Submission to the Special Committee on Electoral Reform

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This submission makes a number of key points. One of these (the stochastic voting system) is rather radical, others might more readily find support. In decreasing order of novelty, my recommendations are:

- Ask voters to explain on the ballot paper why they voted this way; publish this information (Sec. 2).
- Consider a stochastic voting system (Sec. 1.2).
- If electronic voting is introduced, then it will probably cost in the low millions of dollars to hire hackers to steal an election (Sec. 3).
- If you implement multi-member constituencies with ranked ballots, then be careful with the details of the vote counting algorithm (Sec. 1.1.3).
- Please choose a system where voters do not have to second-guess the actions of other voters in order to vote effectively (Sec. 1).

1 Voting Systems

In my opinion, two very important intrinsic properties of a good voting system are that:

1. The most effective vote I can make is a vote for my favourite candidate, and

2. Every vote is of equal effectiveness.

Canada's current first past the post (FPTP) system has neither of these properties. Respectively, tactical voting is often required to vote effectively; and the voters who live in a safe seat and disagree with their local representative will never have their views represented in parliament.

The typical way to provide property (1) is to allow voters to express preferences on the ballot paper rather than to mark a single box (e.g. Alternative Vote (AV), Single Transferable Vote (STV), multi-round systems). When preferences are used with multi-member constituencies, some tactical voting remains possible, but is only relevant when the voter decides that their favourite candidate is certain to be elected by others [1].

The typical solutions to provide property (2) (multi-member constituencies, mixed electoral systems) are more problematic. I will comment only on multi-member constituencies, because I'm most familiar with them.

1.1 Multi-member constituencies

If the number of members per constituency is small, there are some undesirable effects from quota thresholds, as detailed in the next two subsections. By increasing the number of members per constituency, these effects are reduced, at the cost of increasing the number of members in parliament and/or the geographical size of constituencies.

1.1.1 Disenfranchisement of minorities

Consider the simplistic scenario where a minority group all votes for the same candidate, and no-one outside this minority group votes for this candidate. Multi-member constituencies are designed so that if the minority group is large enough, then they get some representation in parliament. But how large should be 'large enough'?

A multi-member constituency with 3 members will consistently disenfranchise minorities of less than 25% of electors. 17% of popular support is required to be elected in a 5 member constituency, and 12.5% is required in a huge 7 member constituency. Surely a party supported by 10% of Canadians nationwide deserves some seats in parliament? This would require a huge 9 members per constituency.

1.1.2 Overstability

Australia has two major parties. For the Senate, the Australian Capital Territory and the Northern Territory each get to elect 2 members. This system has been in place since 1975; since then every election in these territories has returned exactly one senator from each of the two major parties. This pattern will continue until one party's share of the vote (after distribution of preferences from smaller parties and independents) drops below 33.3%. In order to win both seats, a party would need more than 66.6% of the vote. Seeing the same result in every election, voters could come to believe that their votes don't matter and be disillusioned.

Whether a multi-member election is actually a contest depends on the relationship between the number of members and the number of dominant parties. The latter can change so it is unwise to use it to decide the former—nevertheless 3 member constituencies may not lead to a genuine contest in the parts of Canada that are a three-party race.

1.1.3 Vote counting subtleties

On a more technical note, the algorithm used to count senate votes in Australia has led to some perverse results [2]. These could be avoided with a better algorithm, such as the Wright system [3]. These issues will need to be considered if STV emerges as a leading contender for reform.

1.2 Stochastic vote

Here I suggest a novel voting system that has a range of desirable properties, including the two discussed at the start of Sec. 1.

1.2.1 The system

Each riding is represented by one member. To vote, voters mark their preferred candidate on the ballot paper.

The votes are tallied, and the proportion of the vote going to each candidate is announced. For example, candidate A wins 40% of votes, B wins 35%, C 20%, D 3% and E wins 2% of votes. The election winner is then chosen randomly with probability given by the proportion of votes they received. That is, there is a 40% chance that A wins the riding and a 2% chance that E wins. Or, equivalently, one vote is drawn at random and it decides who gets elected.

1.2.2 Advantages

Local proportionality: Within a riding, over enough elections a candidate with x% support can expect to win x% of the time, even if another candidate is always strongly supported by 51% of voters in the constituency (that candidate would win roughly 51% of elections).

National proportionality: Nationwide, a party with y% support can expect to win roughly y% of seats in each parliament (See Table 1).

No threshold: there is no arbitrary number of votes required to get elected, which sidesteps the problems with multi-member constituencies that were highlighted in Sec. 1.1.

No tactical voting: Every vote acts independently from every other, so every voter acts most effectively by supporting their favourite candidate.

No gerrymandering: As long as every constituency has the same number of voters, it is not possible to draw the electoral boundaries in a way that changes the expected number of elected candidates for a particular political party.

No safe seats: currently, incumbents in safe seats can become complacent as they don't need to win extra votes to be re-elected. Under the stochastic system, every vote they earn makes them equally more likely to be re-elected, whatever their margin.

1.2.3 Disadvantages

Individual instability: Politicians are much less likely to get elected for consecutive terms under this system—even if 60% of constituents vote for the

National support level of party	5%	40%	51%	55%
Chance of an outright majority	trace	0.005%	58%	95%
Expected number of seats	17	135	172	186
Worst case number of seats (5% chance)	≤ 11	≤ 120	≤ 157	≤ 171
Best case number of seats (5% chance)	≥ 24	≥ 150	≥ 187	≥ 201

Table 1: Assuming that voter support is uniform across the country, this shows what kind of election results are likely for parties with different levels of popularity. In reality, popularity is not uniform across the country; this does not change the expected number of seats under this system but it does make extreme outcomes less likely—equivalently the 'best case' and 'worst case' outcomes would be closer together. These numbers were calculated by considering a Binomial distribution with $n = 338$ and p given by the first row of the table.

incumbent, there's a 40% chance that one of their non-supporters will get their say instead.

Role of chance: Many citizens may instinctively dislike chance playing a role in the electoral system. Though on the other hand, they may feel empowered by the possibility that anyone's vote could determine the election.

1.2.4 Discussion

Although elections under this system would be unstable on a constituency-level, it would be very stable on a national level, since the House of Commons has many members. For example, within a constituency there is a 40% chance of a win by a candidate with 40% support, but nationally the chance that a party with 40% support gets an absolute majority in the House of Commons is less than 1 in 10,000.

Individual instability could be a problem for good government—imagine half the ministry disappearing at each election, and the very real chance that a party is elected to government without its leader. On the other hand, by acting as a de-facto term limit it may offer a solution to the problem of career politicians who only know life in politics and have no outside experience.

Alternatively, successful candidates who represent a party on the ballot might be allowed to abdicate in favour of another member of their party.

Or stochastic voting this could be introduced as part of a mixed system: an AV system running parallel to a stochastic system, with different sets of

candidates in each. Minorities would be underrepresented in such a system because they will be proportionately represented under the stochastic system and unrepresented in AV; but underrepresentation is better than being totally unrepresented as happens in pure AV. This mixed system would provide a career path for politicians, who could be moved from the stochastic system into the more-predictable AV system when they gain senior responsibilities.

2 Voter Empowerment

A vote is a pretty blunt instrument. It provides public feedback about which candidates and parties have public support, but the 'why' is left to conjecture and is ripe for misinterpretation. Professionals have access to polling data that attempts to quantify why the public voted how they did, but there is no trusted public record of what the public thinks or what the government has a mandate to do.

On every ballot paper, the voter should be prompted to list the top three reasons for voting the way they did. Doing so would be entirely optional. After the election, electronic images of all ballot papers would be released, or (more cheaply!) a few hundred randomly-selected ballot papers from each riding would be scanned and released.

This would give the public vital information about why their fellow citizens voted the way they did. It would also give individual citizens a voice, the chance to tell a candidate "I love your stance on *issue x*" or "I'm voting for you despite your party's views on *issue y*, not because of them." I believe that the chance to be meaningfully heard at the ballot box would increase voter engagement and decrease disillusionment. The request on the ballot paper to give reasons for their vote may also focus voters' minds to think more carefully about their choices.

After an election, I imagine that media groups would go about categorising the responses to report that "Party x's increase in support is due to issue y". It is important that the raw sampled data is publicly available so that anyone can independently analyse the data, rather than having to trust any one institution to categorise the responses correctly.

Providing the public with this tool is likely to provide an antidote to the comments sections of news sites—the hateful comments that often swamp the comments sections are posted by a small self-selected minority of the public. By publishing a random selection of ballot papers, these trolls get

exposed as being a small vocal minority of voters. Similarly it would decrease the power of the pundits who falsely claim to represent silent majorities.

3 Electronic Voting

Votes must not be collected electronically. It is too easy for a hacker to change the result of an electronically-held election, and it is too hard for such actions to be detected. In my opinion electronic voting is acceptable if it takes place in a polling place, and the voter prints their own ballot paper and deposits it in the ballot box, and this ballot paper is their official vote. But it is too dangerous to allow voting across the internet or any other network, and it is too dangerous to store votes electronically.

When votes are collected on paper ballots it is hard to rig an election, and fairly easy to detect attempts to do so. In order to change the result of an election, agents would need undetected physical access to ballot boxes across many different constituencies. Furthermore, if they can't interfere with all the ballot boxes within a constituency then in order to change the result they will need to make big changes to individual ballot boxes. It is easy to notice when all the votes in a ballot box are for a particular candidate. Less blatant abnormalities are also easily detected by comparing the results from one ballot box to other ballot boxes from the same polling place, by comparing the results from a polling place to surrounding polling places, or by comparing the results from a polling place to historical results from that polling place. In order to rig an election without detection, a very large number of individual ballot boxes would need to be tampered with, which requires a very large number of conspirators, and there is high likelihood that at least some of these conspirators' actions would be discovered.

When votes are collected electronically, only one sufficiently talented bad actor is required to rig an election. If no-one with the necessary hacking skills has political motivation to hack the election, then there is a large pool of wealthy individuals (or perhaps even foreign governments) who would be willing to pay someone to rig the election outcome. Consider how many large political donations are made; then consider how large donations might be if they actually determined the result of a federal election.

If a hacker gains access to the vote collection server(s) or the vote counting server(s) then they can choose whatever election outcome they wish. Unlike an on-paper election, one hacker could overwrite every single vote if they

wished, giving their candidates 100% of votes—or they could count all the votes, work out the minimal and most plausible vote changes required to change the election outcome, and then change those votes.

Information security is a losing battle. For example, some malware was recently discovered that was active for at least 5 years on "air-gapped" machines—computers whose security was so important that they were never connected to the internet [4]. The estimated cost to perform this attack, which has at least 50 different capabilities and dozens of separate targets, was "millions of dollars".

It is likely that there are unscrupulous individuals in Canada and abroad who are willing and able to pay for an attack on a Canadian election. It's impossible to guarantee that such an attack could be prevented, or even detected. And in my opinion it's likely that such an attack would be attempted at some point.

In summary, voters must not submit their votes electronically: there are many plausible and affordable ways to compromise the central server, voters' computers/phones, and/or the networks that connect these.

3.1 A safe scenario

Technology can safely have a place in making elections more accessible and convenient. Here is one vision of technology being used safely.

Voters arrive at their nearest polling place. Their names are checked off by an election worker on an electronic electoral roll, which immediately relays this information to a central server. They are given a choice of pen and paper, or a token for the electronic systems.

Some people vote via smartphone app. They download the Elections Canada app ahead of time, fill out their vote, then bring their phone to the polling place. At a booth they insert their token and tap their phone on a reader. Their vote is printed out and the voter places the ballot paper in the ballot box.

Others vote via touchscreen computer (with a separate audio interface for the vision impaired). They insert their token and make their vote using a convenient interface. When done, their vote is printed and the voter places this ballot paper in the ballot box.

The votes are printed clearly and consistently, so it's easy to scan and count them by computer on election night. A manual count proceeds over the following days to confirm the result.

3.1.1 Why it's safe

The most important point about this system is that the "source of truth" for each vote is a piece of paper that the voter put into the ballot box.

If a hacker tries to change a vote before it's cast, then voters will notice that the printed ballot doesn't match their intentions—they will notify election officials, destroy the bad ballot paper, and vote on a fresh ballot paper.

If a hacker tries to change a vote after it's cast, then they either need to tamper with physical ballot boxes (which is hard to do successfully as noted at the start of Sec. 3), or they need to hack the system that counts the votes. If they hack the vote counting system, then this will be discovered in short order when the votes are re-counted by hand.

The other security features of this system follow.

- The electronic electoral roll prevents voters voting multiple times. If it is hacked to disenfranchise large numbers of voters, then this will be obvious to those voters and therefore also to election officials. A paper trail would be required to prevent a hacker from allowing co-conspirators to vote multiple times—but this is a high-risk attack that is unlikely to be very effective.

- The token is to prevent voters from printing multiple ballot papers. It is encoded with the voter's constituency so that they cannot vote in another constituency.

- The app doesn't have access to the electoral roll, the voter's identity, or any other sensitive information or systems. It just provides an easy interface for voting and communicates via NFC or QR code.

- The ballot paper printing computer has its own list of election candidates, rather than trusting a list given by the app.

- Voters (en masse) are trusted to check that the app/computer/printed ballot presented them with the right candidates and correctly recorded their vote.

3.2 Homomorphic encryption

In the academic literature, secure and private voting systems have been proposed that are based on partially homomorphic cryptosystems such as the

Paillier cryptosystem. The implementations of these, such as those described in Ref. [5], are necessarily cumbersome, particularly for systems more complicated than FPTP.

Running one of these systems would be very complicated, both for voters and for officials. Many election observers would be required, and they would probably need to have PhD-level knowledge of the field. I note that the system described in Ref. [5] still requires the voters to be physically present in an election booth and to handle pieces of paper provided by election officials, so in my opinion it has no advantages over the system described in 3.1.

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