



How a Paper Receipt can Enhance Voter Trust and Create an End-to-End Verifiable System.

Executive Summary

Declining voter confidence in the fairness and openness of the U.S. election process stems from perceived obscurity in the ballot reading, collection, and tallying procedures from the perspective of the voter. A proposed verification system addresses this issue by enhancing transparency and verifiability in elections through independent receipt printers and a publicly accessible online bulletin. This system allows voters to verify their ballot selections and ensures accurate tallying, aligning with NIST's 2010 End-to-End (E2E) Verifiable Elections requirements. This paper outlines the operational framework of the verification system and demonstrates its compliance with E2E verifiability criteria, offering a solution to restore confidence in election integrity.





Issue

Voter distrust in U.S. elections is increasing due to a lack of transparency in how ballots are processed and tallied. This opacity undermines confidence in the fairness and accuracy of election outcomes. Existing systems often fail to provide voters with direct, verifiable evidence that their votes are correctly recorded and counted, exacerbating concerns about potential errors or malfeasance. The National Institute of Standards and Technology (NIST) defines E2E verifiability through six criteria: well-formed presented ballots, well-formed cast ballots, recorded as cast, tallied as recorded, consistency, and ensuring each recorded ballot is subject to a “recorded as cast” check. A solution is needed to meet these standards, enhancing voter trust without disrupting existing election infrastructure.

Background

The verification system is an independent framework designed to augment current voting processes by providing voters with tools to verify their ballot selections and monitor election results. It operates through two main components: receipt printers, which generate secure receipts for voters, and a public online bulletin that displays ballot data. The system supports both in-person and mail-in voting, ensuring transparency while maintaining voter anonymity. By adhering to NIST’s E2E verifiability requirements, the verification system aims to address voter concerns about election integrity and provide a mechanism for manual auditing.





Verification System Overview

The verification system's operational framework is designed to enhance transparency while integrating seamlessly with existing voting infrastructure. Below is a summary of its procedures for in-person and mail-in voting:

In-Person Voting

- **Receipt Printer Integration:** Each receipt printer is paired with a single ballot scanner via a hardwired, one-way connection (scanner to printer) to prevent external interference. The printer lacks network connectivity, ensuring security.
- **Ballot Processing:** Upon scanning a ballot, the scanner transmits the voter's selections (without personally identifiable information) to the receipt printer, which generates a unique Audit Code.
- **Voter verification:** Voters can request a receipt printed on watermarked paper, including the polling place details, candidate selections, Audit Code, and the URL of the online bulletin. Voters can discard or cast their vote, with the printer marking the ballot reading accordingly.
- **Data Security and Transfer:** Ballot readings are encrypted using a symmetric cryptographic algorithm and stored on the printer. At the end of election day, an approved representative transfers the encrypted data to a USB drive, which is then uploaded to a secure server. The USB drive is wiped post-transfer.
- **Public Bulletin:** The database is displayed on a secure, publicly accessible website, listing each ballot's precinct, selections, Audit Code, and cast/discard status, alongside aggregated tallies by state, county, or district.

Mail-In Voting

- **Audit Code Inclusion:** Mail-in ballots include a pre-assigned Audit Code on the ballot and a separate Audit Slip (on watermarked paper) with the bulletin URL.
- **Ballot Processing:** A receipt printer, paired with a ballot scanner, records the selections and Audit Code during scanning. No receipt or discard option is provided, as the ballot is automatically marked as cast.
- **Data Handling and Public Display:** The process mirrors in-person voting for encryption, data transfer, and public online bulletin display.

Analysis: Compliance with NIST E2E Verifiability Requirements

The verification system is designed to meet NIST's six E2E verifiability criteria, ensuring voters can verify their votes and detect errors or malfeasance.





Below, each criterion is evaluated:

1. Presented Ballots Are Well-Formed

The verification system does not alter existing ballot formats, other than adding Audit Codes to mail-in ballots. Optical scan ballots remain standard, ensuring voters can verify correct printing. The system does not interfere with current mechanisms for ensuring well-formed ballots, maintaining compliance.

2. Cast Ballots Are Well-Formed

The verification system reinforces existing safeguards against overvotes or negative votes by publishing ballot readings on the public bulletin, allowing anyone to identify irregularities. Any discrepancies between the scanner's and receipt printer's tallies or collusion between devices are detectable via the public tallies.

3. Recorded as Cast

The verification system enhances this criterion by issuing receipts (on watermarked paper) that allow voters to verify the scanner's interpretation of their selections. Voters can discard incorrect readings and restart. Post-election, voters can check their ballot on the public bulletin using the Audit Code. Discrepancies between receipts and bulletin entries provide evidence of malfeasance. For mail-in voters, Audit Slips enable verification, though without in-person confirmation, proof is weaker (e.g., a photo of the ballot). Malicious device behavior (e.g., incorrect cast/discard markings) is detectable through tally discrepancies or voter-held receipts, ensuring robust compliance.

4. Tallied as Recorded

The verification system's public bulletin lists all recorded votes, allowing anyone to verify tallies by summing bulletin entries. Discrepancies between bulletin entries and official tallies indicate errors, detectable by voters with receipts. The system's independence from official tallies ensures no interference with existing processes, guaranteeing compliance. The verification system is not the official vote, it is an audit of the vote.

5. Consistency

The verification system's bulletin and tallies are uniformly displayed to all users, preventing selective manipulation. Any changes to bulletin entries or tallies would create detectable discrepancies with official tallies or voter receipts, ensuring consistency across "recorded as cast" and "tallied as recorded" checks.

6. Each Recorded Ballot Is Subject to the "Recorded as Cast" Check

The verification system prevents duplicate Audit Codes, which could allow vote deletion or injection. For mail-in ballots, unique Audit Codes ensure distinct bulletin entries, detectable if duplicated. For in-person voting, reusing Audit Codes for identical selections is thwarted if voters discard votes, as conflicting cast/discard markings would appear on the bulletin, detectable via receipts. This design ensures all ballots are verifiable.





Benefits

- **Enhanced Transparency:** Voters can directly verify their ballot selections and election tallies, addressing distrust.
- **Security:** One-way data flow, encryption, and watermarked receipts prevent tampering and ensure voter anonymity.
- **Auditability:** Public bulletin and receipts enable manual auditing by voters and third parties.
- **Compatibility:** Integrates with existing voting infrastructure, minimizing disruption.

Challenges

- **Adoption Costs:** Deploying receipt printers and maintaining servers may require investment.
- **Voter Education:** Ensuring voters understand how to use receipts and the bulletin is critical.
- **Mail-In Limitations:** Lack of in-person verification reduces the strength of mail-in voter proof, though Audit Slips mitigate this.

Recommendations

- **Pilot Implementation:** Deploy the verification system in select precincts to test scalability and voter response.
- **Public Outreach:** Launch campaigns to educate voters on using receipts and the online bulletin.
- **Partnerships:** Collaborate with election officials to ensure seamless integration with existing systems.
- **Continuous Evaluation:** Monitor system performance and voter feedback to refine processes

Conclusion

The verification system addresses growing voter distrust by providing a transparent, verifiable election framework that meets NIST's E2E verifiability requirements. Through secure receipt printers and a public online bulletin, it empowers voters to confirm their votes are accurately recorded and tallied while maintaining compatibility with current infrastructure. By implementing this system, election officials can restore confidence in U.S. elections, ensuring fairness and accountability.