Dr. Ben Adida, Executive Director, VotingWorks

Dear Dr. Adida:

We write as members of the State Audit Working Group (SAWG), a group of election integrity experts particularly focused on election auditing. The SAWG has been meeting regularly via teleconferences since 2008 and has worked on recommendations from time to time such as to the *Principles and Best Practices for Post-Election Tabulation Audits*[1] and the EAC's *Voluntary Voting System Guidelines*,[2] and the implementation of Colorado's RLAs.

We appreciate the work that Voting Works has done to implement, maintain, and provide Arlo software to carry out risk-limiting tabulation audits.

Because your organization provides software for risk-limiting audits (RLAs) around the nation, we would like to discuss with you possible changes and improvements in software that would enhance the transparency, accountability and public confidence in the RLA software and processes.

We would appreciate the opportunity to discuss our ideas with you and your organization. This could be during one of our weekly Tuesday calls, 9 AM pacific, or in a separate call,

Our group put together some ideas for improvement, and at this point, direct dialog with you is thought to be the best course as the options should also be informed by your understanding of your software and protocols.

Thank you for your work, and for considering our request.

* Affiliations for Identification purposes only

Luther Weeks, Moderator State Audit Working Group, Executive Director of Connecticut Voters Count

Paul Burke, http://VoteWell.net

John McCarthy, retired computer scientist (Lawrence Berkeley National Laboratory)

Harvie Branscomb, http://electionquality.com, Carbondale, CO; President, Coloradans for Voting Integrity

Ray Lutz, Executive Director, Citizens' Oversight Projects (https://citizensoversight.org)

Celeste Landry, Member, NIST Voting Methods and Tabulation Working Group

Tim White, WA State Election Watcher, State Audit Working Group

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[1] https://electionaudits.org/files/Audit%20Principles%20and%20Best%20Practices%202018.pdf
[2] eac.gov/sites/default/files/TestingCertification/Voluntary_Voting_System_Guidelines_Version_2_0.pdf

TRANSPARENCY IN RISK-LIMITING AUDITS (RLAs)

A primary purpose of RLAs is to provide evidence to the public that the election outcome is correct, but RLAs are a complex process that relies on software for many key operations, decreasing the ability for the public to observe, verify and recreate the RLA results. We hope considering and implementing these suggestions will significantly increase the public's ability to follow the RLA process, review the results independently and verify the results.

In ballot-comparison RLAs, and possibly other RLAs, humans review paper ballots, then enter their interpretations of the vote selections into Arlo or ColoradoRLA, which store these human interpretations and report if they match the election system's interpretations of the vote selections recorded as cast vote records or CVRs.

Risk-limiting audits and, in particular, audit software need transparency for several reasons. Among them are:

(a) So members of the public can independently check the tabulation, and during the audit, independently interpret the ballots.
(b) So members of the public can check the calculations to be able to determine whether the RLA software accurately counted, calculated, and reported the results. .

We believe this transparency will increase voter confidence in the tabulation audit's interpretations and the accuracy of the results.

The public doesn't, and has no reason to, trust a black box. Pew found that in October 2020, only 10% of Trump supporters and 8% of Biden supporters were "very confident that election systems in the U.S. are secure from technological threats."[3] When only officials can see the paper ballots and electronic files, their official audits, if audits are done at all, are opaque self-audits inviting public skepticism. They can't even know if their audit software is hacked while the software is running, perhaps confirming erroneous totals.

We believe letting anyone check audit software performance by hand or with other software increases transparency and public confidence. Risk-limiting audit software should:

1. Publish the data to be audited (election results, manifests, CVRs, etc.) both digitally signed and timestamped in a user-friendly way, before the random selection. If there are legal restrictions on early publication of CVRs, they still must be published later on, and commitments to them (timestamped hashes which don't reveal the contents) must be published before the random selection, so the public can know that the eventual publications are pristine.
2. Check digital signatures of CVRs, manifests, and any other files provided by the election offices and report on the checks. Note that Sigstore/Fulcio provides a new approach to simplify transparency logs and key management for digital signatures.
3. Publish the random number seed and random numbers. These items should be published with their digital signature.

[3] Pew 10/14/2020 https://www.pewresearch.org/politics/2020/10/14/deep-divisions-in-views-of-the-election-process-and-whether-it-will-be-clear-who-won/

4. Publish the algorithm used to generate the sample, and algorithm to determine steps and calculate risk levels, in enough detail to recreate the risk limit from the rest of the data.
5. Preserve on paper the human interpretations of votes on ballots. Auditors need to verify these paper records. Several options are listed in the appendix.
6. Publicly post electronic images of the transcription sheets, with digital signatures.
7. After entering and permanently storing discrepancies, we'd like to discuss the advisability of noting that there are discrepancies on a ballot, or on a series of ballots, so another team can determine root cause and correct incorrect procedures, while any observers are still present.
8. Publish ballot images, with hash value and/or digital signature dated as soon as possible, after creation of the images. Images check the paper ballot chain of custody, and enable investigations by the public, similar to those done by the Secretary of State's staff in Colorado.[4]

Evidence of interpretations

Tally sheets are auditor-verified paper evidence of auditors' interpretations, as hand-marked paper ballots are of voters' intentions. Options for creating tally sheets are in the appendix.

Given an auditor-verified paper record and images of the paper and CVRs with digital signatures, anyone can recreate the RLA with no dependence on the RLA software. The opportunity for such independent checks will build confidence in the outcomes and spread understanding of audits.

In addition, saying votes out loud could help accuracy and can be picked up on a recording.

Computer vulnerability

Determined attackers can penetrate the most fortified networks; as we've seen, the CIA, NSA and other highly defended organizations have been compromised. The intelligence community has warned that we should expect well-resourced nation-state actors to target our election systems and software.[5]

Human vulnerability

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[4] CO SOS has investigated reasons for discrepancies in https://www.sos.state.co.us/pubs/elections/RLA/files/OverviewThreeYearsIn.pdf and https://www.sos.state.co.us/pubs/elections/RLA/2020/general/DiscrepancyReport.pdf

[5] "Vendors represent an enticing target" ~US Senate Intelligence Committee
"Chinese hacking tool that has been able to escape public attention for more than a decade"
"Russians are a professionally proficient adversary who have historically penetrated every American institution worth penetrating."
"Every piece of commercial software... has hundreds if not thousands of vulnerabilities, most of them undiscovered."
2021 University of Cambridge found a dangerous vulnerability in at least 19 compilers (used in all commercial software), it gave 99 days notice, and only 9 of the 19 said they'd fix it. (Horrifyingly, 2 require that bug reports come in by non-encrypted email). Software companies tended to ignore bugs which used an unfamiliar approach.
As early as 2014, "there are two kinds of big companies in the United States. There are those who've been hacked by the Chinese and those who don't know they've been hacked by the Chinese… Their strategy seems to be: We'll just be everywhere all the time."
As early as 2013 the NSA (intelligence agencies in other major powers are not different) "appeared to have acquired a vast library of invisible backdoors into almost every major app, social media platform, server, router, firewall, antivirus software, iPhone, Android phone, BlackBerry phone, laptop, desktop, and operating system."

We must also assume that election officials and workers can be susceptible to error, fraud and intimidation. That is a reason to use great care in providing for independence in the audit design.

Eliminating operations that are dependent only on the software will increase resiliency and transparency. Audit software can be a single point of failure for jurisdictions using it. Paper protects us.

Independently checkable

VVSG 2.0 uses Ron Rivest's meaning of *Software independence*, namely "an undetected error or fault in the voting system's software is not capable of causing an undetectable change in election results." That applies to the voting system, not the audit system. We can use "*independently checkable*" for audit systems which let others check for errors, with no dependence on the original audit software.

Appendix table: Options to create paper record of human interpretations during audit

Options 1-2: Enter human interpretations into a computer, which then prints them on paper, which auditors verify before accepting.
Options 3-6: Enter human interpretations on paper, which is then entered into a computer.
All options 1-6: paper records are preserved, scanned and published with digital signatures, for others to use later.

Options	**Prep by software**	**Team reads from ballots**	**Second step**
Option 0-(Current in some places, no paper record) Enter directly from paper ballot into RLA software	menu of candidates for all audited contests	2 people: one reads, one finds menu entry & enters (No second step)[6] This is a weak method since there is no paper preservation of the human interpretation for later verification of the interpretation and the data entry.	
Option 1-Enter directly from paper ballot into RLA software, print these human interpretations, manually check.	menu of candidates for all audited contests	2 people: one reads, one finds menu entry & enters	2 people: Auditor A reads ballot, B watches; get printout, A reads printout, B checks the ballot
Option 2-Enter directly from paper ballot into spreadsheet software, print these human interpretations, manually check.	prefill contests & candidates on spreadsheet	3 people: one reads, two enter in separate spreadsheets a mark for each voted candidate on the right row, each ballot in the right column	4 people: one reads ballot, one watches, one reads each printout* Software can compare 2 spreadsheets. Humans still need to verify printouts to detect hacked spreadsheets.
Option 3-(Current in some places) Enter from paper ballot onto paper transcription sheet, key into RLA software. Sample transcription sheets are at http://www.votewell.net/tally.htm	generate list of contests & candidates on paper transcription sheet before starting	4 people: one reads, one watches, two circle relevant letter, each on separate paper tally sheet, shown at the end of this document	2 people: each finds right row or menu entry, and independently keys into software.[7]
Option 4-Enter from paper ballot onto paper similar to ballot format, enhanced with spaces to confirm human interpretations of overvotes & undervotes	Generate enhanced paper layout for ballot styles in sample	4 people: one reads, one watches, two transcribe	2 people: key into RLA software, like first step of options 0 and 1, with extra spaces to enter interpretations of over & undervotes
Option 5-On a copy of the paper ballot, mark overvotes, undervotes, and resolve any ambiguous marks	Print copy of each ballot in sample	2 people: work through paper copy together, watching each other, with paper original at hand	2 people: key from copy into RLA software, like first step of options 0 and 1, with extra spaces to enter interpretations of over & undervotes
Option 6-Print voting system's CVRs. Manually compare voting system's CVRs to manual interpretation of the votes on the paper ballots[8]	Print CVRs	4 people: one reads ballot, one watches ballot, two watch CVR, note discrepancies on printed CVR	2 people: much less data entry, since software needs just the discrepancies to choose next step. Either 2 people key independently, or one watches the other person keying.
All: Checking printout ballot-by-ballot lets the ballot be put away immediately, and generates one printout to scan and store for each ballot. Entering & checking in groups means keeping ballots accessible until the group is done, and reduces number of printouts to track.			

[6] 1.1% of the 8,306 ballots sampled in CO in 2020G had errors in classification by the manual audit, in the view of SOS staff. These included 0.3% of the sample where programming erred in mapping contest names, 0.2% where SOS staff thought auditors counted to the wrong ballot (by mistake, or because the ballot file had more or fewer ballots than the CVR file), and 0.6% where SOS staff disagreed with county auditors and thought there was no discrepancy. For remaining discrepancies where SOS staff agreed with auditors, 0.2% of the sample had incorrect adjudication in initial processing, 0.1% had the voting software count a mark crossed out by voter, and 0.04% had ambiguous voter intent. ihttps://www.sos.state.co.us/pubs/elections/RLA/2020/general/DiscrepancyReport.pdf

[7] 0.03% of entries were erroneous after keying by two people and resolving differences, even for hard texts from the 1700s, according to transcription researchers. For more recent texts it has 0.003% errors. https://doi.org/10.4000/jtei.739 Thus double-keying adds little error to any underlying error in RLAs.

[8] Stark (2022) endorses "manually checking a random sample of the voting system's exported records against a manual interpretation of the votes on the corresponding physical batches of ballot cards." https://arxiv.org/abs/2201.02707

List of other issues that differentiate methods of involvement of software in tabulation audits:

A. Role of software in detecting incorrect ballot pull and/or enforcing voter intent interpretation - mark detection or vote interpretation
B. Means of presenting the input into software to observers either in person or remote and in parallel, access to simultaneously see the paper (and maybe scanned image of paper)
C. Opportunity to recognize operational error in audit process in timely manner
D. Feedback to auditors to allow correction of error and improved efficiency and better transparency
E. Archiving of interim decisions including errors of all kinds (no destructive overwrite)
F. Potential for public to replicate and investigate without need for or use of the audit specific software