ACCURATE Slide Bundle

- Avi Rubin, *Project Overview*
- Doug Jones, *Systems-Level Perspectives*
- Dave Wagner, *Role of Cryptography*
- David Dill, *Design for Verification*
- Deirdre Mulligan, *Relating Technology to Policy*
- Mike Byrne, *Usability and Accessibility*
- Dan Wallach, *Education and Outreach*
- David Dill, *Partnership and Tech Transfer*
- Peter Neumann, *Evaluation Plan*

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Project Overview

Avi Rubin
Johns Hopkins University

Why Cybertrust?

- Cybertrust Vision:

  A society in which networked computer systems are:
    - more predictable, more accountable, and less vulnerable to attack and abuse;
    - developed, configured, operated and evaluated by a well-trained and diverse workforce
    - used by a public educated in their secure and ethical operation

- Voting systems:
    - Networked computer systems
        - Round trip from election management system to election management systems with results accumulated
    - Behavior of voting systems must be:
        - Predictable, accountable, invulnerable to attack and abuse
        - developed, configured, operated and evaluated by a well-trained and diverse workforce
            - Poll workers, election officials, social scientists, technologists
        - used by a public educated in safeguarding elections

A perfect match!

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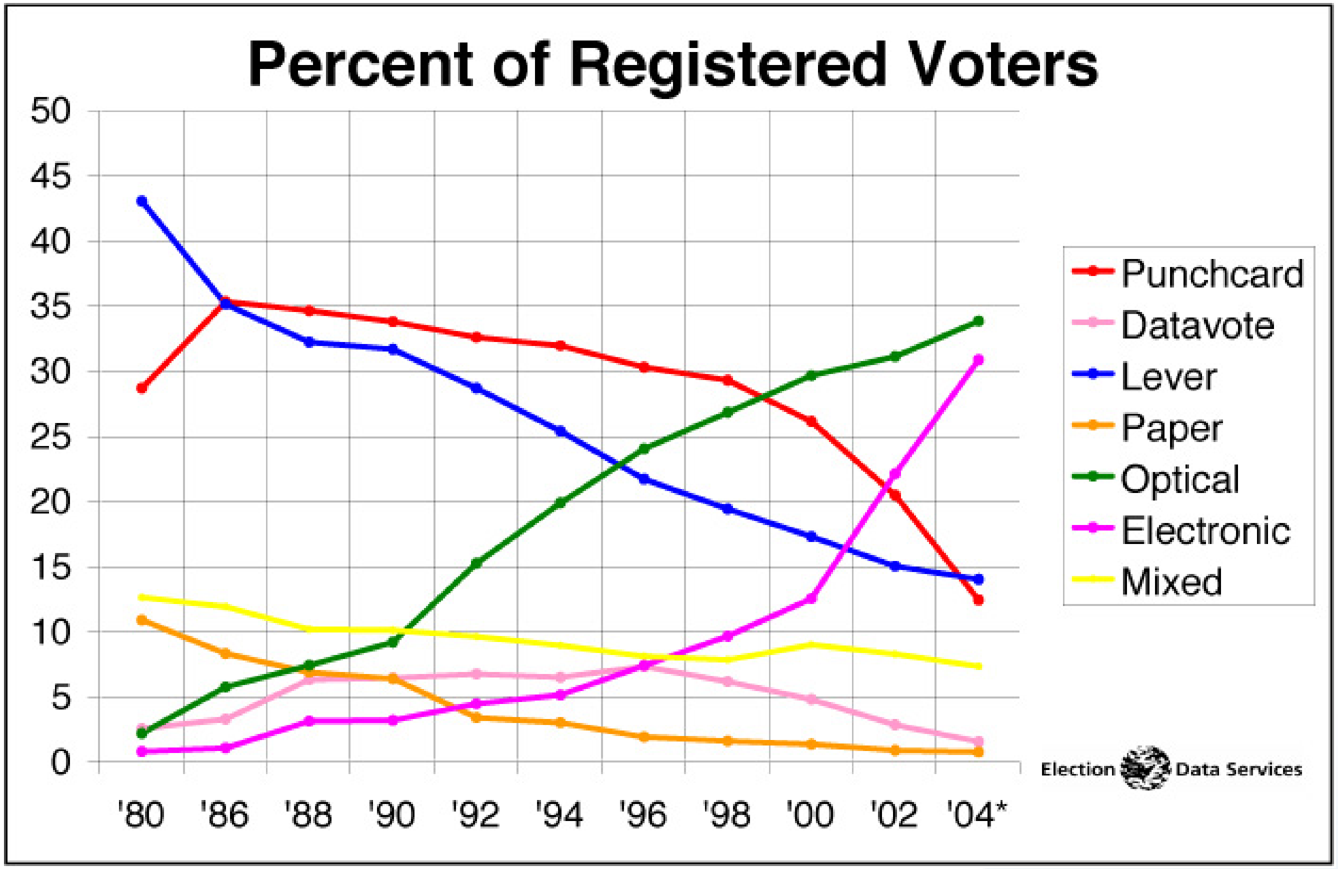
The problem

- The cart before the horse
  - The US has adopted e-voting technology
    - Ad-hoc fashion
    - Before the science was done
- Voting systems have been deployed
  - Highly vulnerable to wholesale fraud
  - Without voter verification
  - Without proper audit capability
- Many challenges
  - Technological
  - Political
  - Social
  - Legal
- Every major study/analysis of today's DREs has concluded that they are highly vulnerable to tampering and disruption

Voting technologies



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Why a center?

- Efforts have already been under way for many years
  - Mostly as an unfunded activity
  - Many hours already going in
- Center can provide infrastructure
  - To coordinate research
  - To manage outreach
  - To influence education
  - To affect policy
- Center will bring together
  - Diverse set of people
    - Computer scientists, lawyers, policy makers, disabled, election officials, vendors, politicians, educators
    - A center strongly encourages cooperation
    - Interdisciplinary collaboration

Partnerships and Tech Transfer

- Involved in organizations
  - Open voting consortium
  - Verifiedvoting.org
  - VSPR
  - Standards Committees, e.g. IEEE P1583
  - Working with election officials
- Participation in running elections
  - Voting machine examiner
  - Election judge
- Interactions with vendors big & small

Technological impact

- Research product from center
  - Applicable to other technology domains
    - Secure auctions
    - Spyware prevention
    - Trusted Computing
    - Network Security
    - Secure Software development
    - Accessible computing

Strategic concept

- Provide Incremental improvements to existing voting systems
- Basic research for far-reaching changes
  - improve the state-of-the-art
  - Meeting technical requirements
    - Correct capture, secrecy, verifiability, auditability, integrity, transparency, availability, administrability, component interoperability, cost conservation
  - human factors, accessibility, security
  - procedures
- Relation of technology to public policy objectives

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Multi-disciplinary

- Computer Science
  - Security, Cryptography, Availability, Hardware, Networking, Administration, Accessibility
- Human Factors
- Public Policy
  - Technology considerations in legislation
  - Disputed election resolution
- Education
  - Existing teachers program
  - Site Research for Teachers grant

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- Social Science
  - Voter turnout, acceptance of technology

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Center coordination

- Semi-annual workshops
- Bay area meetings
  - 6 PIs within one hour drive
- Monthly conference calls
- Impromptu meetings at numerous conferences, workshops and hearings
  - been doing this for years
- Comprehensive web site
- Regular meetings coordinated by area leaders

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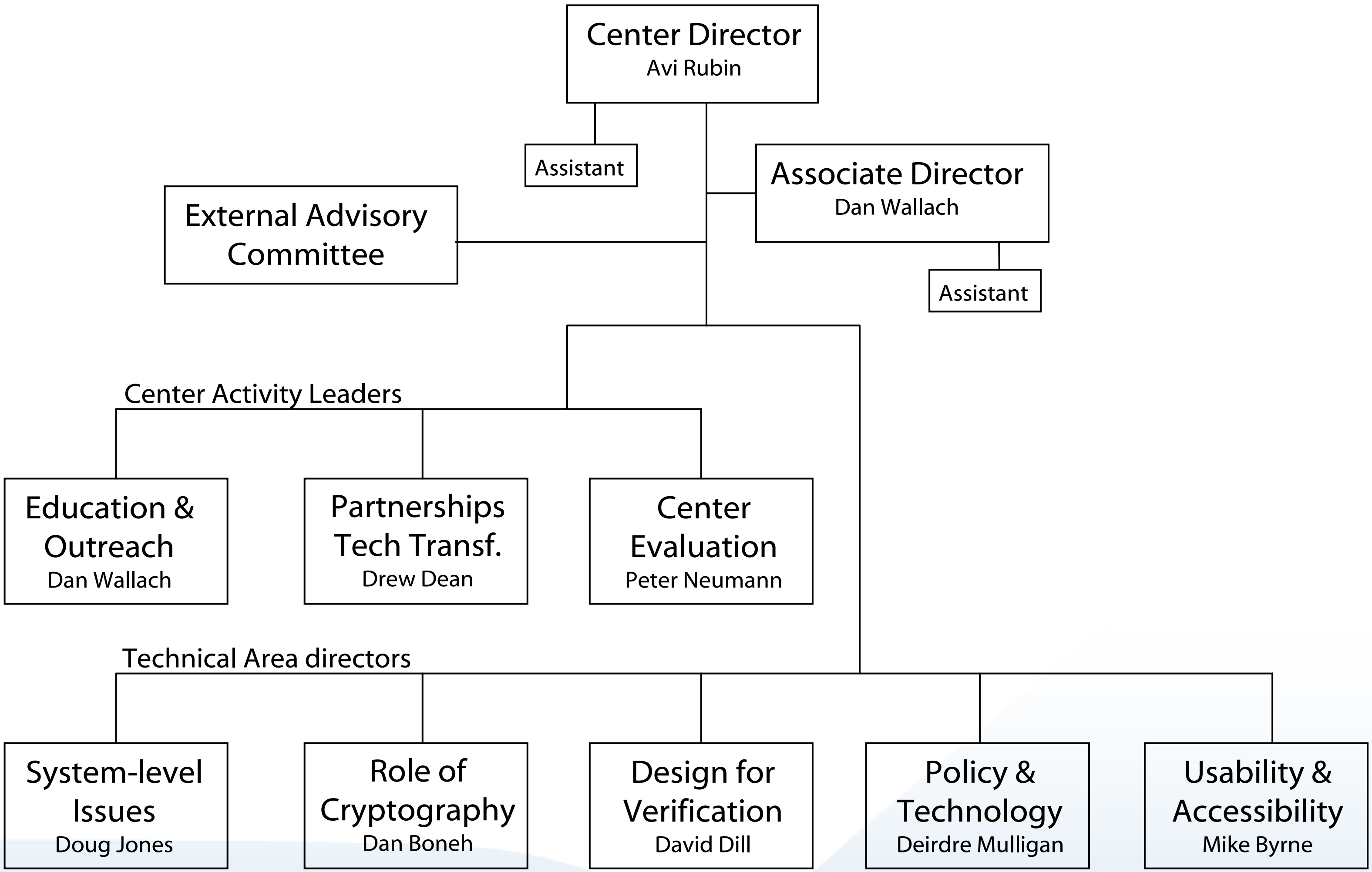
Management


Center Director
Avi Rubin
Assistant
Associate Director
Dan Wallach
External Advisory Committee
Assistant
Center Activity Leaders
Education & Outreach
Dan Wallach
Partnerships Tech Transf.
Drew Dean
Center Evaluation
Peter Neumann
Technical Area directors
System-level Issues
Doug Jones
Role of Cryptography
Dan Boneh
Design for Verification
David Dill
Policy & Technology
Deirdre Mulligan
Usability & Accessibility
Mike Byrne

	System-level issues	Role of cryptography	Design for verification	Relating policy to technology	Usability and accessibility
Michael Byrne	P		P		L
Dan Boneh	P	L	P		
Drew Dean	P	P	P		L
David Dill	P		L	P	
Doug Jones	L	P	P		P
Deirdre Mulligan				L	P
Peter Neumann	P	P	P	L	
Avi Rubin	L	P	P		P
David Wagner	P	P	L		P
Dan Wallach	P	L	P		P
Josh Benaloh		P	P		
David Chaum		P		P	
Cindy Cohn				P	
Chris Edley				P	
David Jefferson	P		P		
Whitney Quesenbery					P
Verified Voting				P	P

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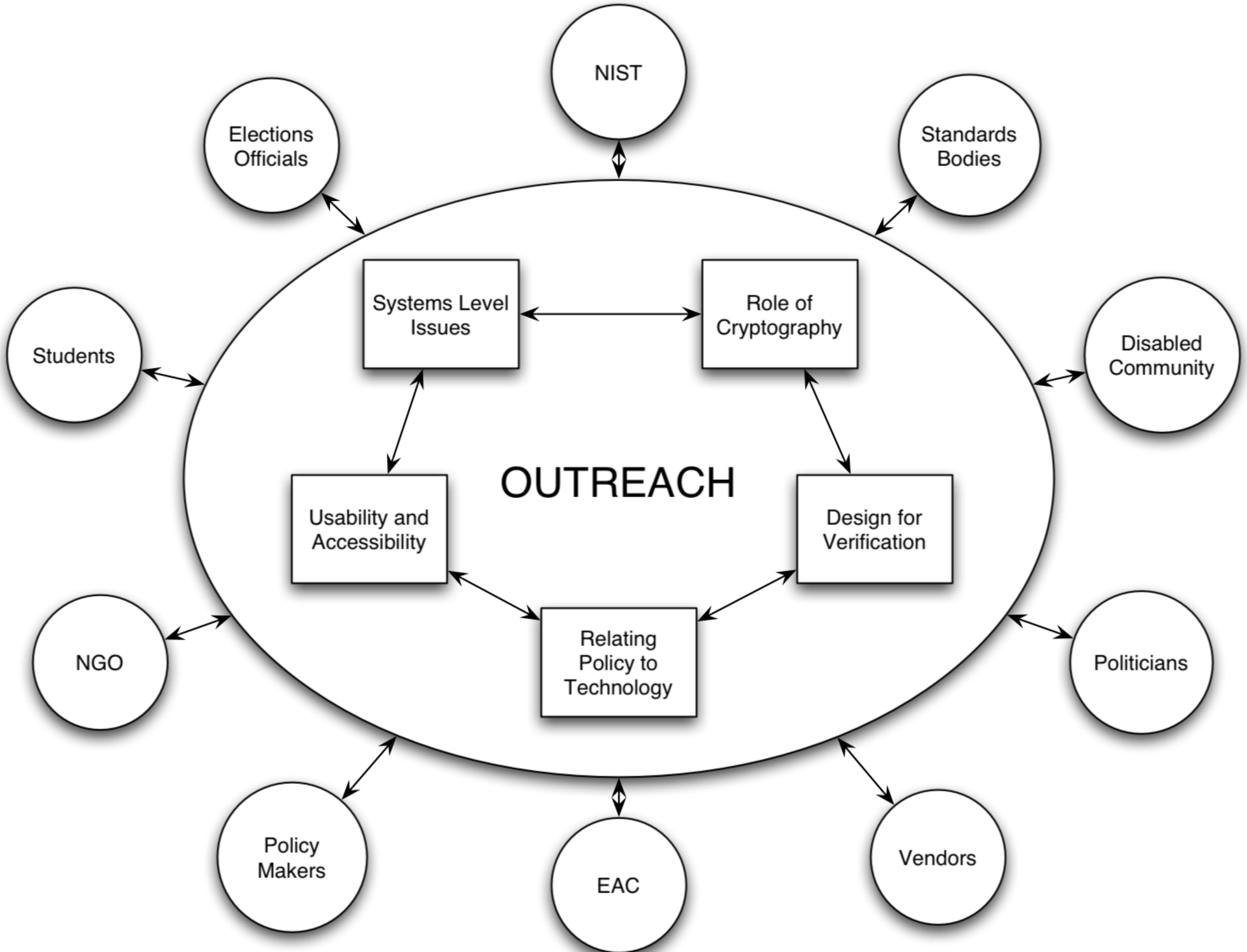
NIST
Elections Officials
Standards Bodies
Students
Disabled Community
Systems Level Issues
Role of Cryptography
OUTREACH
Usability and Accessibility
Design for Verification
Relating Policy to Technology
NGO
Politicians
Policy Makers
EAC
Vendors

Research Milestones

Year 1

- Establish research plan for each focus areas:
  - Problem formulation and initial development of basic techniques
  - Area research leaders establish coordination of collaborative activities

Year 2

- For each focus area
  - Develop prototypes
  - Develop algorithms and protocols
  - Expand collaborative activities
- Examination of applicability of ideas to other security domains.

Year 3

- Alpha release of an experimental platform for proof of concept
- Design and implementation of system development tools

Year 4

- Beta release and large-scale use of experimental platform
- Further development of tools

Year 5

- Final release and documentation of experimental platform

Education Milestones

Year 1

- Begin to develop curriculum around center activities

Year 2

- Further curriculum development
  - Undergraduate courses
  - High school
  - Work with teachers to integrate into their lessons
- Begin using course material
- Exchange of students among center PIs

Year 3

- Integration of center curriculum in several schools
  - College, graduate school, and high school

Year 4

- Revise curriculum to reflect progress of the center
- Increase number of schools using curriculum

Year 5

- Widespread use of center curriculum in colleges, graduate schools, and high schools

Outreach Milestones

Year 1

- Set up center web site
  - Focal point for center participants and activities
  - Presentations and papers from workshops
  - Announcements
  - Distribution of curriculum

Year 2

- Discussions with user communities, industry partners, and policy organizations to formulate challenges and requirements in specific voting scenarios
- Integration of center activities with existing outreach programs
  - Especially those targeting underrepresented minorities
- Release white papers and lecture notes.

Year 3

- Continue work with user communities, industry partners, and policy organizations
- Continue to leverage existing outreach programs
- Public release of source code

Year 4

- Continue to leverage existing outreach programs
- Begin transition plan for center activities beyond 5 year horizon

Year 5

- Continue to leverage existing outreach programs
- Another round of white papers and lecture notes

Evaluation

- Traditional metrics
  - Publications
  - Citation counts
  - Visibility
- ACCURATE-specific
  - Testimony, e.g. Congressional
  - Success in transferring technology to deployment
  - Use of center-developed technology in other domains

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Systems-Level Perspectives

Douglas W. Jones

The University of Iowa

Systems-Level Perspectives

- The Voting System Lifecycle
  - an example trusted system development cycle
- An Election Cycle
  - a single use of this trusted system
- Data Paths we must Secure
  - the distributed system view
- From voter to Canvass (technology matters)
  - guarding the chain of trust

Voting-System Lifecycle

An example trusted-system development cycle

- Development
  - Internal testing by vendor
- ITA Certification
  - Test against FEC (or EAC) standards
- State Qualification
  - 50 states, all do it differently
- County or State Purchasing Process
  - Typically involves sales demo of usability
- Deployment
  - Customer typically does acceptance testing

2 years for a rush job; 5 years is typical

An Election Cycle

- Election Definition
  - Define races, candidates, districts, precincts
- Configure Voting Equipment, Print Ballots
  - Geography makes each precinct different
- Pre-Election Test
  - Verify that everything is ready
- Election Day
  - Open polls, vote, close polls
- Canvassing
  - Compute and publish totals, archive results

We do this about 4 times a year in the US

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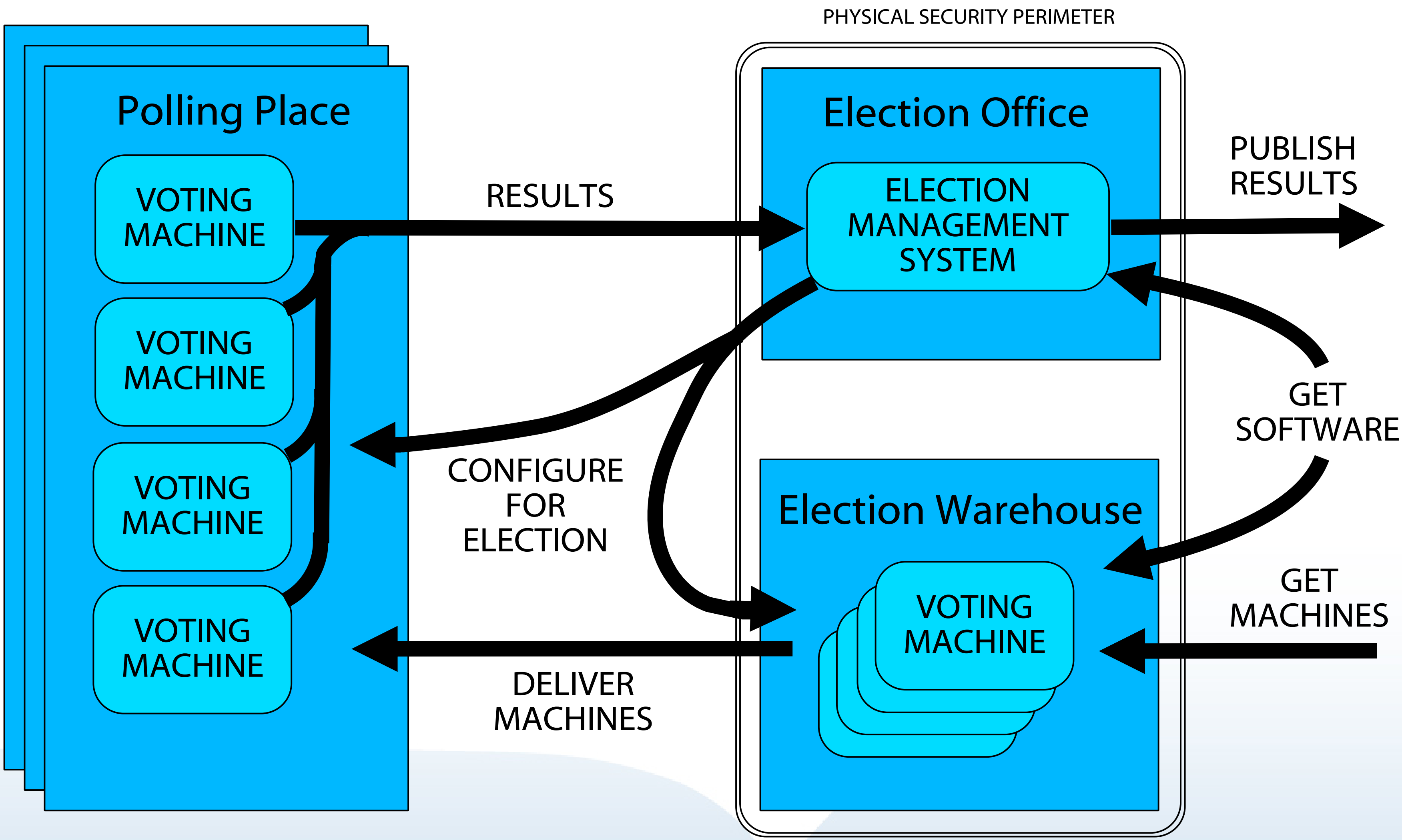
Data Paths to Secure

The distributed system view



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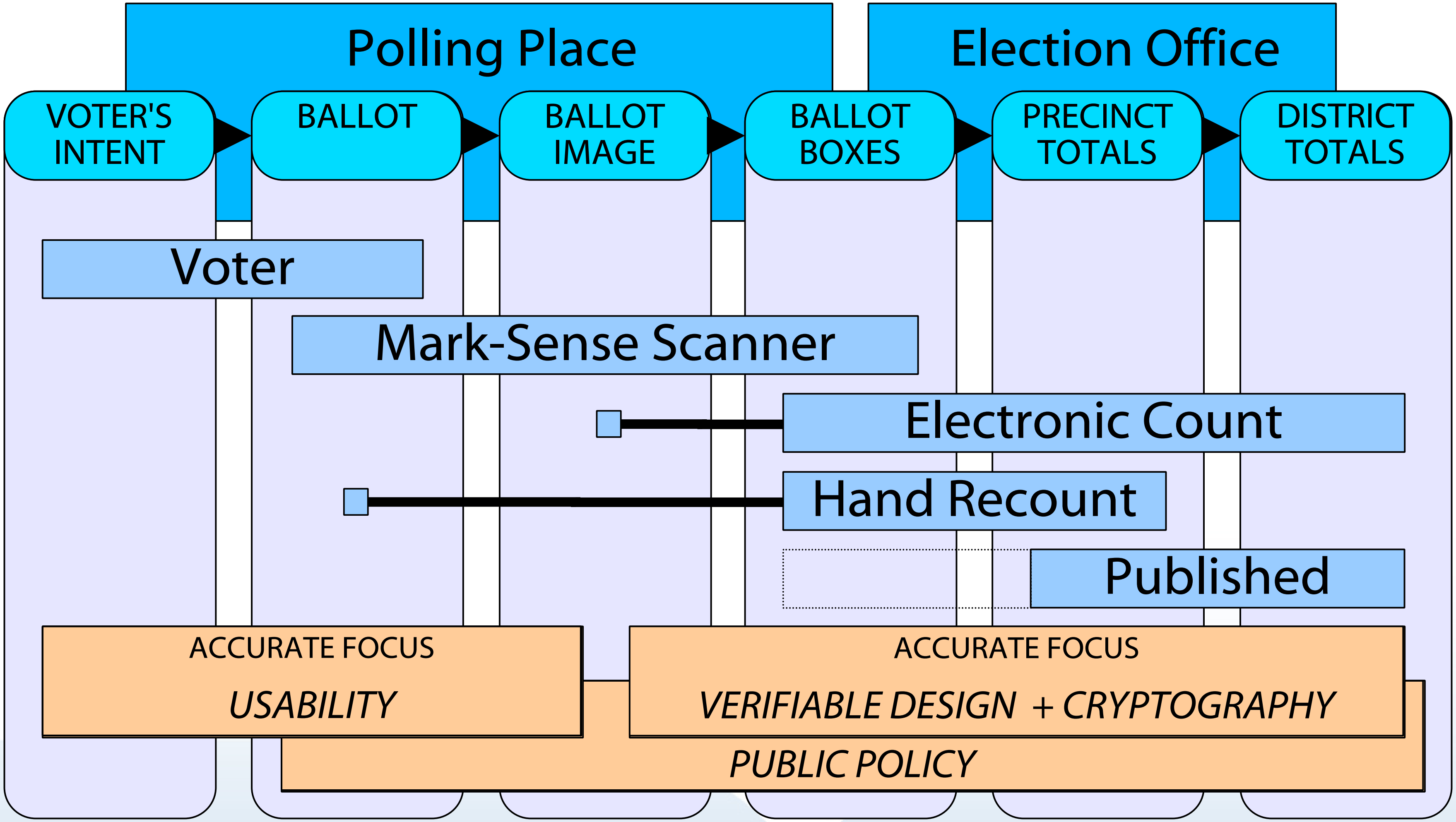
From Voter to Canvass: Mark Sense

Guarding the chain of trust



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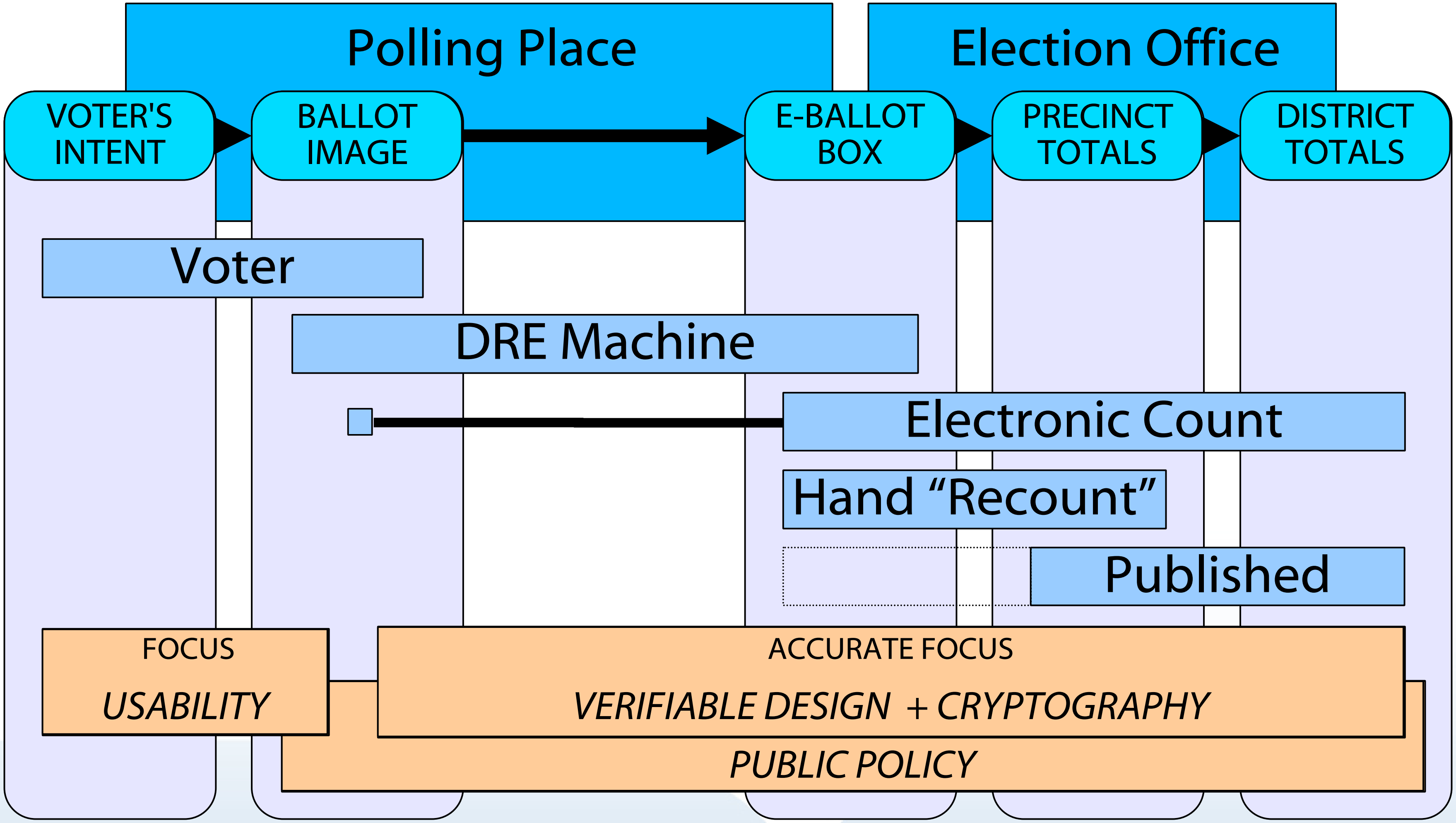
From Voter to Canvass: DRE

Guarding the chain of trust



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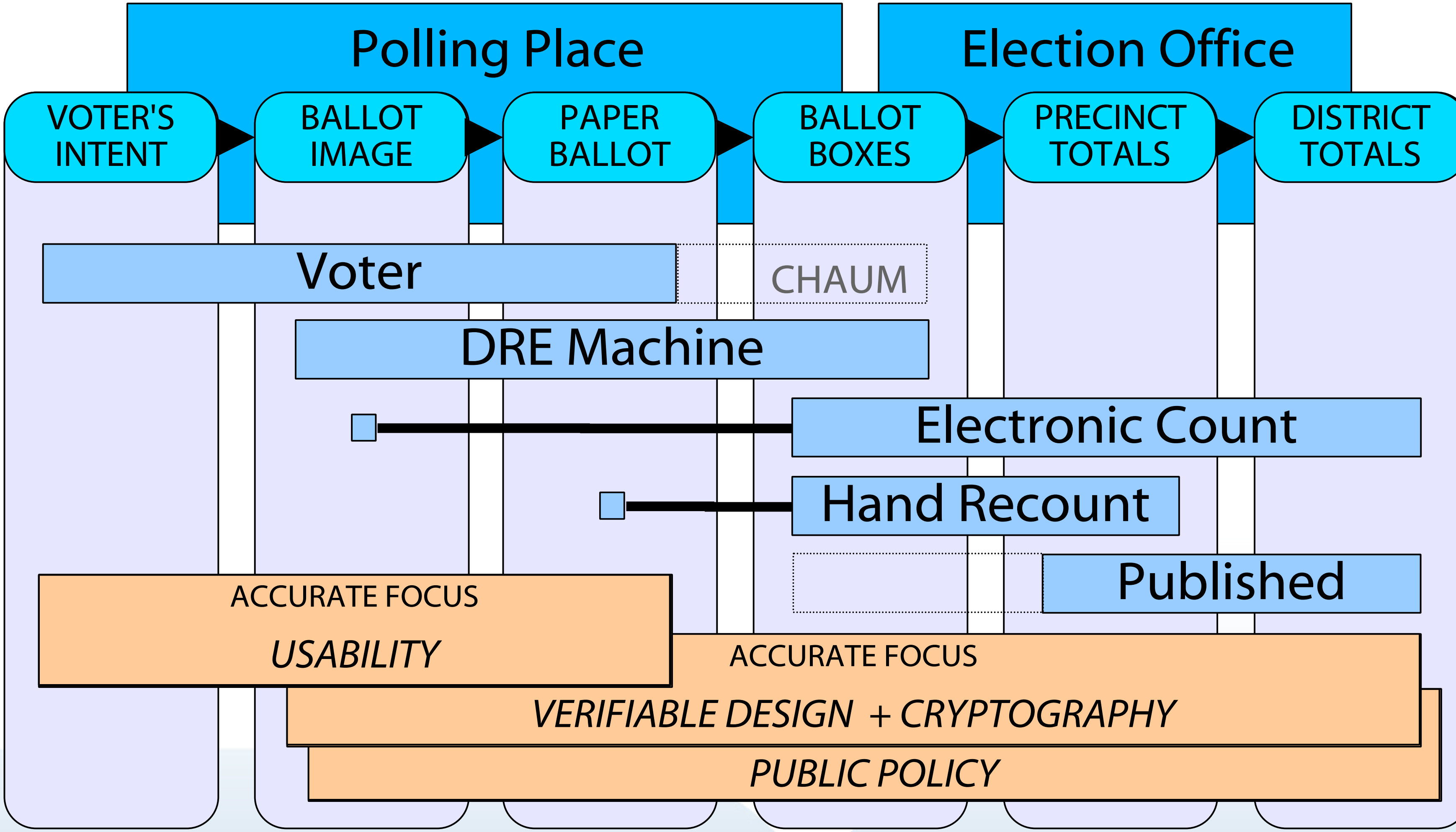
From Voter to Canvass: DRE + VVPT

Guarding the chain of trust



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Participants

Michael Byrne (Rice)
Dan Boneh (Stanford)
Drew Dean (SRI)
David Dill (Stanford)
Doug Jones (U Iowa) – team leader
Peter Neumann (SRI)
Avi Rubin (JHU)
David Wagner (Berkeley)
Dan Wallach (Rice)

Affiliate: David Jefferson (LLNL)

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The Role of Cryptography

David Wagner
University of California, Berkeley

Cryptography: The Big Picture

- Two ways to establish trustworthiness of voting software:
  1. Verify (by manual inspection, code review, or formal methods) that the code will do what is desired
  2. Have the system provide a cryptographic proof that it did what was desired

- This talk: Cryptography for end-to-end integrity in voting systems
  - Benefit: eliminates the need for code verification

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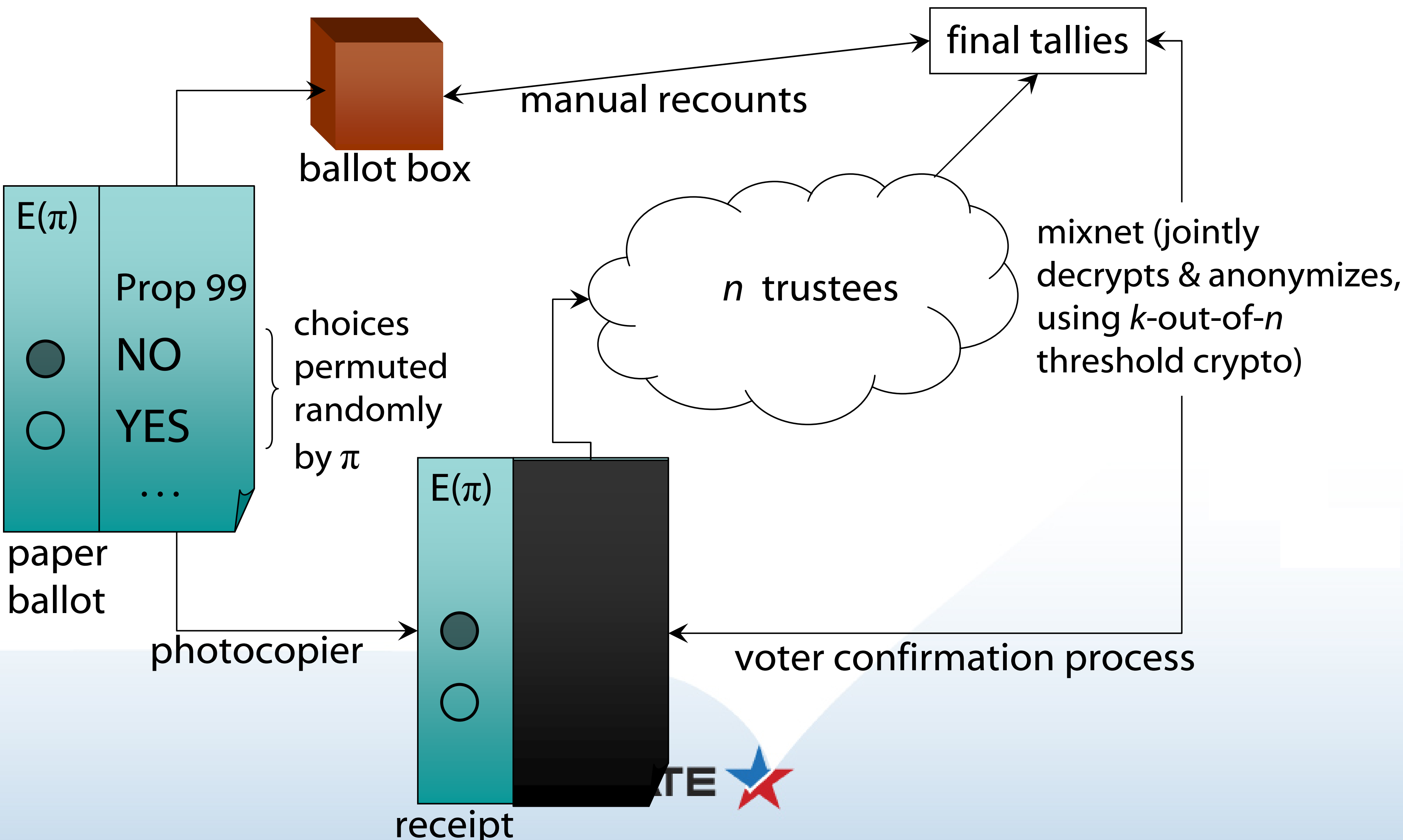
Research Questions

- Can cryptography offer a way to build a trustworthy system out of untrusted components?
- What are the limits of cryptographic voting? What is the best system we can find?
- How can we explain cryptography to the public? How simple can we make the crypto?
- How do we build secure crypto protocols that embed humans into the protocol?
- Can crypto voting provide stronger integrity guarantees than other systems? (e.g., “universal verifiability”)

Example: Chaum's Optegrity



Participants

- Dan Boneh (Stanford) — area leader
- Drew Dean (SRI)
- Doug Jones (U Iowa)
- Peter Neumann (SRI)
- Avi Rubin (JHU)
- David Wagner (UC Berkeley)
- Dan Wallach (Rice)
- Josh Benaloh (Microsoft) — affiliate
- David Chaum (Votegrity) — affiliate

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Design for Verification

David L. Dill
Stanford University

Problems

- Voting systems are *mission critical*
  - Design faults must be minimized.
  - Availability must be maximized.
  - Remaining faults must not compromise data or audit trails.
- Voting systems must be trustworthy
  - “Trust but verify”.
  - Threat model must include attacks by *insiders* (designers and operators), as well as outsiders.

Research Questions

- What can we do, before they are used, to make sure systems are trustworthy?
  - Design in (formal) verifiability.
  - Combine automated deduction, model checking, program analysis technology.
  - Focus on isolation of code for critical properties, to make verification easier.
  - Use formal verification technology to amplify efficiency of software testing.
  - Authenticate system software/hardware.

Results Verification

- Idea: Verify individual computations.
  - Buggy, insecure systems can still be trustworthy if *individual transactions* are verified.
  - Approach: permit voters to verify their votes.
    - Cryptographic methods.
- Application: Electronic verification for blind voters.
- Challenge: Trustworthy electronic audit trail.

Design in Auditability

- Build in logging of auditable events
  - Current audit trails are egregious (Miami Dade)
- Authentication of audit logs
- Auditing configuration management
  - How do we prevent Trojan horses from being installed?
  - Special case of *spyware* problem

Participants

- Drew Dean (SRI)
- David Dill (Stanford) – team leader
- Doug Jones (U. Iowa)
- Peter Neumann (SRI)
- David Wagner (Berkeley)
- Dan Wallach (Rice)

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The Nexus of Policy and Technology

Deirdre Mulligan

University of California, Berkeley

Technology/Policy Nexus

- Policy goals drive security and other performance requirements
  - Requires translation
  - Mechanisms for embedding rules, proving conformance, overseeing use and deployment
- Introduction of new technology requires consideration of whether
  - Original assumptions carry forward
  - Translation of requirements is sufficient
  - Requirements themselves are sufficient

Embedding Policy in Technology

- Conformance tools
  - Standards
  - Certification
  - Testing
- How do we evaluate these tools?
- Pre-requisites for optimal functioning?
- Necessary but not sufficient?

Updating Policy with Technology

- Insufficient attention to technology changes
  - Lack of information about technology
  - Lack of technical expertise
  - Rote application of law
- Reactive nature of law

Intermediate Goals

- Foster communication
- Increase understanding
- Focus on processes of translation
  - Legislation, regulation, standards, qualification, testing, certification, procurement
- Identify technology changes that merit scrutiny due to policy impact

Research and Goals

- Conforming Technology to Policy
  - Understanding and improvement of conformance tools
  - Identification of new conformance mechanisms
- Tools to identify technology changes that matter
- Techniques for crafting technology neutral statements of policy

Team

Deirdre K. Mulligan (UC Berkeley)

David Dill (Stanford)

Peter G. Neumann (SRI)

Affiliates:

Kim Alexander (CVF)
David Chaum
Cindy Cohn (EFF)
Will Doherty (VVF)
Christopher Edley (UC Berkeley)

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Usability and Accessibility

Michael D. Byrne
Rice University

The Usability Problem

- Perfectly reliable, secure, auditable, etc. voting systems can still fail
- Must be *usable* as well
  - Both objectively usable and perceived as usable
  - EAC currently recommends usability evaluation
    - But with little guidance, no standards, and no resources provided

Human Factors of Voting

- Very little human factors research or literature devoted to voting
  - Despite occasional high-profile usability failures (e.g., Florida “butterfly” ballot)
  - General human factors principles and methods should apply
- Voting is an intrinsically challenging human factors problem
  - User population with zero training
  - Most diverse user population anywhere

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Where to Start

- 2004 NIST report suggests ISO usability metrics (2 objective, 1 subjective)
- Effectiveness
  - Votes are for intended candidates; no errors
- Efficiency
  - Voting takes reasonable time and effort
- Satisfaction
  - Voter is confident, voting is not stressful

Metrics

- Need to establish baselines for existing voting systems (optical scan, traditional paper, etc.)
- Assess interactions between systems and subpopulations of voters
  - e.g., are certain systems worse for older voters?
- Requires active recruitment of diverse participant pool
  - Houston has a diverse population but other Center sites will be needed
  - IRB certification in hand
- New systems should be no worse than current ones
  - But, amazingly, nobody knows where that target is

Beyond Metrics

- Need to understand *why* systems score as they do
  - Requires more than simple user testing
  - Engineering analysis, formal methodologies, quantitative models
  - Involve subject matter experts (e.g., election officials); this is also outreach
- Synthesize that knowledge and generate:
  - Guidelines for system designers
  - Evaluation tools/advice/standards for election officials

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Usability Lifecycle

- Best usability achieved when designers consider human factors early in design
  - Vital for Center-produced prototypes and systems to have early access to this knowledge
- Iterative testing also crucial
  - Subject Center-developed prototypes to the same testing and analysis as existing systems
- Similar to security: think usability early and often

Accessibility

- "Accessibility" defined in human factors community as usability for members of special populations
  - Vital to include members of such populations in empirical evaluations
  - Center will attempt to liaison with organizations which represent such populations
- Vendors claim in-principle advantages for electronic systems on accessibility
  - Reasonable face validity
  - But not supported by strong empirical evidence
- Important public policy implications

Participants

- Mike Byrne (Rice) — team leader
- Drew Dean (SRI)
- Doug Jones (Iowa)
- Deirdre Mulligan (Berkeley)
- David Wagner (Berkeley)
- Dan Wallach (Rice)
- Affiliates
  - Whitney Quesenbery (Usability Professionals' Association)
  - Verified Voting

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Education, Outreach, and Training

Dan S. Wallach

Rice University

Professional outreach

Outreach is a top goal of our project

- Disseminate technical results to vendors
- Influence standards and regulatory bodies
- Testimony for state and national legislatures
- Workshops for election administrators
- NGOs (voting rights, civic participation, minority rights, etc.)

Goal 1: Deliver scientific results to our nation's elections officials and administrators in a form they can use.

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Science impacting public policy

Analysis of an Electronic Voting System (IEEE Security & Privacy 2004, with Wallach and Rubin as co-authors)

http://avirubin.com/vote/

- Significant flaws with Diebold system
- Impetus for legislation in several states

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Science impacting public policy

A Security Analysis of the Secure Electronic Registration and Voting Experiment (SERVE) (with Rubin and Wagner as co-authors)

http://www.servesecurityreport.org

- Internet voting has significant risks
- Department of Defense scrapped program

Professional outreach history

- Testimony before government bodies
  - Federal and state legislature committees
  - NIST Technical Guidelines Dev. Committee
  - Carter-Baker Election Commission
  - Local, county, and state political party groups
  - International
- Influential membership / consultancy
  - Iowa Board of Election Examiners (Jones)
  - Miami-Dade County Elections (Jones)
  - NYC Board of Elections (Neumann)
  - Verified Voting Foundation
  - IEEE P1583 standards committee

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ACCURATE annual conference

- Disseminate results to election officials
  - Demonstrate prototype systems
    - And get feedback on practical concerns
- Facilitate discussion
  - Problems with fielded systems
  - Regulatory concerns
  - Financial limitations
- Minimal cost for participants
  - Web video and DVDs for broadest audience

Public outreach

- Over 100 invited talks, panels, lectures …
  - Civic groups
  - Public debates

  (see enclosed *Voting-related and Outreach Experience for the PIs*)
- Countless TV, radio, and print interviews (from the *New York Times* to the *Daily Show with Jon Stewart*)
- Web log (evoting-experts.com)

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Extended outreach

Science applied to an engaging problem

- Teach computer science concepts in an elections context
- High school visits and talks
- Leverage existing university outreach programs to underserved communities

Goal 2: General education.

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Rice outreach programs

- Two public forums on electronic voting security issues
  - One with co-PI David Dill as keynote speaker
- CS-CAMP – support female students in pre-college computer science.
  http://ceee.rice.edu/cs-camp/
- The Science Academy of South Texas
  - Summer programs for lower-income high-school students

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Johns Hopkins outreach

- RET and REU programs
  - Over 200 teachers participated
- BIGSTEP (new NSF program)
  - Local school districts
  - Native American tribal schools
  - Primary focus on environmental engineering and geography
- Long history of outreach programs (organized by Leigh Abts, research scientist at JHU)
- ACCURATE will supplement these programs

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Stanford outreach programs

- Annual *Security Forum* (8 years running)
  - Average 100 people industry attendance

- Engineering Diversity Program (soe.stanford.edu/edp)
  - Math institutes and summer programs for diverse students
  - Undergraduate tutoring, seminars, research

Other outreach programs

- Iowa Upward Bound (upwardbound.uiowa.edu)
  - Low-income high-school students
  - School-year advising / summer courses
- SRI InRoads (www.inroads.org)
  - Internships for under-represented minority undergraduate students
- Berkeley SUPERB-IT (Summer Undergraduate Program in Engineering Research at Berkeley – Information Technology)
  - NSF REU, minority-serving program to develop competitive graduate applicants through undergraduate research www.coe.berkeley.edu/cues/superb/

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Teaching

Goal 3: Curriculum materials (and code) that can be easily adopted.

Goal 4: Undergraduate research involvement.

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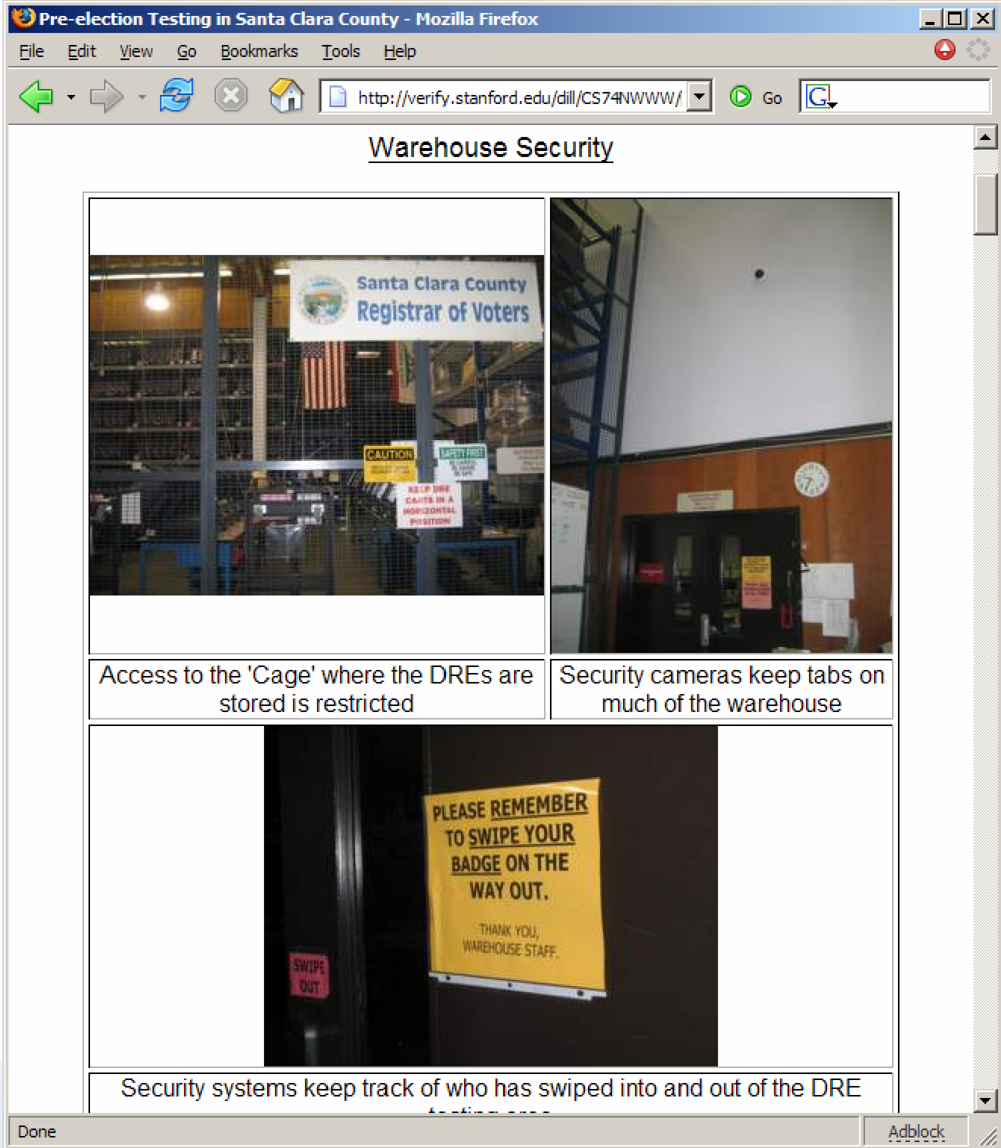
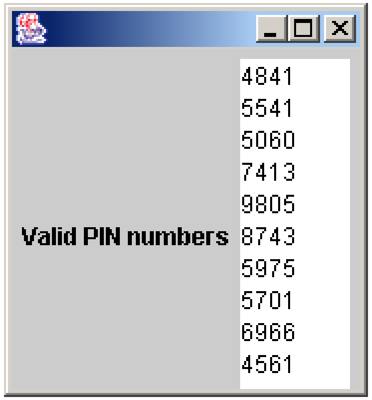
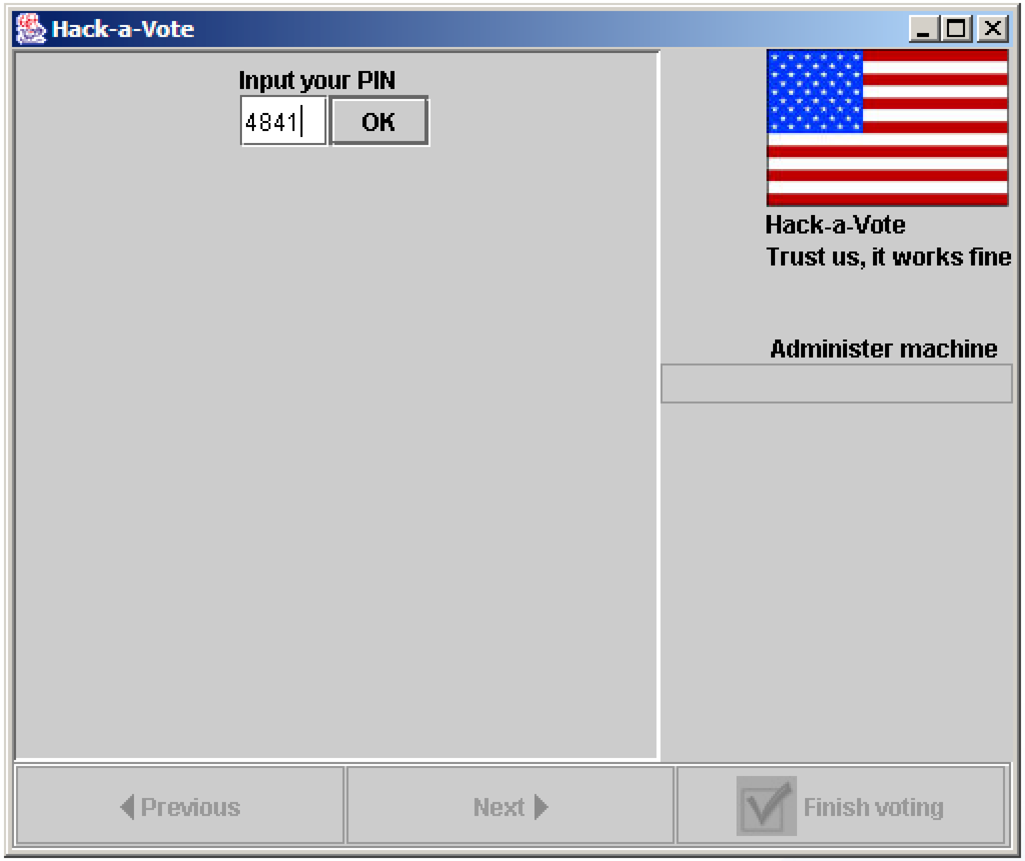
Current teaching

- Voting security lectures in current courses
  - Cryptography at Stanford, Berkeley
  - Systems security at Rice, Hopkins, Iowa
  - Freshman seminar ("Digital Dilemmas") at Stanford



Rice Hack-a-Vote design





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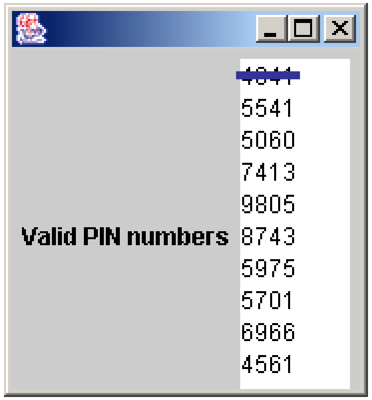

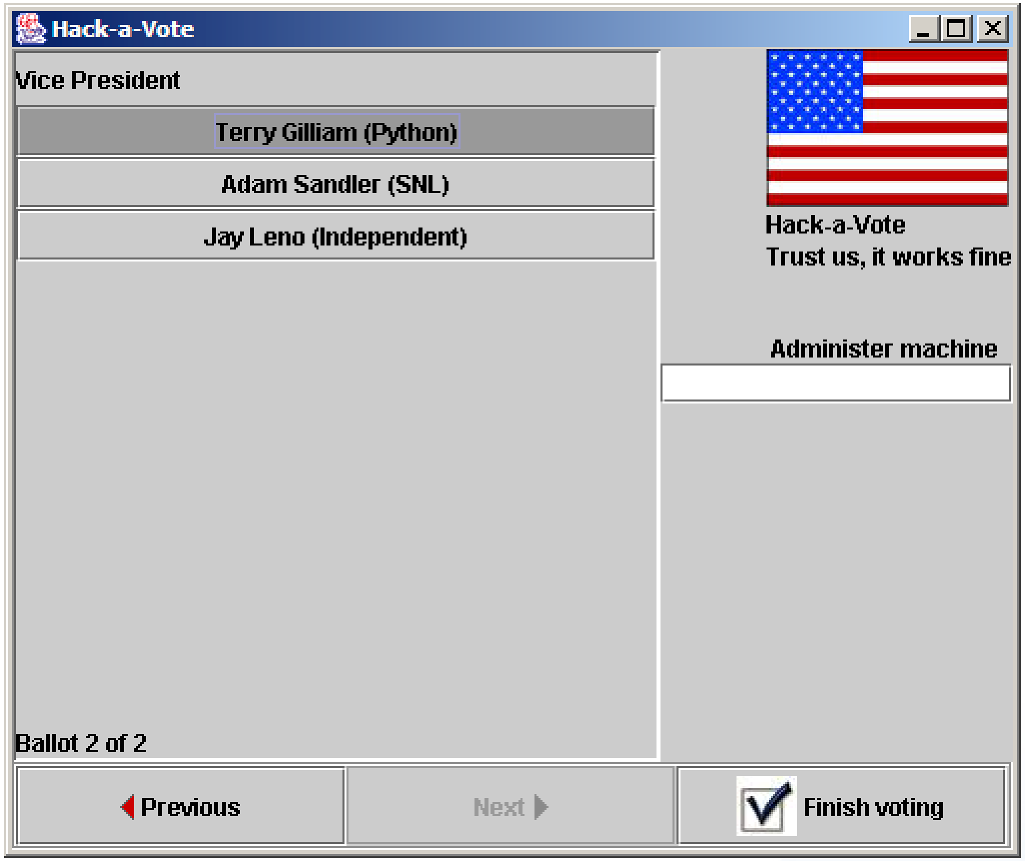

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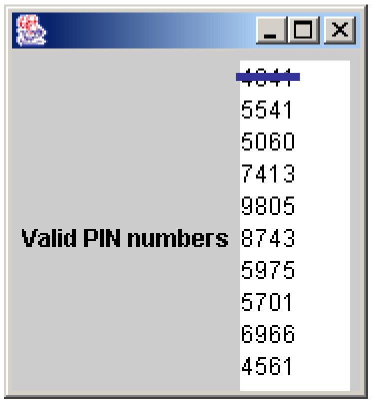
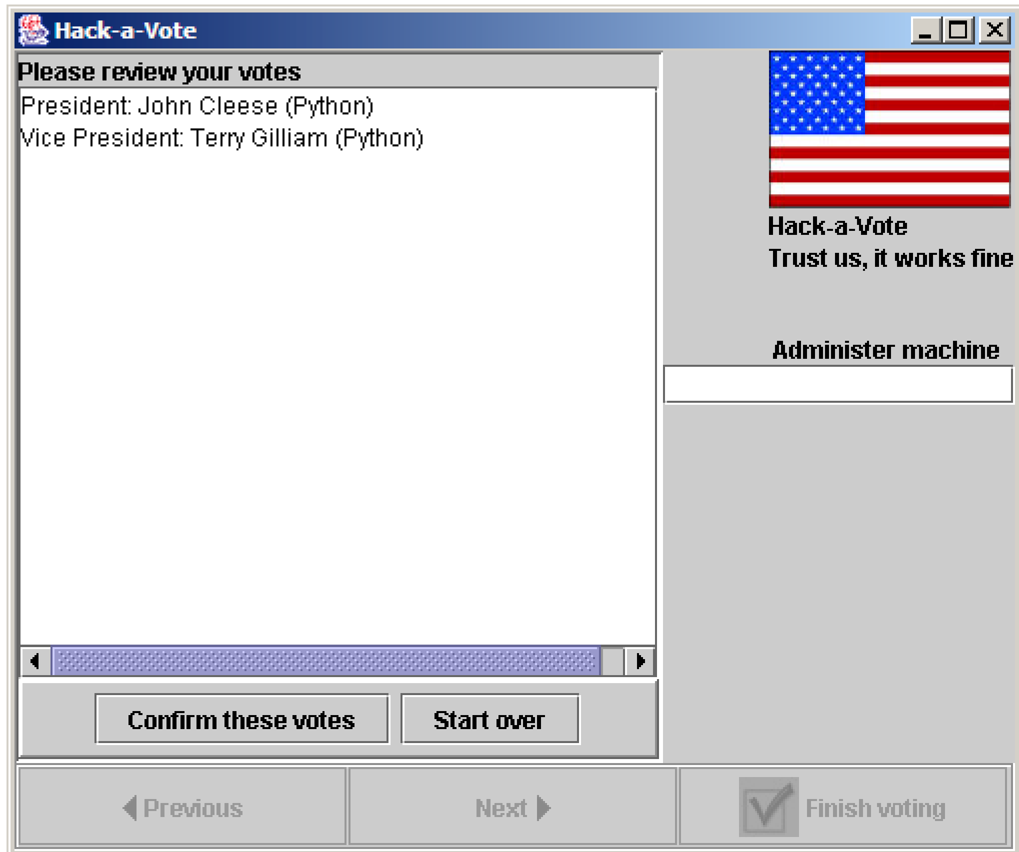
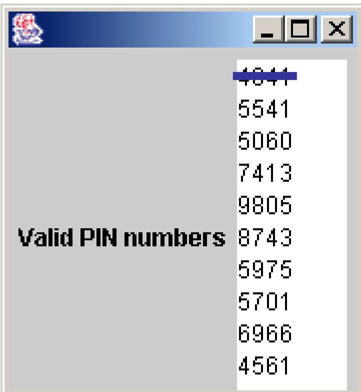
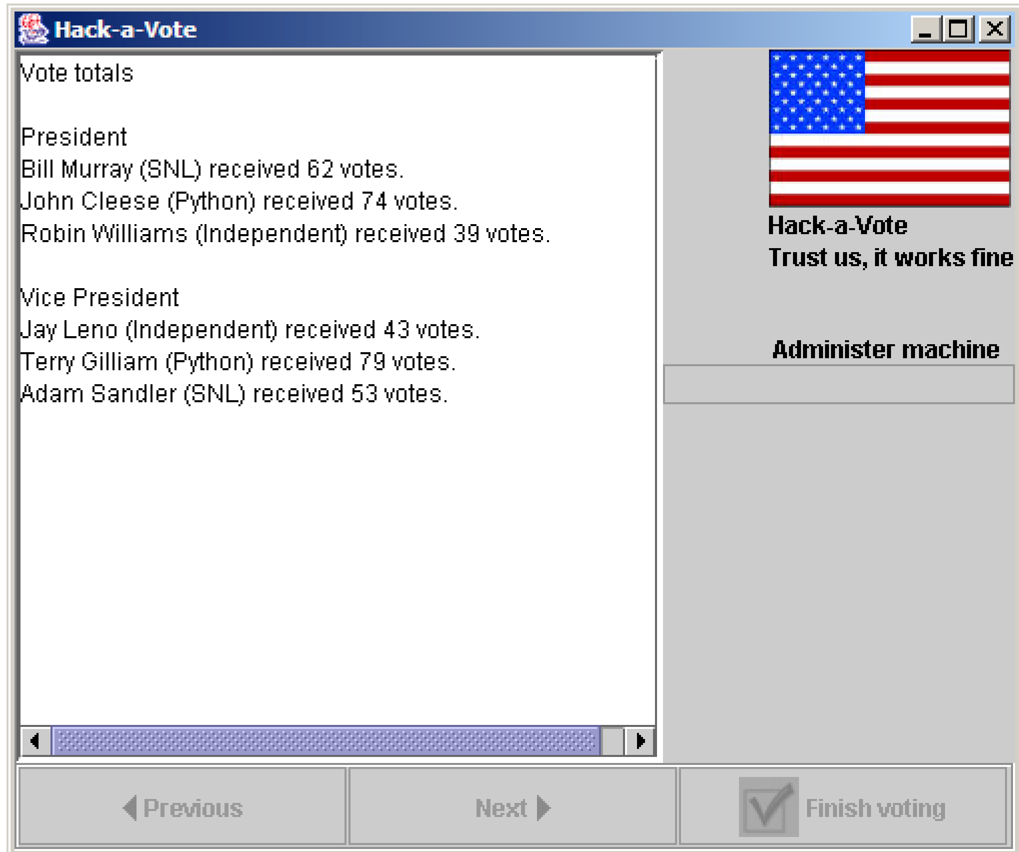




Rice Hack-a-Vote design





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Rice Hack-a-Vote assignment

Students given ~2000 line Java system

Three phase assignment

1) Be evil (2 weeks)
2) Be an auditor (1 week)
3) Design / formally model better version of Diebold smartcard (2.5 weeks)

Clever student attacks

- Manipulate results, violate anonymity, DoS
- Several undetected by audit teams

www.cs.rice.edu/~dwallach/pub/hackavote2004.pdf

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ACCURATE teaching

- Research systems in the classroom
  - Software engineering, crypto, human factors
  - Student engineering effort / feedback improves our production code
- Public dissemination for widespread use
  - Hack-a-Vote under BSD-style license
- Cross-institution opportunities
  - Compare local election procedures
  - Competitive Trojan / auditor exercises

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Undergraduate research

- All PIs have worked with undergrads
  - Including many women and minorities
- Example: Adam Stubblefield
  - Rice undergraduate (BA ’02)
  - Research internships as an undergrad
    - Xerox PARC with Drew Dean (2000)
    - AT&T Research with Avi Rubin (2001)
  - 4 conference, 1 journal paper (undergrad)
  - CRA outstanding undergrad award (2002)
  - Johns Hopkins PhD, May 2005 (w/ Avi Rubin)

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ACCURATE undergrad research

- Class projects to research projects
  - Build on our shared codebase
- Cross-institutional opportunities
  - Example: Darwin Cruz
    - Stanford undergraduate, parents live near Rice
    - Worked with Wallach at Rice in summer ’04
    - Continues working with Dill at Stanford
  - Summer internships → complementary skills
- Leverage existing support mechanisms
  - University programs, REUs

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Summary

PIs already have extensive professional involvement with outreach and education.

Creative pedagogy and undergraduate involvement in research.

Excellent university resources to leverage for impact on minority and underserved communities.

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Technology Transfer and Partnerships

David L. Dill
Stanford University

The Problem

- How will we maximize the impact of our results?
- Specifically, how will we get technological innovations to users?

Some innovations will be specific to voting, others will not.

Transfer of General Tech

- All participating institutions provide support for business development and technology licensing.
- Team members have successful experience with high-tech startups.
- Transfer will be facilitated through open-source products whenever feasible.

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Transfer of Voting Tech

- Technological barriers
- Laws, regulations, and standards
- Equipment vendors
- Choices of local election officials
- Other stakeholders and the general public

Develop the Right Technology

- Transferring inappropriate technology is impossible.
- Voting technology is not as easy as it seems!
  - Simultaneously achieving: accurate, secure, usable, trustworthy, privacy, accessible, multi-language, logistically tractable … systems.
- *Practical* solutions to many voting tech problems do not (yet) exist.
- The proposed work directly addresses these limitations.

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Appropriate Technology

- We understand the technological problems.
- We understand the legal and regulatory environment.
- We work with and advise election officials.
- We work with and understand the needs of many other stakeholders.

Laws & Regulations

- Rules can *require* beneficial technology to be used.
- We're familiar with current and pending legislation
  - We have provided technical advice on many of the pending Federal & state bills.
- We are involved in several standards efforts
  - IEEE P1583
  - Voting Systems Performance Rating
- We are defining "best practices"
  - E.g., Brennan Center for Justice at NYU

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Vendors

- Most voting equipment is marketed through a small number of major vendors.
- We have good communications with all major and most minor vendors.
- Our evaluations of feasibility of technology (e.g., usability, cost) will reduce vendor risk.
- There may be opportunities for new vendors.
  - E.g., third party devices for auditing or accessibility.
  - Some of these could be non-profits.

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Election Officials

- We can influence election officials decision about acquiring (and demanding) new types of voting technology.
- We work with election officials at state and local levels.
  - Proposal includes workshops for election officials
- We'll provide independent, objective advice about election technology.
- We'll help inform election officials about current and future alternatives.

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Public Demand

- The wishes of the public carry great weight in voting technology acquisition choices.
- We are ideally positioned to educate the public about new voting technology.
- Team members get substantial media exposure.
  - Comparison of technological alternatives
  - Commenting on problems that have arisen.

Other Stakeholders

- Interest groups influence voting systems
- We are members of a much larger network of organization concerned with voting technology.
  - Good government groups
  - Voting rights/civil rights groups
  - Citizens groups (e.g., TrueVoteCT)

Unfunded Affiliates

This is a partial list:

- Kim Alexander, President of California Voter Foundation
  - "Digital democracy", incl. E-voting
- Cindy Cohn, Chief Counsel, Electronic Frontier Foundation
  - Technology and law, incl. E-voting
- David Jefferson, voting tech consultant for California
- Whitney Quisenbery, President, Usability Professionals Organization,
  - Technical Guidelines Development Committee of the Election Assistance Commission
- David Chaum, Votegrity
- Josh Beneloh, cryptographer, Microsoft
- Verified Voting Foundation
  - Research and education in voting technology

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Center Evaluation

Peter G. Neumann
SRI International

Traditional success metrics

- Papers published
  - Journals and conferences
- Citation counts and other references
- Popular media appearances
  - Articles, op-ed pieces and editorials
  - TV, radio, Web hits
- Subsequent activities of students supported

ACCURATE-specific measures

- Testimony before government and administrative bodies, NRC study groups, NIST, and EAC
- Impact on legislative and administrative groups
- Adherence to existing usability standards (and new standards that we might evolve)
- Establishing and evaluating against new criteria for interoperability, composability, and compositionality
- Participation in standards groups such as the IEEE
- Interactions with Open Voting Consortium and commercial vendors
- New technical approaches and policies that find their way into practice and next-generation voting systems and into spinoffs for other applications

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