



# The State of the Art in Voting Machine Technology: Just How Reliable Are They?

**Hal Berghel**, University of Nevada, Las Vegas

*Our profession has reason to take pride in the intense study of election integrity in the United States by computer science researchers. One such computer scientist is Douglas Jones.*

**D**ouglas Jones is an emeritus professor of computer science at the University of Iowa. He has been involved in voting technology research since 1995 and was a principal investigator for the National Science Foundation-funded project called *A Center for Correct, Usable, Reliable, Auditable, and Transparent Elections* (<https://accurate-voting.org>). His book with coauthor Barbara

Digital Object Identifier 10.1109/MC.2021.3126494  
Date of current version: 12 January 2022

Simons<sup>1</sup> is a seminal work in the area of current voting technology and is highly recommended to anyone who is concerned about election integrity at the ballot box. The interview that follows resulted from our email exchanges during September and October 2021. This is the third interview with Jones on this subject since 2016. (Note: Some of Jones's published work may be found online at <http://homepage.cs.uiowa.edu/~dwjones/voting/>).

**HAL BERGHEL:** In 2016, we discussed why prominent computer scientists were critical of direct-recording electronic (DRE) voting machine vendors who refused to build their equipment around robust security models. Has anything changed in the past five years?

**DOUGLAS JONES:** There has been a significant shift in the voting equipment marketplace. The era of DRE voting machines is all but over. Most voters today vote on paper ballots that are tabulated by optical scanners. Hand-marked paper ballots dominate in the United States, being used universally for vote-by-mail ballots as well as in two thirds of all polling places.



Twenty years ago, electronic ballot-marking devices (BMDs) emerged as a new technology. These have been widely accepted as assistive devices for voters who are unable to mark a paper ballot, but in recent years, several states have adopted BMDs for all voters, and now one fifth of all polling places operate this way.<sup>2</sup>

Unfortunately, although voters can theoretically verify that the paper ballot marked by a BMD reflects their intent, there have been several research studies that show that most voters do not do so. Although these studies do show that there are interventions that can improve the rate of verification, the rates achieved are not high enough to ensure election integrity.<sup>3,4</sup>

A second problem is created because most of the new BMDs record the voter's selection twice on the paper ballot, once in human-readable print and once in the form of a 1D or 2D bar code. Although voters can verify the text, the scanners for these ballots interpret only the bar code.

Aside from the use of paper ballots, the evidence I have seen about the security of the software inside voting machines and election management systems continues to suggest poor design, at least from the point of view of security. Sadly, the most recent study of this issue remains under a court-imposed seal and has not been released, either to election officials or the voting system vendor.

**BERGHEL:** Also in 2016, you indicated that there was a new generation of optical mark scanners that could read the ballot and record the vote, and also capture the full image of the ballot for auditing purposes. This would seem to be an ideal way to return to paper ballots. What is the status of this technology, and how widely was it deployed in 2020?

**JONES:** Essentially, all of the new ballot scanners are able to retain full images of the ballots, but not all election officials opt to retain these images. The Civil Rights Act of 1960, Section 301, requires that election officials retain "all records and papers which come into his possession" for 22 months. Clearly, any computerized device creates huge numbers of transient records as it performs its function. We cannot require the retention of a complete trace of every computation involved in an election. When a voting system offers the option of retaining or not retaining some record that has traditionally been transient, does Section 301 require retention?

Some states have conducted election audits from the digital images without reference to the original paper ballots, but this is problematic.<sup>5</sup> There is room for additional research on audit methodologies that both authenticate the ballot images and use them as the basis for a machine-assisted audit.

## STRONG SOFTWARE INDEPENDENCE

**BERGHEL:** Much has been made of the increased integrity of voting systems that have strong software independence (that is, the independence of the vote tabulation and audit from any software in use). Current BMDs, and even DRE+voter-verified paper audit trail (VVPAT) systems, are not strongly software independent (SSI), which means that the systems that use them are subject to misconfiguration, hacking, fraud, and so on.<sup>6</sup> Travis County, Texas, (Austin), has experimented with a DRE+VVPAT system called *STAR-Vote* that uses DRE and VVPAT, together with a smart ballot box that authenticates the paper ballot with respect to the vote, held in limbo by the DRE. Does this achieve SSI? Are there any other alternatives of which you know?

**JONES:** *STAR-Vote* tries hard to find such a solution, and indeed, it may be largely software independent under the assumption that the human-readable content of the paper ballots is subject to routine audits comparing it to the electronic record of the election. The weakness of *STAR-Vote* lies in the GUI that collects the voter's selections before the cryptographic commitment step. It shares this weakness with all DRE+VVPAT and BMD voting systems.

The fundamental problem with these systems is that they rely on voters to proofread the paper ballot at the end of the voting session. People are notoriously bad at proofreading. With hand-marked paper ballots, the voter-verification step that matters is the view of the ink flowing from the pen as the voter marks the ballot. That is immediate feedback, not something delayed.

In addition, many studies have found that when voters do find problems while proofreading their ballots, they frequently blame the problems on their own carelessness instead of on the voting machine. If a voting machine cheats on, for example, 1% of the votes, and half of the victims do not notice this, while those who do assume that they made mistakes entering their votes, the machine will have successfully added a one-half percent edge to its favored candidate without creating any suspicion of fraud (see "Fraudulent Elections Versus Voter Fraud"). Even an audit of the spoiled ballots might not notice a problem against the background of ballots spoiled because of genuine voter errors.

**BERGHEL:** When one compares the 2018 Federal Election Commission's list of states that do not require postelection audits<sup>7</sup> with its list of 2020 presidential general election results (<https://www.fec.gov/resources/cms-content/documents/2020presgeresults.pdf>), one notices that all of these states that

## FRAUDULENT ELECTIONS VERSUS VOTER FRAUD

**M**y thanks to Douglas Jones for participating in another interview on election integrity in the United States. I will conclude with my own historical perspective.

As Jones emphasized, there is no such thing as perfect elections. We can only strive for fair ones. William Barr opined that the 2020 presidential election bore no evidence of significant voter fraud. Despite that, we came very close to a coup when one candidate explored extra-electoral options to nullify the results.<sup>S1-S4</sup> For a while in late 2020 and early 2021, the U.S. presidential election began to resemble that of a banana republic. This shows just how fragile the voting franchise is in the United States.

A case can be made for the claim that the Trump campaign's dissatisfaction with the outcome of the 2020 election derives from the fact that the Constitution never guaranteed universal suffrage in the first place. Article II speaks of sundry congressional votes, but nothing of an inclusive popular voting franchise. It must be remembered that the principle of "one man, one vote" wasn't accepted by the Supreme Court as an entailment of the Fourteenth Amendment's Equal Protection Clause until the 1960s. The Constitution dealt with procedural issues, not equity issues.

The power elite in the late 1700s felt that the right to vote should be limited to white, male property holders of European descent. As John Jay, the first chief justice of the U.S. Supreme Court made clear at the time, the people who own the country ought to govern it.<sup>S5</sup> No one could accuse Jay of equivocation on this point. President John Adams insisted that one cannot invest the voting franchise in property-less men. Why if this were allowed, where would the franchise end?<sup>S6</sup> Republican strategist Paul Weyrich embraced a similar sentiment in 1980: "I don't want everybody to vote. Elections are not won by a majority of the people. They never have been from the beginning of our country and they are not now. As a matter of fact, our [Republican] leverage in the elections quite candidly goes up as the voting populace goes down."<sup>S7</sup> The same view has been held by Mitch McConnell<sup>S8</sup> and Donald Trump.<sup>S9</sup> Former Supreme Court Justice Antonin Scalia correctly pointed out that "... there is no right of suffrage under Article II."<sup>S6</sup> When Scalia opposed the preclearance provision of the Voting Rights Act of 1965 as a "perpetuation of racial entitlement" that was not grounded in the constitution,<sup>S10,S11</sup>

he was reaffirming the views of the founding fathers that only the rich, wellborn, and able should participate in the governing of the republic. Voter disenfranchisement is baked into the Constitution of the United States.

The popular vote trend in presidential races over the past 40 years is pretty clear to everyone. One political party is losing touch with the voting public.<sup>S12</sup> Although the 2020 Stop the Steal vote fraud gambit was effective at animating fringe groups of partisans, it proved ineffective at distracting the majority of the public from the facts of the election outcome. I take a slightly different view of this than Jones. The Stop the Steal gambit will not go away, but it will remain indefinitely just beyond the event horizon of a cultural black hole of history, along with chain letters, pyramid schemes, crop circles, vanity license plates, email scams, alien abductions, and beliefs in a flat earth. What will survive, however, is the time-honored tradition of political subterfuge: vote suppression.

The reality is that, in the absence of a popular vote mandate combined with an unwillingness to appeal to a broader segment of the population through substantive policy changes, the only way to win presidential elections is through extra-electoral means, that is, to suppress or ignore the popular vote. As mentioned previously, this has been accomplished five times in the United States by forcing the electoral decision to more partisan and predictable interests in the Electoral College or the House of Representatives. My prediction is that we will see the strategy of vote suppression consume partisan domestic politics for the foreseeable future. Vote suppression will slowly but surely displace stop-the-steal narratives. The 2020 presidential election results confirmed for those intent to undermine democratic elections in the United States in the next decade, that the low-hanging fruit in antidemocratic, partisan politics is to prevent people with opposing views from voting in the first place or to ensure that their votes don't get counted. If I am correct, you'll be able to see it in the background noise of future elections: long wait times at voting precincts, expanded use of purge lists and caging, closed primaries, primary caucuses rather than primary elections, increased dependence on rigid voter ID requirements, gerrymandering, and legislative pressure to abandon practices that encourage increased voter participation, such as early registration, vote by mail, early voting, and absentee voting. In other words,

(Continued)

## FRAUDULENT ELECTIONS VERSUS VOTER FRAUD (Continued)

the emphasis will continue to be on vote-suppression tactics that have been unchallenged by the judiciary.

In the past, the technique that seems most immune to judicial interference is vote dilution by techniques like redistricting and at-large elections. A primary goal of the so-called cracking, stacking, and packing of voting districts is to force the party that is not in charge of redistricting to waste their votes based on the reality that from the perspective of electoral outcomes, all votes over the minimum required to win an election are wasted! Through gerrymandering, a minority of voters have been able to maintain control of some voting districts for centuries. Elbridge Gerry's discovery in 1800 proved that under certain conditions politicians in the United States are legally able to define their constituencies to circumvent the will of the majority.<sup>S13</sup>

In short, anything that will favor noncompetitive elections and discourage universal suffrage will be fair game in future elections, up to and including preventing university professors from serving as expert witnesses in suits against the government on voting rights.<sup>S14</sup> The Federalist sponsors would no doubt be euphoric that the leadership of the state and University of Florida has kept the flame of their alien and sedition acts alive and well in the 21st century.

Given all of the limitations of today's election infrastructure that Jones mentioned in the interview—voting machines that rely on unverified proprietary code, the lack of adequate auditing, the problems of maintaining a secure chain of custody of voting records, the lack of strong software independence, and so forth—it is a wonder that our elections are as reliable as they are. This is in no small measure due to the vigorous investigation of the technology by computer science researchers.<sup>S13</sup>

### REFERENCES

- S1. B. Woodward and R. Costa, *Peril*. New York, NY, USA: Simon & Schuster, 2021.
- S2. C. Leonnig and P. Rucker, *I Alone Can Fix It: Donald J. Trump's Catastrophic Final Year*. New York, NY, USA: Penguin, 2021.
- S3. M. Bender, *Frankly, We Did Win This Election: The Inside Story of How Trump Lost*. New York, NY, USA: Hachette Book Group, 2021.
- S4. M. Bowden and M. Teague, *The Steal: The Attempt to Overturn the 2020 Election and the People Who Stopped It*. New York, NY, USA: Atlantic Monthly Press, 2022.
- S5. "Respectfully quoted: A dictionary of quotations," Bartleby, 1989. [Online] Available: <https://www.bartleby.com/73/764.html>
- S6. T. Campbell, *Deliver the Vote: A History of Election Fraud, an American Political Tradition – 1742-2004*. New York, NY, USA: Carroll & Graf Publishers, 2004.
- S7. P. Weirich, 'I Don't Want Everybody to Vote' – The Roots of GOP Voter Suppression. (Nov. 5, 2012). [Online Video]. Available: <https://www.youtube.com/watch?v=pN7IB-d7Hfw>
- S8. A. Berman, "Mitch McConnell admits that republicans lose when more people vote," *Mother Jones*, Jan. 30, 2019. [Online] Available: <https://www.motherjones.com/politics/2019/01/mitch-mcconnell-admits-that-republicans-lose-when-more-people-vote/>
- S9. S. Levine, "Trump says Republicans would 'never' be elected again if it was easier to vote," *Guardian*, Mar. 30, 2020. [Online] Available: <https://www.theguardian.com/us-news/2020/mar/30/trump-republican-party-voting-reform-coronavirus>
- S10. D. Troutt, "Voting rights: Scalia V. Minority protection," Rutgers CLiME, Newark, NJ, USA, Mar. 5, 2013. [Online]. Available: <https://www.clime.rutgers.edu/blog/voting-rights-scalia-v-minority-protection>
- S11. A. D. Sorkin, "In voting rights, Scalia sees a 'racial entitlement,'" *New Yorker*, Feb. 28, 2013. [Online] Available: <https://www.newyorker.com/news/amy-davidson/in-voting-rights-scalia-sees-a-racial-entitlement>
- S12. A. O'Neill, "Share of popular votes for the Democratic and Republican parties in presidential elections from 1860 to 2020," *Statista*, Feb. 18, 2021. [Online] Available: <https://www.statista.com/statistics/103552/popular-votes-republican-democratic-parties-since-1828/>
- S13. H. Berghel, "Chasing Elbridge's ghost: The digital gerrymander," *Computer*, vol. 49, no. 11, pp. 91–95, Nov. 2016, doi:10.1109/MC.2016.330.
- S14. A. Thomason, "U. of Florida Stops 3 Professors from Taking Part in Voting-Rights Suit, Raising Cries of Censorship," *Chronicle of Higher Education*, Washington, DC, USA, Oct. 31, 2021. [Online]. Available: <https://www.chronicle.com/article/u-of-florida-stops-professors-from-participating-in-voting-rights-suit-raising-cries-of-censorship>

do not require postelection auditing are red states. Coincidentally, it appears that none of these 13 states have any statutory requirement for voting machines to have a paper trail.<sup>8</sup> What accounts for these 13 states' aversion to election verification?

**JONES:** The push for voter-verified paper trails largely grew out of controversies arising from the election of 2000. It is an unfortunate fact that the winner in any election is reluctant to encourage any retrospective analysis of that election or to support any reform proposals resulting from that analysis. To do so could be seen as acknowledging questions about the legitimacy of that election.

In the case of the election of 2000, the Republican party took control of the White House, and the resistance to postelection reforms was strongest in Republican controlled states. After the 2020 election, the tables have been turned, and it is the Republicans who are asking questions about election integrity.

After the election of 2000, it took several years for a consensus to emerge about appropriate changes. The initial reaction, among many, was to ask for technologies that we now know were quite flawed, pure DRE machines, and then DRE+VVPAT and BMD technologies. It took most of a decade for a clearly articulated push for software independence and postelection auditing to emerge.

After the election of 2020, we are seeing some Republican critics of the election demanding major changes. I suspect that some of these changes are as poorly thought out as some of the initial reactions to the election of 2000, but I also see some demands that make sense. Although forensic audits of the type conducted by Cyber Ninjas in Arizona may be seriously flawed, the proponents of these audits are asking for universal use of paper ballots subject to auditing in states that had previously resisted these changes. Perhaps, in time, this will lead to a

national consensus on minimum standards that will satisfy both Democrats and Republicans.

**BERGHEL:** During this past election cycle, the initial automated count, hand recount, automated recount, risk-limiting audit (RLA), and signature audit of absentee-by-mail ballot oath envelopes all confirmed the initial presidential election results and collectively produced no evidence of voter fraud in Georgia during the 2020 presidential election.<sup>9,10</sup> This may have been the most thoroughly analyzed election result in U.S. history, and yet undocumented claims of widespread voter fraud persist.<sup>11</sup> Although Georgia has had a spotty history regarding election integrity,<sup>12,13</sup> the 2020 election results would appear to be as uncontested as might be expected, in Georgia at least. Would you care to speculate on why the Republican state leadership incurred so much wrath from the Trump legal team over this election? Do you think this will become a trend in 2022 and 2024?

**JONES:** On 20 October 2016, then-candidate Donald Trump declared that he would accept the election results if he won. Throughout the 2020 campaign, Trump repeated the claim that the only way he could lose was because of fraud. The net result, in states like Georgia and Arizona, is that a sizable fraction of the Trump base was primed to accept claims of fraud after the election.

In my 25 years of work on election technology, I have had several encounters with lawyers in both parties who clearly stated that their job was to see that their candidate won, by any means. One was working on Trump's challenges to the 2020 election. In light of this personal experience, I don't find the continuing attack on the election results in Georgia or other states to be surprising. Unfortunately, I expect this strategy of contesting election results to continue because it has been effective at

keeping key parts of the Trump base united and engaged.

**BERGHEL:** There has been considerable support for RLAs in the past decade or so.<sup>14</sup> What varieties of RLAs are currently in use? As RLAs are used for the detection of anomalies and not for counting ballots, why aren't they more widely deployed? Also, how do you account for the confusion over what an RLA is (for example, versus a canvass).

**JONES:** RLAs typically involve drawing randomly selected ballots from among all ballots cast. Randomly selecting one particular ballot from among all ballots in such a way that each ballot is equally likely to be selected is easiest if the set of all ballots is sequentially numbered and stored in sequence. This, in turn, is easy in states like Colorado where the majority of ballots are cast by mail and all ballots are counted on centralized scanners. In such a case, the scanners themselves can be equipped to print sequence numbers of the ballots as they are scanned and the scanned ballots can be stored in order.

After a sample of ballots is drawn, the next question is, do you count the votes in the sample and ask if the sample confirms the election result, or do you compare the individual ballots to the result of the first scan. If the ballots are serial numbered in a way that allows each ballot to be compared with the record of scanning that particular ballot, you can do a ballot comparison.

With precinct-count voting technology, a ballot comparison is difficult because retaining the order the votes were cast threatens ballot privacy. Voting is a public act, so observers can directly observe who votes in what order, and in many cases, the check-in process at the polling place creates a record of the order votes were cast. So long as voter coercion or intimidation remain significant threats, both ballot images and the ballots themselves really need to be shuffled before an audit.

As a result, jurisdictions that use precinct-count voting equipment cannot do ballot-comparison audits without first rescanning and serial numbering all of the ballots. This amounts to a complete machine recount as part of the audit. The alternative is a ballot tabulation audit that focuses on counting the votes in the sample.

The next great question is how does the audit respond to a discrepancy. Typical RLAs respond to discrepancies by escalation of the sample size. The initial sample size is chosen to offer a specified level of assurance that the announced election result is correct, assuming that no discrepancies are found. If a ballot comparison audit finds a particular number of discrepancies, the sample needs to be enlarged under the assumption that that rate of discrepancies is typical. If a ballot tabulation audit finds a different winner than the winner that was announced, the sample size needs to be increased to see if that was a statistical fluke, an artifact of taking a small random sample, or actual evidence of a problem.

## THE 2020 U.S. PRESIDENTIAL ELECTION

**BERGHEL:** Let's turn now to the recent "big lie" debacle. A recent U.S. District Court decision addressed the following three specific claims of election fraud by former-President Trump's legal team.<sup>15</sup> The judge found these claims vacuous and dismissed them with prejudice. Was there any substance to these claims?

1. "[T]he absentee voting counts in some counties in Michigan have likely been manipulated by a computer algorithm, and at some time after the 2016 election, software was installed that programmed tabulating machines to 'shift a percentage of absentee ballot votes from Trump to Biden.'"
2. "Smartmatic and Dominion were founded by foreign oligarchs and

*dictators to ensure computerized ballot-stuffing and vote manipulation to whatever level was needed to make certain Venezuelan dictator Hugo Chavez never lost another election."*

3. "The several spikes cast solely for Biden could easily be produced in the Dominion system by reloading batches of blank ballots in files such as Write-Ins, then casting them all for Biden using the Override Procedure (to cast Write-In ballots) that is available to the operator of the system."

**JONES:** I find these claims to be bizarre.

1. By the midsummer of 2020, it was widely understood that Democrats were far more likely to vote absentee than Republicans, largely because of highly partisan COVID-19 denial. The actual election results bore this out in several ways. In-person versus absentee ratios were distinctly different for the two parties in 2020 compared to 2016. This difference does show that the election of 2020 was different from past elections, but the confusing graphs of this data presented by the Trump legal team as evidence of fraud show nothing more than the expected result of the partisan split over absentee voting.
2. Smartmatic was founded in 2000 by Venezuelan expats (expatriates), and it did develop an election system sold for use in Venezuela before buying Sequoia Voting Systems in 2005 from its previous British owners. Smartmatic sold Sequoia in 2008 amid concerns about foreign ownership of U.S. voting companies, and Dominion (originally a Canadian company founded in 2002) acquired all the assets of Sequoia in 2010, the same

year it also acquired the assets of Premier Election Systems (formerly a part of Diebold). In addition to real and serious questions about the security of Diebold's voting systems and about entanglements between Smartmatic and Venezuela, numerous conspiracy theories have swirled around both companies. Unfortunately for Dominion, it has inherited these along with the assets of the companies it acquired.

3. The time-series data for the publicly released partial vote totals do indeed show spikes as totals from different precincts and absentee ballot batches are added to the running totals. Although it is true that the fraud mechanisms suggested would produce such spikes, it is also the case that absentee ballots are counted in batches, and as each batch count is added to the total, there is a spike. Furthermore, in jurisdictions where there are large numbers of absentee ballots, absentee ballot processing is expected to continue after election day. When party affiliation is a factor in the decision to vote absentee, this leads to vote totals that swing after election day. All of this was well known before the election.<sup>15</sup>

**BERGHEL:** One of Trump's attorneys, Sidney Powell, claimed among other things that Dominion Voting Systems rigged their voting machines to allow Biden to win the popular vote. This led Dominion to bring a defamation lawsuit against her, seeking US\$1.6 billion in damages for defamation.<sup>16,17</sup> Powell has undertaken what appears to me to be an extraordinary and tenuous defense. She claims that she can't have defamed Dominion because no "reasonable" person would have taken her accusations seriously in the first place.<sup>18</sup> Is there any evidence that supports her original claims

about Dominion and Smartmatics? Is there any reason to believe that her defense strategy might prevail in federal court?

**JONES:** I find it difficult to find a coherent story in the “evidence” presented by Powell’s lawsuits. Smartmatic controlled Sequoia for three years prior to its purchase by Dominion a decade ago. How this could allow Smartmatic to reach into Dominion’s product line acquired from Premier (formerly Diebold) baffles me. Some of the allegations seem to require unwieldy conspiracies between election

different local election jurisdictions, more than 170,000 precincts, and more than 2,000,000 election workers, including precinct officials and election office employees. Furthermore, most of those election workers are temps (temporary workers), not professionals. In any enterprise this large, no reasonable person should expect perfection. There will be clerical errors, and some of those workers will be less than honest. Barr’s wording carefully avoids the implication of a perfect election.

Paper ballots introduce well-known problems maintaining a secure chain

the 2020 presidential election was stolen, proffered by computer hacking experts. Who were these experts and what was the specific nature of their “proofs”?

**JONES:** Attending that event was a truly odd experience. Lindell advertised that he would reveal 37 TB of Internet packet captures (Pcaps) that proved foreign interference in the election, but only a token fraction of this was released to the technical experts at the event. By the end of the event, the consensus was that there were no Pcaps in this data. My guess is that Mike Lindell was swindled by those who provided him with the purported Pcaps. Although this data was being analyzed, speakers offered other “evidence.”

One featured speaker, Douglas Frank, presented elaborate graphs and charts that I never fully understood, purporting to show that the coefficients of a higher order polynomial were the key needed by an apparently vast conspiracy that has had complete control of U.S. elections since the passage of the Motor Voter Act of 1993. Frank’s allegation implied a complex algorithm that customized the theft of votes based on local demographics.

In contrast, Seth Keshel had data that showed that the election of 2020 was unique while the elections of 2012 and 2016 were normal. Furthermore, his data pointed to a small fraction of the counties in the United States where something was different. He considered those counties to be the ones where fraud was likely. It was my impression that what he had identified were the counties where exurban “Main Street Republicans” were so offended by Trump that they voted Democratic, many for the first time in their lives.

Meanwhile, whenever nothing was going on, there were projected data showing the “fake news” (that is, official) vote totals for Trump and the “real” (that is, Lindell’s) numbers. One of the speakers at the symposium, Shiva Ayyadurai, later pointed out (in

---

Simple measures such as checklists that have been used in safety critical systems since World War II are not being widely used in election setup or takedown.

officials, vendors, and foreign powers, necessarily involving hundreds or even thousands of coconspirators.

I’m not a lawyer, but I certainly find Powell’s “no reasonable person” defense to be bizarre. Her lawsuits have certainly asked the courts to take her allegations seriously, so is she implying that the courts are not reasonable?

**BERGHEL:** William Barr’s response to the Trump campaign’s claim of election irregularity was, “To date, we have not seen fraud on a scale that could have effected a different outcome in the election.”<sup>19</sup> It is noteworthy that he put a negative spin on this. What he did not say is that the available evidence confirms election integrity. Wasn’t the VVPAT environment created so that the public could be assured of election integrity? It appears that either Barr didn’t even find VVPAT results fully compelling, or that his response was politically motivated. What are your thoughts?

**JONES:** A general election in the United States involves more than 5,000

of custody. Under the pressure of election day, election workers sometimes cut corners on properly documenting chain of custody. The so-called “forensic audits” at the behest of Trump supporters after the election have found instances of this, at a low and not shocking level. I have seen evidence that similar problems have been covered up in the Georgia audit and recount. I think that Barr’s wording correctly anticipated that such discrepancies might be found.<sup>20,21</sup>

Much of the press for election auditing has taken for granted that chain-of-custody issues would be dealt with. As these “forensic audits” have shown, current election procedures are not always as good as we would like. Simple measures such as checklists that have been used in safety critical systems since World War II are not being widely used in election setup or takedown.

**BERGHEL:** You recently attended the Mike Lindell Cyber Symposium in Sioux Falls, South Dakota, which purported to offer “proofs” that

an interview with Steve Bannon) that Lindell's numbers were uniformly 4.2% above the official numbers. Ayyadurai's talk at the symposium focused on his experience as a candidate in Massachusetts, not on the presidential race, but in his discussion with Bannon, he said of Lindell's data, "either it's a hoax or people read *The Hitchhiker's Guide to the Galaxy* (in which the number 42 plays a special role).<sup>22</sup>

These different positions are incompatible. A uniform 4.2% theft does not require fancy demographic data or fitting higher-order polynomials the way Frank proposed, and it is not compatible with Keshel's relatively small number of counties. Frank's theory that election fraud has been universal and running for decades is equally at odds with Keshel's data.

**BERGHEL:** What was Bannon's contribution in this symposium? It isn't obvious to me how a partisan political advisor fits into the veil of "proofs" claimed by Lindell.

**JONES:** In addition to producing his War Room podcast from the event, Bannon gave a stirring talk saying that "what happened in Wuhan, that virus, what happened on 3 November, and what happened on 6 January. We'll get our country back on the answer to those questions. ... It's a sucker's play to try to fight the next election, we must go back and unwind the last." This was met by cheers from an audience that included significant numbers of state legislators. This suggests that, to those agreeing with Bannon, there is little room to negotiate for election reform prior to a reversal of Trump's defeat.

**BERGHEL:** Over the past five years, we have had discussions of voting machines<sup>23</sup> and election integrity<sup>24</sup> printed in *Computer*. This year, we add to our list the topic of election delirium. I didn't think it was possible that an election that could produce a popular vote plurality as well as an Electoral College majority could be more

fractious than the five elections where the president was elected by overruling the popular vote (1824, 1876, 1888, 2000, and 2016). It appears that our topics are getting more onerous over time. Are there any grounds for optimism in 2022, 2024, and beyond?

**JONES:** It was hard to find any cause for optimism after listening to Bannon's talk. But Ayyadurai, in his interview with Bannon, ended on a more positive note, suggesting that the questionable numbers being offered by Lindell were a distraction from the real issues of how we conduct elections. Many in the Stop the Steal movement are reading the work done by the election integrity movement over the past 20 years, and despite the fact that radicals are twisting that work to their own ends, there are some who may be open to reasonable reforms.

**BERGHEL:** These interviews are becoming a regular feature with us. Would you care to make a prediction on the topics that will occupy our attention in 2024?

**JONES:** My crystal ball is broken, so I can't really make useful predictions. I expect that the Stop the Steal movement will continue to challenge elections and push for roadblocks to voting for years to come. I also expect that local election jurisdictions will continue to be seriously underfunded, and I expect the shortage of technically knowledgeable election staff to continue.

Despite this dismal situation, some reforms are possible. I hope that more states will require such simple things as rudimentary inventory control and checklists to help reduce the incidence of chain-of-custody errors, double counting of ballot batches, and ignored ballot batches. I hope more states require routine postelection audits, and among the states that audit, I hope that more of them will move toward more rigorous audits such as RLAs.

I don't expect anything rapid in the world of election technology. Voting

equipment is built to last a decade or more, so even if we change our voting system requirements now, most of the hardware and software now in service will still be there in four years. On the other hand, we must find a way to update our requirements so that they take an end-to-end perspective on voting systems instead of merely focusing on the voting machine in the precinct, which is just one link in the chain from voter to the official election result. ■

## REFERENCES

1. Douglas W. Jones and B. Simons, *Broken Ballots: Will Your Vote Count?* Stanford, CA, USA: CSLI Publications, 2012.
2. "The verifier — Election day equipment — November 2022," Verified Voting, Philadelphia, PA, USA, 2022. [Online]. Available: <https://verifiedvoting.org/verifier/#mode/navigate/map/ppEquip/mapType/normal/year/2022>
3. P. Kortum, M. D. Byrne, and J. Whitmore, "Voter verification of ballot marking device ballots is a two-part question: Can they? Mostly, they can. do they? Mostly, they don't," *Election Law J. Rules, Politics, Policy*, vol. 20, no. 3, pp. 243–253, 2021, doi: 10.1089/elj.2020.0632.
4. M. Bernhard et al., "Can voters detect malicious manipulation of ballot marking devices?" in *Proc. 41st IEEE Symp. Secur. Privacy*, May 18–20, 2020, pp. 679–694, doi: 10.1109/SP40000.2020.00118.
5. "Post-election audits," U.S. Election Assistance Commission, Washington, DC, USA, Oct. 23, 2020. [Online]. Available: [https://www.eac.gov/sites/default/files/electionofficials/postelection/Post\\_Election\\_Tabulation\\_Audits.pdf](https://www.eac.gov/sites/default/files/electionofficials/postelection/Post_Election_Tabulation_Audits.pdf)
6. A. Appel, R. DeMillo, and P. B. Stark, "Ballot-marking devices (BMDS) cannot assure the will of the voters," SSRN, Apr. 2018. [Online] Available: <https://ssrn.com/abstract=3375755>
7. J. Lovato, "Risk-limiting audits – Practical application," U.S. Election Assistance Commission, Washington,

- DC, USA, Jun. 25, 2018. [Online]. Available: [https://www.eac.gov/sites/default/files/eac\\_assets/1/6/Risk-Limiting\\_Audits\\_-\\_Practical\\_Application\\_Jerome\\_Lovato.pdf](https://www.eac.gov/sites/default/files/eac_assets/1/6/Risk-Limiting_Audits_-_Practical_Application_Jerome_Lovato.pdf)
8. "Voting system paper trail requirements," National Conference of State Legislatures, Washington, DC, USA, Jun. 27, 2019. [Online]. Available: <https://www.ncsl.org/research/elections-and-campaigns/voting-system-paper-trail-requirements.aspx>
  9. "Historic first statewide audit of paper ballots upholds result of presidential race," Georgia Secretary of State, Atlanta, GA, USA, 2020. [Online]. Available: [https://sos.ga.gov/index.php/elections/historic\\_first\\_statewide\\_audit\\_of\\_paper\\_ballots\\_upholds\\_result\\_of\\_presidential\\_race](https://sos.ga.gov/index.php/elections/historic_first_statewide_audit_of_paper_ballots_upholds_result_of_presidential_race)
  10. "Georgia Secretary of State/Georgia Bureau of Investigation ABM signature audit report," GASOS, Abu Dhabi, United Arab Emirates, Investigations Division Rep. SEB2020-257, Dec. 29, 2020. [Online]. Available: <https://sos.ga.gov/admin/uploads/Cobb%20County%20ABM%20Audit%20Report%2020201229.pdf>
  11. D. Funke, "Fact check: No evidence of fraud in Georgia election results," *USA Today*, Jun. 1, 2021. [Online]. Available: <https://www.usatoday.com/story/news/factcheck/2021/06/01/fact-check-georgia-audit-hasnt-found-30-000-fake-ballots/5253184001/>
  12. K. Ottoboni and P. B. Stark, "Election integrity and electronic voting machines in 2018 Georgia, USA," in *Proc. 2019 E-Vote-ID*, pp. 1–16. [Online]. Available: [https://papers.ssrn.com/sol3/papers.cfm?abstract\\_id=3426250](https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3426250).
  13. S. Rosenfeld, "Georgia's hand count of 2020 ballots was no risk-limiting audit," *billmoyers.com*, Nov. 22, 2020. [Online] Available: <https://billmoyers.com/story/georgias-hand-count-of-2020-ballots-was-no-risk-limiting-audit/>
  14. P. Stark, "Risk-limiting postelection audits: Conservative P-values from common probability inequalities," *IEEE Trans. Inf. Forensics Security*, vol. 4, no. 4, pp. 1005–1014, Dec. 2009. [Online]. Available: <https://www.stat.berkeley.edu/%7Eestark/Preprints/pvalues09.pdf>, doi: 10.1109/TIFS.2009.2034190.
  15. *King v. Whitmer, et al.*, Civil Case No. 20-13134, U.S. District Court, Eastern District of Michigan, Southern Division, filed Aug. 25, 2021. [Online]. Available: [https://www.michigan.gov/documents/ag/172\\_opinion\\_\\_order\\_King\\_733786\\_7.pdf](https://www.michigan.gov/documents/ag/172_opinion__order_King_733786_7.pdf)
  16. N. Rakich and E. Mejia, "When to expect election results in every state," *FiveThirtyEight*, Oct. 31, 2020. [Online] Available: <https://projects.fivethirtyeight.com/election-results-timing>
  17. A. Feuer, "Dominion voting systems files defamation lawsuit against pro-trump attorney Sidney Powell," *NY Times*, Mar. 26, 2021. [Online] Available: <https://www.nytimes.com/2021/01/08/us/politics/dominion-voting-systems-files-defamation-lawsuit-against-pro-trump-attorney-sidney-powell.html>
  18. "Complaint and demand for jury trial, US Dominion, Inc. v. Powell (1:21-cv-00040)," U.S. District Court for the District of Columbia, Washington, DC, USA, Aug. 1, 2021. [Online]. Available: <https://www.courtlistener.com/docket/29090821/us-dominion-inc-v-powell/>
  19. "Motion to dismiss (1:21-cv-00040-CJN document 22-2)," U.S. District Court for the District of Columbia, Washington, DC, USA, Mar. 22, 2021. [Online]. Available: [https://storage.courtlistener.com/recap/gov.uscourts.dcd.225699/gov.uscourts.dcd.225699.22.2\\_3.pdf](https://storage.courtlistener.com/recap/gov.uscourts.dcd.225699/gov.uscourts.dcd.225699.22.2_3.pdf)
  20. J. D. Karl, "Inside William Barr's breakup with trump," *Atlantic*, Jun. 2021. [Online] Available: <https://www.theatlantic.com/politics/archive/2021/06/william-barrs-trump-administration-attorney-general/619298/>
  21. "Fulton county Pennsylvania election system analysis," Wake Technology Service, West Chester, PA, USA, Feb. 19, 2021. [Online]. Available: <https://www.co.fulton.pa.us/files/elections/Fulton%20County%20PA%20EMS%20Assessment%202-19-2021.pdf>
  22. Maricopa County Forensic Election Audit, Volume III: Result Details, *Cyber Ninjas*, Arizona State Senate Republican Caucus, Sep. 24, 2021. [Online]. Available: <https://www.azsenaterepublicans.com/cyber-ninjas-report>
  23. Steve Bannon interview with Dr. Shiva, *Bannon's War Room Episode 1,167*, minute 42 to end, War Room, Aug. 12, 2021. [Online] Available: <https://listen.warroom.org/e/episode-1166-%e2%80%93-the-receipts-are-being-shown-the-final-day-w-seth-keshel-dr-shiva/>
  24. H. Berghel, "Douglas Jones on today's voting machines," *Computer*, vol. 49, no. 10, pp. 84–89, Oct. 2016. [Online]. Available: [Online] Available: <https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7598169>, doi: 10.1109/MC.2016.306.
  25. H. Berghel and D. Jones, "Election integrity 2018: Are we better off than we were in 2016?" *Computer*, vol. 51, no. 11, pp. 90–94, Nov. 2018. [Online]. Available: [Online] Available: <https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8625933>, doi: 10.1109/MC.2018.2885315.

**HAL BERGHEL** is a Fellow of IEEE and ACM and a professor of computer science at the University of Nevada, Las Vegas, Nevada, 89154, USA. Contact him at [h1b@computer.org](mailto:h1b@computer.org).