Test Report - VxScan Outdoor Cyclic Freezing Storage and Full Sun Operation

Dates of testing: Feb 19, 2025 - Feb 24, 2025
Updated Nov 6, 2025 by Pius Wong

Summary

Stress testing the VxScan v4.0 prototype in extreme outdoor environmental conditions (beyond system specifications and VVSG requirements) showed that it could withstand cyclic freezing storage and operation in heat and full sun. This supplemented similar extreme environmental testing in more controlled lab conditions.

Applicable VVSG Requirements

Tests here *indirectly* address the VVSG requirements below, although they are not the final tests for these requirements:

- 2.7-C – Continuous operation – varied environmental conditions
- 2.7-E – Ability to support transport and storage physical environment conditions – non-operating
- 2.7-F – Ability to support storage temperatures in physical environment – non-operating

Devices Under Test

- VxScan, v4.0, Build 0.5.1
- Ballot Receptacle prototype, LP2-1

Purpose

This set of tests intended to observe the response of VxScan to extreme climates and environmental conditions, outside lab conditions. They give more practical case studies of performance in unusual situations in the real world outside system specifications. This testing is *not* required for VVSG2.0, but it should help VotingWorks better understand potential failures in the field and how to prevent or repair them. If results suggested vulnerabilities must be tested further, then more standardized tests could be followed or created.

These procedures test product use over two rarer but potentially destructive scenarios:

1. Storage in cyclic freezing weather, then conditioning inside before use
2. Operation while sitting in full sun

Scenario 1, cyclic freezing storage, could more likely happen:

- in colder climates and seasons
- if products are stored in unconditioned spaces like car trunks, or during shipping, or during outdoor voting
- if election workers make mistakes in storage
- if windows are open around the storage area
- during natural disasters that wipe out power and conditioned storage

Scenario 2, operation in full sun, could more likely happen:

- in sunnier climates and seasons
- if products are used in unsheltered spaces, such as during natural disasters or during outdoor voting
- if products are used by a large window

Materials

1. Test Unit

a. This procedure tested VxScan Build 0.5.1, which was previously tested for Safety Testing under NRTL Eurofins in Austin, Texas. Notably this does not have a forced-air cooling system, unlike the newer Build 1 designs that have been manufactured.

2. Tools to monitor environmental conditions

a. Thermometer-hygrometer: Govee H5075
b. Temperature gauge and thermocouples: 88598 4ch K SD logger
c. Brightness meter on Android app: Physics Toolbox Sensor Suite, Vieyra Software
d. Records of hourly weather conditions from weather.com

3. Tools to test unit performance and function

a. Tools for opening unit as needed (metric hex wrenches, pliers, etc)
b. Camera, and other tools to document any damage.
c. Peripherals to test normal function:
    i. Power cord & power
    ii. USB Drive and smart cards corresponding to a test election
    iii. 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

d. Details on how to check VxScan unit normal function are in this document *VxScan Tests of Normal Function.pdf*.

Procedures

1. Confirm Unit Quality

a. **Check the unit general build quality** before testing.
   i. For Vxscan, confirm how well it:
      1. Attaches to and detaches from the ballot box easily.
      2. Maintains physical security,when attached to the ballot box.
      3. Protects internal electronics and subsystems.
b. **Check the unit for normal function** before testing.
   i. For VxScan, power it up, load the app, and confirm how well it:
      1. Accepts logins in via smartcard
      2. Scans ballots
      3. Stores scans / CVRs
      4. Rejects invalid ballots
      5. Prints reports
      6. Gives visual and audio feedback
      7. Accepts touch inputs
c. **Identify, document, and repair any issues before testing.**
   i. Only open up the unit and inspect internals if needed to identify and/or repair damage. Look, listen, and feel for damage and loose parts to fix. Records notes on observations, following procedures defined in the file *VxScan Tests of Normal Function*.

2. Test Cyclic Freezing Storage

a. Close and lock the test unit.
b. Set up storage space and timing.
   i. Plan to store the unit outside when weather conditions cycle from above to below freezing at least twice.
   ii. Keep the unit secured to a fixed or heavy object during testing.
   iii. Set up appropriate sensors to monitor the environmental conditions during testing.
c. Store the unit for at least 2 cycles below freezing.

   i. Document environmental conditions during testing.
   ii. After the test cycles complete, bring the unit indoors.
d. Before plugging in or operating, condition the unit at room temperature and humidity for at least 24 hours.
e. Inspect the unit. Repair any damage seen, if possible. Document repairs.
f. Confirm unit quality again, as described above, before continuing. If more repairs must be made, then document these.

3. Test Operation in Full Sun

a. Set up the unit to operate where it is completely under full direct sunlight, but in dry conditions. This test setup is outdoors, with the screen facing the sun. Temperature gauges (thermocouples) are attached to areas of interest on the unit. See Appendix: Full Sun Operation Setup, for photos of the setup.
b. Plug in the unit, and confirm unit quality while under full sunlight.
c. Leave the unit plugged in for at least 1 hour and preferably 8 hours in sunlight, while continuing to check app functionality.
d. Remove the unit from sunlight. Inspect the unit. Repair any damage seen, if possible. Document repairs.
e. Confirm unit quality again, as described above, before continuing. If more repairs must be made, then document these.

4. Document and Clean Up.

a. **Compile results in this test report**. See Results.
b. **Clean up the unit and the test setups.**

Results

1. Confirm Unit Quality Before Testing

Main functions were checked according to this procedure: *VxScan Tests of Normal Function*, with raw notes recorded here: *VxScan Normal Function Checklist - 20250219 - Before freeze*

Check the general build quality	Comments on: 1. Attaches to and detaches from the ballot box easily. **PASS** 2. Maintains physical security,when attached to the ballot box.

	PASS 3. Protects internal electronics and subsystems. **PASS**
Check the unit for normal function	Comments on: 1. Accepts logins in via smartcard **PASS** 2. Scans ballots **PASS** 3. Stores scans / CVRs **PASS** 4. Rejects invalid ballots **PASS**, including overvotes, wrong paper 5. Prints reports **PASS,** tallies correct 6. Gives visual and audio feedback **PASS** 7. Accepts touch inputs **PASS**

Issues observed before testing	**Repairs made before testing**
Before the check of normal function above, this unit was reimaged to the latest TRR version. Upon first try at configuring the election, the USB ports did not recognize the USB Drive. Restarting fixed the issue.	None, restarting allowed configuring the election

2. Test Cyclic Freezing Storage

Predicted Weather at Start of Test: See Appendix. At least 2 cycles of freezing were forecast. Freezing was scheduled to start Wednesday by taking the unit outdoors, and to end Friday, taking it back indoors to condition before testing function.

Environmental Condition Checks During Testing:

Date & Time	Temperature	Humidity	Observations & Notes
Feb 19, 2025, 4:15pm	65.2°F (18.4°C)	18%RH	Starting out storing in trunk of car, taken directly from lab
Feb 19, 2025, 6:18pm	34.3°F (1.28°C)	44%RH	Starting out storing outdoors, taken directly from car trunk
Feb 19, 2025, 6:25pm	29.8°F (-1.2°C)	50%RH	Storing outdoors, a few minutes later already below freezing
Feb 19, 2025, 8:36pm	25.0°F (-3.89°C)	64%RH	Storing outdoors, night
Feb 20, 2025, 2:46am	22.1°F (-5.5°C)	72%RH	Storing outdoors, night
Feb 20, 2025, 10:34am	28.5°F (-1.94°C)	47%RH	Storing outdoors, shaded
Feb 20, 2025, 12:42pm	52.2°F (11.2°C)	22%RH	Storing outdoors, under sunlight
Feb 20, 2025, 1:34pm	33.8°F (1.00°C)	40%RH	Storing outdoors, shaded
Feb 20, 2025, 4:05pm	36.5°F (2.50°C)	36%RH	Storing outdoors, shaded
Feb 20, 2025, 7:02pm	33.8°F (1.00°C)	38%RH	Storing outdoors, night
Feb 20, 2025, 11:08pm	32.0°F (0.00°C)	44%RH	Storing outdoors, night
Feb 21, 2025, 3:25am	31.1°F (-0.50°C)	47%RH	Storing outdoors, night
Feb 21, 2025, 7:37am	30.7°F (-0.72°C)	54%RH	Storing outdoors, shaded
Feb 21, 2025, 9:03am	32.6°F (-0.33°C)	52%RH	Storing outdoors, shaded
Feb 21, 2025, 1:29pm	37.2°F (2.89°C)	49%RH	Storing outdoors, shaded

Feb 21, 2025, 1:35pm	41.6°F (5.33°C)	64%RH	Storing outdoors, car trunk
Feb 21, 2025, 1:56pm	43.0°F (6.11°C)	47%RH	Storing outdoors, car trunk
Feb 21, 2025, 2:19pm	63.7°F (17.6°C)	26%RH	Storing indoors in lab, start of condition for at least 24 hours
Feb 24, 2025, 9:15am	73.3°F (22.9°C)	40%RH	Storing indoors in lab

Photos:

Storage in trunk of car at start:

Storage outdoors, unsheltered:

Storage indoors in lab, for conditioning >24 hours:

Conditioning the Unit Indoors:

	Date & Time	Temperature	Humidity	Observations & Notes
Start	Feb 21, 2025, 2:19pm	63.7°F (17.6°C)	26%RH	Storing indoors in lab, start of condition for at least 24 hours
End	Feb 24, 2025, 9:15am	73.3°F (22.9°C)	40%RH	Storing indoors in lab

Issues & Repairs Before Powering on:

Issues observed	Repairs made
None	n/a

Confirming Unit Quality After Testing:

Check the general build quality	Comments on: 1. Attaches to and detaches from the ballot box easily. **PASS** 2. Maintains physical security,when attached to the ballot box. **PASS** 3. Protects internal electronics and subsystems. **PASS**
Check the unit for normal function	Comments on: 1. Accepts logins in via smartcard **PASS** 2. Scans ballots **PASS** 3. Stores scans / CVRs **PASS** 4. Rejects invalid ballots **PASS**, including overvotes, wrong paper 5. Prints reports **PASS,** tallies correct 6. Gives visual and audio feedback **PASS** 7. Accepts touch inputs **PASS** Raw results noted in file *VxScan Normal Function Checklist - 20250224 - After freezes.*

Issues observed after powering it on	Repairs made after powering it on
none	n/a

3. Test Operation in Full Sun

Unit quality was confirmed at the end of the previous test. Testing continued on the same day.

Environmental Conditions During Testing:
Date: Feb 24, 2025

Time	Temperatures	Humidity	Brightness (lux)	Observations & Notes
12:26pm (0 to 30 min in sun)	**Air**: 77.0°F (25.0°C) **Unit surfaces**: **1. Panel above SBC:** 99.7°F (37.6°C) **2. USB bracket:** 93.4°F (34.1°C) **3. Touchscreen display:** 126°F (52.2°C)	35%RH	133k lux (full sun)	1. Accepts logins in via smartcard **PASS** 2. Scans ballots **PASS** 3. Stores scans / CVRs **PASS** 4. Rejects invalid ballots **PASS** 5. Prints reports **PASS** 6. Gives visual and audio feedback **PASS – But flickering observed while temperatures were high after touching. Glare also makes it hard to see.** 7. Accepts touch inputs **PASS**
(after 60-80 min in sun)	**Air**: 76.3°F (24.6°C) **Unit surfaces**: **1. Panel above SBC:** 106°F (41.3°C) **2. USB bracket:** 93.7°F (34.3°C) **3. Touchscreen**	35%RH	131k lux (full sun)	1. Accepts logins in via smartcard **PASS** 2. Scans ballots **PASS** 3. Stores scans / CVRs **PASS** 4. Rejects invalid ballots **PASS** 5. Prints reports **PASS** 6. Gives visual and audio feedback

	display: 137°F (58.3°C)			**PASS – But flickering still observed after touching. Glare also makes it hard to see.** 7. Accepts touch inputs **PASS**

Photos:
Setup at the start and end, outside VxAustin, facing the sun.

Issues & Repairs Immediately After Testing:

Issues observed	Repairs made
None; flickering issue also did not show up when brought back inside and cooled.	n/a

Confirming Unit Quality After Testing:

Check the general build	Comments on: 4. Attaches to and detaches from the ballot box easily. **PASS**

quality	5. Maintains physical security,when attached to the ballot box. **PASS** 6. Protects internal electronics and subsystems. **PASS**
Check the unit for normal function	Comments on: 8. Accepts logins in via smartcard **PASS** 9. Scans ballots **PASS** 10. Stores scans / CVRs **PASS** 11. Rejects invalid ballots **PASS**, including overvotes, wrong paper 12. Prints reports **PASS,** tallies correct 13. Gives visual and audio feedback **PASS** 14. Accepts touch inputs **PASS** Raw results noted in *VxScan Normal Function Checklist - 20250224 - Sunlight*.

Conclusions

The tests in this report did not cause any failures of concern at this time. Specifically:

- Two nights of dry, outdoor subfreezing storage and daytime above-freezing storage, followed by 1 day of indoor conditioning, did not harm function
- 1.5 hours of full sunlight on the system, in 77°F and breezy weather, did not stop essential functions. However, it did degrade the touchscreen display quality temporarily while the unit was warmed up, causing noticeable flickering.

The test suggests some strategies for preventing damage or failures to VxScan in extreme climates. For extreme cold:

- If ever units face subfreezing outdoor climates, recommend that the units be conditioned indoors in a dry space for at least a day before turning on.

For full sunlight operation or other hot environments:

- The forced-air cooling system in the newer VxScan designs may help prevent screen flickering in hot sun or in a heated state in general.
- If ever units must be used in full sun (which is still never recommended, like most consumer electronics), recommend that it only be in weather that is less than 75°F ambient air temperature, dry, and breezy; and to aim the touchscreen away from the sun.

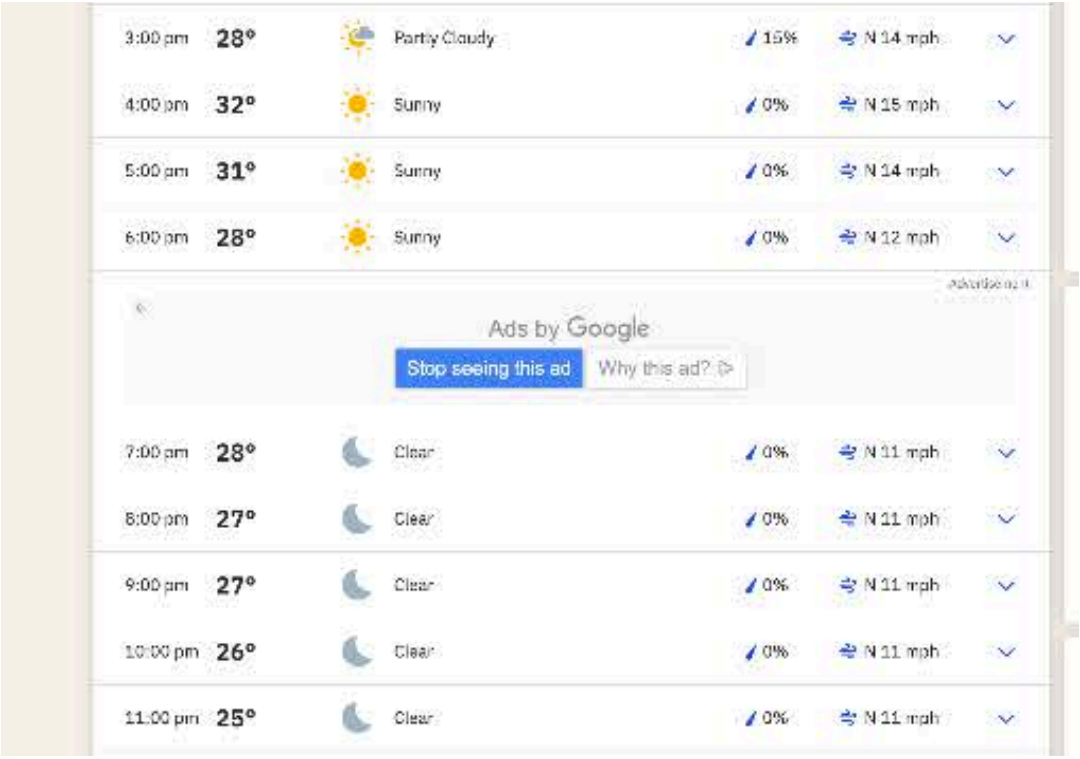
There is no pressing need to test more extreme cold or sunny weather conditions at this time. However, if extra time is available, then these more extreme conditions could be tested to better understand the operational limits of VxScan:

- Cold-cycling storage, but operate it immediately after bringing indoors, without a conditioning phase.
- Full-sunlight operation in hotter ambient conditions, such as summertime temperatures of >95°F, both in shaded and unshaded conditions.
- Wet or rainy storage conditions.

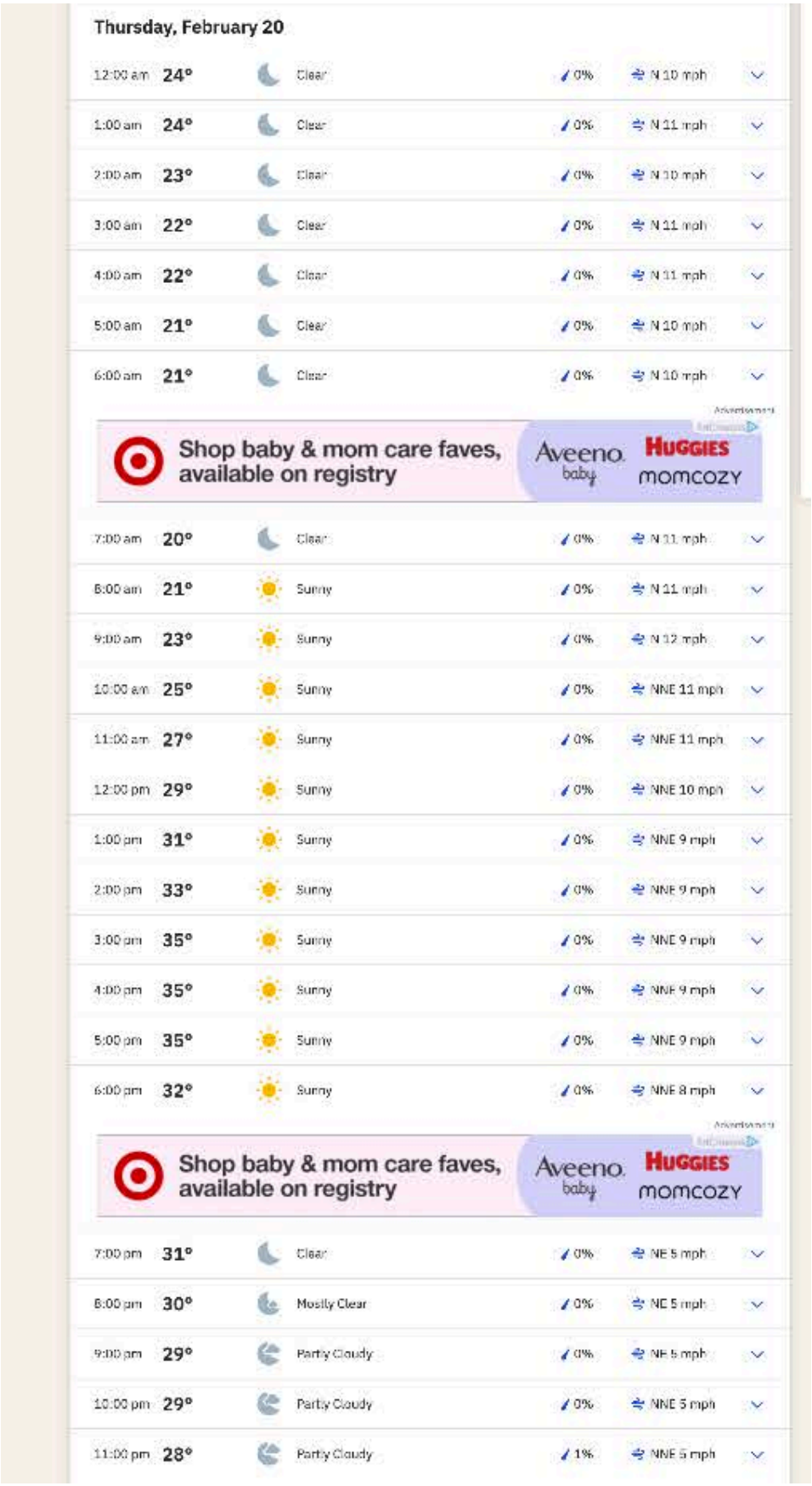
Appendix

Predicted weather at start of test

Taken from Weather.com, for Feb 19, 2025:



Taken from Weather.com, for Feb 20, 2025 :



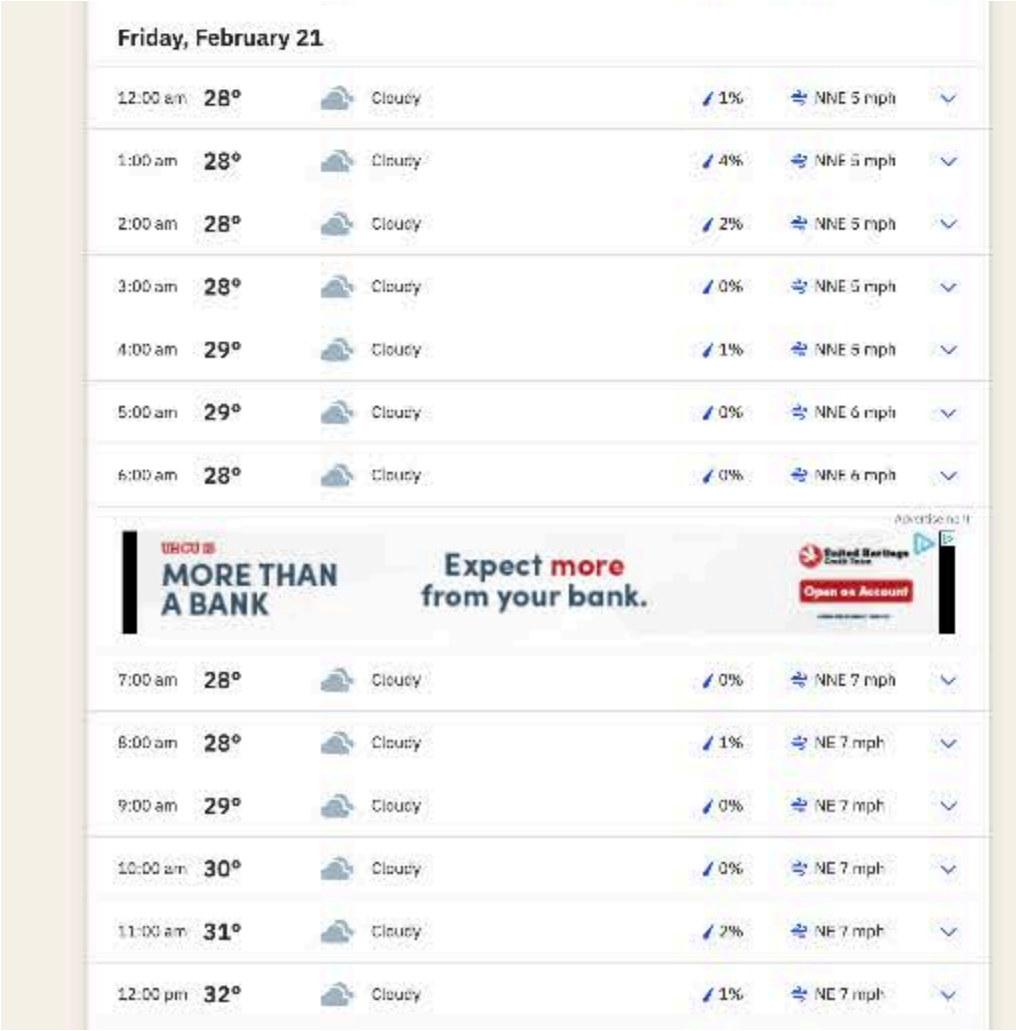
Thursday, February 20

12:00 am	24°	Clear	0%	N 10 mph
1:00 am	24°	Clear	0%	N 11 mph
2:00 am	23°	Clear	0%	N 10 mph
3:00 am	22°	Clear	0%	N 11 mph
4:00 am	22°	Clear	0%	N 11 mph
5:00 am	21°	Clear	0%	N 10 mph
6:00 am	21°	Clear	0%	N 10 mph

7:00 am	20°	Clear	0%	N 11 mph
8:00 am	21°	Sunny	0%	N 11 mph
9:00 am	23°	Sunny	0%	N 12 mph
10:00 am	25°	Sunny	0%	NNE 11 mph
11:00 am	27°	Sunny	0%	NNE 11 mph
12:00 pm	29°	Sunny	0%	NNE 10 mph
1:00 pm	31°	Sunny	0%	NNE 9 mph
2:00 pm	33°	Sunny	0%	NNE 9 mph
3:00 pm	35°	Sunny	0%	NNE 9 mph
4:00 pm	35°	Sunny	0%	NNE 9 mph
5:00 pm	35°	Sunny	0%	NNE 9 mph
6:00 pm	32°	Sunny	0%	NNE 8 mph

7:00 pm	31°	Clear	0%	NE 5 mph
8:00 pm	30°	Mostly Clear	0%	NE 5 mph
9:00 pm	29°	Partly Cloudy	0%	NE 5 mph
10:00 pm	29°	Partly Cloudy	0%	NNE 5 mph
11:00 pm	28°	Partly Cloudy	1%	NNE 5 mph

Taken from Weather.com, for Feb 21, 2025 :

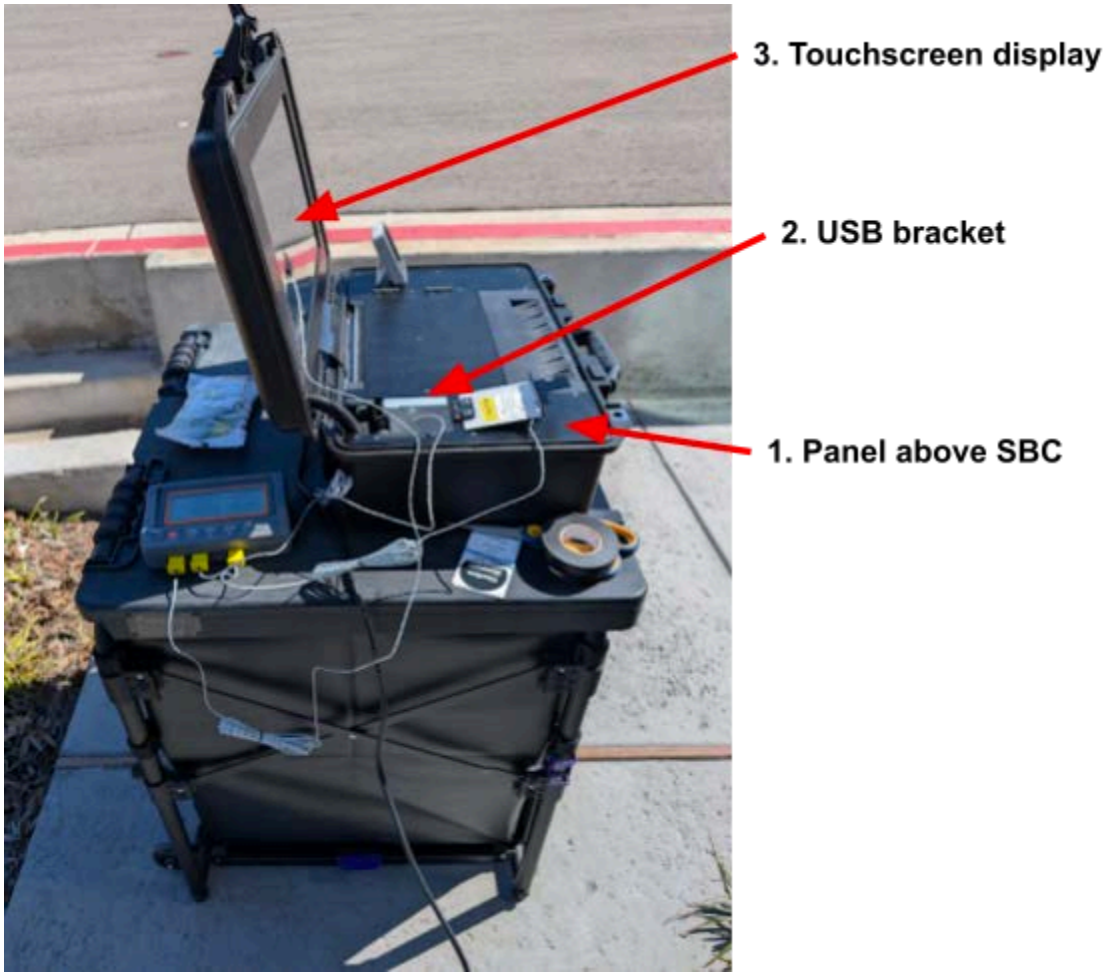


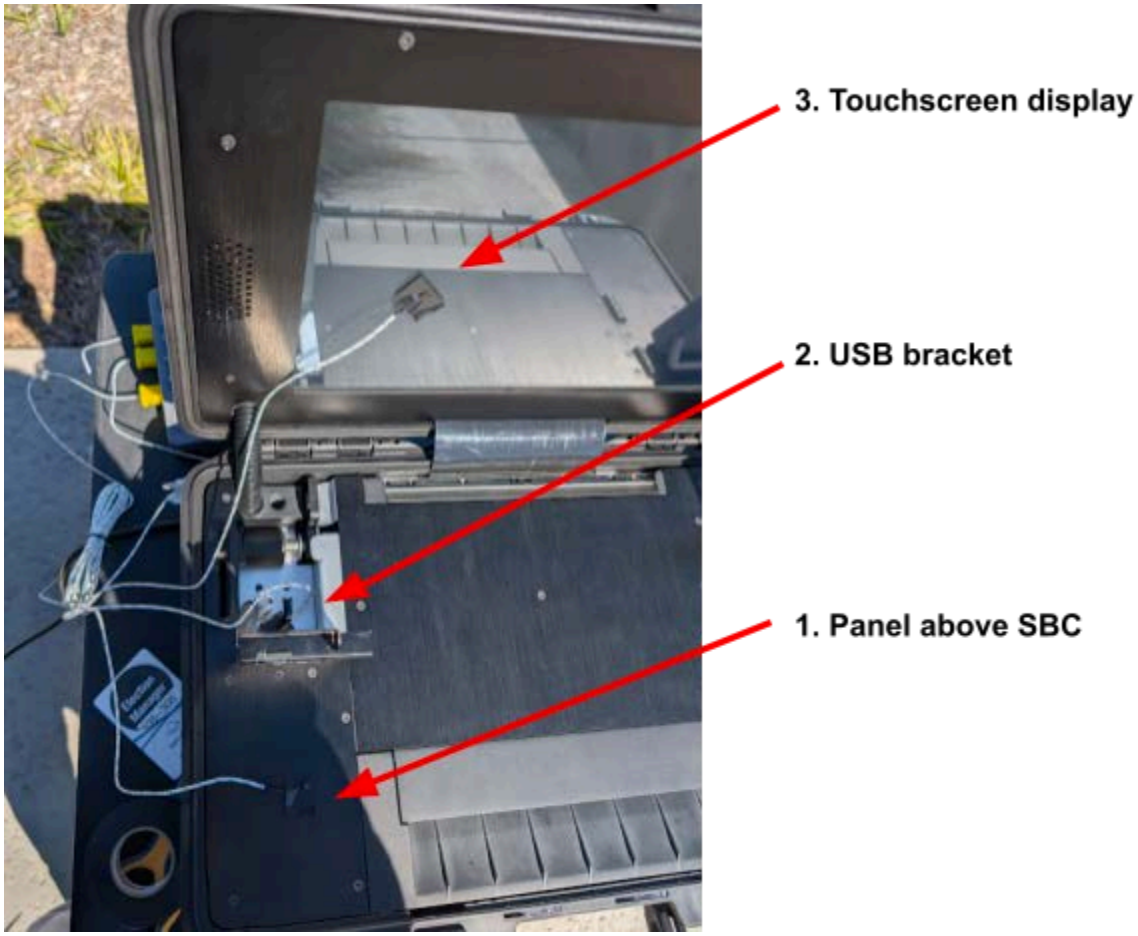
Full Sun Operation Setup

Temperature gauges (thermocouples) were attached to areas of interest on the unit:

1. panel above the SBC
2. USB port bracket, and
3. touchscreen display.

These locations were chosen based on previous observations that they may get the hottest during use. They are shown in the images below:


3. Touchscreen display
2. USB bracket
1. Panel above SBC


3. Touchscreen display
2. USB bracket
1. Panel above SBC