Early Requirements for Mechanical Voting Systems

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***Abstract*—The problem of setting the requirements for voting systems is as old as democracy. With the advent of voting machinery in the 19th century, the problem became more difficult. In most cases, it was the technologists who set out to formally articulate requirements. In many cases, these are clearly stated, as such, in patent applications of the era. Sadly, some of these requirements have been repeatedly forgotten in subsequent years. By the early 20th century, several authors produced concise summaries of these requirements, but their efforts reflect strong vendor bias.**

***Keywords*-History; Privacy; Security; Patents; voting**

I. Introduction

Technology was first applied to elections in the 19th century. While political reformers were speaking broadly about the still controversial right to a secret ballot, technologists began developing machinery intended to guarantee this right. In many cases, the requirements understood by the developers are implicit in the technology itself, but it was very common for voting system developers to explicitly state the requirements they intended to meet. While the technological landscape has changed incredibly in the past two decades, the basic requirements for voting systems have not.

In this paper, I will outline some of the major requirements that were explored in the 19th century, documenting, with each, how that requirement was recognized, and sometimes how it was forgotten before later rediscovery.

Most of the developments discussed here happened in the United States. There are two primary reasons for this. First, general elections in the United States are unusually complicated. Where a British or French voter might cast one vote per ballot, a voter in a general election in the United States typically casts ten or more votes, as illustrated by the ballot in Figure 1. This ballot from 1839 includes votes for 9 distinct races, ranging national to local. Most of these are single seat elections, but there are three multi-seat races in which the voter cast two votes each. Modern ballots in the United States are typically even more complex.

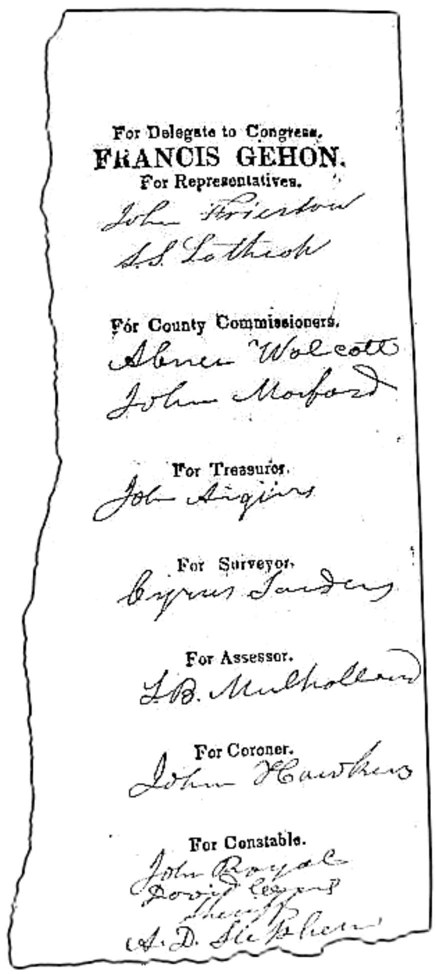

Figure 1. A ballot from an 1839 election in Iowa Territory, showing the complexity typical of U.S. elections. Author's photo, ballot from the Special Collections Dept., Iowa State Historical Society Library, Iowa City, Iowa.

Hand counting of single office ballots can be fast and straightforward, but when the ballots contain votes for many different offices, hand counts are both slow and error prone. This alone might have been enough to justify developing voting machines, but a second consideration is also important. Stories of election fraud circulated widely in the late 19th century, and many inventors saw their work on voting machinery as part of a campaign for election reform[34].

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II. Secret Ballots

While Papal and Masonic elections have long required the use of secret ballots, the use of secret ballots for governmental elections was not immediately obvious and remained controversial through most of the 19th century. The first Chartist petition of 1838 ended with a demand for universal suffrage and the secret ballot. In their 1838 pamphlet, the Chartists published a description of a mechanical voting machine attributed to Benjamin Jolly of Bath England[10]. Another Englishman, Henry Spratt, patented a voting machine in the United States in 1875[53]. The primary purpose of both of these machines was to provide for a secret ballot.

The first practical implementation of the right to a secret ballot came in Australia, with different Australian states adopting different variations on the theme in 1856 and 1857. All of these variations involved paper ballots. Outside of Australia, the idea of the secret ballot came to be known as the Australian Ballot, and if the variations are acknowledged, the variant used in the state of Victoria is usually singled out[47].

John Stuart Mill argued against the secret ballot. He held that without universal suffrage, every non-elector had a right to learn how the electors had voted. This allowed the non-electors to pressure electors to represent everyone and not just themselves. Furthermore, he suggested that in an egalitarian society, voters were unlikely to need the protection of a secret ballot[43].

The right to a secret ballot involves several subsidiary rights. The difference between these is illustrated by the difference between the Ballot Act of 1872 in Great Britain[27] and Virginia's 1902 constitutional guarantee of a secret ballot[37]. Both of these remain in effect today. The British code requires that ballots be serial numbered and that the numbers be recorded on the voter register. The linkage between voters and their ballots is preserved as a state secret and may only be disclosed by order of Parliament or a competent court. We will refer to this as providing conditional secrecy. In contrast, Virginia's code prohibits the placement of any identifying mark on a ballot. We will refer to this as absolute secrecy.

Conditional secrecy allows the linkage between voters and their ballots to be reconstructed in the event of any controversy. If examination of the voter register shows that someone should not have voted, their ballot can be found and excluded from the count. If, in a close election, some ballots are found to be ambiguous, the voters who cast them can be questioned as to their intent.

The risks posed by conditional secrecy illustrate a second distinction. A dishonest election official could unseal the voter register in order to punish or reward voters for their votes. This is a risk posed by any system where the election authority maintains the linkage between voters and their ballots. If voters record the numbers on their ballots, they may sell their votes to someone who can see the ballots, for example, an observer at the count. This risk is posed by any system that permits voters to prove which ballots are theirs, regardless of whether the authorities can link ballots to voters.

Many early voting machines dispensed entirely with any form of durable ballot, and in so doing, they provided absolute secrecy. On these machines, the only record of the vote is in the values of registers inside the machine that are incremented as votes are cast. The early British voting machines already cited worked this way, as did the line of machines that led to the dominant voting machines of the 20th century, starting with Alexander Roney's machine of 1878[50]. Anthony Beranek[17], Jacob Myers[45], Sylvanus Davis[22] and Alfred Gillespie[23] all followed this line.

Other developers took a different approach to ballot secrecy. In 1878, Morris Williams[54] and Steuben Bacon[16] patented registering ballot boxes that not only counted the ballots but serialized them. Williams and Bacon both made it clear that their goal was conditional secrecy. For example, Williams wrote that "any given ballot can be identified ... by noting its number on the register when deposited ... so that repeating and other modes of fraudulent voting can be successfully prevented."

In other cases, the intent of the inventor is less obvious. In 1893, John McTammany patented a voting machine that recorded votes on a continuous paper roll. He recognized that, by recording votes on a continuous roll, "it is possible to identify a man's vote, by counting voters as they go in and afterward counting the rows of marks on the sheet."[38] McTammany's proposed solution was to stagger the rows of marks corresponding to each voter's ballot so that marks corresponding to different voters would be interleaved on the paper roll, making it difficult to reconstruct any particular voter's ballot. This scheme might be considered the first application of cryptography (albeit in rudimentary form) to the problem of ballot secrecy. McTammany eventually abandoned this staggering scheme[41].

Today, there is widespread international consensus about the need for a secret ballot. For example, this right is included in The Charter of Paris for a New Europe, signed by the members of NATO and the former Warsaw Pact[1]. The Council of Europe standards interpret this as absolute secrecy, with Standard 17 guaranteeing "that it is not possible to reconstruct a link between the voter and the vote"[5].

Nonetheless, there remains considerable confusion about the exact meaning of this right. For example, voting machines that record on a continuous paper roll remain in common use today[32]. As a second example, the Scantegrity II voting system[19] requires that a unique identifier be printed on each ballot, placing it clearly in the conditional secrecy category. An experimental use of this voting system is proposed in Maryland, where the law requires that "each ballot shall ... protect the secrecy of each voter's choices"[11]. This example illustrates vagueness on the part of both legislators and voting system developers.

III. Transparency

In 1858, Allan Cummings and Samuel Jollie patented competing transparent ballot boxes[21], [35]. Jollie explicitly stated that his ballot box was designed so "that the bystanders may see every ballot which is put in, see all the ballots that are in, and see them taken out." Jollie sold 1200 of his cast iron and glass boxes to New York City, in time for the 1857 election[12].

A physically transparent ballot box allows voters and observers to verify that the box is empty at the start of the day, that the ballots they put in actually go in, that no voter puts in more than one ballot, and that all the ballots are counted at the end of the day. Any voting system with these attributes can be described as transparent, regardless of whether it is actually made of glass.

In 1860, Miles Shinn patented a registering ballot box[52]. His opaque box included a public counter that registered the number of ballots inserted in the box. The transparency goal was met by allowing the public to see that the counter was zero at the opening of the polls, to see that the counter incremented by one as each ballot was inserted, and to see that the number of ballots removed from the box for counting at the end of the day was equal to the final value on the counter.

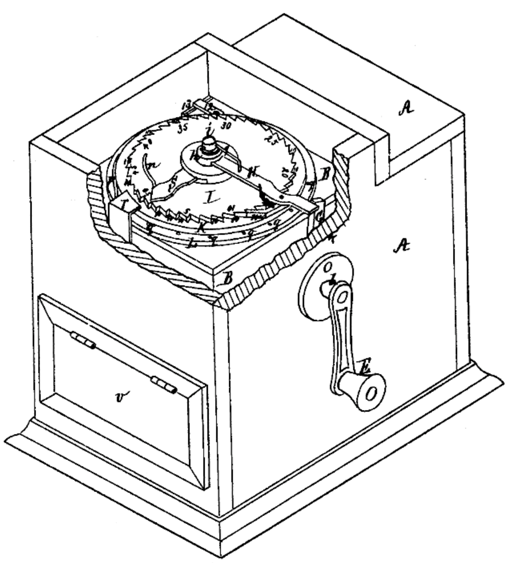

Figure 2. Savage's 1873 registering ballot box. The slot for inserting ballots was in the top behind the register. From U.S. Patent 142,124.

James Savage's 1873 registering ballot box shown in Figure 2 added an endorsing stamp[51]. A turn of the crank would increment the public counter and endorse one ballot dropped into the box. If a dishonest voter inserted a stack of ballots, all would go into the box, but only the top one would be stamped.

In 1884, Massachusetts mandated the use of registering ballot boxes[18]. The need for a public counter was sufficiently obvious that the British inventor, Henry Spratt, included one in his voting machine patent of 1875[53]. This machine was not applicable to U.S. elections because it only supported a single multi-candidate race, but it set the pattern for many of the mechanical voting machines that followed.

The need for a public counter was not universally recognized. Neither Alexander Roney nor Anthony Beranek included public counters in their machines[17], [50]. John Rhines appears to have been the first to correct this omission, incorporating "a registering mechanism operated by the raising of the cover which registers the total number of electors voting[48]. Jacob Myers omitted public counters from his initial voting machines[44], [45] but added one to his 1890 machine[46], well in advance of its first use[14].

Section 2.2.2.9 of the U.S. 1990 standards requires a Public counter[3], and this is restated in the 2005 guidelines[2]. Unfortunately, the original purpose of the public counter seems to have been forgotten in these modern requirements, as they only ask that the counter be visible to "designated officials," not the public at large. There does not appear to be any analogous requirement in the 2004 european standards[5].

IV. Voter Verification

Another way of looking for the origin of transparency requirements is to look for early complaints about a lack of transparency. One of the most compelling of these is found in a dissenting opinion of the Rhode Island Supreme Court. The court was asked whether the player-piano-roll vote record of the McTammany voting machine[41] was a ballot, as defined in state law. Horatio Rogers held that it was not a legal ballot because "a voter on this voting machine has no knowledge through his senses that he has accomplished a result. The most that can be said is, if the machine worked as intended, then he has ... voted"[49]. His complaint clearly applies equally to most voting machinery used over the following century.

To use modern terminology, Rogers' complaint was that voters could not verify that their votes were cast as intended. The first mechanical voting system to clearly address this complaint was patented in 1893 by Urban Iles[33]. His machine used punched-card ballots with a precinct-count tabulating machine. He wrote that "it will be understood that the marks [on the ballot] may be dispensed with, but they are preferably used." Iles did not explain why, but the marks in question were the candidate names and circles marking each punch position. We can conclude that his purpose in preferring these marks must have been so that the voters could verify that the ballots were punched correctly after removing them from the voting machine.

An alternative model for voter verification involves equipping a direct-recording voting machine with a mechanism to produce an auxiliary voter-verifiable paper trail. In 1899, Joseph Gray patented such a machine[28]. This machine enables “the voter to indicate the candidate or candidates for whom he desires to vote upon a ticket having the names of candidates printed thereon and at the same time to register his vote or votes by means of an apparatus designed for the purpose.” From a conceptual point of view, the big difference between Iles’ machine and Gray’s machine was that the paper ballot used in Iles’ machine was the primary record of the vote, while the paper record created by Gray’s machine was an auxiliary record.

Neither of these voter verification mechanisms was successful in the marketplace, and the idea of voting machines supporting voter-verifiable ballots was forgotten until the second half of the 20$^{\text{th}}$ century. The Votomatic voting machine developed by Joseph Harris in 1965[30] is remarkably similar to Iles’ system, particularly when combined with a precinct-count punched-card tabulator, but as typically used, voter verification with this system was impeded because the only printing typically included on the ballot was a numerical code by each punch position.

It was only in the early 21$^{\text{st}}$ century that Rebecca Mercuri provided a compelling argument for the need for voter verification[42] and Kevin Chung developed an electronic voting system that included a printer that duplicated the functionality of Gray’s machine[20].

V. Recountability and Redundancy

With paper ballots, a recount is possible if there is a problem with the first count. When paper ballots are mechanically tabulated, questions about the integrity of the mechanism can be answered by a hand count. All of the voter verifiable schemes discussed above allow such recounts. In contrast, when direct recording voting machines are used, whether mechanical or electronic, the possibility of a recount is not immediately evident.

Early voting machines such as those of Benjamin Jolly[10]. Henry Spratt[53] and Anthony Beranek[17] made no provisions for recounts. In 1889, Jacob Myers filed a patent for a direct recording voting mechanical voting machine that incorporated a redundant memory[44]. Voters cast votes by inserting metal tokens in slots in the face of the machine. To quote Myers, “as the votes are counted as they are cast, the total number can be ascertained rapidly and accurately at the close of the polls without the necessity of counting by hand ..., though this may be done as a check or verification should it be necessary or desirable.” Myers abandoned this requirement in the machines he took to market[45], [46].

John Rhines incorporated an interesting redundant memory in his 1890 voting machine[48]. In his machine, self-incrementing rubber stamps were positioned behind each voting button. Buttons locked down when pressed, and when the voter closed the cover, all the depressed stamps printed on a paper strip, the the strip was advanced, and the stamps released ready for the next voter. Rhines described how, by glancing at the last number printed on each column of the recording strips, the totals could be obtained, while by inspecting the entire strip, corrections could be made for errors and at least some types of fraud could be detected.

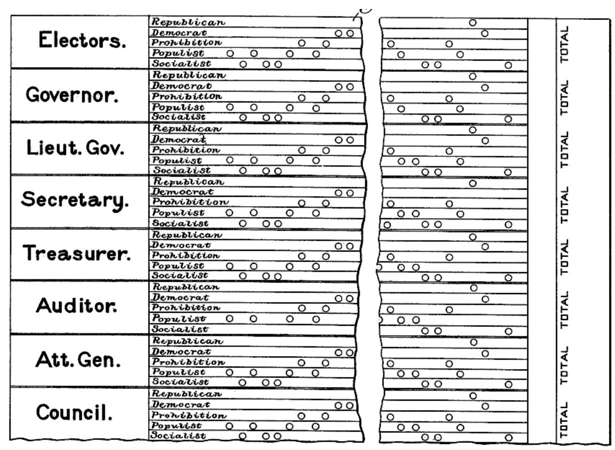

Figure 3. A paper record of the votes cast on McTammany’s 1895 voting machine. From U.S. Patent 550,055.

John McTammany’s patented several voting machines that recorded votes on player-piano rolls, as shown in Figure 3[39], [41]. These were intended to be tabulated by machine[40], but it is obvious that a hand count of the holes in one row of the paper roll is an effective alternative to a machine count.

Rhines’ and Mctammany’s machines illustrate that voter verification is not the same thing as either recountability or redundancy. A recount is possible on these machines, but McTammany’s machines did not provide any form of redundancy, and neither allowed the voter to verify that the machine actually recorded their votes.

As use of voting machines became widespread, the need for recountability and redundancy were forgotten. The McTammany and Rhines machines were abandoned, and by the early 20$^{\text{th}}$ century, the U.S. Standard Voting Machine Company emerged as a monopoly, based on the Gillespie, Myers and Davis patents[6]. The U.S. Standard voting machine included no recount or redundancy provisions.

A century later, these requirements reemerged in Section 4.5 of the U.S. 1990 standards[3]. Standard 26 of the Council of Europe standards also addresses recountability, while Standard 77 implicitly requires redundancy to meet the stated fault-tolerance goal[5].

VI. Ballot Validity

Most elections require that the voter vote for exactly one candidate in each race. The need to enforce this rule was obvious to some inventors from the very start. Henry Spratt's 1875 voting machine incorporated a system of sliding doors so that only one voting knob was accessible at a time, and a counter that limited the number of votes each voter could cast. When set to values above one, Spratt's mechanism allowed multiple votes to be cast for the same or different candidates[53].

Anthony Beranek's 1881 voting machine used a different enforcement mechanism. On this machine, each race in the election was presented as a row of push buttons. Pushing a button to cast a vote drove a wedge between two spacers. The spacers rode in a track behind each row of buttons, with only enough slack to allow one wedge to be driven at a time. This enforced a vote-for-one constraint for each race[17]. Jacob Myers' machines of 1889 used essentially the same interlocking mechanism[44], [45].

An alternative way to enforce the vote-for-one constraint is to select a candidate by turning a knob. Alexander Roney's voting machine from 1878 was the first to take this approach[50]. McTammany's early voting machines had no enforcement mechanism, but in his 1895 machine used a rotary knob candidate selector[41].

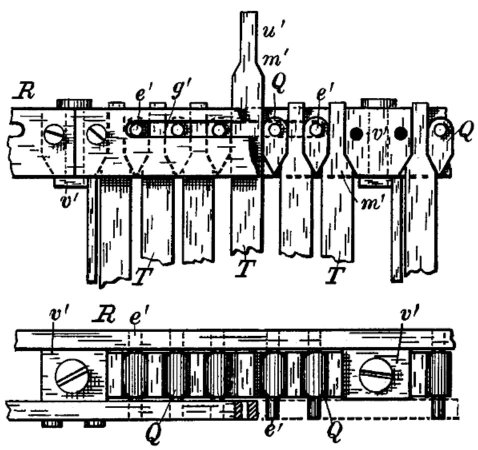

Figure 4. The Davis wedge-and-spacer interlocking mechanism as of 1895, set to enforce the constraint "vote for one out of 6." From U.S. Patent 549,631.

As illustrated in Figure 1, elections for some offices have long permitted voting for more than one candidate. Enforcing a vote-for-n rule cannot be done with candidate selector knobs, but it can be done with wedge and spacer interlocking. In 1894, Sylvanus Davis received a patent for a machine with an elegantly simplified wedge-and-spacer mechanism, as shown in Figure 4[22]. A few years later, Alfred Gillespie used essentially the same mechanism[23]. These machines could be manufactured with each race preset for a particular vote-for-n rule, and Gillespie's machine included removable pins to hold the stops in place. By drilling extra holes in the rails holding the wedge-and-spacer assemblies, Gillespie's machine could be made field-programmable to support different rules from one election to the next. Gillespie's 1904 patent explicitly recognizes this[25].

American political parties of the 19^{th} century had been accustomed to printing their own ballots, known as party tickets. Jacob Myers understood that, to be successful, a voting machine would have to make it very easy for a voter to cast a straight party ticket, and he included a crude but effective mechanism for this in one of his 1889 patents[45]. Davis' 1894 machine included a more elegant straight-party mechanism[22]. Both of these mechanisms required that all candidates for the same party be arranged in a line on the face of the machine. The combination of straight party voting and interlocks to enforce vote-for-n rules forced the arrangement of the face of the machine to be a matrix, with, for example, party columns and office rows.

Some states permit a candidate to run with endorsements from multiple parties. With early mechanical voting machines supporting straight-party voting, cross-endorsed candidates had separate registers for each endorsing party. At the close of the polls, clerks had to manually add these registers. If a cross-endorsed candidate ran in a vote-for-2 race, the presence of two registers meant that the machine could not prevent a voter from voting twice for the same candidate, once under each party. In 1907, Gillespie patented a mechanism to link the registers of cross-endorsed candidates that prevented this[26].

With the addition of straight-party mechanisms and interlocking mechanisms to enforce ballot validity constraints, voting machines became programmable devices. The technician setting up the machine was responsible for linking candidate levers to the straight-party lever for partisan offices and disconnecting this link for non-partisan offices. The technician was responsible for attaching cross-endorsement linkages, and for setting the vote-for-n constraints on each office. Technicians make occasional mistakes, and deliberate machine rigging is difficult to distinguish from such mistake. These interlocks and linkages were sufficiently complex that inspection by an expert could not easily detect mistakes, and designing pre-election tests to make sure all the linkages operated correctly was not trivial. Furthermore, all of these linkages were hidden inside the machine, out of sight of both voters and election observers.

It is interesting to note that voting system regulations formulated in the United States have always accepted, without question, the idea that the voting system should enforce ballot validity rules. The nature of these rules is expected to vary from state to state and even election to election, but the mechanisms are required to be present. This is the case with Section 3.2.4.2 of the U.S. 1990 standards[3], and it has been enacted into law with the Help America Vote Act of 2002[4]. In contrast, the Council of Europe standards are silent on this issue, with the commentary on Standard 13 explaining that this issue is a matter of domestic policy[5].

VII. Additional Requirements

The Australian secret ballot requires that parties formally nominate candidates and that the government print ballots with the names of all party nominees. When this model was adopted in the United States, many states made one addition: A write-in blank was printed for each race on the ballot. This allowed voters to vote for candidates who were not party nominees. No early voting machine supported this option, so each polling place had to accept paper "irregular ballots" for those voters wishing to use the write-in option.

In 1899, Alfred Gillespie patented a mechanical voting machine that included a paper scroll for recording write-in votes for each race on the machine. Opening the door over this scroll could be interlocked with the voting levers, so a vote-for-one constraint could be enforced over both regular and write-in options. The scroll was advanced and the door closed when the voter exited the booth[24]. This mechanism became universal in the mechanical voting machines of the 20$^{\text{th}}$ century.

All of the early push-button voting machines had buttons that locked down until the voter left the voting booth, at which point the votes were recorded. Once a button was pushed, there was no opportunity to undo that action, In contrast, with paper ballots, including punched cards, a voter who had made a mistake could request a replacement ballot.

With John McTammany's mature voting machine, the voter selected candidates by rotating knobs. These knobs could be set and reset with no consequence. On this machine, closing the vote lever over the face of the machine constituted the commit operation that irreversibly punched the vote record[41].

All of Alfred Gillespie's machines had levers on the face of the machine that the voter turned to indicate votes. As with McTammany's machine, these levers could be freely set and reset, so long as the interlocking constraints of the election were obeyed. Only when the voter opened the curtain to exit the voting booth was the final setting on the levers recorded as a vote[23].

VIII. Requirements become Law

Voting machines could not be used without legal authorization. Jacob Myers knew this, and as soon as he received his first patents, he circulated a petition asking for legislation permitting trial use of his machine[13]. The state responded on March 15, 1892, with "an act to secure independence of voters at town meetings, secrecy of the ballot, and provide for the use of Myers' automatic ballot cabinet"[7]. The requirements set by this legislation described existing features of Myers' machine without any hint that the legislature had thought through any requirements of their own.

Sylvanus Davis followed Myer's lead, and on April 21, 1896, New York responded with "an act to enable the towns and cities of this state to use the Davis automatic ballot machines in all elections therein." A similar act governing Myers machine was enacted on May 11, and the next year, yet another machine was approved[8]. These acts still addressed individual machines, but they began to outline requirements. A matrix organization was mandated, with parties on one axis and contests on another. Most of the text of these acts, however, focused on the administration of the machines, not their characteristics.

In 1897, New York created board of commissioners charged with examining voting machines and certifying whether those machines "can be safely used by the voters ... within this state, and whether in their opinion the legislature ought to legalize the adoption thereof"[8]. The act did not set standards, but it did make the voting machine lobbyists approach a board of specialists who, presumably, would understand New York's elections and enforce appropriate standards.

California, in contrast, made a serious effort to understand the competing machines before authorizing use of any of them. A special commission was assembled in 1897 to study the issue, and in 1898, they issued a report that is the first major survey of the voting machine industry[9].

Eventually, most state voting machine laws copied that of New York. The author of the 1911 *Encyclopedia Brittanica* article on voting machines, an employee of the U.S. Voting Machine Company, summarized the common requirements: "The laws require in general that the machine shall give the voter all the facilities for expressing his choice which the Australian ballot gives him, and furthermore, require that the machine shall prevent those mistakes or frauds, which if made on an Australian ballot would invalidate it"[36]. While this may sound reasonable, it is noteworthy that the article does not address any of the requirements others had recognized that were not met by the dominant vendors, notably requirements for recountability and transparency. The article on voting machines in *Appletons' Cyclopedia*[31] also gave a concise requirements summary, but again, the author was a voting machine salesman and only listed requirements his machines met[15].

In 1934, Joseph Harris summarized the legal requirements for voting machines in the United States as follows: "The machines must permit the elector to vote for all candidates and in all referendum questions on which he is entitled to vote, ... It must secure secrecy of the ballot, permit the voter to vote for any person, regardless of whether the name of the person is printed on the ballot; prevent the voter from voting for more candidates for any office than he is entitled to vote; and must provide locks and counters to prevent tampering and fraudulent voting"[29].

Harris was not impressed by the state of regulation of voting machines. He noted that the "laws authorizing the use of voting machines are practically identical in the several states, due, no doubt, to the fact that they were enacted at the instigation of the manufacturers." He would have been more accurate if he said that most of the states took their lead from New York, where the law was, in significant part, crafted by the manufacturers.

IX. Conclusion

It is clear that, from the very first proposal for voting machines, voting system developers have been at the heart of political reform groups pressuring the government to change election laws. This remains true today, and for 150 years, it has been a continuing source of tension.

Developers have been leaders in demands for ballot secrecy, transparency, auditability and similar requirements. These requirements have been most visible to those who see flaws in the established system of elections. Furthermore, many aspects of these requirements are highly technical, and they can be difficult to explain to legislators and administrators.

Some requirements, on the other hand, are clearly the product of the political system. Consider, for example, the combination of multiple races on one ballot, the permissibility of write-in votes, and the election of multi-seat offices. Developers working where these options are part of the political tradition tend to take them for granted, while those working elsewhere tend to be surprised when they encounter them.

In many cases, government and the public have accepted voting technology that did not meet all of the requirements. For example, cross-endorsement for multi-seat offices existed in New York before any machines could enforce the constraints that apply to such elections. Despite this, voting machines were accepted, with voters exhorted not to vote twice for the same person, and election workers required to sum the accumulators for each cross-endorsed candidate. Once mechanisms were developed to enforce appropriate rules for such situations, however, their use became mandatory.

The involvement lobbyists for voting machine manufacturers played a very important role in the early development of voting machine requirements. The risk of allowing vendors to write the specifications for their own machinery is obvious: Regulatory capture. In the United States, the risk of regulatory capture was compounded by the fact that, within a decade of the emergence of practical voting machines, the U.S. Standard Voting Machine Company emerged as an effective monopoly. Nonetheless, it is not obvious that anyone outside the voting machine vendors of the late 19th century understood enough about the technology to write effective specifications.

We have followed many of the same paths during the early years of electronic voting in the late 20th century. Vendors are still deeply involved in the requirements process, and as a result, the threat of regulatory capture remains as strong as ever. The one important difference is that a single monopoly vendor has not emerged.

The central challenge in the 21st century remains much as it was in the 19th. Those who understand that some requirements are not met by our current voting systems frequently do two things. First, they work as political activists, urging that we accept these requirements. Second, they work as inventors, developing machinery that meets them. The Chartists did this in the 1830's, and we are still doing it today. Once the requirements are accepted and solutions enter production, the inventors are at risk of abandoning their roles as activists and becoming lobbyists working to entrench their products. The last decade of the 19th century clearly illustrates this shift in the U.S. voting machine industry. Our challenge is to encourage inventor-activists while discouraging entrenchment and to recognize when the focus shifts from innovation to protection.

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