

VOTING SYSTEMS TEAM REPORT TO THE PILOT ELECTION REVIEW COMMITTEE
MOCK RISK-LIMITING AUDITS IN SELECT UVS PILOT COUNTIES
DECEMBER 17, 2015

A. INTRODUCTION

Colorado law requires county election officials to implement risk-limiting audits (RLAs) in 2017.¹ As a result, this committee's recommendation and Secretary Williams' selection of Colorado's next-generation voting system(s) should depend in part on the ability of the temporarily approved voting systems to support efficient RLAs. Although all pilot counties were required to conduct the statutory post-election audit currently mandated by Colorado law,² the Global Conditions of Temporary Use applicable to all four of the competing voting systems required one pilot county for each piloted system to collaborate with representatives of the Elections Division of the Colorado Secretary of State's office to conduct mock RLAs following the 2015 Coordinated Election.³

Philip B. Stark of the Statistics Department of the University of California at Berkeley is a nationally recognized advocate of and expert in conducting risk-limiting audits in elections. The Secretary of State's office has consulted with Dr. Stark for several years to conduct RLA pilots, and he made a presentation to the Pilot Election Review Committee regarding the topic at its meeting on October 9, 2015. The Secretary of State's office hopes to continue its collaboration with Dr. Stark in the next two years, when we expect to adopt specific rules concerning risk-limiting audits.⁴ We thank Dr. Stark for his assistance and guidance as we continue on the path towards statewide implementation of RLAs in 2017.⁵

¹ Section 1-7-515(2)(a), C.R.S.

² Section 1-7-514, C.R.S.; Colorado Election Rule 11.3.3 (8 CCR 1505-1).

³ Global Conditions of Temporary Use dated October 28, 2015, at ¶ 9 (Retrieved December 15, 2015, and available at <http://www.sos.state.co.us/pubs/elections/VotingSystems/files/2015/20151028GlobalConditionsTempUse.pdf>). We refer to these audits as "mock RLAs" because we focused solely on the piloted voting systems' capacity to facilitate efficient risk-limiting audits. More particularly, our principal concern here was to assess the ability of system users to export ballot-level cast vote records in a non-proprietary, tabular format that is useful, complete, and permits a the independent summation or tabulation of all ballots and votes cast in an election. Due to time limitations, we purposely did not concentrate on other highly recommended and important aspects of risk-limiting audits concerning compliance with legal requirements and business processes that are extraneous to the voting systems themselves. Such important but extraneous features include steps to independently verify compliance with pre-election testing and security protocols applicable to voting system components, chain-of-custody and reconciliation requirements for unused ballot inventories and voted ballots, etc.

⁴ Section 1-7-515(4), C.R.S., requires the Secretary of State to consult with "recognized statistical experts, equipment vendors, and county clerk and recorders," in connection with the promulgation of rules to implement and administer the statutory mandate for RLAs beginning in 2017.

⁵ Due to prior commitments, Dr. Stark was not able to personally participate in or observe the mock risk-limiting audits in the UVS pilot counties. This report should be regarded as the work product of the Voting Systems team of the Colorado Secretary of State's office, and should not be attributed to Dr. Stark in any way.

B. OVERVIEW OF RISK-LIMITING AUDITS

A risk-limiting audit is a method to ensure that, before official results are certified, the hardware, software, and procedures used to tabulate ballots in an election yielded the correct outcome.⁶ The simplest way to conduct a risk-limiting audit is to hand count every ballot cast in the election, and verify that the manual tabulation conforms to the tally generated by the voting system. Although simple in concept, full hand counts of all ballots cast in even relatively small elections are inefficient, because they require a large amount of time and numerous individuals to complete. In addition, any Colorado election official who has observed election judges manually tally their 25 test ballots during logic and accuracy testing knows that hand counts are also frequently inaccurate. These anecdotal experiences are substantiated by a study funded by the National Science Foundation, which showed that the error rate for hand counting is between 1-2%.⁷ In general terms, that error rate is roughly 100 – 400% *higher* than the threshold for an automatic recount under Colorado law.⁸

A risk-limiting audit is more efficient than a full manual recount because it *incrementally* examines and verifies a voting system’s interpretation and tabulation of voters’ markings on paper ballots until the audit yields sufficient evidence that a full and accurate hand count would confirm the original outcome. If the audit yields the sufficient amount of evidence, the audit ends. On the other hand, the audit continues and more ballots are examined for so long as the audit does not produce sufficiently strong evidence of a correct outcome, potentially resulting in a full hand count of all ballots cast in the election.

In RLA parlance, the audit provides sufficient evidence of a correct outcome when the *risk limit* is satisfied or met. The risk limit is the largest chance that the audit will stop short of a full hand tally when the original outcome is wrong. An RLA with a smaller risk limit results in stronger evidence that the original outcome is correct, but also requires the examination of comparatively more ballots than an RLA with higher risk limit. Thus, an RLA with a 1% risk limit will produce stronger evidence of a correct outcome than an RLA with a 10% risk limit, but will require election officials to examine comparatively more ballots, all else being equal.

Unlike most of Colorado’s legacy voting systems, the voting systems piloted during the UVS initiative all capture and generate in some format cast vote records (CVRs) for each ballot tabulated, or “ballot-level CVRs.” A ballot-level CVR shows the manner in which the voting system interpreted and tabulated the voter’s marks on the corresponding paper ballot. Ballot-level CVRs enable auditors to conduct the most efficient type of RLA, called a *comparison audit*.⁹ In a comparison RLA, the election auditors randomly select a paper ballot and then, once the paper ballot artifact is located and retrieved from its secure

⁶ M. Lindeman and P.B. Stark, *A Gentle Introduction to Risk-limiting Audits*, IEEE Security and Privacy, Special Issue on e-Voting Security (Vol. 10, No. 5, September/October 2012), at 42. Retrieved December 15, 2015 from <file:///H:/RLAs/Gentle%20Introduction%20to%20RLAs.htm> [Subsequently cited as “Lindeman & Stark, *A Gentle Introduction*”]

⁷ Rice University. (2012, February 2). Hand counts of votes may cause errors. Science Daily. Retrieved December 15, 2015 from www.sciencedaily.com/releases/2012/02/120202151713.htm

⁸ Section 1-10.5-101(1)(b), C.R.S., requires a recount if “the difference between the highest number of votes cast in [an] election contest and the next highest number of votes cast in that election contest is less than or equal to one-half of one percent of the highest vote cast in that election contest.”

⁹ Lindeman & Stark, *A Gentle Introduction*, at 43.

storage location, compare the voter's markings on the ballot to the manner in which the voting system interpreted and tabulated those markings, as reflected in the corresponding CVR. If the CVR data exactly matches the voter's markings on the paper ballot, the auditors move on to retrieve and review other randomly selected paper ballots for similar verification, until the risk limit is met. Once the risk limit is met, the audit is concluded successfully.

The number of ballots that must be examined in any RLA principally depends on two factors: The risk limit of the RLA, and the smallest margin of the contests being audited. Smaller risk limits and closer margins result in a larger number of ballots being audited; higher risk limits and wider margins result in fewer ballots being examined. Dr. Stark has published an online tool that calculates the number of ballots to be audited and randomly selects the individual ballots to be examined and compared to their corresponding CVRs. The online tool is available at <http://www.stat.berkeley.edu/~stark/Vote/auditTools.htm#>

The mock RLAs were conducted along the following lines:

- The pilot county exported one or more files containing the single-ballot CVRs, in the format supported by the voting system in question.
- We examined the CVR exports from the pilot counties in their native formats, and developed macros to extract and compile the single-ballot CVRs into a single spreadsheet that could be tabulated or summed independently.
- While onsite at the participating pilot counties, we used Dr. Stark's online tools to both calculate the number of ballots to be audited, and to randomly select the ballots to be audited.
 - For purposes of this exercise, we decided to use a risk limit of 10%, and selected Proposition BB (the only statewide contest that appeared on all ballots of the pilot counties) as the contest to audit. We entered the risk limit of 10% and the total votes for and against Proposition BB in each pilot county in the appropriate fields of Dr. Stark's online tool, and the tool calculated the number of individual ballots to examine in order to satisfy the 10% risk limit
 - Dr. Stark's recommended RLA methodology uses an elaborate process for ensuring that the individual ballots to be examined are truly selected randomly. In brief, the auditors randomly select a 20-digit seed number that is then input into a random number generator. The random number generator then specifies, by batch and location within the batch, the individual ballots to be examined during the audit.
- Once the ballots to be examined are randomly selected, election staff of the pilot county retrieved the sealed post-tabulation storage containers with the specified ballot batches.
- County election staff or election judges then counted down through the batch of ballots, to retrieve the randomly selected ballot by its location within the batch. Jefferson County used the imprinting function of the ES&S DS850 scanner to estimate the ballot position in the batch and quickly locate the ballot with the imprinted number.
- Note: We notified the pilot counties in advance that, for purposes of the mock RLAs only, they could use the ballots chosen for the statutory post-election audit, since ordinarily that "universe" of ballots is limited to 500. We provided this guidance because it reduced the number of ballot containers that would need to be unsealed, opened, and resealed during the course of the mock

RLA, but did not impair our ability to evaluate the suitability of the voting systems' CVRs for RLA purposes. Adams and Jefferson Counties chose to use the cast vote records from the complete election to more closely demonstrate how a real risk-limiting audit would be run. The City and County of Denver opted to limit the audit to three actual ballot batches, consisting of a total 634 ballots.

C. MOCK RLAs OF THE PILOTED VOTING SYSTEMS

We observed the following mock risk-limiting audits of the 2015 Coordinated Election:

Pilot Jurisdiction	Voting System Provider	Piloted Voting System	RLA Date
City & County of Denver	Dominion Voting Systems	Democracy Suite 4.19	19 Nov 2015
Jefferson County	Election Systems & Software	EVS 5.2.0.3	20 Nov 2015
Garfield County	Hart InterCivic	Verity Voting 1.0 w/ Data 1.3.3	23 Nov 2015
Adams County	Clear Ballot Group	ClearVote 1.0	24 Nov 2015

Our observations of the separate mock RLAs are set forth on the following pages.

1. City and County of Denver – Dominion Voting Systems Democracy Suite 4.19

The cast vote records from Dominion are in the form of text files:

Name ^	Date modified	Type	Size
 1_1_1_1_RAW.ADJ.DVD.txt	11/10/2015 9:56 AM	Text Document	179 KB
 1_1_1_2_RAW.ADJ.DVD.txt	11/10/2015 9:57 AM	Text Document	182 KB
 1_1_1_3_RAW.ADJ.DVD.txt	11/10/2015 9:56 AM	Text Document	178 KB
 1_1_1_4_RAW.ADJ.DVD.txt	11/10/2015 9:56 AM	Text Document	178 KB

Each text file contains a number of cast vote records. Each cast vote record lists the ballot image file name of the ballot, the contests, and the choices for each contest. The ballot image file name contains the scanner ID, the batch ID, and the position of the ballot within the batch:

```

1_1_1_1_RAW.ADJ.DVD.txt - Notepad
File Edit Format View Help
File contains 211 cast ballots

There were 0 audio sessions, of which 0 were provisional (Initial=0, Published=0, Rejected=0).
Cast ballot: 00014_00001_000121.tif (Scanned ballot)
Results are Published.
Ballot manifestation: 491

Contest: Director At-Large
Vote for = 1, Valid votes = 1, Undervotes = 0, Overvotes = 0
-Robert Speth

Contest: Proposition BB (STATUTORY)
Vote for = 1, Valid votes = 1, Undervotes = 0, Overvotes = 0
-YES/FOR

Contest: Referred Question 1A
Vote for = 1, Valid votes = 1, Undervotes = 0, Overvotes = 0
-NO/AGAINST

Contest: Referred Question 2A
Vote for = 1, Valid votes = 1, Undervotes = 0, Overvotes = 0
-NO/AGAINST

Contest: Referred Question 2B
Vote for = 1, Valid votes = 1, Undervotes = 0, Overvotes = 0
-YES/FOR

Contest: Referred Question 2C
Vote for = 1, Valid votes = 1, Undervotes = 0, Overvotes = 0
-NO/AGAINST

Cast ballot: 00014_00001_000118.tif (Scanned ballot)

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The format of these files does not support an independent summation of the cast vote records. Voting Systems Specialist Danny Casias wrote an Excel macro to open each text file, extract the ballot image file name of the ballot, the contests, and the choices for each contest, and to present the data in a tabular format with the vote totals displayed. Applying the macro to Dominion’s text files yielded the following spreadsheet:

	A	B	C	D	K	L
1	http://www.stat.berkeley.edu/~stark/Java/Html/ballotPollTools.htm			Totals:	30,775	91,209
2				Contests:	Proposition BB (STATUTORY)	Proposition BB (STATUTORY)
3	# of CVRs: 124,119	Sorted CVR List	Batch ID	Position	NO/AGAINST	YES/FOR
4	1	00014_00001_000001	00014_00001	1		1
5	2	00014_00001_000002	00014_00001	2		1
6	3	00014_00001_000003	00014_00001	3		1
7	4	00014_00001_000004	00014_00001	4		1
8	5	00014_00001_000005	00014_00001	5	1	
9	6	00014_00001_000006	00014_00001	6		1

Due to the large number of rows required to store each cast vote record in Excel and limitations on the total number of rows available in Excel, the conversion of the text files had to be performed in many small batches. Denver had 124,119 cast vote records so it took over 6 hours to convert all of the files and combine the results into a single file.

With the scanner ID and batch number available, Denver was able to locate the paper ballots randomly selected for audit by Dr. Stark’s online tool. The paper ballots were then compared to the cast vote records. We did not observe any anomalies or discrepancies when comparing the CVRs to the paper ballots.

Dominion indicated that imprinting a number on each ballot is possible but that the imprinted number may not be captured in the cast vote record.

Conclusions: Dominion’s system captures the ballot-level cast vote records needed to conduct a risk-limiting audit. In its current configuration, however, Democracy Suite 4.19 does not provide an easy way to export the data in a usable format. Ideally, Dominion will agree to further develop the system so that all single-ballot CVRs in the election can be exported quickly and easily into a single file in tabular format that is capable of independent summation. In addition, Dominion should include the ballot style of the ballot in each CVR. Finally, development of a method to imprint the ballot image file name onto the ballot while it is being scanned, and to capture the imprinted number in the CVR export, will also expedite the location of the paper ballot within each batch.

2. Jefferson County – Election Systems & Software’s EVS 5.2.0.3

The ES&S cast vote record export is comprised of 2 separate files – the cast vote record file and the cast vote record table.

The cast vote record file lists the cast vote record number, the ballot style, the contest titles in the header, and the choices in the column for that contest, including undervotes and overvotes:

	A	B	AI	AJ	AK	AL
1	Cast Vote Record	Style	DIRECTOR DISTRICT 3 SCHOOL BOARD	DIRECTOR DISTRICT 4 SCHOOL BOARD	STATE OF COLORADO BB	BALLOT ISSUE 1A
101059	183834	1	Ali Lasell	Tori Merritts	YES/FOR	YES
101060	183835	1	undervote	Amanda Stevens	undervote	YES
101061	183836	1	Kim Johnson	Amanda Stevens	undervote	YES
101062	183837	1	Kim Johnson	Amanda Stevens	NO/AGAINST	NO
101063	183838	1	undervote	undervote	undervote	undervote
101064	183839	1	Ali Lasell	Amanda Stevens	NO/AGAINST	YES

The cast vote record table file lists the cast vote record number, the ballot style, the serial number, and the machine type and serial number. For ballots scanned on the DS850 central count scanner, the serial number is the number that is imprinted on the ballot after the ballot has been scanned – the number is not shown on the ballot image. For a DS200 scanner, the serial number is a random number:

	A	B	C	D	E	F	G	H	I	J
1	Type	Poll Place	Poll Place ID	Style	Style ID	Ballot Style	Disposition	Cast Vote Record	Serial Number	Machine
2	Paper	VOTER SERVICE AND POLLING CENTER	VSPC	1	1	PRODUCTION 001	Valid	150088	166002750	DS850 - 8515040166
3	Paper	VOTER SERVICE AND POLLING CENTER	VSPC	1	1	PRODUCTION 001	Valid	150089	166002751	DS850 - 8515040166
4	Paper	VOTER SERVICE AND POLLING CENTER	VSPC	1	1	PRODUCTION 001	Valid	150090	166002752	DS850 - 8515040166
5	Paper	VOTER SERVICE AND POLLING CENTER	VSPC	1	1	PRODUCTION 001	Valid	150091	166002753	DS850 - 8515040166

Gary VandeStouwe, Technical Director for the Jefferson County Clerk and Recorder’s office, prepared a third file that identified the ballot storage location and position of each ballot by the imprinted serial number:

1	Serial Number	BoxNum	BoxPosition
2069	ee3ce58591d09968	DS200-821	0
2070	f2bf7e2288f3461a	DS200-821	0
2071	f55c196f59372c7c	DS200-821	0
2072	167001416	G1	1
2073	167001417	G1	2
2074	167001418	G1	3
2075	167001419	G1	4
2076	167001420	G1	5
2077	167001421	G1	6

Mr. VandeStouwe then integrated the information from the three files into a single file and supplied it to the Secretary of State's office. Voting Systems Specialist Danny Casias further modified the file, to sequentially number the cast vote records from 1 to 186,136, and to include the choice names and the totals of the votes received:

	A	B	C	D	E	F	AO	AP
21							NO/AGAINST: 57,780	NO: 84,333
22							YES/FOR: 122,683	YES: 95,394
23							overvote: 138	overvote: 61
24							undervote: 5,133	undervote: 5,946
25	# of CVRs: 186,136	Cast Vote Record	Style	Serial Number	BoxNum	BoxPosition	STATE OF COLORADO	BALLOT ISSUE 1A
26	1	82777	6	166008946	P5	1	NO/AGAINST	NO
27	2	82778	6	166008947	P5	2	NO/AGAINST	NO
28	3	82779	20	166008948	P5	3	NO/AGAINST	NO
29	4	82780	6	166008949	P5	4	NO/AGAINST	NO
30	5	82781	6	166008950	P5	5	YES/FOR	NO
31	6	82782	4	166008951	P5	6	YES/FOR	YES

As previously noted, Jefferson County chose to audit the full election. The randomly selected ballots were compared to the corresponding cast vote records. We did not observe any discrepancies between the markings on the paper ballots and the manner in which the voting system tabulated the ballots, as reflected by the CVRs.

The Jefferson County mock RLA demonstrated the value of imprinting the ballots with a unique number, and capturing that number in the CVR. Auditors located the imprinted ballots easily and quickly by finding the expected position of the ballot within the batch, and then confirming the exact ballot by looking for the imprinted number in close proximity. Imprinting also helped when the ballots were stored out of order. For example, the 500 ballots used in the statutory post-election audit had been pulled from other boxes and then stored in a new box after the audit in a random manner. A ballot from this box was randomly selected to be audited and the auditors were able to locate the ballot by looking for the imprinted number. This took substantially longer than the other ballot searches, but without the imprinted number it would have been impossible to locate the ballot.

The Jefferson County audit also demonstrated the value of including the ballot style in the cast vote record. A ballot scanned on a DS200 scanner was randomly selected. The ballot could be located within a box but the random serial number assigned to the ballot prevented the ballot position from being known. With the ballot style information, Jefferson County staff was able to determine that there was only one ballot of that style in the batch, so the ballot could be located. Jefferson County chose not to retrieve or further examine the ballot, out of an excess of caution to preserve voter anonymity. If there were enough ballots of that ballot style in the batch, then a comparison of those ballots with the ballot images would have been made to determine the correct ballot.

Conclusions: ES&S' EVS 5.2.0.3 also captures the ballot-level CVRs necessary to perform a comparison RLA. Like the other systems, though, a user currently cannot quickly and easily export all CVRs in a single file in tabular format. The DS850 (ES&S' central count scanner) demonstrated the value of imprinting a

unique sequential number on the each ballot during the scanning process. In its current state, however, the DS200 scanner does not support an efficient comparative RLAs, because CVRs from ballots scanned on the DS200 are randomized and exported in an order that bears no relationship to the order in which they were actually scanned. This makes associating a particular CVR with a particular paper ballot extremely difficult if not impossible. In preliminary discussions with the Secretary of State’s office, ES&S indicated its willingness to further develop the DS200 so that a county user could disable this CVR randomization feature. Finally, we have several concerns about authorizing counties to purchase the DS200 scanners for use as polling location or central count tabulators. We detail those concerns in part D of this report.

3. Garfield County - Hart InterCivic’s Verity Voting 1.0 with Verity Data 1.3.3

The cast vote records from Hart are in the form of xml files:

Name ^	Date modified	Type	Size
1_0e09cbcd-5fbf-4cd2-9208-6cf20a718313.xml	9/15/2015 11:10 AM	XML File	4 KB
1_0f2e02be-86a2-4303-b368-4fd6dd304a30.xml	9/15/2015 11:10 AM	XML File	2 KB
1_1b322948-68ed-4540-926a-a8a7bbb3b079.xml	9/15/2015 11:10 AM	XML File	2 KB
1_3a035c4d-d244-4ffe-837e-d8685b947cb5.xml	9/15/2015 11:10 AM	XML File	4 KB
1_4450a747-7802-4177-405-086a54b7804a.xml	9/15/2015 11:10 AM	XML File	2 KB

Each xml file contains a single cast vote record. Each cast vote record lists the contests, and the choices for each contest, including undervotes. However, overvoted contests are not flagged as overvoted and the vote totals are not set to 0, meaning that the votes will be included in an independent tabulation of the results if they are not manually found and changed:

```

<?xml version="1.0" encoding="UTF-8"?>
<Cvr xmlns="http://tempuri.org/CVRDesign.xsd" xmlns:xsd="http://www.w3.org/2001/XMLSchema" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
  <Contests>
    <Contest>
      <Name>COLORADO MOUNTAIN JUNIOR COLLEGE DISTRICT FOR BOARD OF TRUSTEES DIRECTOR DISTRICT NO. 6</Name>
      <Id>9479b0d8-95c7-4e1a-85b1-55fcc4bbb461</Id>
      <Options>
        <Option>
          <Name>Patricia M. Chlouber</Name>
          <Id>dc614f40-faf4-4b80-8f99-b5fbec434514</Id>
          <Value>1</Value>
        </Option>
      </Options>
    </Contest>
    <Contest>
      <Name>EAGLE COUNTY SCHOOL DISTRICT RE50J FOR SCHOOL BOARD DIRECTORS DISTRICT A</Name>
      <Id>269a7c68-db9b-4a25-976a-6a92c57a201e</Id>
      <Options>
        <Option>
          <Name>Tessa Kirchner</Name>
          <Id>c615d0de-164f-425f-9374-b19a28c2af43</Id>
          <Value>1</Value>
        </Option>
        <Option>
          <Name>Ryan C. Geller</Name>
          <Id>c27db95c-62cc-4028-a3a3-ad03e78be5a8</Id>
          <Value>1</Value>
        </Option>
      </Options>
      <Overvoted/>
    </Contest>
  </Contests>
  <Contest>
    <Name>COLORADO MOUNTAIN JUNIOR COLLEGE DISTRICT FOR BOARD OF TRUSTEES DIRECTOR DISTRICT NO. 2</Name>
  </Contest>
</Cvr>

```

The format of these files does not support an independent summation of the cast vote records. Voting Systems Specialist Danny Casias created an Excel macro to open each xml file, extract the contests, and the choices for each contest, detect when a contest is overvoted and change the votes from “1” to “Overvote”, and to present the data in a tabular format with the vote totals displayed. Note that batch ID and ballot position information is not included in the xml file or file name, and that Hart purposely randomizes the file name to prevent the cast vote record from being traceable to the paper ballot:

	A	B	C	D	AM	AN
1				Totals:	7	8
2				Contests:	STATE OF COLORADO PROPOSITION BB (STATUTORY)	STATE OF COLORADO PROPOSITION BB (STATUTORY)
3	# of CVRs: 36	Sorted File List	Batch ID	Position	NO / AGAINST	YES / FOR
4	1	1_02252a40-bde9-4bbd-be3f-2d59897e7b88.xml				1
5	2	1_07ce66a9-aa76-41e8-b6ce-f36170d5319f.xml				1
6	3	1_08c59cb1-ee67-438a-aebf-47e054906862.xml				1
7	4	1_0e09cbcd-5fbf-4cd2-9208-6cf20a718313.xml			Overvote	Overvote
8	5	1_0f2e02be-86a2-4303-b368-4fd6dd304a30.xml			Overvote	Overvote
9	6	1_12719242-e703-4a59-9c99-5c8ec658b920.xml				
10	7	1_1b322948-68ed-4540-926a-a8a7bbb3b079.xml			1	

The xml files are exported from the voting system in a zipped file. Garfield County had 11,204 ballots cast in the election and it took about 30 minutes to unzip the files.

The Excel macro was applied to the batch of 11,204 xml files, but after running for 2 hours only about 50% of the xml files had been opened and extracted into Excel. The macro was aborted at that point. At this juncture, we have not been able to extract and aggregate Verity Voting’s CVRs into a single file that can be used to tabulate all votes in the election independent of the voting system itself.

Hart representatives proposed and demonstrated alternative method for conducting a risk-limiting audit in Garfield County. In order to independently tabulate the cast vote records, Hart recommended printing out and manually tabulating the individual, single-ballot cast vote records, and comparing the resulting manual tally to the summary results report generated from Verity. Hart showed Garfield County election staff how to print each of the individual CVRs corresponding to the 500 ballots examined during the statutory post-election audit. We decided against asking the assembled election judges to manually tabulate the individual CVRs. That exercise would have required a substantial amount of time, and the paper ballots themselves already had been hand counted during the statutory post-election audit.

Hart then demonstrated how to use Dr. Stark’s on-line tool to determine the number of ballots to audit, and the location of those ballots in the applicable ballot batches. Two election judges located the randomly selected paper ballots and compared them to the corresponding ballot images displayed in Verity Central. We did not observe any discrepancies between the manner in which Verity Count tabulated the voters’ markings as reflected in the ballot images, and the voters’ markings on the paper ballots themselves.

Although comparing a paper ballot to the corresponding ballot image is fairly straightforward in Verity Voting, as far as we can determine auditors cannot directly compare a paper ballot to its corresponding CVR, because Verity Voting randomizes all individual CVRs. Hart asserts randomization is necessary to preserve voter anonymity. We believe randomization precludes an efficient comparison RLA based on

CVRs rather than ballot images, and is only one of many ways for a county to ensure that audited ballots cannot be traced to the voters who cast them.

Conclusions: Verity Voting 1.0 captures ballot-level CVRs necessary for RLAs, but currently the CVR data is difficult to extract in a format that supports an efficient RLA. Ideally, Hart will further develop Verity Voting to enable a user to export all cast vote records in a single file in tabular format. This would obviate the need and time required to unzip and convert the records. In addition, Hart should include batch ID and ballot position information in the CVR export itself, rather than requiring auditors to compare a paper ballot to the corresponding ballot image, and then trace the ballot image to the CVR. We also recommend that Hart include the ballot style of each ballot in the CVR export, to assist in identifying the randomly selected ballot if the original order of the scanned ballots is not maintained. Further, a method of imprinting the ballot image file name onto the ballot while it is being scanned would help in locating the ballots faster and with more confidence. Finally, we have several concerns about authorizing counties to purchase the Verity Scan device for use as a polling location tabulator and a central count solution. Those concerns are set forth in more detail in part D of this report.

4. Adams County – Clear Ballot Group’s ClearVote 1.0

The Clear Ballot cast vote records are comprised of 5 separate files – the choices file, the contests file, the cvr file, the parties file, and the precincts file. For the UVS pilot only the choices, contests, and cvr files were used:

Name ^	Date modified	Type	Size
 Coordinated_Election_2015.choices.csv	11/23/2015 9:07 AM	Microsoft Excel Com...	4 KB
 Coordinated_Election_2015.contests.csv	11/23/2015 9:07 AM	Microsoft Excel Com...	3 KB
 Coordinated_Election_2015.cvr.csv	11/23/2015 9:07 AM	Microsoft Excel Com...	17,075 KB
 Coordinated_Election_2015.parties.csv	11/23/2015 9:07 AM	Microsoft Excel Com...	1 KB
 Coordinated_Election_2015.precincts.csv	11/23/2015 9:07 AM	Microsoft Excel Com...	7 KB

The choices file lists the ChoiceID, the ContestID, and the ChoiceName:

	A	B	C
1	ChoiceID	ContestID	ChoiceName
2	1	2	Yes/For
3	2	2	No/Against
4	3	14	Yes
5	4	14	No
6	5	12	Yes
7	6	12	No

The contests file lists the ContestID, and the ContestName:

	A	B
1	ContestID	ContestName
2	2	Proposition BB (STATUTORY)-STATE OF COLORADO
3	4	1A-ADAMS COUNTY
4	6	2H-BENNETT
5	8	2J-AURORA
6	10	2K-BRIGHTON
7	12	2L-BRIGHTON

The cvr file lists the BallotID, BallotStyleID, and the choices in numerical order. The BallotID includes the batch ID (i.e., "AB-001") and the scan number of the first page of each ballot. A header card is run for each batch so the first page of the first ballot is "10003":

	A	B	C	D	E	F	G	H	I	J	K
1	BallotID	PrecinctID	BallotStyleID	Status	Remade	Choice_1_1	Choice_2_1	Choice_3_1	Choice_4_1	Choice_5_1	Choice_6_1
2	AB-001+10003	780	21	0	0	1	0				
3	AB-001+10005	782	21	0	0	0	1				
4	AB-001+10007	875	32	0	0	1	0				
5	AB-001+10009	927	48	0	0	0	1				
6	AB-001+10011	927	48	0	0	1	0				
7	AB-001+10013	937	50	0	0	1	0				
8	AB-001+10015	993	47	0	0	1	0	0	1		

The information contained in the cvr file does not support an easy identification of the contests and voting choices by name without referencing information contained in the choices and contests file. Voting Systems Specialist Danny Casias created an Excel macro to consolidate the information in the three files into a single file. Columns are added to number the cast vote records and to show the batch ID and position within the batch. Rows are added to show the choice names, the contest ID, and the contest names:

	A	B	C	D	F	I	J	K	L	M	N
1				Contest:		Proposition BB (STATUTORY)-	Proposition BB (STATUTORY)-	2N-	2N-	2L-	2L-
2				Contest ID:		STATE OF COLORADO	STATE OF COLORADO	THORNTON	THORNTON	BRIGHTON	BRIGHTON
3				Choice:		2	2	14	14	12	12
4				Total Votes:		Yes/For	No/Against	Yes	No	Yes	No
5						48,261	23,719	11,903	5,499	5,211	2,018
6	CVR #	Batch	Position	BallotID	BallotStyleID	Choice_1_1	Choice_2_1	Choice_3_1	Choice_4_1	Choice_5_1	Choice_6_1
7	1	AB-001	1	AB-001+10003	21	1	0				
8	2	AB-001	2	AB-001+10005	21	0	1				
9	3	AB-001	3	AB-001+10007	32	1	0				
10	4	AB-001	4	AB-001+10009	48	0	1				
11	5	AB-001	5	AB-001+10011	48	1	0				
12	6	AB-001	6	AB-001+10013	50	1	0				
13	7	AB-001	7	AB-001+10015	47	1	0	0	1		

Note that because the cvr file is sorted by ChoiceID, the order of the contests does not necessarily follow the order of the contests on the ballots unless the election is programmed that way. This makes it difficult to verify the cast vote record when the results are read from the ballot because an auditor must scroll horizontally to locate the contest being read. Alternately, it is easier to read the results off of the cvr and search for the contest on the ballot.

The paper ballots were compared to the cast vote records without any discrepancies. To assist in locating a ballot in a batch, Clear Ballot supplies a utility that allows the scanner to count to a number and then stop. This method was used to locate many ballots in batches of up to 300 ballots.

The value of including the ballot style with the cast vote record was also proven in the audit. On several occasions, the ballot identified solely by its position within the batch did not correspond to the cast vote record. By comparing the ballot style of the retrieved ballot to the sequence of ballot styles around the chosen cast vote record, it was possible to determine that the count was probably off by one, and that the search should be redone.

Clear Ballot indicated that imprinting a number on the ballot is possible with the two of the high-end Fujitsu scanners, but is not supported on the lower-priced scanners. Whether the voting system can capture an imprinted number in the CVR is an open question.

Conclusions: Clear Ballot captures the ballot-level CVR data needed to conduct a comparison RLA. Like the other systems, Clear Ballot needs to provide an easier method to export all ballot-level cast vote records in a single file in tabular format that includes the choices and contest names. The export should list contests in the order in which they appear on the ballots.

D. RECOMMENDATIONS

All of the piloted systems capture the ballot-level cast vote records needed to conduct comparative risk-limiting audits. As currently configured, however, none of the voting systems provide county election officials with an easy way of exporting all ballot-level CVRs in a single file in tabular format that can be independently summed outside of the voting system. Since Colorado is the only state in the country to mandate statewide implementation of risk-limiting audits, it is not surprising that the piloted voting systems do not provide all of the CVR data in exactly the format we desire and believe is necessary. But for county election staff to successfully implement comparison risk-limiting audits on a statewide basis in 2017, Colorado's next generation voting system(s) should enable election officials to export all ballot-level CVRs for any given election in a tabular format and a single file. Requiring county election staff to run macros against multiple files to extract the data and compile a single spreadsheet is far from ideal and exposes the entire audit to human error. We therefore recommend that Secretary Williams condition his selection of one or more voting systems on written commitments by the selected provider(s) to develop, without additional expense to the acquiring counties, non-randomized CVR exports with specified contents in specified formats, by a date certain, to enable the counties that acquire the new system(s) to efficiently conduct comparative risk-limiting audits by the 2017 Coordinated Election.

We further recommend that the Secretary carefully consider whether ES&S' and Hart's polling location scanners – the DS200 and Verity Scan, respectively – are suitable for use in Colorado after 2016 as central count scanners. ES&S has recommended the DS200 as the central count solution in Tier 2 and 3 counties (i.e., the 49 counties with fewer than 25,000 active electors), and Hart recommends Verity Scan as the central count solution for Tier 3 counties (i.e., the 35 counties with fewer than 10,000 active voters). Both systems currently randomize the CVRs, and both are designed to operate on top of closed ballot boxes, into which ballots are automatically deposited immediately after being scanned. This makes it difficult or impossible for election judges to ensure the ballots are stacked within the ballot box in the same order as they are tabulated. If selected, these providers should be required to demonstrate that table top deployment of these scanners in central count locations is an effective workaround to maintaining the

scanning order of the ballots. In addition, the Secretary should prohibit the use of DS200s and Verity Scans **as polling location tabulators**. In the polling location context, the devices *should* operate on top of their proprietary ballot boxes, which means there will be no way for election judges to preserve the scanning order of the ballots for purposes of the RLA. In practical terms, this prohibition will require ES&S and Hart counties to instruct in-person voters to deposit their voted ballots in sealed, non-proprietary ballot boxes, which must then be delivered by teams of election judges to the central count location, where counting judges can ensure that the ballot scanning order is preserved.

Respectfully submitted,

Voting Systems Team
Elections Division
Colorado Secretary of State