Whose Votes (Were) Counted in the Election of 2016?

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My connection to this election

- Op-ed with Ron Rivest calling for audit
- Testified against SD RoV for not following CA audit law
- Petition to audit the election ($>$330k signatures)
- Conversations with state & local election officials re auditing
- Conversation with Clinton campaign after election re audits & recounts
- Worked with Stein campaign on recount effort:
  - Testimony in Wisconsin
  - Affidavit in Michigan
- Report & op-eds regarding Maryland's not-really-an-audit
- Dozens of interviews, radio & tv appearances, etc.

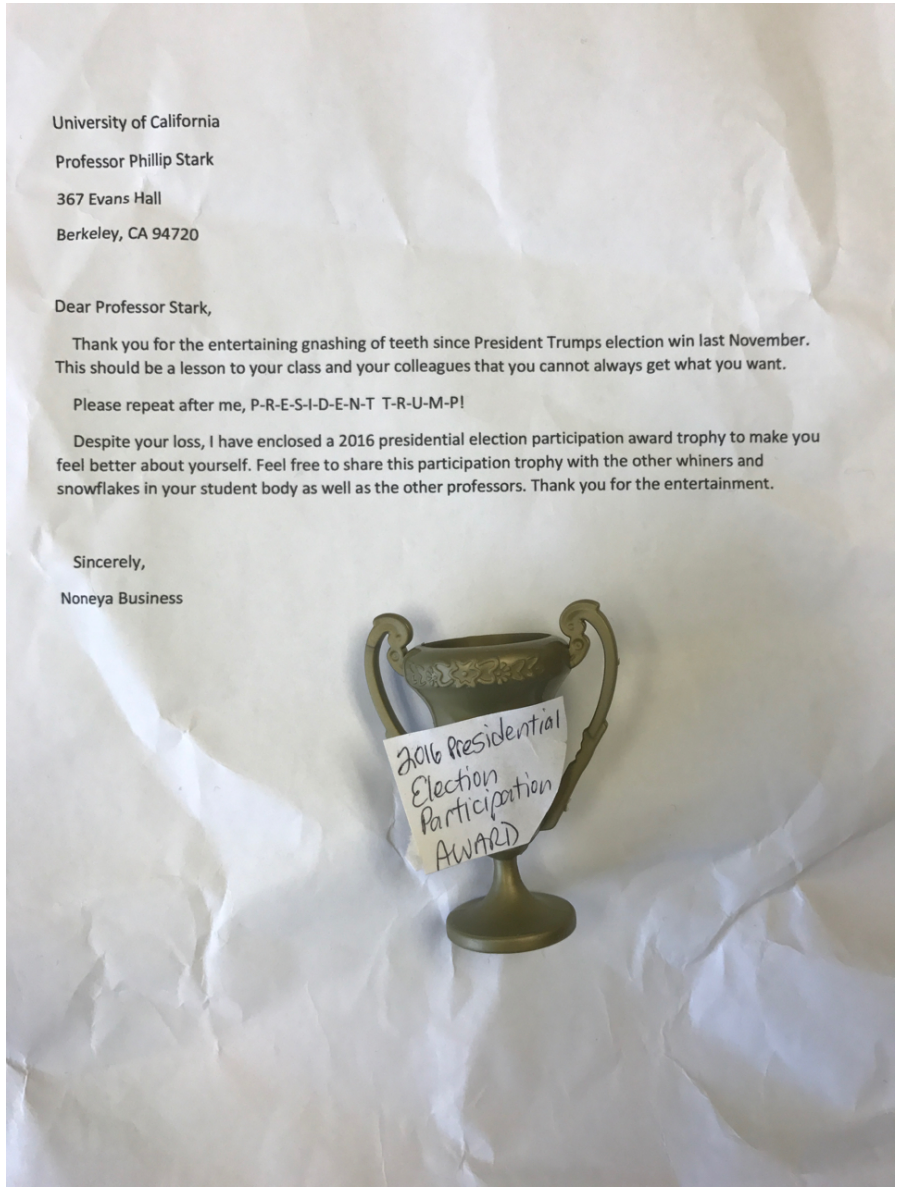

Figure 1: award

Yesterday's news

- https://www.washingtonpost.com/news/post-politics/wp/2017/01/23/at-white-house-trump-tells-congressional-leaders-3-5-million-illegal-ballots-cost-him-the-popular-vote/

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- https://www.nytimes.com/2017/01/23/us/politics/donald-trump-congress-democrats.html
- How could you check?

Sniff test

- ~11 million aliens living in the US
  http://www.wsj.com/articles/number-of-illegal-immigrants-in-u-s-holds-steady-at-11-million-1474394518
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- Turnout rate would need to be $5/8.25 = 61\%$ among illegal aliens for them to account for 5 million votes: higher than the overall turnout, which was about 56%.

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- Imagine drawing a random sample of 250 voters from whole US.
- If indeed 2.16% or more voted illegally, the chance that the sample finds at least one of them is

$$1 - \Pr\{\text{none in sample}\} \approx 1 - (0.9784)^{250} = 99.6\%$$

Hacking

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- Why stop there?

Accuracy

State	Margin (%)	Margin (votes)	Electoral votes
Michigan	0.22%	10,704	16
New Hampshire	0.37%	2,736	4
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- Unusually high undervote rates in some places

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- Don't need to hack all voting machines/systems: a few jurisdictions in swing states would be enough
- Many centralized vulnerabilities. E.g., in MI, 75% of jurisdictions outsource ballot programming to 2 commercial firms, each with fewer than 20 employees.
- Nobody *looked* for evidence of hacking: need to check the paper

http://www.greenbaypressgazette.com/story/news/politics/elections/2017/recount-raised-human-error-concerns/96346840/

> *Marinette County's vote total changed by almost 300 because some voters were given the wrong pens to mark ballots, the Wisconsin Elections Commission said.*

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- No state that I'm aware of has good rules to take care of the paper
- Recount showed that laws & regs make it hard: states & candidates sued to stop recounts!

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- Need laws requiring 3Cs:
  create paper, take care of paper, check results against paper

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- Shouldn't overturn outcome on statistics alone

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- Instead, count by machine, and check a random sample by hand.
- Keep checking until there's convincing evidence that the outcome is right—or until all ballots have been examined and the right outcome is known.

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- Generally, have to check more to make chance smaller

Random Sampling

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- Don't have to walk all over town to tell if it's cold outside: the air is mixed well enough that you just have to step outside to get a pretty good idea.
- Don't have to drink a whole pot of soup to tell if it's too salty: a teaspoon is enough—if the pot has been stirred.
  (Doesn't matter whether the pot holds 1q or 50gal.)

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- Still amounts to putting ballots into a huge cement mixer to stir them, then taking a "teaspoon" of ballots

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- Current procedures for protecting, tracking, and accounting for ballots are spotty. Should be top priority!
- Risk limit *assumes* outcome is wrong in the hardest-to-find way: Max chance outcome won't be corrected.

http://www.usatoday.com/story/opinion/2016/11/18/election-audit-paper-machines-column/93803752/

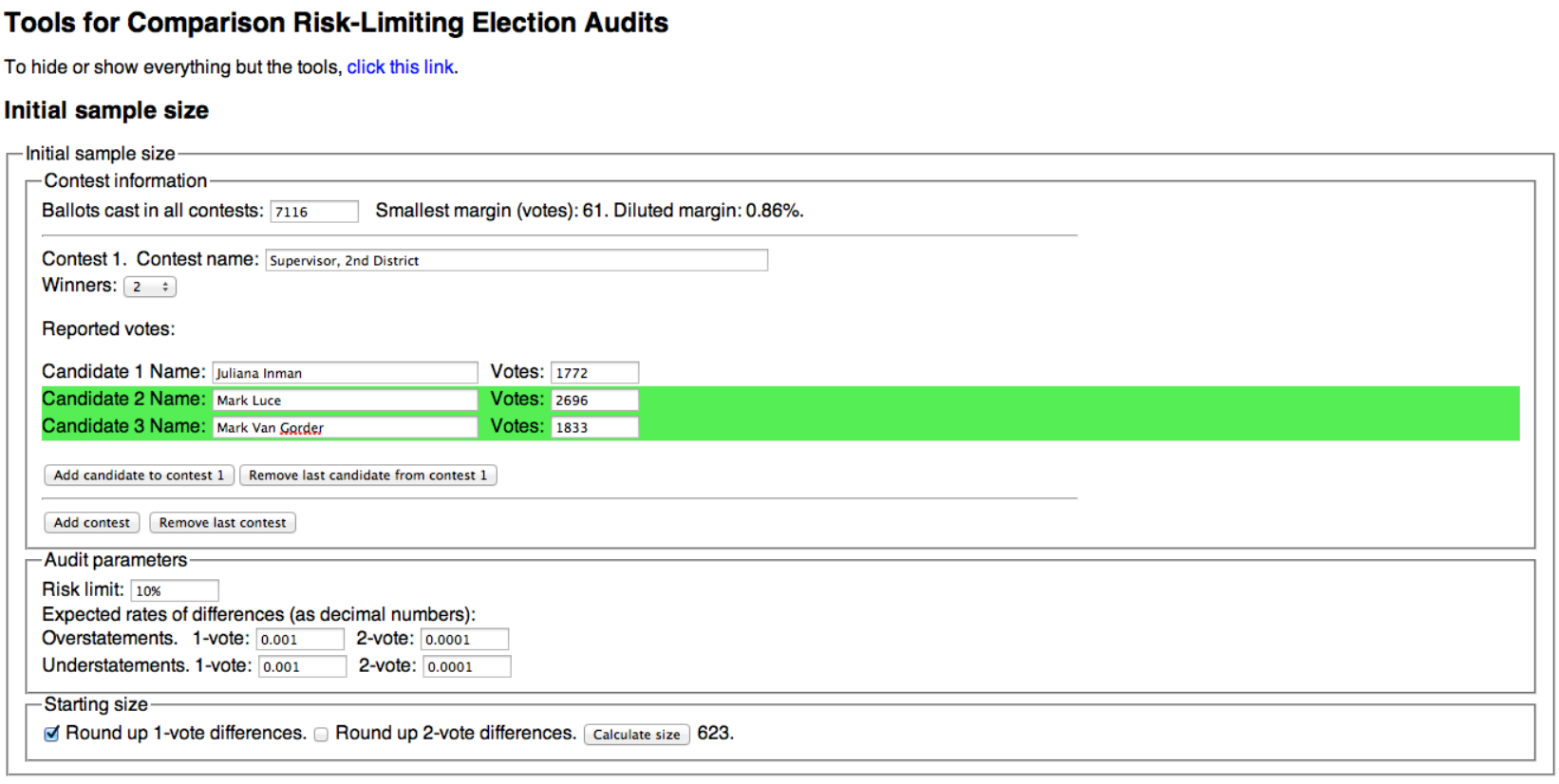

Figure 3: Contest inputs

Figure 4: Dice for PRNG seed

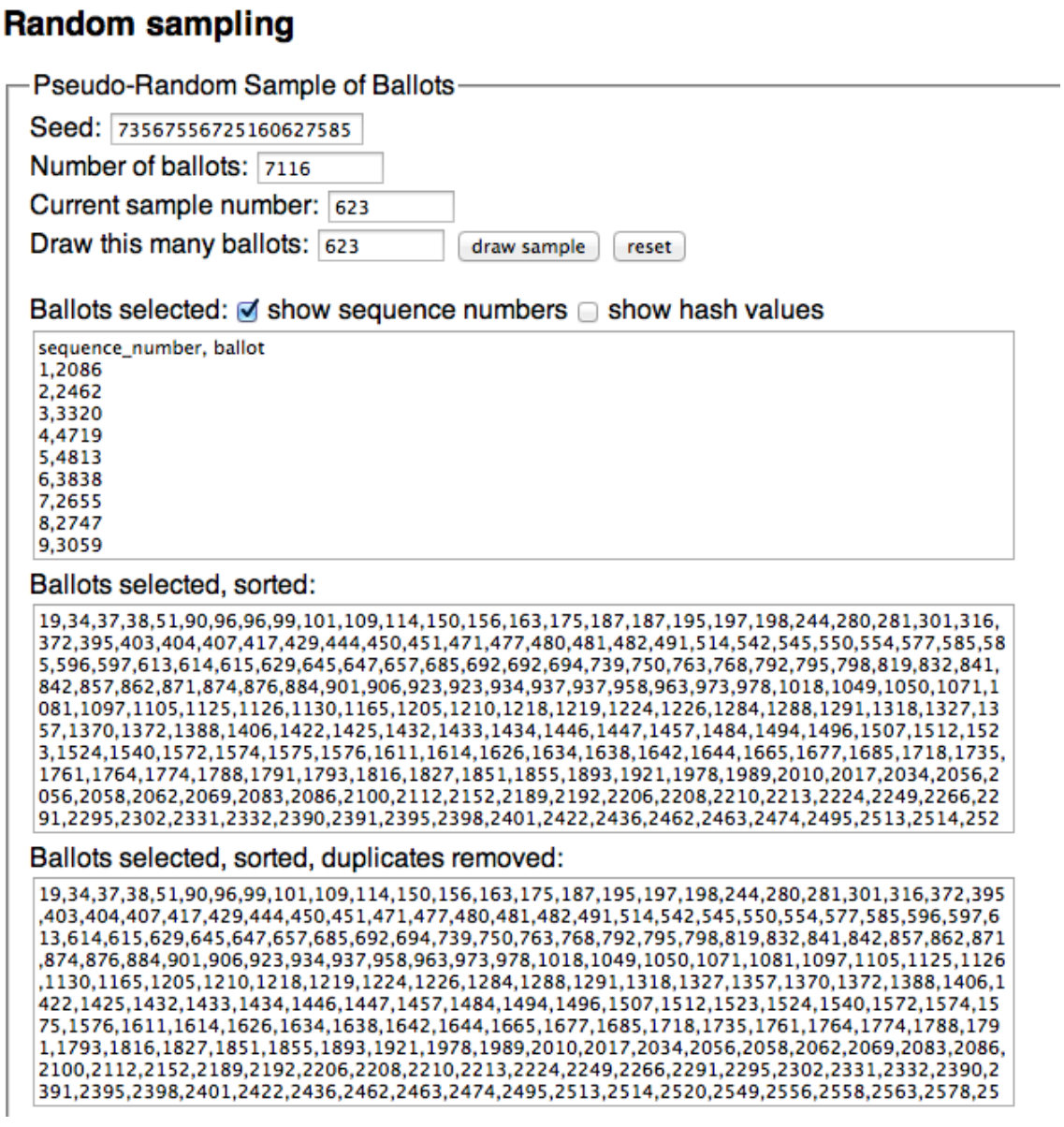

Figure 5: Manifest

Ballot-polling Audits and Comparison Audits

- Ballot polling audit: sample ballots until there is strong evidence that looking at all of them would show the same election outcome.
  Like an exit poll—but of ballots, not voters.
- Comparison audit:
  1. Commit to vote subtotals (or CVRs), e.g., precinct-level results
  2. Check that the subtotals add up exactly to contest results
  3. Check subtotals by hand until there is strong evidence the outcome is right

Tradeoffs

- Ballot polling audit
  - Virtually no set-up costs
  - Requires nothing of voting system
  - Need a ballot manifest to draw sample
  - Preserves voter anonymity except possibly for sampled ballots
  - Requires more counting than ballot-level comparison audit
  - Does not check tabulation: outcome could be right because errors cancel
- Comparison audit
  - Heavy demands on voting system for reporting and data export
  - Requires LEO to commit to subtotals
  - Requires ability to retrieve ballots that correspond to CVRs or subtotals
  - May compromise voter privacy
  - Most efficient (ballot-level) not possible w/ current systems
  - Checks tabulation
  - Ballot-level comparison audits require least hand counting

Ballot-polling Audits are often Cheap for Big Contests

255 state-level presidential contests, 1992–2012, 10% risk limit

BPA expected to examine fewer than 308~ballots for half the contests.

Work expands as margins shrink, but we could get a lot of election integrity at low cost—with any paper-based system.

Ballot-Polling Audit, 2 Candidates, 10% Risk Limit

Winner's share	median	90th percentile	Mean
70%	22	60	30
65%	38	108	53
60%	84	244	119
58%	131	381	184
55%	332	974	469
54%	518	1,520	730
53%	914	2,700	1,294
52%	2,051	6,053	2,900
51%	8,157	24,149	11,556
50.5%	32,547	96,411	46,126

Risk-Limiting Audits

- ~25 pilot audits in CA, CO, and OH; AZ *tomorrow*
- CO law goes into effect this year; CA has pilot law
- simple measures, super-majority, multi-candidate, vote-for-n
- multiple contests audited simultaneously with one sample
- contest sizes: 200 ballots to 121,000 ballots
- counting burden: 16 ballots to 7,000 ballots
- cost per audited ballot: nil to about $0.55
- several jurisdictions have audited on their own—no geeks needed

Evidence-based elections

Principle: Trust, but verify

- LEOs should give convincing evidence that outcomes are right (or say they can't).
  "Trust me" is not convincing.
- Voters create complete, durable, accurate audit trail.
- LEO curates the audit trail adequately.
- Compliance audit to check whether the audit trail is trustworthy enough to determine who won.
  If not, how strong can the evidence be?
- Risk-limiting audit to correct the outcome if it is wrong.
  Presumes audit trail is OK.

Reading

Scholarly-ish articles

- Stark, P.B., and D.A. Wagner, 2012. Evidence-Based Elections. IEEE Security and Privacy, 10, 33–41. http://www.stat.berkeley.edu/~stark/Preprints/evidenceVote12.pdf
- Lindeman, M. and P.B. Stark, 2012. A Gentle Introduction to Risk-Limiting Audits. IEEE Security and Privacy, 10, 42–49. http://www.stat.berkeley.edu/~stark/Preprints/gentle12.pdf
- Bretschneider, J., S. Flaherty, S. Goodman, M. Halvorson, R. Johnston, M. Lindeman, R.L. Rivest, P. Smith, and P.B. Stark, 2012. Risk-Limiting Post-Election Audits: Why and How. http://www.stat.berkeley.edu/~stark/Preprints/RLAwhitepaper12.pdf

Popular media, letters to politicians, etc.:

- http://www.usatoday.com/story/opinion/2016/11/18/election-audit-paper-machines-column/93803752/
- https://www.theguardian.com/us-news/2016/nov/29/security-experts-join-jill-steins-election-changing-recount-campaign (read the pleadings and the expert declarations)
- https://www.scribd.com/document/336463904/Experts-Letter-to-Lindsey-Graham-20170113
- https://epic.org/policy/SHSGAC_EPIC_Bossert_Jan_2017.pdf
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- http://www.detroitnews.com/story/news/politics/2016/12/05/recoun unrecountable/95007392/
- https://www.nytimes.com/2016/12/02/us/trump-recounts-wisconsin-michigan-pennsylvania.html
- https://blogs.scientificamerican.com/guest-blog/election-security-is-a-matter-of-national-security/
- http://www.ktvu.com/news/220330952-story
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