Test Report - VxScan v4.0 Build 0 Drop Test - Bench Handling

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Purpose

VotingWorks needs data on how well VxScan v4.0 withstands drop tests required by VVSG, defined in MIL-STD-810H, Method 516.8: Bench Handling (Procedure VI). This is part of general data on how it withstands drops, impacts, and mechanical shocks, from use, maintenance, and transportation.

This test also includes drop-testing some removable parts of the MCM, such as the printer roll holder. This helps meet the requirement to "configure the item as it would be for servicing," listed in the MIL spec.

This test report is on Build 0 of the v4.0 MCM only. Any damage noted here will suggest more investigation needed in similar areas on Build 0.5 and Build 1 of the v4.0 MCM. A passing test also does not eliminate the need to test newer design iterations, if there are significant changes to connectors, weight, or major components. This test report does not cover the ballot box (BB) or final versions of any of the v4.0 design.

Background

VxScan systems have not undergone standardized drop tests yet. Anecdotally, the MCM has survived unintentional drops or falls during transport and use and maintained regular function, but it has not undergone the MIL spec tests.

It is recommended to perform other potentially destructive mechanical tests after this drop test to provide more worst-case testing scenarios beyond VVSG, according to test vendors consulted in 2024. For example, if a drop test shows no apparent failures, then a vibration test could be performed right after the drop test to see areas of composite vulnerability to vibration.

Materials

1. Workbench and tools
    a. Hard tabletop
    b. Tools for opening unit as needed (metric hex wrenches, pliers, etc)
    c. Measurement tools for ensuring drops from 4 inches, and from a 45° angle.
2. Test unit, testing tools, and documentation tools
    a. MCM
    b. Printout of VxScan v3.1 and v4.0 Tests of Normal Function, along with associated tools, including:
        i. Appropriate ballots within specifications for the system
            1. Bond 28-47lb / 105-177gsm
            2. 8-8.5” width; 11-22” length
            3. Blank ink on white paper
            4. Hand-marked or machine-marked, for an election configuration matching the system
        ii. Metric hex wrenches, pliers, tools for testing fastener security
        iii. light, camera
    c. Printout of benchtop-drop-test-standard.pdf

Procedures

The test procedure below is based on “Test S1” and “Test S2” in broad test plans for VVSG compliance: Testing Plans - VxScan - Linked to VVSG & other requirements. Specific steps are as follows, based on the MIL spec workbench drop test procedure excerpted here: benchtop-drop-test-standard.pdf.

1. Check the unit for normal function before testing.
    a. Follow standard tests to confirm the test unit functions normally before any disruptive tests: VxScan v3.1 and v4.0 Tests of Normal Function. For the VxScan MCM, normal functions include scanning ballots, storing scans, printing reports, rejecting invalid ballots, giving visual and audio feedback, and accepting touch inputs.
        i. For hand-marked bubble ballots, use 28# paper, 8.5”x11” ballots, printed from the August 2024 UAT election definition prepared by VotingWorks. These were available and already printed in VxAustin as of Aug 21, 2024.
        ii. Machine-marked ballots are also available to test, printed from the VxMark system as of Aug 27, 2024, using the same August 2024 UAT election definition.

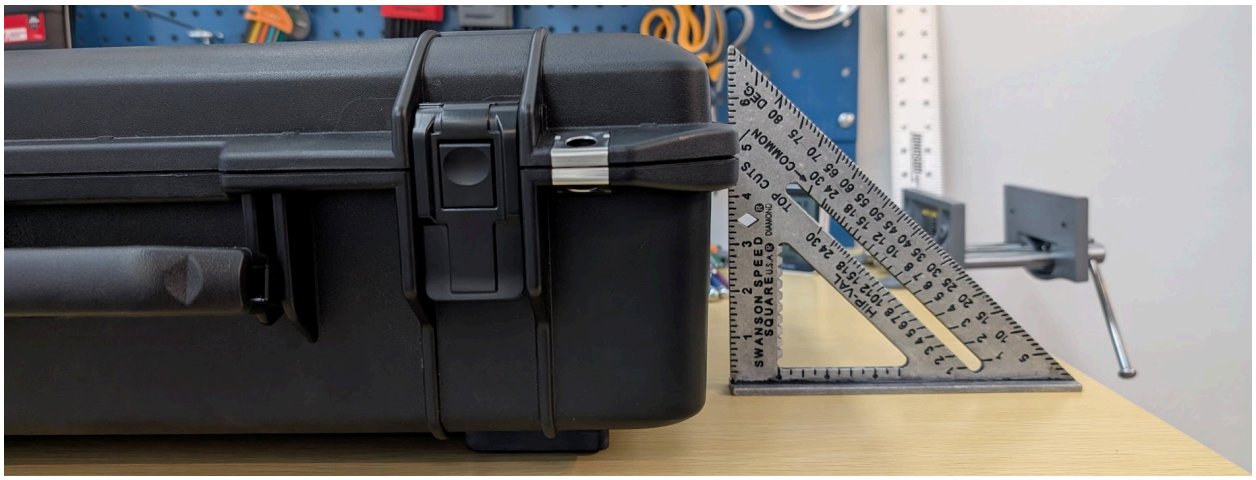
iii. If the ballot box is not available, set up the MCM on an appropriate stand so that the ballots can fall out. For example, see the wood frame used in the Austin lab in the photo below:

b. Document tests of normal function. Record any pre-existing problems. Use a template like this:
VxScan v3.1 and v4.0 Tests of Normal Function - Checklist Template.
c. For long-term tracking of units, you can also record the life cycle history of the unit here: VxScan System Test Histories.
    i. Make a new tab for previously untracked units.

2. Execute drops on standard closed configuration.

a. Refer to the standard procedure for drop tests on the closed configuration, described in MIL-STD-810H, Method 516.8: Bench Handling (Procedure VI). This is summarized in the next steps.
b. Configure the test unit on the testing workbench or table.

c. Using one edge as a pivot, lift the opposite edge of the chassis until one of the following conditions occurs (whichever occurs first).
    i. a. The lifted edge of the chassis has been raised 100 mm (4 in.) above the horizontal bench top. For example, see these photos lifting one edge of the bottom face of the VxScan v4 MCM up 4 inches:



    ii. b. The chassis forms an angle of 45° with the horizontal bench top.
    iii. c. The lifted edge of the chassis is just below the point of perfect balance. For example, see this photo of lifting one edge of the rear face up to its balance point:

d. Drop the unit freely onto the horizontal bench top. Repeat using other practical edges of the same horizontal face as pivot points, for a total of four drops.
e. Repeat the drops along each edge on each face, until it has been dropped for a total of at least four times on each face.
f. Visually inspect the test item, and listen for loose parts, between drops and after all drops are done.
g. Document the results.

3. Execute drops on any removable subsystem.

a. Remove any subsystem from the test unit that is normally meant for users to remove. For the v4 MCM, that is just the thermal printer roll holder.
b. Follow the standard procedure for drop tests on each of the removable subsystems (listed above in Step 2). Inspect the subsystem for any changes, and document the results.

4. Check the unit for normal function after freezing.
    a. Follow standard tests to see if the test unit still has normal function: VxScan v3.1 and v4.0 Tests of Normal Function
    b. Document tests of normal function. Note if any functions have changed. Use a template like this: VxScan v3.1 and v4.0 Tests of Normal Function - Checklist Template.
    c. For long-term tracking of units, you can also record the life cycle history of the unit here: VxScan System Test Histories.

Results

1. Normal function was confirmed before drop tests.
    a. Normal function was confirmed before drop testing, with data recorded in this document: VxScan v4.0 Normal Function Checklist - 20240903 - Build 0 un… All essential functions (scanning ballots, storing data, printing reports, rejecting invalid ballots, giving visual and audio feedback, and accepting touch input) showed regular behavior and no problems.
    b. Long-term tracking of the unit is in its corresponding tab (“VxScan4.0-unit3”) in this spreadsheet: VxScan System Test Histories.
    c. The structure of the unit before drop testing started out with 2 known irregularities, due to previous use and tests:
        i. It was missing the upper bolt holding the mains power port.
        ii. It was missing the rear power cord holder structure.

    These parts had been removed previously to make it easier to change out the inner components in the bottom tub during design explorations and iterations. However, they did not affect the essential functions of the device. See Appendix A for photos of the rear features for details. This did not influence drop testing results, and if anything this would allow observation of worse-case behavior in a drop test, since features would be more likely to move as a result of a drop.

2. The unit underwent standard bench handling drop tests.
    a. Results for the standard closed configuration as listed below:
        i. After dropping on the bottom face (upright) along the 4 edges (4 drops):
            1. No damage was detected.
        ii. After dropping on top face (upside-down) along the 4 edges (4 drops):
            1. No damage was detected.
        iii. After dropping on the rear face (handle up), along the 4 edges (4 drops):

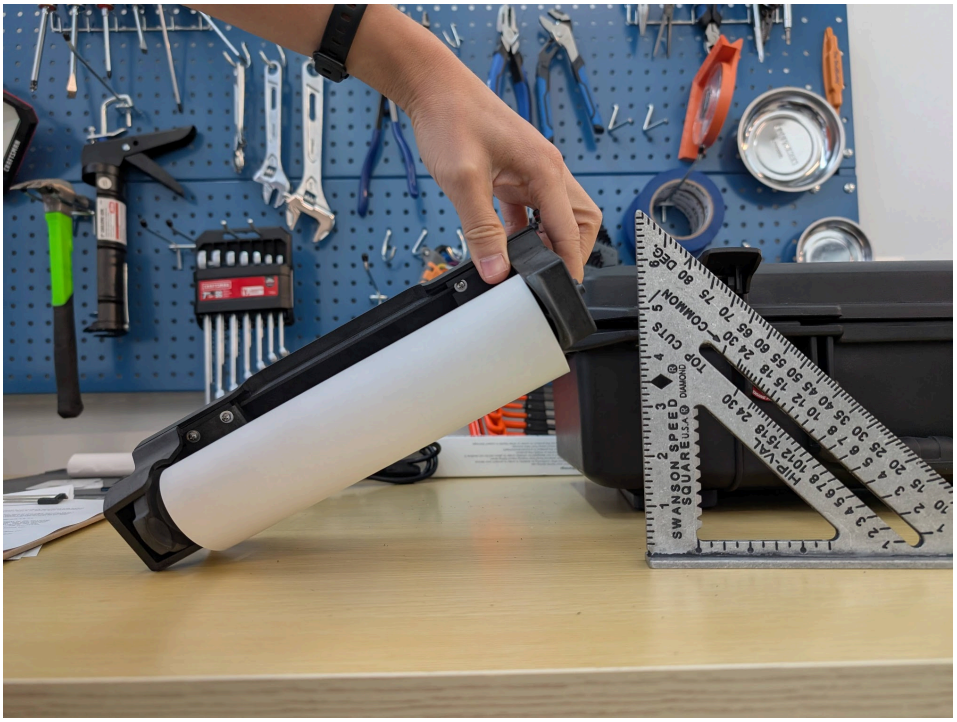
1. A small loose part was audible internal to the bottom tub, sounding like metal-on-metal or potentially a fastener. It could not be found in a quick inspection.

iv. After dropping on the top face (handle down), along the 4 edges (4 drops):
    1. The loose part could not be heard, potentially stuck, or fallen back into place. It was noted to check for it again later.

v. After dropping on the left face, along the 4 edges (4 drops):
    1. Small loose part(s) were audible again inside the lower tub. It could not be found in a quick inspection.

vi. After dropping on the right face, along the 4 edges (4 drops):
    1. Small loose part(s) were audible still inside the lower tub. The scanner access door rear hinge lower segment lost a bolt and nut, and the remaining bolt/nut was loose. This made the scanner access door loose, compromising structural and functional integrity. See this linked video and the photo below, showing the loosened hinge on the left:

3. The removable subsystems underwent bench handling drop tests.
    a. The thermal paper roll holder was removed from the system and drop-tested with the paper roll in it, for a total of 24 drops. See image below for an example setup before dropping:



b. The paper roll was removed from the thermal paper roll holder, and the empty paper roll holder was drop-tested, for a total of 24 drops. Because it was weighted more to one side, it frequently ended up on this side after drops, as shown here:

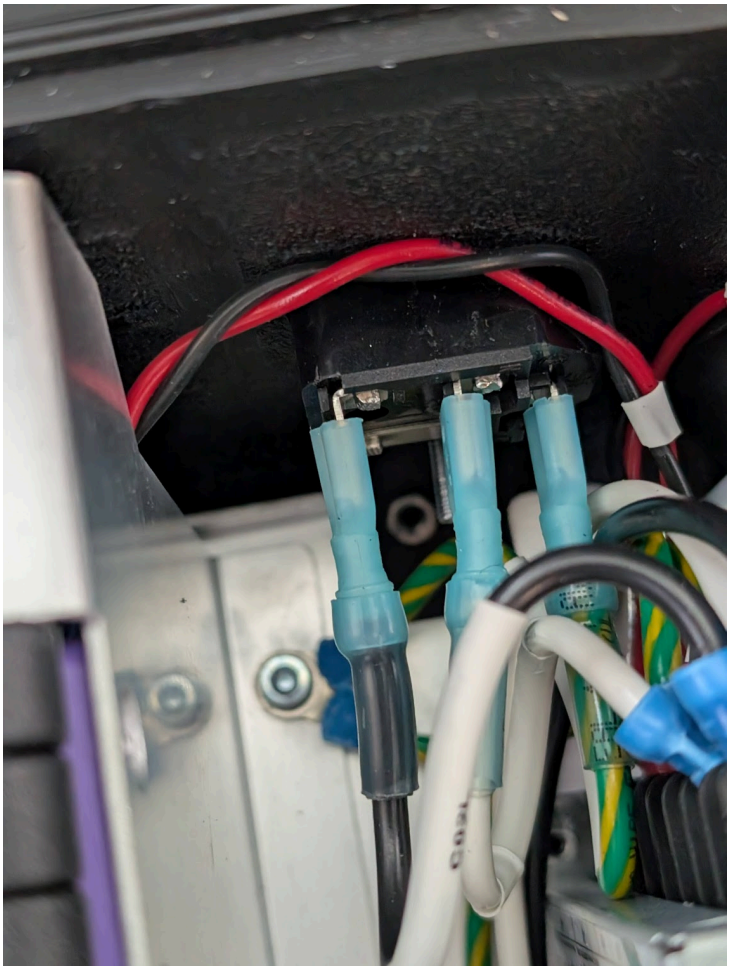
c. No damage was found after all drops. Paper rolls could be removed and reinserted without problems. The holder could be reinserted into the MCM without problems.

4. Benchtop drop testing compromised the structure around panel fasteners lacking a locking mechanism.

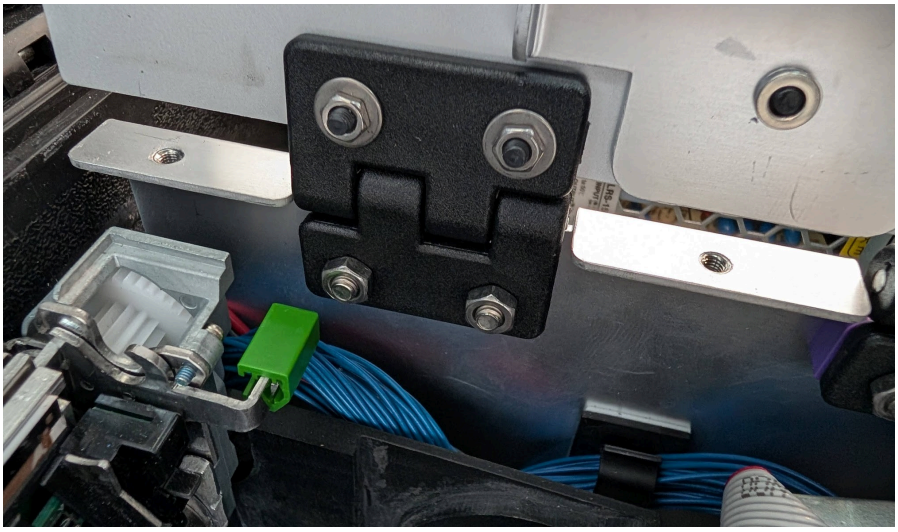
a. Without opening up the device, the only structures compromised by benchtop drop testing were the hinges around the scanner access door (as seen in this linked video already described above).

b. Opening up the bottom tub panels revealed only those loose fasteners. One bolt fell out completely into the bottom of the tub that could be retrieved:

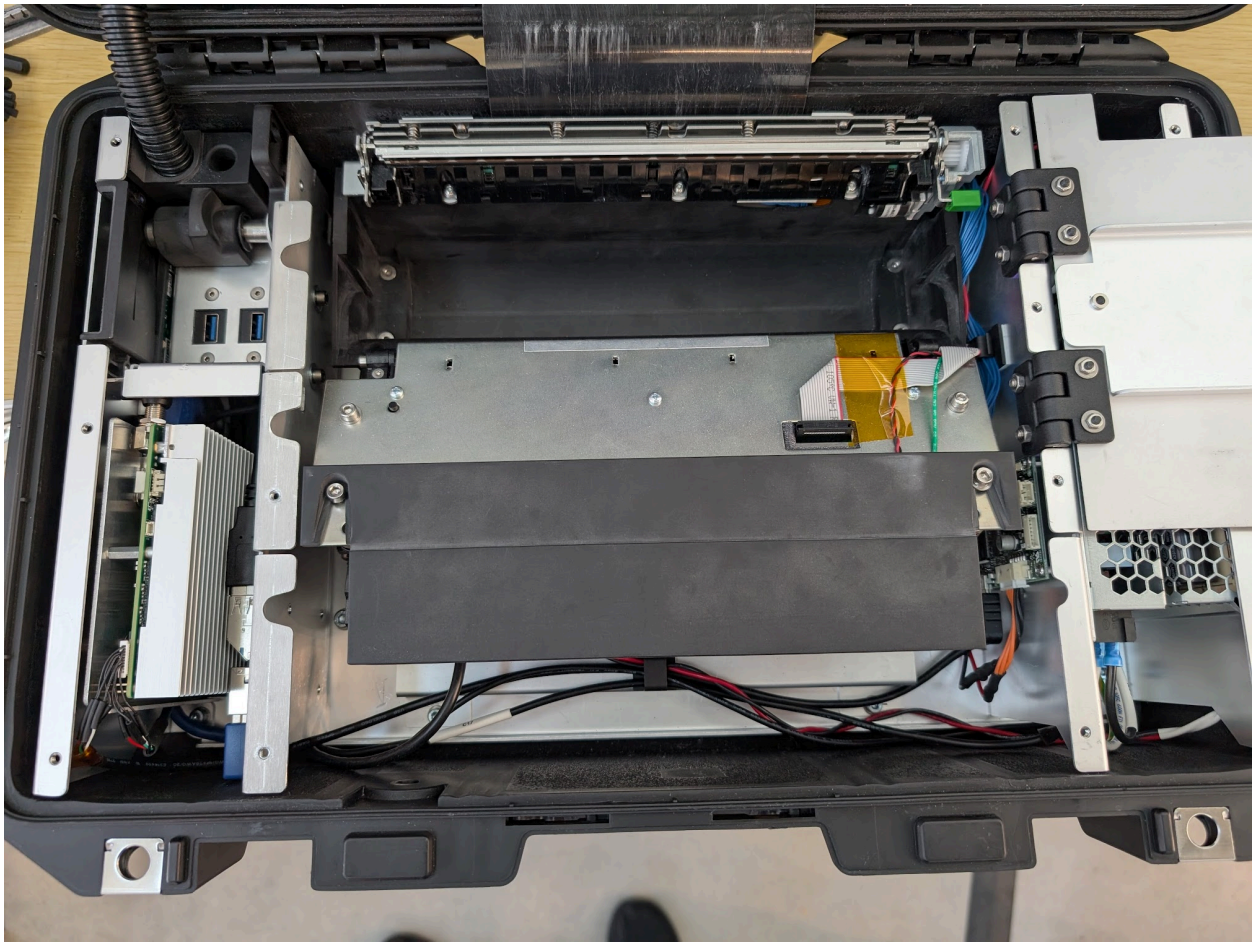
The associated loose nut was difficult to find, as it was under the metal subpanel, between the subpanel and the outer plastic case. The MCM had to be tilted back and forth to roll it into a position near the rear right corner by the mains power port, before it was positioned in a way to be retrieved without detaching more parts. It is shown near the center of the photo below, and it could be retrieved with a tool without disturbing other parts:



No other loose parts were found or heard, so these known loose parts were reattached, and the hinge nuts were tightened:



No other visible damage could be found on the inside of the lower tub, pictured here:



The lower tub panel was reattached.

5. The unit retained all normal function after reattaching loose fasteners.
    a. The unit was tested again for normal function according to standard procedures. All MCM functions continued to perform without issues. The data is recorded here: VxScan v4.0 Normal Function Checklist - 20240903 - Build 0 unit 3 aft…
    b. A visual inspection of all structures showed no noticeable differences from before drop-testing.

Conclusions

Effects of Benchtop Drops on the MCM Build 0

Benchtop drop tests did not affect essential scanning functions, and it did not permanently damage the MCM or change the outward appearance of parts. It had no noticeable effects on the removable thermal paper roll holder.

However, these benchtop drops did loosen fasteners in the scanner access door that had no locking features. This could in turn compromise the security of the MCM Build 0 and should be prevented.

Implications for Future MCM Designs

It is recommended to have a QA system in place to help ensure the appropriate loosening-resistant fasteners are used at all points in manufactured units. Future and final MCM designs should mitigate risks from drops by using locknuts, threadlocker adhesive, or any similar solution that can prevent loosening of fasteners at MCM hinges. Most of the MCM fasteners already have these solutions in place, and Pump Studios expressed desires to ensure all fasteners have it in place in the final designs.

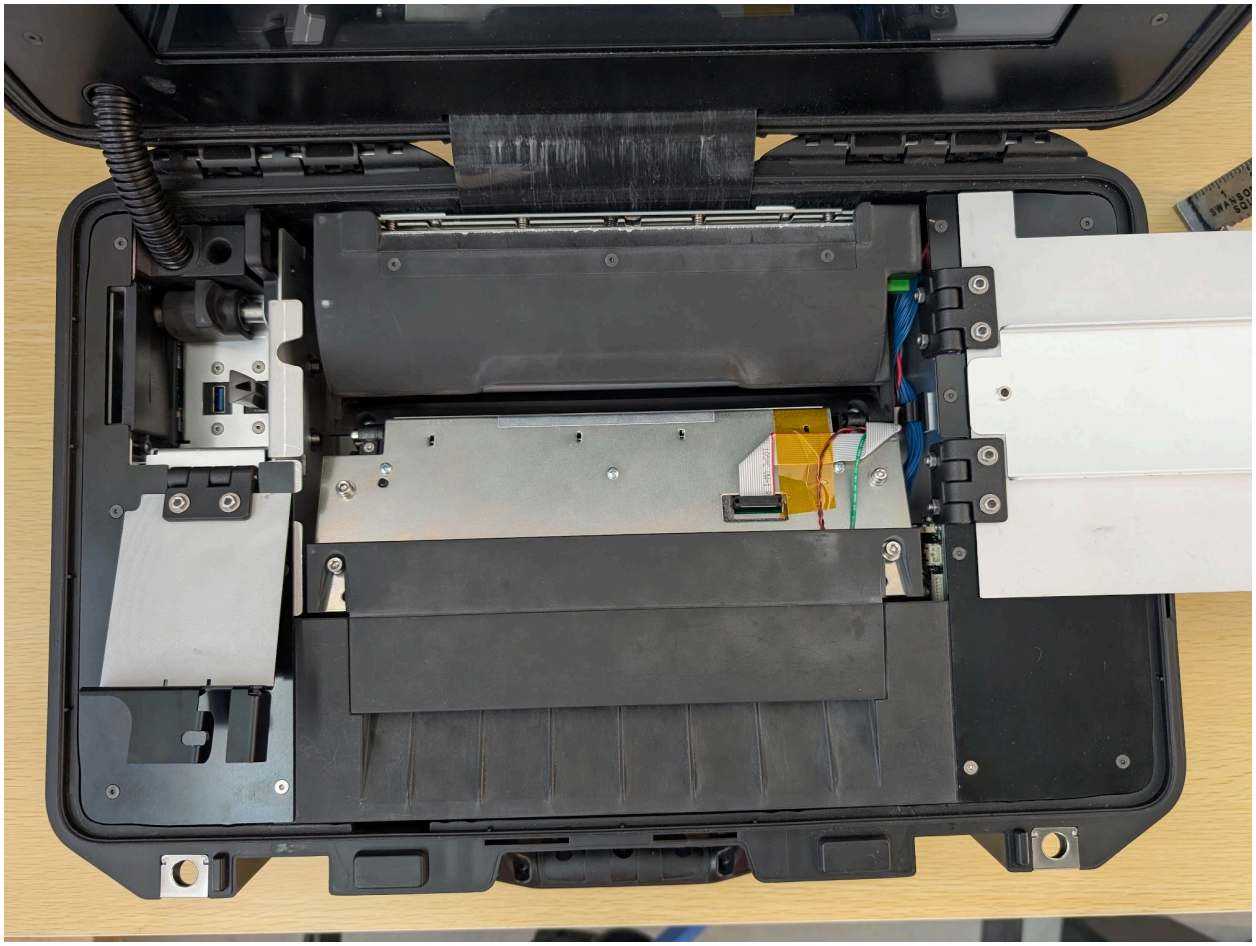
If possible, the system for removing and reattaching the subpanel could also be made easier, in the less likely scenario of having to retrieve small parts from under it. In Build 0, removal of the subpanel means the rear lockout panel can be more difficult to put back on, and so here it was avoided.

References

1. MIL-STD-810H.pdf
2. dFMEA VxScan3.1/4.0 - VotingWorks - 20240207
3. Testing Plans - VxScan - Linked to VVSG & other requirements
4. VxScan v3.1 and v4.0 Tests of Normal Function
5. VxScan v3.1 and v4.0 Tests of Normal Function - Checklist Template .
6. VxScan System Test Histories
7. VxScan v4.0 Normal Function Checklist - 20240903 - Build 0 unit 3 before drop test
8. VxScan v4.0 Normal Function Checklist - 20240903 - Build 0 unit 3 after drop test

Appendix A: Device photos before drops


CRAFTSMAN
Poll Worker



Note: This test unit did not have the rear cord holder or one of the bolts holding the power supply to begin with, due to previous use, as noted in this report.