

Colorado's Groundbreaking RLAs:

Experiences and Future Steps

Election Verification Network conference

Panel: Neal McBurnett, Harvie Branscomb,

Dwight Shellman and Matt Crane

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Introduction

Participants, all pioneers in Colorado auditing:

- Neal McBurnett, Election integrity consultant
- Harvie Branscomb, Coloradans for Voting Integrity
- Dwight Shellman, CO Dept. of State
- Matt Crane, Colorado County Clerks Association

Agenda

- Motivation
- Highlights
- Room for improvement

Importance, Scale of the challenge

- Long-standing widespread, transpartisan consensus on need for both voter verified paper ballots and audits.
- Voting systems are vulnerable, simply put
- "Assume breach"! as CISA and the DoD put it
- Insider attacks - occasional fraud, e.g. ongoing prosecution of clerk in Mesa County Colorado,
- Only robust auditing can protect us from cyber threats
- Redoubled emphasis given that increasingly, on both left and right, folks see some elected official who they really fear wants to hack an election
- How can we set up processes now that will thwart that?
- Need to audit all the contests (+ more aspects of election)
- Only ballot-level audits will do that (in US coordinated elections)

Robust auditing is much harder than it seems

- Elections are increasingly complicated
- You can't easily audit the data you've got
- You can't easily get the data you need
- It can be tricky to properly anonymize some of the data
- Legal and practical hurdles, e.g. transparency
- Political hurdles
- COVID....

Auditability around the country

- Huge steps forward in auditability
- Many states with 100% voter verifiable paper ballots
- More, IF you note scattered exceptions, often UOCAVA or print-disabled voters
- Worrisome steps backwards with BMD-by-default or internet return

Audits around the country

- Lots of learning about audits
- Many pilots, gaining experience
- Typically only focus on top-of-the-ticket races
- No coverage of vast majority of the contests
 - Mistaken notion of auditing "election" that way
 - An audit of one contest does NOT limit risk for other contests
 - Biggest prize is often hacking local bond issue or influential local office
- Widespread lack of transparency, robustness
- Hardly any which even publicize data to be audited before public random selection?

Colorado: best audits in the country?

- ColoradoRLA software: open-source by Free & Fair in 2017; Democracy Works in 2018
 - Now maintained by the state, still open-source!
- Designed and implemented with many EVN participants
- Ballot-level comparison audit: the most efficient
- Audit produces data for ALL contests
 - Ignoring chance that a tiny contest will not be on any selected ballots
 - Not much data for many contests
- Relies on ability to match paper ballot with CVR
 - Only easy for central count, due to anonymity roadblocks from in-person scanners
- Verifiably(*) public random selection across all ballots

Issues with verifiability of public random selection

- Dice rolls were originally conducted in person, but recently via Zoom
- See [video of 2022 random selection via dice roll on Zoom](#)
- No longer convincing to outside observer
- Should be easy to fix

Random Seed Dice Roll – Friday, November 18, 2022, 12 P.M. MST

Roll #1	2	3	4	
				
Roll #6	7	8	9	
				
Roll #11	12	13	14	
				
Roll #16	17	18	19	
				

How to do ballot-level comparison audits elsewhere??

- Note award-winning work at UConn on more efficient small-batch **Adaptive risk-limiting comparison Audits**
- Eager to hear other ideas
- Update: see some exciting new work:
 - **Stark, P.B., ONEAudit: Overstatement-net-equivalent risk-limiting audits. Preprint - To appear at Voting '23**
 - **Stark, P.B., Non(c)esuch ballot-level comparison audits for precinct-count voting systems, Preprint - To appear in Proceedings of the first Election Infrastructure Security Conference**

Colorado County Clerks - Defenders of Democracy, True to mission. Across party lines!

In most places, especially hard these days for folks on the right. Disowned by some colleagues, facing everything from public attack, to losing friends and community, to losing careers.

Easier these days for folks on the left, though the tables have been switched in the past

Who among us will stand up for a properly skeptical view of computerized election outcomes, and push for more robust auditing

That actually supports election officials, giving them evidence, reduce need for trust

Who among us is willing to also speak truth to our own tribe?

A privilege to get to work with them over decades

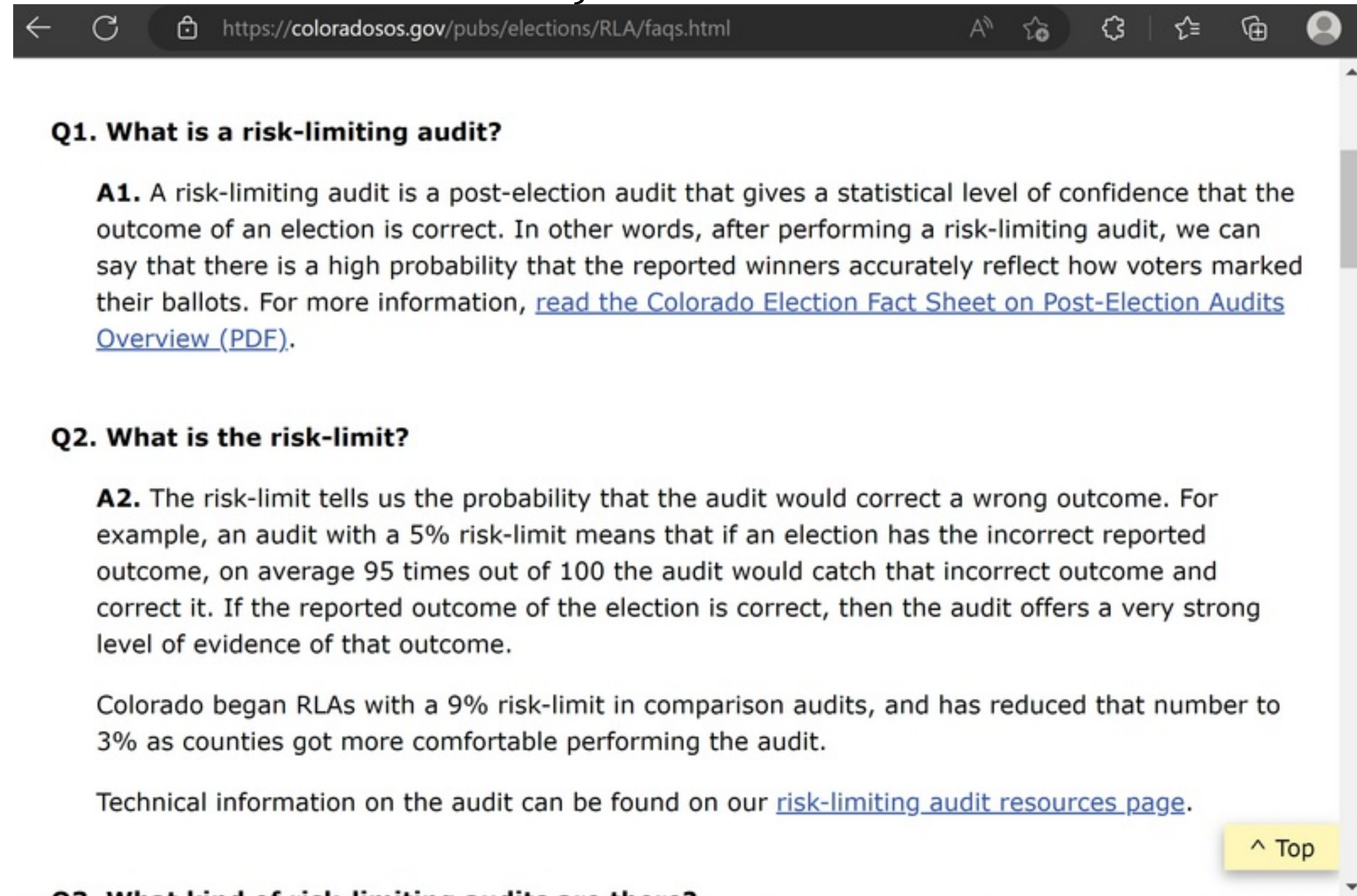
Summarize Audit of 2022 Coordinated election in Colorado (tentative)

- Three rounds over several days
- Most counties done in one day in Round 1
- Risk limit: 3% (overly conservative?)
- > 2508830 ballots cast statewide (undervotes hard to find)
- 3526411 ballot cards in the state (multiple cards per ballot in some counties)
- 6454 ballot cards selected (based on margin, 0.2% overall)
- 233223 votes audited!
- 186 discrepancies - 0.08%, mostly wrong ballot or entry error
- Audit data for 981 contests
- RLAs of 68 contests (some partial and thus artificial...)
- Many more opportunistic contests that actually met risk limit
 - The samples are often not uniformly random, so very hard to calculate rigorous risk levels

County	Contest	Vote For	Lowest Winner	Highest Loser	Contest Margin	Diluted Margin	Risk Limit	Estimated # of CVRs to audit	# of CVR	Remarks
Colorado	United States Senator	1	1,030,331	798,921	231,410	9.34%	3%	78	1,905,052	Audited in all 63 counties
Colorado	Governor/Lieutenant Governor	1	1,085,082	759,989	325,093	13.13%	3%	56	1,905,052	Audited in all 63 counties
Colorado	Secretary of State	1	1,011,329	810,362	200,967	8.11%	3%	90	1,905,052	Audited in all 63 counties
Colorado	State Treasurer	1	973,136	812,686	160,450	6.48%	3%	112	1,905,052	Audited in all 63 counties
Colorado	Attorney General	1	996,172	822,173	173,999	7.03%	3%	104	1,905,052	Audited in all 63 counties
Colorado	State Board of Education Member - At Large	1	952,164	811,758	140,406	5.67%	3%	129	1,905,052	Audited in all 63 counties
Adams	Adams County Sheriff	1	64,428	57,013	7,415	2.94%	3%	248	126,233	
Alamosa	District Attorney - 12th Judicial District	1	3,492	2,172	1,320	22.20%	3%	33	5,946	Single county audit
Arapahoe	Arapahoe County Commissioner - District 2	1	21,917	17,225	4,692	2.77%	3%	263	40,889	
Archuleta	Archuleta County Commissioner - District 3	1	4,494	2,720	1,774	22.63%	3%	32	7,839	
Baca	Baca County Commissioner - District 2	1	1,144	569	575	16.26%	3%	45	1,768	
Bent	Bent County Sheriff	1	800	402	398	27.93%	3%	26	1,425	
Boulder	City of Boulder Ballot Question 2C	1	16,196	8,324	7,872	3.75%	3%	194	30,460	
Broomfield	Boulder Valley School District RE-2 Ballot Issue 5A	1	8,378	5,039	3,339	8.92%	3%	82	15,091	Single county audit
Chaffee	Chaffee County Commissioner - District 3	1	5,592	3,853	1,739	14.82%	3%	49	11,731	
Cheyenne	Amendment D (CONSTITUTIONAL)	1	487	332	155	17.26%	3%	42	898	Single county audit
Clear Creek	Clear Creek County Commissioner - District 1	1	2,726	1,654	1,072	23.05%	3%	32	4,650	
Conejos	Conejos County Sheriff	1	2,169	1,210	959	27.76%	3%	26	3,454	
Costilla	Costilla County Ballot Issue 1A	1	853	663	190	11.09%	3%	66	1,714	
Crowley	Proposition FF (STATUTORY)	1	756	562	194	14.08%	3%	52	1,378	Single county audit
Custer	Custer County School District C-1 Ballot Question 4A	1	1,650	1,060	590	17.61%	3%	41	3,350	
Delta	Amendment D (CONSTITUTIONAL)	1	7,745	6,327	1,418	8.89%	3%	82	15,948	Single county audit
Denver	City and County of Denver Initiated Ordinance 305	1	72,599	48,322	24,277	6.39%	3%	114	126,682	
Dolores	Dolores County Ballot Issue 1B	1	784	460	324	24.94%	3%	29	1,299	
Douglas	State Senator - District 30	1	44,260	38,645	5,615	3.04%	3%	239	88,076	
Eagle	Eagle County Ballot Issue 1A	1	7,018	4,766	2,252	10.22%	3%	71	20,965	
El Paso	City of Colorado Springs Ballot Issue 301	1	71,678	64,470	7,208	3.37%	3%	216	150,185	
Elbert	Proposition 125 (STATUTORY)	1	3,533	3,209	324	4.66%	3%	156	6,950	Single county audit
Fremont	Proposition FF (STATUTORY)	1	10,175	8,935	1,240	6.29%	3%	116	19,707	Single county audit
Garfield	Garfield County Clerk and Recorder	1	10,818	10,135	683	3.12%	3%	234	21,900	
Gilpin	Gilpin County Assessor	1	1,853	1,440	413	12.14%	3%	60	3,401	
Grand	Grand County Commissioner - District 3	1	3,983	3,456	527	6.83%	3%	107	7,715	
Gunnison	Proposition 125 (STATUTORY)	1	4,844	3,859	985	10.68%	3%	68	9,221	Single county audit
Hinsdale	Amendment D (CONSTITUTIONAL)	1	249	172	77	14.75%	3%	49	522	Single county audit

Contest Margin	Diluted Margin	Risk Limit	Estimated # of CVRs to audit	# of CVR	Remarks
231,410	9.34%	3%	78	1,905,052	Audited in all 63 counties
325,093	13.13%	3%	56	1,905,052	Audited in all 63 counties
200,967	8.11%	3%	90	1,905,052	Audited in all 63 counties
160,450	6.48%	3%	112	1,905,052	Audited in all 63 counties
173,999	7.03%	3%	104	1,905,052	Audited in all 63 counties
140,406	5.67%	3%	129	1,905,052	Audited in all 63 counties
7,415	2.94%	3%	248	126,233	
1,320	22.20%	3%	33	5,946	Single county audit
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1,774	22.63%	3%	32	7,839	
575	16.26%	3%	45	1,768	
398	27.93%	3%	26	1,425	
7,872	3.75%	3%	194	30,460	
3,339	8.92%	3%	82	15,091	Single county audit
1,739	14.82%	3%	49	11,731	
155	17.26%	3%	42	898	Single county audit
1,072	23.05%	3%	32	4,650	
959	27.76%	3%	26	3,454	
190	11.09%	3%	66	1,714	
194	14.08%	3%	52	1,378	Single county audit
500	17.61%	3%	11	2,250	

Audit center should note these are only tabulation audits.
Much more is needed for fully evidence-based elections.



The screenshot shows a web browser window with the address bar displaying <https://coloradosos.gov/pubs/elections/RLA/faqs.html>. The page content includes two questions and answers regarding risk-limiting audits. A yellow button labeled '^ Top' is visible in the bottom right corner of the page content area.

Q1. What is a risk-limiting audit?

A1. A risk-limiting audit is a post-election audit that gives a statistical level of confidence that the outcome of an election is correct. In other words, after performing a risk-limiting audit, we can say that there is a high probability that the reported winners accurately reflect how voters marked their ballots. For more information, [read the Colorado Election Fact Sheet on Post-Election Audits Overview \(PDF\)](#).

Q2. What is the risk-limit?

A2. The risk-limit tells us the probability that the audit would correct a wrong outcome. For example, an audit with a 5% risk-limit means that if an election has the incorrect reported outcome, on average 95 times out of 100 the audit would catch that incorrect outcome and correct it. If the reported outcome of the election is correct, then the audit offers a very strong level of evidence of that outcome.

Colorado began RLAs with a 9% risk-limit in comparison audits, and has reduced that number to 3% as counties got more comfortable performing the audit.

Technical information on the audit can be found on our [risk-limiting audit resources page](#).

Q3. What kind of risk-limiting audits are there?

Discrepancy breakdown (tentative)

186 Discrepancies between interpretations of a vote by the voting system vs auditors

By Type:

- 116 Wrong Ballot
- 44 Audit Board Error
- 16 Adjudication Error
- 6 Voting System Limitation
- 3 Voter Mistake
- 1 Ambiguous Voter Intent

The most common voting system error is during adjudication

Very rare to see errors in automated mark detection or reporting

Public data from Audit Center

CVR to audit board interpretation comparison (CSV)

1	county_	contest_name	imprinted_id	choice_per_voting_computer	audit_board_selection	timestamp
2	Adams	Adams County Assessor	101-110-55	"Hieu Truong Nguyen"	"Hieu Truong Nguyen"	2022-11-19 10:52:35
3	Adams	Adams County Assessor	101-128-3	"Hieu Truong Nguyen"	"Hieu Truong Nguyen"	2022-11-19 11:08:52
4	Adams	Adams County Assessor	101-130-61	"Hieu Truong Nguyen"	"Hieu Truong Nguyen"	2022-11-19 11:10:36
5	Adams	Adams County Assessor	101-16-52	"Ken Musso"	"Ken Musso"	2022-11-19 10:34:03
6	Adams	Adams County Assessor	101-176-13	"Hieu Truong Nguyen"	"Hieu Truong Nguyen"	2022-11-19 11:20:22
7	Adams	Adams County Assessor	101-210-39	"Ken Musso"	"Ken Musso"	2022-11-19 11:22:10
8	Adams	Adams County Assessor	101-241-5	"Ken Musso"	"Ken Musso"	2022-11-19 11:30:00
9	Adams	Adams County Assessor	101-246-16	"Ken Musso"	"Ken Musso"	2022-11-19 11:33:15
10	Adams	Adams County Assessor	101-270-38	"Ken Musso"	"Ken Musso"	2022-11-19 11:40:24
11	Adams	Adams County Assessor	101-333-63	"Hieu Truong Nguyen"	"Hieu Truong Nguyen"	2022-11-19 12:28:47
12	Adams	Adams County Assessor	101-335-75	"Hieu Truong Nguyen"	"Hieu Truong Nguyen"	2022-11-19 12:30:38
13	Adams	Adams County Assessor	101-355-16	"Ken Musso"	"Ken Musso"	2022-11-19 12:33:04
14	Adams	Adams County Assessor	101-43-37	"Hieu Truong Nguyen"	"Hieu Truong Nguyen"	2022-11-19 10:36:49
15	Adams	Adams County Assessor	101-444-65	"Ken Musso"	"Ken Musso"	2022-11-19 12:41:48
16	Adams	Adams County Assessor	101-460-62	"Ken Musso"	"Ken Musso"	2022-11-19 12:47:01
17	Adams	Adams County Assessor	101-487-80			2022-11-19 12:48:42

Note unique ID for ballot card (County name, imprinted_id)

Note audit board entry timestamps

233223 lines of data, one per vote comparison

Improve presentation of results

We truly surface a gold mine of data to provide confidence and help improve processes

Need better analysis, presentation of it, engagement with it

CO doesn't emphasize benefits of covering more contests

Open source `rla_report` demonstration code in progress to precisely explain and implement oversight steps.

We should look for help from US Digital Response (USDR)

What improvements does Colorado's risk-limiting audit need?

Needs more transparency:

- Publish manifests (easy) and cast-vote records (tricky) before random selection

Needs better contest selection:

- Currently at discretion of SoS (partisan office)
- Typically picking just 1 statewide, and one local contest per county
- Should guarantee a risk limit (even if large) for all contests
 - or at least all those that wouldn't take more work than currently

Targeted audits

- Report data, analyze via e.g. Stephanie Singer's Election Data Analysis tool or the like
- Anonymize CVRs and images up-front (redistricting, etc)
- Release CVRs before audit starts, including mark density data
 - (Note that VBM already undercuts most Australian Ballot protections)
- Also release ballot images online
- Encourage candidates, public to identify ballots to target interesting ballots for auditing
 - In addition to full random selection audit

Discrepancy reporting

Commendable effort to identify likely root cause for each discrepancy

Typically identified as an auditor error

But ends up promoting the notion that we trust computers, not people

Instead, we should welcome a small number of discrepancies

We should take pride in looking hard enough to find room for improvement

Remember, elections are surprisingly hard!

Discrepancy Investigations

- Should probably inform Audit Board of each discrepancy right after entry. That would help investigation, quality control feedback, and trust in the process.
- Poorvi Vora and Neal have a draft document on how to investigate discrepancies, preserving integrity, efficiency, flexibility
- More data would be invaluable in fine tuning the process

Further options for improvement 1

Stop auditing locally by making up county-level outcomes in statewide contests

Sometimes results in auditing the wrong outcome, e.g. 2022 Republican Primary for Senate, audited the local results in 16 counties, some of which had the opposite "outcome" from the statewide outcome

Need a better determination of how much to audit

Establish reasonable minimum ballot count to audit when there are close contests that were skipped as drivers for the audit

Detailed example of backwards escalation

In perhaps 16 counties, where they chose to audit the (meaningless) local margin in the Republican US Senate race, discrepancy escalation will be backwards.

In the 2022 Republican US Senate primary, O'Dea was the declared winner vs Hanks. In 16 counties, the local tally was selected for audit. The software dutifully calculates the county-wide margin, and picks a sample size. But in 16 of those counties, Hanks was the local "winner" that the audit is trying to "confirm". If there is a vote reported for O'Dea which the auditors determine was actually for Hanks, the audit software will detect that it "widens" the margin, making it even more likely that Hanks won the county, and it will not expand the audit. But of course those are discrepancies which narrow the statewide margin, and merit expansion.

The software still does of course report the discrepancies, which should be followed up for quality control. And as we continue to note, the handling of discrepancies needs lots of work in general

Further options for improvement 2

- Notice and alert when something odd is seen in unaudited contest
- Allow for discretionary escalation
- Avoid extra rounds via a small amount of oversampling
- Faster, smarter discrepancy investigation

Further options for improvement 3

- Commit to data to be audited before random draw
 - Require more transparency around our audits: cryptographically commit to (and eventually publish) the version of the cast-vote records which will be audited, before the random selection is made
 - Redact by contest if necessary to achieve anonymity, so the tallies remain valid
- Invite the public, or at least many stakeholders, to random draw.
 - Involve public or at least a variety of stakeholders in the random seed selection, prove that it is happening in real time either in person or with a real-time bidirectional stream (with audio; the record of dice roll must not be unclear about provenance and timing; consider access by watchers or public to SOS process

Further options for improvement 4

- Allow public to observe details of audit.
- Publish better summaries of progress, results
- Publish times and locations of all audits in a central location so people know where they can go
- Don't require partisan appointment as auditor
- When extra rounds are needed, explain why on the AuditCenter
- Track down confident root causes for discrepancies before certification, and escalate where indicated. Reverse pernicious attitude that all problems are auditor mistakes and the audit never finds anything real.
- Allow recording (pictures, audio, video) during RLA, when nothing should be identifiable.
 - If anything might be identifiable, mark it as a discrepancy. That will require a bit more auditing, but gives more incentive to take the known steps to mitigate that problem
- Audit barcode-to-human readable content
- Check ballot against the ballot image also

Further options for improvement 5

- Provide counties with list of samples that allow them to audit beyond the requirement, possibly according to an intentionally stricter risk limit or additional choices of targeted contests
- Use Title One audit requirement to drive public access to election evidence. Stop relying upon CORA
- Publish CVRs and images from LAT to help observers prepare for audit, learn about styles, etc.
- Publish VRDB (SCORE) files that provide counts of voters by style for upcoming elections to predict any need for redaction to reduce rare styles
- Publish complete CVRs, redacting ALL voter intent, to allow counts of clarifying styles by batch etc.

Further options for improvement 6

- Update Audit Center in a timely manner to facilitate observation; annotate Audit Center to provide simple understandable indication of status
- Publish real time control panel data to facilitate observation; publish schedules for audit process in advance
- Clarify that the audit process is public; allow documentation (including video/audio) to be produced by public, allow watchers to act as public at a public meeting
- Publish images of ballots which were [1 sampled] or [2 found discrepant]

Further options for improvement 7

- Different risk limits for statewide vs CD vs county-wide vs local? {Rule}
- Establish a practical means to handle larger workload audits - financing? special team of auditors? out of county auditors?

Background information

- Overview and History (updated):
 - [The Colorado Risk-Limiting Audit Project \(CORLA\)](#)

Slides: <http://bcn.boulder.co.us/~neal/elections/corla-evn2023/>

Questions?

No time to cover the rest...

Public engagement in verification

- Promote public participation in audit
- Print ballot tracking pages with QR codes
- App to photograph ballot + QR code
- Assist public tweets like "I verified this vote"

Summary

- Colorado provides a gold mine of helpful data
- The process is degrading - less transparency
- Why?
 - COVID made it more challenging to allow in-person oversight
 - Change of leadership
 - Overreaction to baseless political attacks
 - Complacency
- Audits are generally less convincing elsewhere - far less detail, far less transparency
- We need to get to a place where we can
 - Be clear about pride in our work and lack of evidence of major issues,
 - and also be open about needing more auditing for truly evidence-based elections

Remaining Challenges 1

- Since RLAs are defined as auditing against voter-verifiable paper ballots, we should treat electronic-only UOCAVA ballots as non-voter-verifiable, and thus as votes for the losers.
- Foster collaboration between clerks and privacy experts around preserving anonymity, especially for complicated situation with special district boundaries in Colorado
- Some computer systems relevant to elections (e.g. voter registration, signature verification, envelope sorters) are on the Internet or intranets. Continue to address / mitigate those, institute audits.

Evidence presented and checked

- Detailed **Public RLA Oversight Protocol**, Stephanie Singer, Neal McBurnett 2017
- Elements:
 - 1 Chain of Custody
 - 2 Tabulation
 - 3 Manifest
 - 4 Commitment
 - 5 Random selection
 - 6 Ballot card retrieval
 - 7 Ballot Interpretation and data entry
 - 8 Ending the random selection and examination of ballots cards
 - 9 Hand Count
 - 10 Audit Conclusions Affect Outcomes

Convincing Officials of Election Outcomes

- ColoradoRLA includes `rla_export` tool to provide necessary data for Oversight Protocol in csv/json formats
- Open source `rla_report` demonstration code in progress to precisely explain and implement oversight steps.
- Verifiers should of course implement or vet their own processes, code, etc.
- Level 1: Election Administrators
 - Colorado 2017: The counties and state, based on their knowledge of the CVRs etc, dramatically limited the risk of an incorrect tabulation outcome in at least some contests

Far more than most states can say, very efficient!

Convincing Others of Election Outcomes

- Levels 2 and 3: Losers and the Public
 - Much more transparency than in the past
 - Still several crucial holes left in oversight protocol
 - Much summary data not available yet
 - Wrestling with anonymity issues => no CVRs
 - Can't check totals, interpretations, etc.
 - No complaints: amazing ongoing accomplishments by state and counties under very challenging circumstances!
 - More to come!

Principles and Best Practices for Post-Election Audits