



Voting System Anomaly Root Cause Analysis Template v2.0

Root Cause Analysis for:

**VV40ECT-99: UNDERVOTE APPEARED IN VxSCAN
VxSUITE, VERSION 4.0 AND EAC CERTIFICATION #VXS4**

**VOTINGWORKS
548 MARKET ST, STE 53001
SAN FRANCISCO, CA 94104-5401**

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Introduction

This RCA documents a single undervote anomaly detected during the standard 104 hour test of continuous operation with Element and SLI Compliance, according to test requirements VVSG 2.7-B and 2.7-C. No undervotes were expected, since the pre-filled ballots used in the test were known to have no undervotes. It was important to investigate the rare issue, because it was originally hypothesized to be connected to a VxCentralScan test methodology anomaly involving rescanning imprinted ballots but then was shown to be a separate issue with VxScan. Identifying the root cause would prevent similar tallying issues arising in elections.

Anomaly Description

Complete all sections. Descriptions must be as detailed as possible, while being clear and concise since the anomaly is the source of the entire RCA. This detail should include a complete list and/or description of the “symptoms” of the anomaly and the conditions present which the symptoms occurred.

<u>Date of Anomaly:</u> April 10, 2025	<u>Time of Anomaly:</u> 9:29pm
<u>Place of Anomaly:</u> Element, Longmont, CO	<u>Person identifying Anomaly:</u> Tabitha Lehman, VotingWorks
<u>Expected Results of actions leading up to anomaly:</u> The 104 hour test was to be set up according to standard procedures, including a VxScan unit for scanning hand-marked paper ballots individually and two VxCentralScan units for rapidly scanning batches of these ballots. All test reports and vote tallies each hour were expected to align exactly with pre-determined counts using this methodology. No undervotes were expected at any time if following appropriate procedures for use and maintenance.	

EAC (Election Assistance Commission) Root Cause Analysis

Detailed description of the event / anomaly:

A single undervote was identified in a tally report on the fourth day of testing. Investigation revealed it came from a VxScan scan, and it was not reproducible using the same ballots or scanner in the test environment at Element.

If the anomaly is repeatable, provide step by step instructions to recreate it:

Although this is not easily repeatable, separate investigations outside the 104 hour test chamber revealed that this anomaly could be reproduced more reliably by intentionally introducing skew into the ballot scan, such that it will not be rejected but also will sometimes cause an undervote:

- Intentionally miscalibrate the scanner hardware against manufacturer recommendations. This would make the infeed gap changed from production, where the gap size on the left of the infeed is different from the gap on the right.
- Feed ballots into the scanner multiple times until it is accepted and an undervote is detected.

Chronology of Events / Timeline

Provide a detailed chronology of the events leading up to, and following, the anomaly. Add additional events if necessary.

ID	Date/Time	Description	Entity Org/person	Result / Notes
1	4/7/25, 8am Mountain Time	104-hour continuous operation test begins, starting according to original plans, including VxCentralScan units scanning and imprinting the same ballots up to 4x in different orientations.	Chris Pedersen, VotingWorks	No tally issues or overvote problems detected at the start. VxCentralScan had no reported issues. Issues were reported with VxMark ballots not being scanned properly with VxScan, which was resolved and is covered in another Root Cause Analysis document. The 104-hour test procedure was then updated to scan VxMark ballots with VxCentralScan 1x each, while continuing to scan the other pre-filled hand-marked paper ballots 4x each. Later an overvote anomaly would be detected on VxCentralScans, also discussed in another RCA, but unrelated to the anomaly in this RCA.

EAC (Election Assistance Commission) Root Cause Analysis

2	4/10/25, 9:29pm	A single undervote anomaly was reported by testing staff on the fourth day of tests. Ballots were inspected for causes.	Tabitha Lehman, VotingWorks	<p>An undervote was found in a tally report for a proposition ("Proposition 2"). Inspecting the ballots found nothing wrong. The VxCentralScan units were cleaned.</p> <p>Further investigation found that VxCentralScan did not misread any ballots, but that the undervote was scanned by VxScan. The CVRs were obtained and shared with VotingWorks staff to analyze.</p>
3	4/11/25, 7:26am	The ballots, CVRs, and test reports around when the undervote occurred were analyzed.	Tabitha Lehman, Matt Roe, VotingWorks	<p>The timeline when the undervote occurred was narrowed down to between two reports on 4/10 between 6:34pm and 8:18pm. The CVR for the individual undervote was identified as the ballot scan with ID number 92cd4414-fb5d-4a62-9c5e-701e651c8b75. An interpretation debugger reproduced the same behavior on the CVR image.</p>
4				
5				

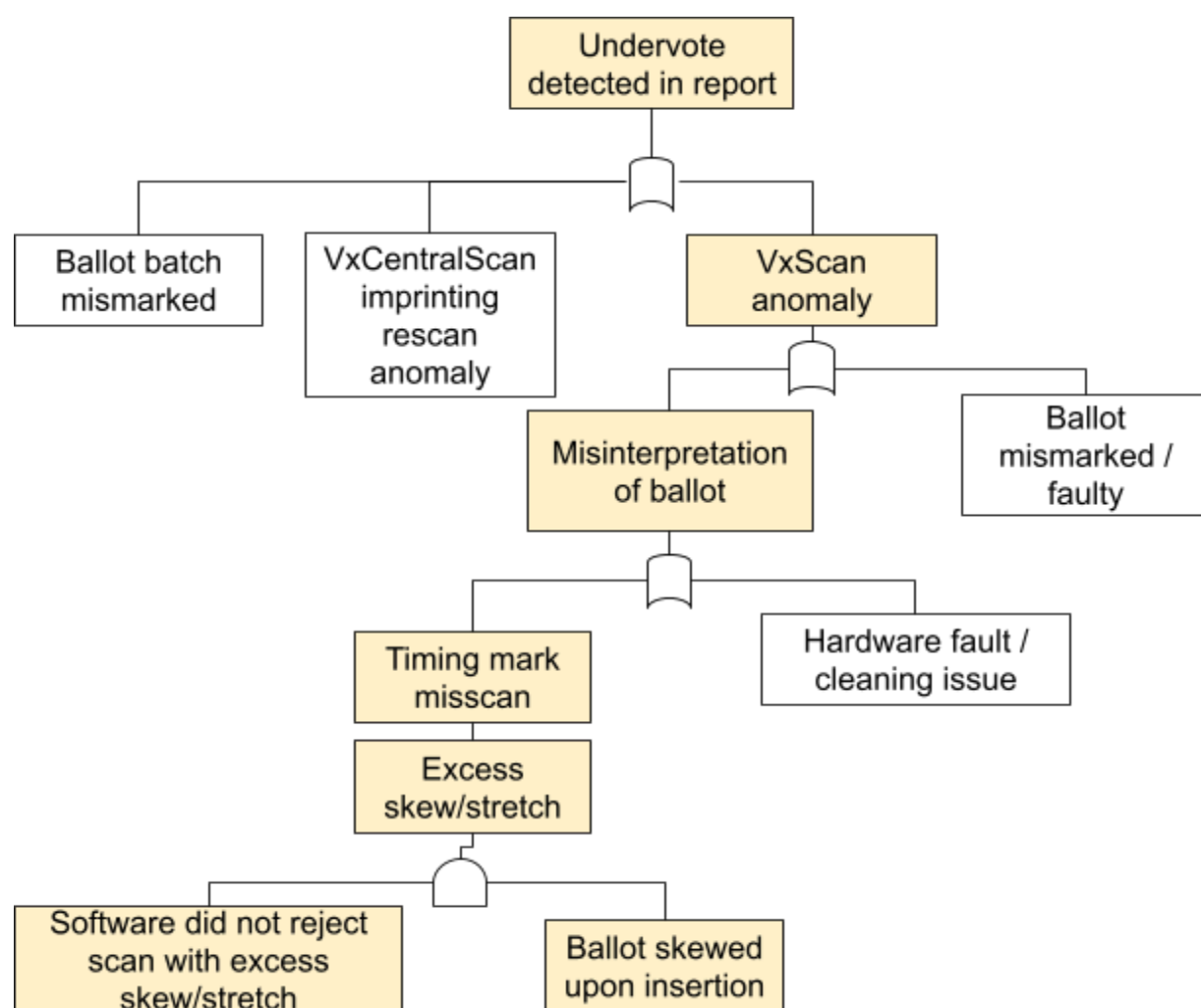
Investigative Team and Method

This section shall describe how the investigative team is assembled by the voting system manufacturer, who it consists of, and how it gathers the data to be used in the analysis. Include the RCA method employed by the manufacturer in conducting the analysis and why this method was used.

Names and Positions of members of the investigation team:
Tabitha Lehman - Customer Success Manager
Matt Roe - Head of Product
Brian Donovan - Software Engineer
Describe the data gathering process:
<p>Tabitha Lehman was present in-person at Element with SLI Compliance during the 104-hour test when this undervote anomaly was reported. She initially analyzed ballots, CVRs, and tally reports, and shared data with the remote VotingWorks team, narrowing down causes related to specific scans on VxScan rather than the ballot sheets themselves.</p> <p>Matt Roe joined the investigation to analyze logs and CVRs with specialized debugging tools, identifying the single undervote scan in question and tying it to interpretation of an unusually skewed scan. After reproducing the issue in a separate test system by forcing improper amounts of skew via scanner hardware miscalibration, he coordinated plans to continue mitigations with the wider VotingWorks team. Brian Donovan also joined at this point to discuss the skew/stretch measurement capabilities of the current production app software and Hardware Test Utility, and discussed plans to adjust both.</p>

Describe which methodology(s) is used to conduct the root cause analysis:

The investigation began with a basic fault tree analysis, analyzing potential fault branches across the different scanner devices under test (VxScan, VxCentralScans). Test methodology was investigated first due to another anomaly previously arising involving test methodology with VxCentralScan, but this was eliminated as a possibility as only VxScan reports were identified as involved. As fault paths were eliminated as possibilities, the logs and CVRs associated with the undervote were analyzed and led to a focus on interpretation of unusually skewed ballots in VxScan. A simplified version of the fault tree analysis diagram is shown below, with the identified root cause fault path highlighted:



Drilldown into these fault paths using the “5 Why’s” technique further led to identifying root causes, detailed in the key findings below. The question “Why did the software not reject a scan with excess skew/stretch?” in this case led to further questions that pointed to a need for more data to better define and identify such ballots with excess skew/stretch.

Findings and Root Cause

Describe the findings of the investigation and explain the root cause(s) based on these findings. If the RCA results in findings that are not directly related to the root cause of the anomaly, these should also be captured as manufacturer product/process improvement steps in an effort to improve the voting system.

Key findings in the investigation were as follows:

- One single ballot scan was identified as causing the undervote (Ballot ID number: 92cd4414-fb5d-4a62-9c5e-701e651c8b75), images of both sides shown below:

Test Ballot
104th Test
March 31, 2025
Longmont, Colorado

Instructions
To Vote:
To vote, completely fill in the oval next to your choice.

To Vote for a Write-in:
To vote for a person whose name is not on the ballot, write the person's name on the "Write-in" line and completely fill in the oval next to the line.

Contest One (1)
Vote for 1
1 year

- ☐ Austin Abrams
- ☐ Beatrice Bagbins
- ☒ Cary Comiskey
- ☐ Dominica Dan

Contest Two (2)
Vote for 1
2 years

- ☐ Wilhelmina Wu
- ☐ Xavier Ximenez
- ☒ Yvette Young
- ☐ Zara Ziegler

Proposition One (1)
This is the description of Proposition 1. The quick brown fox jumps over the lazy dog.

- ☒ Yes
- ☐ No

Proposition Two (2)
This is Proposition 2. Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua.

- ☒ Yes
- ☐ No

Page 1/1
You have completed voting.


Election: b1a3229f Ballot Style: 1 Precinct: Test Precinct Language: English

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- The marked ballot paper itself was not a contributor to the issue, as rescanning it did not reproduce the issue.
- Debugging tools showed that this set of scan images had detected bubbles offset from the actual bubble positions. (See image below, "Proposition Two," green rectangles overlaid on top of ballot bubbles.) This led to an incorrectly detected undervote for the single contest, as a bubble was misidentified as empty.

EAC (Election Assistance Commission) Root Cause Analysis

Expected Bubble Score: 100%
Matched Bubble Score: 100%
Bubble Match Score (100% = perfect alignment)
Bubble Fill Score (0% = no fill, 100% = perfect fill)




Test Ballot


104hr Test
March 31, 2025
Longmont, Colorado

Instructions

To Vote:
To vote, completely fill in the oval next to your choice.



To Vote for a Write-in:
To vote for a person whose name is not on the ballot, write the person's name on the "Write-in" line and completely fill in the oval next to the line.



Contest One (1)

Vote for 1
1 year

<input type="radio"/>	Austin Abrams	90.00%
<input type="radio"/>	Beatrice Baggins	0.29%
<input type="radio"/>	Cary Comiskey	69.42%
<input type="radio"/>	Dominica Dan	0.38%

Contest Two (2)

Vote for 1
2 years

<input type="radio"/>	Wilhelmina Wu	73.85%
<input type="radio"/>	Xavier Ximenez	0.29%
<input type="radio"/>	Yvette Young	75.10%
<input type="radio"/>	Zara Ziegler	78.85%

Proposition One (1)


This is the description of Proposition 1. The quick brown fox jumps over the lazy dog.

<input checked="" type="radio"/>	Yes	69.33%
<input type="radio"/>	No	57.98%

Proposition Two (2)

This is Proposition 2. Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua.

<input type="radio"/>	Yes	71.15%
<input type="radio"/>	No	0.19%



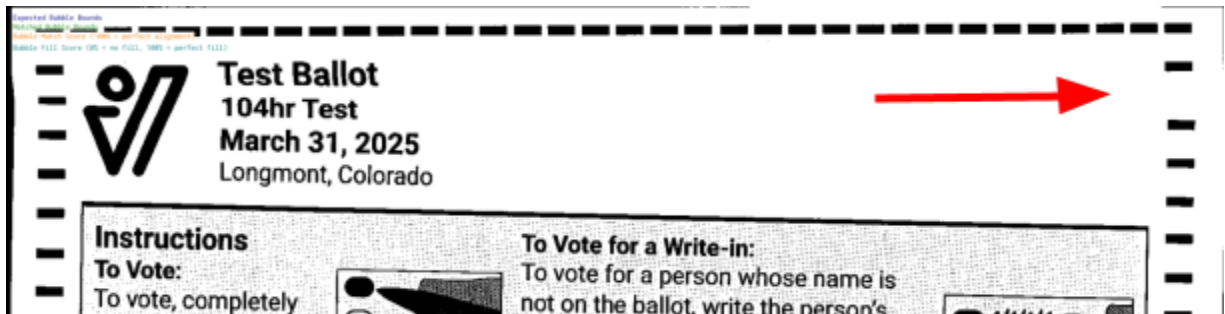
Page
1/1

You have completed voting.

Election: b1a32b9 Ballot Style: 1 Precinct: Test Precinct Language: English

EAC (Election Assistance Commission) Root Cause Analysis

- The underlying problem causing the bubble misalignment was a missing timing mark near the upper right corner of the front side. Note that the 3rd row of timing marks in the image was misscanned with a gap on the right side (see image below). This led to misalignment of the underlying bubble grid interpretation.



- The misscanned timing mark was due to uneven skew and stretching, which can happen rarely when ballots are inserted skewed or gripped unevenly, or if the scanner itself needs mechanical calibration of the infeed gap to grip ballots evenly. The lack of reproducibility rescanning ballots pointed to ballot handling causing the skew.
- Software is expected to reject ballots with excess skew, stretching, or misscanned timing marks.

The root cause of the undervote was a combination of two factors:

- Excess skew and stretch of the ballot scan image, due to uneven ballot insertion or ballot handling, and
- Software acceptance of the ballot scan with the misscanned timing mark.

Corrective Action(s)

The following corrective actions were identified in software and hardware:

- Prevent the issue at the software level by more reliably rejecting mis-scanned ballots with excess stretch/skew, and logging stretch/skew characteristics for diagnostic or maintenance purposes.
- Prevent the issue at the hardware level by adjusting the bracket holding in the scanner to help prevent the scanner gap falling out of calibration.

In order to achieve these corrective actions, the following has started:

- Procedures for more reliably reproducing and analyzing the issue were defined, given the initial rarity. This involves purposely mis-calibrating scanner hardware in a testing environment to induce skew/stretch similar to that seen in this anomaly.
- Hardware Test Utility software updates were defined, to better analyze skew and stretch characteristics of scans more efficiently than in the production app.
- Test plans have been made to measure ballot skew/stretch characteristics at different states of scanner hardware calibration. The production app will be updated to better reject ballot scans with excess stretch/skew based on this data, and from adjusting a feature that could introduce misinterpretation of the timing marks. Details on this are below.

Software Mitigation Plans

The undervote was due to misidentifying the timing mark grid, causing the interpreter to look for the bubbles in the wrong location. The grid was incorrectly identified and accepted as valid because the interpreter will attempt to infer missing timing marks, and inferred a timing mark in the stretch gap between the real timing marks on the right side near the top of the sheet's front side. This essentially caused all the timing marks below the 2nd timing mark on the right side to be off by one, causing greater alignment errors in bubble finding the farther to the right the bubbles were.

Inferring timing marks was necessary on the top (for inverted ballots) and bottom edges of the scanned sheets because of our support for interpreting AccuVote ballots which use the presence & absence of bottom timing marks as bits for encoding ballot configuration. To prevent this issue in the future, we should stop inferring timing marks on the left and right edges and likely stop inferring them at all. We intend only to support ballots with a complete timing mark grid and using a QR code to encode ballot configuration. Had this mitigation been in place, the gap between the 2nd and 3rd timing marks would have remained and the ballot would have been rejected due to being overly stretched according to our existing thresholds for measuring stretch

Solution Management

The purpose of this section is to manage the corrective action(s) moving forward. This should detail all process changes to manage those corrective actions, and steps taken to ensure the actions eliminate the anomaly over time.

Management of the corrective actions spans three areas:

Testing and Product Quality:

- A dedicated cross-functional team was formed to further investigate and monitor the issue across software and hardware.
- Skew and stretch metrics that are already collected in the production software app will be incorporated into an updated Hardware Test Utility. The required materials and procedures for using this utility will be defined, including the appropriate test ballots.
- Research is planned to collect more data to inform product design. Data will be collected to measure how different factors influence the stretch/skew characteristics of ballot scans. These factors include various states of scanner hardware calibration (i.e. scanner infeed gap calibration), vibration, hardware manufacture batch, scan numbers, time, etc. Further analysis will link the resulting stretch/skew characteristics to how often they lead to tallying anomalies, such as undervote anomalies.

Hardware Design and Production:

- Procedures for detecting scanner infeed gap calibration issues in the production process will be refined. This supplements the existing processes for identifying hardware issues in the quality control process. It also supplements the existing infeed design features that prevent skewed insertion of ballots.

Software Design and Maintenance:

- Production software is planned to be updated in v4.0.2 to incorporate better data-driven rejection of ballots with excess stretch/skew.