When Audits and Recounts Distract from Election Integrity: The 2020 U.S. Presidential Election in Georgia

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Abstract: The U.S. state of Georgia was central to efforts to overturn the results of the 2020 Presidential election, including a phone call from then-president Donald Trump to Georgia Secretary of State Brad Raffensperger asking Raffensperger to 'find' 11,780 votes. Raffensperger has maintained that a '100% full-count risk-limiting audit' and a machine recount agreed with the initial machine-count results, which proved that the reported election results were accurate and that 'no votes were flipped.' While there is no evidence that the reported outcome is wrong, neither is there evidence that it is correct: the two machine counts and the manual 'audit' tallies disagree substantially, even about the number of ballots cast. Some ballots in Fulton County, Georgia, were included in the original count at least twice; some were included in the machine recount at least thrice. Audit handcount results for some tally batches were omitted from the reported audit totals: reported audit results do not include all the votes the auditors counted. In short, the two machine counts and the audit were not probative of who won because of poor processes and controls: a lack of secure physical chain of custody, ballot accounting, pollbook reconciliation, and accounting for other election materials such as memory cards. Moreover, most voters used demonstrably untrustworthy ballot-marking devices; as a result, even a perfect handcount or audit would not necessarily reveal who really won. True risk-limiting audits (RLAs) and rigorous recounts can limit the risk that an incorrect electoral outcome will be certified rather than being corrected. But no procedure can limit that risk without a trustworthy record of the vote. And even a properly conducted RLA of some contests in an election does not show that any other contests in that election were decided correctly. The 2020 U.S. Presidential election in Georgia illustrates unrecoverable errors that can render recounts and audits 'security theater' that distract from the more serious problems rather than justifying trust.

Keywords: risk-limiting audit, election recount, evidence-based elections

1 Introduction: The 2020 U.S. Presidential Election in Georgia

Georgia was one of the 'swing states' that determined the outcome of the 2020 U.S. presidential election: its 16 electoral college votes went to Joe Biden. In a well publicized

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recording of then-president Donald Trump to Georgia Secretary of State Brad Raffensperger, Trump asked Raffensperger to 'find' 11,700 votes.[2]

Georgia performed a second machine count and hired VotingWorks to orchestrate a 'risk-limiting audit' of the 2020 presidential contest, including providing software. This paper shows that the audit does not support the election results; that the election, recount, and audit disagree; and that all three were unreliable. Among other issues, some memory cards containing votes were not uploaded in the first machine count. Some ballots were included in the first machine tally at least twice. Some ballots were included in the second machine tally at least three times. And some votes manually tabulated in the audit were not included in the reported audit totals. Moreover, the state of Georgia requires all in-person voters to use Dominion Voting Systems (DVS) ballot marking devices (BMDs) to mark their ballots. These devices are vulnerable to hacking and misconfiguration [Ha23]; voters rarely check BMD printout [Be20, KBW20, HI21]; when voters do check, they are unlikely to notice and report printing errors [Be20, KBW20]; and no feasible amount of pre-election testing, logic and accuracy testing, or election-day monitoring can suffice to show that BMDs misbehavior did not alter the outcome [SX22]. BMD printout is thus not a trustworthy basis for evidence-based elections [SW12, ADS20, AS20], even when voted ballots are curated adequately and proper procedures are followed. While there is no evidence of widespread fraud, the mismanagement of the election, reliance on untrustworthy vote records, lack of physical controls on ballots and other voting materials, lack of sanity checks, and poorly executed procedures make it impossible to know who "really" won.

This story is about Georgia, but the moral is broader: some of the things that can and do go wrong in administering elections result in an untrustworthy vote record. Auditing a poorly run election with an untrustworthy vote record is a distraction from the fact that the vote record is not trustworthy, not a way to justify trust. Auditing cannot restore trustworthiness to a poorly run election; rather, it is a way to "tie a bow around" a *well-run* election to show that whatever might have gone wrong did not alter the electoral outcome.

2   The 2020 audit

Secretary of State Brad Raffensperger claimed, "Georgia's historic first statewide audit reaffirmed that the state's new secure paper ballot voting system accurately counted and reported results. . . . [W]e did a 100 percent risk-limiting audit with a hand recount which proved the accuracy of the count and also proved that the machines were accurately counting

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[2]   See, e.g., https://int.nyt.com/data/documenttools/highlights-of-trump-s-call-with-the-georgia-secretary-of-state-1/b67c0d9dbde1a697/full.pdf visited 11 July 2024. Subsequently, in early 2021, Trump-affiliated parties gained improper access to all components of the voting system in Coffee County, Georgia and copied and distributed the codebase and data. See, e.g., https://www.cnn.com/2023/08/13/politics/coffee-county-georgia-voting-system-breach-trump/index.html, https://apnews.com/article/2022-midterm-elections-technology-lawsuits-donald-trump-voting-6a1324cc6cf45c95ca086a5c81617b15, https://www.washingtonpost.com/investigations/2022/10/28/coffee-county-election-voting-machines/, all accessed 11 July 2024.

it, and that no votes were flipped."[3] VotingWorks Executive Director Ben Adida claimed "Georgia's first statewide audit successfully confirmed the winner of the chosen contest and should give voters increased confidence in the results."[4] Per the official report of the audit, "[t]he audit confirmed the original result of the election, namely that Joe Biden won the Presidential Contest in the State of Georgia. The audit [] provides sufficient evidence that the correct winner was reported."[5]

Secretary Raffensperger has also used the recount and audit in his defense against a lawsuit that seeks to provide all Georgia voters the option to hand-mark paper ballots in person, rather than being compelled to use BMDs (Curling et al. v. Raffensperger et al., Civil Action No. 1:17-CV-2989-AT, U.S. District Court for the Northern District of Georgia, Atlanta Division). Raffensperger has publicly painted the opposing election security experts in this matter—some of the world's top cybersecurity experts—as "stop-the-steal" conspiracy theorists, muddying the waters with false claims about the recount and audit and deliberately conflating "there is strong evidence that the election was poorly run and little evidence that the outcome is correct" with "there is strong evidence that the outcome is wrong and that fraud was committed." Some of the data analyzed below (cast vote records, in particular) were obtained in discovery in *Curling v. Raffensperger*, but most are a matter of public record and can be downloaded from the Georgia Secretary of State's website, from URLs given below.

The so-called 'risk-limiting audit' did not limit the risk of certifying an incorrect electoral outcome for many reasons, starting with its reliance on an untrustworthy record of the votes. The record is untrustworthy because of how it was created (largely BMD printout), curated (a lack of physical accounting for ballots and other materials, lack of pollbook reconciliation, and other elements of a proper canvass), and organized (no "ballot manifest"). The audit *could* have checked the tabulation of the validly cast ballots it found, but it did not check that properly, as proved by documents on the Secretary of State's website.[6]

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[3] https://sos.ga.gov/news/historic-first-statewide-audit-paper-ballots-upholds-result-presidential-race, accessed 11 July 2024.

[4] Ibid.

[5] Ibid.

[6] https://sos.ga.gov/news/historic-first-statewide-audit-paper-ballots-upholds-result-presidential-race accessed 11 July 2024. Audit data at the urls https://sos.ga.gov/admin/uploads/Georgia%202020%20RLA%20Report.xlsx, https://sos.ga.gov/admin/uploads/county-summary-data.pdf, and https://sos.ga.gov/admin/uploads/audit-report-November-3-2020-General-Election-2020-11-19.csv, linked from that page, are periodically unavailable, producing the message "Sorry, you have been blocked. You are unable to access sos.ga.gov." RLA manual tabulation batch sheets were downloaded from https://sos.ga.gov/admin/uploads/Fulton%20RLA%20Batches.zip on 9 January 2022. Precinct-level results for the original machine tally are at https://results.enr.clarityelections.com//GA//105369/271927/reports/detailxls.zip; for the second machine tally, they are at https://results.enr.clarityelections.com//GA//107231/273078/reports/detailxls.zip, both visited 2 September 2024.

2.1 Things the audit did not check

The audit did not check whether BMDs correctly printed voters' selections. No audit can check that [ADS20]. (As a consequence, Secretary Raffensperger had no basis to assert that no votes were flipped.) Expert declarations and testimony in *Curling v. Raffensperger* establish that the Dominion BMDs can be hacked, misprogrammed, or misconfigured to print votes that differ from voters' selections as confirmed onscreen or through audio. Logic and accuracy testing cannot establish that BMDs behave correctly in practice [SX22]. Only voters are in a position to check—but few do, and those who do check generally check poorly (see citations below). Georgia has no procedures to log, investigate, or report complaints from voters that BMDs altered votes, so it is unknown whether voters observed problems.

- The audit did not check whether every validly cast ballot was included in the tally exactly once. The audit *could not* check whether every validly cast ballot was scanned, because Georgia's rules for ballot accounting, pollbook and voter participation reconciliation, physical chain of custody, etc., do not account for every cast ballot.

- The audit did not check whether the number of participating voters differed from the number of cast ballots.

- The audit did not check whether every memory card used in the election was accounted for, nor whether every memory card containing votes was uploaded to a tabulator. During the audit, it was discovered that some cards had not been uploaded, but there was no comprehensive check to confirm that every card was eventually included exactly once. Below are examples of ballots that were erroneously included in machine counts more than once.

- The audit did not check whether scans were duplicated, deleted, replaced or altered.

- The audit did not check whether QR-encoded votes on BMD printout match the human-readable selections on any ballot.

- The audit did not check whether the voting system correctly interpreted any ballot or BMD printout.

- The audit did not aggregate its own manual tallies correctly, as explained below.

The analysis below focuses on Fulton County (Atlanta), but there is no reason to believe the problems are confined to Fulton; indeed, lapses such as failing to upload memory cards occurred in other counties.

2.2 The audit report omitted some batch tallies

The audit was conducted using "sort and stack": teams sorted batches of ballots (including BMD printout) by the presidential vote, then counted the sorted stacks. Batch tallies were manually entered on paper 'Audit Board Batch Sheets,' (ABBSs). Other workers transcribed

the ABBSs into VotingWorks audit software "Arlo" to create a database of tallies; totals were calculated from that database. A spreadsheet of results was produced from Arlo. Every ballot validly cast in Fulton County in the 2020 Presidential Election should be reflected in exactly one ABBS, and data from every ABBS should have been (but was not) entered exactly once into the database from which the audit spreadsheet was exported. The transcription of ABBSs was not observable by the public, but the public could in principle compare posted images of the ABBSs to the posted audit spreadsheet, as described below. (Spoiler alert: they do not match.)

Many ABBSs were not completely filled in. The "Batch Type," signifying the mode of voting (absentee, election day, advance) was often blank, as were many places numbers belonged. The four posted ABBS image files for Fulton County contain a total of 1,927 ABBSs.[7] But the audit spreadsheet contains only 1,916 rows of data for Fulton County. At least eleven ABBSs are entirely missing, not counting possible duplicate entries in the spreadsheet.[8] This sort of "sanity check" is simple to perform, but apparently was not performed by the auditors, VotingWorks, Fulton County, or the Secretary of State.

Table 1 lists 11 ABBSs that do not appear in the audit spreadsheet; the final column indicates which page of which ABBS image file contains the image (for instance, "4 at 162" means page 162 of "Fulton Audit Documents 4_redacted"). The scans of the ABBSs are available at https://figshare.com/s/9819e969a8a6172c25bc (Appendix 1). The fact that the vote data in the last two rows are identical is suspicious, but the corresponding ABBS images are clearly different. Regardless, neither appears in the audit spreadsheet.

	Scanner	Batch	Mode of voting	Trump	Biden	Jorgensen	Write-In	Undervote or blank	Overvote	Image source
1	3	48	absentee	4	93	2	0	0	0	4 at 162
2	2	52	absentee	6	92	0	0	0	0	1 at 1
3	3	12–14	?	12	83	1	0	0	0	4 at 128
4	3	239	?	13	87	0	0	0	0	3 at 177
5	1	80–84	?	118	329	3	2	2	1	3 at 519
6	3	260	absentee	30	66	0	0	0	0	4 at 355
7		AP01A-1	election day	84	62	6	2	1	0	1 at 170
8	3	179–181	absentee	85	224	5	1	2	0	4 at 293
9	2	239	absentee	4	42	0	0	0	0	2 at 153
10	Chastain	12	advance	613	605	24	7	4	0	3 at 351
11	Chastain	114	advance	613	605	24	?	4	0	3 at 270

Tab. 1: Examples of audit board batch sheets (ABBSs, tallies of votes in batches of ballots) that were not entered into the audit results spreadsheet.

There are no data in the audit spreadsheet matching rows 4–11 of table 1. There are data

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[7] Audit subtotals come from the detailed "audit spreadsheet" available at https://sos.ga.gov/admin/uploads/audit-report-November-3-2020-General-Election-2020-11-19.csv accessed 11 July 2024. Images of the Fulton County, GA, RLA manual tabulation batch sheets (ABBSs) were downloaded from https://sos.ga.gov/admin/uploads/Fulton%20RLA%20Batches.zip on 9 January 2022. That file contains five .pdf files, "Fulton Audit Documents 1_redacted.pdf," through "Fulton Audit Documents 4_redacted.pdf," which contain images of ABBSs, and "Fulton Audit Documents 5.pdf" which contains images of "Vote Review Panel Tally Sheets."

[8] However, there is at least one ABBS marked "Dup" (presumably meaning "duplicate") for instance, page 11 of "Fulton Audit Documents 2_redacted.pdf." However, as table 1 shows, at least 11 ABBSs are not accounted for in the audit spreadsheet. Thus, there are presumably duplicated entries in the audit spreadsheet.

that match rows 1, 2, and 3, but with different batch identifiers.[9] There is no reason to doubt that these are genuinely different batches: some identical counts in different batches are to be expected. Indeed, in the entire audit spreadsheet, there are 16,807 rows that duplicate other ABBS vote counts within the same county, out of a total of 41,881 rows.

Vote totals for Trump, Biden, and Jorgensen derived by summing ABBS entries in the audit spreadsheet match the vote totals in the summary audit result spreadsheet posted by the Secretary of State at the URL https://sos.ga.gov/admin/uploads/Georgia%202020%20RLA%20Report.xlsx, downloaded on 9 January 2022. The spreadsheet does not list write-ins, undervotes, or overvotes. Both sources show Trump receiving 137,620 votes, Biden receiving 381,179, and Jorgensen receiving 6,494. Thus, the ABBSs that are missing from the audit spreadsheet are also missing from the audit's reported vote totals.

On the assumption that the ABBSs—the original source of the manual tally data entered into the audit spreadsheet—are correct, the omission of that sample of 11 ABBSs deprived Trump of 1,582 votes, Biden of 2,288, and Jorgensen of 65, not to mention write-ins. This sample alone has a total of over 3,900 votes that the audit tabulated but were not included in Fulton County's audit vote totals, compared with a *statewide* margin of less than 12,000 votes.

The original tabulation in Fulton County showed 524,659 votes; the reported audit results showed 525,293, a difference of 634 votes, about 0.12 percent.[10] Accounting for those 11 omitted ABBSs increases the apparent tabulation error from 634 votes to over 4,569 votes or 0.87 percent, far larger than the statewide margin of victory. It is also larger than 0.73 percent, which Secretary Raffensperger claimed was the maximum miscount in any Georgia county.[11]

There is no way to know whether including those 11 ABBSs would make the audit tabulation a complete count in Fulton County: many ballots might remain untabulated, because Georgia's canvass procedures are lax. The proof some Georgia jurisdictions do not keep adequate track of ballots, memory cards, and other election materials is evidenced by the

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[9] The data that match row 1 are identified as "Scanner 3 Ballot [sic] 162" rather than batch 48. The data that match row 2 are identified as "Absentee Scanner 2 Batch 400" rather than batch 52. The data that match row 3 are identified as Absentee Scanner 3 Batch 253 rather than batches 12–14.

[10] Data from https://sos.ga.gov/admin/uploads/Georgia%202020%20RLA%20Report.xlsx, accessed 9 January 2022.

[11] Per Secretary Raffensperger, "[i]n Georgia's recount, the highest error rate in any county recount was 0.73%." https://sos.ga.gov/index.php/elections/2020_general_election_risk-limiting_audit, accessed 9 January 2022.

fact that thousands of ballots and scans were "discovered" during the audit.[12] There is no trustworthy inventory of ballots to check the results against.

Georgia Governor Brian P. Kemp pointed out similar flaws in the audit, saying the audit report was "sloppy, inconsistent, and presents questions about what processes were used by Fulton County to arrive at the result."[13] Governor Kemp's letter points out that the audit data include duplicated entries.

3   First Count, Audit, and Recount Differ Substantially

Official precinct-level results for the original tabulation were downloaded from https://results.enr.clarityelections.com//GA/Fulton/105430/271723/reports/detailxls.zip and for the recount from https://results.enr.clarityelections.com//GA/Fulton/107292/275183/reports/detailxls.zip to examine the results in precinct RW01, the precinct in which the lead plaintiff in *Curling v. Raffensperger* votes.

Table 2 shows the counts of election-day votes in precinct RW01 for the three presidential candidates, according to the original machine count, the machine recount, and the "audit," and vote-by-mail and advance votes for the original election and the recount. (The audit did not report precinct-level results for vote-by-mail or advance voting.)

Count	Election Day			Advance			Absentee by Mail			Provisional		
	Trump	Biden	Jorgensen	Trump	Biden	Jorgensen	Trump	Biden	Jorgensen	Trump	Biden	Jorgensen
Original	193	88	11	1455	1003	23	619	833	15	9	4	1
Recount	162	73	9	1487	1015	25	619	809	15	5	3	1
Audit	243	88	11									

Tab. 2: Election day, advance, absentee, and provisional vote tallies for Fulton County, GA, precinct RW01 in the 2020 U.S. Presidential election

There are large, unexplained differences among these results.[14] Secretary Raffensperger attributed all differences between the audit and the original count to human counting error, citing a 2012 study that found hand-count error rates as high as 2 percent.[15] While human

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[12] https://www.cbs46.com/news/floyd-county-election-director-fired-after-audit-reveals-2-600-votes-went-uncounted/article_bbd08d90-2aa2-11eb-9e4d-bf96ac56ad54.html, accessed 10 January 2022. https://www.news4jax.com/news/georgia/2020/11/18/4th-georgia-county-finds-uncounted-votes-as-hand-count-deadline-approaches/, accessed 10 January 2022. https://www.mdjonline.com/elections/cobb-elections-finds-350-uncounted-ballots-during-audit/article_0d93e26e-22bd-11eb-8bce-17067aceee33.html, accessed 10 January 2022. https://www.11alive.com/article/news/politics/elections/fayette-county-election-results-ballots-uncovered-during-audit/85-f79dd838-a15c-4407-80b2-9dfbc2466188, accessed 10 January 2022.

[13] Letter from Brian P. Kemp, Governor, to the Georgia State Election Board, dated 17 November 2021, addressing the work of Mr. Joseph Rossi; Review of Inconsistencies in the Data Supporting the Risk Limiting Audit Report, Office of Governor Brian P. Kemp, 17 November 2021.

[14] There appears to be some cancellation of error, but the hand count kept ballots cast in different ways separated (advance in-person, absentee by mail, and election day). It is not clear how misclassification of the mode of voting would affect one candidate's totals much more than the other candidates. Regardless, these discrepancies are large and should be investigated, including inspecting the physical ballots.

[15] https://sos.ga.gov/index.php/elections/historic_first_statewide_audit_of_paper_ballots_upholds_result_of_presidential_race, accessed 10 January 2022.

error presumably accounts for *some* of the difference, there is no evidence that it accounts for most of the difference, much less the entire difference, as Secretary Raffensperger claimed.[16]

The original count and audit agree with each other (but not with the recount) regarding the number of election-day votes for Biden and Jorgensen. The audit found 50 more election-day votes for Trump than the original tally and 81 more than the machine recount found: a difference of almost 50 percent. These differences have not been investigated and are unexplained. A hypothesized error rate of 2 percent in hand counts does not suffice.

The differences might result from discrepancies between the QR-encoded votes and the human-readable votes on BMD printout and/or from misconfiguration, bugs, or malware on the scanners or tabulators. As discussed above, the audit checked none of these things. Possible machine error should have been investigated, rather than assumed not to exist.

The hand count could easily be more accurate than the machine count. Indeed, it is well known that careful hand counts of hand-marked paper ballots are often more accurate than machine counts, in part because human readers can interpret faint, improper, and ambiguous marks better than machines can, even when the machines are working properly, as studies of "residual votes" and statewide recounts show [AR04, An18, AS05, ABS13, AAH13, Ca05].[17]

The scanner settings Georgia uses for its Dominion scanners (low resolution, black-and-white) can cause voters' selections not to appear at all in the images, selections that are obvious to human readers looking at the actual ballots.[18] Manual tallies generally find more valid votes than machine tallies. Hand-count error rates are known to depend on many factors, including ballot design, the method for hand counting ("sort-and-stack" versus "read-and-mark"), and the size of counting teams. They presumably also depend on whether there are additional quality control measures in place, such as checking sorted piles of ballots to ensure that each pile has votes for just one candidate.

The study [GBG12] cited by Secretary Raffensperger to support his claim is a laboratory study with 108 subjects and 120 ballots, each containing 27 contests with two candidates. It used three kinds of "ballots": printout from two kinds of DRE (direct-recording electronic) voting system and an optical scan ballot. The highest error rates were for thermal printout from DREs, which does not resemble Georgia's BMD printout nor Georgia's hand-marked paper ballots. The method with the *highest* error rate was the "sort-and-stack" tally method that Georgia used in its audit. The study did not observe hand tabulation in a real election, nor did it involve BMD summary printout.

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[16] Moreover, RLAs treat the hand count as the correct count: the hand counts should be conducted with adequate care to ensure they are accurate, which typically requires different procedures from those used in initial manual tallies.

[17] Whether hand counts are more accurate than machine counts depends on many variables. The scrutiny and care involved in recounts and manual audits are generally higher than they are in initial hand counts. For instance, [An18] find that *initial* machine counts were often more accurate than *initial* hand counts—by using careful handcounts from statewide recounts as the touchstone for the correct counts.

[18] See, e.g., Judge Amy Totenberg's Opinion and Order of 11 October 2020, in Curling et al. v. Raffensperger, 1:17-CV-2989-AT, at 4, 30, 95, 101, 103, 114–135.

The differences between the original count and the machine recount are large and unexplained; for instance, the difference in the counts of Biden's Absentee votes is almost 3 percent. It is now impossible to know what went wrong, nor whether the differences are primarily attributable to malware, bugs, misconfiguration, or human error.

3.1 The two machine counts in Fulton County

This section assesses the internal consistency of the two machine counts (the original machine count and the machine recount) in Fulton County using data from the election management system (EMS) including cast vote records (CVRs), scanned images of ballots, and BMD printout, and other files made available to the plaintiffs in Curling et al. v. Raffensperger et al. To confirm that the EMS data were the correct data, tallies were calculated and compared to the official results for Fulton County; they matched:[19]

Candidate	1st machine count	2nd machine count
Donald J. Trump	137,240	137,247
Joseph R. Biden	381,144	380,212
Jo Jorgensen	6,275	6,320

Tab. 3: Data used to verify that the EMS download matched the official results in Fulton County, GA.

The number of cast vote records (the voting system's record of the votes on each ballot or BMD printout card, from which the system tabulates results) in the two machine counts in Fulton County were rather different: 528,776 in the first count and 527,925 in the second count, a difference of 851. Fulton County has not explained this discrepancy.

The number of cast vote records in the two machine counts should be equal. Differences might occur if (i) some ballots or BMD printout cards were misplaced or found between the two machine counts, so a different number pieces of paper was scanned in the two machine counts; (ii) malware, bugs, misconfiguration, or a bad actor added, deleted, or altered records in the election management system in one or both machine counts; (iii) Fulton County did not scan every validly cast ballot or BMD printout card exactly once in each machine count; (iv) some scans were omitted or improperly included in one or both counts. Compelling evidence that (ii) or (iii) is true is presented below, but all four could be true simultaneously.

Fulton County did not produce an image file for every cast vote record. For the first machine count, production included images of ballots or BMD printout cards for only 168,726 of the 528,776 cast vote records: 376,863 image files are missing. For the second machine count, Fulton County's production included images of ballots or BMD printout cards for 510,073 of the 527,925 cast vote records: 17,852 image files are missing.

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[19] First machine count results: https://results.enr.clarityelections.com/GA/Fulton/105430/web.264614/#/summary (visited 11 July 2024) Second machine count results: https://results.enr.clarityelections.com/GA/107231/web.264614/#/detail/5000?county=Fulton (visited 11 July 2024)

Entire batches of images are missing from Fulton County's production; for example, images from Scanner 801 batch 117 and Scanner 801 batch 118 are referred to in the cast vote records for the second machine count but the images were not among the electronic records. Without additional information it is impossible to determine whether the missing images are missing because of human error or malfeasance, programming errors (bugs), or malware in Fulton County's election management system (EMS)—possibilities that are not mutually exclusive.

The extant images nonetheless prove that Fulton County's election results included many votes more than once in the reported tabulations. The full extent of multiple-counting cannot be determined without additional information, but there is evidence that it added thousands of bogus votes to the reported machine-count results. That is, thousands of Fulton County voters' votes were included in the reported totals more than once. It is not possible to determine conclusively whether any voter's votes were omitted from the reported totals.

Repeatedly scanning the same piece of paper generally does not produce images that are bitwise identical, because of variations in the alignment of the paper, illumination within the scanner, dirt on scanner lenses, etc. Similarly, a single scan can be altered digitally to produce multiple images that look similar but are not bitwise identical.

Small variations in voters' marks (e.g., not filling an oval completely or straying outside the oval) on hand-marked paper ballots generally make it possible to tell whether two separate scans of hand-marked paper ballots that contain the same votes are scans of the same physical ballot.

It is not generally possible to tell whether two 200dpi black-and-white scans of BMD printout cards are scans of the same piece of paper simply by looking at those two scans, because BMD printout cards containing the same votes may be indistinguishable at low resolution in black-and-white.[20] However, if both scans contain a rare write-in name or rare combination of write-in names, that is evidence of a duplicate. Similarly, if a series of votes is repeated in in the same order (or reverse order) in different scan batches of BMD printout, that is also evidence that they are repeated images of the same collection of paper. If the duplicated (or reversed) vote sequences are long and include rare write-in names, the evidence that they are scans of the same physical pieces of paper is compelling.

There are at least 12 hand-marked ballots from Fulton County precinct RW01 that were scanned twice in the first machine count (the original election). Fourteen pairs of duplicate images are listed in table 4 and are available at the url https://figshare.com/s/9819e969a8a6172c25bc (Appendix 2). The format of the numbers is <scanner number>_<batch number>_<image number>. At least three BMD cards from precinct RW01 appear to have been scanned twice in the machine recount in RW01, based on the

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[20] Differences in the monochrome threshold or scanner maintenance might create discernable differences. A sufficiently high-resolution scan might make it possible to identify differences in the arrangement of the paper fibers [Cl09].

votes and the order in which they were scanned in two batches. In particular, Scanner 801, batches 43 and 44—both comprising scans of advance in-person BMD printout cards—start with images of 214 BMD cards that have the same sets of votes in the same order in both batches. The two batches were scanned within about five minutes of each other, according to the timestamps in the images. Many of the images show write-in votes[21] or votes for third-party candidates, further evidence that the match was not coincidence. Visual inspection of all 214 pairs and confirmed that they match: those BMD cards were scanned twice in the machine recount. The other 211 (214–3=211) duplicated scans are of BMD cards from other precincts in Fulton County.

pair	Image A	Image B
1	05162_00234_000096	05162_00235_000057
2	05162_00234_000093	05162_00235_000054
3	05162_00234_000074	05162_00235_000036
4	05162_00234_000072	05162_00235_000034
5	05162_00234_000068	05162_00235_000030
6	05162_00234_000069	05162_00235_000031
7	05162_00234_000054	05162_00235_000014
8	05162_00234_000031	05162_00235_000090
9	05162_00234_000026	05162_00235_000085
10	05162_00234_000017	05162_00235_000076
11	05162_00234_000013	05162_00235_000072
12	05162_00234_000014	05162_00235_000073
13	05162_00234_000003	05162_00235_000062
14	05162_00234_000001	05162_00235_000060

Tab. 4: Images that were included in the original machine count in Fulton County at least twice. Images are posted at https://figshare.com/s/9819e969a8a6172c25bc (Appendix 2).

There is also one hand-marked paper ballot that was scanned twice in RW01 in the machine recount, and at least seven hand-marked paper ballots that were scanned thrice in RW01 in the machine recount. Twenty-nine images seem to represent only 11 distinct pieces of paper, even though they contributed 29 votes to some contests, including the presidential contest. The sets of images are available at the url https://figshare.com/s/9819e969a8a6172c25bc (Appendix 3). Table 5 lists the pairs and triples.

To confirm that the duplicate and triplicate images were included in the reported vote tabulation, the cast-vote records (CVRs) produced by Fulton County for each image identifier among the duplicates and triplicates of images of RW01 ballots and BMD printout cards were searched electronically. All 24 from the original count and all 29 from the machine recount were among the CVRs. Therefore, the duplicate and triplicate votes were included in the reported machine tabulations, since the vote totals derived from the CVRs agree with the reported vote totals, as mentioned above.

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[21] Write-ins included votes for "Anyone," "XXX," "Willie Nelson," and "Alexander Hamilton," as well as write-in votes for "Donald Trump" for District Attorney, Clerk of the Superior Court, Tax Commissioner, Sheriff, Solicitor General, and Surveyor.

Multiple	Image A	Image B	Image C
1	00801_00044_000168	00801_00043_000168	
2	00801_00044_000083	00801_00043_000083	
3	00801_00044_000042	00801_00043_000042	
4	05160_00074_000023	05160_00067_000008	
5	00794_00017_000024	00791_00026_000091	00791_00019_000010
6	00794_00017_000029	00791_00026_000086	00791_00019_000015
7	00794_00018_000001	00791_00026_000009	00791_00019_000092
8	00794_00018_000011	00791_00026_000019	00791_00019_000082
9	00794_00019_000002	00791_00026_000079	00791_00019_000022
10	00794_00019_000005	00791_00026_000076	00791_00019_000025
11	00794_00019_000006	00791_00026_000075	00791_00019_000026

Tab. 5: Images that were (erroneously) included in the machine recount at least three times. Images are posted at https://figshare.com/s/9819e969a8a6172c25bc (Appendix 3).

For Fulton County as a whole, plaintiffs in *Curling v. Raffensperger* identified images of 2,871 ballots and BMD printout cards that they claim were counted two or three times in the second machine count. Some were identified by visual inspection of the images; others were inferred to be duplicates because a sequence of cast vote records was identical (or reversed) for long portions of two scan batches. I confirmed that 214 of the purported duplicate scans of BMD cards were indeed duplicates. This list of 2,871 is a sample from a larger list of images of ballots and BMD printout cards that plaintiffs assert were included in the tabulation twice or more. All 6,118 images in question were referenced in CVRs in the second machine count, so all contributed to the tabulation.

Nine hundred sixteen (916) of the 2,871 sets of images were images of hand-marked paper ballots. In a random sample of 100 of those 916, I verified visually that 46 contained triplicate images. I confirmed the determination for 98 of the 100 sets. I disagreed about one set, and was unable to verify one set. Treating this conservatively as 98 agreements in 100 random checks yields a 95 percent lower confidence bound that at least 891 of the 916 claimed multiples are genuine multiples.

These observations make it clear that in the original count and in the machine recount, Fulton County did not keep track of which ballots and BMD cards had been scanned and which had not. It is also possible that the electronic records were altered accidentally or intentionally, or that some memory cards were not uploaded or uploaded more than once. The electronic records of the election are not intact. This is a surprising gap: the most basic election safeguard is to check whether the number of voters who participated is equal to the number of ballots and BMD printout cards that were cast and to the number that were tabulated. Moreover, one might reasonably expect all electronic election materials to be backed up onsite and offsite, at least for the U.S. federally mandated retention period of twenty-two months, so the loss of hundreds of thousands of image files from the first

machine count and of nearly 18,000 images from the second machine count is hard to fathom.

Fulton County would have noticed these errors if it had kept track of ballots and BMD printout cards and checked the total number against the number reported in the electronic tabulation. It seems that Fulton County did not know how many ballots and BMD printout cards were cast in the election, how many voters cast votes, or how many pieces of paper were scanned—nor how those numbers compare to each other. Absent basic ballot accounting, pollbook reconciliation, and counting of electronic records, it is unsurprising that the two machine tallies differ so much. The U.S. Election Assistance Commission has published best practices for chain of custody.[22]

Fulton County's lax curation and processing of cast ballots, BMD printout, and electronic records make a true risk-limiting audit impossible because even a perfect tabulation of the votes from the available paper might not show who really won. Voters have good reason to believe that some votes counted more than others, since some votes were included twice or thrice in the totals. There is no way to know how many votes were omitted from the tabulation, absent access to the physical ballots and BMD printout and evidence that the chain of custody is intact. It is impossible to determine whether malware, bugs, misconfiguration, or malfeasance disenfranchised voters or altered the election results.

The audit planning, process, and controls did not detect the double and triple counting. Even if Fulton County did not rely on ballot-marking devices for all in-person voters, the lack of basic accounting controls makes it impossible to determine who really won, even by a perfect hand count of the votes: the record of the vote could easily be incomplete or adulterated. There is no reason to believe that problems of the kinds described above are limited to Fulton County.

4   Summary

An accurate recount of the votes in a trustworthy record can determine the true winners of an election, and a rigorous audit can provide confidence that a well-run election found the true winner(s). But neither a recount nor an audit can compensate for using untrustworthy technology to record votes, for instance, because the election was run poorly and had inadequate physical security controls; in such circumstances, recounts and audits distract attention from the real problems rather than justifying confidence. Absent a trustworthy record of the votes, no procedure can provide affirmative evidence that the reported winner(s) really won.

Georgia lacks such a record for many reasons, including the heavy reliance on BMDs; lack of physical accounting of voted ballots, memory cards, and other election materials; lack of

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[22] https://www.eac.gov/sites/default/files/bestpractices/Chain_of_Custody_Best_Practices.pdf accessed 11 July 2024.

pollbook and voter participation reconciliation; lack of rigorous chain of custody; etc. To provide reasonable assurance that every validly cast vote is counted—accurately—requires systematic improvements:

1. Every voter should have the opportunity to mark a ballot by hand, whether voting in person in advance, in person on election day, or absentee by mail.

2. Reduce the use of ballot-marking devices to a minimum:[23]
   - BMDs do not necessarily print voters' selections accurately. They can be hacked or misconfigured [Ha23, ADS20].

   - A growing body of empirical work shows that few voters check the BMD printout, and those who do rarely catch and report errors [Be20, KBW20, HI21].

   - There is no way for a voter to prove to an election official or anyone else that a BMD malfunctioned. Hence, there is no way to ensure that malfunctioning devices are removed from service if voters notice BMDs misbehaving. And if a device is caught misbehaving, there is no way to reconstruct the correct election outcome [ADS20].

   - There is no way to test BMDs adequately prior to, during, or after an election to establish whether they altered votes, even if they altered enough votes to change electoral outcomes [ADS20, SX22].

3. Implement better procedures and checks on chain of custody of election materials, especially voted ballots. Georgia currently cannot determine whether every validly cast ballot was included in the reported results exactly once, whether there was electronic or physical "ballot-box stuffing," or whether votes were altered.[24]

4. Implement better protocols for using and checking physical security seals on ballots and voting equipment—and check whether those protocols were followed. Require routine scrutiny of custody logs and surveillance video, and other related security measures.

5. Perform internal consistency checks as part of the canvass, including, e.g.:

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[23] Hand-marked ballots should be offered to in-person voters by default, with access to a BMD available upon request. BMDs or other accessible means of marking a ballot should be set up in advance, so that it is available if and when a voter requests to use it. BMD printout should resemble hand-marked paper ballots to the extent possible, to preserve voter privacy: they should the same paper stock, have the same format as hand-marked paper ballots, and the marks should be printed to resemble hand-made marks, e.g., by digitizing actual hand-made marks.

[24] This is evidenced by the fact that the 2020 audit found thousands of untabulated ballots. Per the Secretary of State's office, "[t]he audit process also led to counties catching making mistakes they made in their original count by not uploading all memory cards." https://sos.ga.gov/news/historic-first-statewide-audit-paper-ballots-upholds-result-presidential-race accessed 11 July 2024. Because physical accounting for election materials was lacking, there is no way to know how many more votes validly cast in that election were not included in any of the reported tallies. Moreover, the lax recordkeeping evidently resulted in scanning the same batches of ballots more than once. Similarly, some ABBSs were presumably entered more than once, and as shown above, some were not entered at all.

a) Verify that the number of ballots sent to each polling location (and blank paper stock for ballot-marking devices and ballot-on-demand printers) equals the number returned voted, spoiled, or unvoted. This check should be physical, based on manual inventories, not on reports from the voting system.

b) Check pollbooks and other voter participation records against the number of voted ballots received, including whether the appropriate number of ballots of each "style" were received.

c) Check whether the number of electronic vote records (images and CVRs) agrees with the physical inventory of ballots of each style.

A genuine risk-limiting audit requires a demonstrably trustworthy record of voter intent. Georgia's vote records are untrustworthy for many reasons, starting with the heavy use of ballot-marking devices, which do not produce a trustworthy record of the vote [ADS20, Ha23] no matter how much logic and accuracy testing or election-day monitoring there is [SX22]. The lack of a trustworthy record is exacerbated in Georgia by the lack of ballot accounting, pollbook reconciliation, and other elements of a good canvass. There are also problems with Georgia's verification of voter eligibility and voter participation record. But even if every voter used a hand-marked paper ballot and there were no issues determining voter eligibility, Georgia does not keep track of election materials adequately through physical inventories, custody logs, and other means.

The foundation for a risk-limiting audit is a *ballot manifest*, a physical inventory of the validly cast paper ballots detailing how they are stored: the number of containers, their identifiers, and the number of cards in each. It must be derived without reliance on the voting system or the audit is trusting the voting system to check itself. For example, if some cards were never scanned or some scans were not uploaded (as discovered during the 2020 "audit"), they will be missing from any manifest derived from the voting system. Absent a physical inventory, it is impossible to account for votes reliably and impossible to limit the risk that an incorrect electoral outcome will be certified, even with a careful manual recount or rigorous audit: recounting or applying risk-limiting audit procedures to an untrustworthy collection of ballots is "security theater."

Like many states, Georgia audits only a small number of contests in each election. Even a properly conducted RLA using a demonstrably trustworthy paper trail confirms only the contest or contests that were audited—and no other contests—although election officials sometimes claim otherwise.[25]

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[25] For example, the State of Colorado currently conducts an RLA of two contests in each jurisdiction in each election, but the Secretary of State's website says, "Colorado residents can be confident that official election results reflect the will of voters because we conduct a statewide bi-partisan audit after every election to ensure the integrity of the results." https://www.coloradosos.gov/pubs/elections/auditCenter.html accessed 24 July 2024.

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