



# VSAP BALLOT AND QR CODES

VERIFICATION, AUDITABILITY, ACCURACY AND SECURITY



The Voting Solutions for All People (VSAP) Ballot Marking Device (BMD) is a voting innovation that improves the voting experience for all voters using technology while retaining a paper ballot as the official, durable and auditable record of the voter's selections. The BMD uses a touchscreen to present the voting experience in a way that is intuitive, usable and accessible, and a printer to print the voter's selections on paper. Throughout the voting experience guidance is provided to the voter promoting verification of selections prior to and after printing the paper ballot. Importantly, the BMD does not record votes electronically and does not retain any information about the voter's ballot after the voting session has ended.

Working closely with a Technical Advisory Committee including national experts in the field of election technology over several years, Los Angeles County has invested a great amount of time and resources in the research, design and development of the BMD to ensure the will of the voters is accurately reflected in election results. Central to this assurance is the voter's ability to verify that the BMD accurately recorded the voter's selections on the paper ballot. Los Angeles County conducted usability and accessibility studies involving thousands of people and designed a user experience focused on the voter's interaction with and verification of the paper ballot. It also implemented a security architecture that uses secure boot and trusted computing to minimize the chance that unauthorized and/or malicious software could be installed on the device.

## WHAT IS THE VSAP BALLOT?

The VSAP ballot is printed on specially coated thermal paper designed to be durable enough to ensure retention of the VSAP ballot throughout the legally required period associated with the election. An official tint and watermark for the election, provided by the California Secretary of State (SOS), is printed on the back of the ballot. The VSAP ballot has four areas of information, as can be seen in Figure 1 below.





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**DEMONSTRATION BALLOT**  
**VSAP Demonstration Election**

Ballot Style  
22300  
Serial Number  
1  
Precinct Number  
9950001A

**VSAP**  
Voting Solutions  
for All People

County of Los Angeles

MAYOR		PRESIDENT AND VICE PRESIDENT	
LATOYA WILLIAMSON	4N	CAROL HOW /ANDY WU	N
UNIFIED SCHOOL DISTRICT BOARD MEMBERS		ARD	
SANDRA WOODS	4E	UNITED STATES SENATOR	
No Selection	H	PORTER VANDEVOORDE	Y
No Selection	J		
STATE SENATOR			
DORIS TRAN	3C		
MEMBER OF THE STATE ASSEMBLY			
RUSSEL RIVERA	3K		
UNITED STATES REPRESENTATIVE			
MONIQUE JACKSON	35		
DISTRICT MEASURE A			
YES on Measure A	4S		
COUNTY SUPERVISOR			
KENDRICK YOUNG	45		
JUDGE OF THE SUPERIOR COURT			
KASEY MCCRARY	3Z		
COUNTY MEASURE B			
NO on Measure B	4A		
GOVERNOR			
ANTONY BATHLONE	X		
For Chief Justice of Supreme Court			
NO	3Q		
For Presiding Justice, Court of Appeal, Second Appellate District, Division One			
NO	3S		
For Presiding Justice, Court of Appeal, Second Appellate District, Division Two			
NO	3U		
For Associate Justice, Court of Appeal, Second Appellate District, Division One			
NO	3W		
For Associate Justice, Court of Appeal, Second Appellate District, Division Two			
NO	3Y		

- The Election Header, across the top and down the left side, consisting of the Official Ballot designation, the election title and date, the party (for Presidential Primary elections only), and the County name and seal.
- A Ballot Activation QR code in the upper left corner, which tells the BMD which ballot style to activate. The ballot style, precinct number, and serial number (a numeric ID for the precinct) are also printed to the right of this QR code.
- A Vote Selections Print Area below the election header, where the contest names and vote selections are printed for each contest on the ballot. Printed to the right of each selection (i.e. candidate name or measure response) is the unique ID of the vote selection. This information is the official record of the votes cast and is also used for auditing and recount purposes.
- A Vote Selections QR Code below the County name and seal, which encodes the vote selection IDs in the same order in which they are printed on the ballot. The QR code is used by the VSAP Tally System to read and process the votes cast on the ballot.

Figure 1. Sample of a voted and printed BMD ballot.





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### HOW DOES THE VOTER VERIFY THE BALLOT?

The voting experience on the BMD promotes, by design, the voter's verification of the ballot prior to casting. When the ballot is inserted, the BMD reads the Ballot Activation QR code and presents the associated ballot style to the voter. After making the desired selections, the voter is presented with a review screen to confirm or change the desired vote selections, as shown in Figure 2. The BMD makes the voter aware of any contests that may not have been marked (under voted). Once the voter has completed the review and clicks Next, the voter is asked if they are ready to print (Figure 3). The voter is given the option to go back to the previous screen to continue reviewing the ballot and make any further changes if desired.

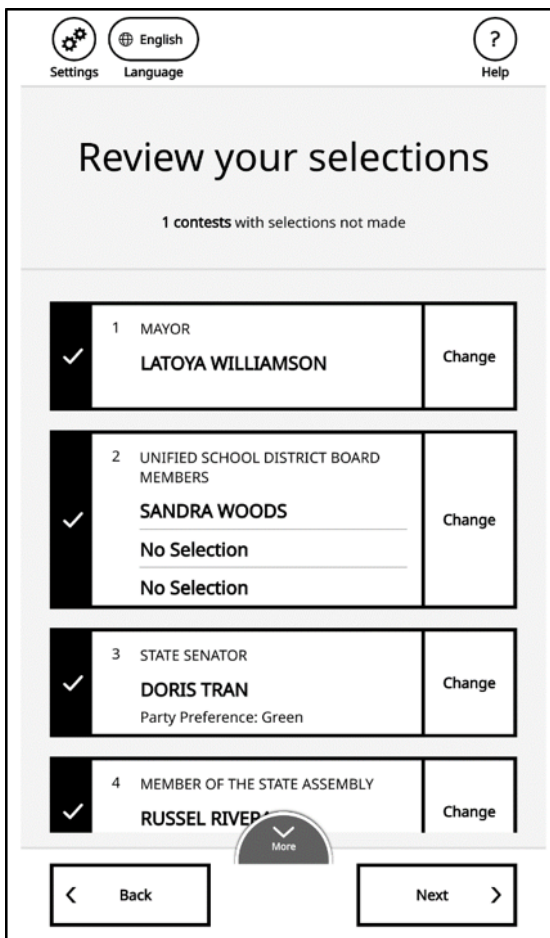


Figure 2. Selections review screen.

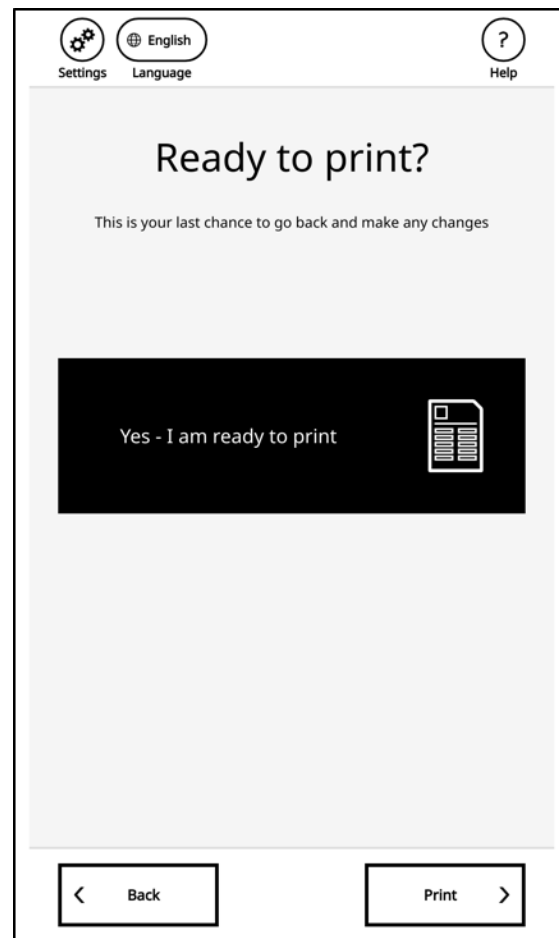


Figure 3. Ready to print screen.





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Upon clicking Print, the BMD prints the voter's selections and the Vote Selections QR code on the VSAP ballot and presents it to the voter for review prior to casting, as shown in Figure 4 below.



Figure 4. BMD paper ballot presented to the voter.

The BMD hardware has been carefully designed for usability and accessibility, placing special emphasis on the interaction between the voter and the printed ballot. The BMD presents the voted ballot onto a lighted deck, making it easy for the voter to review the printed selections without having to handle the ballot. At the same time, the BMD presents a screen (Figure 5) reminding the voter to verify the printed ballot prior to casting it.

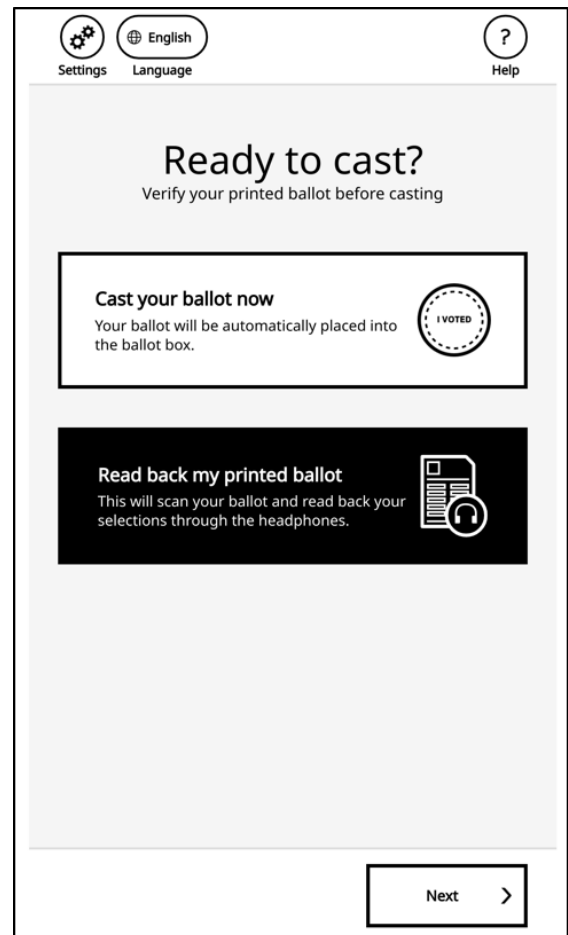


Figure 5. Ready to cast screen with reminder to verify the ballot.





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After the voter has verified the selections printed on the ballot, the voter may cast the ballot into the ballot box integrated into the BMD or have the BMD read back the vote selections for further verification prior to casting, as shown in Figure 6.

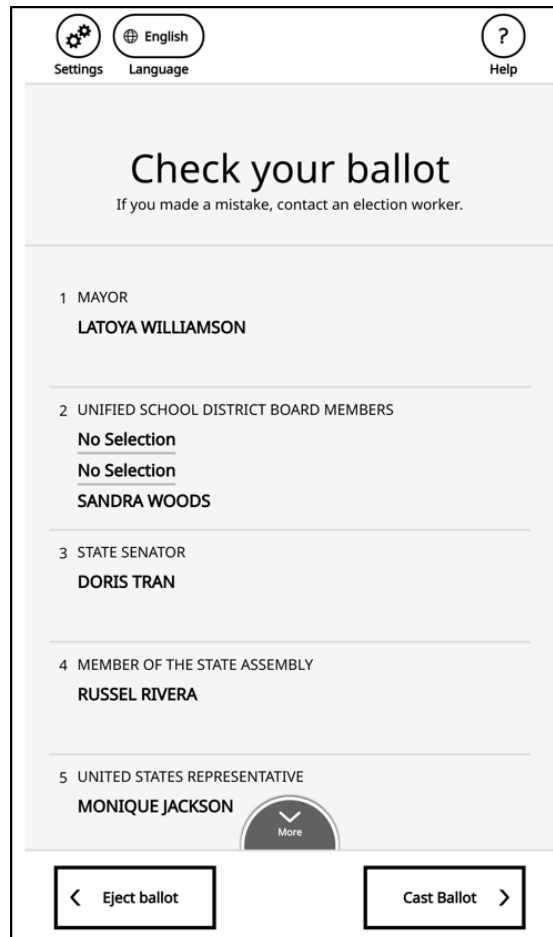


Figure 6. Check your ballot screen.

The BMD reads the vote selections on the ballot from the Vote Selections QR code. After checking the vote selections, the voter may cast the ballot or, if the voter wishes to make changes, they may eject it, spoil it, and request a new ballot. Because selections are read from the Vote Selections QR code on the printed ballot, this step of reading back the voted ballot and casting it may be done on any BMD at a vote center.





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### CAN THE QR CODE BE AUDITED?

The QR code is a widely used, open format for encoding data in a resilient two-dimensional barcode. Because it is an open format, there are numerous applications, many of them free, that are publicly available for scanning and decoding a QR code, so that the contents may be read<sup>1</sup>. A voter could, therefore, use any QR code reader to decode the Vote Selections QR code on their ballot and verify that the selections encoded in the QR code are identical to the selections printed on the ballot.

As an example, when the Vote Selections QR code printed on the ballot shown in Figure 1 is scanned by a QR code reader, the following data will appear:

```
VER:A.SEL:4N/4E/H/J/3C/3K/35/4S/45/3Z/4A/X/3Q/3S/3U/3W/3Y/N/Y.
BMD:0000046.SIG:4R57D5C44QKEJRS3OBF33PL0Z6U9THBR74NTA1VVH
K09E6NFDH4DWXPY8Q9ZF6VD0LAQ1E6IY6AGQC1S4TG095N8NEN3AFOET12.
```

This data is stored as a string of text organized in a key-value pair format designed for the BMD. The table in Figure 7 provides a breakdown and description of the key-value pairs in the example above.

Key	Value	Description
VER	A	Version of the VSAP key-value format
SEL	4N/4E/H/J/3C/3K/35/4S/45/3Z/4A/X /3Q/3S/3U/3W/3Y/N/Y	The vote selection IDs listed in the same order as those printed on the ballot
BMD	0000046	Device ID of the BMD
SIG	4R57D5C44QKEJRS3OBF33PL0Z6U9TH BR74NTA1VVHK09E6NFDH4DWXPY8Q9ZF6VD 0LAQ1E6IY6AGQC1S4TG095N8NEN3AFOET12	The digital signature applied to the data in the Ballot Activation and Vote Selection QR codes by the BMD security module

Figure 7. Description of key-value pairs encoded in the Vote Selections QR code.

To audit the QR code and verify that the correct vote selection IDs are being transmitted to the Tally system, the voter need only compare the SEL key values in the QR code (see text in red above) with the vote selection IDs printed on the ballot (see Figure 1).

<sup>1</sup> For example, on iOS devices like the iPhone there are apps such as QR Code Reader (TapMedia LTD), Barcode Scanner, and others. On Android devices, the native Camera app has QR code reading capabilities, however there are also dedicated apps such as QR Code Reader (TWMobile). You can install one of these apps and point them at the QR code in the image of the ballot at the beginning of this paper and verify that you get the same result as reported below.





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### **ARE QR CODES ACCURATE AND SECURE?**

QR codes utilize a well-known and widely used error correction algorithm to add a checksum to the QR encoding, ensuring the data in the QR code is either read accurately (even when there is partial damage to the QR code) or is not read at all. This feature makes QR codes ideal for the machine-reading of vote selection IDs on the ballot as it prevents the transmission of incorrect data.

The checksum also makes the QR code very reliable and tamper resistant. Once the QR code is printed on the ballot, it would be exceedingly difficult and impractical to modify the printed code in a way that would change the encoded values without also making the QR code unreadable.

Moreover, since the data in the QR code is also digitally signed by the BMD's trusted computing module (using a private key physically rooted in the BMD hardware), it will not be processed by the VSAP Tally System until after it verifies the signature using the BMD public key, ensuring that only authentic VSAP ballots are accepted for tallying.

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<sup>2</sup> See: "Reed–Solomon error correction", [https://en.wikipedia.org/w/index.php?title=Reed%E2%80%93Solomon\\_error\\_correction&oldid=899794439](https://en.wikipedia.org/w/index.php?title=Reed%E2%80%93Solomon_error_correction&oldid=899794439), (last visited June 3, 2019).

