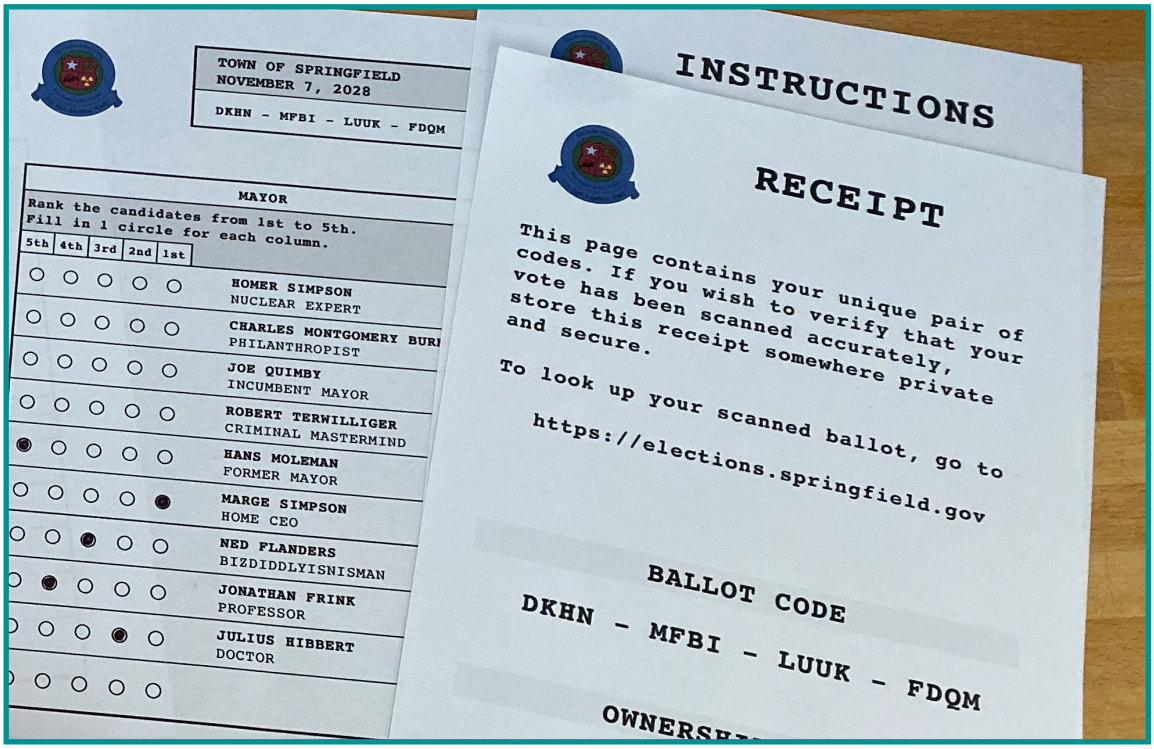
A RECIPE FOR TRUSTWORTHY ELECTIONS

ABACUS VOTING

Abacus Voting is an open-source system that lets voters confirm that their ballots were counted as cast.

It includes:

- a layout engine to create hand-marked paper ballots
- ballot scanning, tabulation, and publishing
- first-class support for alternative voting methods, including ranked choice voting and score voting



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DEMOCRACY UNDER ATTACK

Tyrants and anarchists are plotting to undermine democratic systems.

Their tactic is to sow distrust in election results.

If bad actors aren't enough, nature threatens democracy, too. Cosmic rays bit-flipped a Belgian voting machine in 2003, causing a candidate to receive 4096 extra votes, according to an official report.

How can we redesign voting systems to build trust in the face of both real and imagined threats on the ballot box?

Certainly, trust requires accuracy.

But accuracy by itself isn't enough.

ACCURATE & OPAQUE

BLACK HOLE
(Messier 87)

Accurate but opaque voting systems inspire as much trust as black holes. Unless citizens can confirm that their votes are correctly counted, they're unlikely to feel safe from real or imagined threats to the systems.

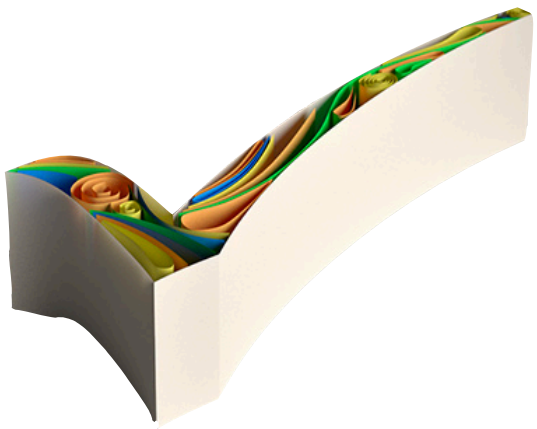
PAPER: THE GOLD STANDARD

Paper is an ancient, well-understood technology.

Paper is more trustworthy than machines.

	MACHINES	PAPER
read / write interface	hardware intermediates people and data	directly readable and writeable by humans
data storage	volatile	durable
behavior	unpredictable	predictable
unit cost	thousand of dollars per voting machine	pennies per page
transmission cost	nearly free so DDOS attacks are cost effective	costs enough that DDOS attacks are uneconomical
scaling of attacks	can be corrupted and silently restored	much harder to scale widespread attacks
auditing	impossible	simple and transparent

With the emergence of Covid-19, shared voting machines and the queues to access them are novel public health risks. No one should be made to choose between voting and risking their life. Abacus allows mail-in ballots that inspire greater confidence the accuracy of the voting process.



TRUST, BUT VERIFY

What are solutions to increase confidence in election results?

At Minimum: Voters should be able to view an auditable paper record of their vote and submit it as a backup.

But how can they know those records won't be destroyed, altered, or miscounted?

Better: The administrator publishes scans of all the ballots.

Best: Each voter can identify which published ballot is theirs while preserving anonymity.

The Abacus process allows true *end-to-end voter-verifiable* elections. Under this process, each ballot includes a paper receipt with two codes:

- **a ballot code**

  This unique random code is also printed on each page of the ballot, e.g.: EPTG - DLEN - CYYM - PNUH - IZID

  Voters can enter their ballot code online to view the image of their scanned ballot and confirm that it was recorded and counted accurately.

  For increased security, the ballot codes are redacted from the public images, while the association is privately maintained on the back end.

  (The chance of guessing a valid 20 letter code like this among a pool of 1 billion ballots is ~1 in 20 quintillion.)

- **an ownership code**

  A voter may use an ownership code to prove that they are the rightful owner of a particular ballot code.

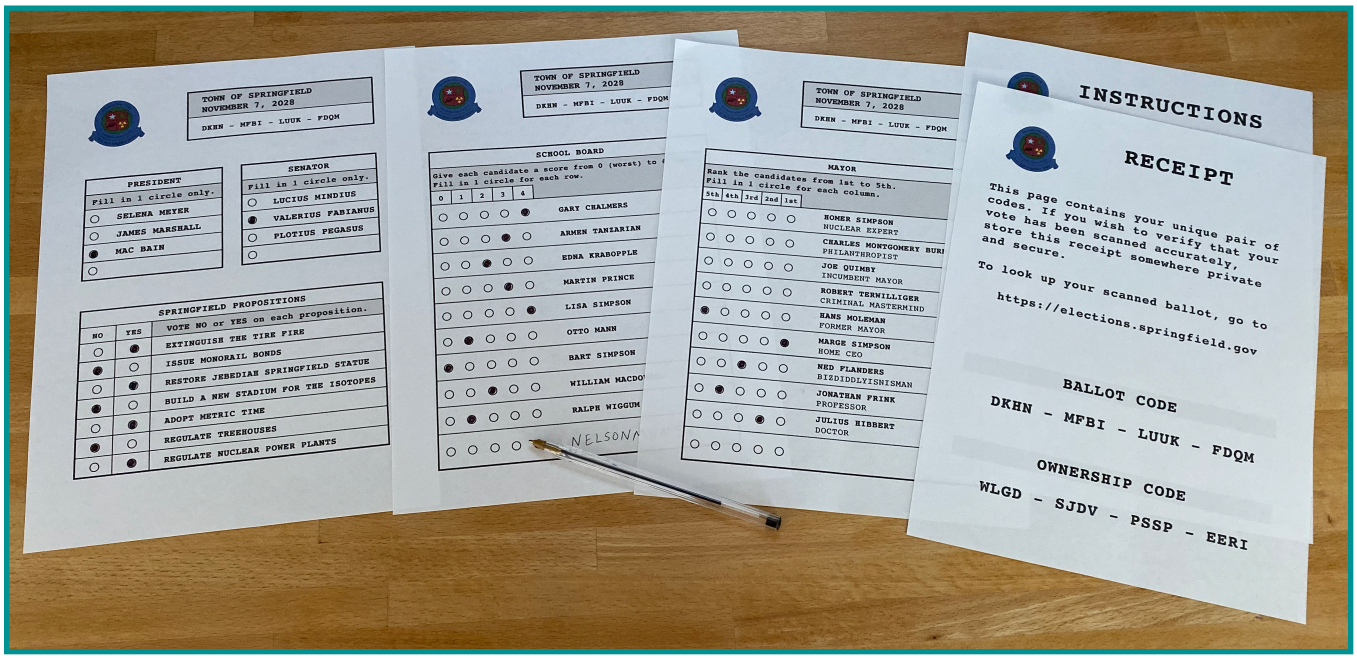
  If a ballot code is somehow stolen, a voter can submit the ownership code to receive a new pair of codes as replacement.

VOTING METHODS

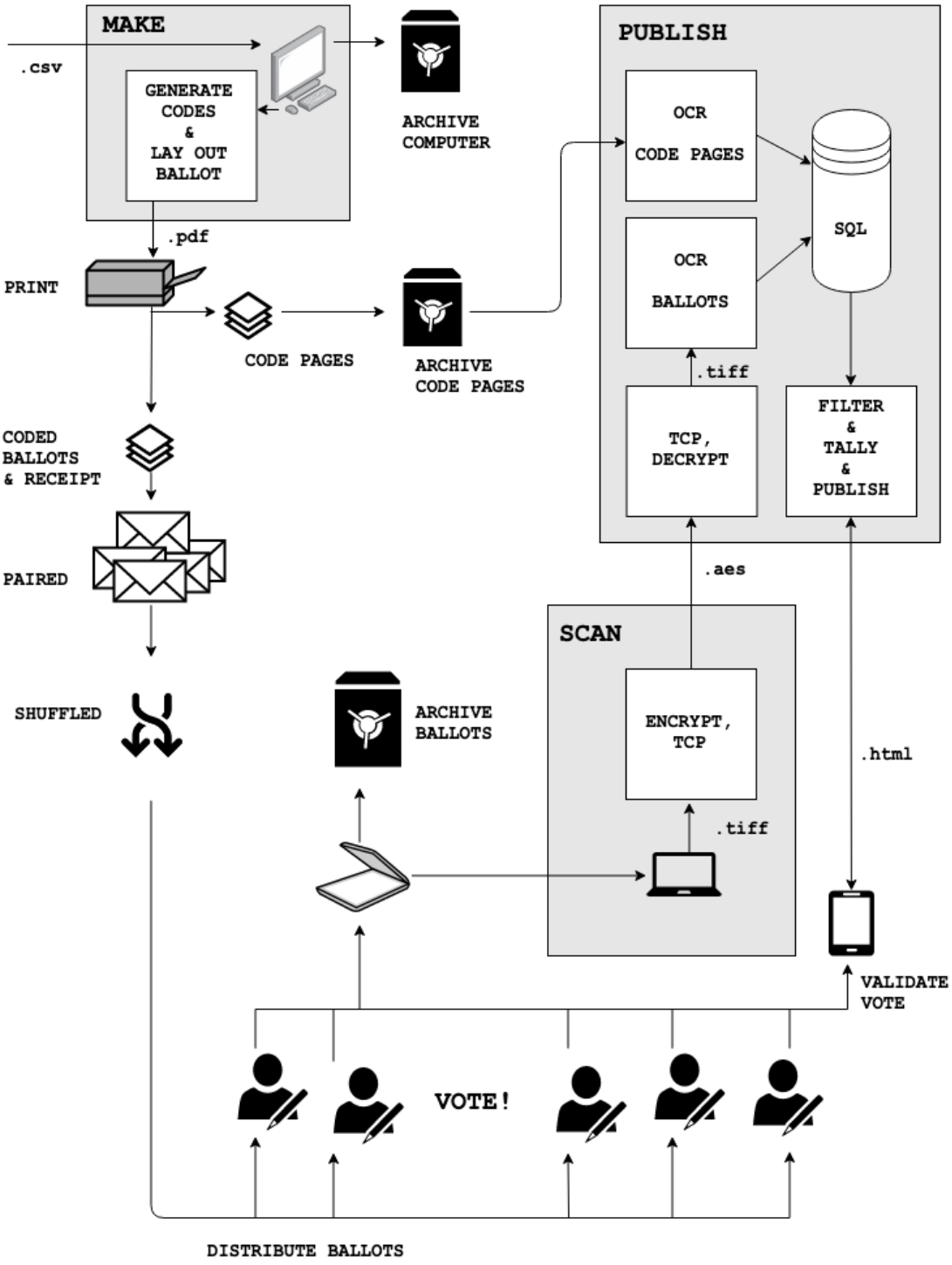
Ranked-choice-voting and score-voting are gaining interest as alternative voting methods, with proponents arguing that they can promote a shift from scorched-earth politics to governance from common ground. Abacus software supports alternative and conventional voting methods with equal vigor.

	CONVENTIONAL	SCORE	RANKED-CHOICE
INSTRUCTIONS	**Vote for exactly one candidate.**	**Give each candidate a score.**	**Rank the candidates from 1st to nth.**
HOW WINNER IS DETERMINED	first candidate with more than half of the vote	candidate with the highest average score	instant runoff (or a similar procedure)

The corresponding ballots are below. Note that the conventional ballot uses a higher density layout. Also note the ballot codes on the bottom of the header.



FLOW CHART


MAKE
.csv
GENERATE CODES & LAY OUT BALLOT
ARCHIVE COMPUTER
.pdf
PRINT
CODE PAGES
ARCHIVE CODE PAGES
CODED BALLOTS & RECEIPT
PAIRED
SHUFFLED
ARCHIVE BALLOTS
PUBLISH
OCR CODE PAGES
OCR BALLOTS
SQL
.tiff
TCP, DECRYPT
FILTER & TALLY & PUBLISH
.aes
SCAN
ENCRYPT, TCP
.tiff
.html
VALIDATE VOTE
VOTE!
DISTRIBUTE BALLOTS

MODULES

Abacus software runs as four independent modules:

LAYOUT

First, the election administrator(s) enters contests, candidates, instructions, and formatting options in a spreadsheet. Using the spreadsheet as input, this module prints coded ballots, collated with instruction and receipt pages. This module also creates a printable database of the codes generated.

VOTE

Voters can hand-mark blank ballots using pens or pencils. Alternatively, this module allows voting through a browser interface. Voters enter their ballot code, set their votes, and print out marked ballots. (Depending on election law, this may be done at precincts or at home.)

* Visually impaired voters are guided with audio feedback.
* Physically impaired voters can interface with the program using third-party hardware like joysticks or puff-and-sip devices.

SCAN

COTS hardware scans the marked ballots. This module then validates the ballots and encrypts the images. This module can be run across many independent computers connected to scanners in the field.

PUBLISH

This module syncs the images, interprets them as votes, filters the ballot codes against a list of valid codes, tabulates and publishes the results.

Voters can enter their codes online to view a text-based readout of how their ballot was interpreted as votes.

By dividing the system into distinct modules, it is easier for security experts to vet the code base.

STEPS

1

The administrator(s) compiles the voter roll on a separate system.

2

The administrator uses an offline computer to generate pairs of ballot and ownership codes.

The administrator prints out the list of valid code pairs and archives the paper in a secure lockbox. (Keeping printed papers in a locked vault is more secure way than storing data on a computer.)

The administrator prints out coded ballots, collated with instructions and coded receipts.

The ballot-generating computer is placed in an offline safe. (Or it is destroyed.)

3

The ballots and receipts are paired and sealed in envelopes.

4

The envelopes are shuffled.

(This ensures that voter secrecy is maintained.)

5

The envelopes are distributed, either by mail or in person at polling stations.

6

Voters mark their ballots and return them, keeping their receipts if they wish to confirm their votes.

7

Ballots are scanned and archived.

For in-person voting stations, scanning is done on-site. For voting by mail, it may take place at a central facility.

8

At a predetermined date, the administrator opens the locked vault and scans the stored codes.

The software then decrypts, filters, interprets, tallies, and publishes the scanned votes.

Each published vote is indexed and includes a running total of the score based on all votes published before it (generated by the software), allowing observers to audit the tally in a decentralized manner.

9

When voters can enter their ballot codes online, they get a link to the corresponding published ballot and how the software interpreted it.

If election rules allow it, they may resubmit ballots to override their previous votes.

10

The administrator certifies the result.

FLEXIBLE ARCHITECTURE

The Abacus procedure supports many election scenarios.

BALLOT PRINTING: CENTRALIZED or DECENTRALIZED

Ballots may be printed centrally. Or, if election rules allow it, voters may print new ballots at home.

VOTING: BY MAIL, IN PERSON, or REMOTE

Voters can vote by mail or in person.

Mail-in ballot packages can include a return envelope with a signature field to curtail voter fraud. Voters overseas can submit a photo of their completed paper ballot with extra codes.

SCANNING: CENTRALIZED or DECENTRALIZED

Scanning may be done centrally or at many locations.

CANDIDATE ORDER: FIXED or RANDOM

Abacus allows candidates to appear in a fixed or random order.

VOTING: REVISABLE or IMMUTABLE

If election rules allow it, Abacus can allow voters to update their ballots using the same ballot code.

SINGLE or MULTIPLE ROUNDS

Abacus can support conventional elections with a round of party primaries followed by a general election.

It can also support multiple rounds of general voting. For example, election rules could winnow down the number of listed candidates each week. For example, the field could be lowered from 100 candidates to one winner over six weeks.

100 → 50 → 20 → 10 → 5 → 2 → 1

Voters can update their ballots or automatically carry forward their ballots from the previous round.

OPEN-SOURCE SOFTWARE & COTS HARDWARE

We believe that sunlight cleanses code.

To maximize trust, our code base is fully open-source, free for anyone to prod and critique.

In addition, transparency increases voters' faith in the process. For example, the most subtle element of the Abacus software is the one that classifies scanned images as votes using optical character recognition (OCR). The element is highly nuanced in how it handles optical stray marks, write-in candidates, spoiled ballots, etc.

With conventional voting systems, this important function is executed as proprietary firmware tied to opaque scanning hardware. This means outside observers cannot inspect its reliability.

Under the Abacus framework, the software and hardware decouple. The ballot images and corresponding output are both published, so anyone can verify that the system is working as intended.

While this approach is motivated by security and transparency, a side benefit is that commercial-off-the-shelf (COTS) hardware can be used. COTS scanning hardware is significantly less expensive than hardware manufactured specifically for elections.

Abacus software runs on open and proven data formats:

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csv, pdf, tiff, aes, sql, html
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