NIST Grant/Contractor Report
NIST GCR 22-033

Gap Analysis for Key Interoperability Scenarios in Election Technology

John Dziurłaj

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Abstract

This document describes potential use-cases for data interoperability in election technology components not previously considered in past efforts. Such components include on-demand ballot printing systems, remote ballot marking systems and electronic poll books. Each component is described along with a set of generalized functions it performs. Existing common data formats are considered for their applicability to component functions. Where gaps are found, suggestions to enhance interoperability are described.

Keywords

Common data format; Election technology; Electronic poll books; On-demand ballot printing; Remote ballot marking.

Acknowledgments

We would like to acknowledge the members of the NIST Common Data Format Research Group who lent their time and expertise to this document.

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1. Overview

NIST produced four common data formats (CDFs) under the auspices of the NIST-EAC Interoperability Working Group. These four CDFs are:

- Cast Vote Records (NIST SP 1500-103)[1] hereafter referred to as CVR,
- Election Event Logging (NIST SP 1500-101)[2], hereafter referred to as EEL
- Election Results Reporting (NIST SP 1500-100)[3], hereafter referred to as ERR and
- Voter Records Interchange (NIST SP 1500-102)[4], hereafter referred to as VRI

Each common data format provides import and export functionality between election system components in support of numerous use-cases. CDF support for a particular use-case is dependent on the proper expression of classes of data and applicable relationships between them. Each CDF has been constructed to support as many use-cases as possible by using a flexible, Unified Modeling Language (UML)[10] based data model.

This document considers interoperability scenarios between components not explicitly covered by the existing NIST Common Data Formats, and how best to support them. Specifically, the following components are considered:

- on-demand ballot printing,
- remote ballot marking,
- electronic poll books, and
- interactions between electronic poll books and VRDBs.

For each component, we consider the functions it performs and the required information to support those functions. Finally, we provide recommendations on how to improve the support for these data exchanges.

1.1. Methodology

The interoperability requirements for each component are identified through structured analysis. Specifically, a data flow diagram is constructed, using Gane-Sarson notation[5]. Each use-case of the component is enumerated as a *process*. The data required for each use-case is specified using *data flows* – arrows pointing from the source of the data to its target. Data can flow between *processes*, *data-info stores*, and *external agents*. Data flowing between the component under consideration and other election technology components are of particular interest; additional details about the classes of data being transmitted are also collected.

Finally, the currently applicable common data formats for each use-case, if any, are listed along with a score that indicates how well the common data format currently supports the use-case. Any required improvements are also noted.

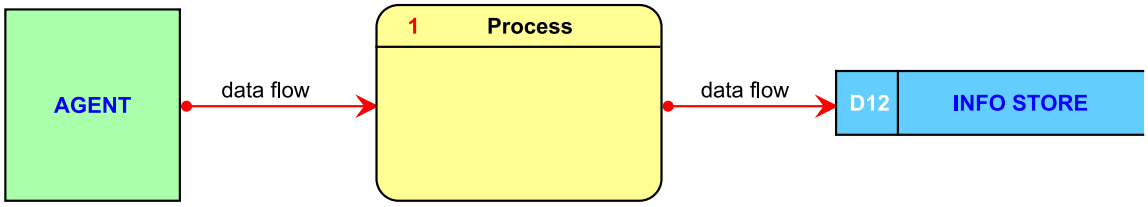

Figure 1 - Shapes used by data flow diagrams

1.2. How to read this document

This document is broken down by election component, with each component receiving its own section. For each component, a data flow diagram (DFD) is constructed. The DFD consists of use-cases (DFD processes), data flows that support those use-cases, data stores (i.e., data stored inside the component) and external participants (such as other systems) to the components. Each component may have one or more DFDs. While the feature sets of each component type may vary by vendor, there are enough similarities between products that this component breakdown is useful.

How well each use-case is supported by an existing CDF is ranked on a qualitative scale (poor, fair, good, excellent):

- Poor – coverage is poor or nonexistent. Interoperability is unlikely to be achieved with current versions of the CDFs.
- Fair – CDFs cover some data points required for the use-case, but not optimally. Interoperability may only be possible in limited scenarios.
- Good – CDFs cover all data points. There may be some minor improvements that can be made to better support the use-case.
- Excellent – CDFs cover all data points and the use-case explicitly.

2. On-Demand Ballot Printing

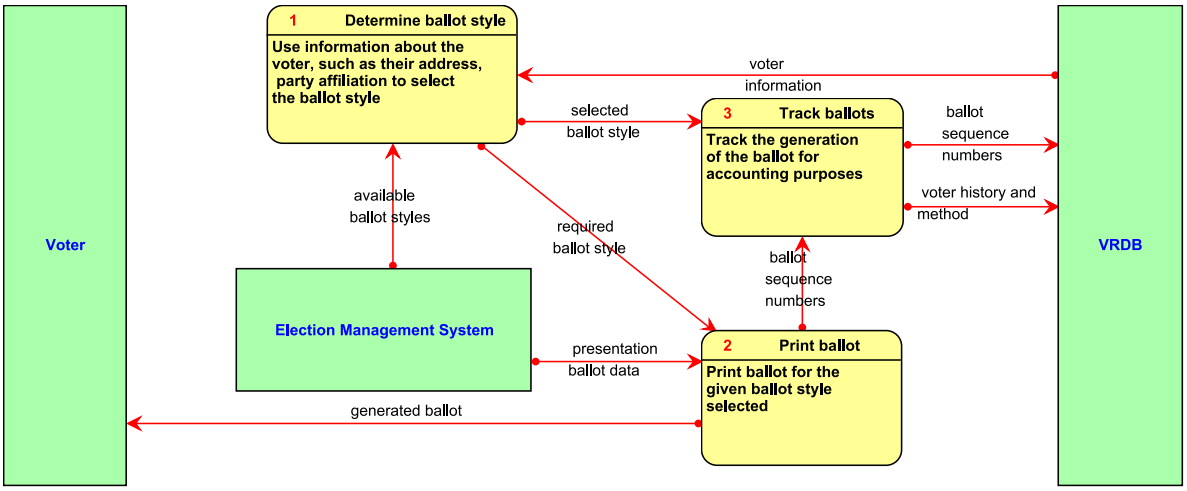

Figure 2 - Data flow diagram of on-demand ballot printing

2.1. Use-Cases

We have identified three use-cases for on-demand ballot printing.

Use-case	Description
Determine ballot style	Use information about the voter, such as their address, party affiliation to select the ballot style
Print ballot	Print ballot for the given ballot style selected
Track ballots	Track the generation of the ballot for accounting purposes

2.2. Description of component

According to the NIST Glossary of Election Terms[6], ballot on demand[1] (on-demand ballot printing) is:

> *A process that produces a paper ballot of the required ballot style that meets a specific voter's needs. The use of this process requires:*
>
> *a system with a printer that can create a tabulatable paper ballot; and*

[1] "Ballot on demand" is a registered trademark of Election Systems & Software, LLC.

a device driving the printer that has all the data needed to print each ballot style and allows selection of the needed style.

On-demand ballot printing systems are usually configured as a commercial off-the-shelf (COTS) personal computer, along with a COTS or modified-COTS printer. On-demand ballot printing systems produce ballots that meet the tabulation requirements of voting system scanners and may provide additional audit capabilities. They can be configured to fall within or outside the scope of the VVSG-defined[7] voting system.

2.3. Analysis

An on-demand ballot printing (ODPB) system might need to interface with two or more systems, the election management system (EMS)—usually part of a larger voting system—and a voter registration database (VRDB) or other system containing data typically associated with voter registration, e.g., an electronic poll book. The EMS contains information related to the ballot styles sufficient to produce those ballots (i.e., ballot styles with presentation details).

The VRDB contains information related to voters within a jurisdiction. Each voter should be assigned to one or more geopolitical units whose ballot style identifiers are shared or derivable by both systems (e.g., the EMS and VRDB). Additionally, voters may be affiliated with, or choose, a party associated with particular ballot style(s) (in states with closed or semi-closed primaries). Finally, some voters may be entitled to vote on only a subset of contests in their precinct based on their situation (e.g., voters who reside overseas and have no intent to return).

The tracking of chain of custody of the ballot (from blank stock to the voter) is important for auditability, and many on-demand ballot printing systems produce data about the ballots themselves, including the number of ballots printed, of which styles, and any associated sequence numbers. Sequence numbers are typically printed on the ballot in such places that the correspondence to the voter can be removed prior to casting.

Such information is typically stored in VRDB, although some jurisdictions may use a purpose-built ballot tracking system.

2.3.1. Use-Case Coverage

Table 1 – Use case coverage for on-demand ballot printing

Use-case	Required Data	Coverage	Current State
Determine ballot style	• available ballot styles • voter information	Fair (VRI)	VRI supports providing one or more ReportingUnit identifiers which could be used to determine a ballot style to use.
Print ballot	• required ballot style • presentation ballot data	Poor (VRI)	VRI supports providing one or more ReportingUnit identifiers which could be used to determine a ballot style to use. Presentation details, either prerendered (PDF) or renderable are not conveyable via any CDF.
Track ballots[a]	• selected ballot style • ballot sequence numbers	Fair (VRI)	VRI can track participation, but no details on ballots (stub numbers, etc.)

[a]Any ballot tracking process must take care to preserve ballot privacy and secrecy

2.4. Recommendations

On-demand ballot printing requires ballot styles, either in a fully rendered (i.e., PDF), or renderable (i.e., interoperable) format. Because a ballot style common data format is currently under consideration, we recommend that the ballot style CDF consider the needs of on-demand ballot printing systems.

VRI[4], one of the published common data formats, already conveys such items as ballot style identifiers and districts. The feasibility of extending the VRI specification to support on-demand ballot printing scenarios more explicitly should be explored.

Because we have identified two required systems to enable the on-demand ballot printing use-cases, it is unlikely that a single common data format will completely support them.

On-demand ballot printing is strongly associated with electronic poll books (EPB). Many of the processes related to on-demand ballot printing can be performed by electronic poll books. If an EPB CDF is considered, it should explicitly support on-demand ballot printing scenarios.

3. Remote Ballot Marking

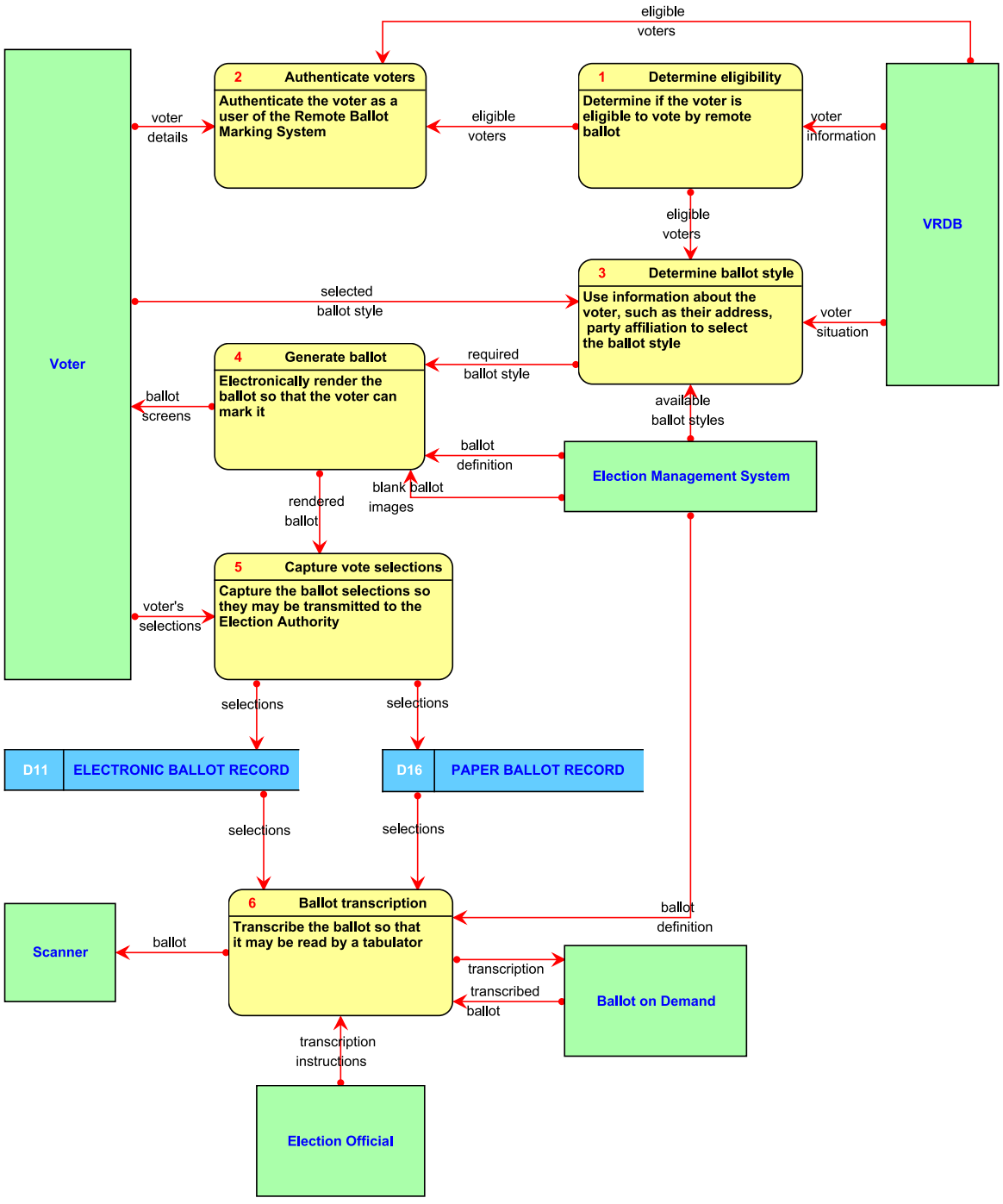

Figure 3 - Data flow diagram of Remote Ballot Marking

3.1. Use-cases

Use-case	Description
Authenticate voters	Authenticate the voter as a user of the Remote Ballot Marking System
Determine eligibility	Determine if the voter is eligible to vote by remote ballot
Determine ballot style	Use information about the voter, such as their address, party affiliation to select the ballot style
Generate ballot	Electronically render the ballot so that the voter can mark it
Capture selections	Capture the ballot selections so they may be transmitted to the Election Authority
Ballot transcription	Transcribe the ballot so that it may be read by a tabulator

3.2. Description of component

Remote ballot marking (RBM) supports the marking of ballots using the electronic means available to a voter, e.g., a personal laptop or tablet. (Note: The NIST-EAC Election Model[11]. has a more general meaning of "remote voting" to refer to any kind of voting that occurs outside of the supervision of election officials). Remote ballot marking systems have seen an uptick in interest as many segments of the voting population perform more of their activities online. Additionally, there are some segments of the voting population poorly served by in-person and postal mail voting, such as voters residing overseas and voters with certain types of disabilities.

Remote ballot marking systems are responsible for authenticating voters to access a remote ballot, providing a means for that ballot to be marked electronically, and a method to produce a marked ballot in a form returnable to the local election authority.

Remote ballot marking systems do not usually produce a directly tabulatable ballot. Some produce paper ballot records that are either transcribed by the election authority via human interpretation or automatically by reading a barcode (usually a QR code). Others may allow an electronic return of the ballot.

3.3. Analysis

The first common data format in this area was IEEE 1622-2011[8] which was a profile of the Election Markup Language (EML) [9] for blank ballot delivery systems. However, because the NIST CDFs are not based on EML, we do not consider EML in our coverage analysis.

Once again, there is a great overlap of use-cases across election technology systems. For example, voters must be authenticated by the system. Voters may also need to sign up for remote ballot marking, which could be seen as a subset of other forms of remote voting, such as absentee. Lastly, the remote ballot marking system needs access to semantically rich ballot styles in order to render a markable ballot electronically. Such ballot styles provide information on not just the layout of the ballot, but ballot instructions and the voting method that is to be used.

3.3.1. Use-case Coverage

Use-case	Required Data	Coverage	Current State
Authenticate voters	• eligible voters • voter details	Good (VRI)	VRI is able to query (using various identity criteria) a VRDB and retrieve a matching set of voters.
Determine eligibility	• voter information	Good (VRI)	VRI supports specifying voter classifications, which may narrow the ballot style the voter may receive or indicate eligibility to use the remote ballot marking system.
Determine ballot style	• eligible voters • available ballot styles • voter situation	Fair (VRI)	VRI supports providing one or more ReportingUnit identifiers which could be used to determine a ballot style to use. VRI has classifications to further narrow down ballot styles.
Generate ballot	• required ballot style • ballot definition data	Fair (VRI) Poor (ERR)	VRI supports providing one or more ReportingUnit identifiers which could be used to determine a ballot style to use. It cannot convey the styles themselves.
Capture vote selections	• rendered ballot • voter's selections	Fair (CVR)	CVR is able to record selections appearing on a ballot. It does support authenticating the ballot on the back end.
Ballot transcription	• selections • ballot definition	(electronic) Good (paper) Poor (CVR)	For ballots transcribed from electronic return, CVR format can be used (good). For return on paper, there is no interoperable ballot selection record format.

3.4. Recommendations

Many of the remote ballot marking use-cases can be handled by expanding the VRI to explicitly cover them. The rendering of the ballot depends heavily on rich ballot data being available, which comes from a voting system election management system. Transcription barcodes may be considered as part of the Ballot Styles CDF for recording “voter’s contest selections”. Support

for remote ballot marking should be made explicit in the upcoming Ballot Styles CDF. The topic of remote return is widely debated in the election and cybersecurity community, we suggest focusing on other, low risk, high impact interoperability use-cases for remote ballot marking.

4. Electronic Poll Books

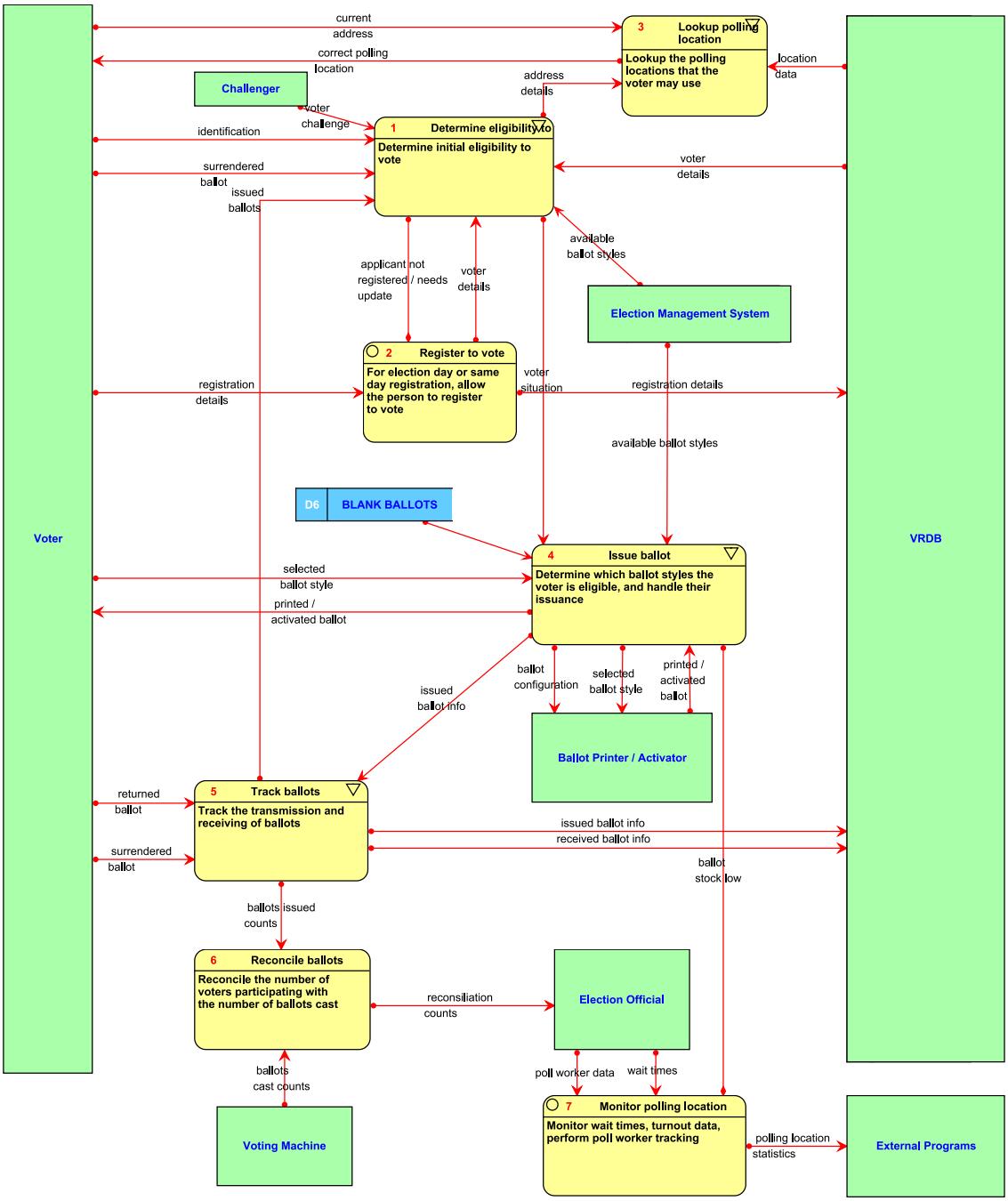

Figure 4 - Data Flow Diagram of Electronic Poll Books

4.1. Use-cases

Use-case	Description
Determine eligibility to vote	Determine initial eligibility to vote
Register to vote	For election day or same day registration, allow the person to register to vote
Lookup polling location	Lookup the polling locations that the voter may use
Issue ballot	Determine which ballot styles the voter is eligible, and handle their issuance
Track ballots	Track the transmission and receiving of ballots
Reconcile ballots	Reconcile the number of voters participating with the number of ballots cast
Monitor polling location	Monitor wait times and turnout data, perform poll worker tracking

4.2. Description of component

Electronic Poll Books (EPBs) are electronic replacements for paper lists of voters that have previously been used to assess the eligibility and record the participation of voters in polling places. The vast storage capacities of EPBs unlock several additional use-cases, such as helping a voter confirm their proper polling place(s) and determine if they have already voted elsewhere, among others. Additionally, EPBs often act as “bridge” devices by interfacing with or serving as ballot activation and on-demand ballot printing systems.

4.3. System Configurations

EPBs are usually configured as discrete components, providing dedicated functionality. However, some may be integrated with another component, often a voter registration database (VRDB). In this case, interoperability concerns between VRDB and EPB are necessarily lessened (there still may be some benefits to EPB interoperability between EMS and the VRDB, however).

4.4. Analysis

Electronic Poll Books broadly overlap the functionality of voter registration databases (VRDBs), including registering voters (for states with election day or same day registration), issuing ballots, and maintaining district-voter associations. Additionally, EPBs require information about available ballot styles, such as a ballot style identifier to pass to a downstream system, or presentation level data to generate the ballot themselves. This data usually comes from the election management system (EMS) of the voting system used.

Because EPBs are provisioned immediately prior to the election period and then put aside until the next one, they do not serve as systems of record for most of the data they store. Instead, data is fed into EPBs during device programming and fed out to voter registration databases after the election.

Electronic poll books are often connected to each other via local area network (LAN) or wide area network (WAN) connections. WANs may also be used to communicate between poll workers and the election authority, as well as to synchronize systems, LAN usage is usually limited to system synchronization and to interface with peripherals, such as printers.

The kinds of data fed into EPBs include lists of eligible voters, and associated data such as:

- residence address, and associated geopolitical data,
- identification information including government issued identifiers, signatures and biometric data,
- party affiliation, for closed primaries, and
- ballot request history (requested / sent / received) for a given election

The kinds of data fed out of EPBs include:

- voter participation information,
- updates to voter information, including, but not limited to, address and personal information, and
- information about new registrations for states that have election day or same day registration

4.4.1. Use-Case Coverage

Use-case	Required Data	Coverage	Current State
Determine eligibility to vote	available ballot styles issued ballots cancelled ballot voter info	Good (VRI) Fair (ERR)	VRI supports providing a set of voter record results which could be used to seed a VRDB (offline scenario). VRI also supports interactive querying of a VRDB (online scenario). ERR can provide a list of ballot styles associated with a geopolitical unit.
Register to vote	registration details applicant not registered / needs update	Excellent (VRI)	Primary VRI Use-case
Lookup polling location	location data address details current address	Poor (VRI)	VRI supports retrieving a polling location associated with a voter record, but not for a given address (EDR/SDR use-cases).

Use-case	Required Data	Coverage	Current State
Issue ballot	selected ballot style available ballot styles voter situation	Fair (ERR)	Supports ballot styles as data or external images. Consider standard for ballot activation, ballot style work.
Track ballots	returned ballot surrendered ballot issued ballot info ballot sequence numbers	Fair (ERR)	VRI supports recording Voter Participation, including the Election, Ballot Style and Party (Response Txn), but not specific details such as issue numbers, dates.
Reconcile ballots	ballots cast counts ballots issued counts	N/A	Consider if data needs roundtripping to an external system (open question).
Monitor polling location	poll worker data wait times	N/A	Consider if data needs roundtripping to an external system (open question).

4.5. Recommendations

Electronic Poll Books are one of the fastest growing segments of the election technology marketplace. New features are continually being rolled out to customers. Despite rapid changes, there is a great amount of commonalty in data requirements between systems.

Because EPBs support so many voter registration tasks, it would make sense to look at extending the existing VRI CDF (NIST SP 1500-102[4]). VRI already supports voter registration and ballot requests transactions; these could be further refined to support specific EPB interoperability scenarios.

Electronic poll books rely heavily on voter registration databases, and to a lesser extent, voting system election management systems. We recommend that the VRI format be used as a template to build out an Electronic Pollbook CDF as needed. The EPB CDF support should also track the future development of a Ballot Styles CDF as the ballot issuance function of an EPB require ballot style data.

5. Interactions between Electronic Poll Books and VRDBs

As part of the gap analysis, a number of data flows between electronic poll book functions and a voter registration database were established. For each of these flows, we identified more granular information structures that are significant to support the functions requiring such data. The required information for each flow is given in the following sections.

5.1. Issued Ballot Info / Received ballot info

The following table describes required information structures to support the tracking of ballots, from the EPB to VRDB.

Name	Examples
ballot style	0010, akron 1-a
date	2020-11-03
political party	democratic, republican
voter identity	name, dob, ssn, dl

5.2. Registration details (to register to vote)

The following table describes required information structures to support the round tripping of voter registered using the EPB (i.e., same day registration) to the VRDB.

Name	Examples
biometric data[a]	thumbprints
geopolitical data	precinct, district, address
voter eligibility information	assertions
voter identity	name, dob, ssn, dl
voter's address	123 anywhere st
voter's signature	written signature

[a]While biometric data is not commonly encountered in EPBs currently, it is used internationally and in UOCAVA systems

5.3. Voter details (to determine eligibility)

The following table describes required information structures to support the looking up voters in an EPB to determine their eligibility. This data is stored in the VRDB and transferred to EPBs prior to and possibly during the election period.

Name	Examples
ballot style	0010, akron 1-a

biometric data	thumbprints
geopolitical data	precinct, district, address
participation history	mail ballot returned
voter identity	name, dob, ssn, dl
voter's address	123 anywhere st
voter's registration status	active, inactive
voter's signature	written signature

6. Prioritization and Conclusion

VRI	CVR	ERR	Overall coverage	Use-Case	Operation
F			**F2 (Fair)**	**ODPB**	determine ballot-style
P					print ballot
F					track ballot
G			**P1-F2 (Poor to Fair)**	**RBM**	authenticate voter
G					determine eligibility
F					determine ballot-style
F		P			generate ballot
	F				capture selections
	P-F				transcribe ballot
G		F	**F2 (Fair)**	**EPB**	determine eligibility
X					register to vote
P					lookup polling location
		F			issue ballot
		F			track ballots
-	-	-	-	-	reconcile ballots
-	-	-	-	-	monitor polling location

Support for on-demand ballot printing is *fair*. Its score suffers from lack of interoperable ballot styles, and some deficiencies in the VRI[4] CDF.

Support for remote ballot marking is *poor* to *fair*. Remote ballot marking performs many of the functions of a voting system, and thus needs a large amount of data from various sources. Key gaps include lack of interoperable ballot styles and for those that support electronic return, the ability to authenticate NIST CVR in a privacy preserving manner.

Support for Electronic Poll Books is *fair.* VRI supports several use-cases well, however, many could be better optimized for EPB usage. Finally, interoperability between EPBs and ballot activators/printers is poor, due to lack of interoperable ballot activation data or ballot styles.

In order to improve interoperability across the components analyzed, we recommend to:

- Extend VRI (1500-102) to support electronic poll books or use as a basis for a separate EPB Common Data Format
- Develop an interoperable ballot styles specification
- Develop a “Ballot Activation” Common Data Format

Development of interoperable ballot styles solves a critical need for remote ballot marking as well as on-demand ballot printing and should be a high priority. As the Election Assistance Commission (EAC) considers a certification program for electronic poll books, we should investigate interoperability requirements that would aid in its implementation. Finally, a Ballot Activation CDF could be used to ease interoperability between EPBs and ballot marking devices.

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Acronyms

Selected acronyms and abbreviations used in this document are defined below.

CDF	Common Data Format
CVR	Cast Vote Record
EEL	Election Event Logging
EMS	Election Management System
ERR	Election Results Reporting
ODPB	On-Demand Ballot Printing
PDF	Portable Document Format
RBM	Remote Ballot Marking
VRDB	Voter Registration Database
VRI	Voter Records Interchange