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Knowing It's Right, Part Two

Risk-Limiting Audit Implementation Workbook

by Jennifer Morrell

ABOUT THE AUTHOR

Jennifer Morrell is a nationally recognized election official with over eight years of experience managing local elections. Her work in Colorado was instrumental in the successful implementation of the first statewide risk-limiting audit and she has been an outspoken advocate of implementing election audit standards beyond just post-election audits and has a vision of creating uniform audit and testing standards for all critical components of the voting system. Bringing extensive expertise in election administration, Morrell serves as a consultant leading the Election Validation Project at Democracy Fund.

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ABOUT OUR PHOTOGRAPHS

The photographs used throughout this report are provided courtesy of the author. Some — including the cover of this report — capture real-world examples of risk-limiting audits being performed by election officials from around the country. The use of these photos is intended solely to illustrate how this work is done and should not suggest the subjects' endorsement of the content in this report.

On Cover: Lori Augino, director of elections, Washington Secretary of State; Kim Wyman, secretary of state, Washington; election officials from Snohomish County & King County, WA. Observing the process of conducting a ballot-level comparison audit as part of Snohomish County, WA pilot RLA.

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Introduction and Overview

This Implementation Workbook for Election Administrators is a complementary piece to **Part One: A Practical Guide to Risk-Limiting Audits**. While Part One is an overview of the field of risk-limiting audits, this workbook seeks to provide soup-to-nuts information on how election officials can conduct this type of audit.

The following summarizes what you will find in Part Two:

- Preparing for an audit by forming an advisory group
- RLA concepts and terms to know, including different types of audits
- Voting equipment and technology specifics to help determine the type of audit that can be conducted
- Checklists to prepare for and conduct a ballot-level comparison audit
- Considerations for developing administrative rules to further define the RLA process
- Post-election feedback recommendations to review the RLA process
- Communication opportunities to talk about the RLA with the public and other stakeholders

1 Successful RLAs Require Time and Teamwork

Successfully implementing any new election process requires careful thought and a considerable amount of planning. The steps outlined in this document are not exhaustive but are meant to provide a foundation for states and local jurisdictions building their own policies and procedures for conducting risk-limiting audits.

Take Your Time

Ideally, it is best to use an entire election cycle to establish the basic framework, set the policies and rules, acquire audit software, conduct at least one pilot audit independently, review feedback, and amend election rules as necessary before committing to an official risk-limiting audit.

The segregation of duties is a basic principle of risk management for businesses and is equally important for conducting a valid RLA. Throughout this document, I refer to duties performed by the **state** and duties performed by the **county** (or equivalent local election official). These duties may be assigned to other entities as appropriate (e.g., independent auditor, a local government auditing agency, etc.).

The essential thing is to understand each function of the audit so that roles and responsibilities can be divided and separated.

By design, each state is unique with respect to their election laws, modes of casting a ballot (absentee, early voting, Election Day voting), voting equipment and technology (DREs, central scan, precinct scan, or hybrid), social choice functions (plurality, majority, super-majority, vote-for-n, IRV, STV), and even their voting culture. These variations make creating a one-size-fits-all template for conducting an RLA difficult. States and localities will need to customize some of the outlined steps to fit their laws, processes, and culture.

Form a Working Group

A collaborative advisory group is an important first step for implementing RLAs at any level and essential if the goal is to implement RLAs statewide. This group ensures a variety of perspectives and expertise are included in defining how the audit will function.

The group should include the individuals responsible for administering the audit (state officials or independent auditors), those who are responsible for conducting the election and retrieving and verifying audited ballots (county or local officials), representatives from the voting system vendor, recognized experts in statistics and auditing, and other stakeholders who may add value or provide necessary buy-in.

The goal of the advisory group is for members to become local RLA subject-matter experts, make recommendations for RLA policy and rules, understand the technology requirements, outline the steps for conducting the audit, assist with training and pilot audits, and provide input on public communication plans.

2 Risk-Limiting Audit Concepts and Terms

A good starting point for the advisory group is to become familiar with some of the common terms used in conjunction with RLAs. To ensure that everyone uses the terminology in a consistent manner, it is helpful to discuss the terms as a group; connect them with tangible forms, reports, and outcomes from prior elections; and practice communicating the meaning of the terms. Understanding the basic components of audits can also be helpful, ensuring that the RLA serves its intended purpose and is not just a pointless obligation. *(See also Appendix B, Basic Audit Concepts.)*

RISK-LIMITING AUDIT

An RLA is a post-election tabulation audit in which a random sample of voted ballots is manually examined for evidence that the originally reported outcome of the election is **correct**. If the originally reported outcome is **incorrect,** there is a pre-specified minimum chance that the audit will correct the result. It corrects the result by performing a full manual tally. As its name suggests, an RLA limits the risk of certifying a contest with the wrong winner.

RISK LIMIT

The risk limit is the largest chance that an incorrect reported tabulation outcome is not detected and corrected in a risk-limiting audit. For example, a 5 percent risk limit provides at most a 5 percent chance that the audit will not correct the outcome if the outcome is incorrect. In other words, there is at least a 95 percent chance that the audit will discover an error and correct the outcome if the outcome is wrong.

OUTCOME

The outcome means the winner(s), not the tabulated vote totals. A **wrong outcome** is when the originally reported outcome disagrees with what a full hand count would show.

DILUTED MARGIN

The diluted margin is the measure used to determine the closeness of the election, for the purpose of determining how many ballots need to be examined in some risk-limiting audit methods. The diluted margin of the target contest is calculated by dividing the smallest reported margin (in votes) by the total number of ballots cast in the collection of ballots from which the sample is drawn. This measure accounts for the possibility that the vote tabulation system mistook an undervote or overvote for a valid vote or vice versa.

TABLE 1: EXAMPLE OF DILUTED MARGIN

Canddiate A	**2,175**	
Candidate B	**1,766**	
Total Votes Cast	*3,941*	(Candidate A Votes – Candidate B Votes) ÷ Total Ballots Cast
Over-/Undervotes	157	(2,175 – 1,766) ÷ 4,098 = .0998, which is 10%
Total Ballots	*4,098*	**Diluted Margin is 10%**

TARGET CONTEST

A target contest is the contest selected for a risk-limiting audit. The target contest determines the number of ballots that must be examined during the RLA and is used to determine if the audit has met the risk limit. It should not preclude the opportunity to audit other contests on ballots already selected for audit. There can be one or more target contests.

CAST VOTE RECORD

A cast vote record (CVR) is the electronic record of a voter's selections in every contest for a given ballot. This record is generated by the voting system and needs to provide enough information to pair the cast vote record with the physical ballot from which it was created. The CVR is the digital representation of each individual ballot that has been scanned and tabulated. It represents the votes cast in each contest after adjudication for voter intent or any other tabulation rules have been applied, e.g., write-in candidates. (*See also Voting Equipment & Technology section for more information*.)

BALLOT-LEVEL COMPARISON AUDIT

A ballot-level comparison audit is a type of RLA in which individual paper ballots are randomly selected, the voter markings are examined and interpreted manually, and the human interpretation of voter intent is compared to the voting system's interpretation of the same ballot, as reflected in the corresponding cast vote records. This type of RLA requires the voting system to create and export individual CVRs in a way that the corresponding physical ballot can be identified and retrieved for manual inspection and vice versa. Methods to link CVRs to the corresponding piece of paper generally rely either on the order in which the ballots were scanned or on imprinting ballots with identifiers after they have been separated from the voter (to preserve anonymity).

Currently, central-count optical scan systems make this easier than precinct-count systems do, because the ballots have already been separated from the voters' identities before the scan occurs. However, most currently fielded voting systems in the United States cannot export CVRs in a way that links them to the corresponding paper ballot. Some do not even create CVRs internally. (*See also transitive audit.)*

BALLOT-POLLING AUDIT

A ballot-polling audit is a type of RLA in which individual paper ballots are randomly selected, the voter markings are examined and interpreted manually. If a large enough sample shows a large enough majority for the reported winner, the audit stops. This type of RLA cannot identify whether a specific ballot was mistabulated, but it can provide convincing evidence about whether the reported outcome is correct. A ballot-polling audit does not require a CVR or other data export from the voting system, nor does it involve comparing human interpretation of voter intent to the machine interpretation of voter intent. It is an RLA method that can be used with any voting system that produces voter-verifiable paper records.

While the set-up costs and equipment requirements for ballot-polling audits are less than those for ballot-level comparison audits, ballot-polling audits generally require manually inspecting more ballots (when the outcome is correct). Ballot polling is a good option when ballots are scanned in polling locations or when the voting system cannot report how it interpreted individual ballots — the situation with most voting systems currently deployed in the United States.

BATCH-LEVEL COMPARISON AUDIT

A batch-level comparison audit is a type of RLA that most resembles a "traditional" audit. In a batch-level comparison audit, the voting system must export subtotals for identifiable physical batches of ballots, such as all ballots cast in a precinct or all mail ballots scanned together as a batch by a particular machine. The auditors add up those batch-level results to verify that they produce the reported contest outcomes. If so, some physical batches are selected at random. The votes in each selected batch are examined manually and tabulated, and the audit counts are compared to the voting system's reported subtotals. Depending on the number and type of discrepancies the audit finds in the sample, the audit either stops or examines more batches manually.

This type of RLA does check the tabulation, whereas ballot-polling audits only check the outcome. Like ballot-polling audits, batch-level comparison audits generally require manually inspecting more ballots (when the outcome is correct) than ballot-level comparison audits do.

TRANSITIVE AUDIT (AKA MACHINE-ASSISTED AUDIT)

A transitive audit involves auditing a voting system that is not the voting system of record but is a more feasible option for conducting an RLA. If the two systems agree, and the audit confirms that the unofficial voting system found the correct winner(s), the official voting system must also have found the correct winners.

Transitive audits can make it possible to conduct ballot-level comparison audits even if the voting system of record does not generate CVRs or cannot export CVRs in a way that can be linked to the corresponding ballot cards. This involves rescanning the collection of ballots to be audited and processing the scans with software that can create and export individual CVRs, allowing a ballot-level comparison audit to be conducted. After rescanning the ballots and processing the images to get CVRs, auditors confirm that the exported CVRs reproduce the results reported by the official voting system. If so, the auditors can then check the accuracy of those unofficial CVRs using the ballot-level comparison method.Transitive audits do not confirm the accuracy of the voting system of record, but they do confirm whether the winner(s) reported by the official system are the true winners.

STRATIFIED SAMPLE

A stratified sample first separates ballots into different groups (strata) and then samples from the groups separately. Stratified sampling can be useful for RLAs in many situations. For instance, if jurisdictions draw their own samples of ballots, that is a stratified sample from the state.

Stratification can be helpful to allow samples to be selected separately from mail ballots versus ballots cast in person, or from ballots tabulated as of election night separately from late-arriving mail ballots and provisionally cast ballots. Stratification can also help deal with multiple configurations of voting equipment — for instance, when some ballots cast in a contest are tabulated using equipment that supports a ballot-level comparison audit, but other ballots are not.

When samples are stratified, the audit will usually require examining more ballots than if sampling is not stratified, all else being equal. However, stratification can substantially simplify logistics by allowing jurisdictions to do most of their work independently. Similarly, if the sample can be concentrated on just those ballots that contain the contest under audit, the sample size

will be smaller than if the sample is drawn from a larger collection of ballots, only some of which contain the contest.[1] Stratification is usually only recommended when it is necessary to combine results from election jurisdictions with different tabulation methods.

SAMPLE WITH/WITHOUT REPLACEMENT

Sampling may be conducted with or without replacement. In sampling **with** replacement, once a ballot has been chosen for examination and its information recorded, it is returned to the collection of ballots and is eligible to be sampled again (if it is selected again, it does not need to be *inspected* again, but its data might enter the risk calculation again). In sampling **without** replacement, a ballot is not eligible to be selected more than once.

In general, sampling without replacement is more efficient, but only slightly so unless the audit ends up looking at a substantial percentage of the ballots cast on the contest. The risk calculations for sampling with replacement are simpler (although those calculations are generally performed by software, regardless of how the sample is drawn).

SAMPLE SIZE/WORKLOAD

The sample size or workload is the number of ballots required to be inspected before the audit can stop. The sample size depends on many things. For ballot-level comparison audits, the total sample size depends on the diluted margin of the contest being audited, the risk limit that has been established for the audit, the sampling scheme, and the discrepancies the audit uncovers as it progresses.

For ballot-polling audits, the workload depends on the true vote shares of each candidate, on the number of ballots that do not contain a valid vote for any candidate in the contest, and on the sampling scheme.

The table below provides an example of how many ballots would need to be retrieved and examined to audit a first-past-the-post contest with two candidates in which every ballot has a valid vote for some candidate. (This makes the diluted margin equal to the margin for illustration.) Notice that the workload for a ballot-polling audit is considerably higher.

The workload will be affected by other factors, as well. Among them are whether the sampling is stratified and whether it is possible to confine the sampling to ballot cards that contain the target contest.

Appendix A has links to workload calculation tools for ballot-polling and ballot-level comparison audits. It is helpful to have the advisory group use the tools to determine the initial sample size from previous election contests.

TABLE 2: EXAMPLES OF NECESSARY SAMPLE SIZES

NUMBER OF BALLOTS TO AUDIT *(TOTAL BALLOTS CAST: 2,422,072)*						
	1% Risk Limit		**5% Risk Limit**		**10% Risk Limit**	
Diluted Margin	Ballot-Level Comparison	Ballot Polling	Ballot-Level Comparison	Ballot Polling	Ballot-Level Comparison	Ballot Polling
8%	92	758	62	497	49	384

BALLOT MANIFEST

A record that documents where and how physical ballots are stored, a ballot manifest is critical for conducting any type of RLA. It is unique to the jurisdiction conducting the audit based on how ballots are organized, scanned, and stored. The information in the manifest should never come from the voting system. It should be created and maintained by the local election official. (*See Voting Equipment & Technology section for more information and examples.*)

RANDOM SAMPLING

RLAs rely on random sampling to ensure all ballots have a known chance of being selected for audit. Taking a step further, the random selection should be done in a way that eliminates the possibility of someone gaming the system by knowing which ballots will be selected for the audit. This is accomplished by generating a random seed to be used in conjunction with a pseudorandom number generator (PRNG) and a rule for determining which ballots to select depending on the numbers the PRNG generates. (*See Appendix C for explanation of how PRNG output is turned into a list of ballots to inspect.*)

A random seed is a sequence of numbers used to begin the process of generating the pseudorandom numbers that will guide the sampling. Several methods can be used to create the random seed, but two key features are important to follow: having a physical source of randomness and inputs from multiple parties.[2]

The random seed should only be generated after the CVR and ballot manifest have been committed for the audit, along with the method for turning the PRNG output into a list of ballots to inspect.[3] A practical way to generate the numbers is through a public ceremony where dice are rolled. The parties invited to the ceremony could include election officials, candidates, political parties, citizens, and other stakeholders.

There is not a prerequisite number for the length of the random seed, meaning the number of dice rolls, but it should be long enough to be unpredictable (more is better). If someone could guess the seed you are starting with, they could know which ballots will be selected for the audit. For the RLAs conducted in Colorado, the random seed is generated by "sequential rolls of 20 individual 10-sided dice".[i] Each digit of the random seed should be recorded in the public meeting after each die roll. Once the dice have been rolled, and the sequence of numbers established, the seed can be entered into audit software using a PRNG with a publicly known algorithm.[4] Integrating a PRNG with a state's RLA software is recommended. The 20-digit random seed, using the Colorado example, is then used to randomly generate numbers corresponding to individual ballots listed in the ballot manifest. Anyone with access to the random seed, ballot manifest, and PRNG algorithm can confirm the ballot sample was selected correctly.

Appendix A provides some additional resources to help educate and inform the advisory group.

Performing a pilot ballot polling audit in Essex County, New Jersey. Kevin Kearns, cybersecurity specialist at NJ Office of Homeland Security and Preparedness; Linda von Nessi, clerk of the Essex County Board of Elections; Robert Giles, director of the NJ Division of Elections; and Jennifer Morrell.

i The Colorado Secretary of State posts a notice of the public meeting for the dice rolling and uses the same notice to record the random seed during the dice roll. Available at: https://www.sos.state.co.us/pubs/elections/RLA/files/2018G/20181116PublicNoticeRandomSeed.pdf.

3 Voting Equipment and Technology

Voting equipment plays a major role in determining the type of audit that can be conducted. This section provides more information on the differences in voting technologies and their implications for designing an audit process.

Cast Vote Record

As stated previously, the cast vote record is the digital representation of each individual ballot card that has been scanned and tabulated. One CVR is created per double-sided ballot sheet (page). It represents the votes cast in each contest after adjudication for voter intent or any other tabulation rules have been applied, e.g., write-in candidates.

Ballot-level comparison audits require voting systems to produce and export CVRs in a way that the corresponding paper ballot can be identified and retrieved and that the CVR corresponding to a particular paper ballot can be identified. Not every voting system generates CVRs, and not every voting system that generates CVRs can export them in a way that allows the corresponding individual physical ballot card to be identified and retrieved, which is required for ballot-level comparison audits. In addition to a voter's ballot selections, the cast vote record may include:[ii]

- Information on all contests and contest options on the ballot in addition to those marked.
- The ballot style associated with the CVR.
- The precinct or voting location associated with the CVR.
- The equipment that produced the CVR.
- The political party associated with the ballot for partisan primaries.
- Images of the entire ballot and images of write-in areas on the ballot.
- An identifier that is also printed on the ballot as it is scanned.
- Indications of how the scanner has interpreted various marks.

ii The CVR features listed here are taken from the NIST Cast Vote Records Common Data Format Specification, Version 1.0. It is highly recommended that future voting equipment purchases meet these specifications.

FIGURE 1: EXAMPLE OF CAST VOTE RECORD

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	2017 Arap	5.2.16.1													
2								City of Aur	City of Au	City of Au	City of Au	City of Au	City of Au	City of Au	City of Aurora
3								Brian E. Ar	Dave Grut	Reid Hetti	Allison Hil	Tim Huffn	Abel Laek	Tom Tobia	Russ Wagner
4	CvrNumbe	Tabulator	BatchId	RecordId	Imprinted	PrecinctPort	BallotType								
5															
6	44851	3	97	70	3-97-70	6273803212	41								
7	44852	3	97	71	3-97-71	6284003450	51	0	0	0	1	0	0	1	0
8	44853	3	97	72	3-97-72	6273703332	44								
9	44854	3	97	73	3-97-73	6273803191	40								
10	44855	3	97	74	3-97-74	6273703239	43								
11	44856	3	97	75	3-97-75	6293603546	30	1	0	0	0	1	0	0	0
12	44857	3	97	76	3-97-76	1260303115	11								
13	44858	3	97	77	3-97-77	6263803142	37								
14	44859	3	97	78	3-97-78	6284103427	51	0	1	0	0	0	1	0	0
15	44860	3	97	79	3-97-79	6284103427	51	0	1	0	0	0	1	0	0
16	44861	3	97	80	3-97-80	6273703240	43								
17	44862	3	97	81	3-97-81	6260303204	45								
18	44863	3	97	82	3-97-82	6294203511	29	0	1	0	0	0	1	0	0
19	44864	3	97	83	3-97-83	6264003453	51	0	1	0	0	0	0	1	0
20	44865	3	97	84	3-97-84	6284003450	51	1	0	0	1	0	0	0	0
21	44866	3	97	85	3-97-85	6273703332	44								
22	44867	3	97	86	3-97-86	6263803167	38								

The columns in the example above represent the following:

- Column A: CVR number
- Column B: scanner identifier
- Column C: batch number
- Column D: ballot sequence number
- Column E: number printed on the ballot (at the time of scanning)
- Column F: precinct number
- Column G: ballot style
- Column H: voter's ballot selection for that particular contest; 0 = no vote, 1 = vote

It is important for election officials to understand the role each field in the CVR plays in conducting the RLA. A good starting point is to ask the voting system vendor for a CVR from a prior election or a sample CVR if you are evaluating vendors for the purchase of a new voting system.

Some other things to discuss with your voting system vendor (or proposed vendor):

- Does the voting system create CVRs?
- How does the voting system export a collection of CVRs? Can the files be exported in a .csv format?
- Are CVR definition files available to ensure you understand what each field represents and how it is structured?
- Does the voting system support ballot-level comparison audits? Is there an identifier in the CVR that can be linked to the corresponding paper ballot?
- In addition to a unique ballot identifier for auditing, does the CVR have fields identifying the CVR number, the scanner name or number, batch number, and ballot sequence number?
- What are the differences between CVRs created by central scanners and voter-facing scanners?
- Does the voting system provide an indication of marginal marks and mark quality/density that can be associated with each contest selection?
- Is the CVR number random? Sequential? What is the ordering logic?
- Does the voting equipment support a mechanical imprinter?
    - On high-speed scanners?
    - On precinct scanners?
- How are multi-card ballots supported?

Imprinting

Identifying the exact location of a specific ballot among thousands of others is the biggest challenge in a ballot-level comparison audit. Having a unique identifier on each ballot that can be tied to the CVR in some way helps ensure the correct ballot has been retrieved.[iii]

CENTRALLY SCANNED BALLOTS

Mechanical imprinters are available on certain models of high-speed scanners (used when ballots are centrally scanned). They provide a way to print a unique identifier on each ballot to assist in the retrieval of ballots in a comparison audit.

This imprinted number might reflect the scanner identifier, batch number, and ballot sequence number, as well as the date and time the ballot was scanned. In some voting systems, it is simply the scanner identifier combined with a sequential number.

FIGURE 2: EXAMPLES OF IMPRINT NUMBERS FOR CENTRALLY SCANNED BALLOTS

03-97-70 11/6/2017 15:23

0175000867

Top: Scanner ID-Batch-Ballot Sequence, Date, and Time.
Bottom: Scanner ID and Sequential Number.

The imprinted number is not the same as the CVR number but a separate, unique field in the CVR (when the number is produced and printed by the voting system).

Some things to consider when using an imprinter are the color of ink and testing the print quality and positioning as part of the logic and accuracy testing.

VOTER-FACING SCANNED BALLOTS

Currently there is no voting system on the market that provides a way to imprint a unique number in conjunction with a precinct scanner.

Because ballots scanned in a polling location can be directly tied to a voter, the order of the CVRs are normally not sequential, and the CVR number assigned to each ballot is a random, nonsequential number. This makes retrieving specific ballots difficult if not impossible.

Also, ballots may not remain in an exact order and may potentially fall into the ballot box at random (depending on the voting equipment). In some jurisdictions, the ballots are moved from the container attached to the scanner to a sealed ballot box or bag and transported to the local election office, further mixing the order.

Ballots scanned in a polling location will need to be audited using the ballot-polling method or by conducting a transitive audit.

A possible solution for the problem of conducing a ballot-level comparison audit on ballots scanned in a polling location might look like this:[iv]

- Fitting scanners with mechanical imprinters.
- Printing a nonsequential CVR number, assigned by the voting system, to each ballot sheet.
- Creating a ballot manifest identifying the scanner name, box/bag number, number of ballots in each box, and seal or container ID.
- Randomly selecting ballots from the ballot manifest using the random sampling techniques previously described.
- Determining that the list of ballots to be retrieved indicates each ballot's sequential location within a specific batch.
- Requiring the audit board to count down or use a scale to find the specific ballot (as done in a ballot-polling audit).
- Modifying the audit tool to allow the audit board to input the imprinted CVR number tying the ballot back to the CVR record for a ballot-level comparison audit.

iii Audit discrepancies can come from the audit board retrieving an incorrect ballot.

iv Concerns about voter secrecy remain with this proposed solution.

Ballot Manifest

A log that documents where and how physical ballots are stored, a ballot manifest is critical for conducting any type of risk-limiting audit. It is unique to the jurisdiction conducting the audit, based on how ballots are organized, scanned, and stored, and may include: an identifier for each scanner used; a unique batch number; the total number of ballots scanned in a batch; and the container ID where the batch of ballots is stored.

The information in the manifest should never come from the voting system. It should be created and maintained by the local election official. The log can be as simple as a paper form or spreadsheet completed by whomever is handling a batch of ballots. If you have technical resources, you can create software to automate some of the process by using labels with bar codes.

TABLE 3: EXAMPLE OF BALLOT MANIFEST

BALLOT MANIFEST *(CENTRALLY SCANNED BALLOTS)*				
County	**Scanner Name**	**Batch #**	**Total Ballots in Batch**	**Container Name**
Union	03	15	100	TC-001
Union	03	16	99	TC-002
Union	03	17	100	TC-002

BALLOTS SCANNED CENTRALLY

Ballots scanned centrally should include a name or number to identify each scanner, a batch number that is unique for each scanner, the number of ballots scanned in each batch, and the name or number of the storage container where ballots will be stored. If ballots will be compared to a CVR, it is helpful to match the naming convention. For instance, every voting system has a unique way of identifying a particular scanner. Normally this is an assigned number of digits. It is helpful to design a process where the ballot manifest and any associated labels or seals use the same naming conventions and format as the CVR. Ballot manifests are also necessary when using an audit tool to conduct the audit. To identify a ballot's specific sequence number within each batch, audit software uses information provided in the manifest including the total number of ballots in each batch.

Using the example above, if we convert the table into a .csv format, a row of data from the manifest would appear like this: Union, 03, 15, 100, TC-001. The audit tool sees there are 100 ballots in the batch and extrapolates that into individual units providing an identifier of 03-15-42. Election officials can interpret this as the 42nd ballot in batch 15, scanned on tabulator 03. The RLA software will connect this data point to the container name, providing a perfect map of where to find a specific ballot.

For centrally scanned ballots, create the ballot manifest template before you begin scanning ballots. To speed up the process, you can pre-fill some of the information on the form such as the scanner name and the batch numbers (if they are assigned sequentially for each scanner). Reconcile the ballot manifest against the CVR report regularly to ensure the total number of ballots recorded on the manifest equals the total number of ballots in the CVR report.

BALLOTS SCANNED AT POLLING LOCATIONS

Ballots scanned at polling locations should include a name or number to identify each scanner, a number to identify the bag/box where the ballots are being stored, the total number of ballots in each box, and an ID or seal number of the ballot storage box.

Most likely, precinct-scanned ballots will be audited using the ballot-polling method. You will still need a ballot manifest to select ballots randomly and compare them to the outcome reported by the voting system.

In this case, the ballot manifest does not need to correspond to the CVR but will still need information to locate and retrieve ballots for audit. The audit software will still use the number of ballots in a batch to identify a sequence number. Using the first row of data from the example below the ballot manifest export would look like: 6273803212, 4567, 1, 236, A95162.

The audit software sees there are 236 ballots in the batch (typically everything scanned on that particular scanner) and extrapolates that into individual units such as 4567-1-97. Meaning the audit team would need to count down to the 97th ballot from ballot box #1, scanned on tabulator 4567. The RLA software will connect this with the seal number to provide an additional piece of data to identify the correct ballot box.

You can create the ballot manifest after the polls close, while workers transfer ballots to storage containers for transport or when they return the scanner/cartridge bins that contain scanned ballots to the election office. The precinct number is not required on the manifest but is an additional piece of information that may be useful in identifying where the ballots are being stored.

TABLE 4: EXAMPLE OF BALLOT MANIFEST

BALLOT MANIFEST *(PRECINT SCANNED BALLOTS)*				
Precint #	**Scanner Name**	**Ballot Box ID**	**Total Ballots**	**Seal #**
6273803212	4567	1	236	A95162
6273803212	4567	2	407	A56823
6273803212	3002	3	23	A36425

RLA Tool & User Interface

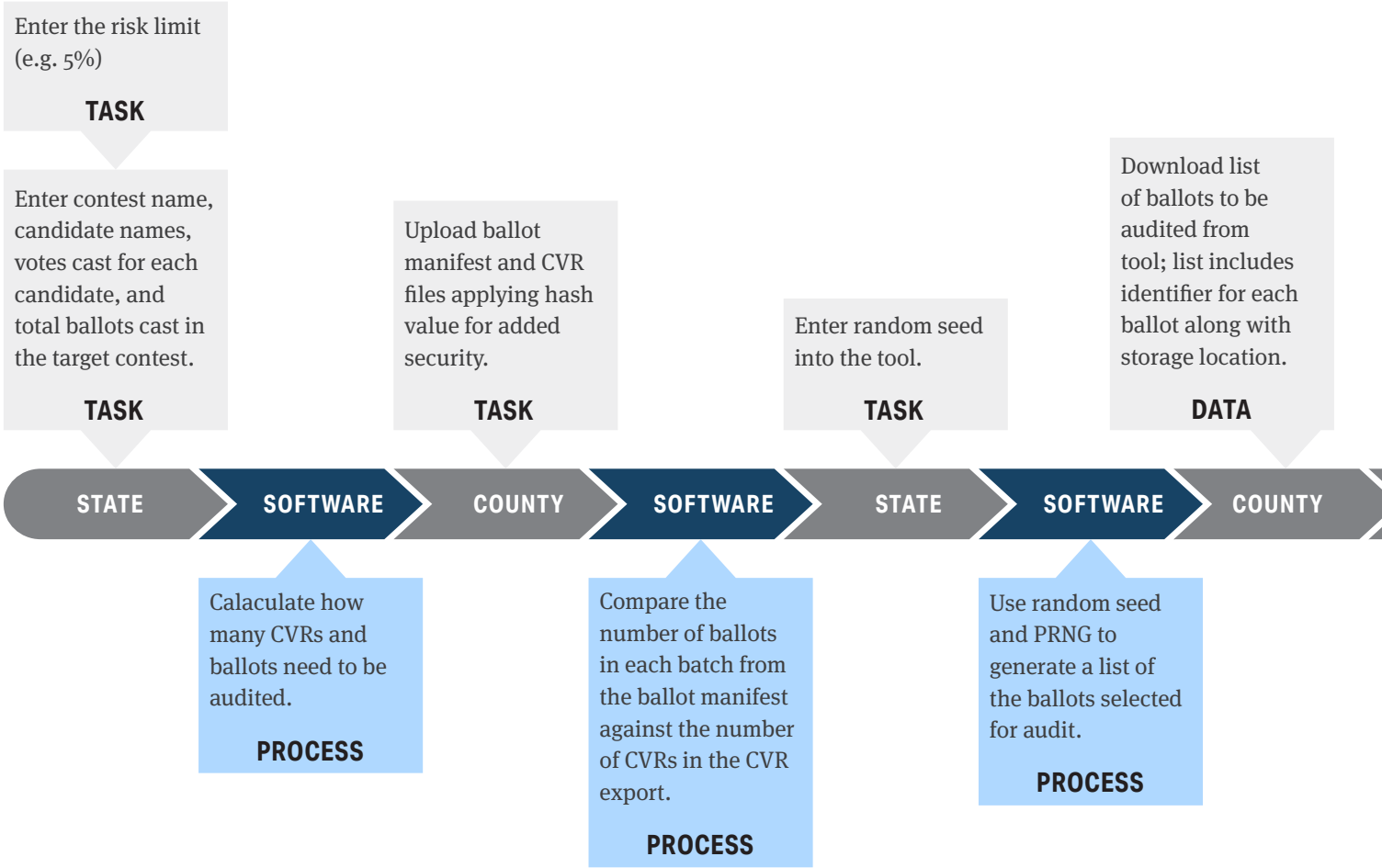
RLAs can be made easier with the help of audit software designed to help election officials manage the data audits rely on and collect and to perform various calculations to conduct the audit, including:

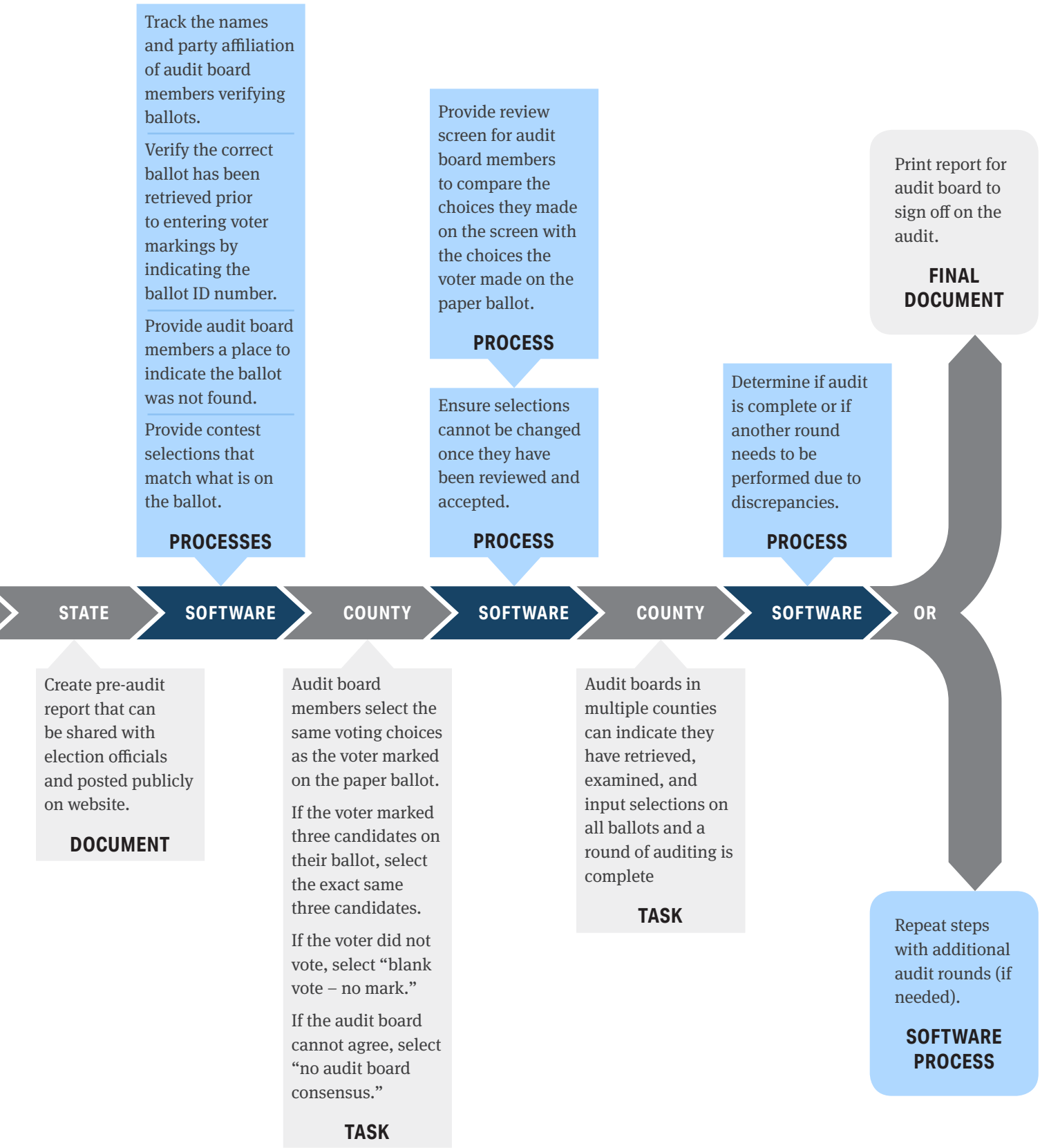
- collecting ballot manifests from local jurisdictions, cross checking the manifests against reported results, assembling statewide ballot manifests, and committing to the manifests;
- in comparison audits, collecting and committing to cast vote records or reported subtotals uploaded by local jurisdictions;
- estimating the number of ballots the audit will need to examine;
- randomly selecting ballots for audit from the ballot manifest (using a random seed and PRNG) and identifying where to find them;
- collecting the auditors' interpretation of voter intent from the audited ballots;
- accounting for discrepancies and determining if the audit should expand;
- calculating when the risk limit has been met and the audit can stop.

At the conclusion of the audit, the software should provide a report for members of the audit board to sign, certifying that the audit was completed and provide a permanent record of the audit.

The following page provides an outline of how the audit software might function.

RLA Software Processes




Track the names and party affiliation of audit board members verifying ballots.
Verify the correct ballot has been retrieved prior to entering voter markings by indicating the ballot ID number.
Provide audit board members a place to indicate the ballot was not found.
Provide contest selections that match what is on the ballot.
PROCESSES
Provide review screen for audit board members to compare the choices they made on the screen with the choices the voter made on the paper ballot.
PROCESS
Ensure selections cannot be changed once they have been reviewed and accepted.
PROCESS
Determine if audit is complete or if another round needs to be performed due to discrepancies.
PROCESS
Print report for audit board to sign off on the audit.
FINAL DOCUMENT
STATE
SOFTWARE
COUNTY
SOFTWARE
COUNTY
SOFTWARE
OR
Create pre-audit report that can be shared with election officials and posted publicly on website.
DOCUMENT
Audit board members select the same voting choices as the voter marked on the paper ballot.
If the voter marked three candidates on their ballot, select the exact same three candidates.
If the voter did not vote, select "blank vote – no mark."
If the audit board cannot agree, select "no audit board consensus."
TASK
Audit boards in multiple counties can indicate they have retrieved, examined, and input selections on all ballots and a round of auditing is complete
TASK
Repeat steps with additional audit rounds (if needed).
SOFTWARE PROCESS

4 Administrative Rules

Administrative election rules provide a flexible and efficient way to further define RLA laws and create policies and procedures. Listed here are some of the questions that an RLA advisory group may want to consider and answer for inclusion in those rules and regulations.

Establishing Dates and Timelines

- ☐ Does the deadline for canvassing and certifying the election need to be pushed back to provide sufficient time to complete the audit and, if a full hand count is necessary, to change the official outcomes?
- ☐ All ballots, including absentee and provisional, should be included in the audit. Do deadlines related to tabulating absentee and provisional ballots need to be pushed back to allow for their inclusion in the audit?
- ☐ When will the risk limit be established and made public?
- ☐ When will the random seed be established?
- ☐ When will target contests be selected?
- ☐ When do ballot manifests and CVRs need to be uploaded by local jurisdictions to the audit software?
- ☐ When will ballots be randomly selected for audit?
- ☐ When can the audit commence?
- ☐ When should the audit be completed?
- ☐ When will RLA reports and data be made public?
- ☐ Do considerations or changes need to be made for existing laws requiring ballots to be impounded for a specific period following the election?
- ☐ Does the period for challenging the certified results of an election need to be adjusted to reflect the auditing timetable?
- ☐ How will recount deadlines affect the audit policies being established?

Establishing Audit Criteria

- ☐ What method(s) of RLA will be defined (ballot-level comparison, ballot-polling, etc.)? Will jurisdictions be restricted in the methods they may use?

- ☐ Will there be a set risk limit, a range, or a maximum limit depending on the type of election and RLA method?
  - If a range or maximum limit, how and when will the risk limit be established for each election?

- ☐ What separation of duties will be established?
  - What role will the state or an independent audit team play?
  - What role will the county/local official play?
  - What role, if any, will a local audit board play?
  - Who will act as the audit board?
  - When will they be designated?
  - Will an audit board be appointed in each jurisdiction?
  - Who will be responsible for retrieving the ballots? The audit board members alone or with assistance from election staff?
  - Who will be responsible for examining and verifying the selected ballots? The audit board members alone or with assistance from election staff?
  - Will there be a requirement for the audit board to certify the audit similar to the way canvass board members certify the election?

- ☐ Will a standard format be established for ballot manifests or left up to local jurisdictions?
  - What are the required fields for ballots scanned at the precinct/polling location?
  - What are the required fields for centrally scanned ballots?
  - What field will tie the ballot manifest to the CVR if doing a ballot-level comparison audit?

- ☐ How will the random seed be generated?

- ☐ How will the target contest be selected? Some factors to consider:[5]
  - The closeness of the reported tabulation outcomes.
  - The geographical scope of the contests.
  - The number of ballots counted in the contests.
  - Any cause for concern regarding the accuracy of the reported tabulation outcome of the contests.
  - Any other benefits that may result from auditing certain contests.
  - The ability of the county to complete the audit before the canvass deadline.

- ☐ What reports need to be generated and submitted to the state or independent auditor and by what date? Example: summary results report, CVR export, ballot manifest.

- ☐ How will transparency and observability be maintained?
  - What audit material and reports will be made public?
  - How will voter anonymity be maintained?
  - How do you plan to facilitate audit observers?
  - Will there need to be any changes to existing laws for credentialing election audit observers?

Other Considerations

- ☐ The number of ballot cards to be audited should be based on the formulas and protocols published in the statistical literature. Presently, the best guide is A Gentle Introduction to Risk-Limiting Audits, by Mark Lindeman and Philip B. Stark. Rather than specify complex calculations in the rules, it may be easier to cite publications directly.

- ☐ Comprehensive voter intent guidelines for hand-marked paper ballots are crucial. They provide consistency between ballots adjudicated during the initial tally and ballots selected for audit that require adjudication for voter intent.[v]

- ☐ When a ballot that was duplicated or remade is chosen to be examined, the original ballot that was marked by the voter, not the duplicated or remade one, must be the source of comparison.

- ☐ Laws defining "election records" may need to be changed.
  - Will the ballot manifest, CVR, RLA reports, and ballot images (if available) be considered an election record?
  - Will they be publicly available?
  - Who will provide them? State or local jurisdiction?
  - Will extra measures need to be taken to redact information that could violate voter secrecy?

- ☐ A target contest will drive the ballot sample size and be used to determine if the audit has met the risk limit. It should not preclude the opportunity to audit other contests on ballots already selected for audit.

- ☐ Audit processes should include a way to respond to circumstances that come to light affecting particular devices, ballots, or contests. How will you respond? Will a separate audit be required?

- ☐ Take the opportunity to consider how your state's voting model might affect the RLA method. Centrally scanning ballots provides an ideal environment for conducting a ballot-level comparison audit and should be something discussed by the advisory group.

- ☐ Carefully review your state's recount requirements. Is there anything that would conflict with conducting an RLA prior to certification? RLAs have the potential to lead to a full hand count if discrepancies in the reported outcome are identified. When the reported outcome is correct, RLAs can provide strong evidence about who won at far less expense than a recount. This provides an excellent opportunity to explore the possibility of reducing the recount threshold, or eliminating it, if an RLA is conducted.

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v Washington, Colorado, and Virginia have developed excellent voter intent guidelines that are available from the respective state election websites.

RLA States

Take time to review the policies from other states that have made RLAs a requirement. Some laws are better formulated than others. Contact state and local officials in those states to get their feedback and ask the following questions:

- ☐ What was the time frame for implementing RLAs?

- ☐ What concerns were voiced during the legislative process from:
  - Legislators?
  - State and local election officials?
  - Other stakeholders?
  - Citizens?

- ☐ What requirements would they change if they had it to do over again?

- ☐ What requirements and documented processes are working well?

5 Pre-Audit Preparation

This section outlines the steps in preparing for a ballot-level comparison audit, as well as conducting the audit. A ballot-level comparison audit requires paper ballots that can be individually identified and compared to the CVR. Ballots counted centrally provide the ideal environment for performing a comparison audit.[vi] Alternatively, ballots scanned at the polling location may be rescanned and retabulated post-election on a central scanner.

Organizing & Tracking

- ☐ Create a documented plan for tracking and reconciling ballots from the time they are cast or received until they are scanned and sealed in a storage container.
  - This plan should include a way to account for the number of ballots in a batch any time they are moved or change hands.
  - It may include a tracking sheet that accompanies the ballots and provides a place for poll workers or staff to annotate how many ballots are in the batch and if a ballot was added or removed for any reason.

- ☐ Predetermine the ballot batch size by considering:
  - The maximum number of ballots the scanner tray can hold.
  - How many ballots the average person can comfortably handle.
  - 100–200 ballots per batch is a good size in a central count process.
  - Jurisdictions without imprinting capability may opt for smaller batches of 25–50 ballots to allow audit teams to "count down" to a specific ballot.
  - Voter-facing scanned ballots that will be rescanned to acquire a CVR or imprinted number may be kept in the same quantities as recorded on the original ballot manifest.

- ☐ Document how batches will be secured and stored.

- ☐ Ensure there is a well-documented process for validating ballot chain of custody.

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vi The Imprinting section discusses the idea of imprinting a unique number on ballots scanned at a polling location. This may provide a feasible way to conduct a comparison audit on voter-facing scanned ballots in the future.

TABLE 5: BATCH FOLDER LABEL

CARTRIDGE REMOVAL	Precinct Scanner ID:	0175
	Initial Count:	100
SCANNING ROOM	Batch Size:	100
	Scanner Name:	2
	Batch Number:	45
	Staff Initials:	JM

TABLE 6: CONTAINER LABEL

CONTAINER ID:		TC-5
Scanner Name	**Batch Number**	**Batch Size**
1123	001	100
"	002	100
"	003	99
"	004	100
"	005	100
	TOTAL BALLOTS:	499
Seal #:		
Staff Initials:		JM/TC

Ballot Storage

- ☐ What will individual batches of ballots be stored in, e.g., folder or envelope?
  - What is the maximum number of ballots the folder can hold and comfortably allow for the ballots to be removed and reinserted?
- ☐ How will the batch folders be labeled?
  - The label on each batch of ballots can also help serve as a tracking sheet as well as a place to record the information that will be entered into the ballot manifest.
  - The label should include the same information entered into the ballot manifest, including the scanner name, batch number, and batch size similar to the example at left.
- ☐ What type of container will the batch folders be stored in, e.g., box or tote?
  - What is the maximum number of batch folders the container can hold and comfortably allow for the folders to be removed and reinserted?
- ☐ How will the containers be labeled to identify their contents?
  - Each container should be given a name or number.
  - Include fields from the batch labels, including scanner name, batch number, and batch size.
  - May also include date and initials from the person who scanned the ballots and seal numbers used to secure the container.
- ☐ Where and how will the containers be stored between the scanning process and the RLA?
- ☐ How will the containers be staged and organized for quick identification?
  - Grouped together by container ID? Scanner ID? Precinct or district?

Ballot Manifest

- ☐ Will the ballot manifest be filled out on a paper log and transferred to a spreadsheet or entered directly into a spreadsheet?
- ☐ Does it contain the information that will tie ballots to the CVR?
- ☐ Is it independent of the voting system?
- ☐ How and when will the information be entered?
- ☐ How and when will the information be verified?
- ☐ Perform a test run of the entire process using the ballot manifest

Ballot Scanning

- ☐ What is the process to validate the total number of ballots scanned in each batch?
- ☐ How will ballots be kept in order?
- ☐ How will individual ballots be correctly identified (if doing ballot comparison audit)?
  - Consider imprinting a number or pre-printing a unique number.

Reconciliation

- ☐ Create a process for comparing the total number of ballots cast by comparing totals from the ballot manifest, the voting system batch summary report, and the voters who have been given credit for voting.
  - Reconciliation should be done daily if ballots are scanned over a period of time.
  - Resolve any discrepancies in the reconciliation before proceeding with RLA.
- ☐ The ballots being audited should be verifiably protected from loss, substitution, alteration, or addition. Ensure there is a standard practice for:
  - Maintaining chain of custody.
  - Reconciling the ballots cast to the poll book/voter registration database.
  - Reconciling the ballots cast to the number of ballots scanned.

Snohomish County, Washington, election staff verify the container number while retrieving ballots for pilot ballot-level comparison audit.

6 Conducting the Audit

This section provides an overview of the steps performed in conducting a ballot-level comparison audit and is formatted as a checklist. Tasks are listed in sequential order and labeled as county or state to illustrate how duties should be separated when conducting the audit. This section assumes the risk limit has already been set, audit board(s) appointed, and target contests selected. It also assumes use of an RLA software tool.

County

1. FINAL TABULATION

- ☐ Finish tabulating all valid ballots — absentee, UOCAVA, and provisional.
  - Alternatively, ballots scanned at the polling location can be rescanned and imprinted with a unique sequential number. A new CVR will need to be generated and compared to the original CVR.
- ☐ Generate a summary results report from the voting system to include overvotes, undervotes, blank-voted contests, and valid write-in votes.
- ☐ Update final tabulated results and make them public.

2. VERIFY CVR AND BALLOT MANIFEST

- ☐ Verify that the total number of individual CVRs in the CVR export equals the aggregate number of ballots in the ballot manifest.
- ☐ Verify totals for all choices in all ballot contests in the CVR export equal vote totals in the summary results report.

3. EXPORT CVR AND BALLOT MANIFEST

- ☐ Export CVR file from the voting system in a format that is compatible with the audit software (such as a .csv format).
- ☐ Format ballot manifest fields as necessary for the audit software.
- ☐ Consider applying a hash value to the CVR export file and ballot manifest for security (if transmitting electronically).
- ☐ Commit both files to the audit by uploading to the audit software.

State

4. RANDOM SEED

- ☐ Host a public convening for establishing a random seed.
  - This can be done by rolling dice, drawing cards, choosing numbers, etc. The following steps assume that 20, 10-sided dice will be rolled.
- ☐ Blindly draw names one at a time (such as out of a hat) to randomly select who from the audience will participate.
- ☐ Dice should also be blindly drawn and rolled one at a time.
- ☐ Provide a way to publicly record each number after it has been rolled.
  - This could be done on a white board or written on a sheet of paper. Participating members of the public should have an opportunity to confirm the random seed before it is committed to the RLA software tool.

5. GENERATE LIST OF BALLOTS SELECTED FOR AUDIT

- ☐ Using RLA software, ballots are randomly selected for audit from the ballot manifest.
- ☐ Generate a report for each county, listing each ballot selected for audit. Report should include:
  - Scanner name
  - Batch number
  - Ballot position in the batch
  - Ballot type
  - Container name

Ten-sided dice are often used to create a "seed" for the psuedorandom number generator.

County

6. RETRIEVE BALLOTS FOR AUDIT

- ☐ Sort the report provided by the state so that it lists ballots using the same logic as they are stored and staged for the audit.
  - The report should be formatted in a way it can be divided between multiple teams of two.
  - The report can be a piece of paper or large label that is attached to a file folder or envelope.
  - A folder or envelope can be used to hold the ballots retrieved for the audit. The ballots should be kept in the same order as they are listed on the report.
  - The report should look something like the tables below depending on the voting system and include fields for indicating the ballot has been retrieved and audited

- ☐ Create a placeholder to replace the ballot pulled for auditing such as a colored piece of cardstock or paper printed with the Ballot ID or Imprint ID.
  - An optional idea for a placeholder is a printed and enlarged version of the ballot image.
  - Print image centered on the section of the ballot with Ballot ID or Imprint ID being careful not to print the full ballot.
  - Print on colored paper.
  - Use to confirm the correct ballot has been retrieved.
  - Creates a placeholder for the ballot removed for auditing.

- ☐ Bipartisan teams retrieve ballots.
  - For example, if 2-13-96 is listed on the report of ballot cards selected for audit, you would find the 13th batch of ballots scanned on Scanner 02 and retrieve the 96th ballot.

- ☐ It is imperative that the ballots retrieved are kept in the same order as they appear on the list when using auditing software.

- ☐ Work areas should be created around ballot storage locations that allows room for teams of two to:
  - Open storage containers.
  - Find the correct ballot.
  - Insert the necessary placeholder.
  - Place the ballot retrieved for audit in the labeled envelope or folder.
  - Initial the form used to track ballots that have been pulled for audit.
  - Initial or complete new security seals for ballot storage container (if required).

TABLES 7 AND 8: BALLOT AUDIT REPORT SAMPLES

SCANNER	BATCH	BALLOT	IMPRINTED ID	BALLOT TYPE	CONTAINER	PULLED	AUDITED
3	1	60	3-1-60	29	1		
3	1	61	3-1-61	51	1		
3	2	66	3-2-66	51	1		
3	3	21	3-3-21	28	2		
3	5	95	3-5-95	40	3		

SCANNER	BATCH	BALLOT	IMPRINTED ID	BALLOT TYPE	CONTAINER	PULLED	AUDITED
1123	A001	60	1123000060	29	1		
1123	A001	61	1123000061	51	1		
1123	A002	66	1123000066	51	1		
1123	A003	21	1123000021	28	2		
1123	A005	95	1123000095	40	3		

TIP: Only allow the use of red pens in the work area.

7. BALLOT VERIFICATION

- ☐ Performed by bipartisan teams with staff assistance as needed in an area with space for the public to observe.
  - Use computer workstations if using RLA audit software.
  - Using a projector or second monitor improves ability for observers to see the process.
- ☐ Verify the correct ballot has been retrieved prior to recording or entering the voter markings.
- ☐ Read out loud the voter markings for the races and contests being audited.
- ☐ Record the votes in the RLA audit software.
- ☐ Read votes back as recorded in audit software tool to confirm it has been recorded correctly.
- ☐ Process should be done blindly, without knowledge of how the ballot was interpreted or tabulated by the voting system.
- ☐ Teams verifying ballots should have clearly written voter intent guidelines to assist in making decisions on voter intent when necessary.
  - Acceptable not to agree on what is a valid vote.
  - RLA audit software should provide a selection when the audit board cannot agree.
- ☐ Indicate on the ballots selected for audit report that the specific ballot has been reviewed and audited. (Reminder again to only use red pens.)
- ☐ Be mindful of the time each team or person is assigned to examine and verify ballots. Rotating people on a regular basis reduces the potential for errors caused by fatigue.

State

8. IDENTIFY ANY DISCREPANCIES

- ☐ Confirm that all ballots selected have been audited.
- ☐ Compare voter markings entered by the audit board to the corresponding CVR for each audited ballot.
- ☐ Identify any discrepancies as understatements or overstatements.[vii]
  - RLA software is the most effective way to identify discrepancies between human verification and machine tabulation in large ballot sets.
  - Should include target and non-target contests if auditing the entire ballot.

9. SATISFY THE RISK LIMIT

- ☐ Determine whether the risk limit is satisfied, or an additional round of auditing is required.
  - Additional rounds will require additional ballots to be selected for auditing.
  - Audit has the potential to escalate until all ballots have been examined.

County

10. CERTIFY THE AUDIT

- ☐ Provide a way for audit teams to affirm that the results of the audit are accurate.

vii See "Should more ballots be audited?" in Tools for Comparison Risk-Limiting Audits to understand how to calculate overstatements or understatements. Available at: https://www.stat.berkeley.edu/~stark/Java/Html/auditTools.htm.

7 Post-Audit Reporting and Feedback

Feedback and data gathered from post-election audits should be analyzed and used to continuously improve all elements of the election process — including the RLA process. This can be done in formal and informal feedback sessions after the audit is complete. It is important to document the thoughts and lessons learned from everyone who participated.

Look for opportunities to improve the process for ballot handling, adjudication, ballot duplication, and ballot organization and storage.

Other data that will be useful to collect and analyze:

- Time to retrieve ballots selected for audit.
- Time to examine a ballot and document the voter markings.
- Expenses incurred in conducting the audit.

8 Communication

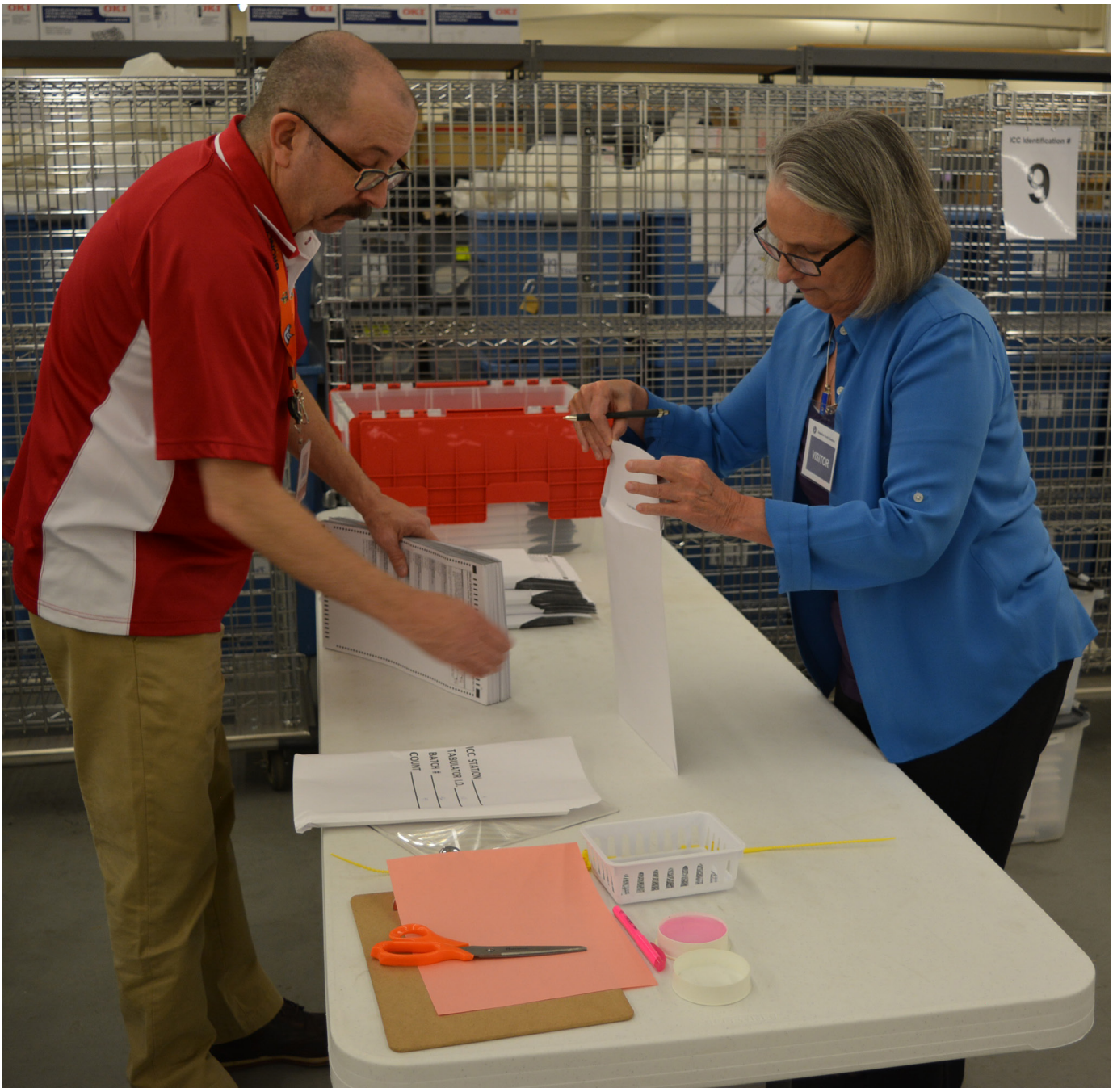
Communicating the RLA process to voters, candidates, election officials, and policymakers in a way that is both meaningful and understandable is a challenge. It is a complex idea that even subject-matter experts struggle to communicate clearly. The definitions are technical, and the formulas for calculating the sample size or when the risk limit has been satisfied, for instance, are grounded in math and statistics that can be difficult to explain.

Are there creative ways to inform voters of the process through information guides, infographics, social media posts, or other methods? Or is it enough for election officials to state: "There is strong statistical evidence that all votes cast were counted and reported accurately"? While we tackle better ways to communicate the RLA process, we should also think about transparency.

Making audit information available on a public website is a good start. Some things to consider posting publicly are:

- Notice of the public meeting to establish the RLA random seed
- Established random seed
- Target contests selected for audit
- Ballot manifests
- Ballots selected for audit
- Total number of discrepancies

The communication issues are not limited to putting the math into words or creating graphics to illustrate the process of retrieving ballots. One major hurdle will be a collaborative effort among RLA stakeholders to create standard terms and definitions that are used consistently when discussing policy and practices.



Todd Davidson, election manager, City and County of Broomfield, CO, assists an audit board member with Arapahoe County, CO 2017 Risk-Limiting Audit. (Todd was Arapahoe County elections voter registration manager at the time of this photo).

APPENDIX A

Risk-Limiting Audit Resources

- **A Gentle Introduction to Risk-Limiting Audits**. A significant but concise technical overview of risk-limiting audits. Available at: **https://www.stat.berkeley.edu/~stark/Preprints/gentle12.pdf**.

- **An Introduction to Risk-Limiting Audits and Evidence-Based Elections.** Testimony provided by Philip Stark to the California Little Hoover Commission regarding compliance audits, efficient methods for conducting RLAs, required resources, and principles for audit legislation. Available at: **https://www.stat.berkeley.edu/~stark/Preprints/lhc18.pdf.**

- **Election Rules, Colorado Secretary of State, Rule 25. Post-Election Audit**. A well-vetted resource for drafting administrative election rules pertaining to risk-limiting audits. Available at: **http://www.sos.state.co.us/pubs/rule_making/CurrentRules/8CCR1505-1/Rule25.pdf.**

- **Post-Election Audits**. A review of post-election audit practices, recent legislative action, and the post-election requirements in all 50 states. Available at: **http://www.ncsl.org/research/elections-and-campaigns/post-election-audits635926066.aspx.**

- **Cast Vote Records Common Data Format Specification**, Version 1.0. (NIST Special Publication 1500-103). Common data format specification for cast vote records that might be included in RFPs for voting system purchases. Available at: **https://github.com/usnistgov/CastVoteRecords/blob/master/NIST%201500-103%20CDF%20Specification%20WERB%202019-02-08.pdf.**

- **Sample Voter Intent Guidelines**.
  - Colorado Secretary of State, Determination of Voter Intent for Colorado Elections. Available at: **http://www.sos.state.co.us/pubs/elections/docs/voterIntentGuide.pdf**.
  - Virginia Department of Elections, Ballot Examples: Hand Counting Printed Ballots for Virginia Elections or Recounts. Available at: **https://www.elections.virginia.gov/Files/ElectionAdministration/ElectionLaw/Examplesfor Handcounting.pdf**.
  - Washington Secretary of State, Voter Intent: Statewide Standards on What Is a Vote. Available at: **https://www.sos.wa.gov/_assets/elections/administrators/2018_voter-intent_web.pdf**.

- **Principles and Best Practices for Post-Election Tabulation Audits.** Available at: **https://electionaudits.org/files/bestpracticesfinal_0.pdf.**

- **Securing the Vote: Protecting American Democracy**. Available at: **https://doi.org/10.17226/25120**.

- **Tools for Ballot-Polling Risk-Limiting Election Audits**. Provides several tools for conducting a ballot-polling RLA, including a tool to determine the initial sample size of a particular contest to be audited, a tool to generate a pseudo-random sample of ballots, and a tool for determining if the audit can stop. Available at: **https://www.stat.berkeley.edu/~stark/Java/Html/ballotPollTools.htm.**

- **Tools for Comparison Risk-Limiting Audits**. Provides several tools for conducting a ballot-level comparison RLA, including a tool to determine the initial sample size of a particular contest to be audited, a tool to generate a pseudo-random sample of ballots, and a tool for determining if the audit can stop. Available at: **https://www.stat.berkeley.edu/~stark/Java/Html/auditTools.htm**.

APPENDIX B

Basic Audit Concepts

Types of Audits

1. A **product audit** is an examination of a particular product (voting system) to evaluate whether it conforms to requirements and performance standards.

2. A **process audit** evaluates an operation against predetermined instructions or standards and asks the questions:
   - Did it conform to the standards?
   - Are the instructions effective?

   The process audit examines:
   - Resources (equipment, materials, people)
   - Environment
   - Methods (procedures and instructions)

3. A **system audit** verifies that applicable elements of the system are appropriate and effective and have been developed, documented, and implemented in accordance with specified requirements. For example, an election system audit would determine if the election system conforms to state and federal policies and requirements.

Phases of an Audit

- **Preparation:** Audit preparation consists of everything that is done in advance by interested parties, such as the auditor, the lead auditor, the client, and the audit program manager, to ensure that the audit complies with the client's objective. The preparation stage of an audit begins with the decision to conduct the audit. Preparation ends when the audit itself begins.

- **Conducting the Audit**

- **Reporting and Feedback:** The purpose of the audit report is to communicate the results of the investigation. The report should provide correct and clear data that will be effective as a management aid in addressing important organizational issues. The audit process may end when the report is issued by the lead auditor or after follow-up actions are completed.

- **Closure:** The audit is completed when all the planned audit activities have been carried out and there is verification of follow-up actions.

Internal & External Audits

First-party audit — when an organization measures its strengths and weaknesses against its own procedures or against external standards.

Third-party audit — performed by an independent audit organization and free of any conflict of interest.

Psuedorandom Number Generators

Understanding exactly how a pseudorandom number generator works is not critical to conducting an RLA, but I am frequently asked for an explanation of how it functions when selecting specific ballots for audit.

"A *pseudo-random number generator* (PRNG) is a deterministic algorithm that, starting with an initial 'seed' value, produces a sequence of numbers that are supposed to behave like random numbers."[6] The random sample of ballots is unpredictable before the seed is chosen, yet can be checked by anyone after the seed is chosen. Generating one random seed can be much faster than selecting each ballot individually.

Some important characteristics of a high-quality PRNG include how many random numbers it will generate before it gets back to the same sequence, uniformity (an equal chance that each ballot will be selected), and randomness (you cannot predict what number will be next).

Using a PRNG

A simple description of how a PRNG may be used in RLA software:

1. Expand the ballot manifest so there is a row for each ballot in every batch.
2. Assign a sequential number from 1 to the maximum total number of ballots in the manifest.
3. Roll the dice to establish the random seed.
4. The algorithm takes in the seed and computes a number to determine the first ballot selected.
5. Subsequent numbers are generated by the PRNG algorithm to determine which ballots are selected.
6. This continues until the sample size has been met.
7. If the PRNG selects a ballot that has already been chosen, it skips this number and moves on to generate another number.

Resources:

- Philip B. Stark, Pseudo-Random Number Generator Using SHA-256. Available at: **https://www.stat.berkeley.edu/~stark/Java/Html/sha256Rand.htm**.
- Ronald L. Rivest, Reference Implementation Code for Pseudo-Random Sampler for Election Audits or Other Purposes. Available at: **https://people.csail.mit.edu/rivest/sampler.py**.

Endnotes

1 Kellie Ottoboni, Phillip B. Stark, Mark Lindeman, and Neal McBurnett, "Risk-Limiting Audits by Stratified Union-Intersection Tests of Elections (SUITE)," Department of Statistics, University of California Berkeley, Verified Voting Foundation, September 12, 2018, Accessed on April 5, 2019. Available at: **https://arxiv.org/pdf/1809.04235.pdf**.

2 Mark Lindeman and Philip B. Stark, "A Gentle Introduction to Risk-Limiting Audits," *IEEE Security and Privacy, Special Issue on Electronic Voting*, March 16, 2012, p. 4–5, Accessed on April 4, 2019. Available at: **https://www.stat.berkeley.edu/~stark/Preprints/gentle12.pdf**.

3 Joseph A. Calandrino, J. Alex Halderman, and Edward W. Felton, "In Defense of Pseudorandom Sample Selection," Center for Information Technology Policy and Dept. of Computer Science, Princeton University, Woodrow Wilson School of Public and International Affairs, Princeton University, Accessed November 13, 2018. Available at: **https://www.usenix.org/legacy/event/evt08/tech/full_papers/calandrino/calandrino.pdf**.

4 "Risk-Limiting Post-Election Audits: Why and How," *Risk-Limiting Audits Working Group*, 2012-10, Version 1.1, October 2012, p. 31, Accessed on April 5, 2019. Available at: **http://people.csail.mit.edu/rivest/pubs/RLAWG12.pdf**.

5 Factors included in Colorado Election Rule 25.2.2 (i). Available at: **http://www.sos.state.co.us/pubs/rule_making/CurrentRules/8CCR1505-1/Rule25.pdf**.

6 Philip B. Stark and Kellie Ottoboni, "Random Sampling: Practice Makes Imperfect," University of California Berkeley, October 26, 2018, Accessed on April 5, 2019. Available at: **https://arxiv.org/pdf/1810.10985.pdf**.

READ MORE

For an overview of the field of risk-limiting audits, please visit the complementary piece to this guide, **"Part One: A Practical Guide to Risk-Limiting Audits."** Where Part 2 provides soup-to-nuts information on how election officials can conduct this type of audit, Part One gives a higher level overview for state and local stakeholders who want to know more about RLAs before moving on to the implementation phase.

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