



ELECTION SCIENCE: A PROPOSED NSF CONVERGENCE ACCELERATOR

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EXECUTIVE SUMMARY

“National-scale societal challenges cannot be solved in a single discipline. Instead, these challenges require convergence to merge ideas, approaches, and technologies from a wide range of diverse sectors, disciplines, and experts.”¹

Ensuring that elections throughout the United States are convenient, trustworthy, and secure is one of the nation’s most compelling challenges. Designing systems, procedures, policies, and technologies to meet these challenges inherently requires marshaling expertise, skills, and perspective from diverse and multiple sectors. The National Science Foundation (NSF) Convergence Accelerator (C-Accel) program provides a natural environment to nurture multidisciplinary teams to address many challenges currently facing American elections.

Election science is a multidisciplinary field that utilizes principles of social science, natural science, mathematics, design, and engineering to analyze the performance of election systems and develop ways to make elections convenient, trustworthy, and secure. The following premises of election science frame successful efforts at improving elections.

1. Ensuring that elections are convenient, secure, and accessible requires conceptualizing the components of election technologies and administration as interdependent systems.
2. Included in these interdependent election systems are *the people* who manage and implement the system; *the technologies* that manage eligibility, record and tabulate votes, and communicate the results; and *the policies and processes* that tie the system together.

This ecological perspective helps to highlight the complexity and multidisciplinary nature of election science. Unlike many of the scientific domains that the NSF typically supports, election science requires the close collaboration of academics of different disciplines and methodological perspectives, as well as public officials and the private sector.

The Principal Investigator (PI) Committee brought together over 110 state and local election administrators, election technology providers, scientists, technologists, federal officials, and policy experts representing a broad cross-section of the U.S. elections community to participate in a professionally-facilitated, four-day, 16-hour, virtual workshop series. Through these highly interactive gatherings, participants provided detailed input into challenges facing elections and potential solutions to these challenges.

¹ U.S. National Science Foundation, “NSF Convergence Accelerator,” <https://www.nsf.gov/od/oia/convergence-accelerator/>.

Participants applied their expertise to identify specific areas of important research that had developed to the point that they could benefit specifically from the discipline of the C-Accel program.

After reviewing the voluminous, thoughtful work product generated by workshop participants, the PI Committee offers fourteen challenges to election administration that would benefit from investment by the C-Accel program. Each is likely to attract several multidisciplinary teams that will propose tangible, deployable approaches to address these challenges within the program's time horizon.

1. Evaluating Tools for Election Administration
2. Ensuring Usability within the Voting Experience
3. Improving Access to Voting
4. Communicating Effectively with the Electorate
5. Detecting Anomalies in Election Management Systems
6. Sharing Election Results for Research, Dissemination, and Anomaly Detection
7. Visualizing Election Data
8. Enhancing Voter Identity Verification
9. Securing Electronic Ballot Delivery & Return
10. Implementing End-to-End Verifiability
11. Improving Cybersecurity for Election Administration
12. Managing Election Geography
13. Promoting Sustainable and Scalable Sharing of Election Technology
14. Developing Next-Generation Voting Technologies

Through the C-Accel program, the NSF has the opportunity to challenge the election science community to focus its efforts over the next few years on making tangible prog-

ress toward translating exciting fundamental and applied research into action. In addition, the NSF has opportunities through its more traditional grant programs to help foster election science research that will pay dividends in the future. With some exceptions, the research done over the past two decades that provides some frameworks for addressing the challenges identified in this report was supported by foundations, private philanthropy, nonprofits, state and local governments, and individual colleges and universities, *but not necessarily the federal government.*

Support from the NSF Convergence Accelerator program can fuel essential and innovative research to solve the fourteen election sciences challenges identified in this report in a few years. But there exist other critical basic, applied, and translational research questions that need study and resolution that reach beyond these fourteen election science challenges. Thus, the NSF, working in partnership with other federal agencies, has a vital role in providing the resources to encourage ongoing fundamental, applied, and translational research in election science.

ELECTION SCIENCE: A PROPOSED NSF CONVERGENCE ACCELERATOR

Ensuring that elections are trustworthy and secure is one of the most compelling challenges facing the United States. The 2020 presidential general election, the first nationwide election conducted during a raging pandemic in recent history, produced a wave of innovations in the administration and conduct of elections across and within the states. Unfortunately, it also produced a significant number of false rumors and misinformation about the integrity of the election, saw state and local election officials come under social media and personal attack, and of course, culminated in the U.S. Capitol riot on January 6, 2021.

Improving the technology and administration of U.S. elections is a critical research priority but is not an activity that any single academic discipline can tackle alone. The complexity of American election administration, viewed at the macro and micro levels, requires that significant problems be addressed in a multidisciplinary, broadly inclusive way, involving academic researchers and election officials, stakeholders, and technology providers, to name a few.

Thus, the crucial importance of elections in the United States, their complexity, the inadequacies of some current practices, and the need for multidisciplinary perspectives on administrative and technological innovation make election science an ideal topic to solicit crosscutting teams to benefit from the National Science Foundation's Convergence Accelerator (C-Accel) program. There

is an array of critical challenges that can be rapidly accelerated with resources from the NSF; these challenges can only be resolved with the focused attention of convergent multidisciplinary research teams.

This report is based on four innovative and interactive workshops organized by the PI Committee in April and May 2021. Building on prior work by the PIs and other researchers, workshop discussions were organized around four umbrella research themes which grouped topics that have been the subject of election science research for at least two decades: (1) humans and voting machines, (2) outreach and information, (3) security, and (4) technology. The ultimate goal behind all of this research, as discussed in the workshop proposal, is to build election confidence, defined as scientific or empirical certainty that the elections were performed accurately and securely and that winners identified, in fact, received more votes than the losers and that the election was conducted fairly.

The PI Committee initially identified the following two overarching premises of election science as characterizing successful efforts at improving elections through the application of election science:

1. Ensuring that elections are convenient, secure, and accessible requires conceptualizing the components of election technologies and administration as interdependent systems.

2. Included in these interdependent election systems are *the people* who manage and implement the system; *the technologies* that manage eligibility, record and tabulate votes, and communicate the results; and *the policies and processes* that tie the system together.

The activity of election science is inherently convergent. Election science requires the coordination of mindsets and methodologies derived from a broad set of disciplines: management science, law, education, communication, economics, public administration, and information technology. It requires researchers who are adept at using in-depth and qualitative methodologies, as well as those who approach election science from a quantitative perspective. Many areas of election science require multimodal research approaches and research teams that can utilize both data and thick description.

Election science is complex because the processes of conducting elections are complicated and decentralized. Since election administration is highly decentralized and the typical election office is small, often composed of no more than two or three permanent staff, a local election official must personally wear many hats.² These persons may not possess degrees, or if they do, they

may not be in management, public administration, or allied fields such as computer science or information security. Delegation to staff is not always an option. In large metropolitan election offices, where most voters live, it may be possible for the local election director to delegate responsibilities to staff that specialize in administration, election law, training, outreach, and computer systems. Nonetheless, whether a local election office is small or large, a successful election requires integrating multiple systems, technologies, and perspectives to serve a diverse electorate.

Among the competencies that must be utilized for the successful conduct of an election are the following:

- » Contract Administration
- » Project Management
- » Federal & State Election Law
- » Finance and Budgeting
- » Real Estate Management
- » Site Selection
- » Americans with Disabilities Act (ADA)
- » Physical Security
- » Cybersecurity
- » Information Technology
- » Process Improvement
- » Data Analysis
- » Geographic Information Systems
- » Public Relations / Media Relations / Crisis Communications
- » Human Resources and Staffing
- » Community Outreach
- » Language Access
- » Training Development and Management
- » Logistics and Supply Chain Management
- » Shipping and Receiving
- » Auditing
- » User Experience/Human-Computer Interaction

²The 2020 Democracy Fund/Reed College Survey of Local Election Officials found that less than half of local officials had a college degree. Only 45 percent make more than \$50,000 a year. Three-quarters of jurisdictions serving more than 5,000 registered voters have only one staff member working in the elections office; 25 percent of jurisdictions serving between 5,000 and 25,000 voters have only one elections staffer. In the largest jurisdictions, by contrast, almost 85 percent of election offices have 10 or more staff members, and many have more than 50. See Reed College Early Voting Information Center, “The Democracy Fund/Reed College Survey of Local Election Officials,” <https://evic.reed.edu/leo-survey-summary/>.

Contrary to prevailing thought, conducting an election is not undertaken in a matter of days or weeks. Preparation occurs across many months, requiring the application of specialized skills, proficiencies, and responsibilities. Voter registration takes place year-round. Preparing equipment and personnel for an election begins months before the event itself.

In fact, the term “Election Day” is a misnomer. Voting today can spread out across weeks. Voters avail themselves of multiple modes of voting — in-person early voting, absentee voting, voting by mail, curbside voting, drive-through voting, and military and overseas voting. After Election Day, officials process ballots, tabulate votes, and aggregate the results right up to the official canvass. Canvassing entails confirming every valid ballot cast and counted.³ Increasingly, elections are audited, either as a part of the canvass or later on, to improve the voting process.

Despite all of these complexities of election administration, the inherently multidimensional nature of election science has periodically fostered interdisciplinary efforts to improve the voting experience, improve the accuracy of tabulation, and secure the process against malicious attacks and errors. Examples include collaborations between data scientists and information technology practitioners to uncover anomalies in voter registration databases; between operations researchers and political scientists to improve the flow of voters through polling places; between computer scientists and designers to decrease voter errors; between

data scientists and demographers to uncover the misassignment of voters to polling places; and between survey researchers and communications specialists to ensure that voters do not fall prey to misinformation about the election process.

By necessity, collaborations such as these cannot be effective if they involve only scientists and engineers working alone, even if the innovation itself is multidisciplinary. For example, when they have been effective in improving elections, it has only been because scientists and technologists have worked as partners with the officials responsible for the conduct of elections. Election science should not be conducted in an ivory tower to be effective at improving the conduct of elections. Researchers need to collaborate with election officials to take advantage of their expertise, obtain crucial information and data, and have the ability to directly observe the complexities of administrative practices and technologies. Furthermore, election scientists must communicate the results of their research to election officials in terms that election officials can use when they need to conduct an election.

Multidisciplinary collaborations that have sprung up over the past two decades to improve the electoral process have been episodic. However, the importance of elections to the quality of American democracy often dwarfs the infrastructural capacity of American election administration to innovate in times of institutional strain. The discipline and resources marshaled through the NSF C-Accel program would boost institutional capacity so that the national response to the current challenges to American election administration match the importance of the task.

³ U.S. Election Assistance Commission, “Canvassing and Certifying an Election,” Election Management Guidelines, 2010, chap. 13, https://www.eac.gov/sites/default/files/eac_assets/1/6/EMG_chapt_13_august_26_2010.pdf.

THE ELECTION ECOSYSTEM AS A CONVERGENT SPACE

The NSF has identified convergence research as a means for solving complex societal problems. “It entails integrating knowledge, methods, and expertise from different disciplines and forming novel frameworks to catalyze scientific discovery and innovation. Convergence research is related to other forms of research that span disciplines — *transdisciplinarity, interdisciplinarity, and multidisciplinarity*.”⁴

A statement like this can easily be thought of as pertaining to scientists and engineers whose everyday business is fundamental or translational research. However, it has a special meaning in the area of elections. At a minimum, scientific and engineering innovation cannot be successfully implemented without the active cooperation of election administrators. As already noted, those administrators wear many hats and themselves personify multidisciplinarity. Furthermore, to be effective, innovations must respond to the needs of voters across all segments of society.

Thus, the elections ecosystem is a convergent space that involves scientists, technologists, administrators, and citizens in activities to improve elections. While it is evident that no single individual or organization possesses all the necessary depth or breadth of expertise in all of the above areas of election administration to improve it comprehensively, a less obvious thing is

⁴U.S. National Science Foundation, “Convergence Research at NSF,” <https://www.nsf.gov/od/oia/convergence/index.jsp>.

also true: even “small” parts of the ecosystem invoke multiple perspectives, experiences, and competencies. Even if we talk about the entire elections system or any component of it, cooperation is necessary.

In the context of the need for cooperation to achieve improvements in election administration, numerous organizations have arisen over the past two decades that have taken responsibility for improving elections in the United States. Members of these organizations have played significant leadership roles in innovation and dissemination. Organizations and individuals such as these would be involved in any convergence accelerator activity that tackled a specific challenge faced by the system. We have grouped representative organizations into seven categories, noting that this is not an exhaustive list.

1. State and Local Election Officials & Associations of Practitioners.

State and local jurisdictions bear responsibility for the actual conduct of elections; any innovation must involve them as partners. Election jurisdictions vary along numerous dimensions — size, rurality, population demographics, and whether officials are elected or appointed.

Individual jurisdictions have been known to partner with academic researchers to harness technology to improve elections. Notable examples include, but are not limited to, the Los Angeles County, California

Registrar-Recorder/County Clerk Voting Solutions for All People (VSAP); Travis County Clerk, Texas (STAR-Vote); Orange County, California, Registrar of Voters; Douglas County, Nebraska, Douglas County Election Commission; Oregon Secretary of State; Washington Secretary of State (voter file integrity assessment); Rhode Island Board of Elections; Virginia Department of Elections (polling place line management); City of Tacoma Park, Maryland (Scantegrity voting system software pilot); and the New Mexico Secretary of State (election auditing and integrity research).

State and local election officials form themselves into associations, which occasionally serve as partners to spur innovation, but more often serve as a conduit to diffuse innovation among their members. The peak associations of statewide officials are the National Association of Secretaries of State (NASS) and the National Association of State Election Directors (NASED). The Electronic Registration Information Center (ERIC) is a membership organization composed of state election departments. National associations of local officials include the International Association of Government Officials (IGO) and the National Association of Election Officials (The Election Center). In addition, almost every state has an association of election officials who partner together to promote innovations, such as the California Association of Clerks and Election Officials (CACEO), Florida Supervisors of Elections (FSE), and Voter Registrars Association of Virginia (VRAV).

2. Members of Academic Disciplines.

Individual scholars have long been involved in doing research, alone and in collaboration, to improve the practice of elections. Increasingly, this research is done in collab-

oration with election officials, either to advance fundamental science or to translate fundamental research into practice. The individuals are too numerous to mention and come from the following disciplines, among others: communications, computer science and engineering, cybersecurity, data science, design, education, industrial and systems engineering, law, management science, mathematics, political science, public administration, social psychology, statistics, and usability. In addition, universities, notably Auburn University and the University of Minnesota, sponsor academic degree and certification programs to enhance the professionalization of election administration and translate disciplinary innovations into practice.

3. Academic Research Organizations.

These organizations, typically associated with universities, assemble teams of faculty, research scientists, graduate students, and undergraduates to conduct fundamental research in election science. At the core of these organizations is building partnerships between university researchers and election practitioners to improve election administration. They include the Auburn University Graduate Program in Election Administration; Ball State University Voting System Technical Oversight Program (VSTOP); Brigham Young University Center for the Study of Elections and Democracy (CSED); Caltech/MIT Voting Technology Project (VTP); MIT Computer Science and Artificial Intelligence Laboratory (CSAIL); MIT Elections Data and Science Lab (MEDSL); New York University Brennan Center for Justice; Princeton Election Consortium; Reed College Early Voting Information Center (EVIC); Stanford Internet Observatory; Tufts University Metric Geometry & Gerrymandering Group

(MGGG Redistricting Lab); University of Connecticut Center for Voting Technology Research (VoTeR Center); University of Florida U.S. Elections Project; University of Rhode Island Voter Operations and Election Systems (URI VOTES); University of New Mexico Center for the Study of Voting, Elections, and Democracy (C-SVED); University of Pennsylvania Penn Program on Opinion Research and Election Studies (PORES); University of Wisconsin Elections Research Center; University of Southern California Center for Inclusive Democracy; and University of Southern California Schwarzenegger Institute for State and Global Policy.

4. Federal Departments & Agencies.

Although election administration is primarily a state and local responsibility, federal agencies often partner with states and localities. In addition, many of these agencies have promoted innovation in this area, often by convening experts and funding research. Among the most prominent of these agencies are the U.S. Election Assistance Commission (EAC); U.S. Department of Defense Federal Voting Assistance Program (FVAP); U.S. Postal Service (USPS); National Institute of Standards and Technology (NIST); U.S. Access Board; National Science Foundation (NSF); and U.S. Department of Homeland Security Cybersecurity and Infrastructure Security Agency (CISA).

5. Technology & Service Providers.

The private sector has an important role to play in the administration of elections in the United States. Most visibly, technology providers supply voting equipment, such as voting machines, ballot scanners, and electronic poll books, that is indispensable to elections. Less visibly, technology providers often supply services to election officials to

manage the complexity of conducting elections and service the technologies that jurisdictions have bought or leased.

It is widely recognized that the small number of providers who supply the bulk of election systems inherently limits the scope and pace of innovation in this area and increases costs compared to other areas of business practice. Nonetheless, existing technology providers will, in many cases, be natural partners in innovation. In other cases, new technology companies are regularly emerging to fill the niches that exist. Legacy and emerging providers of voting systems and other election technology solutions include BPro, Inc.; Clear Ballot Group, Inc.; Democracy Live, Inc.; Dominion Voting Systems Corp.; Election Systems & Software (ES&S); Enhanced Voting; Hart InterCivic, Inc.; K&H; KNOWiNK, LLC; Runbeck Election Services, Inc.; Smartmatic; Tenex Software Solutions; Unisyn Voting Solutions; VOTEC Corporation; VR Systems, LLC.; Scytl; Voatz; and Voting-Works.

An essential source of technological capacity is located in companies that specialize in geographic data and applications. For example, companies with a notable presence in election administration are Caliper Corporation, Esri, Google, and Mapbox.

The complexity of management challenges has resulted in the recent emergence of institutes and small start-up management groups with expertise in election administration. These groups can arbitrage between different technology approaches and bridge the knowledge gap of election officials that arises because of geographic isolation. Among these institutions are Brady Analytics, LLC; Center for Civic Design (CCD); Center for Election Innovation

and Research (CEIR); CyberDefenses, Inc. Democracy Research, LLC; The Elections Group; Lafayette Group; Magenta Sage Strategies, LLC; National Vote at Home Institute (NVAHI); and The Turnout, LLC.

Although large technology firms have historically been shy to enter the voting technology market, Microsoft has been an exception to a limited degree. Instead, social media and search firms have been more engaged. Google, Facebook, Twitter, and other technology leaders have worked with election offices to boost official election pages, created ways to flag misinformation, provided programs to promote voter registration efforts, supported the Voting Information Project (VIP), and have provided direct financial support through grant programs.

6. Civic Technology Providers and Non-Governmental Organizations (NGOs).

Not surprisingly, there is a large, active ecosystem of citizen groups who concern themselves with all aspects of elections. Within this extensive collection of groups, a small subset is devoted to the improvement of election administration. Civic technology providers often serve as the point of translation between technological innovations in academia and the private sector, on the one hand, and election administrators, on the other. Thus, they have dual competencies in election administration and technology. Among these groups are the Center for Tech & Civic Life (CTCL), Democracy Works, and VoteShield.

A set of non-governmental organizations consists of state and local governments whose responsibilities include elections and whose missions extend well past elections.

These groups serve important convening and innovation-diffusion functions and include the National Association of State Chief Information Officers (NASCIO), National Conference of State Legislatures (NCSL), The Council of State Governments (CSG), and the National States Geographical Information Council (NSGIC).

Professional associations, as well, have occasionally weighed in to lend expertise to efforts to improve election administration. Among these are the American Association of Geographers, American Institute of Architects (AIA), Institute for Industrial & Systems Engineers (IISE), and Institute for Operations Research and the Management Sciences (INFORMS).

Finally, membership and advocacy groups have played an important role in advocating for access to the elections process and technological innovations to facilitate that access. Among these groups are the National Coalition for Accessible Voting (NCAV), National Council on Independent Living (NCIL), and National Disability Rights Network (NDRN).

7. Other Stakeholders.

The election reform ecosystem has benefited from the support of a variety of other organizations, primarily foundations, that have not only provided funding for interdisciplinary innovation in election administration but have served as matchmakers between practitioners and scientists working in the field. Among these organizations are the Carnegie Corporation; Democracy Fund; German Marshall Fund of the United States; William and Flora Hewlett Foundation; Joyce Foundation; Knight Foundation; Newmark Philanthropies; and the Pew Charitable Trusts.

THE ELECTION ECOSYSTEM AS A CONVERGENT SPACE

No one person or organization, in isolation, can solve the complexity that is American election administration, but in alignment with the NSF C-Accel's mission, a collaborative, convergent community working together can. In one way or another, these individuals and organizations have all participated in the betterment of the United States voting experience. It is not an exhaustive list, and, of course, the C-Accel program provides the opportunity for even other organizations and individuals to become involved.



ASCERTAINING OPPORTUNITIES FOR CONVERGENCE AND ACCELERATION

The NSF Convergence Accelerator Workshop for Election Science was planned by the PI Committee during April and May 2021. The goal was to provide a blueprint for translating the many years of scientific discovery, applied research, and academic-practitioner collaboration into an agenda that would result in U.S. elections being more secure, accurate, and trustworthy. Despite its national importance, the larger election ecosystem is fragmented, under-financed, and facing an increasingly hostile environment, thus requiring significant collaboration.

Experts representing a variety of fields integral to the conduct and study of U.S. elections participated in four virtual half-day workshop sessions led by a team of professional facilitators from Knowinnovation, Inc. (KI). The sessions were highly interactive, and participants provided detailed input into the subjects covered in the sessions.

Over 110 leaders and practitioners representing a broad cross-section of the U.S. elections community — state and local election administrators, election technology providers, scientists, technologists, federal officials, and policy experts — responded to the invitation. All participants attended at least one of the four sessions, with the majority participating in all four.⁵ This is quite remarkable for a virtual event and unparal-

leled for the election community, especially considering that these very busy individuals were asked to donate significant time, energy, and ideas. Post-workshop series feedback indicated that individuals participated in order to help advance election science by sharing their understanding of needs in both election practices and technologies. Several participants spontaneously expressed a desire to have similar events in the future, beyond the C-Accel program.

The four workshops were sequenced to narrow down a set of topics, starting with a long list of areas that could benefit from further research in election science, eventually narrowing them down to a smaller set of ripe challenges for convergence and acceleration. The beginning list of twenty research areas was identified by the PIs and is included in Appendix II.

The Session 1 workshop invited attendees to review the twenty areas and give feedback about whether they would be ripe for convergence and acceleration. Attendees were also prompted to suggest other areas that might be added. To seed the moderated discussions about promising research areas, workshop participants viewed pre-recorded video interviews with seven diverse election officials, who reflected on election administration challenges from their perspective and the opportunities for research. The workshop session itself led off with a moderated discussion among these

⁵See Appendix I

administrators that explored issues raised in the interviews. The rest of the session was structured to allow participants to give feedback about the organization of the remaining workshop sessions.

Sessions 2 and 3 were organized to challenge participants to apply their expertise to distinguishing between research areas that were important for the improvement of elections and those that, in addition to their importance, were also developed to the point that they could benefit specifically from the discipline of the C-Accel program. To help focus expertise, topics were grouped into four focused themes: (1) humans and voting machines, (2) outreach and information, (3) security, and (4) technology. Two groups were formed to consider each of the four themes. This means that much of the work of testing and refining ideas occurred in groups of between six and twelve individuals who could use the online collaboration platform provided by KI (termed “KISTorm”) to engage in productive conversations.

Each of the smaller working groups was asked to make a pitch to the larger plenary at the end of Session 3 about one or two challenges that, in their opinion, would most benefit from attention in the C-Accel program. The pitch template required the groups to be specific about current research and collaborative activities. In addition, they were asked to give evidence that these challenges were critical national problems, were inherently multidisciplinary, and had reached a level of development so that an investment by the NSF would plausibly yield results within the time parameters of the C-Accel program. While the pitches were being made, questions, concerns, and suggestions were addressed to each of the

pitches through KISTorm. All of this material was reviewed by the PI committee.

After Session 3, the PI Committee reviewed the pitches, the responses, and the material generated at the other two sessions. They synthesized this material into a presentation given at Session 4 that constituted a report back to the participants about the progress of the workshops. These presentations provoked feedback from participants, which was also captured on the KISTorm platform.

After reviewing the feedback from Session 4 along with all the other materials generated at the preceding sessions, the PI Committee offers the following fourteen challenges to election administration as likely to benefit from investment with the C-Accel program. By that, we mean that each challenge is critical to the security, convenience, and trustworthiness of elections. Moreover, each is likely to attract several multidisciplinary teams that will propose tangible, deployable approaches to address these challenges within the program’s time horizon.

ELECTION SCIENCE CHALLENGES RIPE FOR CONVERGENCE AND ACCELERATION

CHALLENGE 1: EVALUATING TOOLS FOR ELECTION ADMINISTRATION

With shifting landscapes and increasing voter participation, the election community needs evidence-based tools to respond to current and future challenges for in-person voting. Various tools have been made available in the last several decades to support election administrators with data-driven decisions (e.g., locating polling locations, performing resource allocations). However, despite their availability, the promotion and adoption of these tools is limited. At present, there is no method of evaluating these tools, making it challenging to identify which technologically-based tools are being used and those that remain under-utilized.

The design, transparency, and evaluation of the voter's experience with these tools is both an area for acceleration and convergence. Each tool should be evaluated, their success measured, and feedback provided so that designers and toolmakers can make improvements. It is standard to review and improve processes within election administration, yet there appears to be no method for tools developed for election administrator use. How accessible these tools are for all different types of services directly impacts their feasibility and utility; therefore, clarity is needed concerning whether cost, level of data, training, and experience are required or optional to use these tools. While most of these tools are open source to

a degree, their scalability to communities/jurisdictions of all sizes or even to different types of voting systems is either not generalizable or applicable. The development of evaluation and measurement methods is critical in adopting equitable, scalable, and accessible tools for election planning.

An immediate opportunity for acceleration is encouraging the transformation of tools made in response to the particular challenges of recent elections to more permanent, inclusive, and generalizable resources. Concurrently, these current voter-impacting tools should be reviewed and evaluated for their effectiveness and the successes and challenges of implementation for election officials. Tool assessment can assist in their iterative updating after conducting testing and pilot studies.

In parallel, accelerating the design and development of new tools for effective and efficient election administration for voting, such as equipment allocation (i.e., in-person polling location, vote centers, and vote tabulation centers), layout design, voting location identification, and ballot drop box placement, are necessary to progress the use of data-based tools for decision-making. These ideas can assist in polling places' safe and efficient operation while ensuring voter convenience and equitable service to all communities. Yet, designing these technological tools to help election administra-

tors should be measured, accessible, scalable, and equitable.

Finally, the consolidation of these tools (i.e., temporary, revised, or new) should provide examples and connections to election administrators for further dissemination. By addressing these challenges to existing tools collectively, democracy will be supported through their applications and techniques to ensure that election administrators acquire all necessary information before their difficult decision-making process.

Any election administration tool is inherently collaborative, as they are developed and applied in preparation for various elections based on specific conditions. Currently, tools are provided by several academic researchers and non-governmental agencies. Successful convergence would need to continue between these researchers, tool-makers, and state and local election officials. Additional convergence growth opportunities are to work with collectors of election data (e.g., GIS, transactional logs, ballot marking time studies, ballot return dashboards) as well as voting system providers, community-based organizations (especially those representing lower frequency voters), nonpartisan policy & nonprofits, and other government agencies in the areas of planning and operations.

CHALLENGE 2: ENSURING USABILITY WITHIN THE VOTING EXPERIENCE

Making the ballot accessible to all voters for all methods of submission (e.g., paper, ballot marking devices, audio ballot readers, envelopes, and provisional ballots) will assist in making it easier to vote. In addition, the design and evaluation of these technologies through testing, surveys, and auditing methods will improve the usability of

voting equipment for a more voter-centric and user-friendly experience while increasing voter confidence.

Additionally, Executive Order 14019, signed in March 2021, requires that federal agencies analyze barriers to private and independent voting for people with disabilities, including access to voter registration, voting technology, voting by mail, polling locations, and poll worker training.⁶ This project would help inform and enhance those efforts.

Voting equipment does not change quickly, as moving fast can introduce additional vulnerabilities. For the two decades after the enactment of the Help America Vote Act (HAVA) in 2002, states used funds to purchase updated voting equipment to improve the accuracy of elections. While some equipment was indeed more up-to-date, the implementation of the new technology significantly impacted the voting system. Furthermore, the rise of convenience voting has given voters more options than ever to obtain and cast a ballot. To facilitate these experiences, most voters interact with information technology, especially for in-person voting. Specific processes occur when a citizen votes by interacting with the ballot and where technology can assist them in marking, reading, recording, scanning, and/or counting their votes.

There is a long-standing tradition of assessing the degree to which these processes and others are accurate, usable, and secure in scholarly research. In research, a significant amount of ballot design characteristics regarding unrecorded votes and usability

⁶Executive Office of the President. "Promoting Access to Voting," <https://www.federalregister.gov/documents/2021/03/10/2021-05087/promoting-access-to-voting>.

ity has been explored, but not necessarily always related to other overlapping effects (e.g., ballot type or election outcomes, or comprehensive technology comparison across multiple election systems). The first opportunity would be to expand the knowledge of ballot design and its effect on usability. While some research has attempted to fill in gaps in this area, this area is ripe for acceleration to establish comprehensive guides on ballot layout, characteristics, length, and language to improve ballot usability.

The second opportunity would be to conduct a comprehensive technology comparison across multiple election systems for complete usability testing through experimental design to establish what works and does not work for different voter communities. Next would be to create a data-informed approach to measure and evaluate voting materials' usability and accessibility. Centralized standards and best practices could also be developed and disseminated to inform updates to Voluntary Voting System Guidelines (VVSG) 2.0.⁷ This is followed by another research opportunity to measure and evaluate the wide-scale distribution and adoption of these standards and practices. Other potential research areas include, but are not limited to, surveys of incoming/outgoing voters, understanding voter intent and its interaction with usability of the ballot, assessing voting errors (e.g., over-voting, and, in some cases, under-voting), facilitating effective multi-language ballot options in an equitable and scalable way, executing and analyzing the implementation of ranked-choice voting, and es-

tablishing means of reporting and storing voting machine usability assessments.

Leading groups on this best practices and research area are the Center for Civic Design (CCD) and the Voting Solutions for All People (VSAP) program in Los Angeles County, California. Voter and language accessibility advisory committees can be organized to facilitate disseminating knowledge to election officials, which can help with the diffusion of federal and state accessibility requirements to the local level. When looking at the voting equipment analysis literature for ballot casting, specific areas for convergence align with professionals in human-computer interaction and user experience.

CHALLENGE 3: IMPROVING ACCESS TO VOTING

Changes frequently occur in election administration due to natural disasters (e.g., pandemics, hurricanes, tornados, floods), election law revisions, or the introduction of new technology or processes. Making voting easy, convenient, and accessible for all is made difficult because of these frequent changes, requiring election administrators to continually plan and adapt.

The election process can be viewed through different lenses: (1) the planning phases and implementation for election administrators; (2) accessibility to voting through registration, ballot requests, and all other methods of voting; and (3) physical access and transportation to these locations (e.g., early voting locations, satellite election offices, polling locations, vote centers). It takes a great deal of coordination and collaboration between various stakeholders and levels of government to facilitate the experience of voting.

⁷ U.S. Election Assistance Commission. "Voluntary Voting System Guidelines," <https://www.eac.gov/voting-equipment/voluntary-voting-system-guidelines>

Recently, new gaps arose when multiple voting processes evolved quickly to administer elections during the COVID-19 pandemic. Not all of these solutions, however, were considered ideal, optimized, or even permanent. Acceleration is required to capture the presence and feasibility of voting methods and systems to improve election administration for future elections. The election experience must be assessed from the voter's perspective to identify problems and gaps. A comprehensive gap analysis study will both qualify and quantify the experience of voting from the registration process through successfully casting a ballot. Studying the how, when, and where (e.g., early voting, vote-by-mail) will create an inclusive, data-informed understanding of voting system accessibility through metrics for continuous evaluation.

Meanwhile, another research opportunity is to evaluate and suggest ways to study inconsistencies among various state and federal requirements concerning voter assist terminals. Additionally, research should explore other ideas for getting people to vote, such as curbside voting, drive-thru voting, and mobile voting to address issues of accessibility. Understanding voting travel behavior for all could significantly reduce travel as a means of potential disenfranchisement for various communities (e.g., homebound voters, residents of long-term care facilities, unserved groups and communities). Physical accessibility to polling locations, either through public transit, parking, and ramps or walkways, should be easier and more equitable for all. Capturing this information could establish means of reporting and storing accessibility assessments.

Another research opportunity ripe for acceleration is a comprehensive vote-by-mail drop box location analysis. With the sig-

nificant recent increase in vote-by-mail, research needs to explore the design (e.g., capacity, official designation), location (e.g., where and why, establishing quantity, security, monitored or unmonitored, permanent or temporary, ADA accessibility), and access (e.g., hours, parking, public transportation) to ballot drop boxes.

Next, although poll worker training has been a constantly evolving field of study, it is ripe for acceleration based on the new ideas and progress made during the pandemic; ideas include evaluating the effectiveness of virtual training, memory retention, and potency of group training models (i.e., an entire polling location at the same time, as a unit). An additional idea is creating comprehensive guidance on contingency systems (e.g., provisional ballots, drop boxes) and planning and assessing needs in real-time for local election officials. Other potential research ideas include, but are not limited to voter registration operations and maintenance, the standardization and certification of credentialing for poll watchers (and revocation), a series of small group networking workshops for new inclusion of stakeholders, and allowing the voter to self-audit the process through appropriate feedback venues.

Due to the nature of the industry, there are natural areas for convergence in this challenge, combining effort from non-governmental agencies and state and local election officials, other community planners, and academic researchers to improve access to voting.

CHALLENGE 4: COMMUNICATING EFFECTIVELY WITH THE ELECTORATE

Many voters and eligible citizens do not understand how elections are administered, which allows the spread of rumors and misinformation. Educating the electorate establishes knowledge of what is expected when voting, interacting with voting technology and functionality while setting expectations and building confidence. In addition, voting equipment information and knowledge transfer to voters can assist with acknowledging what these systems can and cannot do.

Voting technologies continue to evolve, and voters are regularly faced with using new equipment. The transition away from paperless direct-recording electronic devices (DREs) and their replacement by the ballot marking devices (BMDs) is the most visible part of the current evolution in technology, but even the replacement of optically scanned paper ballots with digitally scanned ballots introduces new procedures to voters and opportunities for mistakes. New approaches to voting technologies spawned by the adoptions of VVSG 2.0 may give rise to unanticipated adaptability challenges once the next-generation voting equipment is developed. Therefore, there is a constant need to effectively communicate with the electorate about how to use voting systems to ensure efficacy, trust, and confidence in their vote.

Knowing that voter confidence is directly tied to voter experience, whether one's preferred candidate wins, and the fairness narratives of political actors make this area ripe for convergence. The first research opportunity is determining how to effectively communicate about how election processes work. How might the public, local and regional journalists, local organizations, and

voter groups communicate intuitively with diverse voters about how voting systems work? Second, how might the election community collaborate with other experts to research, rethink, create, and test materials for different target audiences with different access and accessibility needs? Third, what factors affect the wide-scale distribution and adoption of these communication materials?

There are already numerous groups, bipartisan and partisan organizations, working to inform voters about various voting processes and counter efforts to misinform the public. Within the election administration and election science communities, there are many communicators developing and delivering accurate and helpful information, as well as developing best practices, multimedia, and packets for engaging with voters. Opportunities for convergence align with academic communications specialists, instructional designers, persuasive communication experts, journalists, state and local election officials, non-governmental organizations, and other stakeholders. Uniting this network can establish communication materials for voters to appropriately assist them in registering, obtaining and casting their ballot, and ensuring that their vote is secure.

CHALLENGE 5: DETECTING ANOMALIES IN ELECTION MANAGEMENT SYSTEMS

Access to the ballot box in most of the country is predicated on being registered, which operationally means having one's name and other information in a voter registration database. Since the passage of the Help America Vote Act in 2003, states have been required to have:

“...in a uniform and nondiscriminatory manner, a single, uniform, official, centralized, interactive computerized statewide voter registration list defined, maintained, and administered at the State level that contains the name and registration information of every legally registered voter in the State and assigns a unique identifier to each legally registered voter in the State.”⁸

Even before the interoperability and networking of election systems, ensuring that registration data were accurate and reliable was recognized as a challenge, which was one motivation behind another HAVA requirement — that states institute provisional ballot procedures that allowed voters to cast a ballot when they arrived at a polling place and their registration information was either missing or incorrect. The networking of election systems, their size (millions of records with scores of fields in each state), and the need to give hundreds of users access to update records, raises the specter of countless errors being inadvertently introduced and not detected, as well as concerns about the penetration of these systems for fraudulent reasons.

Election officials need computer applications and procedures to help prevent, detect, and correct efforts to corrupt election administration data. Such systems can be thought of as part of a forensic toolbox with an external reporting system that flags anomalies in state or local election data systems and monitors other election-related data flows to alert officials about problem areas.

These systems can build upon efforts that have already been developed through the work of academics who have partnered with state and local election officials, ERIC, and other stakeholders.

CHALLENGE 6: SHARING ELECTION RESULTS FOR RESEARCH, DISSEMINATION, AND ANOMALY DETECTION

Election administration rides on data. The flow of data among the core information systems — voter registration, election management, vote capture and tabulation, and election night reporting — should be seamless. A seamless flow of information would not only facilitate the sharing of information between systems and applications, but also improve auditing, encourage the development of commercial-off-the-shelf helper applications, facilitate the use of data to manage processes and diagnose problems, and reinforce the role of state and local officials as trusted sources of election results information. Additionally, this information flow adds transparency to the process by allowing the public to analyze the data, understand the processes, and disseminate findings.

Despite the complexity of political geography and the dispersed nature of the elections ecosystem, a process coordinated by NIST has been at work to develop Common Data Formats (CDFs) to gain control over this complexity and encourage the interoperability of systems. This project has already produced specifications for cast vote records, election event logging, election results reporting, and voter records interchange, with two other projects — election business process modeling and voting methods — currently underway. These projects have been broadly inclusive of technology providers, government agencies

⁸ Help America Vote Act, § 303(a)(1)(A).

(federal, state, and local), private citizens, media organizations, and citizen groups. With CDFs being developed, the next step is their widespread adoption.

Widespread adoption of the CDFs carries additional benefits for those interested in studying the elections process. Researchers, the media, and those seeking to monitor election data anomalies would benefit from a data hub with the ability to intake election data in conformance with the CDF specifications. Such a hub could clean and standardize data from different jurisdictions and consolidate nationwide data sets in a non-partisan public repository. The creation of a data hub for this purpose would streamline access to comprehensive data for election officials, data experts, academics, advocacy groups and media outlets to foster a more complete understanding of election data nationwide.

CHALLENGE 7: VISUALIZING ELECTION DATA

The deluge of data associated with managing elections presents a challenge of presenting it so that the public, candidates, and officials can fully grasp the results and the nuances of election management. The need begins with communicating election results and the progress of vote counting. An increasing need is communicating the results of election audits and other procedures designed to assure the public that the initially reported election results were correct. Overarching all of this is providing platforms such that state and local election offices are sought out first for authoritative information about the results of elections, broadly defined.

An increasing number of election jurisdictions have begun communicating election outcomes visually, but the degree of

sophistication is limited, as is the quality of user interfaces. Creating compelling visualizations requires the collaboration of teams of data scientists, technology providers, usability experts, and election officials. Pockets of collaboration have emerged, but a broader adoption of sophisticated visualization awaits a concerted effort to identify best practices and methods for disseminating them.

CHALLENGE 8: ENHANCING VOTER IDENTITY VERIFICATION

Confirming the identity of an eligible citizen or voter is an important component of securing elections in the United States. In order for an eligible citizen to successfully register to vote, for an eligible registered voter to obtain an absentee ballot and return it for counting, or for an eligible registered voter to cast a vote in person, authentication of the voter's identity is crucial. Election officials must be able to confirm the identity of those seeking to participate and the democratic process.

However, the existing standard biometric identifier, a wet signature, is becoming less useful as a means to confirm the identity of citizens and voters. Wet signatures are difficult to collect, verify, and use in many situations. Also, over time, individual wet signatures can change, leading to other problems with their use. It is clear that the time has come for research on the development of new, accurate, and usable, messages for indicating voter identity.

There are many possible new and emerging technologies that can be used for verifying the identity as an eligible citizen or eligible voter. These include current biometric identifiers (like fingerprints, retinal scans, or facial identification), but their integra-

tion with current election administration practices and technologies in the U.S. needs research. Also privacy issues regarding the connection of new and emerging biometric identifiers with voter registration and other voting information, needs close examination.

Election administration is not the only area where the need for new biometric identification is pressing; other governmental functions and operations need to use more accurate individual identification methods, and using new biometric identifiers is an important priority in the private sector. Thus, there are many others who have the same need for improving identification technologies, and who are seeking solutions. Additionally, academic researchers in computer science, independent researchers in the security and accessibility fields, and nonprofits are working on these issues.

CHALLENGE 9: SECURING ELECTRONIC BALLOT DELIVERY & RETURN

The widespread use of voting-by-mail in the 2020 presidential election surfaced many of the issues with using the physical mail system for ballot delivery and return. While these issues have been researched for some time, in the 2020 election significant concern arose about lengthy ballot delivery and return times, the accuracy of information on mail addresses in administrative datasets, and the potential for misdelivery of balloting materials. Also, issues regarding the usability and accessibility of by-mail ballots have been raised by many researchers.

Election officials across the U.S. have been using electronic technologies for ballot delivery for some time, and some allow ballot materials to be returned electronically as

well to assist with resolving the aforementioned issues. This has been especially true for voters with specific voting rights issues — including voters with disabilities, voters covered by the Uniformed and Overseas Citizens Absentee Voting Act (UOCAVA), and voters living under a declared state of emergency (e.g., hurricanes, wildfires, and floods). While election officials are using a wide variety of electronic technologies for ballot delivery and return, they do so under widely varying laws and regulations, and very different security standards.

As there is no doubt that electronic ballot delivery and return systems will continue to be used by election officials in upcoming elections, providing research to better secure the delivery and return of balloting materials electronically is a pressing challenge. There are a number of ways that this challenge could be met. A first research opportunity is to develop comprehensive risk assessment methods for electronic ballot delivery and return, and to use those methods to identify the likely significant risks and threats. This research could be used by convergent teams of technologists, stakeholders, and election officials to identify standards that would improve on current practices. Furthermore, research on how to audit electronic ballot delivery and return, and on how to build more secure, accurate, accessible, and usable systems is a high priority.

CHALLENGE 10: IMPLEMENTING END-TO-END VERIFIABILITY

End-to-end (E2E) verifiability is a set of technologies that allow voters themselves to confirm that their votes have been accurately included in reported election tallies without having to trust any software, hardware, or personnel involved in the election.

E2E verifiability has origins dating back to the 1980s as an academic exercise, and it has evolved steadily since that time to become a practical option for real elections.

Despite a small number of pilots in U.S. public elections, E2E verifiability is still not generally available to voters. An important reason is the challenge of deploying an academic technology into a market with little capital or incentive to innovate. Implementing E2E verifiability requires specialized expertise that is rarely found outside of academic research. There are also challenges in educating voters about the capabilities offered by E2E verifiability, and further research is needed to find effective ways to apply E2E verifiability to alternative voting methods such as vote-by-mail.

These challenges create great opportunities. Although E2E-verifiability could be built and deployed today, it will not be effective without greater emphasis on education, careful usability studies on how voters can best understand and utilize the technology, and research on better ways to deliver the technology and expand the technology to areas where it isn't yet supported.

CHALLENGE 11: IMPROVING CYBERSECURITY FOR ELECTION ADMINISTRATION

In recent elections there have been public reports of cybersecurity threats and attacks on election offices and infrastructure. Other threats may not have been detected, and still others may not have been made public. Because election administration is highly decentralized, elections are often conducted by municipal or county election officials, who may not have the staff or resources to research and implement new cybersecurity solutions. In addition, the threat environment is rapidly evolving; the types of

threats and attacks that were potentially issues in 2016 and 2020, may no longer be the threats of concern in 2022 and 2024.

There are four specific challenges that are opportunities for accelerated research:

1. Threat assessments for election technologies, especially regarding the technologies being used for ballot generation, delivery, marking, return, and tabulation. These assessments need to determine potential threats, their likelihood, and identify how the threats can be addressed.
2. Threat assessment of election data management systems and data flows. Research is needed to determine the threats to election administration data systems, especially voter registration databases and technologies, to monitor those systems for intrusion, and to ensure that these systems can provide robust operations during high demand periods. Similarly, research should focus on how to secure the data flows between remote polling locations and election offices, and between election offices and other agencies or organizations (for example, between county and state election offices).
3. Research is needed to develop methods to detect threats to the personal security of election officials, in particular on social media.
4. Finally, research should focus on developing and implementing methods for auditing and monitoring the cybersecurity of election offices and their electronic systems.

During the 2020 election cycle, many election officials, technology providers, government agencies, nonprofit organizations, and academics began to examine the potential

cyber and information security threats and determine more specific threats to election infrastructure and election officials. These efforts need to be broadened and accelerated for 2022 and 2024, to strengthen best practices, assess the threats, develop technologies to address these risks, and continually update threat assessment to keep pace with the evolving security threats to elections.

CHALLENGE 12: MANAGING ELECTION GEOGRAPHY

Election administration has a heavy geographical component, particularly with respect to managing administrative geographies (like precincts) and relating them to electoral geographies (like districts). Administrators must locate and manage polling places, inform voters about their modes and locations of voting, and generate the correct ballots for voters based on the “district combo” associated with their residence. Geographic challenges are also at the core of expanding voting access to underserved communities, for instance by choosing polling locations or supporting alternative voting modalities in areas with generally poor infrastructure, such as on tribal lands and in urban and rural areas that have experienced decades of infrastructure disinvestment.

For many election administrators, geographic information systems (GIS) are a technology of the future, but in less-resourced local election jurisdictions, the software and the expertise are regarded as expensive luxuries. Many of our attendees reported being in the process of transitioning to a GIS-enabled election management system, but indicated that the timeline was uncertain. Furthermore, off-the-shelf GIS tools are not purpose-built for the full

range of applications relevant to election administration.

To accelerate our engagement of this challenge, we can learn from those states and local jurisdictions that are farther along in their GIS integration, such as the pilot states of the NSGIC geo-enabled elections project. We can learn from other agencies, projects, and use cases that are geographically intensive, such as NextGen 911, highway departments, high-growth jurisdictions, and the USPS. Numerous academic groups, as well, have already partnered with election officials to find one-off solutions to pressing administrative problems. What has yet to occur is the development of comprehensive GIS-based solutions to the myriad of challenges that state and local election officials face.

CHALLENGE 13: PROMOTING SUSTAINABLE AND SCALABLE SHARING OF ELECTION TECHNOLOGY

The administrative organization of elections in the U.S. is highly decentralized. This decentralization has direct implications for the adaptation of existing and emerging technologies for use in election administration. In particular, the decentralization of administration also disperses technological expertise, making the sharing of technological solutions difficult, and putting local election officials at a strategic disadvantage in working with commercial vendors to adapt technologies to their particular situations. This is especially true when small-to-medium-size local jurisdictions seek to create solutions that involve commercial-off-the-shelf (COTS) and open source technologies.

Efforts have been made in recent years to overcome this barrier to innovation due to

ELECTION SCIENCE CHALLENGES RIPE FOR CONVERGENCE AND ACCELERATION

decentralization. For instance, in recent years there was an effort spearheaded by DemocracyWorks, working with election officials, to create a co-op for the sharing of homegrown technological solutions in election administration. This effort did not move forward, due to questions around developing licensing and economic models to sustain the operation. With promulgation of VVSG 2.0, election administrators look forward to being able to adapt more flexible technologies to their needs. Innovation would be sped up by the creation of a technological platform that is designed with election administration in mind.

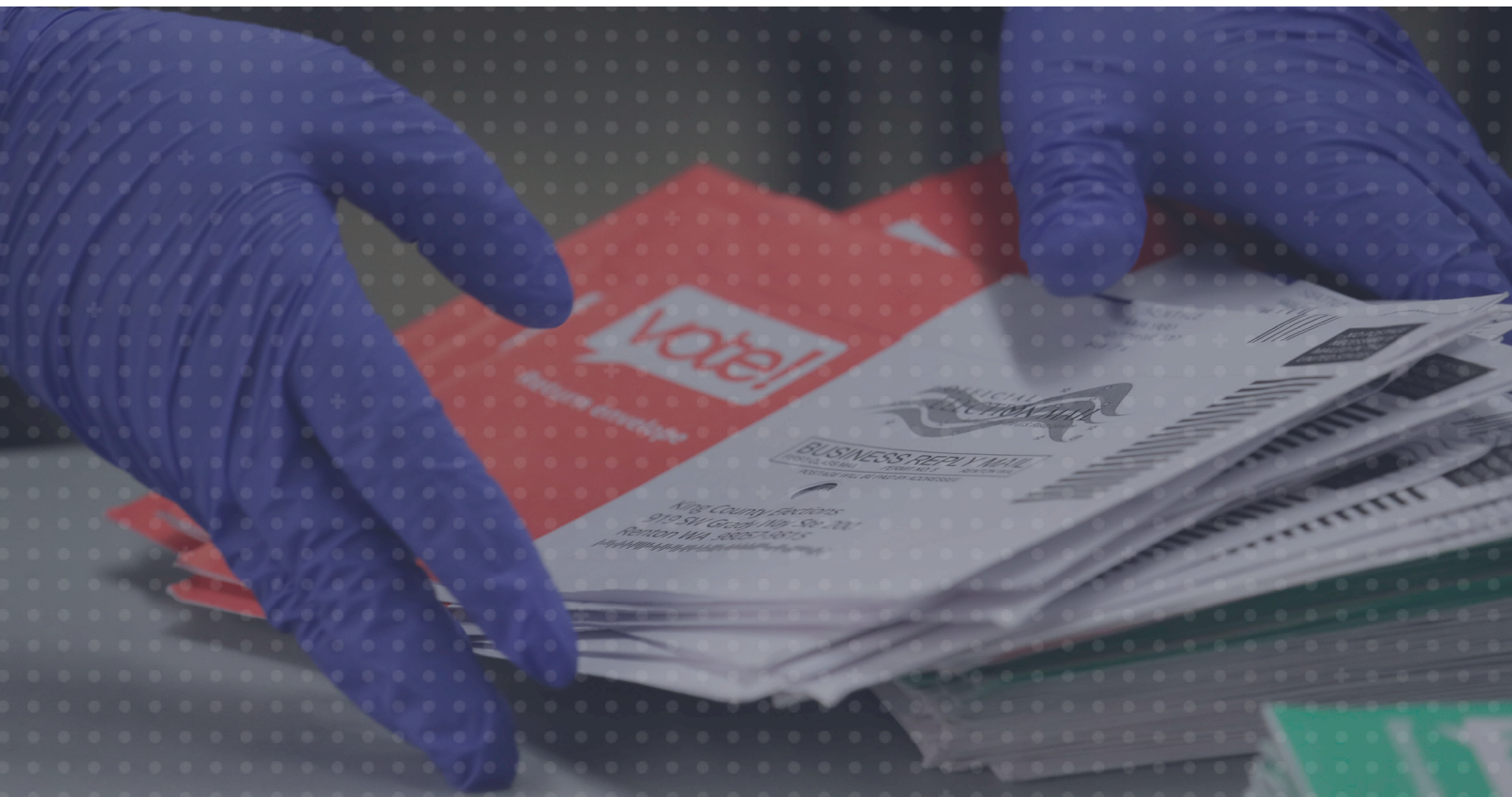
CHALLENGE 14: DEVELOPING NEXT-GENERATION VOTING TECHNOLOGIES

Delays in the promulgation of updates to the VVSG 2.0 have created a logjam in the application of new information technologies and the associated flexibility and scalability that the new guidelines promise. This logjam exists in parallel with aging voting technology infrastructure in much of the country. The confluence of new guidelines

with pent-up demand for new systems provides new possibilities, but also threatens to produce a chaotic innovation environment in the coming years.

Furthermore, the market for voting technologies is very small, compared to other areas of technological application; the number of technology providers is also small, sometimes characterized as an industry with “two and a half vendors.” In the current uncertainty, there is a possibility that legacy providers could end up dominating the next generation voting technology market, minimizing the opportunities for the hoped-for innovation that VVSG 2.0 is supposed to initiate.

In this moment, there is an opening for developing processes to help move innovation in voting technologies to market. For instance, a role could be found for the use of competitions for developing secure, accurate, and usable ballot marking, ballot tabulation, and election management systems within the VVSG 2.0 framework.



AN ENHANCED ROLE FOR THE NSF IN ADVANCING FUNDAMENTAL, APPLIED, AND TRANSLATIONAL RESEARCH IN ELECTION SCIENCE

This report has provided information about the suitability of election science for inclusion as a track in the NSF C-Accel program. The challenges outlined here were highlighted because they thread the needle of being national in scope, critical for the functioning of trustworthy election systems, complex enough to require the collaboration of multiple disciplines and perspectives, and developed enough that an intense, focused effort could yield tangible payoffs within the program's timeframe. Embedded within these challenges continue to be topics that would benefit from fundamental, applied, and translational research but fall outside of the C-Accel program's remit.

Thus, while the NSF has funded some election science projects in the past two decades, after hosting our workshops and listening to the magnitude and scope of basic science issues identified by election officials, technologists, and academic researchers, the PI Committee believes that election science has been underfunded and that the NSF needs to consider new ways to support, and fund sustained research in this area.

The PI Committee is aware that there are more areas of deserving attention for fundamental research than are reflected in the fourteen election science challenges identified above. Therefore, the committee has refrained from including challenges that it believes are probably not primed for acceleration at this time. These are challenges, often vexing or highly complicated, such that research has not reached the point where applications could be implemented in the short time frame anticipated by the C-Accel program.

Thus, the NSF has the opportunity to support research in election science through its traditional grant programs. It is the PI Committee's opinion, often reflected in remarks made by workshop participants, that the NSF could play a more active role in the support of research to expand the fundamental knowledge-base of election science. With some exceptions, the fundamental research that forms the foundations for addressing the challenges we identify as ripe for acceleration was supported by foundations, private philanthropy, nonprofits, state and local governments, and individual

colleges and universities, but not necessarily the federal government.

Over the past two decades, there have been many calls for a stronger federal role in funding basic research in election science. Most recently, in 2018 by a panel of the National Academies of Sciences, Engineering, and Medicine (NASEM), in their report, *Securing the Vote*. Recommendation 7.3 reads as follows:⁹

Congress should authorize and fund immediately a major initiative on voting that supports basic, applied, and translational research relevant to the administration, conduct, and performance of elections. This initiative should include academic centers to foster collaboration both across disciplines and with state and local election officials and industry.

The U.S. Election Assistance Commission, National Institute of Standards and Technology, U.S. Department of Homeland Security, National Science Foundation, and U.S. Department of Defense should sponsor research to:

- » *determine means for providing voters with the ability to easily check whether a ballot sent by mail has been dispatched to him or her and, subsequently, whether his or her marked ballot has been received and accepted by the appropriate elections officials;*
- » *evaluate the reliability of various approaches (e.g., signature, biometric, etc.) to voter authentication;*
- » *explore options for testing the usability and comprehensibility of ballot designs created within tight, pre-election timeframes;*

- » *understand the effects of coercion, vote buying, theft, etc., especially among disadvantaged groups, on voting by mail and to devise technologies for reducing this threat;*
- » *determine voter practices regarding the verification of ballot marking device-generated ballots and the likelihood that voters, both with and without disabilities, will recognize errors or omissions;*
- » *assess the potential benefits and risks of Internet voting;*
- » *evaluate end-to-end-verifiable election systems in various election scenarios and assess the potential utility of such systems for Internet voting; and*
- » *address any other issues that arise concerning the integrity of U.S. elections.*

Most of the challenges identified in this report as being ripe for inclusion in the C-Accel program are related to the specific topics that the NASEM panel and past studies have recommended for attention by federal research agencies. Even as election science progresses as a potential track in the C-Accel program, the NSF should avail itself of other opportunities to promote the improvement of American elections through its ongoing programs that encourage fundamental, applied, and translational research. These basic research challenges will involve different academic disciplines and methodologies, and may require the sustained focus across different NSF programs and directorates.

⁹National Academies of Science, Engineering, and Medicine, *Securing the Vote: Protecting American Democracy*, National Academies Press, 2018, p. 123.

APPENDIX I

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APPENDIX I

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APPENDIX I

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- » Director of Intergovernmental Affairs, Department of State, New Jersey Secretary of State

APPENDIX II

RESEARCH AREAS RIPE FOR RESEARCH TO IMPROVE CONFIDENCE IN ELECTIONS

1. The security of election systems, particularly voting machines, electronic poll books, and tabulation infrastructure
2. Securing voter registration databases and systems
3. Setting standards for innovation in election systems
4. Usability and comprehensibility testing of ballot designs
5. The verification of votes on ballot marking devices by voters
6. Accessibility of election systems for people with disabilities
7. Using the Internet to transmit marked and unmarked ballots
8. Using geospatial tools for the accurate and efficient conduct of elections
9. Resource allocation for the safe and efficient operation of polling places
10. Polling place facility layout planning for their safe and efficient operation
11. Locating polling places to ensure voter convenience and equitable service of underserved communities
12. Developing management and technologies to improve and secure remote by-mail ballot delivery and return
13. Designing human-facing systems such as ballots, election-night reporting systems, and instructions for voting
14. Using biometric identification for voter authentication
15. Providing access to voting among disadvantaged groups
16. End-to-end-verifiable election systems
17. Risk analysis of election systems
18. Auditing election tabulation, voter registration databases, assignment of voter to precincts, and election processes
19. Voter confidence in the veracity of the verdict announced by election officials
20. Improving communication infrastructure for the detection and mitigation of voter misinformation efforts

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Caltech/MIT
Voting
Technology
Project



MIT ELECTION DATA
+ SCIENCE LAB