

System Performance & Specifications

This document covers supported capabilities and system limits that, alongside the System Overview, constitute the VxSuite Implementation Statement.

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Supported Voting Variations & Languages

Supported Voting Variations

- N-of-M contests
- Yes/No contests
- Partisan Primary Elections
 - The voting system itself does not have a concept of an open vs. closed primary as primary ballot styles are restricted to one party, but can support both types of primaries through procedurally restricting a voter to a given ballot style.

Supported Languages

- English
- Spanish
- Chinese (Simplified & Traditional)

Voter-facing content in an election package can be translated to additional left-to-right languages and imported into VxSuite, but is not formally supported or tested by VotingWorks.

System Limits

Election Definition Limits

Limit Type	Per	Value
Precincts	Election	1,000
Candidates	Election	1,000
Contests	Election	1,000
Ballot Styles	Election	1,000
Candidates	Contest	100
Vote For	Contest	50
Characters	Name, Title, Label	100
Characters	Proposition Description	10,000

Component Limits

VxAdmin

- The total number of CVRs that can be imported is limited by the total disk space on the laptop (~200GB). The exact number of CVRs depends ballot size, ballot selections, tabulator used (VxScan or VxCentralScan), and other factors that determine expected CVR size.

VxCentralScan

- The total number of ballots scanned is limited by the total disk space on the laptop (~200GB). The exact number of ballots depends on ballot size, complexity, and selections made that influence determine the CVR and ballot image sizes.
- VxCentralScan is limited by the batch scanner maximum tabulation rate: [Maximum Tabulation Rate](#)

VxMarkScan

- VxMarkScan only supports 8" x 11" and 8" x 13.25" ballot sizes as specified in [Paper Ballot Specifications](#).
- VxMarkScan ballot styles are limited to 25 contests.
- A contest allows voting for **n** out of **m** candidates/choices. The general limits for **n** and **m** are listed in the above table: **n** = *Vote For per Contest* and **m** = *Candidates per Contest*.
 - On VxMarkScan, for any one contest, **n** is limited to 25 (lower than the general limit), and **m** is limited to 100 (the same as the general limit).
 - Take the sum of **n** across all contests on a ballot style to be **N** and the sum of **m** across all contests on a ballot style to be **M**. On VxMarkScan, **N** is limited to 75, and **M** is limited to 135.
- Each VxMarkScan write-in is limited to 40 characters. The sum of write-in characters across all contests on a VxMarkScan ballot is limited to 60.
- The ballot box supports up to 200 ballots before needing to be cleared.
- VxMarkScan can activate, mark, verify, and cast up to 20 ballots per hour. Exact rate depends on time spent by user marking and verifying a ballot before casting.
- VxMarkScan has a maximum available disk space of 9GB.

VxScan

- The ballot box supports up to 3000 ballots in the main compartment before needing to be cleared.
- The ballot box auxiliary compartment supports up to 100 ballots before needing to be cleared. Ballots longer than 19" must be folded.
- Total ballots scanned for a given VxScan configuration are limited to 10,000 ballots. This limit is set based on the disk space available on specified external disks to ensure adequate disk space in the case of needing to re-sync CVRs.
- Ballot tabulation rate depends on election content / ballot length. A typical 11" ballot sheet is scanned and tabulated in 3 seconds.
- An user can feed a ballot sheet every 10 seconds. At that feeding rate, the maximum tabulation rate is 360 sheets per hour.

Hand Marked Paper Ballots

In addition to the design requirements specified in [Hand Marked Ballots](#), ballots are constrained by the following limits.

Bubble Positions

VxSuite hand marked paper ballot interpretation supports fractional grid coordinate positions, which enable bubble positions to be placed anywhere within the timing mark grid. However, the density of bubbles on a given ballot is limited to the total number of timing mark grid intersections to ensure accurate interpretation.

For example, an 11" ballot has a 32 × 39 timing mark grid. The QR code and the footer typically occupy the bottom two rows of bubbles so the usable grid is 32 × 37, giving a maximum number of ballot positions of 1,184 per page or 2,368 per sheet. The maximum number of ballot positions increases for longer ballots due to the longer grid.

Candidates Per Contest

The total number of candidates per contest is limited by ballot design requirements restricting contest options to one column and one page (7.3-B.1). Therefore, the maximum number of candidates in a contest is the maximum number of bubble positions in a column. For a 22" ballot, there is a maximum of 83 possible bubble positions in a column. The maximum number of candidates per contest may be lower than 83 when accounting for instructional text and contest information in the ballot design.

Maximum Tabulation Rate

The maximum tabulation rate for batch-fed scanners is primarily limited by the hardware scanning speed limit for each central scanner model:

- Ricoh fi-8170: 80 sheets per minute
- Ricoh fi-7600: 100 sheets per minute

The sheet per minute rate is reduced by the need to interpret ballot images. Ballot interpretation speed varies based on the following ballot variables:

- Ballot type
 - Ballot marking device ballots are slower to interpret than hand marked paper ballots.
- Sheet length
 - Shorter (such as 11") ballots are faster to interpret than longer (such as 22") ballots.
- Ballot content
 - Ballots with more contests and contests selections are slower to interpret.

Taking these limitations into consideration, batch scanners can be expected to scan approximately 50 sheets per minute for typical elections configurations.

In addition to the sheet per minute rate of a given batch, the maximum tabulation rate is also limited by the maximum batch size for each scanner. Due to the paper weight range supported by VxSuite, VotingWorks recommends a smaller batch size than the original manufacturer recommendation:

- Ricoh fi-8170: 30 sheets per batch
- Ricoh fi-7600: 100 sheets per batch

Finally, the maximum tabulation rate over the course of a day is limited by the daily volume limitations of each central scanner:

- Ricoh fi-8170: 10,000 sheets/day

- Ricoh fi-7600: 44,000 sheets/day

Paper Ballot Specifications

The following defines the minimal specifications for VxSuite paper stock. Ballot layout requirements are enumerated in [Hand Marked Ballots](#) and [Machine Marked Ballots](#) in the System Overview.

Hand Marked Ballots

VxSuite supports a wide range of paper for hand-marked paper ballot style printing within the following supported specifications:

- **Width:** 8.5"
- **Length:** 11", 14", 17", 19", 22"
- **Weight:** 105-177gsm
- **Coating:** uncoated
- **Opacity:** >90%
- **Color:** white or any pastel color ≥ 70 brightness. Contrast ratio of printed black text is 21:1 for white paper and will exceed 10:1 on other paper colors of specified brightness.
- **Watermarking:** none
- **Ink:** typical oil-based or soy-based inks are appropriate for printing presses; typical laser toner or inkjet ink are appropriate for smaller printers & copiers.
- **Folding:** ballots should not be folded through bubbles.
- **Bleed-through:** bleed through should not be present when using recommend paper weight (105-177 gsm) and marking method (ball point pen).
- **Margins:** the paper margins listed below are required for proper timing mark interpretation and adequate space for VxCentralScan imprinting outside of the ballot selection area and timing marks:
 - Left/right: 5mm (0.19685 in)
 - Top/bottom: 12pt (0.16667 in)
- **Scale:** 100% — all VotingWorks ballot PDFs must be printed at 100% scale. Any print scale deviation will render the ballot imprecisely.

- **Print Run Size:** defer to your print vendor's established best practices for quality assurance. In the absence of a vendor recommendation, we recommend that print runs are a consistent size between 500 to 1,000 sheets — consistency eases ballot accounting and the moderate size allows for semi-frequent quality checks.

Ballot Marking Device Ballots

VxMarkScan requires a specific type of thermal paper ballot stock as required by the VSAP BMD 150 component:

- **Manufacturer:** Mitsubishi
- **Model:** Thermoscript TF 1467
- **Width:** 8"
- **Length:** 11, 13.25"
- **Corner Cut:** 16mm, 45° cut, top-right of thermal coated side

TF 1467 paper is only provided in one configuration on white paper with a weight of 140gsm, an opacity greater than 90%, and thermal coating on one side.

VxMarkScan expects the thermal side to be fully blank and therefore pre-printing attributes such as watermarking, ink, and margins are not applicable. Similarly, these ballots are only to be used with ballot marking devices and attributes specific to hand-marking such as folding and bleed-through are also not applicable. Printed text contrast ratio of blank ink on white paper is 21:1.

Reliably Detectable Marks

Marks are determined valid and counted by the system if the amount of darker pixels in the bubble area exceeds a configurable "definite" mark threshold set in the [Election Package](#) system settings file. This mark threshold can be adjusted to have a stricter or looser interpretation of what is considered a valid mark. On both VxScan and VxCentralScan, the voting system does not process any marks as ambiguous. All marks are either valid or invalid.

The recommended and default threshold is 7%. With this threshold setting, hand marked paper ballot interpretation detects a valid mark per the mark conditions described by VVSG 1.1.6-H.

At this default threshold, marks such as a light dot, a fold through a bubble, a stray mark outside of the bubble, or a small line just on the corner of a bubble will be considered invalid. Marks such as a completely filled bubble, half filled bubble, or an X in a bubble will be considered valid.

Examples of invalid and valid marks along with the score for that mark (in green) are shown below.

The mark threshold set on a scanner can be checked by an election official at any point by viewing the readiness report for that device as described in [Diagnostics](#) (see also [VxScan Diagnostics](#) & [VxCentralScan Diagnostics](#) in the user manual).

Invalid Marks

Josiah-Bartlett-1bb99985	79.23%	2.98%
John-Langdon-5951c8e1	79.71%	3.27%
Jeremiah-Smith-469560c9	80.77%	0.00%
Anne-Waldron-ee0cbc85	80.19%	0.00%
James-Poole-db5ef4bd	84.04%	3.27%
Obadiah-Carrigan-5c95145a	80.77%	0.00%
Mary-Baker-Eddy-350785d5	79.04%	0.00%
Samuel-Bell-17973275	78.65%	0.00%
Abeil-Foster-ded38e36	78.94%	0.00%



Valid Marks

Josiah-Bartlett-1bb99985	95.67%	59.42%
John-Langdon-5951c8e1	94.81%	57.79%
Jeremiah-Smith-469560c9	88.27%	28.94%
Anne-Waldron-ee0cbe85	89.33%	31.35%
James-Poole-db5ef4bd	85.19%	21.73%

Marginal Marks

The system also supports setting a marginal mark threshold for flagging ambiguous marks close to but not quite over the definite mark threshold. If a marginal mark threshold is set and marginal mark adjudication is enabled, the definite mark threshold can be increased without having to worry about completely missing marks.

Safety, Security, Privacy, and Continuity of Operation

The following article and linked related articles are intended to cover VVSG 2.0 3.1.2-A.4.

Safety

Per VVSG 2.0 8.1-K - Eliminating Hazards, devices associated with the voting system are certified in accordance with the requirements of UL 62368-1. See [Eliminating Hazards](#). VxSuite hardware is designed to eliminate hazards from shock, radiation, heat, and mechanical dangers when used and maintained in accordance with the [VxSuite User Manual - v4](#).

Security

The system's provisions for security are detailed in the [System Security, Auditing & Logging](#) section.

Privacy

The provisions for voter privacy on VxScan are described in [Preserving Voter Privacy](#). The provisions for voter privacy on VxMarkScan are described in .

Continuity of Operation

Error Recovery

The voting system is designed to recover from errors as gracefully as possible. Displayed error messages, as enumerated in the error message sections in the [VxSuite User Manual - v4](#), are written to guide users to address the error. If the user encounters a recoverable error, the error message will instruct them to how to properly continue operation. For example if a smart card is inserted backward, the

message will prompt the user to insert it correctly. If the user encounters an unrecoverable software error, the error message will prompt the user to restart the machine. The vast majority of problematic software states are resolved by a restart. After restarting, operation can continue.

Machine Replacement

If a machine is damaged to the point of being inoperable, a replacement machine of the same type can be used. For larger customers, VotingWorks recommends that customers buy and maintain their own backup machines. For smaller customers, VotingWorks can provide replacement machines. If a replacement takes place in the middle of an election, users can take the following steps to substitute equipment:

- **VxScan** - Switch to scanning on the replacement VxScan and, at the end of the election, aggregate the cast vote records from both the damaged and replacement VxScans.
- **VxMarkScan** - Voters should start new voting sessions on the replacement VxMarkScan.
- **VxCentralScan** - The document scanner can simply be swapped. If the laptop is damaged and cast vote records were never exported, the scanned ballots should be re-scanned with the replacement laptop.
- **VxAdmin** - If the laptop is damaged, the laptop should be reconfigured with the election package and any cast vote records should be reloaded from the various USB drives.

Paper Processes

VxSuite is ultimately a paper-based voting system and in the case of multiple overlapping failures, a part or the whole of the election can be transitioned to run on paper. If VxScan is damaged, ballots can be deposited in a ballot box and scanned later on VxCentralScan. If VxCentralScan is damaged, ballots can be fed into VxScan. If all scanners are damaged, ballots can be hand-counted.

Processing Capabilities

The processing capabilities of the system are enumerated in the [System Overview](#).

Specifically, capabilities that may be bypassed or enabled by the user are configured in the system settings file within the [Election Package](#).