

Worcester Polytechnic Institute Digital WPI

Interactive Qualifying Projects (All Years)

Interactive Qualifying Projects

April 2013

Investigation of Voting Systems for the WPI Faculty

Dolan Patrick Murvihill
Worcester Polytechnic Institute

Doran R. Smestad
Worcester Polytechnic Institute

Louis Adrian Fogel
Worcester Polytechnic Institute

Matthew R. Heon
Worcester Polytechnic Institute

Follow this and additional works at: <https://digitalcommons.wpi.edu/iqp-all>

Repository Citation

Murvihill, D. P., Smestad, D. R., Fogel, L. A., & Heon, M. R. (2013). *Investigation of Voting Systems for the WPI Faculty*. Retrieved from <https://digitalcommons.wpi.edu/iqp-all/1262>

This Unrestricted is brought to you for free and open access by the Interactive Qualifying Projects at Digital WPI. It has been accepted for inclusion in Interactive Qualifying Projects (All Years) by an authorized administrator of Digital WPI. For more information, please contact digitalwpi@wpi.edu.

Investigation of Voting Systems for the WPI Faculty

An Interactive Qualifying Project submitted to the faculty of
Worcester Polytechnic Institute
in partial fulfillment of the requirements for the Degree of Bachelor of Science

Submitted By:

Lou Fogel

Matthew Heon

Dolan Murvihill

Doran Smestad

Submitted To:

Professor Kathryn Fisler, Project Advisor

April 30, 2013

Abstract

The Committee on Governance tasked the team with examining options for moving the election process for faculty committees to a web-based, electronic system to simplify the counting process. We identified issues important to voting in small community elections, paying special attention to WPI's specific requirements. Using that knowledge, we created a set of criteria for evaluating a proposed system's suitability for WPI faculty elections. Using the results of these evaluations we provide concrete steps to improve faculty elections.

Acknowledgements

We would like to thank our advisor, Professor Kathryn Fisler, for her patience and continued dedication to our project. Additional thanks go to the Committee on Governance for their interest in our findings and insightful feedback on our evaluation criteria. Penny Rock provided invaluable information on the current system for elections from her unique perspective as the Faculty Governance Coordinator. Professor Kinicki's expertise both as a computer scientist and former secretary of the faculty was critical to developing our final recommendation. Professor Matthew Ward and Professor David Brown provided us with an abundance of helpful information on interface design. Finally, we would like to thank all members of the WPI faculty who responded to our survey, especially those who followed up with an interview. Without the guidance, insight, and support from all of these people this project would not have been possible.

Table of Contents

Abstract	2
Acknowledgements	3
Executive Summary	7
1. Introduction	11
2. Literature Review	16
2.1. Security Issues and Solutions	18
2.2. Privacy	18
2.3. Authenticity	20
2.4 Integrity	22
2.4.1. Auditing in Voting.....	24
2.4.1.1. Individual Verifiability	24
2.4.1.2. Universal Verifiability	25
2.5. Current and Former Systems	26
2.5.1. Helios	26
2.5.2. SERVE.....	27
2.6. Voter Trust	29
2.6.1. Establishing Trust.....	31
2.7. Voting System Usability	32
2.7.1. Effective Voting Systems	33
2.7.2. Effective Ballot Design	34
2.7.3. Voter Satisfaction.....	35
2.7.4. Usability and Security	36
3. Methodology	38
3.1. Introduction to Methodology	38
3.2. Survey	39
3.3. Presentation to Committee on Governance	40
3.4. Interviews	41
3.4.1. Survey Follow-up.....	41
3.4.2. Previous Attempt Interview.....	42
3.4.3. IT Professional Interview	42
3.4.4. Existing System Expert Interview	42
3.5. Evaluation Criteria	43
3.6. Evaluating Systems	44

4. Data and Analysis.....	45
4.1. Introduction to Data and Analysis.....	45
4.2. Survey.....	45
4.2.1. Analysis of Survey Results.....	47
4.2.2. Survey Utility.....	48
4.3. Meeting with Committee on Governance.....	49
4.4. Interviews.....	50
4.4.1. Interviews with Survey Respondents.....	50
4.4.2. Interview with WPI Information Security Officer.....	52
4.4.3. Interview with Former Secretary of the Faculty.....	52
4.4.4. Interview with the Faculty Governance Coordinator.....	53
5. Evaluation Criteria.....	55
5.1. Final Evaluation Criteria.....	55
5.1.1. Security Criteria.....	55
5.1.2. Trust Criteria.....	56
5.1.3. Usability Criteria.....	56
5.1.4. Institutional Requirements Criteria.....	57
5.2. Reasoning behind the Criteria.....	58
5.3. Evaluation of Systems.....	60
5.3.1. Current System.....	60
5.3.2. Helios.....	60
5.3.3. Scantegrity.....	61
5.3.4. EBallot.....	62
5.3.5. SurveyMonkey.....	62
5.3.6. Presently Deployed Systems.....	63
5.4. Recommendations.....	64
6. Usability Study.....	68
6.1 Creation of Interface Prototypes.....	68
6.2 Consultation with Usability Experts.....	70
6.3 Testing with Community Members.....	70
6.4. Initial Ballot Design.....	71
6.5. Refinements.....	74
6.6. Usability Study Results.....	79
7. Conclusion.....	85
7.1. Development Considerations.....	85
7.2. Contingencies.....	90
7.3. Notes for Future Implementers.....	91

7.4. Final Remarks.....	93
Works Cited	94
Appendix A. Survey of Faculty.....	96
Appendix B. Faculty Interview Questions	100
Appendix C-0. Scorecard for System Evaluation	102
Appendix C-1. Current System Evaluation	105
Appendix C-2. Helios Evaluation	111
Appendix C-3. Scantegrity Evaluation	117
Appendix C-4. EBallot Evaluation	123
Appendix C-5. SurveyMonkey Evaluation	129

Executive Summary

Faculty elections at WPI are currently conducted with paper ballots that are sent through intra-campus mail and painstakingly hand counted. This creates a significant amount of paper waste and takes election officials hours or even days to count. The use of intra-campus mail makes it difficult (and sometimes impossible) for faculty members who are off campus to cast a ballot. Even when off-campus faculty can vote, the privacy of their vote is compromised because they must send their ballot via e-mail to the Faculty Governance Coordinator. Finally, because the ranked voting system used by the faculty is complex, several ballots are found to be invalid and thrown out in each election. Because of these issues, faculty government previously attempted to replace the paper system with an electronic one; that attempt failed because faculty were concerned about the security and maintainability of such a system. This paper explores the implications of moving faculty elections to an electronic system and provides the faculty with a recommendation for a course of action to make lasting improvements to faculty elections.

Electronic elections offer a number of potential advantages over the system currently in use. The first is the potential for electronic vote counting, which would save hundreds of hours for election officials by automating the complex vote tabulating system described in the faculty handbook. Additionally, an Internet-based voting system would allow faculty members to vote conveniently and privately from anywhere with an Internet connection. Finally, an interactive ballot interface could reduce the number of invalid ballots by warning voters when they have not completed their ballot correctly. These

improvements, alongside many other features only possible with a redesign of the voting system, provide compelling reasons for the faculty to change the way elections are conducted.

With that being said, electronic elections are not without their challenges. The real and perceived threat of attacks on the elections is increased in an electronic system. A properly secure election system should be able to provide its voters with assurances as to their privacy, the integrity of election results, and the eligibility of all participants. Keeping the votes of faculty members private is especially critical because of the social implications of voter identities being disclosed. Ensuring that all votes are cast by eligible voters and that their votes are accurately reflected in the results is also important however, because otherwise the election is not necessarily a true representation of the opinions of voters. Solving these problems is not only necessary for creating a good voting system, but also for building trust in a system that is likely to face challenges from faculty members skeptical of its trustworthiness.

To determine the best course of action for WPI it was necessary to review the literature on election design, obtain feedback directly from faculty, and contact experts on information security. The literature on electronic elections explores the major fields of security, usability, and trust. The team augmented this with a survey and a series of interviews, focused on determining how this knowledge applied to WPI's specific context and whether any issues were not addressed at first. The survey revealed a large discrepancy between the number of voters who believe faculty elections are important (92%) and the number who actually vote in those elections (84%). The team hypothesized that part of the

reason for this discrepancy may be the 40% of respondents who reported they had not voted in at least one election because it was inconvenient. The survey also indicated strong support for changing the voting system; 84% of faculty supported this change. Additionally, the team performed a usability experiment which had promising results for the voting interfaces the team designed.

The team used all information gathered to develop and refine a set of evaluation criteria for voting systems. The purpose of these criteria was to represent a set of requirements for a faculty voting system for WPI. These requirements could be used to evaluate a system to determine its suitability for use at WPI, or to aid in the development of a new system. These criteria were divided into four parts, each representing an important set of requirements for a voting system: Security, Trust, Usability, and Institutional Requirements (representing the unique needs of WPI that do not fall under another category). The criteria were also ranked in terms of relative importance to a voting system at WPI, from required criteria (mandatory for a system to be successful) to advantageous criteria (things that would be nice to have in a system, but are not particularly important to its success). The criteria themselves are available in Chapter 5 of this paper.

Once the evaluation criteria were completed, the team used them to evaluate the current system and several existing solutions to determine their suitability for use at WPI. None of these systems satisfied the evaluation criteria to a degree that recommended their adoption, however. WPI uses a unique vote-counting algorithm (based on a common system known as Instant Runoff), which is not supported by any existing system, which means that no voting system could be adopted without modifications of some degree. The systems that

were most promising for use at WPI were also the ones that would require the most modification to use.

Based on these findings, the team recommends that WPI implement a new web-based voting system. The development could be done by an MQP team or the Computing and Communications Center (CCC). Such a system could be built using the requirements laid out in the team's evaluation criteria, which would yield a system with a high likelihood of success. Such a system would have to be built with an emphasis on maintainability and excellent documentation, so that it can be used for years to come, even after its designers leave the institution.

1. Introduction

The Committee on Governance (COG) of the WPI faculty has asked an Interactive Qualifying Project team to examine the possibility of building an electronic voting system for use in the faculty committee elections. The team worked for fourteen weeks to study the options and develop a recommendation for how to proceed. This paper documents the process and the results of that study, and presents the team's findings to the COG, along with recommendations for how to move forward.

The Faculty is responsible for advising policy on degree requirements, courses, and recommending students for graduation. The Faculty also advises decisions on the university policy and budgets through the Committee on Administrative and Financial Policy (FAP), and has a major role in appointing, promoting, and recommending tenure for faculty members through the Committee on Tenure and Academic Freedom (CTAF). The Faculty's powerful role in academics, admissions, finance, instructor appointment, and student life makes its elections very important to the entire WPI community.

For the details of its business, the faculty relies on eight standing committees; in some cases, as in making recommendations for granting tenure, the standing committees are able to act on their own. Other times, the committees can only make recommendations to the general faculty. The Committee on Governance (COG) also has the power to create ad-hoc committees as necessary. The president and the provost of the university are granted *ex officio* membership in certain committees and may appoint representatives to others, but the faculty at large elects the remaining members.

Currently, faculty members vote on paper ballots submitted through the WPI intra-campus mail system. The election is a two-step process with a nominating ballot followed by an electing ballot. The faculty members receive in their mailboxes an anonymous green envelope with a nominating ballot. The ballot contains a list of faculty members and the committees they are eligible to sit on. Voters nominate candidates for each committee by circling the name of the candidate and sending the ballot in its green envelope to the faculty governance coordinator. Voters then receive another ballot (the electing ballot) used for the final election of committees. For each committee, faculty members rank their preferred candidates by writing numbers next to their names on the ballot. They then send the electing ballot back in the green envelope to the faculty governance coordinator. Off-campus faculty members must send in their nominating and electing ballots by e-mail.

Once received, nominating ballots are tabulated in the faculty governance office by the faculty governance coordinator and COG. From the tabulated results, the coordinator determines the nominees differently for each committee; Faculty Bylaw One, as described in the Faculty Handbook, defines these procedures. When determining the winner on an electing ballot, the coordinator sorts all of the ballots by their first preference; if a nominee has a majority of first-ranked votes, that person wins a seat. Otherwise, the nominee with the fewest first-ranked votes is eliminated. Either way, the ballots for the candidate that has been removed from the pool (by election or elimination) are redistributed according to the next-ranked vote. The process is repeated until all seats are filled. This system is based on a common voting algorithm called instant run-off, but has some differences and is unique to WPI.

The Committee on Governance has commissioned a study on the possibility of moving to electronic voting because it believes electronic voting could repair some problems inherent to voting on paper ballots. First, counting ballots is an extremely cumbersome process that takes far too long; the faculty governance coordinator and COG have to tally votes for days to find a result. Second, the current vote-by-mail system provides no way to authenticate a voter at the time the ballot is cast; as a result, people who are unenfranchised but manage to obtain a ballot can vote, and some legitimate voters can easily vote more than once. Third, off-campus faculty members may not cast an anonymous ballot, which compromises their privacy. Finally, there is no way to fix incorrect ballots; voters who fill out their ballot incorrectly simply have their vote thrown away. Since there is no way to determine whom the ballot belongs to, there is no way to notify the voter that their vote was not counted. Without this feedback, people might inadvertently develop a habit of submitting incorrect ballots - those voters are unwittingly disenfranchised.

The goal of the project was to initiate lasting improvement in the way voting is conducted; the team identified three objectives it must meet in order to initiate an improvement. First, the team must propose high-level requirements for voting systems that address most if not all of the problems inherent to the current system without introducing any significant new problems. Any solutions will most likely be electronic to facilitate easy counting while still making voting accessible. Second, the team must be aware of the many problems inherent to Internet voting and make sure the system manages them effectively. Finally, the team must develop a compelling argument for moving to the new system; this argument must provide details of how the system works in order to build trust with the

faculty. These requirements served to guide the team in its exploration of options for faculty elections.

The team began its exploration by gathering information on electronic voting in general and about the needs of the WPI faculty in particular. The team took a three-pronged approach: gathering expert information on electronic voting by reading existing security, usability, and political science research in the field; gathering information about the wants and concerns of the WPI faculty by sending out a poll and interviewing voters and election officials; and gathering information about the particular institutional and technical requirements at WPI by interviewing IT staff members and the COG. The team used this information to determine the requirements of the system, which they distilled into a set of *evaluation criteria*. The evaluation criteria are features the team feels are crucial to any voting application on campus, as well as other features that make a voting system more attractive. They serve as a framework for the team to evaluate existing systems, as well as a roadmap for anyone designing a new system from scratch. The evaluation criteria come with a *scorecard* that provides an at-a-glance view of how suitable a system is and how it compares to other systems.

The team identified several electronic and paper voting systems that exist today; using the scorecard the team judged how well each system fit the evaluation criteria. The team created a set of trade-offs to recommend the best system it can for the WPI community. The team also evaluated the current system to see whether the most beneficial option would be to make no change. Finally, the team conducted an experiment in voting system usability to develop recommendations for a suitable user interface for a new voting

system. Using information collected through research, interviews, and experiments, the team developed a recommendation for the system most suitable for WPI. This recommendation explains the reasons that system was selected over the others, highlighting the advantages and disadvantages of the system, and providing a plan for implementation moving forward.

2. Literature Review

Identifying key nuances in the design of electronic voting systems is critical to selecting a course of action for WPI. Increasingly, researchers now believe that moving to electronic elections is a good idea: potential benefits include savings in both time and money, along with increases in voter turnout due to increased convenience (Volkamer et al. 2011, 1). However, electronic elections are often viewed as too problematic for practical consideration (Adida et. al. 2009, 2). To get the full picture, the team set out to identify specific advantages and disadvantages in electronic elections by studying existing work on the topic. Identifying prior research into electronic elections, especially in the specific context of university elections, is very important to support any recommendation made to the Committee on Governance, or the Faculty as a whole.

Researchers have discovered a number of problems, which, while not insurmountable, do present challenges in the design of any electronic voting system. As one researcher put it, “[O]ne cannot simply install a piece of software and expect an election to run smoothly” (Adida et al. 2009, 13). Using a public network such as the Internet or a broadcast-based protocol such as WiFi increases the threat that communications may be intercepted and personally identifiable addresses may be stored. Designers of an electronic voting system must construct a system secure against these threats and others. The challenges aren’t just security related, however. Successful new election systems need the support of the voters, which means election designers must be able to build trust in a system that voters may have never seen before. Many users are also not technologically

inclined, and a voting system with a complicated or difficult user interface could be a huge step back from paper and pencil in terms of participation and user experience; conversely, the presence of computers provides exciting opportunities to make ballots less confusing and more informative. Electronic elections raise three serious issues that are nontrivial to solve and deeply intertwined: security, trust, and usability. The team's main objective when performing research was to identify technical features and policy details that maximize an electronic voting system's performance in each of these three areas. The research helped the team develop deep knowledge about these issues and laid the groundwork for the design of the evaluation criteria.

Most of the literature on electronic elections revolves around national-scale elections, while much less discusses small-scale elections like those of a faculty. A number of issues in national elections become significantly less important in small elections; conversely, some things that are unimportant in large-scale elections become paramount in a university setting. By being aware of these similarities and differences, the team was able to derive useful information from the literature while avoiding false comparisons. In spite of their differences, the WPI faculty elections and large-scale elections share much in common. The same issues exist in both: voters still care about vote-privacy, the system must be secure against election fraud, etc. The differences between small and large elections are, for the most part, in the relative importance of these issues.

In small elections, voters will typically know almost every other voter, which makes vote privacy far more important. Furthermore, due to the small number of people voting, it is often possible to swing the results of a small election with only a few ballots. Experts on

small elections agree "Loss of anonymity, bribery, and coercion are more serious issues in small-scale voting than in large-scale voting" (Endo et al, 1287). In small elections (particularly the WPI faculty elections), the results of the election typically have more direct impacts on the daily lives of the voters. By identifying ways in which different types of elections are analogous, the team was able to put the research in context and gain a much better understanding of the dynamics of security, trust, and usability in small-scale elections.

2.1. Security Issues and Solutions

Security researchers typically identify three properties that comprise security: privacy, integrity, and authenticity. The foundation for the team's approach to evaluating voting system security was identifying strengths and weaknesses with respect to these properties. In this case, privacy means no person can gain information about how another person cast his or her vote. Integrity means all votes cast are recorded and counted correctly, and the election result is based solely on the votes that were cast. Authenticity means all eligible people are given an opportunity to vote, only eligible people vote, and no person votes more times than he or she is allowed. To ensure legitimate results, each election must meet baseline requirements in each of the three categories. The team's major challenge while gathering information on security was identifying the baselines.

2.2. Privacy

Ensuring the secrecy of the ballot is perhaps the most important concern for election designers in small-scale elections. In WPI's case, maintaining voter privacy is

arguably even more important than ensuring a fair election because while privacy breaches might seem unlikely in WPI faculty elections, the implications are too severe to ignore. Most voters know one another, and election outcomes more directly affect them. Even if privacy failures do not cause problems with the legitimacy of the election, a breach could damage interpersonal relationships and severely affect the WPI community.

There are three places an attacker could violate the privacy of an election: at the server hosting the voting, at the devices participating in voting, and at the connection between. Any election security system must provide secrecy at all three locations (Jefferson 2004). Vote-privacy, the ability of a voting system to prevent a voter's ballot from being linked with their identity, is a critical feature of electronic voting systems, particularly for small elections. In fact, researchers recommend small elections guarantee coercion resistance, a property that prevents a voter under duress from cooperating with a coercer to prove he voted in a certain way (Adida et. al. 2009, 13). Elections are of limited meaning without assurances that malicious parties cannot influence the results, and thus preventing coercion of voters is important to democratic elections. In small elections voter intimidation, coercion, and bribery are much more likely to influence the result of an election (Endo et. al 2008, 1287).

Research shows that there are ways of mitigating the risk of disclosing the identity of voters in electronic systems. Luckily, cryptographic methods have been developed to prevent a voter's vote from ever being determined for certain. End-to-end encryption on the connection between the voter and vote-counter will prevent attackers from directly intercepting ballots to connect them to voters. This can be easily accomplished with

SSL/TLS, the protocol used for secure connections on the web (along with other internet applications). Researchers have developed systems that have been mathematically proven to prevent voter-coercion (Juels et. al. 2005, 4). These systems involve the use of “anonymous credentials” which cannot be directly linked to the identity of the voter. This scheme allows authenticity without compromising secrecy. The idea of separating voter-identifying information from the ballot is critical to ensuring vote-privacy. A simpler way of doing this is storing voter identifiable information in the database unencrypted, but separately from ballots; this ensures privacy except against an extremely determined and technically competent attacker. Such methods could help alleviate the previously mentioned issue of voter coercion in small elections, like those that are conducted at WPI.

2.3. Authenticity

Although the current system for faculty elections does not provide a method for authenticating voters at time of ballot completion, any proposed system would need to. In voting systems it is necessary to go beyond simply asking voters for identifying information because there is a possibility of voters lying about their identity. Authentication is the process of verifying a user’s (or in this case a voter’s) identity. Electronic voting systems should have some sort of authentication mechanism to prevent those who would defraud the election from voting for other people. Because only certain users are allowed to vote, and voters are only allowed a single vote, it is also necessary to make a determination of authorization to vote. This determination can only be made by obtaining a good level of certainty of the identity of the voter, which again requires voters to authenticate (Sandler 2009, 6).

The current system's lack of authentication on the ballot itself (though the ballots are only sent to authenticated voters) seems to be the result of an attempt at so-called "anonymity by obscurity" but the privacy of voters in an electronic system would not necessarily be compromised with the addition of an authentication system, should the methods described in the previous section on Privacy be observed. Failing to authenticate users in faculty elections makes it impossible to determine their eligibility to vote, and could allow people to vote multiple times. Additionally, it may not stop unenfranchised parties from voting. In the current system, a malicious party would need to forge a ballot and specially printed envelope to cast a ballot; in an electronic system without authentication they would simply need to click the submit button (presuming they had the URL for a ballot, which could be gained from a voting faculty member's computer or email). Luckily, this problem can be easily solved in ways that actually provide more security than the current system.

Authenticating voters can be accomplished easily in an electronic system, perhaps even employing systems already in place at WPI. The researchers responsible for Helios, a voting software system, recommend using an institution's central authentication system (Adida et al 2009, 4). The requirement for users to log into an authentication system to vote (for example, using their standard WPI username and password) provides a simple method of ensuring the identity of voters and preventing them from voting when they should not be allowed to. Additional measures could also be put in place to provide further security. In an election conducted with Helios, all eligible voters had a password unique to the election generated and emailed to them upon registration as an additional security measure (Adida

et. al. 2009, 4). Other identity verification measures could include entering one's ID number or birthday. If the system failed to authenticate voters it would be susceptible to manipulation by malicious users casting multiple votes or by unenfranchised parties casting illegal votes. This could even happen if a voter accidentally voted improperly. Regardless of the intention of the illegal voter, failing to prevent these votes would undermine the legitimacy of the electoral process. Authenticating voters with unique identifying information would solve this problem with few, if any, disadvantages.

2.4 Integrity

Provably ensuring the integrity of election results is critical to the success of an election system because without assurances that malicious users cannot change the results, the election is meaningless. Electronic voting systems add additional risks for voter manipulation over and above that of conventional systems, including the potential for a ballot to be modified without the voter noticing or realizing. In a poorly designed system it is possible for an attacker to compromise the integrity of a ballot in three separate places. The first is before the voter actually submits it; this would occur if there were a virus or other malicious program on the user's computer that changed their vote or if a person left the ballot open and their computer unattended (Krimmer 2008, 226). The vote could also be changed while the ballot is in transit from the voter's computer to the server where the votes will be counted. This is mostly remedied by client-server encryption commonly used in e-commerce applications. The last way an electronic ballot can be manipulated is in the database on the server before the final count has been made. WPI requires the ballots from a particular election to be stored for long periods of time (several years, at least) in case the

results of the election are disputed or other circumstances requiring their examination arise. For this reason it is important to keep the database safe by establishing rules and procedures for the handling of election data. It would be unfortunate if a WPI election system fell victim to the same issue that plagued a British electronic election system, where an administrator distributed his (all-access) username and password to all election officials, leaving their databases to be easily modified by system administrators after the election, eliminating the chance for any auditing of access to stored votes (Xenakis 2004). A system designed with these issues in mind should be capable of mitigating them.

Security measures can be employed to prevent malicious users from altering results of the election. This problem best solved in web-based systems with the same methods used to secure any web system: SSL/TLS (Secure Sockets Layer/Transport Layer Security, a common method for encrypting web traffic), and basic server security. SSL/TLS encryption will ensure that if a ballot is modified on the way to the server it will be invalidated. The problem of malware on the user's computer is a bit more difficult to defeat. In fact, most large e-voting systems (such as the US Government's SERVE experiment) that have been attempted have failed in a large part because it is nearly impossible to secure a user's local PC to ensure the integrity of their ballot (Jefferson 2004, 14). One proposed solution to this problem is so-called "code voting". Code voting schemes utilize up to three separate codes (alphanumeric values derived from a cryptographically secure pseudorandom number generator). The codes are delivered to the voter separately from the ballot, so that an attacker would need to intercept both to compromise the election. These codes are then used to place a vote, verify that it has been counted, and confirm that the ballot was

received (one code per task). The major disadvantage of code voting is that it makes voting more difficult because the codes are not obviously connected to their corresponding actions. When code voting is used specifically to prevent attacks through malicious programs on a voter's computer, the codes can be delivered through captchas, which most Internet users are familiar with (Oppliger et al 2008, 224). Code voting, as well as cryptographically secured connections should be considered for inclusion in electronic voting systems, as they promote integrity.

2.4.1. Auditing in Voting

Even when the designers of an election system are careful to prevent security breaches that could compromise integrity, it is important that the system is able to demonstrate its integrity with each election (Sandler 2009, 12). In most cases, auditing election results can assure the integrity and trustworthiness of elections. Auditing is the process of verifying the integrity of election results after the election has been conducted. Depending on the method, auditing can be done by election officials, by voters, or by the general public. Auditors can verify that ballots were collected, handled, and counted correctly, or that only authorized voters actually cast ballots, or a combination of those properties. When used effectively, auditing can guarantee the integrity and authenticity as well as increasing users' trust in the election system (Adida 2008, 345).

2.4.1.1. Individual Verifiability

It is beneficial for a system to be able not just to count a user's vote correctly, but to prove that property to the voter. This builds trust in the system and provides a mechanism to detect fraud. A property called "individual verifiability" encompasses the verification of

individual votes by the voters who cast them. Individual verifiability is a powerful tool for gaining voter trust because it allows the user to obtain proof that their vote was interpreted correctly (provided they trust and understand the verification mechanism). Verification mechanisms help to alleviate the feeling that voters must place blind trust in the system (Adida 2008, 345). Individual verifiability can be very easy to implement, and can even be done without compromising the property of receipt freeness using cryptographic hash functions (although this makes it harder for users to understand). Such hashes provide the user with a receipt that uniquely identifies their vote, but cannot be easily used to identify whom they voted for (Adida 2008, 345). This would require the user to remember a hash (a seemingly random series of characters of significant length) which could be inputted into the system to verify their vote. Distributing these receipts via email would partially solve the issue of remembering them, but these emails could still be lost or deleted, at which point the voter would lose the ability to verify their ballot.

2.4.1.2. Universal Verifiability

Some users may not want to take the time or effort to verify their vote, which is why some voting systems go a step further and offer “Universal Verifiability,” a property that affords anyone the opportunity to verify the results of the entire election. Electronic elections present a unique opportunity to allow voters to build trust in elections by verifying the results themselves. Universal verifiability is the property of an election to be independently verified by a third party without that third party being granted any special access to ballots or election data. These elections, so-called “open-audit elections” are designed with mathematically proven cryptographic functions that an auditor can leverage

to verify that election results were recorded and counted correctly without compromising voter secrecy (Adida 2008, 335). Researchers have developed systems with this property for use in the real world, and they have even been tested within the context of university elections (Adida et al 2009, 1). The researchers responsible for such a test freely admit “Even voting experts who recognize that open-audit elections are ‘the way we’ll all vote in the future’ seem to envision a very distant future, not one we should consider for practical purposes yet”(Adida et al 2009, 1). However, because tested software already exists that includes these features, WPI could consider it for faculty elections because it comes at no cost and makes elections more verifiably correct.

2.5. Current and Former Systems

2.5.1. Helios

Helios is an open-source electronic voting system project freely available online, and is currently in its third major version. This system was developed as a platform to prototype open-audit voting and provides an example of a modern, cryptographically secure e-voting system. Helios, as a system, is mostly concerned with the integrity of elections (provided by the previously-mentioned open auditing capability). The architect and primary contributor to the system states that “Helios values integrity first, and voter privacy second” (Adida 2008, 338). To ensure the integrity of the vote, Helios publishes an encrypted record of every vote that is cast, which can be combined using the open algorithm Helios uses for counting to verify the election, all without knowing the contents of the encrypted votes. Every user is also presented with their encrypted ballot record upon submitting their vote, enabling them to verify that their vote was counted. These two

assurances (individual and universal verifiability) form the core of Helios' design paradigm (Adida 2008, 335). This provides assurance of an election free of fraud at the cost of additional complexity. Systems like Helios often assume that the candidates can hire or enlist a trusted person to verify election results, making the extra complexity justifiable.

Helios is an example of a successful Internet voting system. Its success stems, in part, from its proven security; the novel implementation of open-audit voting is a boon for organizers facing voters who may have reservations about the integrity of elections conducted online (Adida 2008, 335). Another critical aspect of Helios is its well-defined limited scope; the creators make no claims as to the coercion resistance properties of the election system (though they do attempt to mitigate coercion), an openness that allows election organizers to decide on the importance of that particular property (Adida et. al. 2009, 2). Finally, Helios has already been proven in the small-scale elections it was designed for without any serious issues arising (Adida et. al. 2009, 1). The system has already been used to conduct campus elections, for example at Belgium's Université Catholique de Louvain (Adida et. al. 2009, 1) and Princeton University.

2.5.2. SERVE

The United States Army looked into and rejected an Internet voting system in the years leading up to the 2004 election. The prototype system, developed under the name SERVE (Secure Electronic Registration and Voting Experiment), would enable soldiers serving overseas to vote just as easily and conveniently as if they were serving at home. SERVE was a web-based system that securely transferred votes to a central server, and again to individual districts for counting. It was designed as a web application primarily to

avoid dependence on voter hardware and software, although some browsers were not supported. The system was discarded for security reasons – a report on the viability of the system (or lack thereof) describes Internet voting systems as having “fundamental security problems” which cannot easily be remedied, as they are “fundamental in the architecture of the Internet and of the PC hardware and software that is ubiquitous today” (Jefferson 2004, 2).

A security review of the proposed SERVE system showed that it was nearly impossible to prevent vote fraud in such a system. The many potential vectors of attack on Internet voting systems are part of the problem; the PC that is being used to vote, the secure connection between servers and the user, and the servers themselves are all targets for attack. While existing security solutions are adequate for e-commerce and electronic purchasing, they are insufficient to adequately secure national elections. The security requirements are further complicated by the demands of a secret ballot – the anonymity of data collected by such a voting system makes it difficult to detect intrusion or fraud of votes. Finally, the existing local voting system is highly decentralized, ensuring that any attacker who wanted to significantly alter an election would have to compromise numerous different voting stations, whereas if a centralized internet voting system were compromised, the entire election's results could be easily altered (Jefferson 2004).

Many of the criticisms that struck down the SERVE project are not relevant to a small-scale voting system, like one that would be used at WPI. The security requirements of a national election with world-reaching consequences are understandably higher than those of a college faculty election. The concern that the breach of a single server could

compromise the entire election, for example, is dubious in small elections and exists in the current system. Still, the consideration that anonymity makes security and accountability difficult remains; voting systems are, by necessity, a study in compromise (Jefferson 2004).

2.6. Voter Trust

Building a secure system is obviously an important consideration when moving the faculty to e-voting, but security alone is hardly enough to ensure acceptance. A new voting system will need to be approved by voters before it can be implemented. The system will not be adopted, nor will it survive if the majority of people using it do not trust it. Electronic voting systems, unlike paper balloting systems, are more difficult for voters to understand. As a result, voters must place some trust in the organizers of the election and the technical experts designing the system unless they themselves are experts (Oostveen 2005, 305). As those involved in an ill-fated voting machine project can attest,

“Securing a system even to the maximum imaginable extent alone will hardly increase any trust among the public. ... We must not only ask ourselves how to make systems that are more secure. The focus should rather lie on the primary, superordinate question of how to establish trust itself and in particular trust that lasts” (Volkamer 2011, 2).

Failing to gain acceptance would cause obvious problems for adoption of an electronic voting system, but that is not the only risk. If a new system failed to gain the trust of faculty it could cause voters to abstain or vote in a different way - “trust in the technology and fear for surveillance may influence the decision to vote and the vote itself.” (Oostveen 2005, 308) This type of influence has the potential not just to cast doubt on the merit of the electronic system, but the legitimacy of the election itself.

Election designers must be careful to create a system that is actually trustworthy, for voters can trust a system for the wrong reasons. For instance, it is possible to build trust among voters in a voting system with poor security; that strategy, besides being disingenuous and unethical, would fail in the long run. Systems that are already in place face less skepticism because they seem to already be “proven”, regardless of their actual merit. This so-called “trust based on unawareness” creates a dangerous situation where unrecognized vulnerabilities undermine the electoral process and voter confidence in the system. Security compromises can also erase confidence in administrators, which is even more disastrous than a loss of confidence in the system itself (Volkamer 2011, 1). Because electronic voting systems require more technical expertise to understand than their paper-based counterparts, getting users to trust e-voting will always require them to put some trust in the designers of the system (Oostveen 2005, 305). The increased technical barrier puts the onus on the designer to make the system both secure and understandable. Failing to provide these properties creates a dangerous potential for distrust.

Even systems that deserve to be trusted can suffer from distrust if the electorate does not understand them. In a study of multiple voting systems, each with a different perceived level of trust, it was found that the level of trust voters had in the system directly affected the results of an election (Oostveen 2005, 309). These findings indicate that designers of election systems must consider the perceived level of security seriously. When the only basis for trust is a lack of security issues in the past or vague claims by election organizers, even the most minor irregularities can significantly erode voter trust (Volkamer 2011, 1). Test elections can also greatly increase confidence in a system by allowing voters

to familiarize themselves with it in a relaxed setting (Adida 2009, 11). They can also identify any issues that might cause a loss of trust before an actual election, so that they may be remedied before they have actual negative effects.

2.6.1. Establishing Trust

The key to establishing lasting, well-founded trust in an election system is transparency (Volkamer 2011, 2). Lasting trust occurs when voters understand the security features and shortcomings of the system and have realistic expectations. Providing transparency leverages the actual security benefits of the system - with high transparency, a well-designed system is its own advocate. The other advantage of this approach is that the system does not receive undue trust from complacent voters; it must be good enough to withstand scrutiny even if it receives none.

Electronic elections hold the potential for many features that aren't possible with traditional voting systems; many of those features are designed to improve users' trust in the system. An example would be the verifiability properties discussed previously, which build trust by showing the user that the election is not being tampered with. Another is the ability to change one's vote after it has been cast, often referred to as "vote updating" in the literature, is a simple feature that can positively affect voter trust. Vote updating allows voters less sure of their technical ability to correct any mistakes they may make, which reduces apprehension around the actual act of casting an electronic ballot. Voters can even use the feature to cast an example ballot with someone showing them how the system works and then later re-cast a real ballot later in secret. It also makes voter intimidation more difficult (though not impossible), because it allows voters to change their votes after

showing a coercer they vote they are looking for. The use of vote updating for these purposes has been studied in real-world university elections to increase voter confidence in new electronic systems (Adida et. al. 2009, 9). In elections conducted at the Université Catholique de Louvain (UCL) in Louvain-la-Neuve, Belgian researchers found that the feature was used by less than 1% of voters but concluded that it's presence increased voter trust in the new system (Adida et. al. 2009, 12). The security and usability that vote updating provides is transparent to users which makes it an effective way of making voters more comfortable with an electronic voting system (Volkamer 2011, 2).

Finally, electronic voting opens up the potential for voting interfaces that could potentially be easier to use, which would increase trust. Security features are important to designing a trusted voting system, but they are not the only consideration. Researchers have found that voters may be less likely to vote if they do not trust their own technical abilities (Volkamer 2011, 1). Voters are unlikely to support or use a voting system that they can not figure out. Failing to capture a part of the electorate because users distrust the usability of the system is a catastrophic failure. It is therefore the duty of the designers of the system to ensure that voters are capable of voting correctly with minimal instruction.

2.7. Voting System Usability

A usable voting system is effective, efficient, and provides a satisfactory voting experience. The International Standards Organization (ISO) identifies these properties as the three metrics critical to assessing system usability (Everett 2006, 2547). The necessity of effectiveness, the ability of a system to correctly represent a voter's intent,

is obvious; elections are held to let voters make decisions and if a voting system can not accurately express the opinions of voters it has no purpose. A usable voting system also needs to be efficient in collecting votes; if the process cannot be performed quickly and without undue difficulty, the individual cost of voting will outweigh the benefits; this is referred to as “The Paradox of Voting”. If voters are not satisfied with the system, that is, if they do not believe it has effectively or efficiently recorded their vote then the system has also failed (Everett 2006, 2547). Because elections are pointless without voters, ensuring that the voters are able to use the voting system, and use it correctly, should be the first priority in designing any election system.

2.7.1. Effective Voting Systems

Effective voting systems succeed in determining and recording a voter’s vote as they intend it. While this task may seem trivial on the surface there are a number of ways it can go wrong, tainting the results of an election. Researchers have found that confusion on ballots can account for error rates up to 4.2% (Everett 2006, 884), a significant enough margin to alter the outcome of a close election. Undervoting, failing to record a vote at all on a particular ballot, is the first way that a ballot can fail to be effective. Overvoting, recording more votes than a valid ballot should allow, is another. Finally, and perhaps even more disastrously, ballots can record votes incorrectly (e.g. for the wrong candidate), not only failing to capture the intent of the voter but actually further damaging the election by contradicting the voter’s opinion (Everett 2008, 885). These problems have been observed in real world elections; the most infamous example is the 2000 US Presidential election where researchers believe that the notorious “butterfly ballots” (a particularly difficult to

understand ballot layout) in Florida caused enough voter confusion to alter the outcome of the election (Everett 2008, 883). Research has shown that bubble balloting appears to have the greatest usability by the most number of people (having an error rate of 1.5%) (Everett 2008, 884). Designing effective systems is critical to conducting meaningful elections.

Researchers have not found that electronic ballots have a significantly different error rates from paper-based voting methods, however so-called “post-completion errors”, which stem from voters not knowing they need to complete some final step (i.e. a submit button) to complete their voting, make electronic elections more susceptible to undervoting (Everett 2008, 891). Web-based voting systems can attempt to mitigate this problem by reminding voters that their ballot has not yet been submitted when they try to navigate away from the page. Inside of a voting booth however, this issue is much harder to mitigate. Voters who fail to submit their electronic ballots are termed “fleeing voters” because the voter simply walks away before finishing. Preventing bias inherent to the ballots is important in designing effective elections.

2.7.2. Effective Ballot Design

An important part of designing effective voting systems is mitigating effects that ballots can have on voters that bias the election results. Researchers have found that the order of names on a ballot causes a statistically significant bias in election results (Barker et al, 521). While it seems intuitive to think that more educated voters would be less likely to be susceptible to this so-called “alphabetic bias”, a study conducted at the University of Leiden disproved this hypothesis. Researchers conducting an election at the university found that regardless of the number of voters, number of candidates, voter turnout, or

number of parties or affiliations (Barker et al, 524). Researchers were additionally unable to find a correlation between the education levels of voters and the occurrence of alphabetic bias in voting. This conclusion stems from results indicating that the occurrence of alphabetic voting was statistically indistinguishable between student and faculty elections (Barker et al, 524). Alphabetic voting bias in the studied elections accounted for a difference in results of up to 7.6% (Barker et al, 525). Any new election system for WPI faculty should recognize that such a large bias could affect the outcome of an election and take steps to prevent it. Ideally a system for faculty elections would capture 100% of what voters intend. While that goal may not be practical, identifying the factors that decrease system effectiveness will help to minimize the error rates.

2.7.3. Voter Satisfaction

Voters must find a system satisfying in order for it to succeed; even if everyone manages to cast their vote quickly and correctly, if they feel confused or frustrated then the system has failed to be sufficiently usable. Failing to satisfy voters with their voting experience undermines the electoral process by discouraging people from voting (Everett 2008, 884). When voters feel that their time has been wasted they do not see enough of a benefit in voting to outweigh the costs; researchers call this phenomenon the “paradox of voting”. Researchers have shown that, in the specific context of university elections, the paradox of voting can affect the outcome of electoral contests (Niemi 1970, 99). When voters feel that the system has failed to convince them of its effectiveness, the perceived benefits of voting are negated. Voters do not believe their vote actually impacted the result of the election, as they have no confidence that their vote was accurately counted. This

mistrust also increases the effect of the paradox of voting on the result. Researchers have found that voter satisfaction is not always tied to the objective metrics of system usability. Studies show that electronic voting systems generally have higher levels of voter satisfaction than their paper-based counterparts (Everett 2008, 887). Neglecting voter satisfaction could have disastrous results and should be weighed alongside other considerations that may reduce it.

2.7.4. Usability and Security

Usability goals are often in conflict with other design considerations such as security. A system that is totally secure might be completely impossible for the typical voter to understand and as a result, it would be completely useless. On the other hand, a system that is incredibly easy to use but fails to prevent even simple attempts to manipulate it is equally meaningless as a decision-making mechanism because its results cannot be trusted to reflect the opinions of voters. Not all security is intrusive; SSL/TLS encryption and authentication is done entirely by the voter's web browser and will not interrupt the user unless there is a problem authenticating, which is likely a critical error with the voting server. Other security features, such as code voting, can be much more intimidating to users but may be made easier by replacing hard to remember codes with CAPTCHAs, images with distorted letters and numbers to test for humanity that are ubiquitous on the web (Oppliger 2008). It is important to recognize that security features which fail to take usability into account are often less secure in practice; for example, a very strict computer password policy may make users safer in theory, however it may also cause them to start storing their passwords insecurely, or to use simple, easy to predict patterns. While it might be easy to

separate usability and security in research, the distinction is not so clear in practical system design.

3. Methodology

3.1. Introduction to Methodology

The team began the project completely unaware of the technical and social issues involved in small-scale Internet voting. Literature review helped highlight the general issues, but the team still lacked information about WPI's particular requirements, technical infrastructure, and political climate. The team gathered information from many sources:

- The team sent the faculty an electronic survey to gather statistics regarding their general feeling about Internet voting.
- Team members presented their research findings and solicited input from the WPI Committee on Governance (COG).
- Team members interviewed specific faculty members to get a deeper view of faculty opinions and the reasoning behind them.
- The team interviewed several knowledgeable employees, including the Faculty Governance Coordinator and the WPI Information Security Officer, to gather expert knowledge about the institution.
- Team members designed mockups of potential user interfaces and performed a usability study to determine what recommendations could be made.

The team used all of the data collected to create an evaluation criteria document; the evaluation criteria define requirements (and their relative weights) for a system that can be used at WPI. The evaluation criteria are the ultimate product of the information-gathering phase - they are the gold standard that all proposed systems must meet.

3.2. Survey

Based on literature research, the team identified important issues which were deemed important enough to deserve opinions from WPI's faculty. As the primary stakeholders in the proposed new voting system, their input was invaluable for setting priorities and determining important features for a proposed system. A number of features identified by the team were listed as highly desirable for some voting systems, but of questionable utility in WPI's case. By obtaining faculty input, the team was able to determine the desirability of these features in the eyes of those who would use it. Additionally, the survey contained questions formulated to obtain more general faculty attitudes on electronic voting, and faculty voting in general. Through the survey, a picture of faculty attitudes on voting could be obtained. This could be used to gauge whether the project was supported or would face significant opposition from the faculty, and whether faculty elections in general were important to WPI's voting faculty. A final question invited faculty members with strong opinions to provide their e-mail in order to be interviewed about their views on the matter. The team promised respondents anonymity of survey responses - that is, it would be not be possible to determine how anyone who provided their email address answered the remaining questions.

The final version of the survey contained 14 questions (available in Appendix A), none of them forced response. No respondent was obligated to answer any specific question if they felt it was not important, did not know what was being asked, or did not want to spend the time to answer. The survey asked three questions to determine the background of survey respondents (their voting habits in faculty elections, and whether they felt such

elections were important), four questions on respondents' opinions on whether an electronic system could adequately replace the current system, six specific questions on electronic systems (desirable features and concerns about such a system), and a final question requesting potential candidates for follow-up interviews. Several questions at the end of the survey were text boxes paired with relatively open questions intended to allow faculty to notify the group if something important or concerning to them was not mentioned on the survey.

To deploy the survey, the team obtained approval from the WPI Institutional Review Board to e-mail a survey to the mailing list for voting faculty at WPI. The survey itself was constructed and hosted off of a local WPI server (cerebro.cs.wpi.edu) so that responses to potentially sensitive questions would not leave the campus, and a WPI login was required to vote. After obtaining IRB approval, the team had an administrator send an email informing faculty members of the survey on the team's behalf. The group initially targeted the break between terms for deployment of the survey, the day that final grades for C term were due, to ensure that most faculty would not be too busy to complete the survey. However, requesting distribution of the survey pushed survey deployment back to the first week of D term.

3.3. Presentation to Committee on Governance

After the survey provided valuable data, the team decided to make a presentation to the faculty Committee on Governance to gain the input of the people largely responsible for faculty elections. The goals of this meeting were to present early results of the survey and

literature review, to obtain input on important issues the team had identified (some of which were included in the survey, while others were discovered from survey responses), and present a draft of the evaluation criteria for voting systems to the committee. In particular, the team wanted to obtain input on vote updating, use of the WPI Central Authentication System (CAS) to authenticate voters, and next steps in gathering information. Based on these questions, and the Committee's input on the team's evaluation criteria for systems and literary review, the group adjusted the evaluation criteria to more accurately match the needs of WPI (exact changes are discussed in Chapter 5).

3.4. Interviews

3.4.1. Survey Follow-up

The team conducted a number of interviews with survey respondents who indicated a desire to further discuss electronic voting. The intent of these interviews was to obtain the views of those with strong opinions on either electronic voting or the voting process in general. The team hoped that interviewees from both sides of the issue, strongly in favor of e-voting and strongly opposed to it, would be available. Through these interviews the team could gain insight into any questions or concerns faculty might have as well as the benefits they perceived to come from e-voting. The team could thus verify that the survey did not miss any important concerns of the faculty, obtain a more detailed picture of faculty views on the benefits and shortcomings of the current voting system, and gain a better picture of faculty attitude towards a change in voting systems. An interview was conducted with each of the three faculty members who requested such a meeting on the survey.

3.4.2. Previous Attempt Interview

From the follow-up interviews, the team identified an additional person of interest who was interviewed for his involvement in the previous development of a similar system. Professor Robert Kinicki, during his time on the COG, led an effort to deploy an electronic system for voting in faculty elections. However, the faculty never adopted this system. The team decided to prioritize conducting an interview with him, as knowledge of why his previous system failed could be invaluable. Ideally the team could address the shortcomings of the previous system to prevent the failure of a proposed new system, or identify shortcomings that could not be addressed, which could result in the team recommending that the existing system be retained.

3.4.3. IT Professional Interview

Based on concerns expressed by Professor Kinicki in his interview, the team decided to interview a member of the WPI IT staff to determine what requirements, if any, they had for a voting system to be deployed at WPI. Phil Denault, WPI's information security officer, was identified as the person most likely to have relevant information and feedback, and an interview was scheduled. Questions were developed, both from the team's research and Professor Kinicki's interview. After the first interview, a follow-up interview was also conducted to review the team's proposed evaluation criteria and identify any deficiencies.

3.4.4. Existing System Expert Interview

A final interview was conducted with someone intimately familiar with the current voting system. Penny Rock, the secretary for faculty governance, is a key part of the present election process. The team learned of her role in current elections both from the Committee

on Governance and other interviews. This interview allowed a glimpse into the behind the scenes process of vote counting and distribution in the current system at WPI. Furthermore, by discussing the current system's advantages and flaws with one very knowledgeable, the team could gain a better understanding of the justifications for a new voting system and the areas in which improvement was desirable.

3.5. Evaluation Criteria

Through interviews and literature review, the team obtained an understanding of desirable characteristics for a voting system, with the goal of creating a set of accurate, detailed, and complete requirements that faculty governance must take into consideration when making a decision on what actions to take. The criteria provide a method for grading a voting system's suitability for use at WPI. They are almost as important, or perhaps just as important, as the final system proposal, as they represent a concrete set of requirements that can be used to identify or build voting systems suitable for use at WPI. The team's goal was to develop an understanding of the requirements of a faculty voting system, both in general and specific to WPI, and to apply this knowledge to concretely state these requirements and rank them by importance.

The evaluation criteria were initially developed from the team's review of literature, and evolved from new information obtained from interviews and the Committee on Governance. The original set of criteria from the research were mostly general matters of importance to all voting systems. The meeting with the Committee on Governance and survey allowed the evolution of a subset of requirements unique to a voting system at WPI,

to supplement the previous criteria. Interviews provided supplementary data to refine the previously created criteria and create more, where needed. The interview with Professor Kinicki, for example, provided several new evaluation criteria. The importance of the criteria, and the team's method of measuring it, also evolved as time went on. All criteria were graded as required (considered to be necessary for system success), strongly recommended (valuable features which could recommend a system over another which lacked them), and advantageous (nice to have features, but not more desirable than others). A scorecard, contained in Appendix F, was built from the evaluation criteria for at-a-glance evaluation of the suitability of a system. This scorecard was structured to permit easy evaluation of systems for suitability.

3.6. Evaluating Systems

Using the scorecard, the team evaluated a number of existing systems to determine their suitability for use at WPI. The team tested each system to the fullest extent it could. In some cases, the team could not do much, as it could not obtain demos or samples of several proprietary systems it evaluated. From testing and available literature about each system, the team determined whether each evaluation criterion was met by the system as-is, could be met with reasonable modifications to the system, or could not feasibly be met. Based on these evaluations, the team identified a course of action to move forward and made a proposal for the type of system WPI should implement.

4. Data and Analysis

4.1. Introduction to Data and Analysis

Finding and evaluating systems based on their suitability for the specific context of WPI faculty elections requires more than a review of literature; it was necessary for the team to conduct surveys, interviews, and usability studies to identify relevant problems, including institutional and human problems that a potential system might face. Using all of this information, in combination with lessons learned from the review of literature, the team developed a set of criteria to use in evaluating the viability of potential systems for WPI Faculty elections. Using these criteria the team evaluated a number of existing systems, including the system that is currently in use, to determine how well suited they are for faculty elections. These evaluation criteria were integral to the process of creating a recommendation, and should stand as a way of finding alternatives, should implementation of the team's final recommendation uncover unforeseen challenges.

4.2. Survey

The survey was emailed out to the faculty shortly after the beginning of WPI's 4th academic term of the year, near the beginning of March. Over the period of approximately two days the team received fifty responses. The respondents of the survey indicated strong support for moving faculty committee elections to an electronic system provided it was done correctly. As the team expected there were some concerns raised about the security of such a system. There also was negative feedback about moving non-election proceedings online, such as a vote to revoke tenure from a member of the faculty; such procedures was

not something the team had considered. Learning from this, the team was sure to clarify in later writings that recommendations would not include such proceedings.

Following the aggregation of data from the survey responses, the team noted the following results:

- **92%** of respondents indicated faculty elections matter to them.
- **84%** of respondents voted in most elections.
- **26%** of respondents believe an electronic voting system would be less likely to keep their vote private.
- **14%** of respondents believe an electronic voting system would be more susceptible to tampering.
- **82%** of respondents felt that electronic voting would make it more convenient to vote, allow off-campus private voting, and greatly reduce the time to count votes; and found these compelling reasons to switch.
- **84%** of respondents support a switch to an electronic voting system.
- The major concerns faculty members presented throughout the survey were concern about disclosure of the public record of who voted, and the potential ability of a voter to vote more than once.
- Some respondents, misunderstanding the team's intentions, indicated concerns about using an electronic voting system when motions are raised during faculty meetings.
- Two respondents noted concerns of losing ballot-notification emails an electronic voting system might send out among the multitude of incoming WPI email.

4.2.1. Analysis of Survey Results

In all, the survey respondents feel that switching faculty committee elections to an electronic voting system is a good idea. Because the survey itself is electronic, the true percentage of voting faculty in support is most likely lower than 84%, but the team still suspect that responses would not have been so positive if there were not a clear majority. There is the thought among a few survey respondents that electronic voting will increase the susceptibility of tampering (12%) and decrease the ability of the system to keep their vote private (26%). The team made note of this and will adequately address these issues in the final proposal. This aside, respondents indicated the belief that many of the concerns raised by the literature, and their own feedback, are equally likely to occur in either paper-based or electronically-based voting systems. If an electronic system is adopted however, respondents requested voting reminders still be sent out on paper to mitigate lost votes due to the oversight of an email. Faculty also indicated some interest in additional features an electronic system can offer, such as a publicly visible validation of a vote.

Survey results indicated that the current system may actually cause some faculty not to vote. 92% of the survey respondents indicated that elections are important to them, but only 84% actually vote consistently. The team believes that this interesting discrepancy is due to a failure of the voting system as 40% of respondents indicated they did not vote in an election because it was inconvenient. Furthermore, 82% of respondents indicated they believe having an electronic voting system will make the voting process more convenient, especially for voters not physically present on campus during elections. Based on those

results, the team strongly believes casting a ballot under the new system should take no more time than under the current system.

4.2.2. Survey Utility

The construction and deployment of the survey contained several mistakes that must be understood to evaluate its usefulness. The first of these was that the faculty member contacted to send mail to the voting faculty list misread the team's email and, instead, deployed the survey to the general faculty list. The survey permitted anyone with the link, including those not able to vote in faculty elections, to vote in the survey. It is thus difficult to determine whether the survey portrays an accurate picture of WPI's voting faculty, as a number of non-voting faculty members may also have responded. That said, the number of respondents who claimed to vote in faculty elections would seem to indicate that at most a few respondents were disenfranchised or unenfranchised faculty. Furthermore, as previously mentioned, the survey was conducted electronically, and notification of it was sent via e-mail. It is likely that any faculty who successfully completed such an electronic survey would also be comfortable with using an electronic voting system, due to the similarity of the two concepts. It is also possible that the survey was ignored by some who strongly oppose an electronic voting system as they also oppose the use of electronic surveys for privacy reasons and refused to answer. Thus, using an electronic survey to ask questions about electronic voting was less than ideal - if more time were available, a followup paper survey could be deployed at a faculty meeting to obtain additional data. In an attempt to mitigate this bias, the team's advisor announced at the next faculty meeting

that the team was looking for responses and faculty could send a response directly to the advisor instead of utilizing the web-based survey form.

4.3. Meeting with Committee on Governance

The team presented the first draft of the evaluation criteria to the Committee on Governance (COG) along with summaries of research and data that had been completed. The purpose of this meeting was to gauge the level of support that faculty governance had for the project and to ensure that the evaluation criteria were not missing anything that COG members thought was critical. The team found COG to be very supportive of the project and interested in seeing a new voting system in place soon. Members of the COG seemed equally accepting of both off-the-shelf solutions and student created (MQP) solutions. COG members seemed willing to accept that the nuances of the WPI system might require a custom solution and agreed that students could tackle this problem.

The COG strongly supported leveraging existing information technologies already in use on campus. Specific technologies mentioned included Bannerweb, myWPI (blackboard), and WPI's Central Authentication System (CAS). After presenting the evaluation criteria, team members drew specific attention to criteria deemed controversial, specifically coercion resistance and vote updating. The justification for coercion resistance and similar properties related to privacy were well received; COG members agreed that while incidents involving breaches voter privacy are unlikely, steps should be taken to prevent them. Vote updating was not as well received because it had no analogue in the current system. Members of the COG expressed skepticism around the necessity of vote updating because it

is not necessary in the current system and has not been specifically requested by faculty. After a brief discussion on usability the COG recommended including support for a mobile app to increase ease of access to an electronic system. Overall, the COG was pleased with the evaluation criteria and seemed eager to see the results of evaluations along with a final proposal.

The COG provided helpful insight into where priorities should be in the evaluation criteria. Meeting with the COG helped to cement the idea that strong security mechanisms would be beneficial to the system as long as they do not interfere with other priorities, but will probably never be necessary. This is reflected in the evaluation criteria on privacy and coercion resistance. The COG emphasized that system usability should be considered first and foremost, which is also reflected in the required usability criteria. As a direct result of the COG's doubt around vote-updating the team decided that although vote updating might be beneficial according to the literature, it is not a priority for WPI faculty. The COG agreed with the team that using CAS would make the system much easier to use and would be very beneficial provided it does not compromise privacy. Presenting the team's initial findings to the leaders and organizers of faculty governance was critical to developing the relevant criteria for evaluating voting systems.

4.4. Interviews

4.4.1. Interviews with Survey Respondents

As a part of the survey, the team asked if there was anyone who wanted to further discuss the election process. Three faculty members indicated they would like to be

interviewed. One was a relatively new faculty member who specializes in computer security, another was a longtime faculty member who had served on COG, and a third was a young proponent of e-voting in the social science department. No faculty member interviewed believes the current voting system is inconvenient; they all think the process of getting a ballot, ranking the candidates on it, and returning it in the provided ballot envelope is a very effective and usable process; in fact, one faculty member suggested that the current system should serve as a baseline standard for usability.

The interviewed survey respondents expressed a number of concerns about faculty elections. Two interviewees expressed a belief that the current paper-based voting system is an unnecessary waste of paper; they would like to see voting go electronic for environmental reasons. In fact, one interviewee suggested that even paper reminders were wasteful, though other faculty members expressed concern that paper reminders were necessary to supplement email notifications. Another common concern was that a new electronic voting system would be less usable, especially for less technically inclined faculty members. One faculty member expressed concern that less technical voters might throw up their hands and give up even at the sight of a mistyped password error. It became clear during the interviews that even a slight loss of usability could decrease a response rate that is already quite low. From that consensus, the team discerned that it is very important that voting electronically be extremely easy; any loss of easy voting would severely reduce the traction of a proposed voting system change.

4.4.2. Interview with WPI Information Security Officer

The WPI Information Security officer believes the sensitivity of the system is very low, as it contains very little information that, if leaked, could cause financial damage to WPI. The worst consequence of a total release of all ballots would be some embarrassment and angry faculty members, but the lack of credit card numbers, personal addresses, and other sensitive data makes security a low priority from his perspective. He unequivocally believed that local, onsite hosting would be much less expensive than off-campus hosting, but pointed out that any system should be easy for administrators to deploy and maintain. In particular, he said there should be complete, reliable documentation on how to set up and administer the tool. He also said it would be a plus if there was a third party company that could be paid to support the tool, as the faculty voting system is not used commonly enough to make it worth having an administrator learn to configure yet another tool. Failing third-party support, third-party training would help get the IT department up and running with an electronic system faster than just providing documentation. Lastly, the Information Security Officer pointed out that it is important for maintainability to separate the backing database from the frontend.

4.4.3. Interview with Former Secretary of the Faculty

Professor Kinicki, a CS faculty member and former Secretary of the Faculty who oversaw an attempt to implement an electronic faculty voting system in the past, brought up a number of concerns which he believed caused his prior attempt to fail. First among them was political opposition; Professor Kinicki said there is a very vocal minority of faculty members who are adamantly opposed to electronic voting. In conducting the survey and

interviews, the team did not manage to gather detailed input from any members of this group, so it is difficult to determine whether resistance will be as strong now that several years have passed. Another strong concern of Professor Kinicki's was maintainability - the prototype system he proposed was developed by himself and one other person, a member of the IT department whom many believed would retire soon; faculty members raised questions about who would maintain the system with the author leaving the university. On top of those concerns, Professor Kinicki stressed the importance of authenticating users while keeping their vote private. Professor Kinicki also addressed one of the biggest questions overshadowing the entire project: will the response rate increase or decrease as a result of moving to an electronic system? The response rate might increase due to lower voting barriers to off-campus faculty members, but it might decrease due to distrust of the new system or confusion as to its use. Professor Kinicki stressed that usability must be the paramount concern for any proposed system.

4.4.4. Interview with the Faculty Governance Coordinator

The team also interviewed the faculty governance coordinator, a staff member named Penny Rock. Ms. Rock is responsible for many election-related activities, such as determining eligible candidates, printing and distributing ballots, and tallying ballots to determine winners. She is a strong proponent of an electronic system as some aspects of the current system, particularly the counting of ballots, are extremely time-consuming for her. Furthermore, there are issues with ballots (around 5 to 10 per year) being incorrectly completed, forcing her to discard them. This occurs every year, and as there is no way to trace a ballot back to whoever submitted it, Ms. Rock cannot notify those faculty that they

are completing their ballots incorrectly. In all likelihood, these faculty, with no one to tell them they were using their ballots incorrectly, have continued to do so, and effectively disenfranchised themselves. Ms. Rock feels that an electronic system could prevent this problem, though her primary concern is reducing the amount of time required to determine the winners of an election - under the current system, this can consume several days of her time. She is concerned, however, about allowing too many people access to raw voting data (ballots), which she feels could adversely impact efficiency and privacy in the new system. Ms. Rock feels that she, a member of the Committee on Governance, and any required IT staff should be the only people with access to raw ballots and other such information in the new system.

5. Evaluation Criteria

5.1. Final Evaluation Criteria

The final set of evaluation criteria generally follows logically from the team's research and interviews. These completed criteria represent a set of requirements the team believe will produce a voting system suitable for WPI. The criteria themselves are listed below followed by explanations of several criteria the team felt were interesting or controversial. As previously noted, the evaluation criteria are all graded based on the team's determination of how important they are to a voting system for WPI, with required being the criteria most important to a system's success and advantageous being the least important.

5.1.1. Security Criteria

- *Required:* The system verifies the voter's identity and eligibility before a ballot is distributed or submitted.
- *Required:* No person is easily able to gain identifiable information from the system about another person's vote. This includes WPI System Administrators and Election Officials; while a user may (or may not) see other votes, they cannot determine who was responsible for casting them
- *Required:* The system takes reasonable measures to prevent any voter from casting a second vote.
- *Strongly Recommended:* The system limits its trust in the physical security of voter owned hardware.

- *Strongly Recommended:* The system leverages other entities that the faculty already trusts to be secure (e.g. the WPI Central Authentication System).
- *Advantageous:* The system does not provide a voter any information which he or she could use to prove his or her vote to an attacker (i.e. the voter receives no receipt).

5.1.2. Trust Criteria

- *Strongly Recommended:* Complete source code and technical specifications for the system are freely available. It is possible to provide any voter or researcher who asks all the information needed to construct an exact replica of the system.
- *Strongly Recommended:* A brief summary of how the system works, understandable by nontechnical readers, is easily available for review by the public.
- *Advantageous:* The system provides a way for voters to ensure that their vote was recorded and counted correctly (individual verifiability).
- *Advantageous:* The system enables voters to independently verify that all votes were recorded and counted correctly (universal verifiability).
- *Advantageous:* The system enables one to change one's vote after it is first cast (vote-updating).

5.1.3. Usability Criteria

- *Required:* The user is able to cast a ballot without extensive training.
- *Strongly Recommended:* For a voter experienced with both the current and proposed system, casting a ballot does not take more time than the current system.
- *Strongly Recommended:* Voters are not required to install any new software on their personal computer beyond a supported web browser in order to vote.

- *Strongly Recommended:* The system contains effective measures to prevent the voter from accidentally recording under-votes (absence of a candidate vote) and over-votes (voting for multiple candidates in the same election).
- *Strongly Recommended:* The voting interface clearly depicts to the user which candidates their vote will support in an attempt to mitigate mis-voting.
- *Advantageous:* The system does not require the voter to remember information (e.g. codes) or carry a physical item in addition to what he or she already carries/remembers as a result of being a WPI faculty member.
- *Advantageous:* The system uses a proven method to mitigate the adverse impact of alphabetic voting on the election outcome.
- *Advantageous:* The system provides an interface that is usable for voting on smartphones and/or tablets.

5.1.4. Institutional Requirements Criteria

- *Required:* The system must count votes in accordance with the method described in the WPI faculty handbook. This includes support for recounts.
- *Required:* The team finds the cost of implementing and maintaining the system and running an election acceptable.
- *Strongly Recommended:* Complete technical documentation for deployment and maintenance of the system is available.
- *Advantageous:* The system can perform an electronic recount of an election if a candidate is removed from the election.

- *Advantageous:* Technical support for the system is available by the producing company or a third party.

5.2. Reasoning behind the Criteria

The team decided upon a relatively lax coercion resistance criterion, only recommending that no receipt of which candidates were voted for be distributed (receipt freeness). While the team feels that coercion or vote buying are a concern in a voting system at WPI (while unlikely, they can completely swing the results of an election), it is very difficult to achieve coercion resistance with an uncontrolled voting environment. For example, any coercion resistance included is pointless if the coercer is watching the voter as they cast their vote, which cannot be prevented. Receipt freeness is a reasonable standard of coercion resistance that is not difficult to ensure and, at the very least, hinders coercion or vote buying. The survey and interviews reflect that coercion and vote-buying is not particularly concerning to anyone who chose to share their thoughts with the team, helping to justify the decision not to include stronger coercion resistance requirements.

The team recommended that vote updating be included in any system deployed at WPI, though it is not considered a very important addition. Vote updating is an important usability addition to any voting system, for several reasons. Firstly, an instructor can actually walk a voter through the process of voting for a candidate in a system with vote updating, while standing beside them; the voter can then cast their actual ballot afterwards, with confidence that they know how to do so. Vote updating can also act as a form of coercion resistance, allowing voters to change their ballots after having been coerced.

Finally, it can increase trust in a new voting system, as less-than-confident first time users know that, even if they complete their ballot incorrectly, they can always try again. Many of the the interviewees expressed skepticism about the need for vote updating and voiced potential disadvantages, including hackers altering a voter's ballot after gaining access to their system. Despite this reaction team believes that the advantages of vote updating make any system including it stronger, though it is not a requirement for any new voting system.

The team decided to use the current system as a baseline for usability (in terms of time taken to vote, and ease of vote completion) for any proposed new voting system. This evaluation criteria was initially controversial amongst team members, and attempts were made to locate a reasonable measure of voting system usability, with regards to time - a specific amount of time it should take a voter to complete a ballot, for example. No such efficient metric could be found through the team's review of relevant papers. However, follow up interviews to the survey unanimously noted that the current system was perfectly fine from the perspective of voters, taking minimal time and effort to complete a ballot. Consequently, stating that the proposed system takes as much time to complete a ballot as the old system ensures that voters will be satisfied with the amount of time it takes to cast a ballot, at minimum. This will help prevent a drop in response rate from tedious to complete ballots that might deter voters.

Based on the evaluation criteria as described above, the team created a scorecard to evaluate proposed systems. This scorecard contained a listing of all evaluation criteria, listed by rated importance. This scorecard (located in Appendix C-0) is meant to gauge the relative suitability of a system for WPI. It does not take into account measures which can be

taken external to the system, or modifications that could be made, which would improve a system's suitability.

5.3. Evaluation of Systems

5.3.1. Current System

To begin the process of recommending a replacement for the current voting system, the team evaluated the current voting system using the evaluation scorecard developed for rating replacement systems. The results of this evaluation are contained in Appendix C-1 and were generally unsurprising. The current voting system is, overall, quite suitable for use at WPI. Its main deficiency rests in the time it takes to tally an election under the current system. The system otherwise offers a great degree of convenience to the common voter, supported by the team's interviews - no interviewee expressed concern about usability from the voter's perspective. It is worth noting that the current system does not offer checks on ballot validity, which allows voters to submit invalid ballots; this causes a small number of ballots to be thrown out in every election. Despite this, there are many upsides to the current system, and there are no guarantees that attempts to solve this problem would be successful. The current system thus represents a solid baseline to compare other systems to in terms of voter experience.

5.3.2. Helios

Helios, a highly secure auditing-friendly internet voting system (described in Chapter 2.6.1, evaluated in Appendix C-2, and online at <http://heliosvoting.org/>), provides an example of a freely available, high-quality internet voting systems available. The system is generally promising, but is unsuitable for use by WPI in its present state. No provision is

made for ranked voting in Helios as presently released, nor the instant runoff counting method used by WPI. Changing the algorithm used to determine winners would not be particularly challenging, but adding the capability to perform ranked voting could be much more complex. Helios is a cryptographically secure system, and adding a new type of vote (ranked) could potentially require modification of the integrated cryptographic code. In addition, Helios as a system focuses on integrity of the ballot and counting, emphasizing it over the privacy of voters. Helios permits votes to be tied to those who cast them by an administrator; something several interviewees noted might be a concern for WPI faculty. Given these considerations, the team considers Helios to be worthy of further consideration, but by no means a drop-in solution to meet WPI's needs.

5.3.3. Scantegrity

Scantegrity, an scanned-ballot paper voting system (evaluation available in Appendix C-3, and online at <http://www.scantegrity.org/>), offers an interesting, more secure counterpoint to the current paper system. Scantegrity offers the definite benefit of being a scanned-ballot system, using a computer to count ballots instead of manual counting. This remedies one of the major flaws of the current WPI system, though it retains others (inability to privately vote while off campus and less environmentally friendly than a paperless electronic system). Scantegrity also includes integrated auditing tools permitting voters to verify that their votes were counted. However, aside from this integrated auditing, Scantegrity offers little advantage over independently implementing a solution using scanned ballots, and Scantegrity would need to be adapted to use WPI's counting system (and ranked voting as well). As such auditing was not particularly concerning to faculty (as

indicated by the survey and interviews), it is difficult to recommend Scantegrity over a locally developed scanned ballot system, should a paper system be desirable.

5.3.4. EBallot

EBallot, a commercial cloud-hosted Internet voting system (Evaluation available in Appendix C-4, and online at <https://eballot.votenet.com/>), is one of the few successful (commercial) dedicated e-voting systems available. Details available are limited, as no public, usable demo of the system is available. The system does support ranked voting, though they do not specify the counting algorithm used. However, as WPI's counting system is a locally developed variant of Instant Runoff, it can be safely said that EBallot does not use the WPI system. Thus, for EBallot to be considered, the company who manages it must be contacted to verify they would be willing to adapt their program to use WPI's counting algorithm. Additionally, the system, being externally hosted, would host a record of the votes of faculty members on EBallot's servers. This is a significant risk to privacy, and one that interviews indicated there might be concern about. The team finds it difficult to recommend the use of EBallot given this.

5.3.5. SurveyMonkey

SurveyMonkey, a commercial cloud-hosted survey system (Evaluation available in Appendix C-5, online at <http://www.surveymonkey.com/>), is an example of an application not dedicated to voting that could be used to perform elections. SurveyMonkey is frequently used to conduct surveys on campus and it was evaluated because faculty are already familiar with it. Though the familiarity of the software would be beneficial, the team finds that it offers few other reasons to recommend it over a dedicated voting system.

SurveyMonkey itself cannot tally results to determine winners, though it can export all ballots as an Excel spreadsheet. A program could then be written to determine winners from this spreadsheet. However, the effort of locally developing this program is likely almost as much work as adapting an existing, dedicated voting system, which would offer a superior, more integrated experience for both voters and election officials. Furthermore, SurveyMonkey is weak on privacy front. SurveyMonkey is not designed to implement authentication and privacy at the same time; it can have either authentication, or privacy, but not both simultaneously. If a voter authenticates to a SurveyMonkey survey, their name is stored with their vote, enabling election officials to tie every voter to their ballot. This, combined with SurveyMonkey being a cloud-hosted system (with concerns similar to EBallot), would likely be very concerning to WPI faculty, given information from interviews. Thus, the team does not recommend that SurveyMonkey be pursued as an alternative to the current voting system.

5.3.6. Presently Deployed Systems

MyWPI (WPI's local Blackboard installation) and Bannerweb were discarded early in the evaluation process. For Bannerweb, the team cannot adequately evaluate the system due to a lack of familiarity and available documentation. However, anecdotal evidence suggests that, while it could be used to collect ballots, it would also collect the identity of those voting, a significant loss of privacy. The Blackboard software that runs MyWPI is incapable of performing ranked elections through its quiz system according to its documentation - the type of question necessary to produce an effective ballot simply cannot be asked. Specifically, creating a "proper" ballot would require separating each candidate

into a separate question and prompt for the voter's rating of the candidate, and no error-checking to ensure that more than one candidate did not receive the same ranking could be effectively performed by MyWPI. This makes it easy to submit an invalid ballot unintentionally. While either of these systems could potentially be adapted to meet the needs of WPI's voting faculty, the amount of effort involved would likely be comparable to adapting or developing a dedicated voting solution which would offer a more usable and secure voting system (being purpose-built with these qualities in mind).

5.4. Recommendations

Based on these evaluations of existing systems, the team finds that it cannot recommend any existing system as a suitable solution for WPI. The unique needs of a campus voting system (and a WPI voting system) are not adequately met by any of the systems the team located. The Helios or EBallot systems could potentially be adapted for use at WPI, but even adapted they would have significant deficiencies. Helios, for example, stores identifying information with votes in its database, permitting system administrators to identify how individual faculty members voted. This would be extremely difficult to remove due to the way Helios is written, and violates a core concern of many faculty members - that their votes be kept absolutely private, not able to be identified by anyone. EBallot is a commercial product, so the changes to the software for use at WPI would have to be made by the producing company, who would likely charge a large fee for making such modifications. It is also a cloud-hosted solution, which some WPI faculty have expressed concern about (placing private information about WPI faculty on servers external to WPI). This makes it difficult to recommend either of these systems.

A further alternative would be to create a custom voting system for WPI. This would, in the team's opinion, be a project of roughly (large) MQP scale, though it could also be created by IT staff. Given WPI's unique variant of Instant Runoff for vote counting and need for nominating ballots with somewhat complex rules, a brand-new system would likely be better-suited to WPI's needs than either EBallot or Helios could be, even with extensive adaption. The team believes that the evaluation criteria that were created to evaluate existing systems would serve as an excellent set of requirements for such a system, were it to be created. The team has confidence that a new system satisfying the required evaluation criteria and a large number of recommended and advantageous criteria would be an excellent fit for WPI and would satisfy the concern of many in the faculty. WPI CS faculty and the IT staff's Information Security team could audit such a system after its creation to ensure it was secure, free of preprogrammed backdoors, and reliable enough for regular use at WPI. The team believes that this solution, creating a new, customized voting system, is the best fit for WPI, given the state of alternative systems.

The team recommends that any newly built system be constructed with an emphasis on privacy. Helios performed generally well in team's evaluations, but its strong focus on ballot integrity was actually a detriment in some cases. Administrators are trusted with the knowledge of who cast each ballot, and what candidates they voted for, to enable some of its integrity and coercion resistance properties. A stronger emphasis on privacy should be made in any system built for WPI, as this is one of the major concerns of WPI faculty; in particular, an effort should be made to prevent anyone from associating a ballot from the person who cast it. There is a natural balancing act between integrity, privacy, and

authenticity in any voting system, and while the team believes that privacy is the most important of these, this does not mean that the others are unimportant.

The team feels that the individual verification feature of Helios and other voting systems is a desirable feature for a new voting system to include. Having evaluated Helios and investigated the use of this feature, the team believes that this feature will add little complexity from a voter's perspective and offer the assurance of integrity - every voter can verify that his or her ballot was counted. As there is some concern among faculty that an electronic voting system could be easily manipulated to change the winners of elections, adding an assurance that ballots were counted could increase trust in the new system. Universal verification, the counterpart of individual verification that enables entire elections to be securely audited, could also be included, but it is a technically difficult feature (involving large amounts of complex cryptography) and potentially has negative privacy implications (revealing vote counts publically as a possible example). Consequently, the team does not recommend the inclusion of universal verification in a system written for WPI.

An advantage of a custom-written solution would be satisfying the unique institutional requirements of WPI. Sometimes, faculty elections need to be recounted after being conducted when an elected committee member must decline their seat due to other obligations. No existing system supports recounting an election with one candidate removed, but a custom-written solution could include support. Furthermore, a new system could assist in automating the process of determining eligibility for committee nomination. Presently, the secretary for faculty governance manually determines who is eligible to be

placed on the nominating ballot based on a large number of determinations made by the Committee on Governance. A custom-written voting system could automatically perform this task, further lowering the workload required to conduct an election.

6. Usability Study

Existing literature, which often discusses the failure of electronic voting systems, raises concerns regarding the usability of the ballot. In an attempt to find ways of minimizing these issues, the team started the process of designing an interface for the voting system. The team is concerned with making a user-interface that will protect the privacy of the user, streamline the voting process so that it has minimal cognitive effort, mitigate voter errors, and provide the interface without extra work to the voter. For the benefit of system developers, the team created testable mockups of several voting interfaces. The team showed these mock-ups to experts in the field of human-computer interaction (HCI), who gave feedback that the team used to develop second drafts. The team then performed a study on the usability of the mockups to determine any defects.

6.1 Creation of Interface Prototypes

The team began with a brainstorming session to gather ideas that could be useful and dismiss those which were discussed negatively in the existing literature. For example, the team wanted to use existing notions of interactivity such as drag-drop ordering and the expected behavior of buttons while avoiding common mistakes, such as the much-derided butterfly ballots of Florida's 2000 presidential election. These considerations led to a nomination process retaining the existing paradigm of checking a box to nominate, but also adding a feature which allows the user to arrange the list of names into groups: alphabetical by last-name, alphabetical by first-name, or by department. Creating an interface for the voting side of the election process was more complex. The team did not want to completely

deviate from the voting interface, yet wanted to create an environment which cannot lead to overvoting or accidental undervoting. The result was an interface which allows a voter to rank their candidate choices via drag-and-drop (shown in Figure 1).

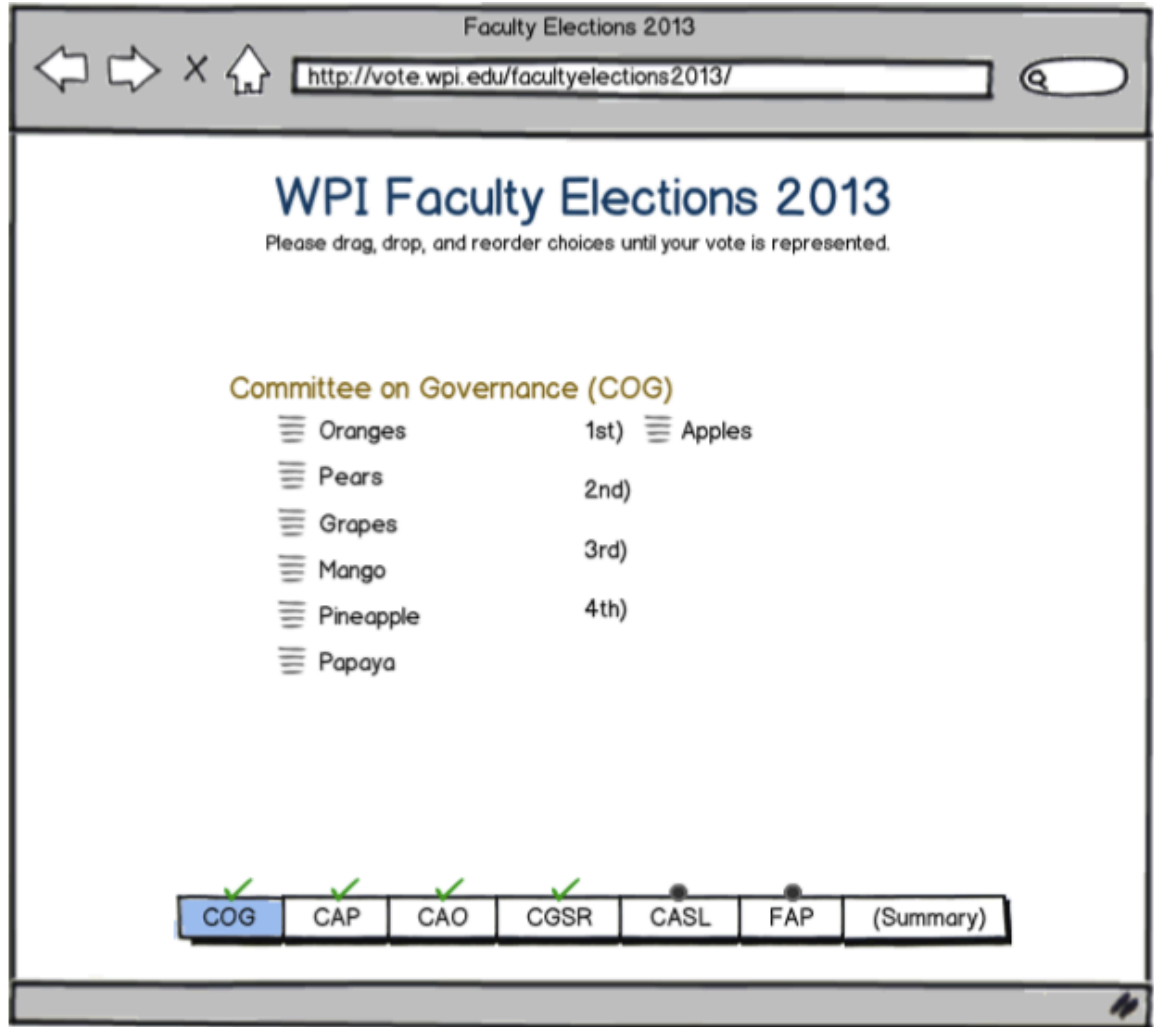


Figure 1: Initial Drag-Drop Interface

Drag and drop retains the heart of the current ballot, representing a voter's choices by a numerical ordering, but looks and behaves very differently. The team also created an

interface which operates nearly exactly the same way as the current system, except numbers are typed (instead of written) next to candidates' names (Shown in Figure 2).

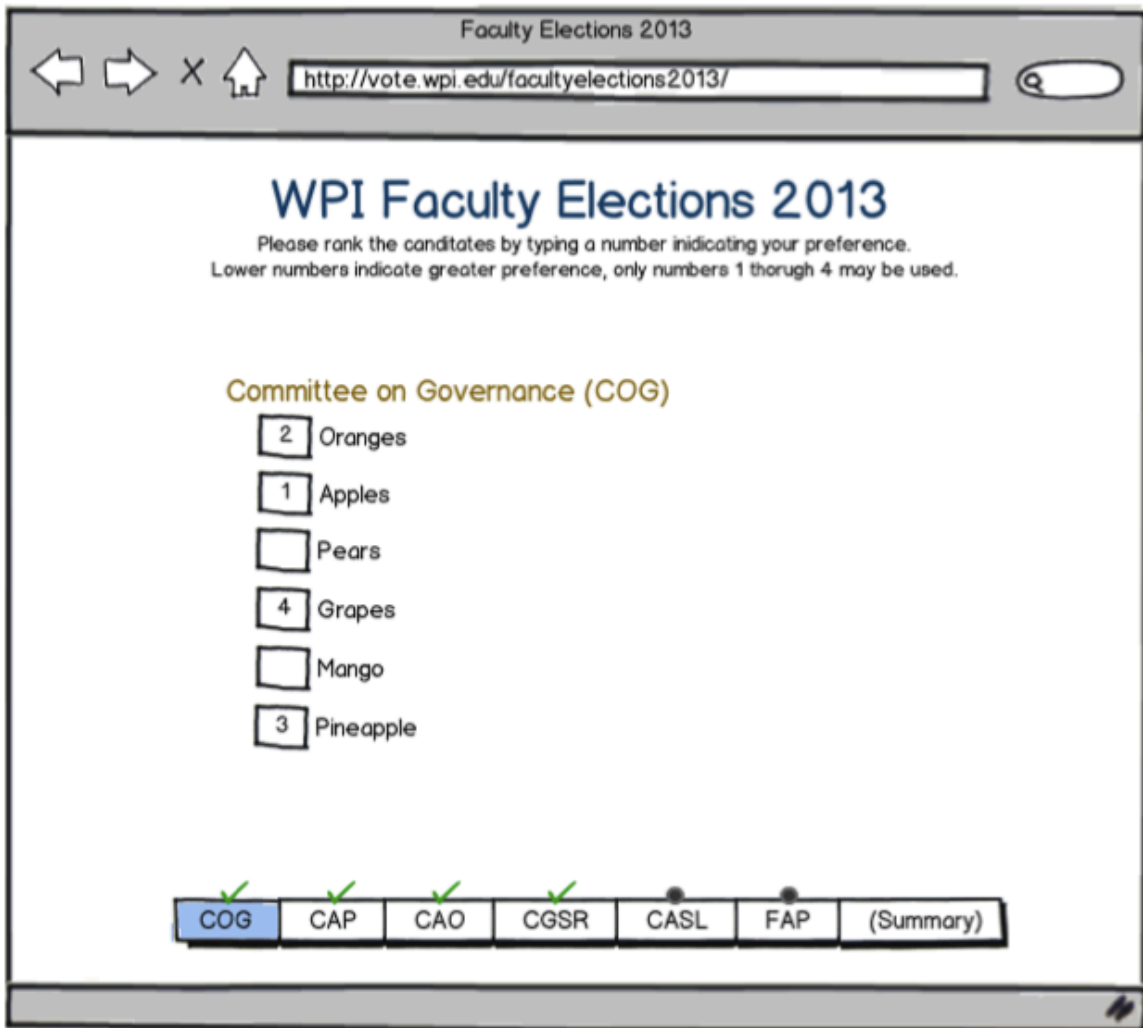


Figure 2: Initial Alternative Voting Interface

6.2 Consultation with Usability Experts

The team presented its three interface mockups (one for nominations and two for voting) to usability experts for input. The team reached out to Professors David Brown and Matt Ward, both professors in the Computer Science department with expertise in human-

computer interactions, and asked them to review the team's mockup interfaces. Both provided feedback on ways to increase the usability and effectiveness of the interface designs. Given that usability is often counterintuitive, obtaining input from trained professionals was invaluable. Hence meeting with two HCI professors gave the team different approaches to improving the interface, and parts of both were included in the final design. Their detailed recommendations are discussed in Chapter 6.4.

6.3 Testing with Community Members

After consulting with experienced HCI instructors, the team decided it would be useful to have additional users try to use the interface and expose any major issues that might remain. To quickly gather feedback from as many people as possible, the team sat at a table in the WPI campus center. Passersby were asked to spare a few minutes of their time to assist an IQP by walking through the proposed interface. Upon arrival at the table, the participant would be given a piece of paper with the starting screen of the interface and would be instructed to vote on different types of fruit. In order to determine whether the participant could accurately use the voting interface, the team handed the participant a slip of paper containing the order of preference he or she should indicate. The participant would use their finger as a mouse and tap ("click") where they believed was necessary in order to accomplish their task. The participant was given a pencil to use as a keyboard to "type" when necessary. The experiment consisted of four "screens" that were presented to the user. A start screen providing an option for a tutorial and a summary of votes cast were consistent between both iterations of the experiment. The screen used for voting varied between trials and was either a mock-up of the team's proposed "drag-and-drop" interface

or the alternative numerical fill-in (analogous to the current ballot). The team observed how the user navigated through the interface without assistance, and made note of any mistakes, confusion, or stumbles by the user. After all the participants completed their ballots, the team pooled the data and used the most common errors to streamline the proposed voting interface.

6.4. Initial Ballot Design

The team designed the interface to be simple, quick, and intuitive; that is, the interface should be clean and organized, take no longer than the current system to cast a vote, and be easily learned by a new user. The team's initial efforts produced a general format for a voting interface composed of three screens to complete a ballot (both for nominations, and the actual election ballot). The actual ballots initially designed were shown previously on Fig. 1 and Fig. 2; the additional 2 screens in the election ballot process are shown below in Fig. 3 and Fig. 4. In order to aid the user, there is an optional instruction video on the first screen. Also, the overall layout is similar to the current ballot, and the two

share a common process to complete the ballot.

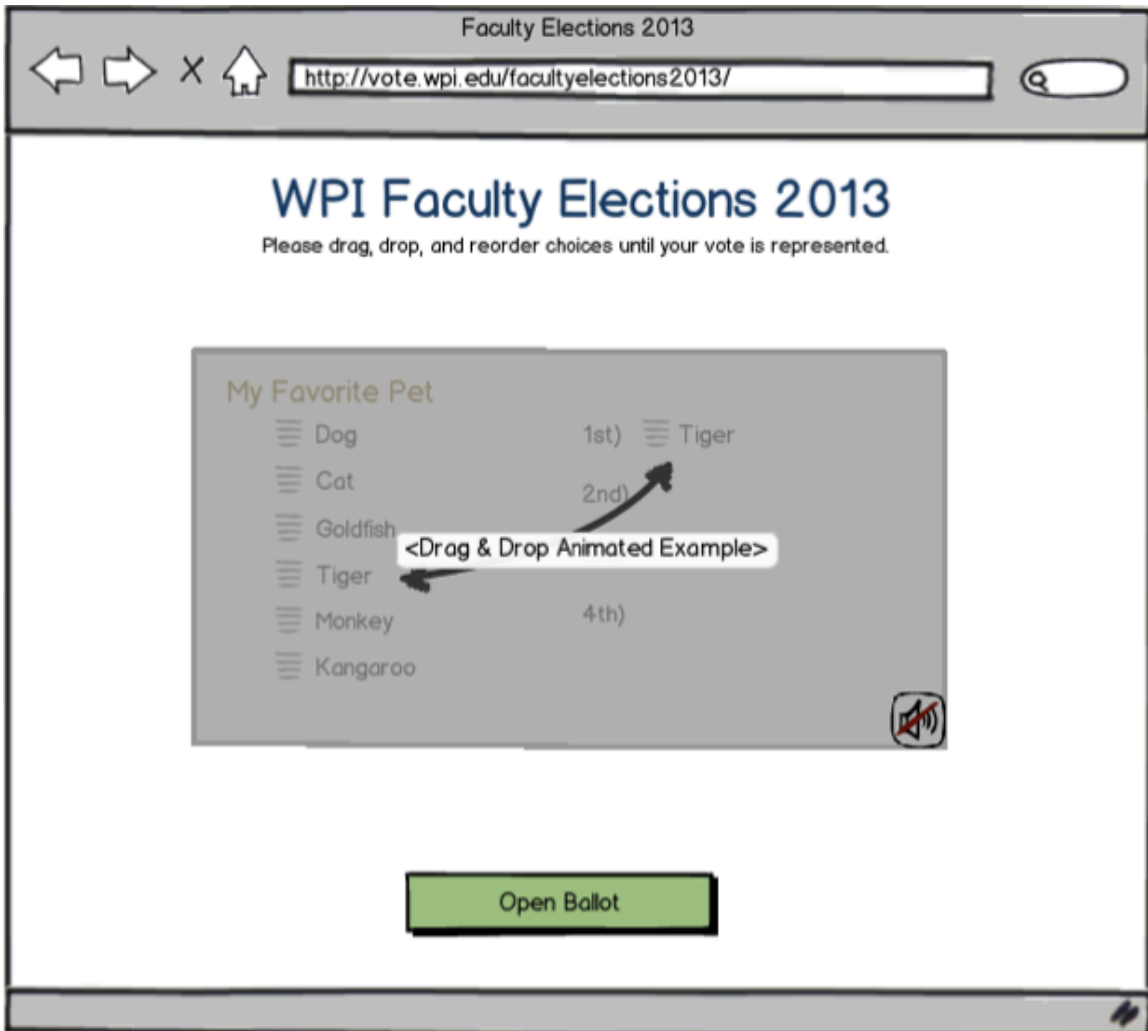


Figure 3: Initial Voting Start Screen

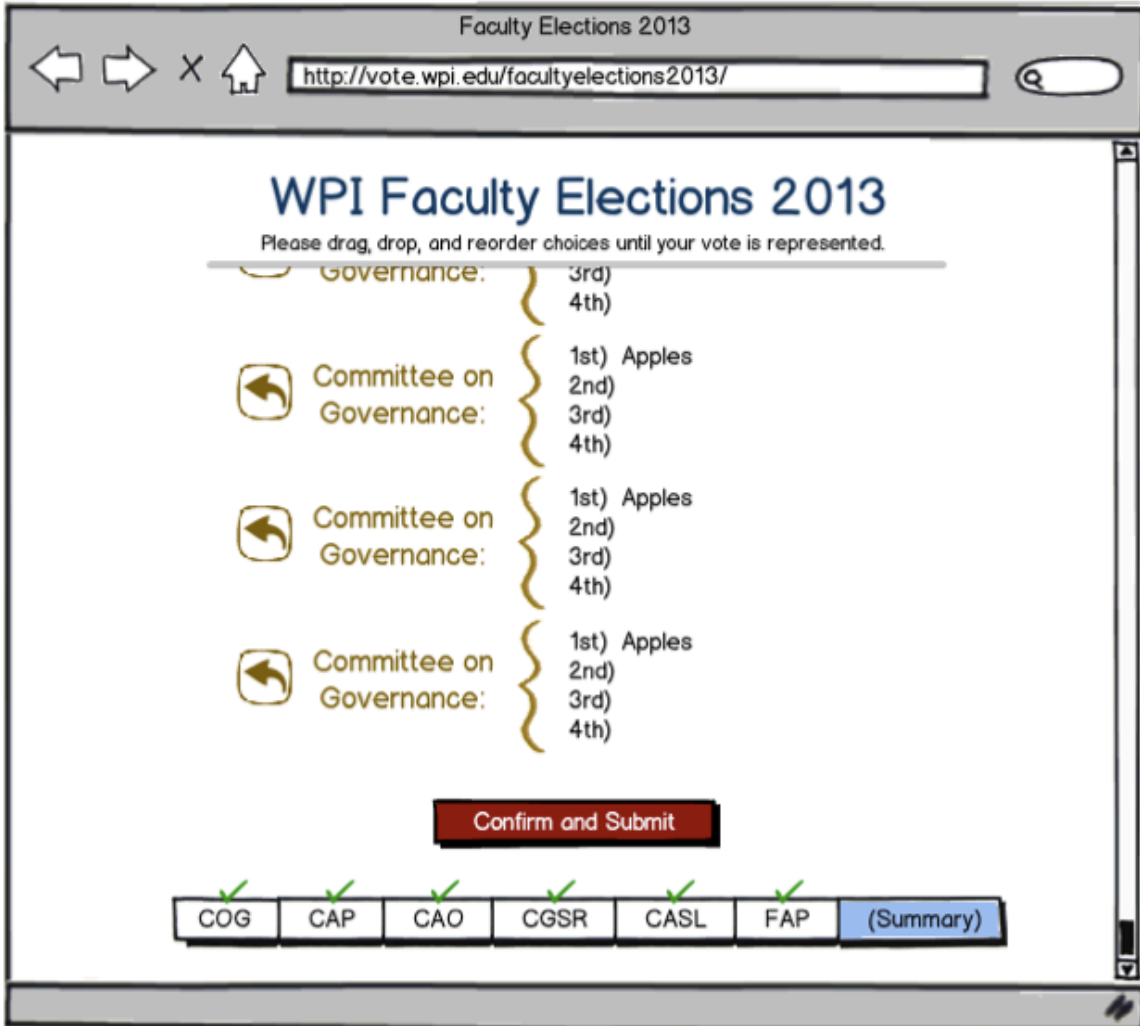


Figure 4: Initial Vote Confirmation Page

When designing the details of the nomination and election workflows, the team decided the nomination process needed little change, whereas the election procedure might benefit from the dynamic elements web-based voting can offer. The election ballot in its current state has received complaints about error rates, so the team looked for alternative methods which would inherently prevent user mistakes. The initial result was the drag-and-drop ballot shown in Figure 1. The user drags a name a name from left to right on the screen

to rank candidates according to their preference, with instant visual confirmation of their actions. While the team believes this to be ideal, the alternative design, shown in Figure 2, retains the existing voting procedure of filling in boxes with a numeric representation of preference, which has the benefit of familiarity because it is almost identical to the existing interface. Either of these two designs require some amount of programmatic error-checking by the voting interface to ensure there are no user errors and enforce any election constraints (for example, restricting electees to one faculty member per department).

6.5. Refinements

After the team's meeting with Professor Brown, the team made many changes based on their feedback. As shown by the revised mockup in Figures 5 to 7, the team changed the titles of the screens to be more representative of the content within. For example, in the nominating ballot (Figure 5), instead of saying "Faculty Committee Nominations" the title was edited to be "Nomination Ballot." Additionally, a new method of showing user errors (red X marks next to incorrectly-marked sections) was added to the nominating ballot (Figure 5).

Faculty Committee Nominations 2013

Nomination Form

Please use the checkboxes to nominate, then review and submit your choices in the summary

Committee on Governance (COG): Please remember that you may only nominate a single member per Department.

Department of Computer Science

<input type="checkbox"/> Bugs Bunny	<input type="checkbox"/> Marvin the Martian
<input type="checkbox"/> Daffy Duck	<input type="checkbox"/> Yosemite Sam
<input type="checkbox"/> Elmer Fudd	<input checked="" type="checkbox"/> Tasmanian Devil

Department of Computer and Electrical Engineering

<input type="checkbox"/> Ceylon gooseberry	<input type="checkbox"/> Biribi
<input checked="" type="checkbox"/> Costa Rican Guava	<input type="checkbox"/> (The) Burmese grape
<input checked="" type="checkbox"/> Bilimbi	<input type="checkbox"/> Avocado

Department of the Social Sciences

Error: Cannot select more than one person per department.

<input type="checkbox"/> John Smith	<input checked="" type="checkbox"/> Jane Doe
-------------------------------------	----------------------------------------------

Figure 5: Modified Nomination Form

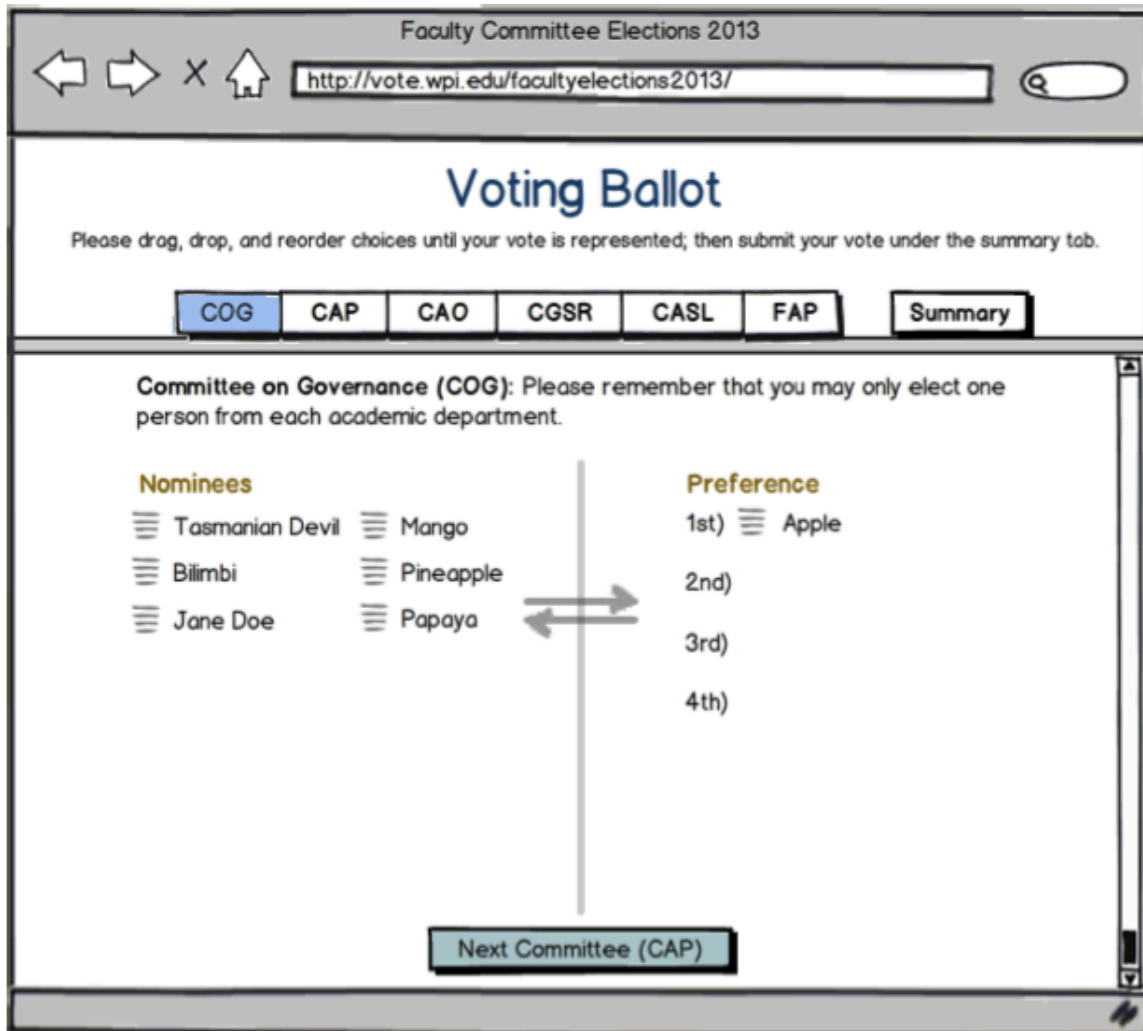


Figure 6: Modified Drag-Drop Ballot

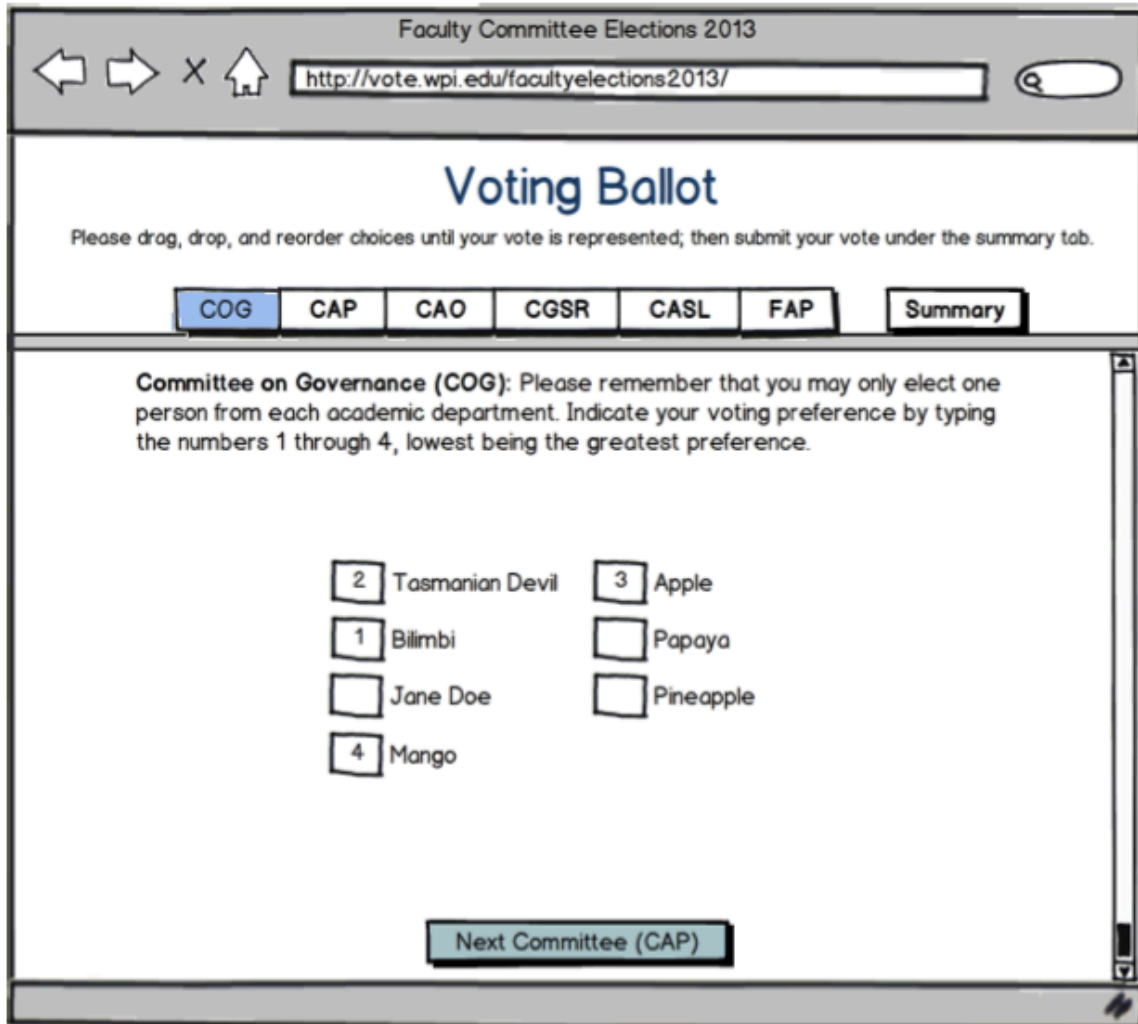


Figure 7: Modified Numeric Fill-in Ballot

In order to open up more space in the interface and allow natural scrolling at the bottom of the page, the election-selection tab bar previously located at the bottom of the screen was relocated to the top. The change also brought the proposed interface in line with the expected behavior of a tab-bar: the content below updates to match the selection. The team put some thought into possible scrolling and layout issues for a variety of screen dimensions. It was decided that at a resolution of 1024x768 pixels, which is considered

somewhat standard, a screen should be able to display two side-by-side columns; wider resolutions should automatically adjust to display more columns whereas a smaller screen should have the capability to render only a single column. During the conversation with Professor Brown, the team was told that drag-and-drop interfaces tend to be a hard action for users to perform with a mouse. Prof. Brown recommended a click-based method to move names around instead of drag-and-drop. However, the brief usability study indicated a preference for drag-drop interfaces. Further research and usability testing is required to more fully understand the issues at work.

6.6. Usability Study Results

The team obtained six complete trials and one aborted trial from its usability study. Each of the trials, whether it was drag-and-drop or numerical fill-in, took approximately one minute to complete. When starting, most respondents “clicked” on the video and listened to the team give a thirty second introduction to the system. The team later discovered that a number of those who clicked on the “video” (shown in Fig. 8, the initial screen of the election ballot interface, below) believed that was the correct action to move to the next screen.

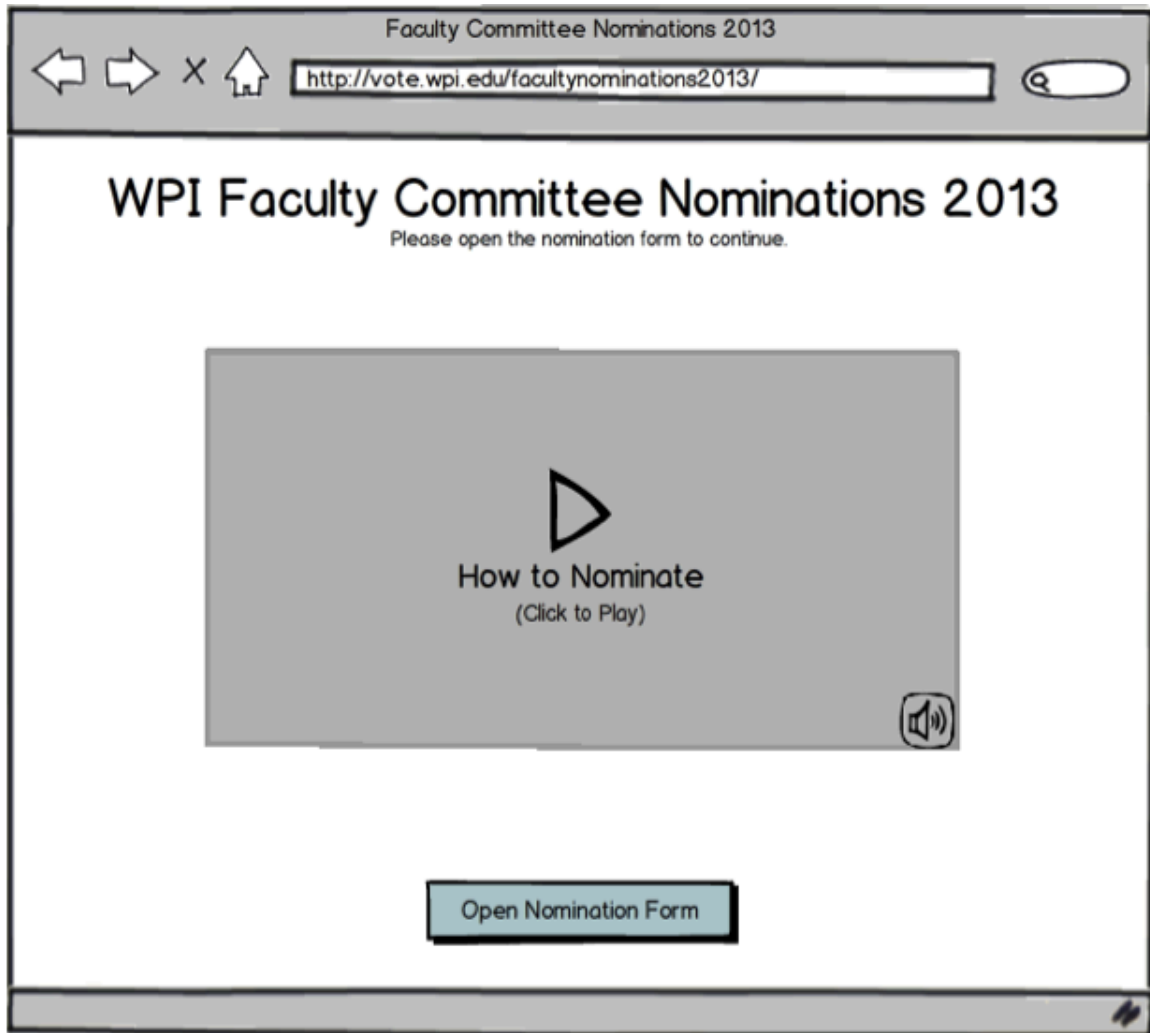


Figure 8: Modified Intial Vote Screen

The second time users voted with the interface, there was typically a significant improvement in speed. The team attributes this to the respondents learning the general process of the interface (and usability study) and applying this knowledge, spending less time determining how the ballot worked. Overall, the participants indicated that they preferred the Drag and Drop interface over the numerical fill-in interface due to it being “more aesthetically pleasing” and “needing less explanation.” Respondents further indicated

they believed the electronic interfaces shown in the study would be more usable than the present paper ballots.

The team interprets these results as a successful demonstration of the usability of the proposed interface; but will maintain the example video for those who want to learn the system before using it. Participants who watched the video were quicker to perform the actual vote, but due to the duration of the video the overall time taken was greater than those who did not. Users who are less comfortable when presented with a new interface might still find the video useful. One user reported “I wasn’t sure what to do with the paper” and first tried to click on the drag-drop option. Following their experience, this user stated that it might have been better to watch the video. Another user reported that they did not need the video, but that it could still be beneficial to others. In all observed cases users were able to successfully use the interface without help from the video. With that being said, providing the option for help has no risks and is likely to provide a more satisfying voting experience for some users.

While the usability study failed to uncover any major errors, there are variables and biases which prevent its results from being conclusive. Those interviewed were whichever members of the community walked through the campus center, and all complete trials were with WPI students. This introduces a selection bias to the results. The use of a paper mock-up for the drag and drop interface caused some issues. At times, the paper would be crumbled or overlap causing delays that would not exist in a computer system. Additionally, because they were provided with paper and a pencil, many participants believed that they were supposed to follow paper-based usability conventions instead of conforming to the

finger-to-click/pencil-to-type paradigm they were asked to use. Finally, some confusion occurred when the “video” had started. Had the experimenters been more clear about when the “video” actually started, confusion might have been avoided. Because of these issues, it is difficult to make a final determination about the proposed interface, but so far all results are promising.

Moving forward, the team recommends that the following steps be taken:

- Further iteration to refine proposed interface, particularly Drag and Drop and Nominating Ballot interfaces.
- Further investigation into implementing Drag and Drop ballots with a mouse
- Investigation into interfaces across multiple device types and web browsers
- Testing with faculty focus groups to determine issues with and effectiveness of interfaces. This testing should involve prototype interactive interfaces and several device types (smartphones, tablets, and PCs/Laptops).
- Further consultation with Professors Ward and Brown to obtain feedback as interface designs progress.

7. Conclusion

After careful consideration of relevant research and factors unique to WPI, the team has determined that an electronic voting system would be beneficial to faculty elections. Furthermore, the team has concluded a custom solution developed using the personnel and resources of the university would best suit the needs of WPI Faculty Elections. Much of the reason for this comes from the difficulty of finding an existing system that is capable of supporting the unique vote counting system described in the WPI Faculty Handbook. A custom designed system could be easily built with this unique system in mind. The development of a custom system holds greater potential for faculty input at each stage of the development, which increases the chances of easy acceptance of the system.

If a student project were used as the primary source of labor for the project, development costs would be minimal. This project presents significant educational value because of the wide range of design considerations (security, usability, maintainability, etc). However, there is significant risk involved with using a student project to produce this system in terms of long-term maintainability and quality of code. With that being said, the team has identified ways to mitigate risk in deploying a custom voting system for WPI faculty elections; these steps are outlined below.

7.1. Development Considerations

Non-binding test-elections are a good way to introduce nervous voters to a new system and would also provide an opportunity to find problems before the system goes live.

These elections could, for example, ask the favorite color of faculty members (or some equally innocuous question). This would prevent any voter anxiety about an unfamiliar system being used for a high-stakes decision. Any potential system, WPI built or otherwise, should successfully be run through one or more non-binding test elections to identify any problems before official deployment. These experimental elections should be used to establish error rates as well as to collect more subjective voter satisfaction data. These elections will also uncover usability issues, bugs in the program, and other situations that designers may overlook. Without real world testing to serve as a proof of functionality, WPI faculty may be skeptical of the software. Additionally, without this testing disastrous software problems may show up in the first deployment of the system and do irreparable damage to voter trust in the software (no matter how trivial the fix). Any step that can be taken to encourage voter trust in the system is beneficial.

Before a system is deployed on the WPI network security professionals to minimize the risk of the system being compromised should review it. Requiring that the system pass a security and reliability review by a professional security team, external or internal to WPI (such as WPI Information Security) is especially necessary because some voters may be skeptical that a student project will really be good enough to keep their votes confidential. Additionally, this step is an important part of the introduction of any new software service, because WPI Information Security must ensure that the software does not pose a threat to other systems. Independent review will ensure that the MQP team does not make any critical mistakes that could allow the system to be compromised. Finally, taking this step

allows voters to place trust in parts of the system they may not understand because they trust the professionals performing the audit.

Any voting system implemented for faculty elections should be built to last. Custom software solutions are often discovered to be unmaintainable. The faculty should not adopt an electronic voting system if the WPI CCC is not confident in their ability to maintain the software without its developers. Changing the voting system is too difficult to do frequently. An MQP group (or other on-campus development team) should consider that maintainability, in the form of both instructions for administration and documentation for further development, will make or break the acceptance of their system. The CCC should be consulted well before a system is approved for use in faculty elections. Faculty governance should only move forward with changes if those changes are demonstrated to be both beneficial and lasting.

No system should be used for faculty elections without multiple iterations of usability testing to ensure that WPI faculty can easily use the system. Usability is the first priority in voting system design, because if voters can't figure out how to vote, nothing else about the system matters: It is useless. Usability testing with focus groups and observation of individuals will provide critical feedback to developers on how to design ballots for the (often confusing) ranked voting system. These tests could, like the small usability study conducted by the IQP team, be conducted on students for the first several iterations. However, the system should be tested on WPI faculty at some point before deployment, to ensure there are no differences in the behaviors of age groups when it comes to comfort with the interface. If faculty are satisfied with their voting experience they will become

much more likely to trust the system as a whole. Additionally, it is likely worth retaining paper notifications that an election is occurring; several faculty members expressed concern that they would miss an email notification to vote.

As has been stated before, the only way to successfully conduct elections is with the full support of voters. The easiest way to accomplish this is to develop a system that provides a satisfying voting experience. Usability is the most critical design consideration because, unlike with other software, when a user decides that voting software is too hard to use to be worth their trouble it actually affects all the other users (by potentially changing the outcome of the election). Providing vote-privacy is the second most important consideration in building voter trust because people expect their votes to be kept private. Ensuring that ballots cannot be changed after they have been submitted comes next in importance for voter trust. Finally, ensuring that only enfranchised voters can vote, and that even they can vote only once, is necessary to demonstrate that elections are provably legitimate. For true lasting trust to be established all of these properties must be included in the system, but the priorities should give a rough idea on how much time should be spend on each property. A system built with security in mind will never lose voter trust because of a security breach, and good design will allow the system to gain a certain level of trust before the system is even implemented.

To prevent wasting time on building a system the faculty will never use, the general body of the faculty should approve proceeding with the project of building a new election system. To avoid ending up like the ill-fated previous attempt to move WPI faculty elections to an electronic system, Professor Kinicki recommends demonstrating faculty support for

the change with a vote. The most significant risk associated with the MQP is the potential for political issues to make completely functional software a total waste of time. The IQP team and Professor Kinicki believe that WPI faculty are ready to embrace electronic elections, though there may be some opposition. With that being said, if faculty support is taken for granted, the time and effort of the system designers will again have been wasted. Assuming that the faculty does approve a change to electronic voting, an MQP group (or other group of developers on campus) will have a lot of work to do.

With this IQP and its recommendations for faculty governance complete, the next step is handing off the project for an MQP team to build a system for elections. The process of establishing the project should begin with the COG. As the overseers of faculty governance, it is the duty of the COG to inform the faculty of any changes that may occur and it is within their power to call for a measure to be passed which changes the way that elections work. The next step would be finding one or more members of the faculty to serve as advisor(s) to the MQP team. Advisors to the MQP team would be responsible for finding students to participate in the MQP after the project gains approval from the general body of the faculty. Once students are located it will be their job to design a system based upon the evaluation criteria found in Chapter 5. Once this system is designed it will need approval from the COG before it is built. After the system is built and satisfactorily tested the MQP team will present their product to the COG and WPI Information Technologies so that it may be used.

7.2. Contingencies

In the event that an MQP is not possible, or the product of an MQP is not suitable, the evaluation criteria should lay the groundwork for finding another system. The recommendation that this paper provides may be the obvious way forward for faculty governance, but if that plan fails there should not be a need for another IQP. The team designed the evaluation criteria with the intention that they could be used to evaluate any election system worth consideration for WPI faculty elections. The system evaluations contained in the appendices demonstrate how systems can easily be identified as practical or not in this context. A viable alternative to the final recommendation is a modified version of the Helios software discussed earlier in the paper. Some modifications to this open source software could make it a very good option for WPI Faculty Governance.

Should local development be undesirable, the EBallot voting system offers a further option to investigate. EBallot is a commercial, cloud-hosted voting system that could be adapted to WPI's needs, but would require the company producing it to modify the system to use WPI's ballot counting algorithm. This could, depending on their backend systems, be fairly trivial or extremely involved. The team was not able to obtain pricing details for this system. It would be desirable to at least contact the company (VoteNet Solutions) about the possibility of adapting EBallot to WPI's needs, though the team feels that a locally developed solution would likely be a better fit for WPI.

7.3. Notes for Future Implementers

The team found three papers which are extremely useful to election designers; teams implementing a system in the future should read them carefully.

- Adida 2008 and 2009 papers on the Helios voting system's design and use. Helios is a modern voting system that contains many features desirable for a voting system for use at WPI.
- Volkamer's paper was a very detailed list of features and procedural details that can dramatically increase the trust users place in your system - the team highly recommend an MQP team act on Volkamer's suggestions to increase voter's confidence in any new systems.
- Consulting the people below should prove extremely useful to election designers.
- The customer for this project is the Committee on Governance; meeting with them early in the project and keeping them in the loop for major milestones will help ensure a successful system is produced.
- Penny Rock is the faculty governance coordinator - she is the person who will have to interact with any new system the most, and making things convenient for her to administer and use is very important.
- Professor Robert Kinicki led the implementation of a previous attempt at e-voting here, and he has unique knowledge of the technical and political challenges that will be encountered.

- It would be best to work with Professor Matthew Ward and Professor David Brown as much as possible when designing the user interface. They are experts in human computer interaction and ease of use is among the most important aspects of the project.
- Phil Deneault, the WPI Information Security officer, should be brought in twice during the project - once to get his input on the specification and once to have him test the final product. The approval of a trusted security professional will go a long way to increasing the electorate's trust in the system.
- Keep the CCC as involved in the project as they would like to be - they will ultimately have to maintain the system, and so should have input on how it is built.

Based on the findings of this project, the team has a few recommendations for any following projects.

- Emphasize good documentation over working code. A partially completed product with detailed instructions is far more useful to the faculty than an unmaintainable mess that the CCC cannot support.
- Use a bug tracker. The system will not be perfect at implementation, and all encountered bugs should not be forgotten after the implementers are gone. It's also excellent for distributing miscellaneous tasks like writing.

- Set firm dates for deliverables, as this project involves many components which must be completed in order to produce a successful system - missed deadlines will quickly snowball out of control.

7.4. Final Remarks

The current system for faculty elections at WPI has served the faculty well for almost fifteen years, but the benefits of change are too great to ignore. An electronic system for elections would save hundreds of hours of time for election organizers, it would save paper, it would be easier to access, and it would increase the ease of casting a valid ballot. Each of these advantages on its own might be a compelling reason for change, but the potential for all of them makes adoption of a new system seem inevitable. That is not to say, however, that changing faculty elections will be easy. The challenges that the designers and proponents of an electronic election system will face are great; but with careful consideration they are not insurmountable. The path to electronic elections is paved, and the direction to go is forward.

Works Cited

- Adida, Ben. "Helios: Web-based open-audit voting." In USENIX Security Symposium, vol. 17, pp. 335-348. USENIX Association, 2008.
- Adida, Ben, Olivier De Marneffe, Olivier Pereira, and Jean-Jacques Quisquater. "Electing a university president using open-audit voting: analysis of real-world use of Helios." In *Proceedings of the 2009 conference on Electronic voting technology/workshop on trustworthy elections*, pp. 10-10. USENIX Association, 2009.
- Barker, Eric A., and Areno Lijphart. "A crucial test of alphabetic voting: the elections at the University of Leiden, 1973–1978." *British Journal of Political Science* 10, no. 04 (1980): 521-525.
- Dreier, Jannik, Pascal Lafourcade, and Yassine Lakhnech. "Vote-independence: A powerful privacy notion for voting protocols." *Foundations and Practice of Security* (2012): 164-180.
- Endo, Tsukasa, Isao Echizen, and Hiroshi Yoshiura. "Electronic voting scheme to maintain anonymity in small-scale election by hiding the number of votes." In *Availability, Reliability and Security, 2008. ARES 08. Third International Conference on*, pp. 1287-1293. IEEE, 2008.
- Jefferson, David, Aviel D. Rubin, Barbara Simons, and David Wagner. "A security analysis of the secure electronic registration and voting experiment (SERVE)." *New York Times* (<http://www.servesecurityreport.org>) (2004).

- Juels, Ari, Dario Catalano, and Markus Jakobsson. "Coercion-resistant electronic elections." In *Proceedings of the 2005 ACM workshop on Privacy in the electronic society*, pp. 61-70. ACM, 2005.
- Morrell, Dan. "Secret Ballots, Verifiable Votes." *Harvard Magazine*, May-Jun2010, <http://harvardmagazine.com/2010/05/secret-ballots-verifiable-votes> (accessed February 25, 2013).
- Oostveen, Anne-Marie, and Peter Van Den Besselaar. "Trust, identity, and the effects of voting technologies on voting behavior." *Social Science Computer Review* 23, no. 3 (2005): 304-311.
- Oppliger, Rolf, Jörg Schwenk, and C. Lhr. "Captcha-based code voting." In 3rd International Conference on Electronic Voting. 2008.
- Sandler, Daniel Robert. *VoteBox: A tamper-evident, verifiable voting machine*. ProQuest, 2009.
- Tideman, Nicolaus. "The single transferable vote." *The Journal of Economic Perspectives* 9, no. 1 (1995): 27-38.
- Volkamer, Melanie, Oliver Spycher, and Eric Dubuis. "Measures to establish trust in internet voting." In *Proceedings of the 5th International Conference on Theory and Practice of Electronic Governance*, pp. 1-10. ACM, 2011.
- Xenakis, Alexandros, and Ann Macintosh. "Procedural security analysis of electronic voting." In *Proceedings of the 6th international conference on Electronic commerce*, pp. 541-546. ACM, 2004.

Appendix A. Survey of Faculty

Electronic Voting for Faculty Elections

WPI Faculty elections are currently conducted using an entirely paper based system that employs intra-campus mail as the main mechanism for casting ballots. With the knowledge and support of Secretary of the Faculty John Sullivan, our IQP group is exploring the advantages and disadvantages of moving faculty elections online. The purpose of this survey is to gather input so that our research can be tailored to the respective needs of the faculty. We are most interested in finding out what aspects of the issue are most important to you and becoming aware of any concerns that should be addressed in our report.

All questions in this survey refer only to the context of WPI faculty elections; they do not refer to national, municipal, or statewide elections.

Section I: Relevant Voter Background

1. How much do faculty elections matter to you?
 - Greatly
 - Somewhat
 - Not very much
 - Not at all
2. How often do you vote in faculty elections?
 - Every election
 - Most elections
 - Some elections
 - No elections)
3. How often have you not voted because it was inconvenient?

- Every election
- Most elections
- Some elections
- No elections

Section II: Electronic versus Paper Elections

Switching WPI elections to an online voting infrastructure, we would expect it to:

- Make it more convenient for faculty members to vote (possibly increasing voter turnout)
- Allow faculty members who are off campus (e.g. at a project center) to vote privately, and
- Greatly reduce the time and effort needed to determine the election results.

1. Do you agree that online voting would accomplish these results?
 - Yes, and I find them compelling reasons to switch.
 - Yes, but I do **not** want to switch because of these results.
 - No, but if online voting could accomplish these results I would be more inclined to switch.
 - No, and even if it did these results would **not** encourage me to switch.
2. Do you think an electronic voting system would be more, less, or equally likely to keep your vote private compared to the current voting system?
 - More
 - Less
 - Equally Likely
3. Do you think an electronic system would be more, less, or equally susceptible to tampering (malicious manipulation of the election process) than the current voting system?
 - More
 - Less
 - Equally Likely
4. How easy to use do you think an electronic system would be? Easier, harder, or the same as the existing system?
 - Easier
 - Harder
 - About the Same

Section III: Potential Concerns and Advantages around Electronic

Voting

1. How do you feel about moving faculty elections to an electronic system?
 - Strongly Support
 - Support
 - No Opinion
 - Oppose
 - Strongly Oppose
2. What features would you most like to see in an electronic voting system? (Checkboxes)
 - Ability to verify that your vote was counted correctly while maintaining privacy.
 - Requiring proof of identity in addition to WPI username and password when voting (Two Factor Authentication such as WPI ID number).
 - Additional Features: *<Optional Text Box for Additional Features>*
3. What concerns, if any, do you have about conducting faculty elections electronically?
 - The ability of a voter to vote multiple times
 - The public record of who has voted
 - Some voting systems feature safeguards to prevent would-be manipulators from coercing voters into voting in a specific way. Are you concerned about voter coercion in faculty elections?
 - Other concerns: *<Optional Text Box for Additional Concerns>*
4. Would you be more, less, or equally inclined to vote using an electronic system?
 - More
 - Less
 - Equally likely
5. Is there any circumstance or situation under which you would **not** vote electronically? (Text-box)
6. Similarly, are there any circumstances where you **would** prefer to vote electronically? (Text-box)

Section IV: Optional Information

We will be conducting interviews to gather more detailed information regarding this issue. **If** you would like us to interview you, you may **optionally** enter your WPI e-mail address below. Your e-mail address will be **removed** from your survey and stored in a separate database to keep your answers anonymous. (Text-field)

Appendix B. Faculty Interview Questions

Just like in the survey there were no forced responses. It was made clear that the interviewee could always choose to not answer a question. The bulleted questions represent follow-up questions. Individual interviews followed the flow of discussion; if it made more sense to ask questions in a different order, it was done so. If at all possible, all questions were asked. Interviews were conducted in pairs. One member of the interview team took detailed notes while the other performed the interview.

Questions:

- What do you like about the current voting system?
 - Do you think this would stay the same in a move to an electronic system?
- What don't you like about the current voting system?
 - Do you think this could be fixed by a move to an electronic system?
- Has there been a time you did not vote because the system was too inconvenient?
 - If so, can you tell us why it was inconvenient?
 - Do you believe an electronic voting system could prevent this from occurring again?
- What advantages do you see to moving faculty elections to an electronic system?
 - Do you find these advantages compelling reasons to switch, and Why?
 - **(If no:)** What would convince you of the merit of an electronic system?
- Have you ever used an electronic voting system before?
 - **(If so:)** What was your experience with it?
 - Are there things you wish that system could have done better?
- What concerns do you have about moving faculty elections to an electronic system?
 - What would cause you to oppose an electronic voting system?

- Are there a set of circumstances where you would not want to use an electronic voting system to vote?
 - How could the designers of the system help to mitigate these concerns?
- An example of a concern we received through the survey was losing important election emails among the many received daily.
 - Do you share this concern?
 - Do you believe having a paper reminder as well would mitigate this concern?
- Do you feel voter-coercion is a concern in the WPI faculty elections?
 - Our research suggests it is that is a bigger issue in smaller elections than many believe it to be (Endo et. al., 1287)
 - (If you do not mind telling us) In your experience, does voter coercion occur in WPI Faculty Elections?
- Are there any specific features you would like to see in a new voting system?
 - Are there any features that would make the system easier for you to use?
 - Are there any features you consider critical to the security of the system?
 - Would these features make you more likely to support/use the new system?
- How do you think an electronic voting system would be received by the faculty as a whole?

Appendix C-0. Scorecard for System Evaluation

Required

Criteria	Not Satisfied	Satisfied after changes	Satisfied
S: The system verifies the voter's identity and eligibility before a ballot is distributed or submitted.			
S: No person is easily able to gain identifiable information from the system about another person's vote. This includes WPI System Administrators and Election Officials; while a user may (or may not) see other votes, they cannot determine who was responsible for casting them			
S: The system takes reasonable measures to prevent any voter from casting a second vote.			
U: The user is able to cast a ballot without extensive training.			
I: The system must count votes in accordance with the method described in the WPI faculty handbook. This includes support for recounts.			
I: The team finds the cost of implementing and maintaining the system and running an election acceptable.			

Strongly Recommended

Criteria	Not Satisfied	Satisfied after changes	Satisfied
T: Complete source code and technical specifications for the system are freely available. It is possible to provide any voter or researcher who asks all the information needed to construct an exact replica of the system.			
S: The system limits its trust in the physical security of voter owned hardware.			
T: A brief summary of how the system works, understandable by nontechnical readers, is easily available for review by the public.			
U: For a voter experienced with both the current and proposed system, casting a ballot does not take more time than the current system.			
U: Voters are not required to install any new software on their personal computer beyond a supported web browser in order to vote.			
S: The system leverages other entities that the faculty already trusts to be secure (e.g. the WPI Central Authentication System).			
U: The system contains effective measures to prevent the voter from accidentally recording under-votes (absence of a candidate vote) and over-votes (voting for multiple candidates in the same election).			
I: Complete technical documentation for deployment and maintenance of the system is available.			
U: The voting interface clearly depicts to the user which candidates their vote will support in an attempt to mitigate mis-voting.			

Advantageous

Criteria	Not Satisfied	Satisfied after changes	Satisfied
S: The system does not provide a voter any information which he or she could use to prove his or her vote to an attacker (i.e. the voter receives no receipt).			
T: The system provides a way for voters to ensure that their vote was recorded and counted correctly (individual verifiability).			
T: The system enables voters to independently verify that all votes were recorded and counted correctly (universal verifiability).			
T: The system enables one to change one's vote after it is first cast (vote-updating).			
U: The system does not require the voter to remember information (e.g. codes) or carry a physical item in addition to what he or she already carries/remembers as a result of being a WPI faculty member.			
U: The system uses a proven method to mitigate the adverse impact of alphabetic voting on the election outcome.			
U: The system provides an interface that is usable for voting on smartphones and/or tablets.			
I: The system can perform an electronic recount of an election if a candidate is removed from the election.			
I: Technical support for the system is available by the producing company or a third party.			

Appendix C-1. Current System Evaluation

Required

Criteria	Not Satisfied	Satisfied after changes	Satisfied	Notes
S: The system verifies the voter's identity and eligibility before a ballot is distributed or submitted.			X	Ballots are distributed only to faculty members who can vote. As a caveat, if a faculty member who cannot vote acquires a ballot, they can submit it.
S: No person is easily able to gain identifiable information from the system about another person's vote. This includes WPI System Administrators and Election Officials; while a user may (or may not) see other votes, they cannot determine who was responsible for casting them			X	Efforts to gain the identity of on-campus voters would require significant effort. However, off-campus voters are notably denied privacy as they must submit their votes via email to the Secretary for Faculty Governance, compromising their privacy.
S: The system takes reasonable measures to prevent any voter from casting a second vote.			X	While any voter may photocopy their ballot, custom-printed envelopes are required for ballot submission, which should prevent the submission of more than 1 ballot.
U: The user is able to cast a ballot without extensive training.			X	Ballots are quite easy to fill out. As a caveat, one does need to read the directions to do so, and a

				number of incorrectly completed ballots are submitted each year.
I: The system must count votes in accordance with the method described in the WPI faculty handbook. This includes support for recounts.			X	The Secretary for Faculty Governance is responsible for counting ballots, and uses this system to do so.
I: The team finds the cost of implementing and maintaining the system and running an election acceptable.			X	The cost of the current election is minimal monetarily, but consumes a large amount of time for those responsible for counting the votes.

Strongly Recommended

Criteria	Not Satisfied	Satisfied after changes	Satisfied	Notes
T: Complete source code and technical specifications for the system are freely available. It is possible to provide any voter or researcher who asks all the information needed to construct an exact replica of the system.			X	The current system is described completely in the WPI faculty handbook.
S: The system limits its trust in the physical security of voter owned hardware.	X			Ballots do not authenticate their users, so if an unauthorized user obtained a ballot, they could successfully submit it.
T: A brief summary of how the system works, understandable by nontechnical readers, is easily available for review by the public.			X	The WPI Faculty Handbook summarizes the current system.
U: For a voter experienced with both the current and proposed system, casting a ballot does not take more time than the current system.			X	This is the current system, and by definition cannot take longer than itself.
U: Voters are not required to install any new software on their personal computer beyond a supported web browser in order to vote.			X	No computers are involved in the process.
S: The system leverages other			X	Uses faculty mailboxes

entities that the faculty already trusts to be secure (e.g. the WPI Central Authentication System).				and intra-campus mail.
U: The system contains effective measures to prevent the voter from accidentally recording under-votes (absence of a candidate vote) and over-votes (voting for multiple candidates in the same election).	X			There are no measures to ensure a ballot is filled in correctly, leading may lead to incorrect ballot submission.
I: Complete technical documentation for deployment and maintenance of the system is available.			X	The description in the handbook documents the complete process, though a number of rules (e.g. on nomination, and breaking ties) have been decided separately by the Committee on Governance.
U: The voting interface clearly depicts to the user which candidates their vote will support in an attempt to mitigate mis-voting.	X			There is no confirmation that a ballot has been filled in, and that it has been filled in correctly.

Advantageous

Criteria	Not Satisfied	Satisfied after changes	Satisfied	Notes
S: The system does not provide a voter any information which he or she could use to prove his or her vote to an attacker (i.e. the voter receives no receipt).			X	No receipt of voting is given.
T: The system provides a way for voters to ensure that their vote was recorded and counted correctly (individual verifiability).	X			No provision is made for this.
The system enables voters to independently verify that all votes were recorded and counted correctly (universal verifiability).	X			No provision is made for this.
T: The system enables one to change one's vote after it is first cast (vote-updating).	X			No provision is made for this.
U: The system does not require the voter to remember information (e.g. codes) or carry a physical item in addition to what he or she already carries/remembers as a result of being a WPI faculty member.			X	Nothing beyond the ballot is required to vote.
U: The system uses a proven method to mitigate the adverse impact of alphabetic voting on the election outcome.	X			Ballots are not randomized and sent out in multiple versions.
U: The system provides an interface that is usable for voting on smartphones and/or tablets.			X	Users are not tied to their computers, which is the spirit of this criterion.

I: The system can perform an electronic recount of an election if a candidate is removed from the election.	X			All counting is manual.
I: Technical support for the system is available by the producing company or a third party.	X			All support for the election is in-house.

Appendix C-2. Helios Evaluation

Required

Criteria	Not Satisfied	Satisfied after changes	Satisfied	Notes
S: The system verifies the voter's identity and eligibility before a ballot is distributed or submitted.			X	Provision is made for the authentication of voters through several means.
S: No person is easily able to gain identifiable information from the system about another person's vote. This includes WPI System Administrators and Election Officials; while a user may (or may not) see other votes, they cannot determine who was responsible for casting them	X			Ballot storage in Helios relies on the security of the database. Strong encryption guarantees the security of votes while they are being cast and sent to the server. That being said, those with access to the server could gain information on voters.
S: The system takes reasonable measures to prevent any voter from casting a second vote.			X	The Helios method is interesting in that anyone may submit any number of votes, but only the last one submitted is the only one counted - effectively, only one vote is cast.
U: The user is able to cast a ballot without extensive training.			X	The voting process is quite simple.
I: The system must count votes in accordance with the		X		Helios does not support ranked multiple winner

method described in the WPI faculty handbook. This includes support for recounts.				elections, but could support the current WPI system with (potentially extensive) modifications
I: The team finds the cost of implementing and maintaining the system and running an election acceptable.			X	Helios is open source, free software. It might require extensive modification time, however.

Strongly Recommended

Criteria	Not Satisfied	Satisfied after changes	Satisfied	Notes
T: Complete source code and technical specifications for the system are freely available. It is possible to provide any voter or researcher who asks all the information needed to construct an exact replica of the system.			X	Source code is licensed under the GNU GPL, and technical papers on the system are available.
S: The system limits its trust in the physical security of voter owned hardware.			X	Votes are encrypted on the client's machine, and the unencrypted results are removed from memory. However, there is no timeout on voting - this could be added easily, though.
T: A brief summary of how the system works, understandable by nontechnical readers, is easily available for review by the public.			X	Such a summary is available on the Helios website.
U: For a voter experienced with both the current and proposed system, casting a ballot does not take more time than the current system.	X			The submission process includes verification of the voter's selections and an encryption process, which lengthen the process.
U: Voters are not required to			X	Only a supported web

install any new software on their personal computer beyond a supported web browser in order to vote.				browser is required to vote.
S: The system leverages other entities that the faculty already trusts to be secure (e.g. the WPI Central Authentication System).			X	Helios supports OAuth, also supported by the WPI Central Authentication System.
U: The system contains effective measures to prevent the voter from accidentally recording under-votes (absence of a candidate vote) and over-votes (voting for multiple candidates in the same election).		X		The current implementation does not match WPI's vote optional criteria, but could be easily modified to do so.
I: Complete technical documentation for deployment and maintenance of the system is available.	X			While installation and maintenance documentation is available, it cannot be called complete.
U: The voting interface clearly depicts to the user which candidates their vote will support in an attempt to mitigate mis-voting.			X	Before encrypting their ballot, the voter is prompted to confirm who they wish to vote for.

Advantageous

Criteria	Not Satisfied	Satisfied after changes	Satisfied	Notes
S: The system does not provide a voter any information which he or she could use to prove his or her vote to an attacker (i.e. the voter receives no receipt).			X	While a voting receipt is provided, it only verifies that a vote has been counted, not who was voted for.
T: The system provides a way for voters to ensure that their vote was recorded and counted correctly (individual verifiability).			X	Individual voters can easily verify their votes were counted.
The system enables voters to independently verify that all votes were recorded and counted correctly (universal verifiability).			X	Helios is an open-audit system and provides this capability.
T: The system enables one to change one's vote after it is first cast (vote-updating).			X	Any number of ballots can be submitted, only the last one is counted.
U: The system does not require the voter to remember information (e.g. codes) or carry a physical item in addition to what he or she already carries/remembers as a result of being a WPI faculty member.			X	Nothing beyond the voter's WPI login would be required.
U: The system uses a proven method to mitigate the adverse impact of alphabetic voting on the election outcome.		X		Ballots are not randomized presently, but this is a trivial change.
U: The system provides an interface that is usable for voting on		X		A custom voting interface would

smartphones and/or tablets.				need to be developed.
I: The system can perform an electronic recount of an election if a candidate is removed from the election.		X		Could be added, but presently no provision is made.
I: Technical support for the system is available by the producing company or a third party.	X			No third party support is available for the system

Appendix C-3. Scantegrity Evaluation

Required

Criteria	Not Satisfied	Satisfied after changes	Satisfied	Notes
S: The system verifies the voter's identity and eligibility before a ballot is distributed or submitted.		X		Paper ballots. Provision could be made for this, but it is not inherent to the system.
S: No person is easily able to gain identifiable information from the system about another person's vote. This includes WPI System Administrators and Election Officials; while a user may (or may not) see other votes, they cannot determine who was responsible for casting them			X	Ballots contain no identifiable information beyond a serial number
S: The system takes reasonable measures to prevent any voter from casting a second vote.		X		No inherent provision in the system for protection against this, but provision could be made by methods similar to the current system
U: The user is able to cast a ballot without extensive training.	X			Requires demonstration of the completion process, at a minimum, to be used effectively.
I: The system must count votes in accordance with the method described in the WPI faculty		X		Counting system does not support ranked multiple winner, or

handbook. This includes support for recounts.				instant runoff counting. Changing this would require new vote-counting hardware.
I: The team finds the cost of implementing and maintaining the system and running an election acceptable.				Insufficient data. A custom ballot-counting machine and annual purchase of ballots would be required, cost unknown. Consultation with Scantegrity required.

Strongly Recommended

Criteria	Not Satisfied	Satisfied after changes	Satisfied	Notes
T: Complete source code and technical specifications for the system are freely available. It is possible to provide any voter or researcher who asks all the information needed to construct an exact replica of the system.			X	Source code and technical documentation are both freely available.
S: The system limits its trust in the physical security of voter owned hardware.	X			Physical security of the ballots is essential.
T: A brief summary of how the system works, understandable by nontechnical readers, is easily available for review by the public.			X	Description is available on Scantegrity's website.
U: For a voter experienced with both the current and proposed system, casting a ballot does not take more time than the current system.	X			Completion of a ballot with the additional step of recording voting codes is more time-consuming than the current system
U: Voters are not required to install any new software on their personal computer beyond a supported web browser in order to vote.			X	A special pen is required to vote, but no software is necessary. Vote verification is performed via web browser.
S: The system leverages other entities that the faculty already trusts to be secure	X			No authentication mechanism is included. The system could use

(e.g. the WPI Central Authentication System).				campus mail and WPI IDs to authenticate users.
U: The system contains effective measures to prevent the voter from accidentally recording under-votes (absence of a candidate vote) and over-votes (voting for multiple candidates in the same election).	X			The voter is not notified if their ballot is incorrect or incomplete. This is inherent to the system and cannot be changed.
I: Complete technical documentation for deployment and maintenance of the system is available.		X		Such documentation is not publicly available. However, it is presumably available from Scantegrity upon purchase of the system. This information could then be made available to voters.
U: The voting interface clearly depicts to the user which candidates their vote will support in an attempt to mitigate mis-voting.	X			No reminder of candidates being voted for is built into the system. This is not possible in paper systems.

Advantageous

Criteria	Not Satisfied	Satisfied after changes	Satisfied	Notes
S: The system does not provide a voter any information which he or she could use to prove his or her vote to an attacker (i.e. the voter receives no receipt).			X	While vote receipts are distributed, they contain no information that should tie a voter to the candidates they voted for.
T: The system provides a way for voters to ensure that their vote was recorded and counted correctly (individual verifiability).			X	Confirmation codes permit voters to confirm their vote was correctly recorded.
T: The system enables voters to independently verify that all votes were recorded and counted correctly (universal verifiability).			X	All steps performed to obtain the final winner can be independently reproduced to verify the result.
T: The system enables one to change one's vote after it is first cast (vote-updating).	X			No provision is made for this. It would be nontrivial to add.
U: The system does not require the voter to remember information (e.g. codes) or carry a physical item in addition to what he or she already carries/remembers as a result of being a WPI faculty member.	X			A vote receipt must be retained to audit one's vote, but this is not necessarily for simply casting a ballot. However, a special pen is required to place a vote.
U: The system uses a proven method to mitigate the adverse impact of alphabetic voting on the election outcome.	X			No provision is made in the system for this, but it could be added by providing multiple ballot forms but this

				would make counting difficult.
U: The system provides an interface that is usable for voting on smartphones and/or tablets.			X	As long as the special voting pen is present, voting can be conducted anywhere.
I: The system can perform an electronic recount of an election if a candidate is removed from the election.	X			To the best of our knowledge, no provision is provided for this.
I: Technical support for the system is available by the producing company or a third party.				Technical support for the system is presumably available from Scantegrity, but details are not publicly available.

Appendix C-4. EBallot Evaluation

Required

Criteria	Not Satisfied	Satisfied after changes	Satisfied	Notes
S: The system verifies the voter's identity and eligibility before a ballot is distributed or submitted.			X	Authentication is natively supported.
S: No person is easily able to gain identifiable information from the system about another person's vote. This includes WPI System Administrators and Election Officials; while a user may (or may not) see other votes, they cannot determine who was responsible for casting them			X	Ballots can be anonymous, or not anonymous, set at time of election creation.
S: The system takes reasonable measures to prevent any voter from casting a second vote.			X	Yes, such measures are taken.
U: The user is able to cast a ballot without extensive training.			X	Though a demo of the complete ballot completion process is not available (login to ballot submission), released screenshots appear simple enough
I: The system must count votes in accordance with the method described in the WPI		X		The system almost certainly does not count using WPI's unique instant

<p>faculty handbook. This includes support for recounts.</p>			<p>runoff system, and does not reveal what algorithm they actually use. It may be possible to convince the producing company to modify the product to include this algorithm.</p>
<p>I: The team finds the cost of implementing and maintaining the system and running an election acceptable.</p>			<p>Insufficient information to determine. Cost is likely high, but exact details are only available via consultation</p>

Strongly Recommended

Criteria	Not Satisfied	Satisfied after changes	Satisfied	Notes
T: Complete source code and technical specifications for the system are freely available. It is possible to provide any voter or researcher who asks all the information needed to construct an exact replica of the system.	X			No, closed-source and cloud-hosted product.
S: The system limits its trust in the physical security of voter owned hardware.				Information on this is either not publicly available, or only available via consultation.
T: A brief summary of how the system works, understandable by nontechnical readers, is easily available for review by the public.			X	Yes, marketing material is available on the product's website.
U: For a voter experienced with both the current and proposed system, casting a ballot does not take more time than the current system.			X	Difficult to say as complete process is not available as a demo, but appears to not take particularly long.
U: Voters are not required to install any new software on their personal computer beyond a supported web browser in order to vote.			X	Only requires a supported browser
S: The system leverages other entities that the faculty already trusts to be secure (e.g. the WPI Central		X		No documentation on whether WPI CAS and EBallot's authentication are presently

Authentication System).				compatible, but support could be added by producing company.
U: The system contains effective measures to prevent the voter from accidentally recording under-votes (absence of a candidate vote) and over-votes (voting for multiple candidates in the same election).				No information available on this part of the voting process
I: Complete technical documentation for deployment and maintenance of the system is available.	X			No, cloud hosted system - documentation neither available nor required.
U: The voting interface clearly depicts to the user which candidates their vote will support in an attempt to mitigate mis-voting.				No information available on this part of the voting process

Advantageous

Criteria	Not Satisfied	Satisfied after changes	Satisfied	Notes
S: The system does not provide a voter any information which he or she could use to prove his or her vote to an attacker (i.e. the voter receives no receipt).		X		Receipts are distributed by default, but it would likely be trivial for the company to disable them.
T: The system provides a way for voters to ensure that their vote was recorded and counted correctly (individual verifiability).	X			No provision
The system enables voters to independently verify that all votes were recorded and counted correctly (universal verifiability).	X			No provision
T: The system enables one to change one's vote after it is first cast (vote-updating).	X			No provision
U: The system does not require the voter to remember information (e.g. codes) or carry a physical item in addition to what he or she already carries/remembers as a result of being a WPI faculty member.			X	Administrators need a code to perform administrative actions, but this is not required of ordinary voters
U: The system uses a proven method to mitigate the adverse impact of alphabetic voting on the election outcome.		X		Not included by default, but likely would be trivial to implement
U: The system provides an			X	Yes, standard feature

interface that is usable for voting on smartphones and/or tablets.				
I: The system can perform an electronic recount of an election if a candidate is removed from the election.	X			No, no provision
I: Technical support for the system is available by the producing company or a third party.			X	Yes, cloud-hosted - support is provided by producing company.

Appendix C-5. SurveyMonkey Evaluation

Required

Criteria	Not Satisfied	Satisfied after changes	Satisfied	Notes
S: The system verifies the voter's identity and eligibility before a ballot is distributed or submitted.			X	There is provision for authentication, but it requires custom coding in the survey.
S: No person is easily able to gain identifiable information from the system about another person's vote. This includes WPI System Administrators and Election Officials; while a user may (or may not) see other votes, they cannot determine who was responsible for casting them			X	SurveyMonkey is an anonymous survey system
S: The system takes reasonable measures to prevent any voter from casting a second vote.			X	SurveyMonkey has provisions to prevent one computer from voting twice. It is unknown whether this will prevent users from voting twice on different computers, however.
U: The user is able to cast a ballot without extensive training.			X	Simple, standard survey system which is commonly used at WPI.
I: The system must count votes in accordance with the method described in the WPI faculty handbook. This includes		X		No provision for tallying ballots by ANY system, but the ballots themselves can be

support for recounts.				downloaded. Thus, an external program could be written to tally.
I: The team finds the cost of implementing and maintaining the system and running an election acceptable.			X	Professional version of system is very affordable, priced so individuals can purchase.

Strongly Recommended

Criteria	Not Satisfied	Satisfied after changes	Satisfied	Notes
T: Complete source code and technical specifications for the system are freely available. It is possible to provide any voter or researcher who asks all the information needed to construct an exact replica of the system.	X			Closed source, cloud hosted system
S: The system limits its trust in the physical security of voter owned hardware.	X			No timeouts or other measures
T: A brief summary of how the system works, understandable by nontechnical readers, is easily available for review by the public.			X	Very commonly used and documented systems
U: For a voter experienced with both the current and proposed system, casting a ballot does not take more time than the current system.			X	Very simple to complete surveys

U: Voters are not required to install any new software on their personal computer beyond a supported web browser in order to vote.			X	No additional software required
S: The system leverages other entities that the faculty already trusts to be secure (e.g. the WPI Central Authentication System).			X	CAS integration could potentially be achieved as both systems support OAuth, but this is untested at this time.
U: The system contains effective measures to prevent the voter from accidentally recording under-votes (absence of a candidate vote) and over-votes (voting for multiple candidates in the same election).	X			SurveyMonkey was designed for surveys, where no response or an incomplete response is perfectly acceptable, and consequently does not notify on these situations.
I: Complete technical documentation for deployment and maintenance of the system is available.	X			Neither available nor required, given this system is cloud-hosted
U: The voting interface clearly depicts to the user which candidates their vote will support in an attempt to mitigate mis-voting.	X			No provision, surveys are meant to gauge opinion in most cases.

Advantageous

Criteria	Not Satisfied	Satisfied after changes	Satisfied	Notes
S: The system does not provide a voter any information which he or she could use to prove his or her vote to an attacker (i.e. the voter receives no receipt).			X	No receipt is distributed as surveys are meant to be anonymous
T: The system provides a way for voters to ensure that their vote was recorded and counted correctly (individual verifiability).	X			No provision
The system enables voters to independently verify that all votes were recorded and counted correctly (universal verifiability).	X			No provision
T: The system enables one to change one's vote after it is first cast (vote-updating).	X			No provision
U: The system does not require the voter to remember information (e.g. codes) or carry a physical item in addition to what he or she already carries/remembers as a result of being a WPI faculty member.			X	No additional authentication requirements.
U: The system uses a proven method to mitigate the adverse impact of alphabetic voting on the election outcome.			X	Randomization of option ordering available by standard.
U: The system provides an interface that is usable for voting on smartphones and/or tablets.			X	Usable mobile interface is standard.
I: The system can perform an	X			No provision for

electronic recount of an election if a candidate is removed from the election.				counting, nevermind recounting.
I: Technical support for the system is available by the producing company or a third party.			X	Technical support is available from the producing company.