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# MEMORANDUM

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Date: February 6, 2017

To: The Honorable Chair and Members  
Pima County Board of Supervisors

From: C.H. Huckelberry  
County Administrator

A handwritten signature in black ink, appearing to read "C.H. Huckelberry", is written over the typed name and title.

Re: **Elections Integrity Commission and Mock Risk Limiting Audit**

On Wednesday, January 25, the Pima County Elections Integrity Commission (EIC) met and conducted a mock Risk Limiting Audit (RLA) using 30,000 ballots prepared for such an effort. An RLA attempts to ensure the validity of election results by reviewing a statistically valid random sample of the ballots cast and the votes reflected on those ballots. The closer the race, the larger the sample of ballots that would need to be reviewed as part of the RLA to validate the election results. Last year, the EIC had expressed interest in conducting an RLA to determine the merits of such. Pima County Elections Director Brad Nelson and his staff worked closely with EIC members to enable the EIC to conduct such an audit on a mock election. Ballots were printed with six ballot questions related to the Oscars (best picture, best actor, etc.) The votes were tabulated and the RLA included the use of a website created by the inventor of the RLA, Dr. Stark of UC Berkeley, to calculate how many of the ballots should be selected for audit based largely on the closeness of the closest race and the total votes cast. Attached are the instructions the EIC used for this RLA.

The EIC will meet next on February 17 and members will likely discuss their opinions of the RLA at that time. Mr. Nelson's initial impression after the exercise was that it was well worth the time, but that it may be too complex and time consuming to pursue further. I will certainly communicate to the Board the EIC's conclusions regarding the RLA after their February meeting.

Since 2008, Pima County has been implementing a hand count audit of twice as many ballots than required to be hand counted by state law. This typically occurs the Saturday after an election and involves designees of the registered parties. It is one of numerous elections security and transparency measures implemented by Pima County since 2006.

It is somewhat ironic that the same day the EIC conducted this mock election audit, President Trump announced he would be "asking for a major investigation into voter fraud, including those registered to vote in two states, those who are illegal and even, those registered to vote who are dead (and many for a long time)." This followed his unsubstantiated claims that 3 to 5 million people voted illegally. While ensuring accurate election tabulation results is separate from ensuring against voter fraud, our democracy relies upon the public's confidence in the integrity of the entire elections system from start to end.

Arizona Secretary of State Michele Reagan and Pima County Elections Director Brad Nelson, where both interviewed on Wednesday by Arizona Public Media about these allegations, and responded confidently about Arizona and Pima County's protections against voter fraud. Chris Roads, Chief Deputy Pima County Recorder and Registrar of Voters, provided the following details concerning the President's allegations:

1. Regarding "those registered to vote in two states," the Pima County Recorder's office regularly compares the voter registration file to the United States Postal Service National Change of Address database, at a minimum of twice each year, in order to keep the voter rolls current. Most of the Pima County database was checked six different times between October 2015 and November 2016 due to the five countywide elections and the mass mailing of identification cards that occurred during that time. Voters identified as having moved are blocked from receiving early ballots until they update their registration record or contact the Recorders Office to confirm an error with the postal system.

For several years, the State of Arizona has participated in a comparison of the Arizona voter registration database with the voter registration databases of a majority of other states. Any person identified as possibly being registered in more than one state is flagged. Both states investigate to determine if it really is the same person and which state should keep the record active. The record in the other state is then cancelled. Persons identified as having voted in two states during the same election are referred to both states' Attorney General's Offices to determine whether criminal charges should be filed. This record check generally occurs during the spring of an odd numbered year after a federal election. The last check resulted in several thousand "false positive" matches who turned out to be two different people with the same name.

2. Regarding "those who are illegal," the Pima County Recorder's Office confirms proof of citizenship in a number of ways depending on the method by which the individual registers to vote. Often the proof of citizenship provided is a driver's license number, which is confirmed by comparing the data to Motor Vehicle Department records.
3. Regarding "those registered to vote who are dead," the Pima County Recorder's Office is informed of a voter's death through multiple sources including newspaper obituaries, the Arizona Department of Health Services, recorded documents and contact with family members. Registrations are cancelled immediately upon receiving reliable information of a person's death. In Pima County, there has been only one incident of a person attempting to cast a ballot for a deceased relative in the past 10 years. That vote was cast by early ballot. The issue was identified during the regular

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signature verification process (the signature on the early ballot affidavit was invalidated during the signature comparison process) and the Pima County Attorney's Office investigated the incident.

4. Finally, although not mentioned specifically by the President, there are instances where a voter may vote by early ballot and then attempt to vote a second time at the polls on Election Day. At that point, the early ballot has usually already been counted. According to state law, any voter who receives an early ballot is required to vote only by provisional ballot at the polls on Election Day. The provisional ballots are sent to the Pima County Recorder's Office to determine validity immediately after Election Day. Any provisional ballots that were cast by people who had already voted by early ballot are disqualified and sent to the County Attorney's Office for investigation. Approximately half of those are submitted by elderly voters who, according to historical investigation information, "forgot" that they voted by early ballot. Others have been either inexperienced voters who were unaware that the early ballot was an actual ballot, or were reported to have been misinformed of the process by poll workers. To date, the County Attorney's office has not filed criminal charges in these instances as the system correctly blocked the second ballot from being counted. The review for the 2016 election is still in process and will not be resolved for several months, as each voter must be contacted directly as part of the investigation.

CHH/dr

Attachment

- c: The Honorable F. Ann Rodriguez, Pima County Recorder  
Brad Nelson, Director, Elections Department  
Chris Roads, Chief Deputy Recorder, Pima County Recorder's Office  
Nicole Fyffe, Executive Assistant to the County Administrator  
Pima County Elections Integrity Commission

## **Step-by-Step Instructions for a Risk Limiting Audit Using the Ballot Comparison Method**

### **Introduction**

The Risk Limiting Audit (RLA) involves comparing the interpretation of ballots by the voting system to human interpretations of the same ballots. Differences between the two interpretations are noted. Determining whether the audit can stop depends on the number and nature of those differences, the number of ballots examined so far, the risk limit, and the vote margin; the smaller the risk limit or the smaller the margin, the larger the number of ballots that must be audited.

The comparison of interpretations can be neutral, an *understatement*, or an *overstatement*, depending on the effect of changing the voting system interpretation of the ballot to match the hand interpretation. Consider the pairwise margin between each winner and each loser in a contest. For instance, a city council election might involve voting for three candidates from a pool of ten, to fill three seats on the council. Each of the three winners can be paired with each of the seven losers, giving twenty-one pairwise margins in that contest. If changing the interpretation of a ballot according to the voting system to make it match the human interpretation of the ballot would widen every pairwise margin in every contest under audit, that ballot has an *understatement*. Understatements do not call the outcome into question. If changing the interpretation according to the voting system to match the human interpretation would narrow any pairwise margin in any contest under audit, the ballot has an *overstatement*. If enough ballots have overstatements, the outcome could be wrong.

Efficient RLAs generally perform ballot interpretation comparisons until there is convincing evidence that the outcome according to a full hand count would agree with the outcome under audit. If convincing evidence is not forthcoming, the audit progresses to a full hand count, which is used to correct the outcome under audit if the two disagree.

Because the mock election will use previously prepared ballots, the exercise will not accurately mimic a real election in all ways. For example, the prepared ballots have no write-ins or overvotes and write-ins can't be added because any such modification will create overvotes that are treated differently than real write-in ballots. The only write-ins that might occur will be from the 300 ballots filled out by EIC members. While overvotes could be added to the mock election ballots, they would not have any effect on the election or RLA because they would just need to be rescanned and assigned new sequential ID numbers.

As this mock election RLA is a pilot study, we do not need to conduct a full audit for all contests. We can select any sample size, but the objective is to obtain an estimate of the time and resources involved in conducting RLAs for larger more realistic elections.

For this mock election, we will begin by conducting a Logic and Accuracy (L&A) test that will consist of about 300 ballots filled out by EIC members. Each member will provide a spreadsheet report of the vote totals in their ballot set. These will be combined to obtain expected tallies for

the full 300 ballot set. These 300 ballots will be added to the general population of 29,699 mock election ballots.

### **Step-by-Step Scanning and RLA Instructions**

**1. Scan ballots and track ballot storage locations.** Scan ballots in batches, imprinting a unique serial number on each ballot. Keep ballots in the order in which they were scanned and create labeled stacks or boxes of scanned ballots with labeling designed so that individual ballots selected during the audit can be retrieved efficiently. If ballots need to be rescanned for any reason, take precautions to rotate the ballot so that the new serial number is not printed on top of an older one. Create a "ballot manifest" that lists how scanned ballots are organized (labeling of stacks, listing the number of ballots in each stack – see Step 7). Write-in ballots must be tracked separately from the general population. Conduct quality control measures to ensure that each stack of ballots contains the number of ballots listed in the manifest. During the audit, ballots will be randomly selected from the ballot manifest. Reconcile the ballot manifest against other accountings of the number of ballots and against poll books to the extent possible. Resolve any discrepancies before the audit begins.

**2. Create a Statement of Votes Cast (SOVC)** or other report or canvass with final vote tallies for each contest.

**3. Create a list of Cast Vote Records (CVRs),** a spreadsheet in which each record specifies how an individual physical ballot was interpreted by the tabulation system. Each record must include the CVR number and the ballot serial number. The audit will compare a sample of physical ballots with the CVRs that correspond to those ballots. The serial numbers on the physical ballots will be used to identify the corresponding CVR.

**4. Validate the CVRs.** Use a program to read the CVRs and tabulate the votes in all the contests contained therein. The results of this process should yield final tallies that are identical to those shown in the SOVC. If they are not, the CVRs and/or the SOVC are inaccurate. However, if the ballot manifest and the CVRs agree on the total number of ballots in each contest, and agree on the winners of each contest, the audit can proceed. In that case, the margin that should be used in the computation below is the margin according to the re-tabulation of the CVRs, rather than according to the SOVC.

**5. Determine the contests to be audited.** The contests to be audited may be determined by state or local laws or they may be selected randomly by agreement among local observers, political parties and election officials. If most of the contests are on the ballots of most precincts in the jurisdiction, there is not much time penalty to pay in auditing all the contests simultaneously. If however, a specific contest involves only a small part of the jurisdiction, it may be more efficient to audit that contest separately.

**6. Determine the size of the initial audit sample.** The initial sample size depends on the "diluted margin" which is the margin of victory in votes divided by the total number of ballots cast in each contest to be audited (not the number of valid votes in a contest). Dividing by the

number of ballots accounts for the possibility of confusing undervotes or overvotes for a valid vote, or vice versa. Go to the [Post-Election Audit Tools Website](#) and follow the instructions to enter contest data. The elections official may instead develop software tools based on the audit model (See Appendix). For purposes of the pilot program, the risk limit setting should be left at 10%.

Illustration: For zero expected over/understatements, the math is simple. The number 4.8 divided by the diluted margin provides the initial sample size for a 10% risk limit:

Diluted Margin	Equation	Initial Sample Size
50%	4.8/.5	10
30%	4.8/.3	16
10%	4.8/.1	48
2%	4.8/.02	240

### 7. Randomly select ballots for the sample:

1. Ask public observers to roll ten to twenty 10-sided dice to generate a “seed” number for a public-source pseudo-random number generator.
2. Enter the seed on the “Random Sampling” section of the [Audit Tools Website](#).
3. Enter the number of ballots in the contest(s) to be audited.
4. Click “draw sample” to select ballots.
5. Each random number corresponds to one ballot. For the mock election RLA the audit tools website can be used to randomly select CVR numbers. Each CVR number corresponds to a unique serial number. The serial numbers should be sorted to identify the set of serial numbers in each box of ballots so that ballot boxes are only visited once.
6. For each serial number, check the CVR to see if the ballot is a write-in, in which case the search for the specific ballot can be limited to the separated write-in subset.
7. Given the selected serial numbers, the ballots are retrieved by a small team of “retrievers.” Insert colored paper as a place-holder for each ballot so that extracted ballots can be easily reinserted after Step 8.

Note: the “ballot manifest” is any tracking tool that facilitates these steps. We are expecting that this will take the form of a spreadsheet that can be sorted, searched, and highlighted.

**8. Compare ballots in the sample with the corresponding CVR entries.** Because risk-limiting audits involve comparing individual ballots to the voting system results for each ballot, the audits do not involve a “tally” or count in the traditional way a 1% manual tally is conducted. That is, a 1% manual tally ballot counters are assembled to tally entire precincts or batches of ballots and compare the hand tally totals to the totals produced by the voting system for the same precinct or batch. For risk-limiting audits, a human eye interpretation of each ballot is compared to the CVR for that ballot as recorded by the voting system, so ballots are not “tallied” or counted up and totaled in the usual manner. Instead, we will track any discrepancies we find.

Compare each ballot as follows:

1. Retrieve the ballots chosen for the sample. Those designated to retrieve ballots should not have access to the CVRs for the ballots they retrieve in order to ensure the integrity of the audit.
2. Retrieve the CVR entry for each ballot using the serial number on the ballot (the highest serial number if there are multiple serial numbers) and determine whether the entry matches the human eye interpretation of the votes on the corresponding ballot. Existing ballot interpretation methods may be used, including local rules for determining voter intent.
3. Ensure public observers have the opportunity to compare the CVR entry with the physical ballot. If the public observers or auditors disagree about the interpretation of the votes on the ballot, record the disagreement in a log of the audit process.
4. Record the interpretation of the vote on the physical ballot as determined by the auditors in the log of the audit process. This will be used if the audit escalates to all ballots.
5. Document and share with the public any differences found between the human interpretation and the voting system interpretation. Keep accurate track of all observed discrepancies and the specific candidates they apply to. Tally the understatements and overstatements, if any; they are needed to size the escalated audit sample, if necessary.
6. Document and share with the public any instances in which one or more public observers disagreed with the comparison.
7. Establish procedures to handle observer challenges to the audit. The public must be allowed to observe, verify and point out procedural problems without interfering with the process.
8. Return each sample ballot to their original boxes.

**9. Stop or escalate the sample size if necessary.** Depending on the number and type of overstatements and understatements found in the initial sample, the audit may need to be expanded to look at more ballots. To determine how many more ballots should be hand tallied, if any, assuming a similar rate of over/under statements:

1. Go to the [Post-Election Audit Tools Website](#) and follow the instructions to determine whether escalation is necessary.
2. If escalation is necessary, the elections official should explain to the public that the audit might lead to a full hand count if significant differences persist.
3. Retrieve the additional ballots, if any, required by the escalation instructions, and continue the ballot interpretation comparison process until either the process terminates (no additional escalation) or all ballots have been compared.

**10. Finish and publish results.** If the audit process terminated before all ballots have been compared (the most likely case), then the outcomes (winners) reported by the tabulation system in the SOVC are accepted. If the process terminated because all ballots were compared, then the set of vote discrepancies observed during the audit and the log of ballot interpretations can be used to adjust the outcomes reported in the SOVC. In this case, the outcomes of the election are those resulting from the audit. In either case:

1. Release the results of the audit to the public and the Secretary of State.
2. Record and report the time it took to conduct the audit, with a breakdown of the time needed to scan ballots compared to the time needed to conduct the RLA.
3. Record and report the cost of the audit.

**Appendix.** Detailed Procedures for the RLA in case someone wants to implement all the steps rather than using the online Audit Tools Website.

1. Validating the CVRs in Step 4. This step requires a program that accumulates ballot selections for each contest. This program will need to be specific to the format of the CVRs or the list of CVRs in spreadsheet form (LVR).
2. Initial sample size in Step 6. The initial sample size is given by the formula:

$$n_0 = -2g \log_e(a) / ((m + 2g(r_1 \log_e(1 - 1/(2g)) + r_2 \log_e(1 - 1/g) + s_1 \log_e(1 + 1/(2g)) + s_2 \log_e(1 + 1/g))))$$

with

m = diluted margin,

a = risk limit,

g = 1.03905,

r<sub>1</sub> = expected rate of 1-vote overstatements per ballot,

r<sub>2</sub> = expected rate of 2-vote overstatements per ballot,

s<sub>1</sub> = expected rate of 1-vote understatements per ballot, and

s<sub>2</sub> = expected rate of 2-vote understatements per ballot.

The diluted margin is the smallest margin in votes, divided by the total number of ballots cast for each contest, including undervoted and overvoted ballots.

The number  $n_0$  is then adjusted to take into account the fact that differences must be round numbers, as follows: The expected number of differences in the sample of each type is  $n_0$  times the expected rate of those differences. The expected numbers are either rounded to the nearest whole number, or rounded up. Then those numbers of discrepancies are plugged into the stopping rule described below, to determine how many ballots would have to be audited if the estimated number of differences of each type were to be observed in the sample. That number is then used once again to estimate the number of differences of each type the sample would contain; the results are rounded to the nearest integer and plugged into the stopping rule a second time. The result is then the starting sample size.

3. Random number generator in Step 7. The AuditTools page implements a good pseudo-random number generator based on the SHA-256 hash function. There are [many other possibilities](#), both programs and servers.
4. Stopping rule and escalation size in Step 9. The stopping rule implements the following formula:

$$\text{stopping sample size} = -2g(\log_e(a) + o_1 \log_e(1 - 1/(2g)) + o_2 \log_e(1 - 1/g) + u_1 \log_e(1 + 1/(2g)) + u_2 \log_e(1 + 1/g)) / m$$

with

m = diluted margin,

a = risk limit,  
 o1 = number of 1-vote overstatements in the sample,  
 o2 = number of 2-vote overstatements in the sample,  
 u1 = number of 1-vote understatements in the sample, and  
 u2 = number of 2-vote understatements in the sample.  
 g = 1.03905, but any value greater than one can be used. For g = 1.03905, a two-vote overstatement increases the sample size by five times as much as a one-vote overstatement. The estimates based on differences continuing to occur at the observed rate are based on the method described above for estimating the initial sample size, including the method of rounding the expected number of differences of each type.

5. Outcome adjustment, if necessary, in Step 10. If the audit goes to a full hand count, the vote totals in the SOVC will need adjustment according to the recorded discrepancies (under-counts and over-counts for each candidate), together with the manual tracking in step 8.4.

### **The January 2017 Mock Election**

The mock election, as originally planned, consists of 29699 ballots, all with the same 6 contests. Since these ballots have already been scanned, we know the official outcomes:

#### Best Picture (vote for 3)

Bridge of Spies	15500
Mad Max Fury Road	17699
The Big Short	16499
The Brooklyn	8200
The Martian	13400
The Revenant	12000
The Room	5000
The Spotlight	799

#### Best Actor in a Leading Role (vote for 1)

Eddie Redmayne	5000
Leonardo DiCaprio	799
Matt Damon	12000
Michael Fassbender	11900

#### Best Actress in a Leading Role (vote for 1)

Brie Larson	5500
Cate Blanchett	5000
Charlotte Rampling	6900
Jennifer Lawrence	5799
Saoirse Ronan	6500

Best Actor in a Supporting Role (vote for 2)

Christian Bale	16900
Mark Ruffalo	10500
Mark Rylance	10500
Sylvester Stallone	7299
Tom Hardy	14199

Best Actress in a Supporting Role (vote for 2)

Alicia Viander	14200
Jennifer Jason Leigh	12699
Kate Winslet	6500
Rachel McAdams	11299
Rooney Mara	14700

Oscars be Funded by the US Government? (vote for 1)

No	14999
Yes	14700

These ballots will be scanned again during the mock election so it is possible that a few ballots will be interpreted differently. There are no undervotes on these ballots.

The diluted vote margin for each of these contests and the corresponding initial sample sizes (for a 10% risk limit and zero anticipated understatements and overstatements) are as follows:

Category	Diluted Margin	Initial Sample Size (4.8/margin)
Best Picture	$(15500-13400)/29699=0.071$	68
Best Actor	$(12000-11900)/29699=0.0034$	1426
Best Actress	$(6900 - 6500)/29699=0.0135$	357
Best Supporting Actor	$(14199-10500)/29699=0.125$	39
Best Supporting Actress	$(14200-12699)/29699=0.051$	95
Oscars Funded by U.S.?	$(14999-14700)/29969=0.010$	480

These 29699 ballots will be augmented with 300 ballots filled out by Commission members. The outcomes (winners) are unlikely to change, but the margins and initial audit sizes may be adjusted slightly.