

## Principle 9 AUDITABLE

The voting system is auditable and enables evidence-based elections

9.1 - An error or fault in the voting system software or hardware cannot cause an undetectable change in election results.

### 9.1-A – Software independence

The voting system is software independent.

Applies to: Voting Device

#### Discussion

Software independence means that an undetected error or fault in the voting system's software is not capable of causing an undetectable change in election results. All voting systems need to be software independent in order to conform to the VVSG.

There are essentially two issues behind the concept of software independence, one being that it must be possible to audit voting systems to verify that ballots are being recorded correctly, and the second being that testing software is so difficult that audits of voting system correctness cannot rely on the software itself being correct. Therefore, voting systems must be 'software independent' so that the audits do not have to trust that the voting system's software is correct; the voting system must provide proof that the ballots have been recorded correctly, e.g., voting records must be produced in ways in which their accuracy does not rely on the correctness of the voting system's software.

This is a major change from previous versions of the VVSG, because previous versions permitted voting systems that are software dependent, that is, voting systems whose audits must rely on the correctness of the software. One example of a software dependent voting system is the DRE, which is now non-conformant to this version of the VVSG.

There are currently two methods specified in the VVSG for achieving independence: 1) through the use of independent voter-verifiable paper records and E2E cryptographic voting systems.

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### 9.1-B – Tamper evident records

The voting system **must** produce tamper-evident records **that** enable detection of incorrect election outcomes.

Applies to: Voting Device

#### Discussion

Tamper-evident records include paper ballots and artifacts from an E2E voting system.

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### 9.1-B.1 – Voter verification

Tamper-evident records **must** provide individual voters the opportunity to verify that the voting system correctly interpreted their ballot selections.

Applies to: Precinct Count Optical Scan and Vote Capture Devices using VVPAT

#### Discussion

Precinct-based voting systems are the only way to accomplish this goal. Entirely separate voting channels, such as remote postal voting do not offer the voter with this opportunity.

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### 9.1-B.2 – Tamper-evident record creation

A tamper-evident record of the contents of each vote **must** be captured at the time of each ballot's casting.

Applies to: Precinct-based voting systems

#### Discussion

Precinct-based voting systems are the only way to accomplish this goal. Entirely separate voting channels, such as remote postal voting do not offer the voter with this opportunity.

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### 9.1-B.3 – Tamper-evident record of errors

Detected errors **must** be recorded in a tamper-evident manner.

Applies to: Voting device

#### Discussion

This ensures that identified issues and other problems cannot be lost or unintentionally modified once they are discovered.

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### 9.1-C – Auditor verification

Voting systems records **must generate records that would** enable external auditors to verify that cast ballots were correctly tabulated.

Applies to: Voting device

#### Discussion

The voting systems themselves cannot make records available to the public. The manner and decision to make these records available is made by a state and or local jurisdiction. This requirement only ensures that the records themselves are generated and can be easily consumed without additional software or assistance from the voting system manufacturer. This requirement is meant to enable external auditors to perform their own count of the election results.

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### 9.1-C.1 – Auditable with compromised software or firmware

The voting system **must** enable a meaningful audit in the presence of compromised or malicious software resident on the system.

Applies to: Voting system

#### Discussion

The production of tamper evidence records protects against this scenario.

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### 9.1-C.2 – Auditable with **compromised hardware**

The voting system **must** enable a meaningful audit in the presence of compromised or malicious hardware components.

Applies to: Voting device

#### Discussion

The production of tamper evidence records protects against this scenario.

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### 9.1-C.3 – Documented **verification procedure**

The voting system manufacturer **must** provide a documented procedure to verify that cast ballots were correctly tabulated.

Applies to: Voting system

#### Discussion

This documentation includes procedures and technical practices that need to be informed to verify the results post-election.

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### 9.1-C.4 – Auditable with **software faults or errors**

The voting system **must** enable a meaningful audit in the presence of faults or errors in software components.

Applies to: Voting device

#### Discussion

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### 9.1-C.5 – Auditable with hardware faults or errors

The voting system must enable a meaningful audit in the presence of faults or errors in hardware components.

Applies to: Voting device

#### Discussion

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### 9.1-D – Voter reported errors

Voting system documentation must describe a method, either through procedural or technical means, for voters to report detected errors or incorrect results.

Applies to: Voting System

#### Discussion

This may include alerting an election worker, or some input that could be provided to the machine.

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### 9.1-E – Paper-based or cryptographic E2E system

Voting systems must meet the requirements within the Paper-based System Architectures and / or Cryptographic E2E System Architectures section.

Applies to: Voting device

#### Discussion

Both of these architectures are software independent, but they may both be used within the same voting system. In this case, the system would need to be compliant with both sets of requirements.

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### 9.1-E.1 – Documentation of mechanism

A voting system manufacturer **must** document the mechanism used to provide software independence.

Applies to: Voting device

#### Discussion

Without knowing the **specific** mechanism, it is difficult to determine if the system truly is software independent.

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Paper-based system architectures

*The following requirements apply to paper-based voting systems.*

### 9.1-F – Paper record production

The voting system **must** produce an **independently verifiable** paper record of the voter's ballot selections.

Applies to: Paper-based system architectures

#### Discussion

Voting systems that use independent voter-verifiable records can satisfy the software independence requirement and thus achieve conformance to the VVSG

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### 9.1-F.1 – Paper record retention

The voting system must retain a paper record of the voter's ballot selections.

Applies to: Paper-based system architectures

#### Discussion

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### 9.1-F.2 – Paper record intelligibility

The recorded ballots selection **must** be presented in a manner understandable by the voter.

Applies to: Paper-based system architectures

#### Discussion

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### 9.1-F.3 – Matching selections

All representations of a voter’s ballot selections produced by the voting system **must** agree with the selections made by the voter.

Applies to: Paper-based system architectures

#### Discussion

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### 9.1-F.4 – Paper record transparency & interoperability

All representations of a voter’s ballot selections **must** use an open and interoperable format.

Applies to: Paper-based system architectures

#### Discussion

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### 9.1-F.5– Identification of errors

The voter **must** have the opportunity to identify ballot errors before it is cast.

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Applies to: Paper-based system architectures

#### Discussion

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#### 9.1-F.6 – Ballot error correction

The voting system must allow a voter to restart a voting session if a ballot is deemed unacceptable.

Applies to: Paper-based system architectures

#### Discussion

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#### 9.1-F.8 – Unique identifier

Each paper ballot that is counted MAY contain a unique identifier.

Applies to: Paper-based system architectures

#### Discussion

This requirement is related to 9.4-B. Voting systems are not required to affix a unique identifier to ballots, but all voting systems that are certified with risk-limiting audit (RLA) capabilities must be able to affix a ballot identifier.

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#### 9.1-F.8.1 – Unique identifier application

Paper ballot identifiers MAY be printed onto the ballot or affixed via some other external mechanism.

Applies to: Paper-based system architectures

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Each ballot's integrity SHALL be maintained throughout the voting process. ¶  
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**Cryptographic E2E system architectures**

The following requirements apply to voting systems using cryptographic E2E technology.

**9.1-G – Cryptographic E2E transparency**

The underlying cryptographic E2E protocol must be publicly available, without an explicit request, for open review for 2 years prior to entering the voting system certification process.

Applies to: Cryptographic E2E system architectures

**Discussion**

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**9.1-G.1 – Cryptographic E2E voter verification**

Individual voters must have the opportunity to confirm that the voting system correctly interpreted their ballot selections.

Applies to: Cryptographic E2E system architectures

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**9.1-G.2 – Opportunity to identify errors**

The voter must have the opportunity to identify ballot errors before their ballot is cast.

Applies to: Cryptographic E2E system architectures

## Discussion

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### 9.1-G.3 – Ballot receipt

After inputting ballot selections, the voter receives a receipt that allows them to verify that their ballot has been correctly recorded and tallied by the system.

Applies to: Cryptographic E2E system architectures

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### 9.1-G.3.1 – Receipt & ballot secrecy

Receipts provided to voters must not display any ballot selections made by voters.

Applies to: Cryptographic E2E system architectures

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### 9.1-G.3.2 – Prevention vote buying & voter coercion

Receipts must not enable voters to prove to others their selections on any cast ballots.

Applies to: Cryptographic E2E system architectures

## Discussion

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### 9.1-G.4 – Ballot receipt transparency & interoperability

Receipt data must be represented in an open and interoperable format.

Applies to: Cryptographic E2E System Architectures

#### Discussion

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### 9.1-G.4.1 – Ballot receipt identifier

Each ballot receipt must contain a unique identifier.

Applies to: Cryptographic E2E system architectures

#### Discussion

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### 9.1-G.5 – Receipt transparency

The voting system must be capable of exporting receipt batches in an open format.

Applies to: Cryptographic E2E system architectures

#### Discussion

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### 9.1-G.6 – Mandatory ballot availability

The voting system must make available all encoded ballots for public posting.

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Applies to: Cryptographic E2E system architectures

#### Discussion

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### 9.1-G.7 – Verification of encoded votes

Voters must have the opportunity to verify that their ballots are included within the tabulation results.

Applies to: Cryptographic E2E system architectures

#### Discussion

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### 9.1-G.7.1 – Sufficient information for verification

The receipt provides sufficient information for voters to verify that their cast ballots are uniquely contained within the publicly available list of encoded ballots.

Applies to: Cryptographic E2E system architectures

#### Discussion

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### 9.1-G.8 – Additional EAC Requirements

The voting system must meet any other requirements for E2E architectures set forth by the Election Assistance Commission or other certifying body.

Applies to: Cryptographic E2E system architectures

## Discussion

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9.2 - The voting system produces readily available records that provide the ability to check whether the election outcome is correct and, to the extent possible, identify the root cause of any irregularities.

### 9.2-A – Compliance audit procedures

The voting system documentation must specify the election procedures necessary to perform a compliance audit.

Applies to: Voting device

#### Discussion

A compliance audit ensures that the election audit trail is sufficiently accurate to reconstruct the outcome according to how voters cast their ballots. Compliance audits provide assurance that a full hand count of the election audit trail shows the outcome according to how the voters really voted.

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### 9.2-B – General post-election audit procedures

The voting system documentation must specify the election procedures necessary to perform a post-election audit.

Applies to: Voting device

#### Discussion

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The voting system allows any individual to verify that the encoded votes were properly tabulated. ¶  
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A voting system manufacture SHALL document the procedure to determine the number of ballots which need to be checked to reach an election official specified margin of error, for a given contest. ¶  
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To ensure that the election outcome is correct with a specified margin of error, a minimum number of ballots must be checked. This may be paper records in paper-based system architectures which are checked by election officials; or checks by voters in cryptographic E2E system architectures. This is important to understanding how efficient the system is at detecting changes due to an error or fault. ¶  
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### 9.2-C – Generation of per-ballot CVRs

The voting system must be capable of recording and reporting a cast vote record for each ballot.

Applies to: Voting device

#### Discussion

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### 9.2-D – Reporting intermediate results

The voting system must be able to report intermediate results as the audit is being conducted.

Applies to: Voting device

#### Discussion

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### 9.2-E – Reporting Anomalous Audit Events

The voting system must be capable of reporting problems as they arise (e.g., matching failures).

Applies to: Voting device

#### Discussion

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### 9.2-F – Reporting Format

The voting system manufacturer **must** document the intermediate and final election audit results in an open format.

Applies to: Voting device

#### Discussion

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### 9.2-G – Ballot count

Voting systems **must** count and report the number of ballots cast.

Applies to: Voting system

#### Discussion

This should be granular enough to have voting devices and tabulators count and report the number of ballots cast.

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9.3 - Voting system records are resilient in the presence of intentional forms of tampering and accidental errors.

### 9.3-A – Data Protection Requirements for Audit Records

All voting systems must meet the requirements listed within 13.1 and 13.2

Applies to: Voting system

#### Discussion

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The voting system SHALL be able to report the final results of the audit.  
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## 9.4 - The voting system supports efficient audits.

### **9.4-A – Efficient compliance audit**

The voting system must produce records to enable an efficient compliance audit.

Applies to: Voting systems

#### **Discussion**

Voting systems need to provide information that will assist election officials in conducting compliance audits, whenever possible. While compliance audits check that procedures are followed, voting systems can provide information that aids in conducting this audit. For example, inspection of event logs, is much more efficient if the logs are available in human readable text format. The use of event codes in logs, which requires manual decoding, are an example of a record which impairs the efficiency of compliance audits.

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Gap notes: \_\_\_\_\_

### **9.4-B – Efficient risk limiting audit**

A voting device that produces paper records must allow election officials to conduct an efficient risk limiting audit.

Applies to: Optical scanners, BMDs

#### **Discussion**

Voting systems contain information which enables election officials to conduct efficient risk limiting audits. For example, by providing a human readable ballot manifest the voting system makes the process of ballot sampling more efficient.

Status: New  
Updated: Feb. 6, 2018  
Source: \_\_\_\_\_  
Gap notes: \_\_\_\_\_

### **9.4-C – Unique ballot identifiers**

Election auditors must be able to uniquely address individual ballots.

Applies to: Auditing system

#### **Discussion**

This is a mandatory capability needed to support RLAs.

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Status:                      New  
Updated:                      Nov. 29, 2017  
Source:                       
Gap notes:                     

### 9.4-D – Multipage ballots

The voting system must be able to appropriately manage multipage ballots.

Applies to: Auditing system

#### Discussion

Status:                      New  
Updated:                      Nov. 17, 2017  
Source:                       
Gap notes:                     

**Deleted:** *The following requirements apply to voting systems, or auditing systems, that perform risk limiting audits.*

*Auditing system refers to either a component of the voting system which assist with the performance of audits, or an external system which assists with the performance of audits..*

#### **9.4-AC – Defining Minimum Risk Limiting Audit RLA Functionality**

The voting auditing system's risk limiting audit logic SHALL use the audit trail to guarantee that there is a large, pre-specified probability that the audit will correct a preliminary outcome if the preliminary outcome is wrong.

[icon] Requirement source → Applies to: Voting DeviceSystem or External Auditing System  
(Add icon)

#### **Discussion**

Status: → New  
Updated: → Nov. 17, 2017  
VVSG 1.1: →  
Gap notes: →

#### **9.4-BD – Unique Ballot Identifiers**

Election auditors SHALL be able to uniquely address individual ballots.

[icon] Requirement source → Applies to: Voting Device or External Auditing System  
(Add icon)

#### **Discussion**

Status: → New  
Updated: → Nov. 29, 2017  
VVSG 1.1: →  
Gap notes: →

#### **9.4-DC – Multipage Ballots**

The voting system SHALL be able to appropriately manage multipage ballots.

[icon] Requirement source → Applies to: Voting Device or External Auditing System  
(Add icon)

#### **Discussion**

Status: → New  
Updated: → Nov. 17, 2017  
VVSG 1.1: →  
Gap notes: → EauditingSystem or External Auditing System

#### **9.4-FD – Notification of Full Count Efficiency**

The voting system or auditing system is capableable to of alerting alert election officials when a full count would be more efficient than conducting the risk limiting audit.

[icon] Requirement source → Applies to: Voting DeviceSystem or External Auditing System  
(Add icon)

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## 9.1-H – Determining minimum number of ballots to check

A voting system manufacture SHALL document the procedure to determine the number of ballots which need to be checked to reach an election official specified margin of error, for a given contest.

[\[icon\] Requirement source](#)

[Applies to: Voting System](#)

### Discussion

To ensure that the election outcome is correct with a specified margin of error, a minimum number of ballots must be checked. This may be paper records in paper-based system architectures which are checked by election officials; or checks by voters in cryptographic E2E system architectures. This is important to understanding how efficient the system is at detecting changes due to an error or fault.

|            |               |
|------------|---------------|
| Status:    | New           |
| Updated:   | Jan. 29, 2018 |
| VVSG 1.1:  | N/A           |
| Gap notes: |               |

## 9.1-H.1 – No fixed margin of error

The voting system SHALL NOT be bound to specific margins by the manufacturer, rather the margin is determined by the election officials.

[\[icon\] Requirement source](#)

[Applies to: Voting System](#)

### Discussion

This effectively requires the documentation of the margins to be specified as an equation. Additional inputs such as margin of victory, total number of voters, number of voters for each candidate, actual ballots, or an audit trail, may be needed to determine the number of ballots needed.

|            |               |
|------------|---------------|
| Status:    | New           |
| Updated:   | Jan. 29, 2018 |
| VVSG 1.1:  | N/A           |
| Gap notes: |               |

## 9.1-I – Random number generation

If a voting system generates random or pseudo-random numbers the manufacture SHALL document the method used to obtain the numbers, and how the random number are used within the voting system.

[\[icon\] Requirement source](#)

[Applies to: Voting System](#)

## Discussion

Various systems used to implement software independence require random numbers, whether for ballot selection for audits, or cryptographic purposes, we want to make sure that the system chosen is appropriate for how it will be used.

There are several reasons for this requirement, chief among them is to ensure that cryptographic protocols requiring random numbers use a TRNG or a CSPRNG as required.

Status: New  
Updated: Feb. 6, 2018  
VMSG 1.1: N/A  
Gap notes:

*The following requirements apply to voting systems, or auditing systems, that perform risk limiting audits*

*Auditing system refers to either a component of the voting system which assist with the performance of audits, or an external system which assists with the performance of audits..*

### 9.4-AC – Defining Minimum Risk Limiting Audit RLA Functionality

[FJM(1)][FJM(2)][FJM(3)]

The voting auditing system's risk limiting audit logic [MS4][HGE(5)][FJM(6)][FJM(7)] SHALL use the audit trail to guarantee that there is a large, pre-specified probability that the audit will correct a preliminary outcome if the preliminary outcome is wrong.

[icon] Requirement source Applies to: Voting DeviceSystem or External Auditing System

(Add icon)

## Discussion

Status: New  
Updated: Nov. 17, 2017  
VMSG 1.1:  
Gap notes:

### 9.4-BD – Unique Ballot Identifiers

Election auditors SHALL be able to uniquely address individual ballots.

[icon] Requirement source Applies to: Voting Device or External Auditing System

(Add icon)

#### Discussion

Status: New  
Updated: Nov. 29, 2017  
VMSG 1.1:  
Gap notes:

### 9.4-DC – Multipage Ballots

The voting system SHALL be able to appropriately manage multipage ballots.

[icon] Requirement source Applies to: Voting Device or External Auditing System

(Add icon)

#### Discussion

Status: New  
Updated: Nov. 17, 2017  
VMSG 1.1:  
Gap notes: EauditingSystem or External Auditing System

### 9.4-FD – Notification of Full Count Efficiency

The voting system or auditing system is capableable to of alerting alert election officials [MS8][HGE(9)][FJM(10)]when a full count would be more efficient than conducting the risk limiting audit.

[icon] Requirement source Applies to: Voting DeviceSystem or External Auditing System

(Add icon)

#### Discussion

Status: New  
Updated: Nov. 17, 2017  
VMSG 1.1:  
Gap notes:

### 9.4-GE – Selection of Sample or Batch Size

The voting system or auditing systemThe voting system SHALL be able to assist election jurisdictions with selecting a sample size and/or batch size.

[icon] Requirement source Applies to: Voting DeviceSystem or External Auditing System [MS11][HGE(12)]

(Add icon)

#### Discussion

Status: New  
Updated: Nov. 17, 2017  
VVSG 1.1:  
Gap notes:

### 9.4-HF – Notification of Reaching the Desired Confidence Level

The voting system or auditing systemThe voting system is able to alerts an auditor once the desired confidence level is attained.

[icon] Requirement source Applies to: Voting DeviceSystem or External Auditing System

(Add icon)

#### Discussion

Status: New  
Updated: Nov. 17, 2017  
VVSG 1.1:  
Gap notes:

### 9.4-IG – Modifying the Desired Confidence Level

The voting auditing system is able tocan modify the desired confidence level for each audit.

[icon] Requirement source Applies to: Voting Device or External Auditing System

(Add icon)

#### Discussion

Status: New  
Updated: Nov. 17, 2017  
VVSG 1.1:  
Gap notes:

#### 9.4-JH – Concurrently Auditing Multiple Contests

The voting auditing system SHALL be able to audit multiple contests concurrently.

[icon] Requirement source Applies to: Voting Device or External Auditing System

(Add icon)

##### Discussion

Status: New  
Updated: Nov. 17, 2017  
VVSG 1.1:  
Gap notes:

#### 9.4-IK – Tracking Audited Ballots

The voting auditing system SHALL keep track a queryable list of which ballots were already audited[MS13][HGE(14)].

[icon] Requirement source Applies to: Voting DeviceSystem or External Auditing System

(Add icon)

##### Discussion

Status: New  
Updated: Nov. 17, 2017  
VVSG 1.1:  
Gap notes:

*The following requirements apply to voting systems that perform ballot level comparison audits.*

#### 9.4-LJ – Accepting Audit Input

The voting auditing system SHALL be capable of manually accepting ballot information from election auditors.

[icon] Requirement source Applies to: Voting Systems performing Ballot Level Audits(Add icon)

#### Discussion

Status: New  
Updated: Nov. 17, 2017  
VVSG 1.1:  
Gap notes:

### 9.41-MK – Selecting Individual Ballots

The voting auditing system SHALL be capable of selecting which individual ballot to audit.[MS15]

[icon] Requirement source Applies to: Voting Systems performing Ballot Level Audits(Add icon)

#### Discussion

Status: New  
Updated: Nov. 17, 2017  
VVSG 1.1:  
Gap notes:

*The following requirements apply to all systems.*

### 9.4-L – Efficient Compliance Audit

The voting system SHALL produce records to enable an efficient [MS16][HGE(17)][FJM(18)]compliance audit.

[icon] Requirement source Applies to: Voting Systems

#### Discussion

Voting systems need to provide information that will assist election officials in conducting compliance audits, whenever possible. While compliance audits check that procedures are followed, voting systems can provide information that aids in conducting this audit. For example, inspection of event logs, is much more efficient if the logs are available in human readable text format. The use of event codes in logs, which requires manual decoding, are an example of a record which impairs the efficiency of compliance audits.

Status: New  
Updated: Feb. 6, 2018  
VVSG 1.1:

Gap notes:

### 9.4-M – Efficient Risk Limiting Audit

A voting system SHALL produce records that allow election officials to conduct an efficient risk limiting audit.

[\[icon\] Requirement source](#)

[Applies to: Voting Systems](#)

#### Discussion

Voting systems contain information which enables election officials to conduct efficient risk limiting audits. For example, by providing a human readable ballot manifest the voting system makes the process of ballot sampling more efficient.

|            |              |
|------------|--------------|
| Status:    | New          |
| Updated:   | Feb. 6, 2018 |
| VVSG 1.1:  |              |
| Gap notes: |              |