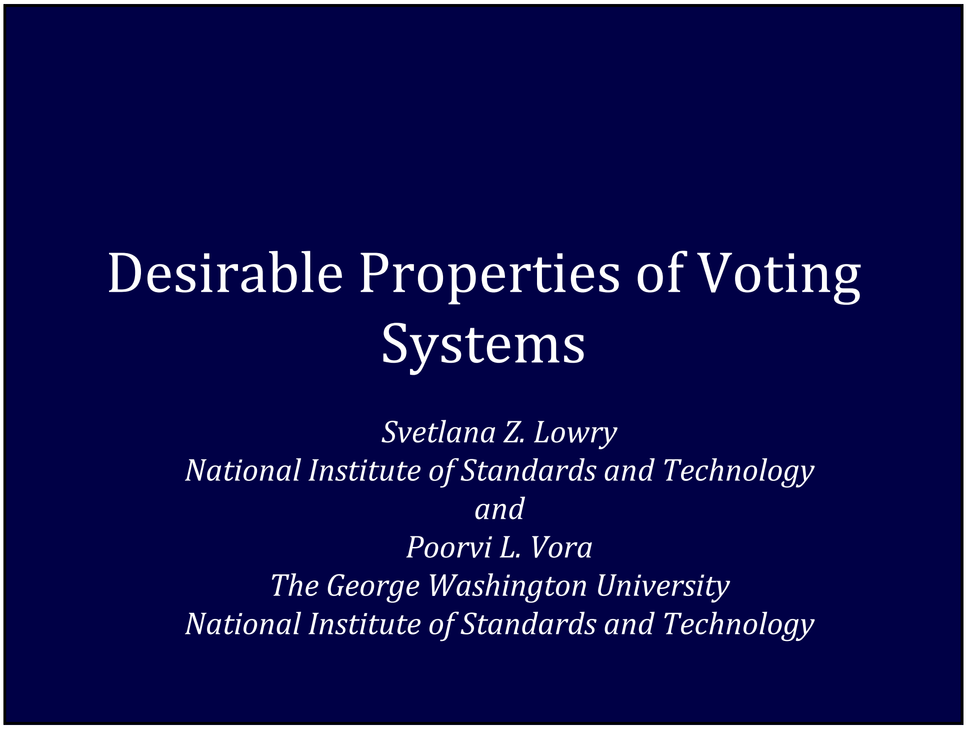
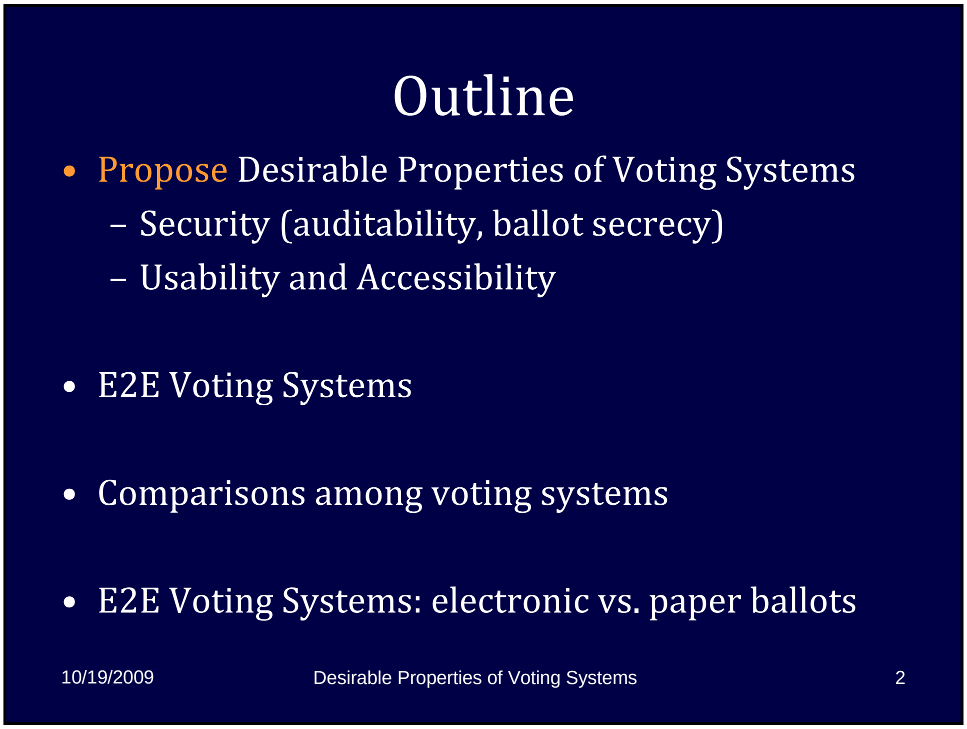


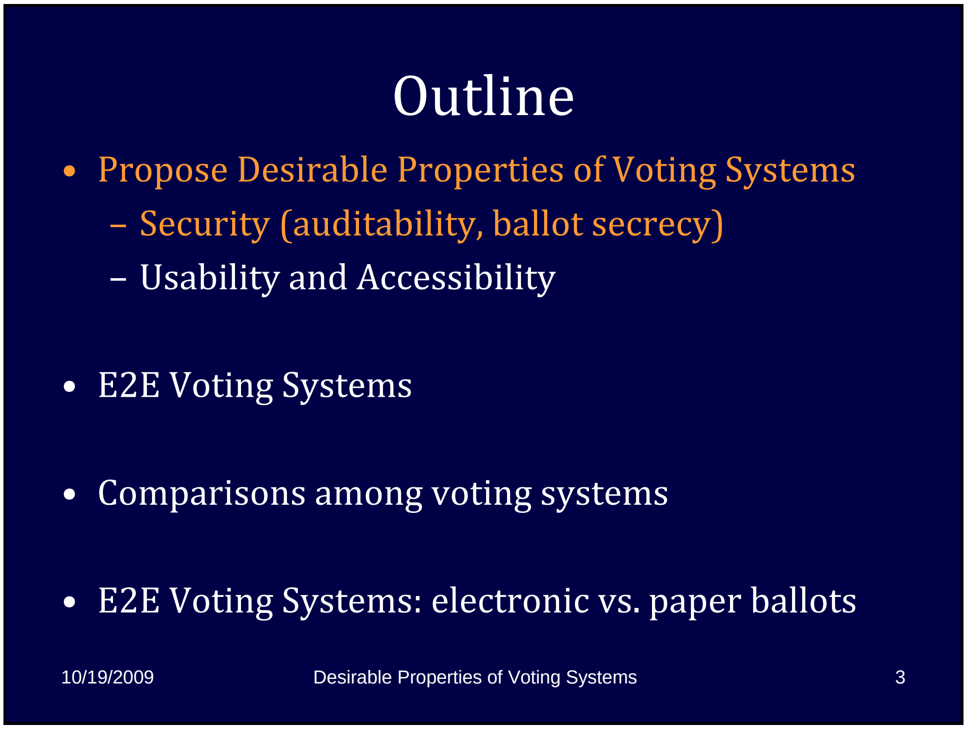
Desirable Properties of Voting Systems

Svetlana Z. Lowry
National Institute of Standards and Technology
and
Poorvi L. Vora
The George Washington University
National Institute of Standards and Technology



Outline

- Propose Desirable Properties of Voting Systems
  - Security (auditability, ballot secrecy)
  - Usability and Accessibility
- E2E Voting Systems
- Comparisons among voting systems
- E2E Voting Systems: electronic vs. paper ballots



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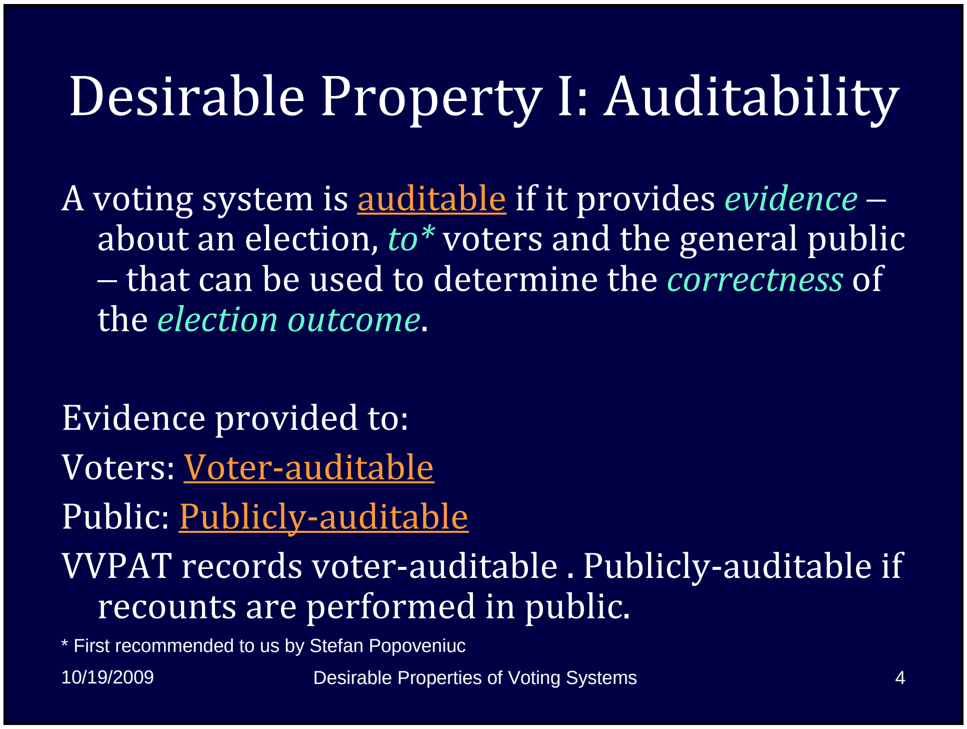


Desirable Property I: Auditability

A voting system is auditable if it provides *evidence* – about an election, *to** voters and the general public – that can be used to determine the *correctness* of the *election outcome*.

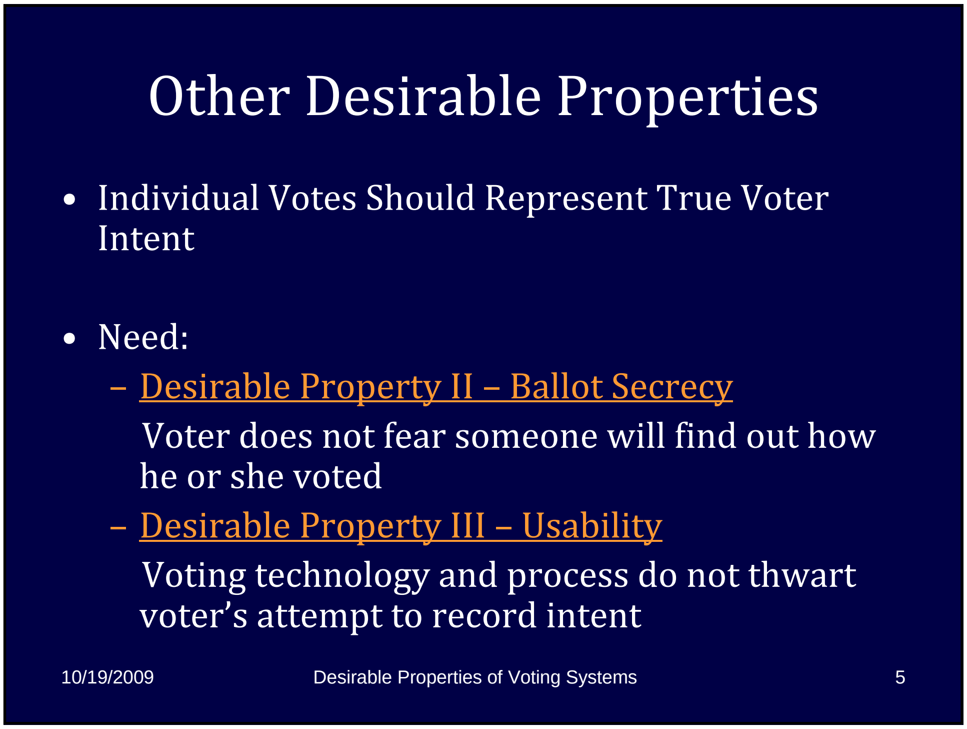
Evidence provided to:

Voters: Voter-auditable

Public: Publicly-auditable

VVPAT records voter-auditable . Publicly-auditable if recounts are performed in public.

* First recommended to us by Stefan Popoveniuc

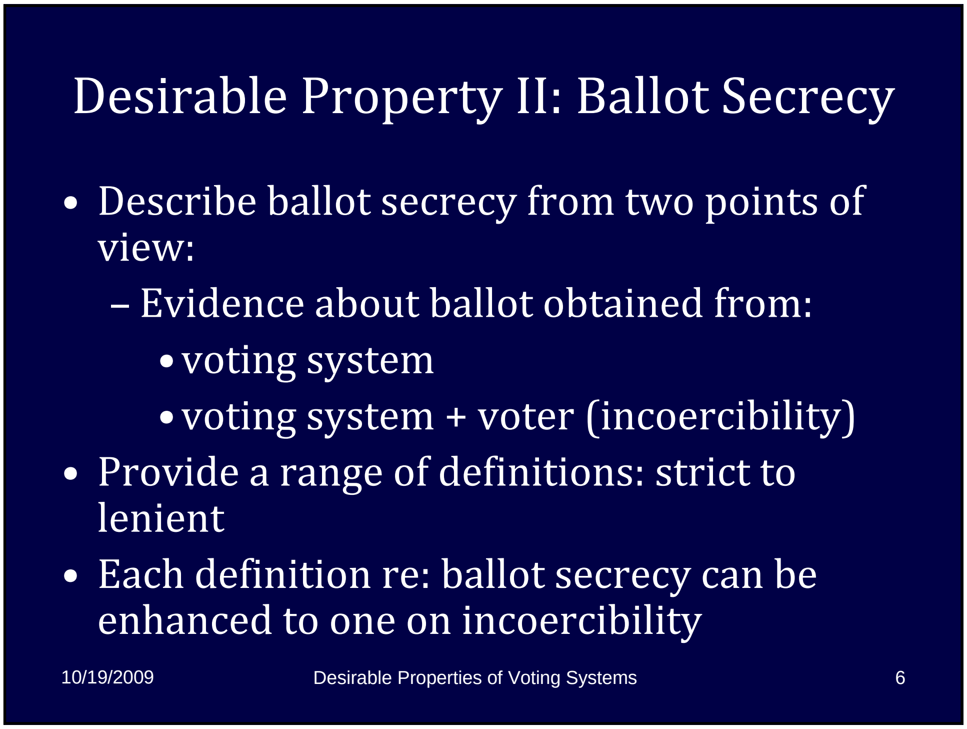


Other Desirable Properties

- Individual Votes Should Represent True Voter Intent
- Need:
  - Desirable Property II – Ballot Secrecy

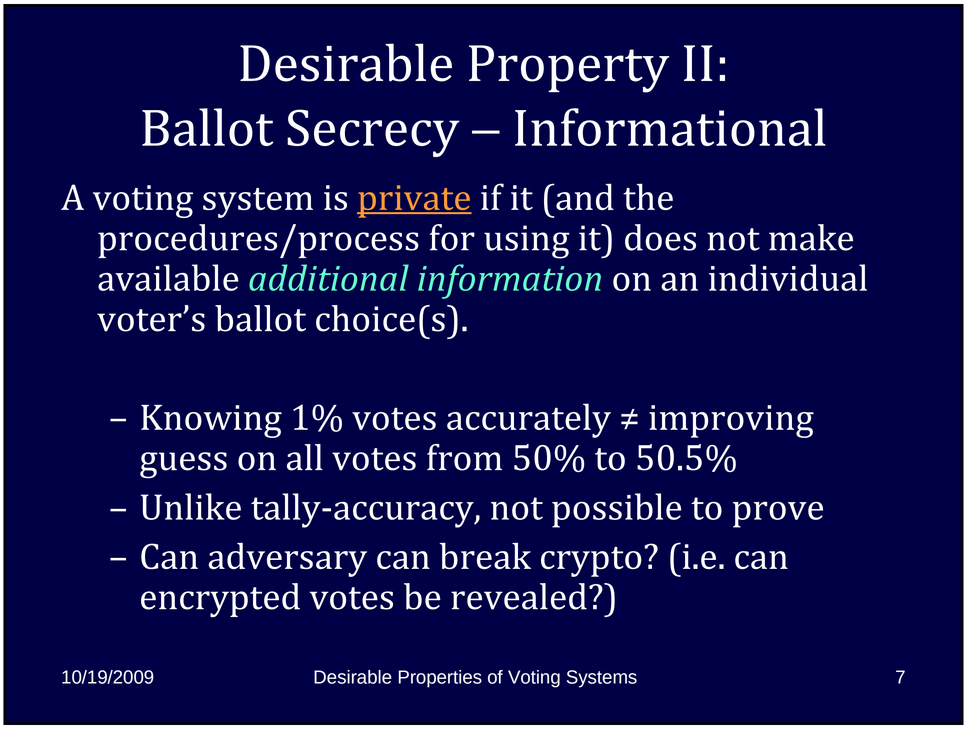
    Voter does not fear someone will find out how he or she voted
  - Desirable Property III – Usability

    Voting technology and process do not thwart voter's attempt to record intent



Desirable Property II: Ballot Secrecy

- Describe ballot secrecy from two points of view:
  - Evidence about ballot obtained from:
    - voting system
    - voting system + voter (incoercibility)
- Provide a range of definitions: strict to lenient
- Each definition re: ballot secrecy can be enhanced to one on incoercibility



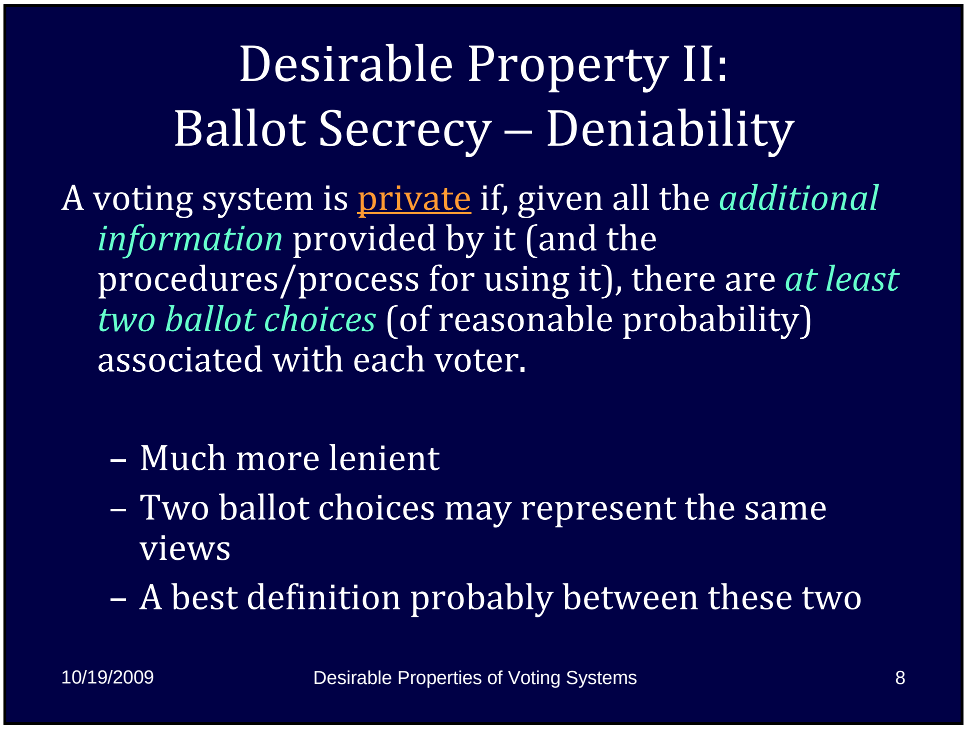
Desirable Property II: Ballot Secrecy – Informational

A voting system is private if it (and the procedures/process for using it) does not make available *additional information* on an individual voter's ballot choice(s).

– Knowing 1% votes accurately ≠ improving guess on all votes from 50% to 50.5%

– Unlike tally-accuracy, not possible to prove

– Can adversary can break crypto? (i.e. can encrypted votes be revealed?)



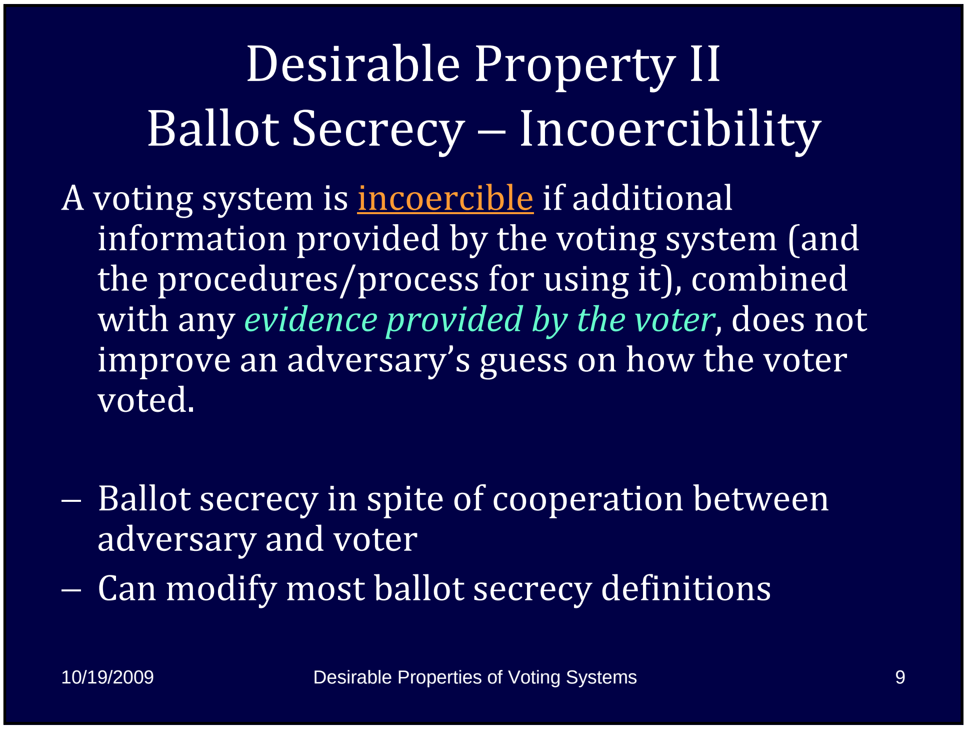
Desirable Property II: Ballot Secrecy – Deniability

A voting system is private if, given all the *additional information* provided by it (and the procedures/process for using it), there are *at least two ballot choices* (of reasonable probability) associated with each voter.

– Much more lenient

– Two ballot choices may represent the same views

– A best definition probably between these two

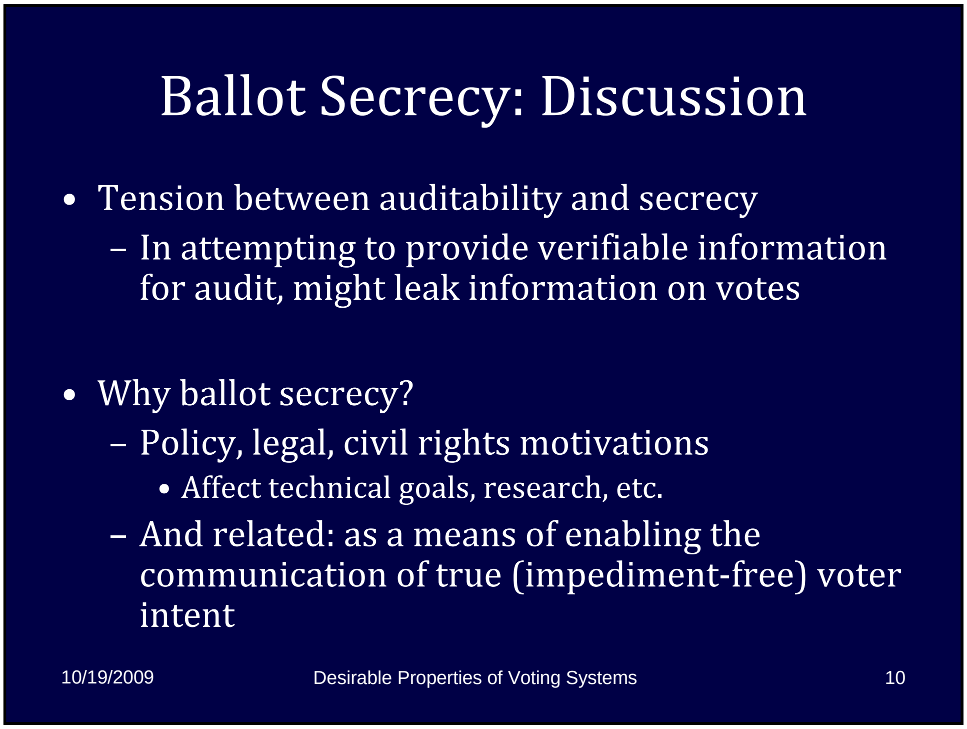


Desirable Property II
Ballot Secrecy – Incoercibility

A voting system is incoercible if additional information provided by the voting system (and the procedures/process for using it), combined with any *evidence provided by the voter*, does not improve an adversary's guess on how the voter voted.

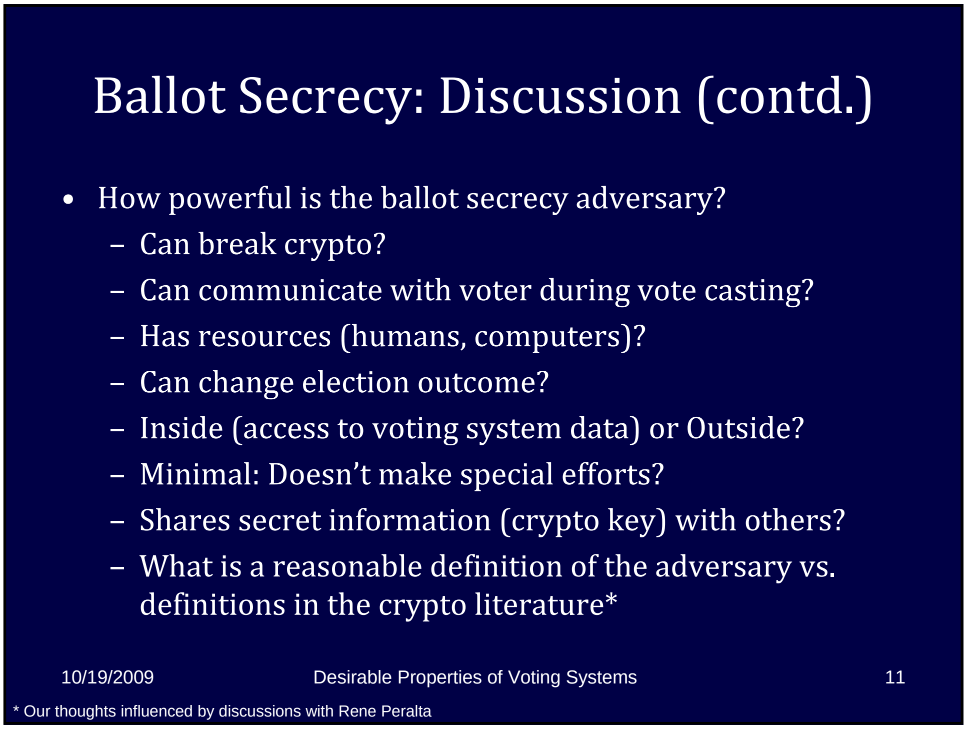
– Ballot secrecy in spite of cooperation between adversary and voter

– Can modify most ballot secrecy definitions



Ballot Secrecy: Discussion

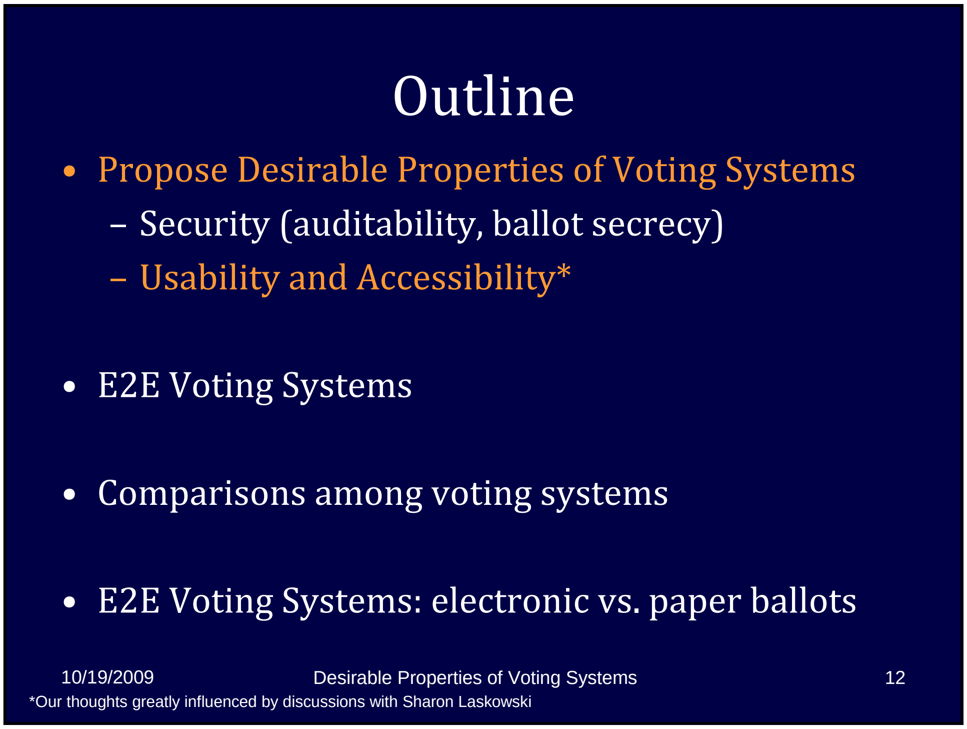
- Tension between auditability and secrecy
  - In attempting to provide verifiable information for audit, might leak information on votes
- Why ballot secrecy?
  - Policy, legal, civil rights motivations
    - Affect technical goals, research, etc.
  - And related: as a means of enabling the communication of true (impediment-free) voter intent



Ballot Secrecy: Discussion (contd.)

- How powerful is the ballot secrecy adversary?
  - Can break crypto?
  - Can communicate with voter during vote casting?
  - Has resources (humans, computers)?
  - Can change election outcome?
  - Inside (access to voting system data) or Outside?
  - Minimal: Doesn't make special efforts?
  - Shares secret information (crypto key) with others?
  - What is a reasonable definition of the adversary vs. definitions in the crypto literature*

* Our thoughts influenced by discussions with Rene Peralta



Outline

- Propose Desirable Properties of Voting Systems
  - Security (auditability, ballot secrecy)
  - Usability and Accessibility*
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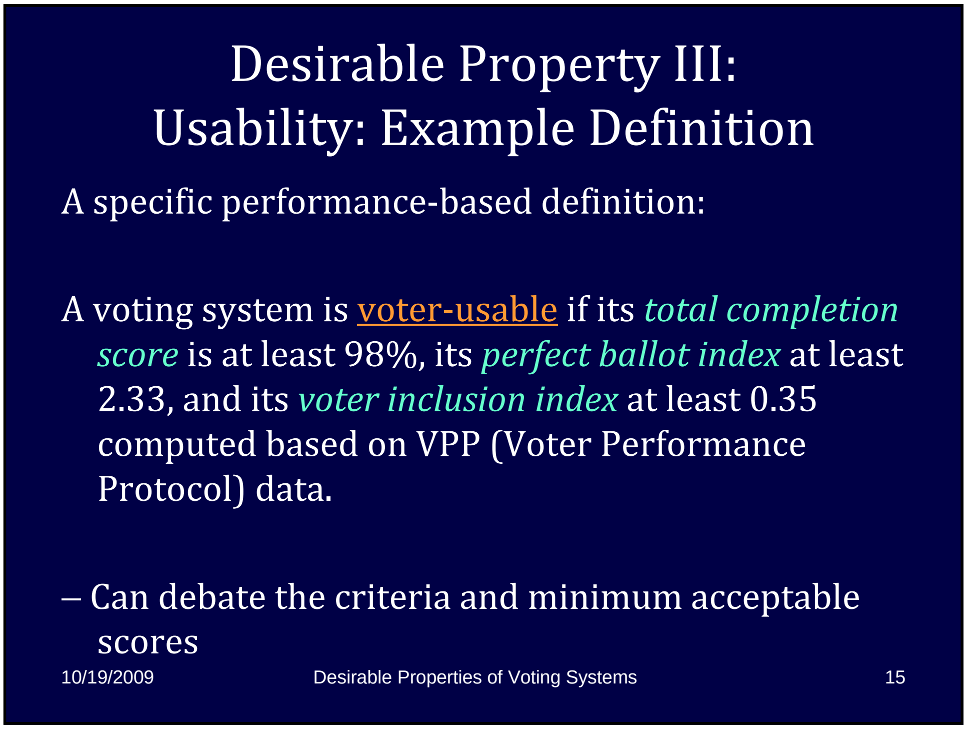
*Our thoughts greatly influenced by discussions with Sharon Laskowski

Desirable Property III
Usability – General

- Learnability
- Efficiency
- Memorability
- Errors
  - how many
  - how severe
  - how easy to recover
- Satisfaction

Desirable Property III:
Usability, in TGDC-Recommended VVSG

TGDC-Recommended VVSG defines usability as a measure of the effectiveness, efficiency, and satisfaction achieved by a specified set of *users* with a given *product* in the performance of *specified tasks*.

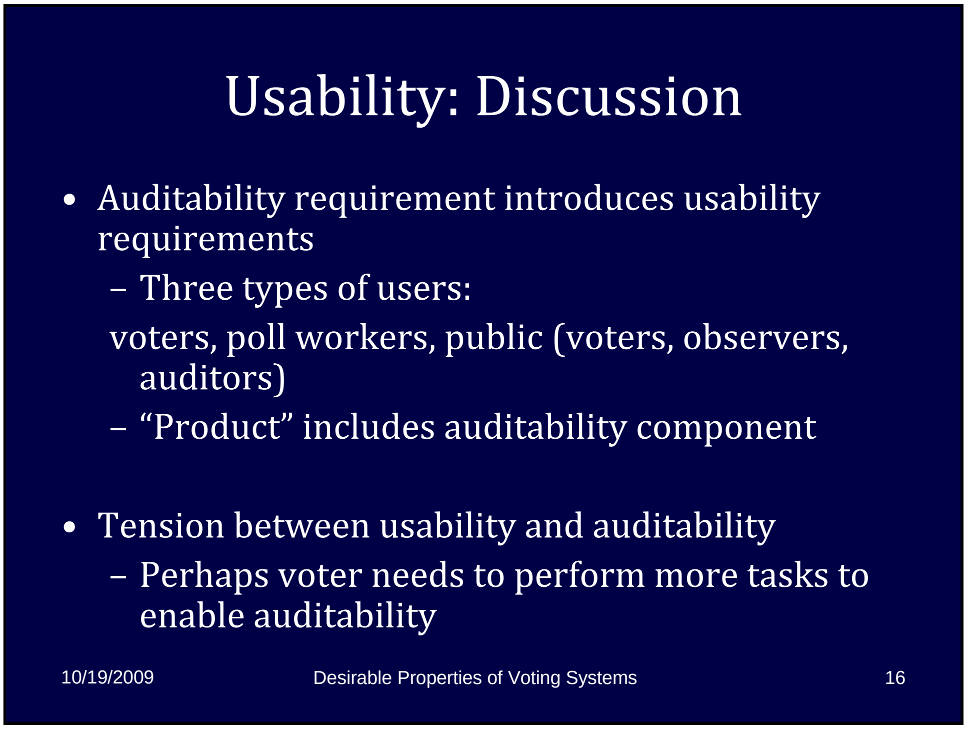


Desirable Property III: Usability: Example Definition

A specific performance-based definition:

A voting system is voter-usable if its *total completion score* is at least 98%, its *perfect ballot index* at least 2.33, and its *voter inclusion index* at least 0.35 computed based on VPP (Voter Performance Protocol) data.

– Can debate the criteria and minimum acceptable scores

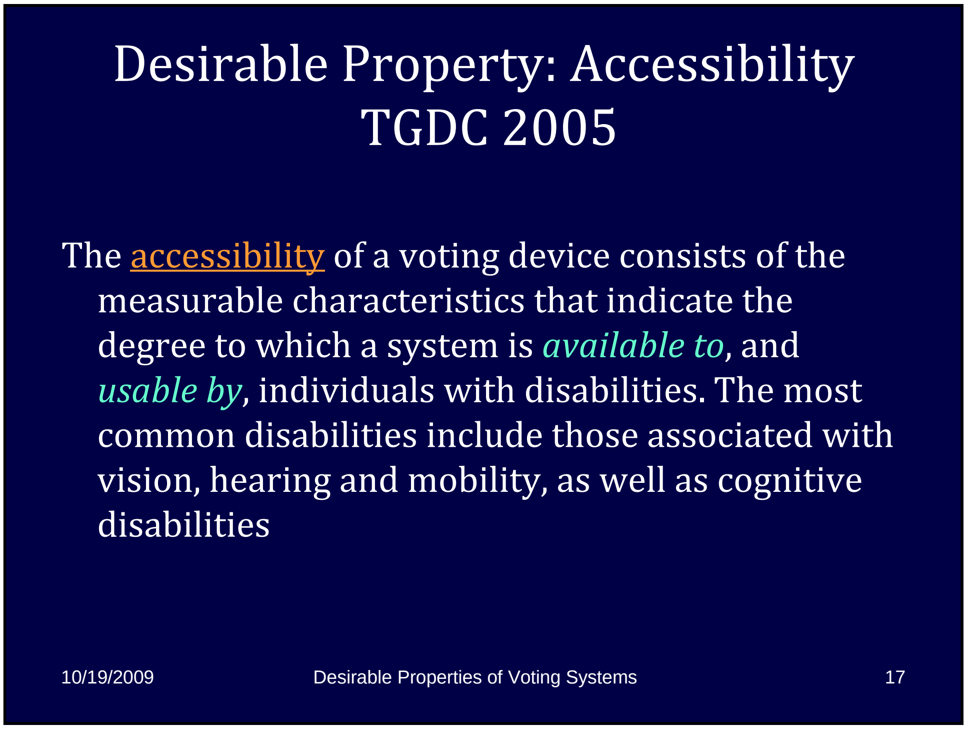


Usability: Discussion

- Auditability requirement introduces usability requirements
  - Three types of users:

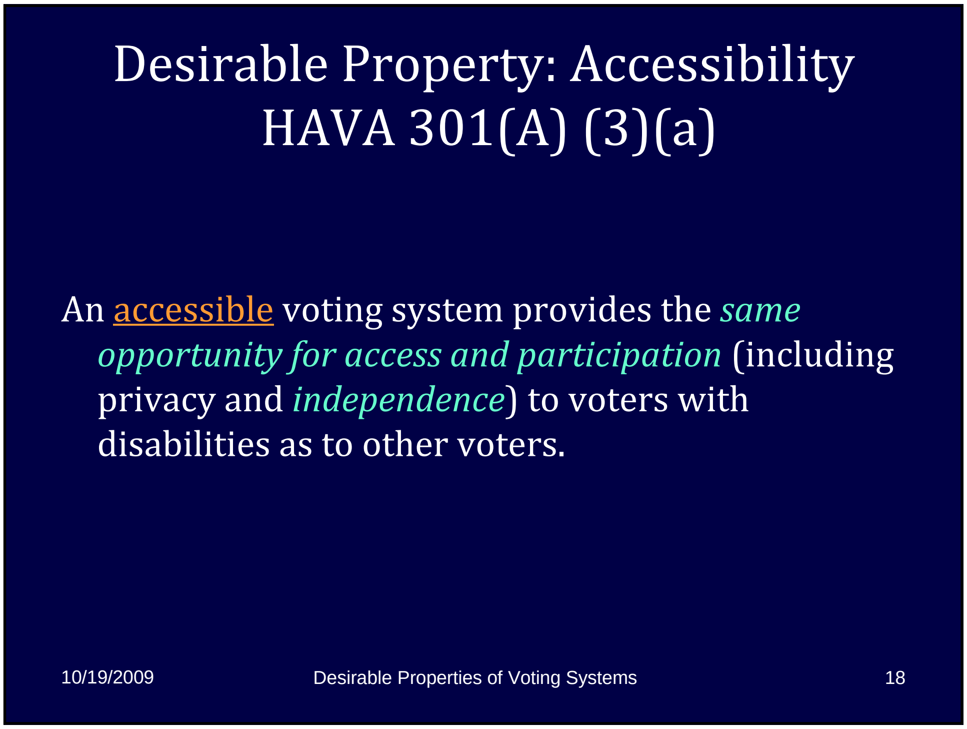
  voters, poll workers, public (voters, observers, auditors)
  - "Product" includes auditability component

- Tension between usability and auditability
  - Perhaps voter needs to perform more tasks to enable auditability



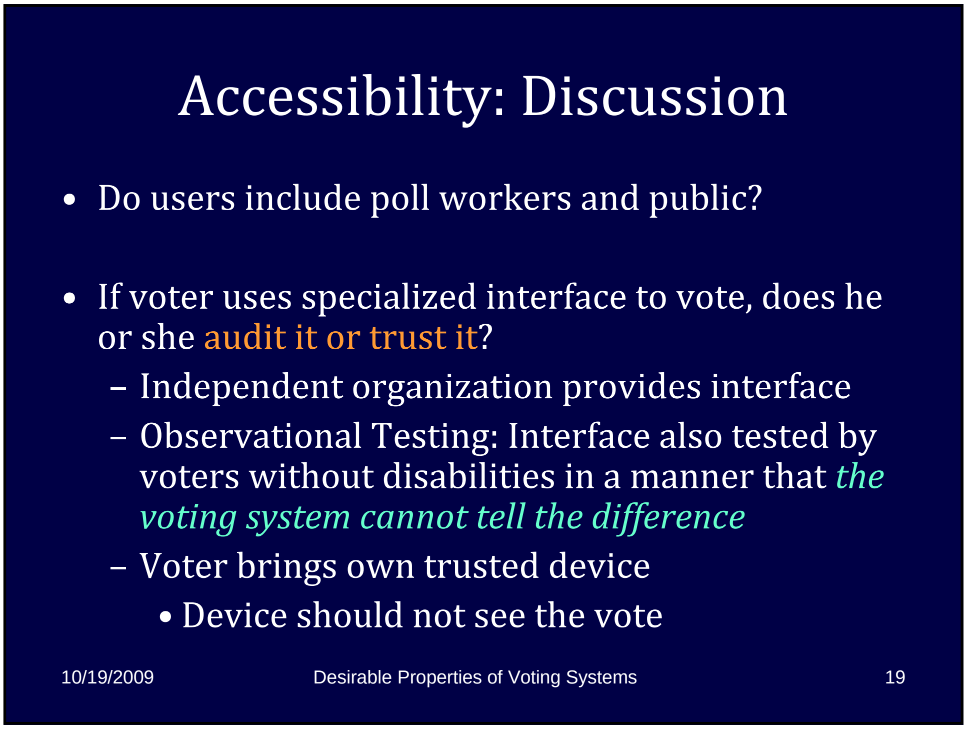
Desirable Property: Accessibility TGDC 2005

The accessibility of a voting device consists of the measurable characteristics that indicate the degree to which a system is *available to*, and *usable by*, individuals with disabilities. The most common disabilities include those associated with vision, hearing and mobility, as well as cognitive disabilities



Desirable Property: Accessibility HAVA 301(A) (3)(a)

An accessible voting system provides the *same opportunity for access and participation* (including privacy and *independence*) to voters with disabilities as to other voters.



Accessibility: Discussion

- Do users include poll workers and public?
- If voter uses specialized interface to vote, does he or she audit it or trust it?
  - Independent organization provides interface
  - Observational Testing: Interface also tested by voters without disabilities in a manner that *the voting system cannot tell the difference*
  - Voter brings own trusted device
    - Device should not see the vote

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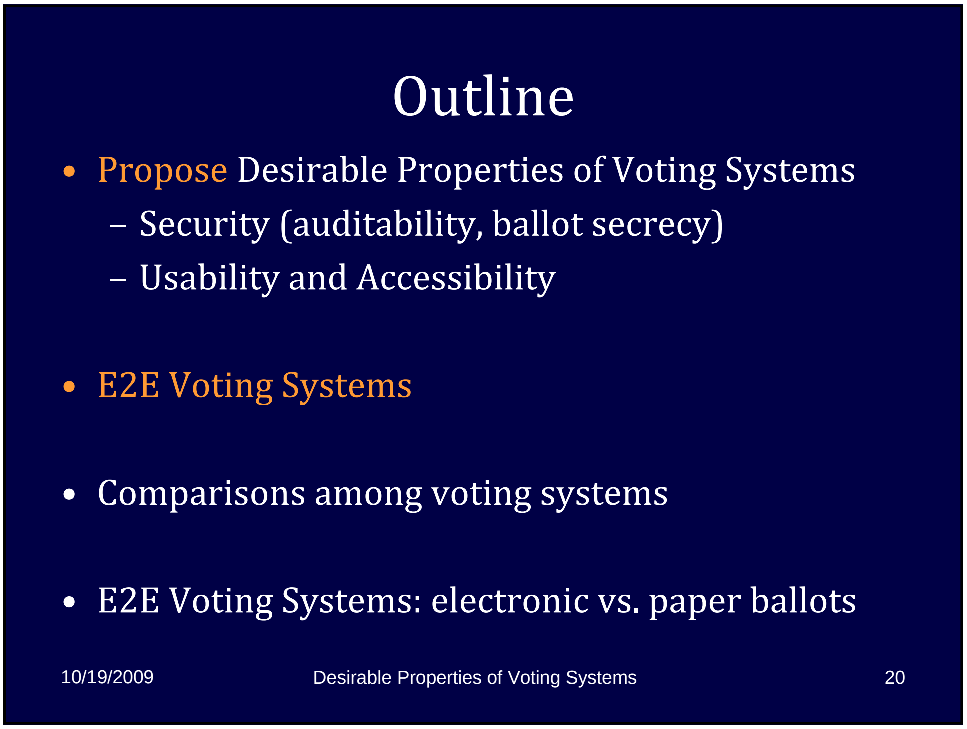

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Trust Model: Typical Assumptions

- Procedures are followed, count is correct
- Secure Chain-of-Custody
- Error-free Software
- Secure Hardware
- Secure Cryptographic Algorithms
- Trusted specialized user interfaces

Recall Software Independence*

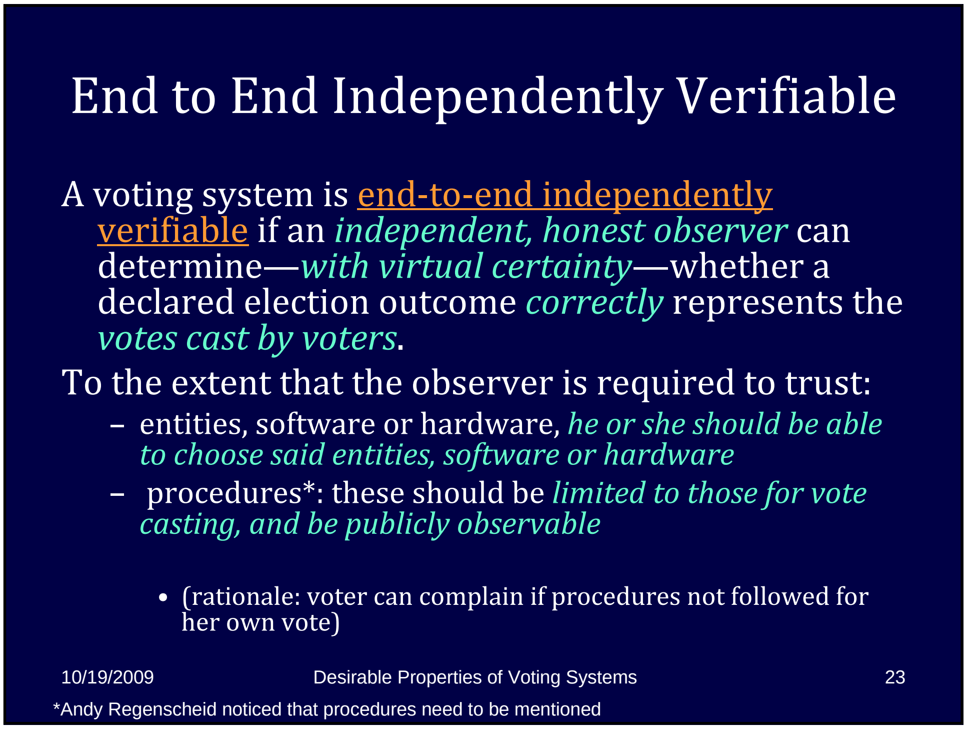
A voting system is <u>software independent</u> if an (undetected) change or error in its software cannot cause an undetectable change or error in an *election outcome*.

≠ Don't use software

= Error-free software is not an assumption

– Depends on the manner in which software is used to determine election outcome

* Our paper is modeled on the one on SI by Rivest and Wack



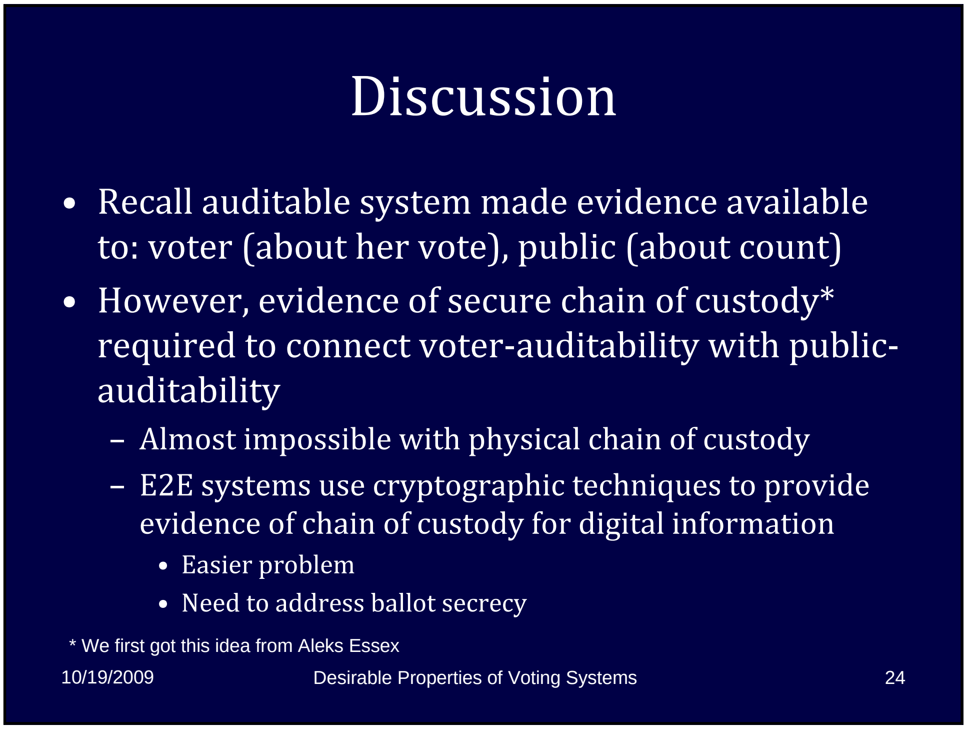
End to End Independently Verifiable

A voting system is end-to-end independently verifiable if an *independent, honest observer* can determine—*with virtual certainty*—whether a declared election outcome *correctly* represents the *votes cast by voters*.

To the extent that the observer is required to trust:

- entities, software or hardware, *he or she should be able to choose said entities, software or hardware*
- procedures*: these should be *limited to those for vote casting, and be publicly observable*
  - (rationale: voter can complain if procedures not followed for her own vote)

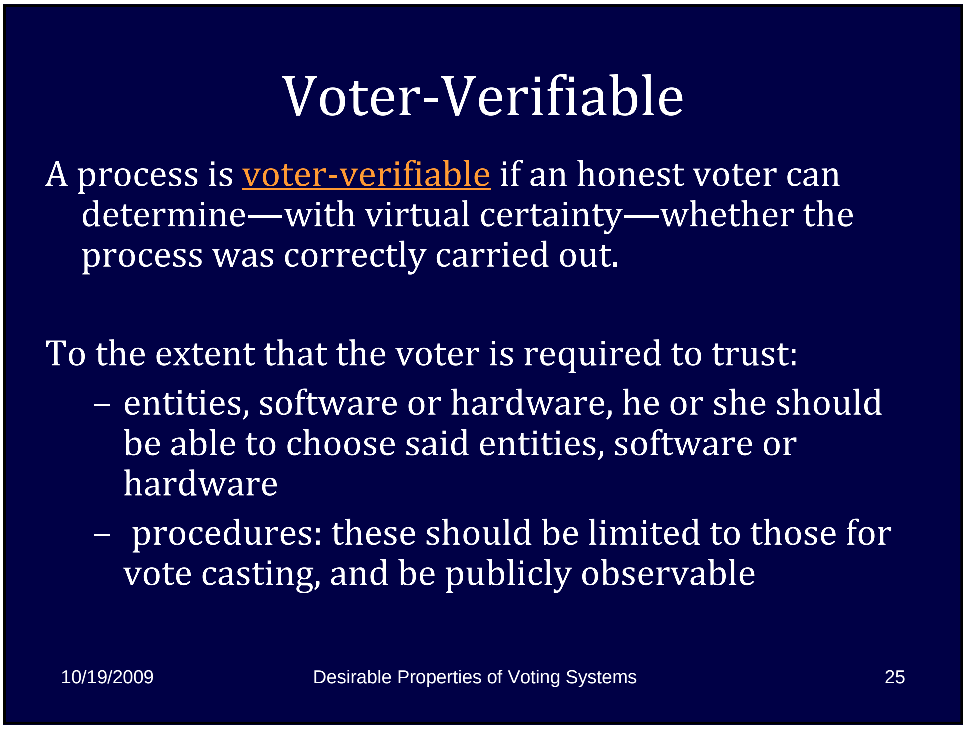
*Andy Regenscheid noticed that procedures need to be mentioned



Discussion

- Recall auditable system made evidence available to: voter (about her vote), public (about count)
- However, evidence of secure chain of custody* required to connect voter-auditability with public-auditability
  - Almost impossible with physical chain of custody
  - E2E systems use cryptographic techniques to provide evidence of chain of custody for digital information
    - Easier problem
    - Need to address ballot secrecy

* We first got this idea from Aleks Essex

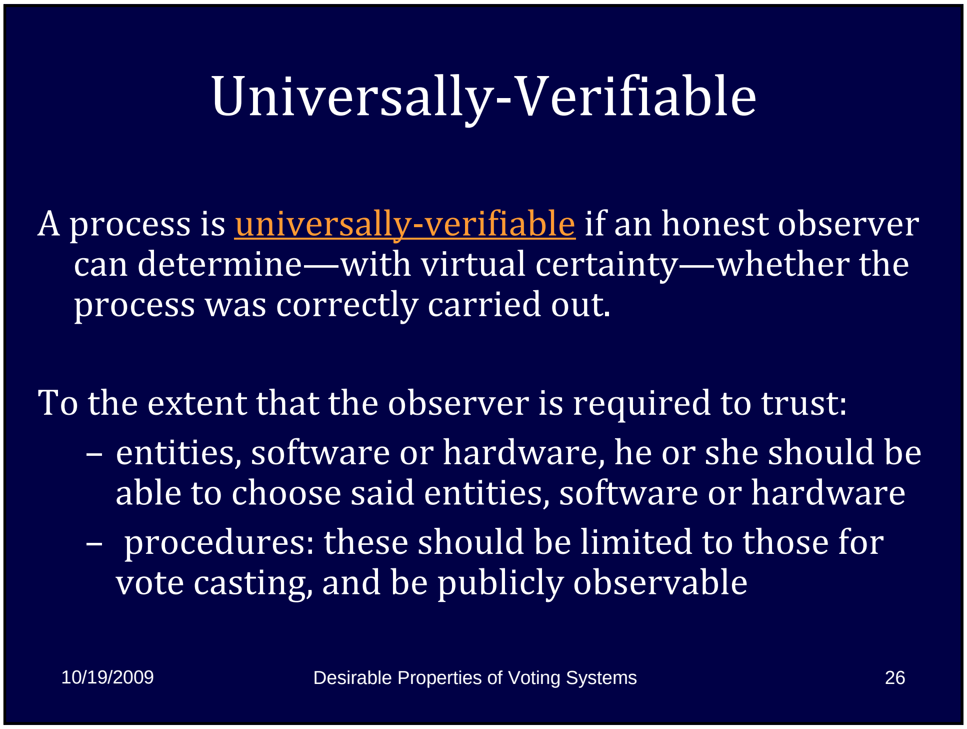


Voter-Verifiable

A process is voter-verifiable if an honest voter can determine—with virtual certainty—whether the process was correctly carried out.

To the extent that the voter is required to trust:

- entities, software or hardware, he or she should be able to choose said entities, software or hardware
- procedures: these should be limited to those for vote casting, and be publicly observable



Universally-Verifiable

A process is universally-verifiable if an honest observer can determine—with virtual certainty—whether the process was correctly carried out.

To the extent that the observer is required to trust:

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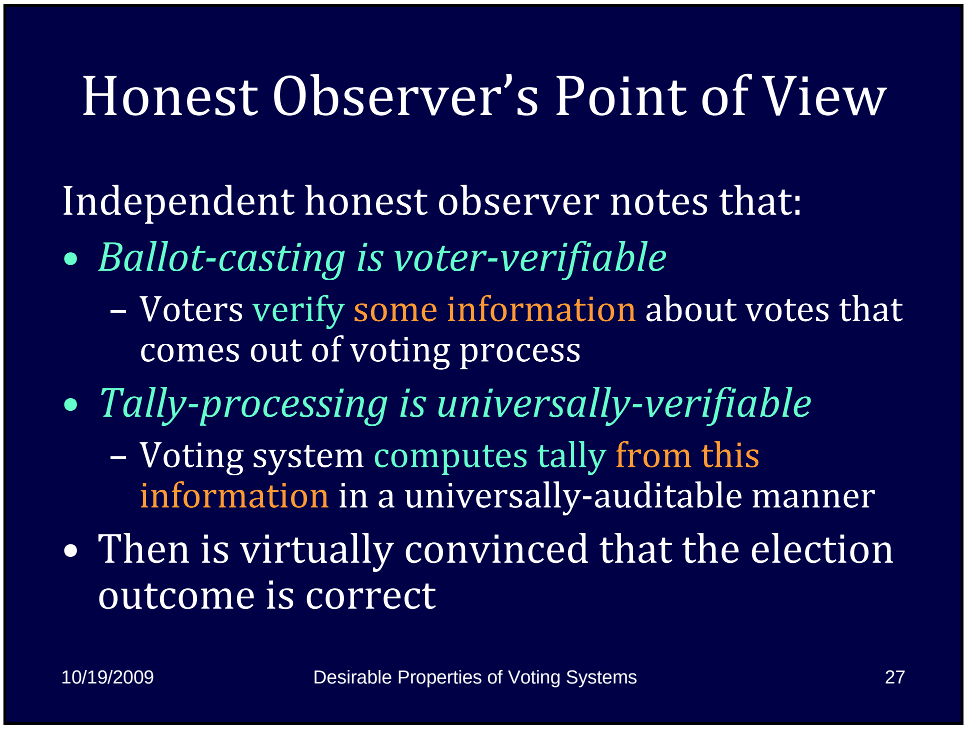
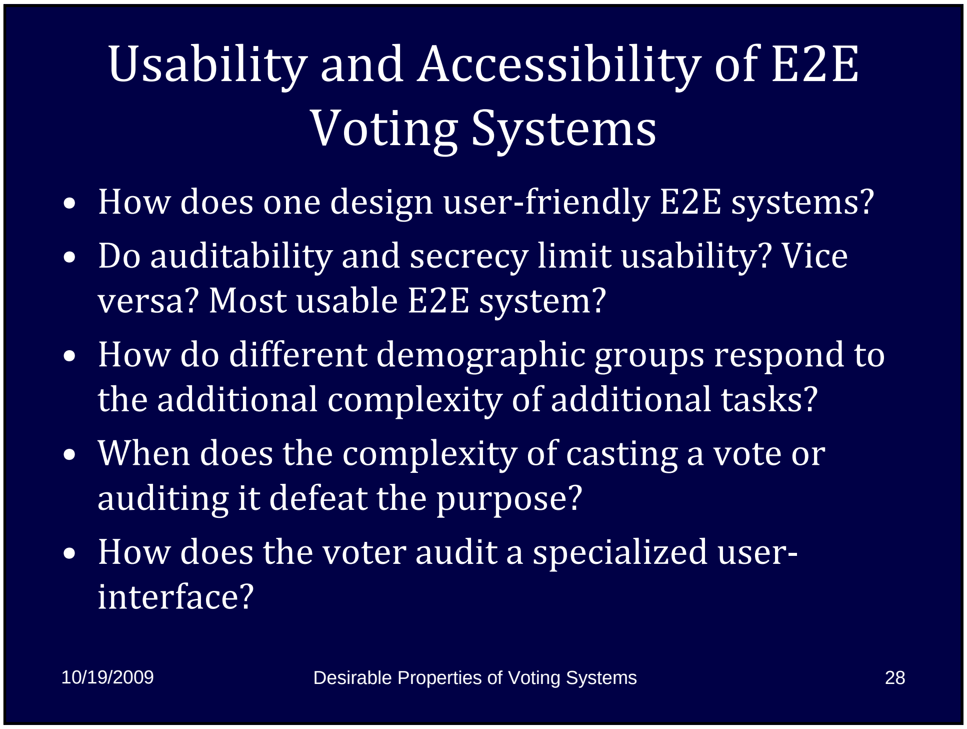
- procedures: these should be limited to those for vote casting, and be publicly observable



Honest Observer’s Point of View

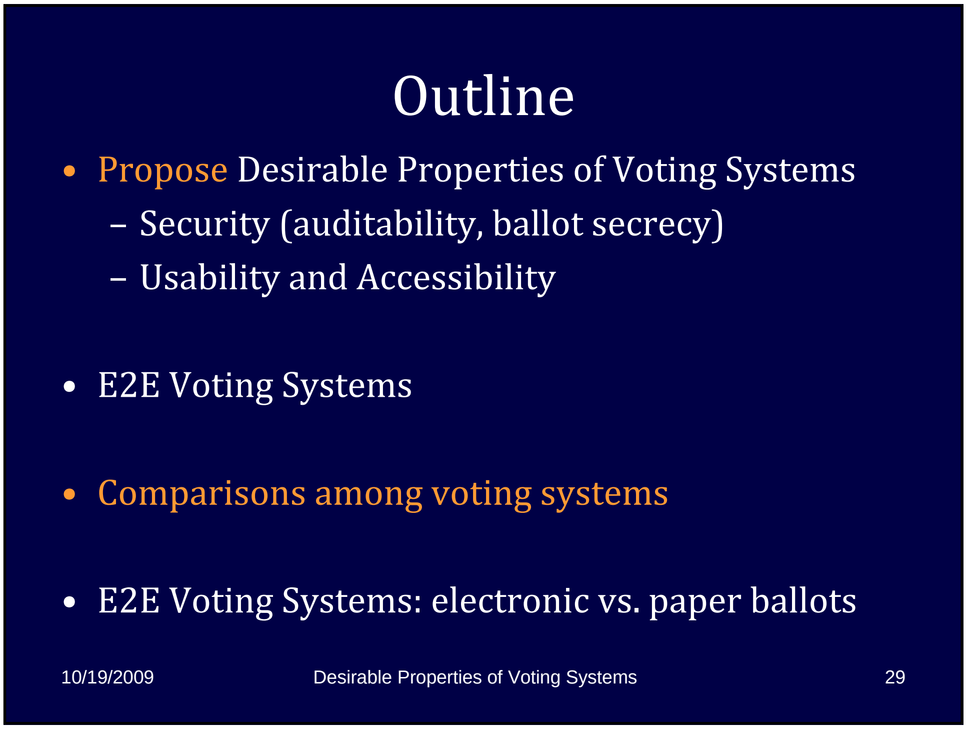
Independent honest observer notes that:

- *Ballot-casting is voter-verifiable*
  - Voters verify some information about votes that comes out of voting process
- *Tally-processing is universally-verifiable*
  - Voting system computes tally from this information in a universally-auditable manner
- Then is virtually convinced that the election outcome is correct



Usability and Accessibility of E2E Voting Systems

- How does one design user-friendly E2E systems?
- Do auditability and secrecy limit usability? Vice versa? Most usable E2E system?
- How do different demographic groups respond to the additional complexity of additional tasks?
- When does the complexity of casting a vote or auditing it defeat the purpose?
- How does the voter audit a specialized user-interface?



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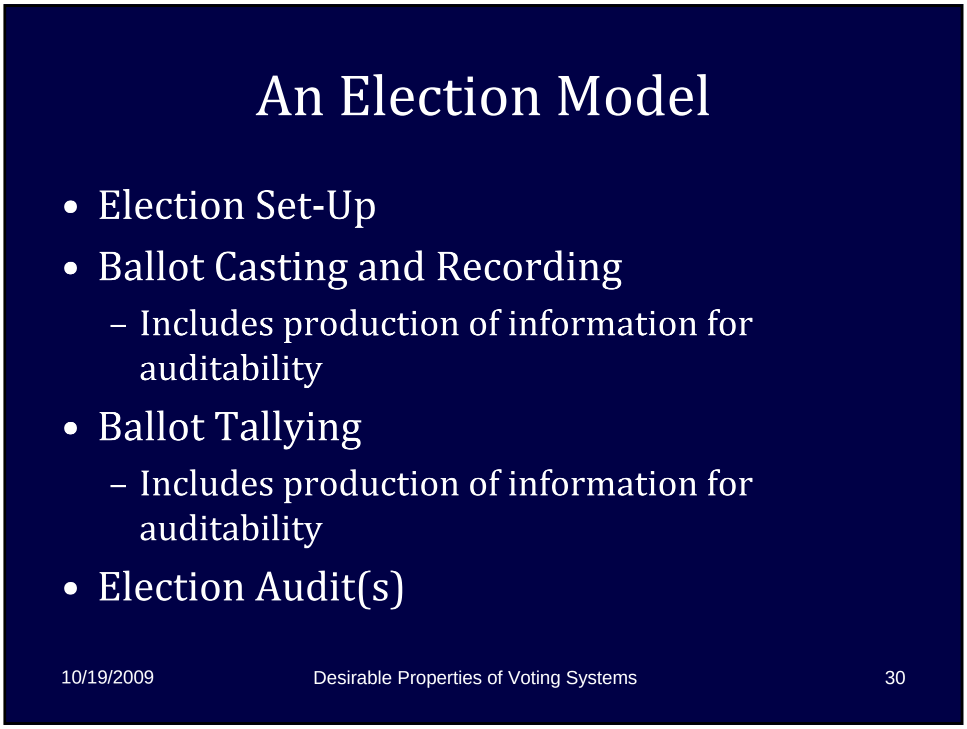
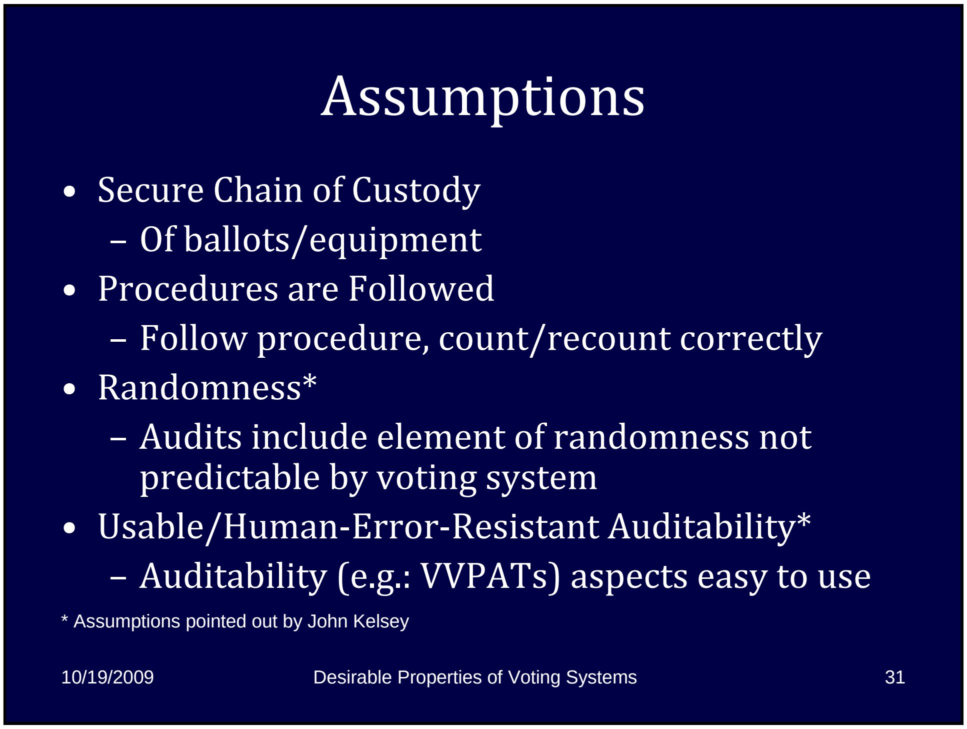


An Election Model

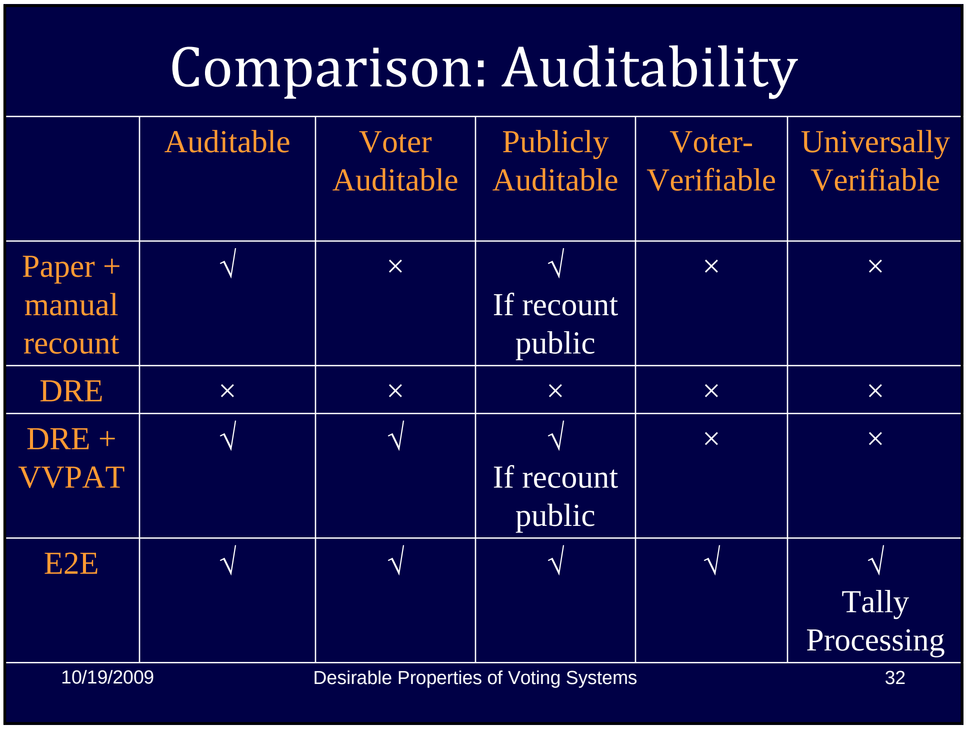
- Election Set-Up
- Ballot Casting and Recording
  - Includes production of information for auditability
- Ballot Tallying
  - Includes production of information for auditability
- Election Audit(s)



Assumptions

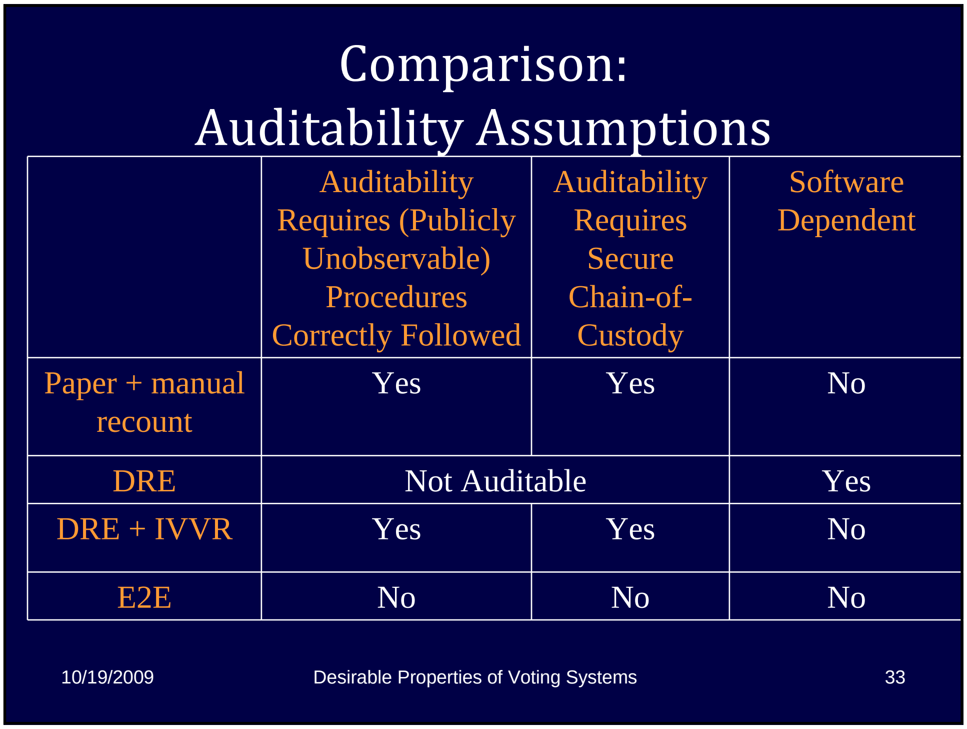
- Secure Chain of Custody
  - Of ballots/equipment
- Procedures are Followed
  - Follow procedure, count/recount correctly
- Randomness*
  - Audits include element of randomness not predictable by voting system
- Usable/Human-Error-Resistant Auditability*
  - Auditability (e.g.: VVPATs) aspects easy to use

* Assumptions pointed out by John Kelsey



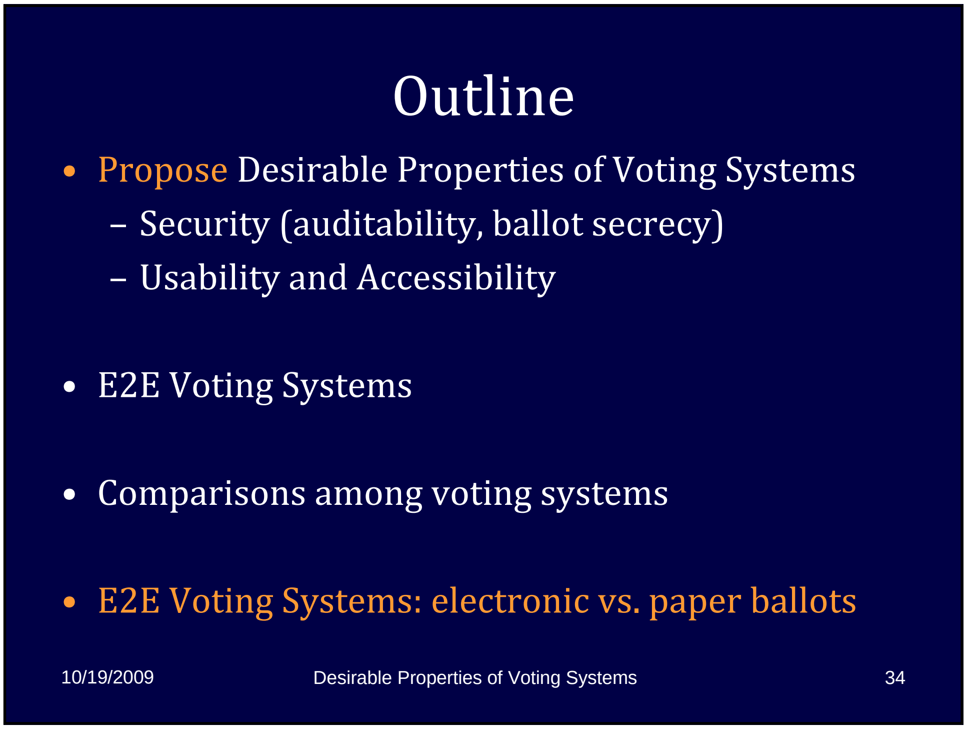
Comparison: Auditability

	Auditable	Voter Auditable	Publicly Auditable	Voter-Verifiable	Universally Verifiable
Paper + manual recount	√	×	√ If recount public	×	×
DRE	×	×	×	×	×
DRE + VVPAT	√	√	√ If recount public	×	×
E2E	√	√	√	√	√ Tally Processing



Comparison: Auditability Assumptions

	Auditability Requires (Publicly Unobservable) Procedures Correctly Followed	Auditability Requires Secure Chain-of-Custody	Software Dependent
Paper + manual recount	Yes	Yes	No
DRE	Not Auditable		Yes
DRE + IVVR	Yes	Yes	No
E2E	No	No	No



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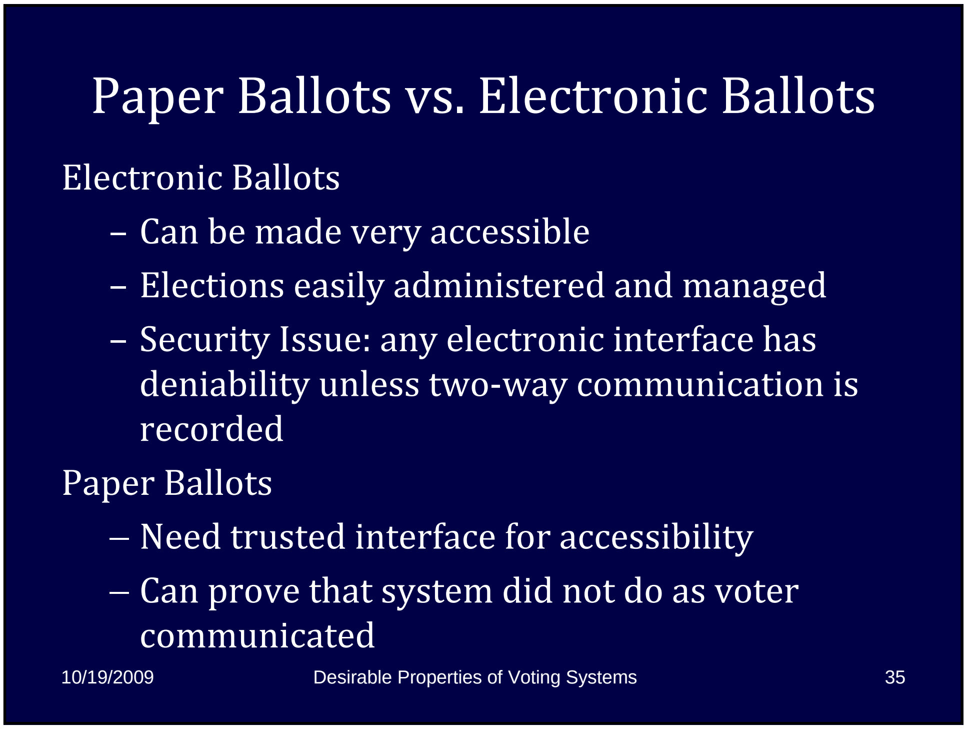


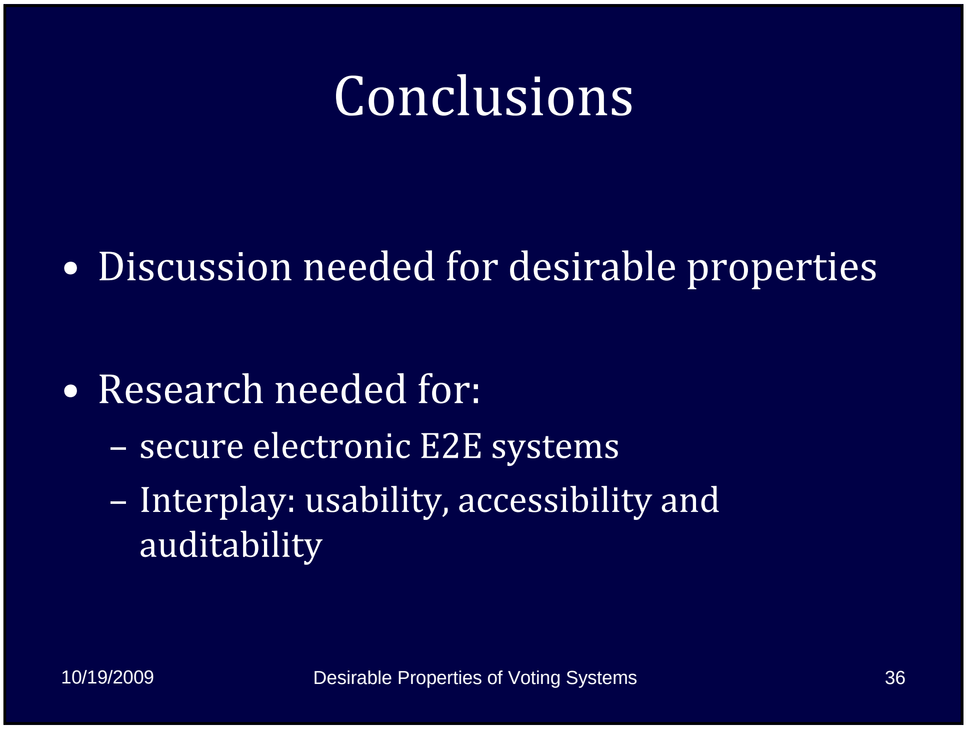
Paper Ballots vs. Electronic Ballots

Electronic Ballots

- – Can be made very accessible
- – Elections easily administered and managed
- – Security Issue: any electronic interface has deniability unless two-way communication is recorded

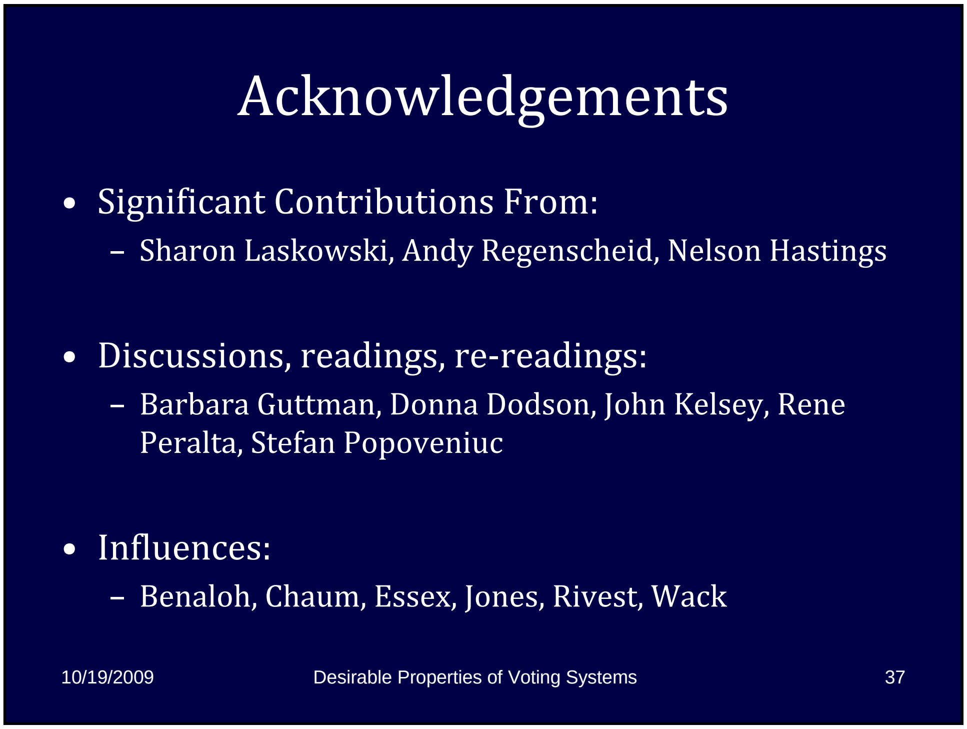
Paper Ballots

- – Need trusted interface for accessibility
- – Can prove that system did not do as voter communicated



Conclusions

- Discussion needed for desirable properties
- Research needed for:
  - – secure electronic E2E systems
  - – Interplay: usability, accessibility and auditability



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