Analysis of the Election Data from the 6 November 2018 General Election in South Carolina

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EXECUTIVE SUMMARY

We have been analyzing the South Carolina election data since 2010 on behalf of the League of Women Voters of South Carolina and more generally the citizens of South Carolina. Our analysis of the 6 November 2018 General Election is presented here. This analysis will include some of the analysis done on the 12 June 2018 First Primary.

We note that the software used in the ES&S paperless Direct Recording Equipment (DRE) iVotronic voting computers[1] was upgraded for the 12 June First Primary, as was the county headquarters software for configuring and managing elections. Given the extensive documentation on the shortcomings of the ES&S system [EVEREST], and our first-hand knowledge of two bugs that have led directly to votes not being counted in South Carolina or to votes being counted incorrectly, we might have hoped that the known and obvious errors and problems would have been fixed in the upgraded software. We cannot tell whether both of the errors are still present, but certainly one is still present and caused several hundred votes to be counted incorrectly. We have not seen that the incorrect count led to an incorrect outcome, but we certainly can question the software quality control or the vendor.

We commend the South Carolina State Election Commission for ensuring that the data from the elections is consistent with itself. This was mostly true by 2016 and seems to have remained true with the 2018 data. We cannot excuse the Commission for its failure pro-actively to ensure that reconciliation of the data was done beginning more than a decade ago with the initial use of the ES&S system, but we acknowledge now that attempts to make the election process more transparent have been successful. We have seen many of the back-and-forth emails from the Commission to the counties subsequent to the 2016 election. These resulted in rather clean data from that election, and the data from the 2018 election is similarly clean.

By "clean" data we mean primarily that questions that would be raised about the process or the results of the elections of 2016 and 2018 can in fact be addressed by analyzing the data. We cannot determine if the actual

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[1] We refer to the iVotronics as "computers" and not "machines" so that voters will understand that the iVotronics are, as would be expected, subject to all the thousand natural flaws that computers are heir to.

cast votes are what voters intended, but at least we have the data to examine and we can answer questions that are raised. We believe this to be a major improvement in the ability to justify the results to the voting public.

Transparency, however, does not equate to correctness. Problems with the system have nearly always been laid at the foot of "human error" rather than flaws in the election system. We do not agree with this glib dismissal of responsibility. The ES&S election system is complicated, with (per the EVEREST report) more than 515 thousand lines of code in nine different programming languages on five different hardware platforms. And, from the errors that we have seen and our discussions with election officials using the system, it appears that there have been few, if any, software interventions provided in the ES&S system that would make it harder for election officials to get it wrong at the end of a long Election Day. One of our major complaints through the years has been that the election system seems to have been designed and produced as if best-case scenarios were the norm. In any use of computers, the opposite must be assumed. Murphy's Law ("if anything can go wrong, it will") must be taken as the primary truth, with Murphy's Second Law ("Murphy was an optimist") following close behind.

In summary, we commend the State Election Commission for ensuring that the data has been collected, archived, and examined. With the 2018 elections, we observe that most of the problems come from the election system itself, and not from "human error".

On the other hand, we are compelled to remark yet again that the issues that are exposed by a detailed analysis of the election data seem to be clear indicators of software of unacceptably low quality for use in something so important as elections in the United States. The analysis in the EVEREST report of the software originally used in South Carolina was devastatingly negative. An analysis of an alleged "upgrade" of that software, that still shows major flaws, suggests that perhaps the EVEREST report was insufficiently derogatory regarding the software itself and the ability of the vendor to produce acceptable software.

INTRODUCTION

This is a report on our analysis of the election data for the South Carolina General Election of 6 November 2018. We have analyzed the data using updated versions of the software we have written and have been using since the 2010 General Election.

We emphasize that we make no claims that our analysis uncovers all possible problems or complications. We can only discover anomalies that present themselves in the data.

As in the past, we have used the EL152 event log file from the iVotronics, the EL155 cast vote record from the iVotronics, the EL68A system log of the computer at county headquarters, and the EL30A file that lists vote count results by precinct. We commend the state of South Carolina for being probably the most transparent state in the nation with regard to release of this election data.

CHANGES FOR 2018

By the time of the 12 June 2018 First Primary, all counties were to have upgraded the software with newer, certified, versions of code—both the firmware in the iVotronic voting computers and the election management system on a Windows desktop at county headquarters. One could see upgrades happening in various counties in the data from spring 2018 special elections; for the 12 June First Primary it did appear that all counties were using the new software.

There has been salutary simplification in processing the data that has come from the upgrade. In the past, although the counties were allegedly using the same software, there were slight variations in the EL30A report from county HQ that reports the actual election results for each precinct. Although it was possible for us to read and process all reports, the slight variations caused us to implement some special cases in our analysis programs.

For the 12 June First Primary and now for the 6 November General Election, it appears that all counties except Fairfield and Marlboro have the same format for presenting the data in the EL30A. This makes our programming job much simpler. In addition, the EL30A reports now include a column reporting vote totals loaded from the flash memory cards. This probably happens when iVotronics fail to function properly or when the PEB cannot close the iVotronic. This would be one of several possible anomalies that would be flagged by our programs and would require human checking to ensure that processing had in fact gone properly.

The major change, from the point of view of our analysis, is in the event log reporting that becomes the EL152 report. These are the individual events recorded in each iVotronic, and the changes with the new software required some minor modifications to our programs. Most of these are inconsequential. Dates are now yyyy-mm-dd instead of mm/dd/yyyy in the EL152, for example. (This is a very sensible change in that a standard lexicographic sort on date produces a list in the proper order; the older format would require breaking the date apart to be able to sort first on year, then on month, and then on day.) The biggest changes are that some event codes have been dropped or are no longer used and some have been added. The 0001510, 0001511, 0001512., etc. codes were used in the earlier software for "vote cast" events. (Code 0001510 was the most common "Vote cast by voter" event.) These now all seem to be 0002900, 0002901, 0002902, etc., with code 0002900 ("Vote cast by voter – Visual") apparently replacing the 0001510 code. There are a number of codes that appear for the first time in the 2018 data and a number of codes that are not seen in 2018.

Among the codes that do not appear frequently in 2018 is the "Terminal shutdown" code 0001633 that we could never get anyone to explain. We had heard several different explanations for what that meant, but none were reasonable given the data, and we were told in a direct conversation with a programming manager at ES&S that

they didn't know either. There were 86,044 instances statewide of this code (0001633) in the 2016 General Election, but only 7 in the 2018 General Election.

MAJOR ERRORS

We remark at the top on two different major errors that have led to votes counted incorrectly.

Counting Votes Twice

In Wallace Precinct in Marlboro County in the First Primary, there were apparently 148 voters who had the distinct privilege of voting twice. This error was not caught by the county or the state, and the totals as reported are simply wrong. There was an iVotronic, serial number 5123479, that was clearly failing. Instead of adding in just the five votes from that iVotronic into the totals, the other 148 votes in that precinct were added to the totals from their memory cards in spite of the fact that the votes had been added in with the usual PEB-based process. Instead of 153 total votes in the precinct, the total was reported as 301 by double counting the 148 to get 296 and then (correctly) adding in 5 more.

Counting Votes for the Wrong Contests

We have previously observed (for the first time in 2010 in Bluffton 2C Precinct in Beaufort County) that when the iVotronic has a different list of contests for a given precinct than are in the county's central computer, the votes from the iVotronic are added in based on cell location in a spreadsheet, not based on keys for the contest names. Thus in 2010, when Bluffton 2C precinct had only one of the two county council contests in the iVotronics, essentially all the vote counts from that point down to the bottom of the ballot were shifted up one row and added in. The result in this case was that Amendment 4, the last item on the ballot, received no votes for and no votes against, in spite of the fact that 725 people voted in that precinct.

The existence of this problem does appear in the record. In the EL68A, the line "less cands than results" indicates that there are as in Bluffton 2C fewer candidates in the iVotronic than in the central computer's files. The line "more cands than results" indicates the opposite, that is, that there are more candidates in the iVotronic than in the central computer's files for that precinct.

There can be no question that this is a software failure due to two problems with the software design. First, good design would not have allowed votes to be added in without ensuring that they were added in by a key (contest name and candidate, for example). Second, it would certainly seem to be bad design that the ballot as stored in the iVotronic would differ from the ballot on the central computer. The ballot for an iVotronic in a precinct should be generated only once, and verified to be correct, and then copied internally if there is a need to have the ballot format in more than one location.

We would have hoped, given the egregious nature of this failure to write good software, that the first design error would have been fixed. However, the same error as in Bluffton 2C in 2010 showed up in the November General Election data in Bamberg's South Bamberg Precinct (Precinct 11). There were two county council districts (2 and 3) in the central computer, but only district 3 appeared in the iVotronic. The 420 votes for Larry Haynes (district 3) were shifted up and assigned to Sharon Hammond of District 2, and so on down the ballot.

Compounding the problem of bugs in the software is the additional observation that the "audit" by the SEC failed to notice this problem. The SEC was able in Aiken County to notice a "more cands than results" error, or at least to find the votes and ensure they were counted, but it failed to notice the problem in Bamberg County.

MISSING/INVALID DATA

No EL152 event log file has been provided by the SEC for Orangeburg County, so analysis has not been possible.

Laurens County is a more interesting case because it highlights a major shortcoming in the State Election Commission's analysis. The EL152 file seems to have been garbled near the end in its transmission to the SEC. The garbles, manifesting as character codes corresponding to no legitimate characters, cause our programs to break.

We note, however, that by looking at the Commission's report for Laurens County we can argue that the state's programs and its analysis are highly suspect. The report for Laurens County contains the page included below. It is impossible to believe that reasonable analysts would have read this page and not known that something had gone wrong and should be looked into. The content of this page derives directly from the garbles in the EL152 and would have been recognized as such by any reasonable observer.

We were able to do an analysis on Laurens County by manually removing the offending lines from the 152 file and then running our program again. This isn't a perfect solution, because the missing data suggests anomalies that aren't in fact problems, but it does permit some reconciliation and analysis.

Laurens 2018 Statewide General Audit Report

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|                     | Delta from EL155 |
+---------------------+------------------+
|                     |      218 |
+---------------------+------------------+
|        Cast By Voter |    19817 |
|     Cast By Poll Wkr |       12 |
|    Blank Cast by PW  |        0 |
+---------------------+------------------+
|    Cancelled Ballots|      103 |
+---------------------+------------------+
|        Wrong Ballot |       29 |
|       Voter Left AB |        2 |   (AB = After ballot selected by poll worker.)
|       Voter Left BB |        6 |   (BB = Before ballot selected by poll worker.)
|       Voter Request |       16 |
|     Printer Problem |        3 |
|    Terminal Problem |       15 |
|        Other Reason |       32 |
+---------------------+------------------+
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Number of audio (ADA) events in this election: 0

Note: The following machines(s) have audit records but no ballots were cast on them: áՈ^HüՈ, "Іöš°ð9, Ո-úmë-a, ¥q®"'äõ, ž![V©c}, É P~Ո ˙,
x°ÁKQxÅ, jw"h4‹·, Ո¹)Ýx9], Óİ$p!R/, @úOª÷Q, E˙|Äö„- , ℅V¿¥¿EU, Õik+¤dó, c=êõ®‚å‚ Xö; ÖՈÁ‚ „ÁÉf}×ç‚ yâí† Ö‚ ՈÖ-êՈ$3‚ uÁ¦|ÉfՈˊ‚ áÑ‹Ûgh‚‚
+.D¤ủ¿ä‚ ÖZÑsq˙‚ àåNgá~D‚ 6¿äkó€0‚ ‚ʾüô-
Ö‚ Q¥Û-‚ skÝ̇-}_‚ aՈ4Ñã̇Y‚ õŲÄ¿ö‚ (¦̇ t*Ⅲ‚ ‡˙)Æµ)R‚ ‚~ÉR‚œ¯‚ É EՈ]|Ù‚ žsyՈÖ
‚ °"Xn(± ‚ SՈv/³Ã˙‚ 3¤H)ՈÞĐ‚ yýwûÁ¦o‚ ՈpՈ;ŠR
kúv=™—÷‚ í.0a7c‚ ñ˙\‚Y-‚ %Р¡é4M‚ ‚_ƒ»Ù• €‚ ×h]ÉÁ×D‚ TÁçn-²‹‚ •°í-&‡U‚ cãĪu'B†‚ ª_SՈÔՈ‚ É ÔՈˊa£‚ ˊÏ̇[à;Y‚ ù¡-Àêa‚ ÄᴄᴌᴌՈ‚ ÔՈˊ+øyՈ‚ °áB˙÷š×‚
¹-Ո‚pՈ"‚ 1æÉՈa~‚ …ÅâZÛiw‚ +ÕՈnÖµ‚ (3±:×oT‚ ;)ՈՈՈz˙‚ ²íՈↄ-¥‚ ýCũ<˙_‚‚ yú‹]¤ÛA‚ GՈՈÖ¯Z<‚ Î]±ôÃ‹…‚ ÉgՈe¢T   ‚ ‹b7•m‚JՈ‚ ô¨öÝÉˊJ‚
Dᴄ†t#ÜՈ‚ 3øՈՈՈé‚ [Ö›ÕNõ‚ Ûaܦ ôՈ‚ X»‹"t1Û‚‚ ä®ß4šóv‚ ÔnÛ1Õŝ‰‚ ª‚‚4Ün]¹‚ u sdiwx‚ ՈÝu.õÖJ‚ "nõ×®ó‚ ÆqՈ9fՈ‚ ÜՈ©ý5¯1‚ ìzäՈbP¿‚ yՈÛfՈ¡‚ ˊ℀~Ñ¦œ_‚
;¤s—ø€L‚ -)Õ«[Ce
        Because they do not have ballots cast, they cannot be matched to a precinct. This is not
        an issue as long as the EL30A Ivo Ballots, the EL155 Ballots and the EL152 Ballots match
        in the table immdiately above.

How to read this report.

This is the ballot level report. It compares the number of ballots cast in the tabulation report,
the EL30A with the number of ballots cast in the audit data.

Page 3

WHAT WAS DONE RIGHT

We commend the State Election Commission for (apparently) requiring the counties to produce the data, for archiving the data, and for running reconciliation programs[2] against the data. When we first began analysis, we noticed that a substantial number of counties had failed to collect the data (as required by HAVA) and thus no reconciliation of the results was possible. By 2016, and now in 2018, that issue has been rectified. Almost every one of the 12,500 plus memory cards has had its data collected (there seem always to be a few memory card failures). The vote totals obtained by the various possible mechanisms by which totals could be computed seem to agree with each other.

It does appear at this point that the election officials statewide are able to run through the process of an election using the ES&S system. What we have focused on, then, are the hardware problems (that are increasing) and on the possible problems of which election officials should be advised but are not advised because the software fails to provide sufficient warnings of tasks not completed. We believe that software written for use by volunteer poll workers on an occasional basis should be bulletproofed. The software should require completion of the necessary tasks to ensure evidence for the results; instead, the software seems not only not to require completion of tasks but to provide no information as to what tasks might remain to be done.

SPECIFIC CONCERNS

As stated above, our major issues have turned from a failure of election officials to run an election according to "the standard procedure" to the problems that election officials (and eventually the voters) have in trusting an election run using suspect software.

Event codes with no explanation

We have been troubled since we began analyses by the fact that a number of events were deemed important enough to record in the EL152, but no one ever bothered to finish the software job to report what those events were.

An event in the iVotronic is almost certainly recorded as a timestamp for when the event occurred, the PEB[3] serial number if a PEB was used in the event (like opening and closing the iVotronic), and a code number for the event. This compact and probably fixed format for log information would then be expanded at county HQ into the EL152 report, with the code numbers being used in a lookup table to expand into their English explanation. We don't know for sure that this is how the software works, but we suspect this is what is done because something like this would be the natural way to write software for this purpose.

It is in our opinion a strong statement about poor software quality in this election system that there are event codes that expand into the explanation "UNKNOWN". This means that the programmer felt that an event was worth recording, but never finished the job of putting the English explanation in the table for the EL152. It also means that neither quality control for the project nor management at ES&S bothered to ensure that all codes were expanded.

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[2] In some earlier writing we have referred to this as an "audit". We no longer use this term and feel that "reconciliation" is more correct, since all we can do is verify that the data is consistent with itself.

[3] "Personalized Electronic Ballot"; this is the handheld device used by poll workers to open and close iVotronics and to download ballot definitions.

We observed that eleven of the "UNKNOWN" event codes in the 12 June First Primary data *do not appear* in either the 2014 or the 2016 General Election data. In the rewrite first used on 12 June, were there new codes added for which sloppy practice resulted in no explanation in the table? Were there changes in the software that resulted in triggering existing codes for the first time? And if the latter, was there no one noticing that prior sloppy practice was now newly exposed? We do not understand how these anomalies could occur in a software production environment with proper quality control and testing.

We note that in one instance, code 0000180, text was added to the central database, or else the use of that code number changed. That code was "UNKNOWN" in 2012 and 2016, but in the 2018 General Election data, code 0000180 now expands to "Select: Collect PEB Audit Data". It would seem that at some point the existence of "UNKNOWN" codes was noted, but no one beyond the level of that particular programmer did anything about it.

We have seen a total of 84 different event code numbers whose expansion into English is "UNKNOWN". Of these, 42 appeared either in the 12 June First Primary data or in the 6 November General Election data, or both. And 28 of the 42 appeared only in one of the two 2018 elections, that is, in the new and "upgraded" code.

In addition to the "UNKNOWN" codes, we notice two codes in the data, 0000000 and 0001648, that have no English text expansion in the EL152 log.

What is especially troubling is the frequency with which the "UNKNOWN" codes appear in close proximity to the shifts in time inside the iVotronic. We discuss the timestamp anomalies below.

Missing log data, and extra votes in the EL155

We have observed a phenomenon in the 12 June First Primary and the 6 November General Election that is something of a concern. For a small number of iVotronics and a small number of votes, the EL152 log ends abruptly and there are more votes in the EL155 cast vote record than there are 0002900 "Vote cast by voter" events in the EL152 log. We have seen situations before in which misbehaving iVotronics could not be closed and their votes were gathered by some other mechanism. It is apparently possible to flush the EL152 and EL155 internal data to the memory card without generating a "close terminal" event. This seems to have happened on occasion in the past. What is new here is that an otherwise normal EL152 record ends abruptly. It is as if the last output buffer has not been written. (This is a common error in programming; the steady state process is to write the buffer in the loop when it fills, but when one runs out of data at the bottom the partially filled buffer needs to be written out by code outside the loop.)

The number of votes involved is small, so we are not concerned about changes in the outcomes from the small miscounts that are observed. What does concern us is the implication for software quality that comes from such anomalies. We should not expect to see log files that are not complete; the purpose of a log file is to be a complete record of actions taken. We have not seen these anomalies prior to 2018, and we have not seen these anomalies related to a difference in the vote counts. What is of concern is the fact that this kind of unexplainable anomaly is often indicative in software of errors deeply hidden in the code.

And finally, we take these errors as part of a major concern: Even when the iVotronics are recording messages (or failing to record them?) that indicate that the software or hardware might not be functioning properly, the votes are counted from inside those iVotronics as if they were functioning properly. It is a huge vulnerability in the electoral process that warnings about hardware or software failures are completely ignored, and a huge flaw in paperless DRE-based elections that when such problems occur there is no remedy whatsoever.

Problems that might indicate hardware failure

Given the lighter turnout of a primary, it was harder with the First Primary data to project iVotronic failures. However, we note that in the primary nearly every county had at least one iVotronic that failed to open properly. In Williamsburg County in November, there were 30 iVotronics that were present but not actually used. This seems like a high number compared to the 86 that were used for gathering votes. We have been told that this resulted from a hardware error, related to the PEBs, that was seen in the runoff primary in Richland County and in Miami, Florida, in the November General Election.

In contrast to iVotronics that probably totally failed to function, we also observe some serious differences from one county to the next with regard to late openings of iVotronics. Since the internal timer in the iVotronic doesn't really control anything[4], internal times in the absence of additional information are not conclusive. We note 907 of the 10,224 iVotronics were nominally opened after 7:00am on 6 November. Of these, 422 were opened before 7:30am and thus might not be considered genuinely anomalous. Of greater concern would be the 250 or so iVotronics that were opened after 9:00am.

We note that 5135355, in Kershaw County, was cleared on 23 August, configured on 11 October, and then shows no events until it began collecting votes on *7 November 2018*. From the looks of the event log we can't tell that fraud was in process, but if this were not fraud then it is a significant additional indictment of the internal logging software. A similar phenomenon is observed for 5134369 and 5140418 in Darlington County, where the votes are cast on 8 November, and in 5122553 in Newberry County, with votes cast on 11 and 12 November, although at least in the case of 5134369 the time and date are reset on Election Day.

In our analysis, we have defined "Election Day events" to be events in the EL152 that occur after 7:30am on 6 November 2018. Technically, we might start the counting at 7:00am, when the polls are supposed to open, but we have permitted the poll workers a 30 minute grace period before considering an iVotronic to be opened late or to be calibrated for Election Day. We note also that our definition will fail to include events that occurred on an iVotronic whose internal clock was incorrect.

Screen Calibration

One of the constant complaints about the use of touchscreen voting computers is that voters touch one check box, only to have another box lit up. Calibration of the touchscreens is necessary to decrease the number of times this is actually a problem, and we might infer that increases in the need to calibrate screens (especially during Election Day) would be an indicator of the expected atrophy of the touchscreens themselves. For that reason, we specifically look at the number of screen calibration events in the EL152 file.

We also note that screen calibration events seemed much more common than in the past. There were 2150 "Calibrate screen" (code 0000169) events AFTER 9:00am on 12 June. These would presumably not be an initial calibration for quality control; those would have happened no later than the opening of the polls. The 2150 calibration events are more than the number of code 0000169 events for the 2016 General Election and should therefore be a cause for concern.

We present in Table 1 a longitudinal analysis of Election Day screen calibrations. The numbers represent the percentage of all iVotronics that showed an 0000169 screen calibration event on Election Day after 7:30am. For example, in the November 2018 General Election, 11.44% of the 10,224 iVotronics in use registered a screen calibration event in this time period. We would assume that prudent county election directors would calibrate screens prior to Election Day, and that these events result from voter complaints and not the initialization of the iVotronics for use.

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[4] To the best of our knowledge, the only thing the internal clock determines is that an additional window will pop up to ask (essentially) "Are you sure?" if the iVotronic is opened up to allow a vote cast after the official close of the polls.

There is a huge variance in the numbers seen, with Cherokee County and Richland County clearly having calibration problems greatly in excess of the average. We have not looked into the numbers for, say, Hampton County, which started in 2010 with even higher rates of screen problems but had in 2018 a very low rate of screen problems.

We note that the zero entries in Table 1 are sometimes the result of missing data and do not mean that there were no calibrations; if there was no EL152, we don't know how many calibrations there were.

Internal Memory Issues

The iVotronic has several internal memory chips and also uses an external flash memory card for saving the coded form of the EL152 and EL155 files. The cast vote record is saved in three redundant memories that are checked on an ongoing basis during use to be identical. This and other data stored or used by the iVotronic make use of a cyclic redundancy check (CRC) to detect garbling of the bits (and possibly also to correct some garbling). Several of the event codes seem to refer to memory problems. (We assume that "TF" stands for "Terminal Flash".)

0002202	CF – SN mismatch
0002206	Invalid index value
0002207	TF – chip vs chip crc error
0002208	Terminal flash chip compare failed
0002209	Memory block-to-block compare failed
0002303	TF – write failed
0002304	TF – operation timed out
0002306	TF – data compare mismatch

Of these, only the 0002209 code appears with any frequency, which is perhaps a good thing, and there does not seem to be an increase in recent data of these codes. We present in Table 2 the raw counts of the 0002209 code and in Table 3 the percentages of the iVotronics in a given county of the 0002209 code. There have been fifteen such counties since 2010, and only two of those (Darlington and Pickens) had 0002209 events in the past but not in 2018.

The primary concern from among these error codes would clearly seem to be the 0002209 code, "Memory block-to-block compare failed". We are reasonably sure that this relates to the internal check that the three internal memories have the same cast vote record stored in them. There were 6, 2, 3, and 4 terminals that had these errors in 2010, 2012, 2014, and 2016, respectively, but 57 such terminals in the First Primary and 71 in the General Election of 2018. That represents a huge change and could indicate aging equipment. If one restricts to Election Day events after 7:30am, the numbers are 0, 2, 2, 4, 25, and 49; the dramatic increase should be somewhat alarming. It is possible that the increase is artificial, either because the earlier software didn't report all the events it should have, or because the new software has decided indeed to report them all. Each of these options would be a bad sign.

We have been concerned all along, and are now more concerned, that iVotronics that report hardware errors like the 0002209 code continue to be used for voting and their votes are counted as if there had been no such error event recorded. iVotronic 5128090 in Georgetown County, for example, recorded 1335 instances of error code 0002209, and yet its 67 votes were collected as if no error had occurred. The 49 iVotronics reporting 0002209 events on Election Day reported 11,752 such events, an average of 240 per iVotronic; when things go wrong, they stay wrong, and yet there is no recourse except to ignore the warnings and count votes as usual.

We remark that we do not see the number of iVotronics reporting 0002209 errors concentrated in the larger counties that might expect to see a higher number of such problems. The counties with the largest numbers of these events – Aiken, Dorchester, Fairfield, Lexington, and Greenwood, accounting for 30 of the 49 Election Day problems, are not the largest counties in the state. (Lexington is fourth in terms of the number of iVotronics used in the General Election; Aiken is ninth.)

It is additionally troubling that the events recorded now seem different. In the past, closing the iVotronic would always trigger an event 0001416 "Copy audit data from TF 1 to CF" ("Terminal Flash to Compact Flash). In the case of errors like the 0002209, we would see events 0001417 and 0001418 recording the copying of the second and third terminal memories to the flash memory card; this would permit the usual two-out-of-three vote as to what the cast vote record was and which memory of the three was the outlier. We see in the 12 June primary data no instances of code 0001416 and no record that the internal memories have been copied to the memory card. Either all the verification of which memory was in error is now being done in the iVotronic, or no use of the redundancy is happening, or this valuable message has simply been dropped. We believe this to be bad practice.

We finally comment on the disturbing fact that several iVotronics, in Horry, Lexington, and Marlboro Counties, recorded different numbers of votes from what was included in the official counts. It has always been possible to count the number of "vote cast" events in the EL152 and the number of votes in the EL155 cast vote record and verify that the numbers came to the same value. For the first time, in the 12 June primary, we have several iVotronics that had different numbers. Invariably these were instances in which the iVotronic was clearly failing. In these iVotronics, the log file ends abruptly, there is no record of closing, and there are fewer "vote cast" events (by one or two) in the EL152 than there are instances of cast votes in the EL155. In the General Election, this happens in Anderson, Darlington, Greenville, Greenwood, Richland, and Sumter Counties.

It is not clear, once again, whether the discrepancies are the result of hardware failure or of flaws in the software. Either should be a major concern.

Power and battery problems
We remark that anecdotal comments frequently arise with regard to battery or other power problems in the iVotronics. We heard this in 2012 regarding the debacle in Richland County, for example. However, we fail to see event log records of such problems. The relevant event codes would seem to be "0001602 Terminal power is low" and "0001603 Terminal voltage read failed". We see in all our data, however, only one instance of each event. If this is a problem, it is not causing events to be recorded.

Timestamp anomalies

Perhaps correlating with the event codes problems mentioned just above, we note that the EL152 timestamps continue to go forward and backward in time, contrary to what anyone would expect in anything that purports to be a system log. A look at an EL152 excerpt from Chester County for the First Primary says it all:

```
5132179   130966   SUP    2018-05-23 13:57:41    0001607 Clear-n-test terminal flash successful
                   SUP    2018-05-23 13:58:20    0000116 Select: Configure Terminal
                   SUP    2018-05-23 13:58:26    0001650 Terminal - exited service menus
          123887   SUP    2018-05-23 14:02:14    0001001 Confirm PEB ballot failed by user
          147244   SUP    2018-06-12 06:55:17    0001303 Transfer PEB vote data to terminal
          143916   SUP    2018-06-11 19:32:43    0001319 Update PEB's terminal record
                   SUP    2018-06-12 06:55:23    0000019 UNKNOWN
          143400   SUP    2018-06-10 09:25:04    0001024 UNKNOWN
          146732   SUP    2018-06-10 18:31:29    0000066 UNKNOWN
          146728   SUP    2018-06-10 09:25:24    0001882 UNKNOWN
          146732   SUP    2018-06-10 18:31:58    0000019 UNKNOWN
          146728   SUP    2018-06-10 09:19:32    0001920 UNKNOWN
          147244   SUP    2018-06-12 06:58:49    0002006 Print task was cancelled
```

```
          SUP    2018-06-12 06:58:53    0001672 Terminal Opened
123887    SUP    2018-06-12 07:05:22    0000621 Warning: Terminal reset from voting
          SUP    2018-06-12 07:07:12    0002900 Vote cast by voter – Visual
```

Concomitant with several "UNKNOWN" events, we see the clock going back two days in time, then jumping forward and backward nine hours on the 10 June date, and then returning to what is probably the correct time and date.

We also see instances in which the timestamp is a genuinely bogus value, such as
    1994-01—1. -14:-26:
We have in the past seen timestamps that were all zeros, and we have seen some that were midnight on 1 January 1994 (this would appear to be the epochal beginning of time for the iVotronics), but we have not seen before a timestamp that did not expand properly into an actual date and time.

Another concern about the software comes from looking at the EL152 from Barnwell County. Serial number 5120526 begins Election Day with what appears to be a normal setup process. Suddenly, at 2:29pm on Election Day, the timestamp reverts to 12 June 2018 (the day of the First Primary), and 58 votes are collected on that (alleged) date. This problem has been seen on this iVotronic before. In the 2014 election, the log has a "0001510 Vote cast by voter" event at 14:27:58 on 4 November and the next event is a 0001510 event at 16:30:26 on 10 June. This occurs again in 2016 with a jump from 8 November to 28 June, again with two 0001510 events, followed later by a jump from 28 June to 22 June with two 0001510 events.

These anomalies simply will not happen with high-quality software.

Counting votes twice

There were apparently 148 voters in Wallace Precinct in Marlboro County who had the distinct privilege of voting twice in the 12 June primary. This error was not caught by the county or the state, and the totals as reported are simply wrong. There was an iVotronic, serial number 5123479, that was clearly failing. Instead of adding in just the five votes from that iVotronic into the totals, the other 148 votes in that precinct were added to the totals from their memory cards in spite of the fact that the votes had been added in with the usual PEB-based process. Instead of 153 total votes in the precinct, the total was reported as 301 by double counting the 148 to get 296 and then (correctly) adding in 5 more.

Curiously, one of the five votes on this iVotronic occurs backwards in time, on 11 June:
```
          SUP    2018-06-12 07:46:15    0002900 Vote cast by voter – Visual
          SUP    2018-06-12 08:15:09    0000621 Warning: Terminal reset from voting
135993    SUP    2018-06-11 18:36:48    0002900 Vote cast by voter – Visual
136057    SUP    2018-06-12 08:22:21    0000585 UNKNOWN
135993    SUP    2018-06-11 18:44:48    0002816 Terminal-FlashFull:Vote Saved state
```

CONCLUSIONS

We are pleased that the data is available for analysis; we believe this strengthens voter trust in the election process.

We continue to be concerned that votes are collected and counted iVotronic terminals that declare themselves to be malfunctioning, although we see no good remedy for this. To choose not to count votes from iVotronics

with errors is to disenfranchise the voters who were directed to those iVotronics. To choose to count the votes is deliberately to include votes that might not be cast as intended. We believe this highlights the problem of using computers for elections when there is no means for determining ground truth and no backup capability.

We are concerned about an increase in the number of iVotronics that have highly anomalous event logs, especially when the anomaly relates to the number of votes cast on the device.

We find disturbing the continued presence in an "upgrade" of the software of at least one error known to cause votes to be counted correctly.

We find very disturbing the event log problems that seem to indicate of poor quality control and a lack of management attention in the software development process.

REFERENCES

EVEREST   Ohio Secretary of State. EVEREST: Evaluation and Validation of Election-Related Equipment, Standards and Testing initiative. December 2007. https://www.eac.gov/documents/2017/03/21/everest-report-state-voting-systems-voting-technology/, last accessed 23 December 2018.

	2010	2012	2014	2016	2018 Primary	2018 General
Table 1: Code 0000169 Screen calibration, percentages of county iVotronics with this event on Election Day						
Abbeville	8.62	9.80	16.33	6.67	8.33	5.26
Aiken	55.72	15.68	12.60	12.06	20.40	13.55
Allendale	16.00	30.00	17.86	18.52	0.00	10.00
Anderson	6.77	18.31	9.04	11.39	16.73	22.60
Bamberg	12.20	0.00	17.02	25.00	10.00	2.70
Barnwell	6.56	4.62	1.54	19.40	8.33	70.49
Beaufort	5.33	4.24	7.52	4.56	10.80	9.72
Berkeley	5.12	4.67	9.57	10.62	23.73	10.97
Calhoun	4.65	2.27	16.67	10.42	16.67	0.00
Charleston	3.45	8.82	8.47	8.08	9.14	5.94
Cherokee	0.75	8.51	19.29	35.71	12.64	37.10
Chester	16.09	11.58	9.38	6.06	3.75	5.43
Chesterfield	4.60	3.09	5.10	9.09	3.03	2.00
Clarendon	22.81	0.00	12.90	3.70	11.59	8.45
Colleton	3.30	6.09	6.96	2.65	2.33	7.00
Darlington	2.42	5.81	13.14	3.12	12.64	2.86
Dillon	4.11	10.84	15.49	7.35	8.70	10.29
Dorchester	12.89	14.38	11.07	14.89	14.78	8.99
Edgefield	0.00	6.35	4.29	2.90	0.00	3.03
Fairfield	0.00	2.63	1.33	2.60	2.90	0.00
Florence	4.14	4.48	2.87	8.24	6.78	3.83
Georgetown	3.57	4.94	2.56	7.32	9.02	0.65
Greenville	2.77	4.96	7.82	4.63	7.12	5.19
Greenwood	1.13	1.09	1.09	2.09	0.56	2.04
Hampton	44.62	19.72	27.94	13.43	3.08	4.76
Horry	8.99	6.39	13.64	9.41	9.62	8.47
Jasper	2.44	5.17	1.54	4.41	3.08	1.52
Kershaw	6.94	2.53	5.77	10.90	3.05	8.61
Lancaster	0.00	2.15	1.82	2.62	1.38	2.70
Laurens	3.36	11.46	5.41	2.99	0.00	3.14
Lee	1.92	6.67	7.14	0.00	0.00	12.07
Lexington	11.09	13.84	36.01	7.36	20.24	15.67
Marion	6.25	10.00	3.49	7.37	4.94	2.35
Marlboro	0.00	6.25	12.70	9.38	0.00	8.33
Mccormick	3.85	6.25	3.12	6.06	7.14	6.06
Newberry	3.19	2.08	6.19	12.00	3.23	2.08
Oconee	5.00	5.59	2.48	5.62	0.76	3.57
Orangeburg	0.00	32.68	16.26	6.07	8.82	0.00
Pickens	2.02	1.52	3.58	2.93	0.00	2.00
Richland	10.02	13.41	10.13	27.79	24.71	38.18
Saluda	1.96	5.77	3.77	1.79	4.65	6.12
Spartanburg	1.13	1.05	2.29	3.49	4.43	3.25
Sumter	5.85	6.64	9.29	60.08	12.69	4.31
Union	21.11	1.16	3.33	14.29	10.84	6.10
Williamsburg	0.00	6.52	14.86	3.09	4.08	1.90
York	14.52	19.61	20.08	10.42	16.77	12.23
Statewide	9.27	8.88	10.60	10.83	11.83	11.44

Table 2: Counts of "0002209 Memory block-to-block compare failed" events						
	2010	2012	2014	2016	2018 Primary	2018 General
Abbeville	0	0	0	0	820	0
Aiken	0	0	0	0	0	1152
Anderson	0	0	0	0	80	3104
Beaufort	0	0	0	0	30	0
Berkeley	0	0	0	0	0	20
Charleston	0	0	0	0	0	20
Chester	0	0	0	0	780	0
Chesterfield	0	0	0	0	0	1652
Darlington	0	0	1	0	0	0
Dillon	0	0	0	0	40	543
Dorchester	0	0	0	0	0	920
Fairfield	0	0	0	0	0	342
Florence	0	2	0	0	0	20
Georgetown	0	0	0	0	1490	0
Greenville	0	0	0	0	440	20
Greenwood	0	0	0	0	0	1060
Hampton	0	0	0	0	0	40
Horry	0	12	25	49	0	20
Jasper	0	0	0	0	380	0
Kershaw	0	0	0	0	420	0
Lancaster	0	0	0	0	0	927
Lee	0	0	0	0	83	0
Lexington	0	0	0	0	1260	106
Pickens	0	0	0	6	0	0
Richland	0	0	0	0	0	20
Saluda	0	0	0	0	20	0
Spartanburg	0	0	0	0	20	2
Union	0	0	0	0	740	20
Williamsburg	0	0	0	0	20	0
York	0	0	0	0	380	1764
Statewide	0	14	26	55	7003	11752

Table 3: Counts of "0002209 Memory block-to-block compare failed" events					
Percentages of iVotronics in each county with this event					
	2010	2012	2014	2016	2018 Primary	2018 General
Abbeville	0.00	0.00	0.00	0.00	2.08	0.00
Aiken	0.00	0.00	0.00	0.00	0.00	2.30
Anderson	0.00	0.00	0.00	0.00	0.36	0.72
Beaufort	0.00	0.00	0.00	0.00	1.20	0.00
Berkeley	0.00	0.00	0.00	0.00	0.00	0.31
Charleston	0.00	0.00	0.00	0.00	0.00	0.13
Chester	0.00	0.00	0.00	0.00	3.75	0.00
Chesterfield	0.00	0.00	0.00	0.00	0.00	1.00
Darlington	0.00	0.00	0.57	0.00	0.00	0.00
Dillon	0.00	0.00	0.00	0.00	1.45	2.94
Dorchester	0.00	0.00	0.00	0.00	0.00	2.52
Fairfield	0.00	0.00	0.00	0.00	0.00	6.94
Florence	0.00	0.37	0.00	0.00	0.00	0.38
Georgetown	0.00	0.00	0.00	0.00	2.46	0.00
Greenville	0.00	0.00	0.00	0.00	0.27	0.11
Greenwood	0.00	0.00	0.00	0.00	0.00	2.04
Hampton	0.00	0.00	0.00	0.00	0.00	3.17
Horry	0.00	0.16	0.16	0.16	0.00	0.19
Jasper	0.00	0.00	0.00	0.00	1.54	0.00
Kershaw	0.00	0.00	0.00	0.00	0.76	0.00
Lancaster	0.00	0.00	0.00	0.00	0.00	0.54
Lee	0.00	0.00	0.00	0.00	1.85	0.00
Lexington	0.00	0.00	0.00	0.00	0.71	0.83
Pickens	0.00	0.00	0.00	1.10	0.00	0.00
Richland	0.00	0.00	0.00	0.00	0.00	0.10
Saluda	0.00	0.00	0.00	0.00	2.33	0.00
Spartanburg	0.00	0.00	0.00	0.00	0.23	0.19
Union	0.00	0.00	0.00	0.00	1.20	1.22
Williamsburg	0.00	0.00	0.00	0.00	1.02	0.00
York	0.00	0.00	0.00	0.00	0.30	0.36
Statewide	0.00	0.02	0.02	0.04	0.32	0.48