# Colorado's
# Risk-Limiting Audits (RLA)



# Our Journey

Presentation to the LWVBC Voting Methods Team, February 2018

# Overview of the Journey

- Post-Election Audits are Important
- Kinds of Audits
- Why RLA is better and Challenges
- Data Format Standards
- Definitions
- How RLA Works in CO – The Basics
- Status of RLA Process in Colorado and Beyond
- Using RLA with Non-Plurality Voting Methods
- Website 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 misinterpret ballots, and humans mismark ballots.
•Routine audit in Palm Beach County, FL in 2012 revealed two city council contests were certified with the wrong outcomes.

# Kinds of 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 – Examples: STAR-Vote, Scantegrity

# Why Risk-Limiting Audits are Better

- We want vote counts to be at least accurate enough to correctly determine the outcome
- Traditional audits usually either
  - require more work than necessary to confirm an outcome
  - yield too little information to be conclusive.
- An RLA uses statistics to check enough voted ballots to get strong evidence that election outcome is correct.  Once the strong evidence is found, the audit can stop.  Efficient!

STOP

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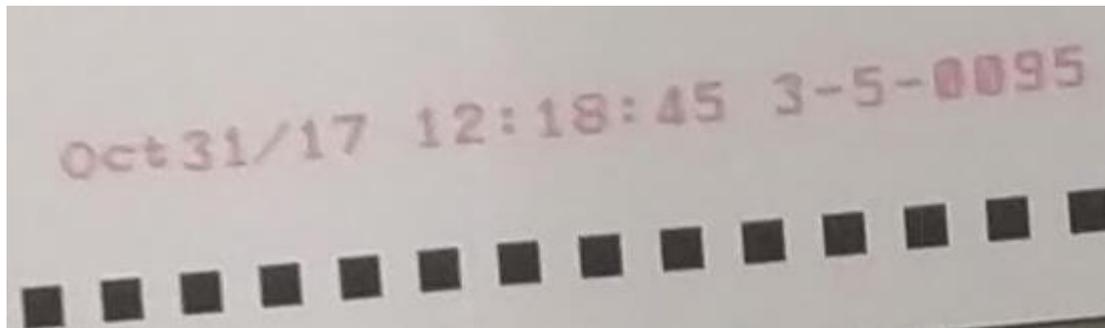
Source: http://bcn.boulder.co.us/~neal/elections/rla-nasem.pdf

# A Ballot Selected for Audit

## A Ballot and Its Tracking Sheet
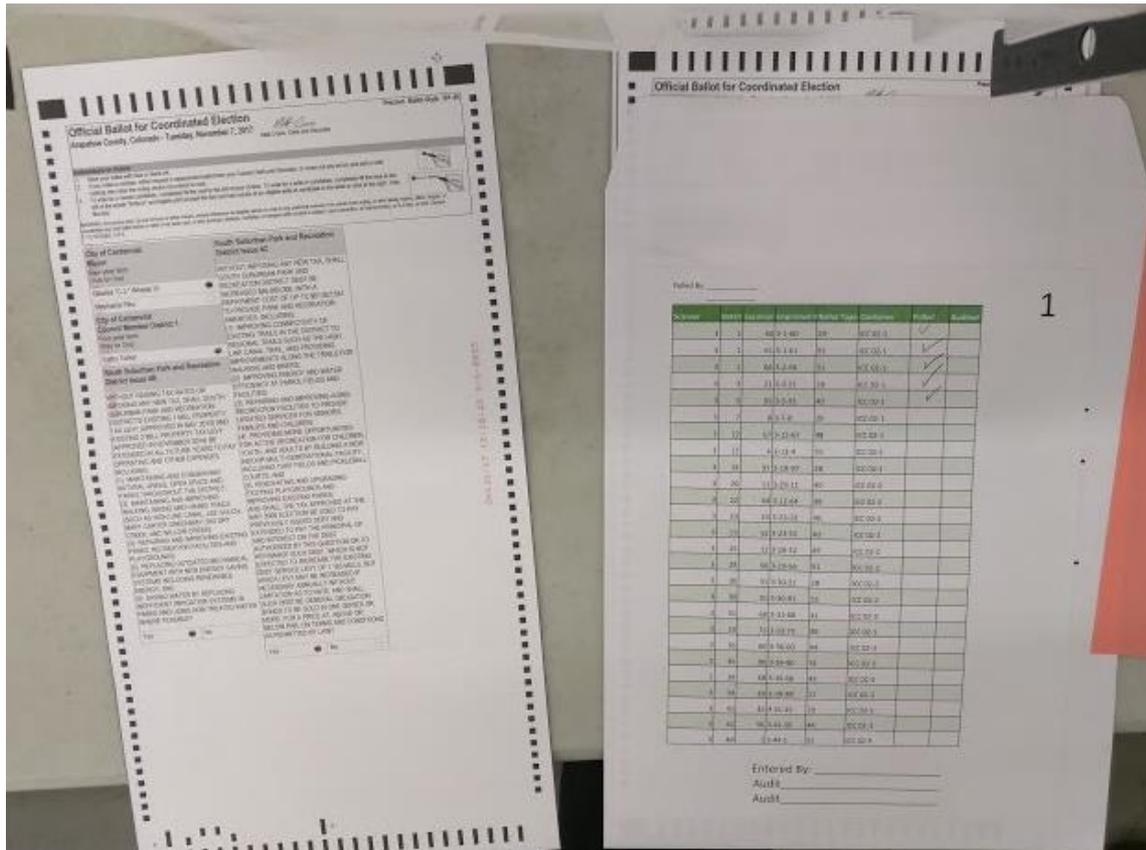
# Ballot Identification

**Imprinted ID** showing a ballot was scanned on October 31$^{st}$ at 12:18:45 and positively identified as ballot card "**3-5-0095**" –
    the 95$^{th}$ card of batch 5, scanner 3

# 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", from 4 different vendors in CO

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

- Generate a full report for each batch, 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 ballots cards
9 Hand Count
10 Audit Conclusions Affect Outcomes

See http://bcn.boulder.co.us/~neal/elections/PublicRLAOversightProtocol.pdf
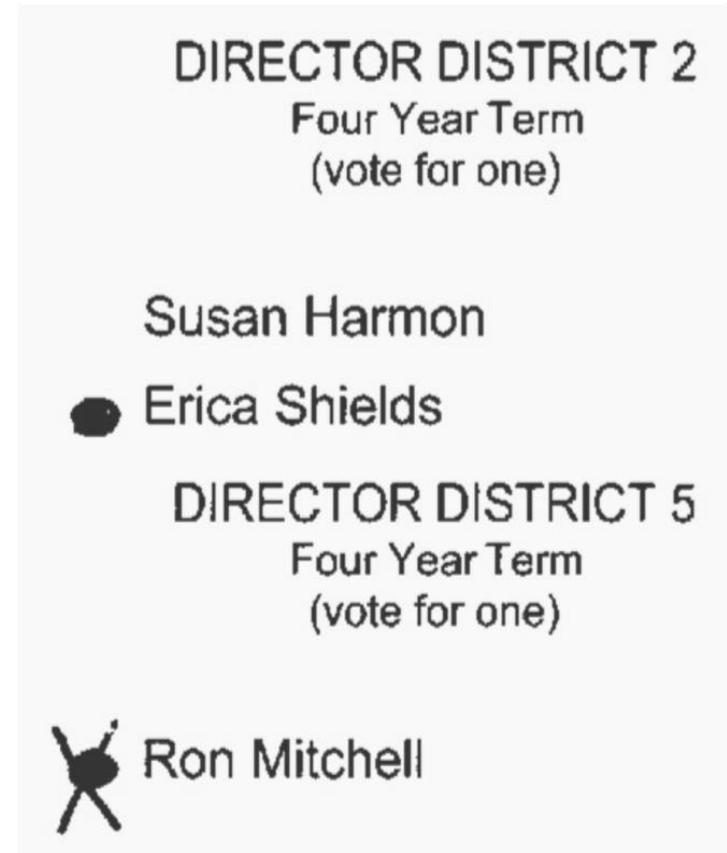
# Public engagement in verification

- Promote public participation in audit

- 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 cards

- 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

DIRECTOR DISTRICT 2
Four Year Term
(vote for one)

Susan Harmon

● Erica Shields

DIRECTOR DISTRICT 5
Four Year Term
(vote for one)

Ron Mitchell

# Definitions:
# Types of Risk-Limiting Audits

- **Ballot comparison** – audit individual ballots
  - Verify that the Cast Vote Record (machine interpretation) is correct
- **Batch Comparison** – audit entire batches or precincts (less efficient but required if reporting is inadequate)
- **Ballot Polling** – random sample of ballots if auditable counts aren't available. Less efficient by factor of 1/margin

# 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 0, 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 dice.
- Put the 20-digit number into a public pseudo-random number generator to determine which ballots to audit

# 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
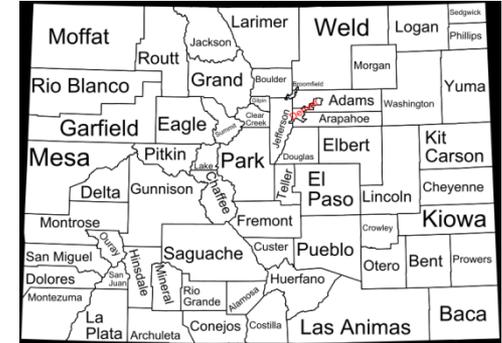
- Breakdown in 2017:
  - 50 counties: Ballot Comparison
  - 6 counties: Ballot Polling (CO Risk Limit = 20%)
  - 2 counties: Hand Count Ballots
  - 6 counties: No Coordinated Election
- Targeted only 1 Contest per county. Others audited "opportunistically".

# Status of RLA in CO: Successes

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

# Status of RLA in CO: Remaining work

- Share results for opportunistic audits. Allow Public RLA Oversight (publish CVRs, `rla_export` data)
    - Requires addressing anonymity issues better
- Develop support for multi-county and sub-county contests
- Handle non-voter-verifiable ballots properly (e.g., received by email)
- Support in-person scanners (most states) which have anonymity issues
- Support Ballot Polling audits

# Status of RLA Process
# in Colorado and Beyond

- Upcoming hearing to review SoS-proposed changes to Rule 25 and public comments for other changes
  - Transparency concerns around ballots and audit reports
  - More auditing, e.g., simultaneous audits
  - Should Sec of State select the statewide and county contests to audit?
- In February CO Sec of State to brag about RLA at National Association of Secretaries of State (NASS) Conference.  If implemented in other states, will they copy CO model?
- 2018 will include a statewide contest – NEW!

# 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 very, very hard.

- Bayes audits (Rivest & Shen) can estimate the risk for any voting method. No traditional frequentist approach is available for most.

# RLA and
# Single-Winner Voting Methods

- Plurality (easy)
- Approval (easy)
- Score (easy??)
- Score Runoff (Bayes)
- Instant-Runoff Voting (Bayes)
- Cumulative Voting (easy?)

# RLA and
# Multi-Winner Voting Methods

- At-Large Plurality (easy)
- Sequential Proportional Approval Voting (Bayes)
- Score (easy?)
- Single Transferable Vote (STV) (Bayes)
- STV with reduced runoff  (Bayes)

# Website Resources (1 of 2 pages)

- CO Risk-Limiting Audit Project (CORLA):
http://bcn.boulder.co.us/~neal/elections/corla/

- *Risk-Limiting Post-Election Audits: Why and How*
https://www.stat.berkeley.edu/~stark/Preprints/RLAwhitepaper12.pdf

- CO Sec 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

- Tools for Comparison Risk-Limiting Election Audits:
https://www.stat.berkeley.edu/~stark/Vote/auditTools.htm

- Harvie Branscomb's Election Quality website:
http://electionquality.com/

- *Next Steps for the Colorado Risk-Limiting Audit (CORLA) Program* (for auditing multi-county contests):
https://arxiv.org/abs/1803.00698