

# Risk-Limiting Audits (RLA)



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# Overview of the Journey

- Post-Election Audits are Important
- Evidence-Based Elections and BMDs
- RLA vs other kinds of Audits
- Data Format Standards
- How RLA Works in CO – The Basics
- Status of RLA Process in Colorado and Beyond
- Using RLA with Alternative Voting Methods
- Web Resources

# Why Audits are Important

- Ensure that votes are counted accurately and securely, while protecting voter privacy. Want to **confirm** election **outcomes** and **correct** errors.
- Machine interpretation is recorded in a Cast Vote Record, but machines can fail and also might misinterpret ballots marked by humans.
- Routine audit in Palm Beach County, FL in 2012 revealed two city council contests were certified with the wrong outcomes. See also RI, PA, etc.

# Evidence-Based Elections

- We can't certify the accuracy of computer-based voting systems
- We must audit and certify each contest in each election => **Evidence-Based Elections**
- **Risk-Limiting Audits (RLAs)** check the **tabulation** of a set of voter-verifiable paper ballots
- RLAs should be used in conjunction with other audits (**ballot reconciliation, signature verification, chain-of-custody**, etc.) to support Evidence-Based Elections

# Auditable Voting Systems

- Top priority is having **voter-verified paper ballots**
- Traditional **Hand-Marked Paper Ballots (HMPB)** are in best conditions already verified
- Ballot Marking Devices (BMD)** were introduced for accessibility, hard to get voters to verify paper
- The easiest tabulation method to audit is **central count** of HMPB (e.g. Colorado)
  - Possible to check the match of each anonymous ballot with a corresponding Cast Vote Record
- More common are **precinct-count** which require much more auditing

# BMDs and Voter Verification

- Ballot Marking Devices (BMDs) produce paper ballots that voters often don't actually look at or verify.
- Vulnerable to presentation attacks, printing a ballot which doesn't match what was shown on screen
- The less voters verify, and the more ballots are cast via BMD, the weaker the overall evidence and the more the actual outcomes remain vulnerable to hacking
- Stationing an election worker in front of each scanner, encouraging voters to look at and verify their paper ballot, is one way to increase verification rates
- => **Minimize BMD use, or innovate on verification**

# Kinds of Tabulation Audits

- Fixed Percentage – Example: 2% of precincts
- Fixed Size – Example: 1,000 ballots
- Tiered Samples
  - depending on reported margin of victory
- Risk-Limiting Audits
- End-to-end open audits via ElectionGuard.  
cf. STAR-Vote, Scantegrity



# Why Risk-Limiting Audits are Better

- We want vote counts to be at least accurate enough to produce a corrected outcome
- Traditional tabulation audits usually either
  - require more work than necessary to confirm an outcome, or
  - yield too little information to be conclusive.
  - An RLA uses statistics to check voted ballots until it has strong evidence that election outcome is correct according to the evidence provided to them. Then the audit can stop. Efficient!





# Definitions:

## Types of Risk-Limiting Audits

- **Ballot comparison** – audit individual ballots
  - Verify that the Cast Vote Record (ballot specific machine interpretation) is correct
- **Batch Comparison** – audit entire batches or precincts (less efficient and less informative)
- **Ballot Polling** – random sample of ballots if auditable counts aren't available. Less efficient by factor of  $1/\text{margin}$

# Challenges

Why is it taking so long to adopt robust audits?

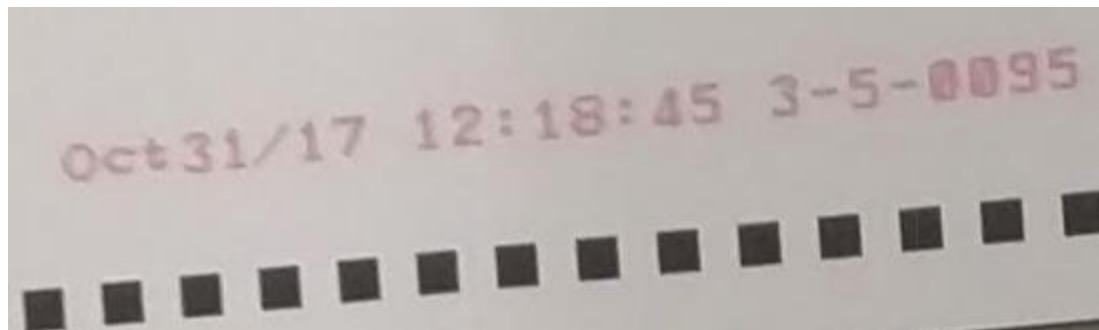
- Elections are increasingly complicated
- You can't easily audit the data you've got
- You can't easily get the data you need
- *Critical Common Data Standards* work by Election Assistance Commission (EAC) / NIST

Source: <http://bcn.boulder.co.us/~neal/elections/rla-nasem.pdf>



# Ballot Identification

**Imprinted ID** showing a ballot was scanned on October 31<sup>st</sup> at 12:18:45 and positively identified as ballot card “**3-5-0095**”:  
scanner 3, batch 5, 95<sup>th</sup> card



# Data Format Standards: Critical!

## You can't easily audit the data you've got

- Need to look thru all 200,000 ballots to find the ones you selected
- Different formats, often undocumented or "proprietary", previously from 4 different vendors in CO

## You can't easily get the data you need

- Generate a full report for each batch, may need to calculate batch totals from differences
- Implemented in Boulder, starting in 2008 election
- Big step forward with first open source code (ElectionAudits) and Boulder County Clerk Hillary Hall and her amazing team who made it their own in following years (Excel etc)

Source: <http://bcn.boulder.co.us/~neal/elections/rla-nasem.pdf>

# Common Data Formats

- We need format standards! OASIS. IEEE. EAC/NIST
  - John Wack: Overview of VVSG-Interoperability Common Data Formats (two presentations)
- Election Results CDF V1 published as SP 1500-100.
  - Used in OH, NC, LA County, other states in progress.
- V2 synchronizes with Google/VIP 5.1, adds JSON.
- Election Log Export CDF soon published as SP 1500-101.
- Voter Records Interchange CDF slated for review by VR vendors and then published as SP 1500-102.
  - Initial use in OH and by OSET.
- Cast Vote Records CDF schema approved by WG, to be published as SP 1500-103.
- Continued development and documentation of election process business models and voting method descriptions.

Source: <http://bcn.boulder.co.us/~neal/elections/rla-nasem.pdf>

# 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 ballot cards

- 9 Hand Count

- 10 Audit Conclusions Affect Outcomes

See <http://bcn.boulder.co.us/~neal/elections/PublicRLAOversightProtocol.pdf>

# Public engagement in verification

- Promote public participation in audit
  - e.g. attend dice roll and manual interpretation
  - Access to scanned images and CVRs
- Print ballot tracking pages with QR codes
- App to photograph ballot + QR code
- Assist public tweets like "I verified this vote"



# Example of a misinterpretation

## Early Summary

- In audits of "driving" contests: 20 possible discrepancies out of 3015 audited ballot sheets
- Of 4 investigated discrepancies, 3 seem like entry errors.  
Note entry is blind, and no feedback is given at the time.  
4th was inconsequential: a vote that shouldn't be counted for sole candidate in contest



# Definitions:

## Risk-Limiting Audit Theory

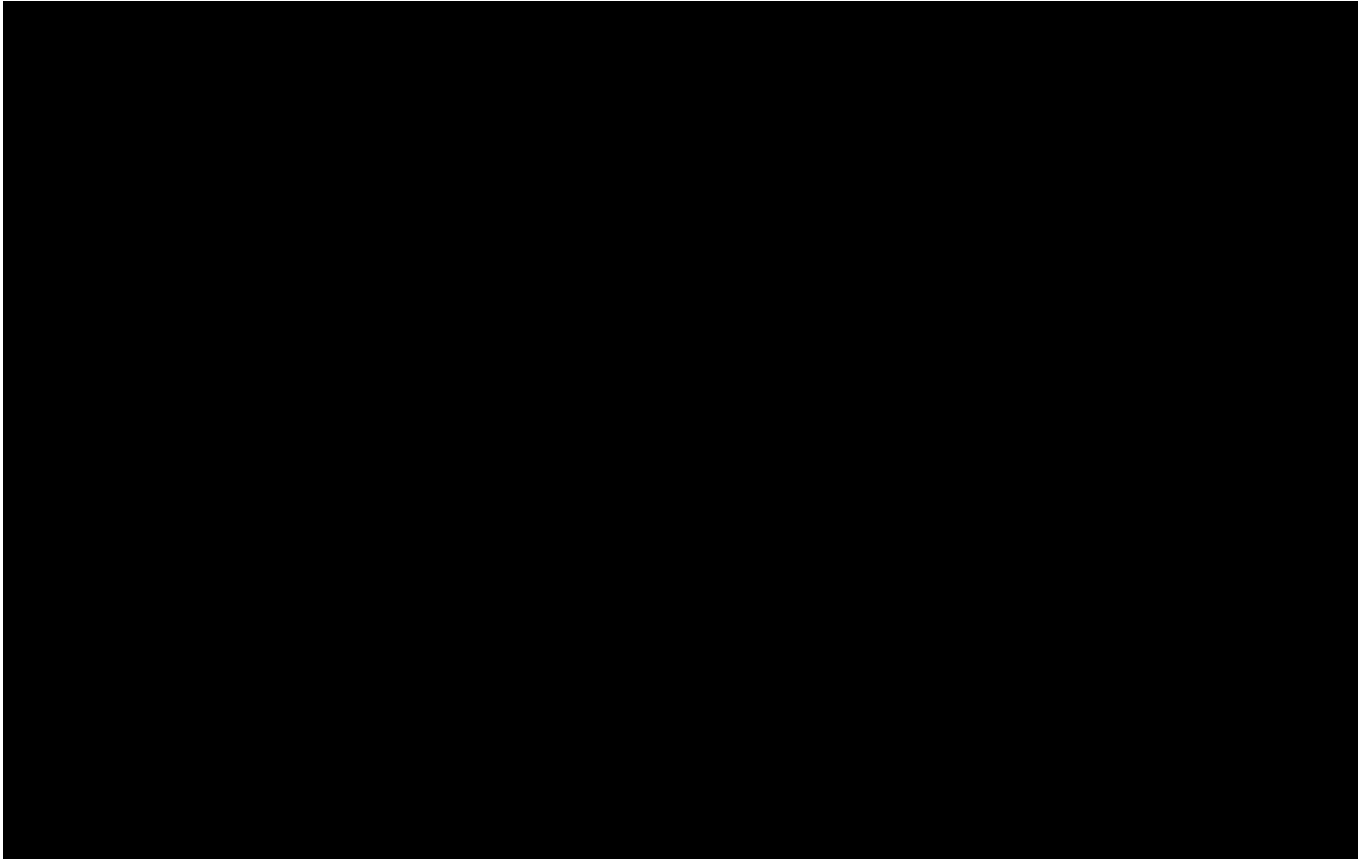
- **Risk Limit** – largest statistical probability that an incorrect reported tabulation outcome is not detected and corrected in a risk-limiting audit. Worst-case scenario! E.g. 5%, 20%
- **Diluted Margin** – the smallest margin (in any contest) as a fraction of all the ballots subject to the audit
- **Vote Overstatement** (narrows the margin) and **Vote Understatement** (increases the margin)
  - Based on pairwise margins in a contest
  - Over or under by 1 or 2

# Definitions:

## Logistics

- **Publicly Verifiable Random Seed** – a starting point for randomly selecting ballots to audit
  - A 20-digit number, e.g. 84437724778708423271
  - 20 stakeholders each roll a 10-sided die.
  - Put the 20-digit number into a public pseudo-random number generator to determine which ballots to audit from a prepared ballot manifest

# Public Meeting to Establish the Random Seed – Nov 9, 2017



Video: <https://youtu.be/SU8kYvsQCC0>

# Definitions:

## Logistics (continued)

- **Ballot Manifest** – a list detailing where each ballot is located

# Ballot Manifest (Excerpt)

## Boulder County

County	Device ID	Batch	# of Ballot	Location
BOULDER	1	1	146	1
BOULDER	1	2	142	1
BOULDER	1	3	147	1
BOULDER	1	4	140	1
BOULDER	1	5	142	1
BOULDER	1	6	139	1
BOULDER	1	7	147	1
BOULDER	1	8	147	1
BOULDER	1	9	133	11
BOULDER	1	10	141	11
BOULDER	1	11	144	11
BOULDER	1	12	146	11
BOULDER	1	13	146	11
BOULDER	1	14	144	11
BOULDER	1	15	149	11
BOULDER	1	16	145	11
BOULDER	1	17	150	21
BOULDER	1	18	149	21
BOULDER	1	19	119	21

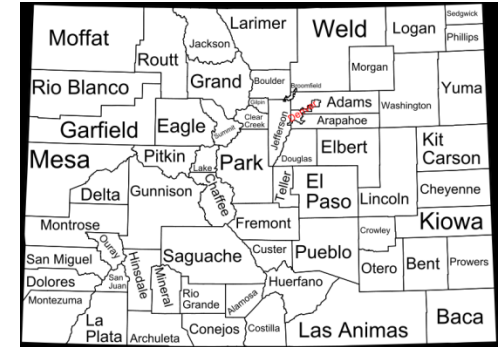
# Definitions:

## Logistics(continued)

- **Ballot Cards** – individual pieces of paper that together constitute a single ballot containing all of the contests an elector is eligible to vote

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# How RLA Works in CO – The Basics



- Breakdown in 2019:
  - 62 counties: Ballot Comparison
  - 2 counties: Hand Count Ballots
- Targeted only 1 contest per county, 1 statewide
- Others could be audited “opportunistically”.



# Status of RLA in CO:

## Successes

- Efficiently-auditable tabulation
- All contests subject to audit (but not reviewed)
- Open Source Software developed for ballot-level RLAs
- Publicly verifiable random selection
- Officials could check risk measurements

# Status of RLA in CO:

## Remaining work

- End SOS (especially as a candidate) from responsibility to choose audited contests
- Target the most interesting, closest contests, to a larger risk limit if necessary, and target all remaining contests with a reasonable estimated workload
- Share results for opportunistic audits. Allow public RLA oversight (publish CVRs, `rla_export` data, images)
  - Requires addressing anonymity issues better
- Handle non-voter-verifiable ballots properly (e.g., received by email)

# RLAs in Other States

- Auditing more challenging in most states: in-person scanners require randomization of CVRs => can't match with paper ballots
- Require **Batch Comparison** or **Ballot-Polling audits**
- New **Arlo** software, in Python
- *Aurror* math for more efficient Ballot-Polling audits from Professor Poorvi Vora and team

# RLA Laws, Pilots Spreading

- RLAs now required by law in CO, RI, NM, CA (for some equipment)
- Pilots done in IN, VA, MI, NJ, RI, VA, PA, OH, GA and more

# Using RLA with IRV or STV

- In instant-runoff voting (IRV) or single transferable vote (STV), even determining the margin (minimum number of changed ballots that could lead to different outcome) is tricky!
- Groundbreaking 2019 IRV audit, San Francisco
- Bayes audits are more flexible, provide metrics for any voting method, but not always risk limits
- No traditional frequentist approach is available for STV yet.

# RLA and Single-Winner Voting Methods

- Conventional (easy)
- Approval (easy)
- Score (SHANGRLA)
- STAR Voting (SHANGRLA)
- Cumulative Voting (SHANGRLA)
- Instant-Runoff Voting (SHANGRLA+RAIRE)

# RLA and Multi-Winner Voting Methods

- Conventional tabulation (easy)
- D'Hondt and related Proportional Representation (SHANGRLA)
- Sequential Proportional Approval Voting (Bayes)
- Score (SHANGRLA)
- Single Transferable Vote (STV) (Bayes)
- STV with reduced runoff (Bayes)

# Auditable Voting Systems

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# Website Resources (1 of 2 pages)

- CO Risk-Limiting Audit Project (CORLA):

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

- CO Secretary of State Audit Center:

<http://www.sos.state.co.us/pubs/elections/auditCenter.html>

- A Gentle Introduction to Risk-Limiting Audits*

<https://www.stat.berkeley.edu/~stark/Preprints/gentle12.pdf>

# Website Resources (2 of 2 pages)

- Software for auditing:

<https://github.com/ron-rivest/ElectionAuditWareRepo>

- Harvie Branscomb's Election Quality

website: <http://electionquality.com/>

- This presentation:

<http://bcn.boulder.co.us/~neal/talks/rla2019.pdf>