Voting System Anomaly Root Cause Analysis Template v2.0

Root Cause Analysis for:

VV40ECT-101: VxScan Internal Connection Problem Printer is Disconnected - Rev. 2 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 an instance of the VxScan precinct scanner failing to scan and displaying an error indicating, "Internal Connection Problem: Printer is disconnected," 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. This is a programmed error message, and it occurred after 6,100 scans, 61 hours into the test.

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.

Date of Anomaly: April 9, 2025	Time of Anomaly: 10:13pm
Place of Anomaly: Element, Longmont, CO	Person identifying Anomaly: Tabitha Lehman, VotingWorks
Expected Results of actions leading up to anomaly: The VxScan unit would allow scanning and printing as normal with no error messages. The 104 hour test was to continue without issue, with no errors expected to occur if following appropriate procedures for use and maintenance. No reboots were expected to be needed.	
Detailed description of the event / anomaly: After scanning 6,100 ballot sheets, the VxScan unit displayed the error message, "Internal Connection Problem" with subtitles of "Printer is disconnected. Please ask a poll worker for help." The unit then functioned as expected when error messages are displayed, by not allowing scanning or printing until the error was resolved, but allowing access to settings and administrative actions. A reboot of the unit resolved the error and allowed normal function again.	

If the anomaly is repeatable, provide step by step instructions to recreate it:
This anomaly is not reliably repeatable in operational conditions. Printer disconnection errors that resolve on reboot occur because of transient data disconnections detected in software. These rare data disconnections could be due to unpredictable electrical or mechanical disturbances during operation.

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.	Chris Pedersen, VotingWorks	No connection issues reported for VxScan unit. Test methodologies changed in the first hours due to VxMark ballots not scanning through VxScan. The new revised methodology would have VxScan only scan the regular pre-filled hand-marked paper ballots throughout this test.
2	4/9/25, 10:13pm	VxScan unit is reported to have displayed an "Internal Connection Problem" and "Printer is disconnected" message and would not scan.	Tabitha Lehman, Jessica Myers, Matt Roe VotingWorks	VotingWorks staff reviewed the known documented causes of this, as either: ● Wrong image installed on VxScan ● Temporary software disconnection requiring reboot, with no hardware issues ● Hardware disconnection of wiring internally requiring physical reconnection
3	4/9/25, 10:51pm	VxScan was rebooted, and the issue was resolved.	Tabitha Lehman, VotingWorks	Logs were collected from the test unit to analyze.
4	4/11/25, 12pm	VotingWorks staff analyzed logs from the anomaly and reviewed potential root causes. Hardware issues were ruled out.	Arsalan Sufi, Jesse DeWald, Jonah Kagan, VotingWorks	The symptoms seen ruled out various hardware causes, except rare transient ones. The software was analyzed to understand its behavior when reacting to disconnection. It was noted that the original error message was not obtained in software logs.

5	4/17/25	Error logging was updated to report printer status error messages when it does not reconnect.	Jonah Kagan, VotingWorks	Printer code functionality was updated to report more details if reconnection attempts do not work. Details of the software update are in the [pull request linked here]().

6	5/23/25	VotingWorks was able to reproduce the observed behavior in the anomaly using a specific OS-level rapid disconnect and reconnect.	Arsalan Sufi, VotingWorks	Anomaly behavior was reproduced by issuing the following commands to the printer on a development VxScan, where '3-4' is the thermal printer's device string:
				
				`echo '3-4' | sudo tee /sys/bus/usb/drivers/usb/unbind`
				
				`sleep 1`
				
				`echo '3-4' | sudo tee /sys/bus/usb/drivers/usb/bind`
				
				Analysis of this reproduction confirmed that the VxScan application code still works as intended for physical disconnects, and the root cause lay in an underlying Node of Linux USB library.

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
Jessica Myers - Head of Compliance
Matt Roe - Head of Product
Arsalan Sufi - Head of Software
Jesse DeWald - Head of Hardware
Jonah Kagan - Software Engineer

Describe the data gathering process:

Tabitha Lehman and Jessica Myers coordinated the initial data collection and communications at Element with SLI Compliance, as they were present in-person during testing. Tabitha first learned of the issue and shared information with VotingWorks staff.

Matt Roe, Arsalan Sufi, and Jesse DeWald joined the investigation from afar to find root causes. Matt shared the known procedural solutions of rebooting or physically reconnecting disconnected cables. Jesse presented more detailed potential hardware causes for the error, and Arsalan discussed the potential software causes. Jonah joined the investigation after it was known that a reboot resolved the issue, to plan out further software mitigations.

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

The investigative team used a fault tree analysis strategy to identify the root cause. It was known that the pre-programmed error only occurred from a limited number of causes, either:
1. wrong software was installed/imaged on the unit, or
2. a physical disconnection of the printer occurred, or
3. a transient USB data disconnection occurred.
It was known that the software was correctly installed, so fault branch #1 was ruled out.

Fault branch #2 discussed hardware causes. A printer disconnection error only would occur if:
1. the 10 pin connector to the printer came loose at the computer connection (but the card reader error should show instead, as they're on the same header and it takes precedence), or
2. the printer cable at the printer came loose (but a reboot would not fix this), or
3. the power supply to the printer had a fault or came loose (but a reboot would not fix this).
None of these hardware causes were consistent with the evidence (explained in parentheses above), and so more transient faults in the USB data connection were considered.

Fault branch #3 discussed a rare transient disconnection of the USB data stream while there is no physical disconnection. Further analysis was done in-depth on how to reproduce this disconnection by manipulating software below the regular VxScan application layer. The software then follows the standard error recovery protocol to require a reboot before reconnecting without issue.

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.

The investigative team received logs for the VxScan unit that presented this issue during the 104 hour continuous operation test. Analysis of the logs identified a printer disconnection error aligned with the reported anomaly. A restart confirmed no physical disconnection.

Analysis of the logs also confirmed that the behavior found in testing aligns with rare behavior previously identified during internal testing of the thermal printer subcomponent where USB disconnections occur without a physical disconnection. The VxScan application code attempts to reconnect to the thermal printer if the connection ever drops. We manually verified that this reconnection logic works properly when a VxScan is opened up and (1) the printer USB cable is detached and reattached, or (2) the printer power supply is turned off and back on. During the continuous operations test anomaly, however, this reconnect was attempted but failed, and an internal connection error persisted on screen. This error has only been seen in 1 per 10,000+ ballot scans outside the 104-hour test here, and it is not predictably reproducible in VxScan units with production software both inside and outside normal operating conditions.

We were able to reproduce the anomaly behavior on a development VxScan, by issuing the following commands to the printer, where '3-4' is the thermal printer's device string:

```
echo '3-4' | sudo tee /sys/bus/usb/drivers/usb/unbind
sleep 1
echo '3-4' | sudo tee /sys/bus/usb/drivers/usb/bind
```

This sequence simulates a rare but possible rapid disconnect and reconnect of the device at the operating system level, one level lower than the VxScan application code.

The VxScan application code registers the disconnect and responds by trying to reconnect, but the reconnect fails at this step:

```
const legacyDevice = findByIds(VENDOR_ID, PRODUCT_ID);
```

This step is shown in context in the thermal printer code linked here:
https://github.com/votingworks/vxsuite/blob/809ae7ac7dc75de6044883aff0d6e42f050493cf/libs/fujitsu-thermal-printer/src/driver/driver.ts#L40

The `findByIds` call returns nothing, indicating that the Node USB library was unable to find the thermal printer. We are, however, able to find the thermal printer with the same command if we open a new Node shell on the same machine or restart the machine's backend server. This suggests that the root cause of the failed reconnect is that either the Node USB library or the underlying Linux libusb library is using stale connection data.

Corrective Action(s)

This very specific kind of disconnect should be exceedingly rare (less than 1/10,000 scans), but VotingWorks has intentionally built a final fallback that asks the user to restart the machine when our application code reconnect fails. In our testing, we have always been able to reconnect to the printer on restart.

We do not recommend any other corrective action at this time as our recovery mechanism is working as expected, and this case is exceedingly rare. This has never been reported on our 40+ v4 VxScans deployed in the field.

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.

The indication to restart after the anomaly was confirmed to be expected behavior, and no additional corrective actions are recommended.

However, VotingWorks is still implementing a complementary software change to more directly report the details of this error if it happens in the future. The change includes more verbose logging of the thermal printer subcomponent to report disconnection error messages. The previous code treated an error from the printer status as a sign that the printer is disconnected, and attempting to reconnect nearly always worked by reinitializing the printer driver. In the rare anomaly in this report, the original printer error message was not logged and not available. The error message would have indicated directly if the operating system was using stale connection data, preventing the need to reproduce and explore the issue at the same depth as in this RCA. The updated code ensures that the original error message is logged even in outlier cases like this one (detailed in the pull request linked here: https://github.com/votingworks/vxsuite/pull/6303). This code update will be incorporated in the next software version.