/18

- Table 1: Barbara Holland Cooper, Margaret Doody, Louise Gosselin, Celeste Cook, Iris Altilio
- Table 2: Judy Silva (pm), Maynard Goldman (am), Cassie Givara, Pat Grant, Dawn Lincoln, Jennifer McDaniel
- Table 3: Judy Strakalaitis, Don Riley, Cindi Rice Conley, Jonathan Kipp, Deborah Caputo

Day 4, 5/19

- Table 1: Jean Lightfoot, Jean Mullen, Barbara Holland Cooper, Sara Persechino, Louise Gosselin
- Table 2: Dan Healey, Joan Dargie, Pat Grant, Nicolas Wallner, Paul Inderbitzen, Suzanne Cheney
- Table 3: Don Riley, Julie Seely, Deborah Caputo, Jonathan Kipp, William Cote, Judy Strakalaitis

Day 5, 5/20

- Table 1: Jean Lightfoot, Louise Gosselin, Debra Messer, Patricia Chaffee, Kathleen Seigars
- Table 2: Juliana Hale, Pat Grant, Nicolas Wallner, Jennifer McDaniel, Chester Bowles
- Table 3: Judy Strakalaitis, Bonnie Winona MacKinnon, William Cote, Don Riley, Jonathan Kipp, Jean Barnes

Day 6, 5/21

- Table 1: Heidi Hamer, Catherine Lovas, Jean Lightfoot, Louise Gosselin, Barbara Holland Cooper
- Table 2: Julianna Hale, Scott McGuffin, Deborah Caputo, Howard Roundy, Dean Bouffard
- Table 3: William Cote, Bonnie Winona MacKinnon, Don Riley, Judy Strakalaitis, Charlie Nelson

Appendix B: Other election official volunteers

- 5/12: Judy Strakalaitis, Louise Gosselin, Barbara Holland Cooper, Joanna Waring, Todd Rainier, Dick Mark, Jean Lightfoot, Jean Barnes, Don Riley, Clay Mitchell, Lynn Christensen, Joan Dargie, Dan Healey, William Klein
- 5/13: Judy Strakalaitis, Louise Gosselin, Bill Klein, Dan Healey, Lynn Christensen, Joan Dargie, Pete Basiliere, Bonnie Winona, Anita Flanagan, Joanna Waring, Jean Barnes, Clay Mitchell, Sherry Ferrell, Kaley Dvorak
- 5/14: Judy Strakalaitis, Joanna Waring, Jean Barnes, Joan Dargie, Kelly Waters
- 5/17: Joanna Waring, Linda Dodge, Jean Barnes, Lynn Christensen, Cassie Givara
- 5/18: Joanna Waring, Jean Barnes
- 5/19: Joanna Waring, Jean Barnes
- 5/20: Joanna Waring, Kelly Walters
- 5/21: Joanna Waring, Jean Barnes, Nicholas Wallner, Cassie Givara
- 5/22: Jonathan Kipp, Debbie Caputo, Jean Barnes, Jean Mullen, Sherry Farrell, John Farrell
- 5/24: Pat Grant, Debra Messer, Jean Lightfoot, Judith Knapp, Nick Wallner, Jean Barnes
- 5/25: Louise Gosselin, Jean Lightfoot, Jean Barnes
- 5/26: Louise Gosselin, Nicholas Wallner, Jean Barnes

Appendix C: Volunteer test deck ballot marking teams

Group 1:

1) Thomas Barton Jr.
2) Mark Kovacs
3) Anthony Roman

Group 2:

1) Jean Mullen
2) Roland Shrull
3) Juliet Harvey Bolia (State Rep)

Appendix D: Hand count documentation

The following pages reproduce the tally sheet template (scaled down from 8.5” x 14”), the detailed instructions provided to tally teams, and New Hampshire voter intent instructions based on the state’s Election Procedure Manual.

Election Audit Tally Sheet, Windham, NH

Batch ID ______ **Tally #** ______

Use | marks (or number of undervotes or overvotes).

		GOVERNOR						U.S. SENATOR						STATE REPRESENTATIVES											
	Ballot ID #	Perry	Feltes	Sununu	write-in	undervote	overvote	O'Donnell	Shaheen	Messner	write-in	undervote	overvote	St. Laurent	Azibert	Roman	Sigureanu	Soti	Griffin	Lynn	McMahon	write-in	undervote	overvote	Flagged ("yes")
1																									
2																									
3																									
4																									
5																									
6																									
7																									
8																									
9																									
10																									
11																									
12																									
13																									
14																									
15																									
16																									
17																									
18																									
19																									
20																									
21																									
22																									
23																									
24																									
25																									

Tallier ______

Caller ______

Watcher ______

Date/Time Complete ______

Data Entry ______

Date/Time Complete ______

Tally Instructions

Your team will hand-tally 25 ballots at a time for the three contests on the tally sheet: governor, U.S. senator, and state representative for Rockingham County District 7 (vote-for-four). The tally sheet should reflect voter intent, consistent with the description in the New Hampshire Election Procedure Manual. (We have provided an illustrated summary of the voter intent guidelines.)

The team has five members:

- A caller who reads off the ballot ID and the sequence of contests and votes cast.
- A watcher who confirms or disputes the caller's interpretation.
- Two talliers who record the ballot IDs and interpretations.
- A flagger who records ambiguous ballots (those with a possible difference between the team's interpretation of voter intent and how an AccuVote scanner might "read" the ballot) and other relevant notes.

Caller instructions

When you receive a scan batch (usually several hundred ballots), set aside the orange cover sheet. Your team will count the scan batch in smaller **tally batches** of up to 25 ballots apiece.

For each tally batch, take the tally batch cover sheet with the next available tally batch ID. Tally batch IDs look like **T2-020** (tally team 2, batch #20). Write the scan batch ID information (box, part, and stamp) in the corresponding fields on the cover sheet.

Read the tally batch ID aloud. Each tallier will write it on a blank tally sheet; the flagger will write it on a blank Tally Flagger Log.

Now, the following sequence repeats for every ballot in the tally batch, up to 25 ballots:

1. Wait for the talliers to confirm the ballot sequence number within the batch (1 through 25).
2. Take the next ballot and turn it to the back, displaying the ballot ID. Ensure that the watcher can clearly see the ballot ID; the watcher may hold the ballot if necessary to confirm. Read the ballot ID and wait for talliers to write it down.
    - If the ballot ID is illegible but can be determined from the adjacent ballots, in consultation with the watcher, you may *rewrite* the ballot ID underneath the original version -- do not alter the original version. If the

ballot ID is illegible and cannot be reconstructed, be sure that the flagger record the ballot and issue in the Tally Flagger Log.

3. Then turn the ballot to the front, displaying the contests being audited. Slowly, clearly call the first contest and your interpretation, for instance: "**governor: Sununu**." Wait for the watcher to confirm or question your interpretation, and for the talliers to log it. (Again, the watcher may hold the ballot if necessary.) Then proceed to the next contest, until all three have been interpreted and recorded.

   - Apply the voter intent rules as carefully as possible. If you run into an unusual situation, consult the summary of voter intent guidelines and discuss with the team.

   - If you and the watcher disagree or are uncertain, the talliers and flagger will record the lack of agreement in the Tally Flagger Log. Please bring the issue to the attention of the audit team. (This is not a recount, so there is no need to establish a definitive interpretation.)

   - The contests are "**governor**," "**U.S. senator**," and "**state representatives**." (You do not have to read the district description.)

   - If the voter writes in a candidate whose name does not appear on the ballot for that contest, announce **"write-in for [last name]."** These names will not be recorded, but reading them allows others to verify

   - In the state representative contest, you may describe a ballot as cast for **"all four Democrats"** or **"all four Republicans."** (Please do not use any other shorthand for "straight-ticket" votes.) Otherwise, you should slowly read **the last names of each candidate with a valid vote (if any), followed by the number of undervotes or the number of overvotes.** The number of valid votes plus the number of undervotes or overvotes must equal four.

   - If you believe that the ballot is ambiguous, have the flagger log the issue in the Tally Flagger Log. An "ambiguous ballot" is one that the AccuVote scanners *would or might* interpret the ballot differently than the audit team did, perhaps due to non-standard voter marks, anomalous use of the write-in column (such as darkening the write-in oval without naming a candidate), a printing error, or a fold mark through a voting target.

At the end of each tally batch, after the two tally sheets are reconciled, place the tally batch cover sheet on top of the tally batch, and place the two tally sheets and the Tally Flagger Log on top of that. If this is the last tally batch in a scan batch, also put the orange scan batch cover sheet on top. Have a runner deliver (1) the tally sheets (and, if applicable, the scan batch cover sheet) to the data entry team and (2) the tally batch, with cover sheet, to check-in.

Watcher instructions

See the instructions for the caller. Your responsibility is to independently review the same information. Do not rely on the caller to be correct. When you agree with the caller's interpretation of ballot ID or vote, say so explicitly: "Yes" or "Confirmed." If you are not *sure* that the caller is right, ask for a closer look.

Tallier instructions

At the beginning of each tally batch, fill in the tally batch ID as provided by the caller.

Before each ballot, one tallier states the ballot sequence number, 1 through 25: for instance, "Number 7." The other tallier confirms: "Number 7."

Be sure to record the ballot ID for each ballot. Throughout the process, if the caller attempts to proceed before you are ready, ask the caller to wait. It is important not to hurry.

For governor and U.S. senator, make sure you have marked exactly one box with a tally mark |. (Do not use "X" marks.)

For state representative, you may be recording a combination of tallies and the *number* of undervotes or overvotes. For instance:

- If the voter votes for just two candidates, mark the two candidates with a tally mark |, and mark "2" undervotes.
- If the voter attempts to vote for five distinct candidates, the caller and watcher will report an overvote. Mark 4 overvotes (there are no valid votes).

To make a correction: cross out any incorrect mark(s) and write in the corrections. Instruct the flagger to log the correction.

If the caller, watcher, and/or flagger determine that a ballot should be recorded in the Tally Flagger Log, note "yes" in the Flagged column.

At the end of each tally sheet, the two talliers should total the counts in each column and then reconcile the totals. All totals must correspond. Also, the counts (including write-ins, undervotes, and overvotes) must total the number of ballots -- usually 25 -- for the governor and U.S. senator contests, or four times the number of ballots -- usually 100 -- for the state representatives contest.

When the tally sheets are reconciled, add your name and the date and time. Have the caller and watcher add their names to both sheets.

Flagger instructions

At the beginning of each tally batch, start a new Tally Flagger Log with the tally batch ID. You will submit this even if no ballots in the batch are flagged.

You have two important roles. One is to carefully document any issues raised by other team members, such as ambiguous ballots for which the machines might not capture voter intent, ballots for which the caller and watcher disagree, or tally corrections reported by talliers.

The other is to look for distinctive issues that the caller and watcher might overlook. These may be issues with particular ballots that should be logged, such as a fold line that might affect the scanner, or a ballot that suspiciously differs in appearance from others. Or they may be process issues such as the caller getting ahead of the talliers. In either case, intervene to assure that the issue is addressed and, for ballot issues, logged.

When you log a ballot, write both the sequence number (1 through 25) and the ballot ID written on the ballot. If the ballot issue involves an ambiguous ballot (difference between audit team interpretation and likely/possible AccuVote interpretation), briefly state how the AccuVote interpretation may differ from the audit team interpretation. (For instance: "AccuVote may see an overvote.")

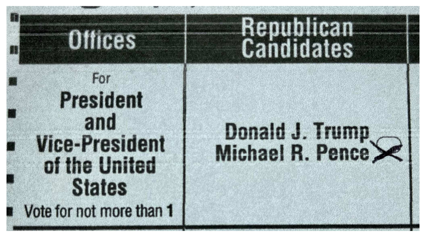
Use as many lines, and as many pages per batch, as necessary. Remember to fill in the batch ID and page number each time you start a page.

When each tally batch is complete, fill in your name and the date and time finished on each log page for that batch. Hand these pages to the caller to be delivered to data entry along with the tally sheets.

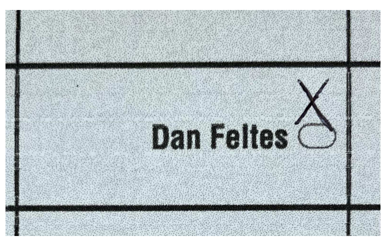
New Hampshire Voter Intent Instructions [v. 0.1]
Windham, NH Audit 2021
Instructions taken from New Hampshire Election Procedure Manual: 2020-2021

Count any mark that makes it more likely than not that the voter intended to fill in the oval as a vote for that candidate or choice for a question

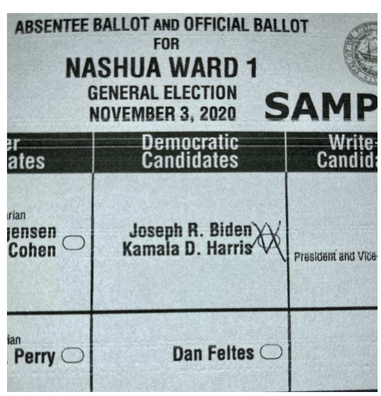
A. If a cross "X" is marked on a ballot in an imperfect manner, count it if it is possible to determine the intention of the voter from the mark.



B. The mark also is valid outside the oval or square if it is near enough to the oval/square or in line with the name such that it indicates the intent of the voter.

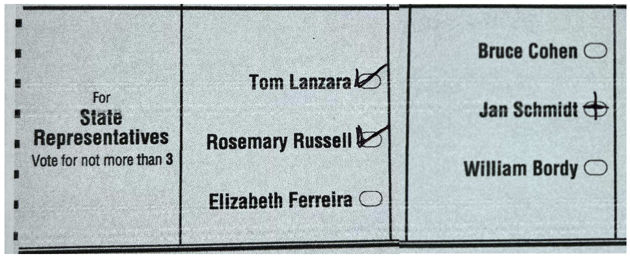


C. A double cross, overlapping Xs, is valid if it is distinguishable from an attempt to obliterate a choice on the ballot.



D. Cross marks or filling in ovals are a directive of the law. However, the Supreme Court directs that a vote be counted if the voter's intent can be determined, even if the voter did not follow the marking instruction. The uniform use of a mark other than "X" or completely filling in an oval is a valid marking of the ballot. The shape of the mark may change somewhat or be somewhat irregular and still be considered uniform and therefore valid.

E. When there is a different kind of mark (i.e. a ballot marked with checks and crosses intermingled) the marks may be valid.



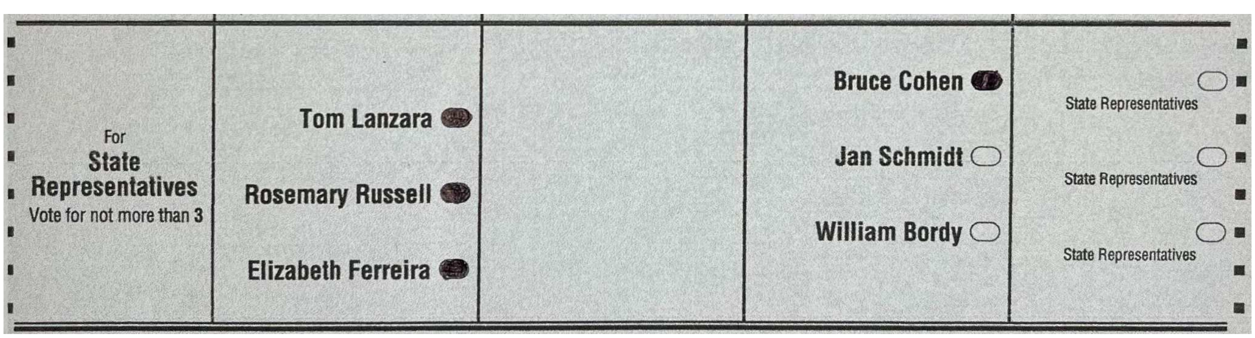
F. Erasures and obliterations: when two candidates have marks and one of the marks is erased or obliterated, the ballot counts for that office only if the erasure or obliteration is complete.

G. When examining a questionable mark, look at how the voter has marked other races or questions. The pattern of marking used in other areas of the ballot may reveal the intent of the voter.

OVERVOTES

If a voter votes for more names than there are persons to be elected to that office (an overvote), his ballot shall be regarded defective for that one office and the vote(s) shall not be counted for that office. Treat the ballot as if the voter, for that office or question, did not vote for any candidate or for either choice of a question.

If the ballot instructions state, “Vote for not more than 3,” and the voter marks 4 candidates for that office, there are more than the permitted number of votes for the office, and the number of overvotes is 3, because the voter has given up 3 choices.



How to Handle Write-In Votes

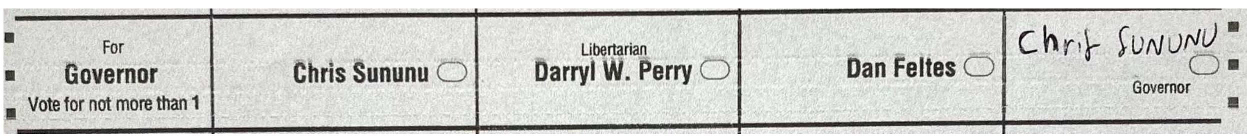
Write-ins: To vote for a candidate by write-in, the voter needs only to write the name of the person he wishes to vote for on the appropriate line. A mark does not need to be placed in the [oval] opposite the write-in line.

WRITE-IN VOTE FOR CANDIDATE WHOSE NAME IS ALSO PRINTED ON THE BALLOT

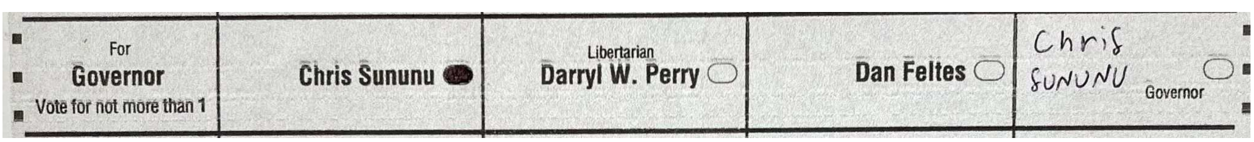
In the case of a write-in vote for a candidate whose name also appears on the ballot as a nominee of a party for the same office or as a candidate at a general election, count the ballot as one vote for that candidate for that office.

For this explanation "Jane Doe" is a candidate for Governor whose name is printed on the ballot [We use candidate "Chris Sununu" for illustration purposes]. Three possibilities exist:

1. The oval beside the printed "Jane Doe" is blank, and the voter writes "Jane Doe" on the write-in line. The oval on the write-in line is blank. Count one vote for "Jane Doe."



2. The oval beside the printed "Jane Doe" is marked and the name "Jane Doe" is written on the write-in line, but the write-in line oval is blank. The device counted one vote for "Jane Doe" based on the marked oval next to the printed name. Only one vote for "Jane Doe".



3. The oval beside the printed "Jane Doe" is marked and the name "Jane Doe" is written on the write-in line and the write-in line oval is marked. The device counted the ballot as an overvote (voted for two in a "vote for one race"). The device sees only one vote for a candidate printed on the ballot and a second vote for a write-in. This is only one vote for "Jane Doe".