Security Metrics-Driven Evaluation,
Design, Development, & Deployment

Log Your CRUD

Design Principles for Software Logging Mechanisms

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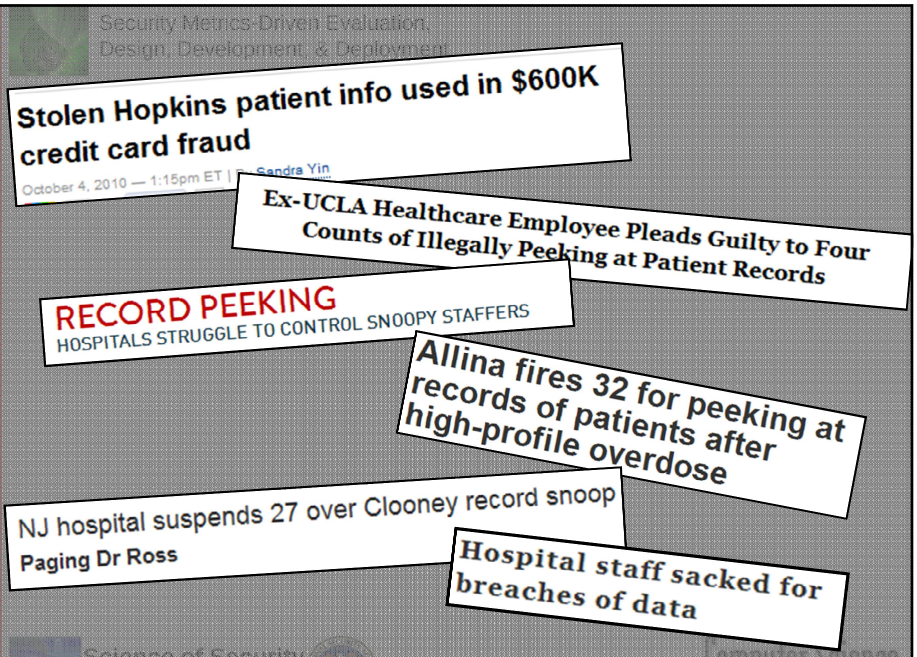

Stolen Hopkins patient info used in $600K credit card fraud

October 4, 2010 — 1:15pm ET | By Sandra Yin

Ex-UCLA Healthcare Employee Pleads Guilty to Four Counts of Illegally Peeking at Patient Records

RECORD PEEKING
HOSPITALS STRUGGLE TO CONTROL SNOOPY STAFFERS

Allina fires 32 for peeking at records of patients after high-profile overdose

NJ hospital suspends 27 over Clooney record snoop
Paging Dr Ross

Hospital staff sacked for breaches of data

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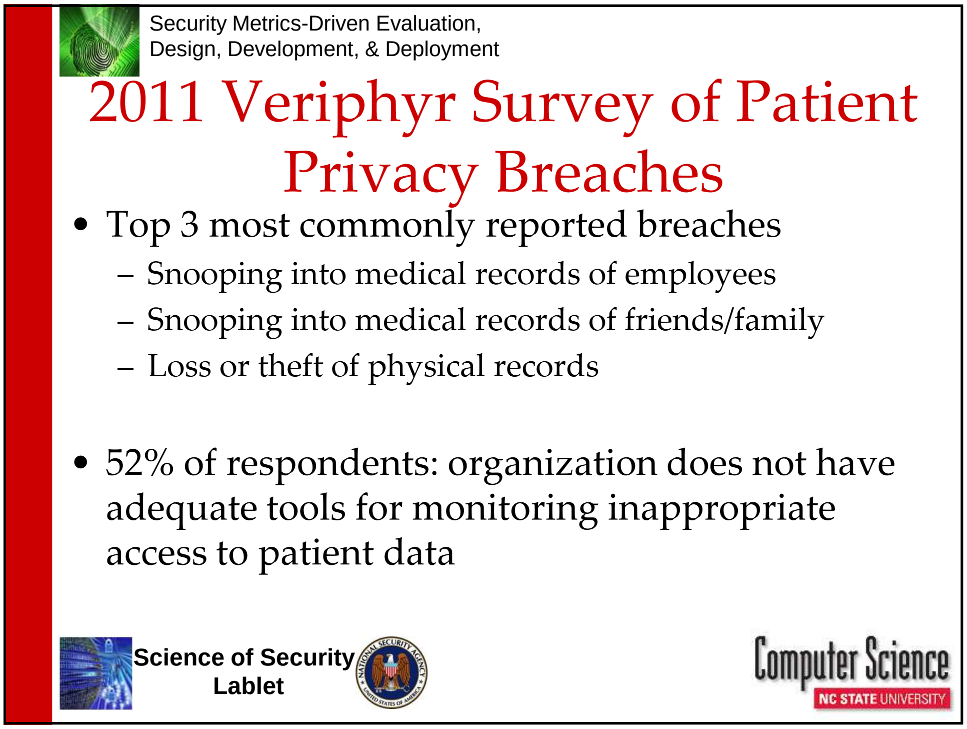

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2011 Veriphyr Survey of Patient Privacy Breaches

- Top 3 most commonly reported breaches
  - Snooping into medical records of employees
  - Snooping into medical records of friends/family
  - Loss or theft of physical records
- 52% of respondents: organization does not have adequate tools for monitoring inappropriate access to patient data

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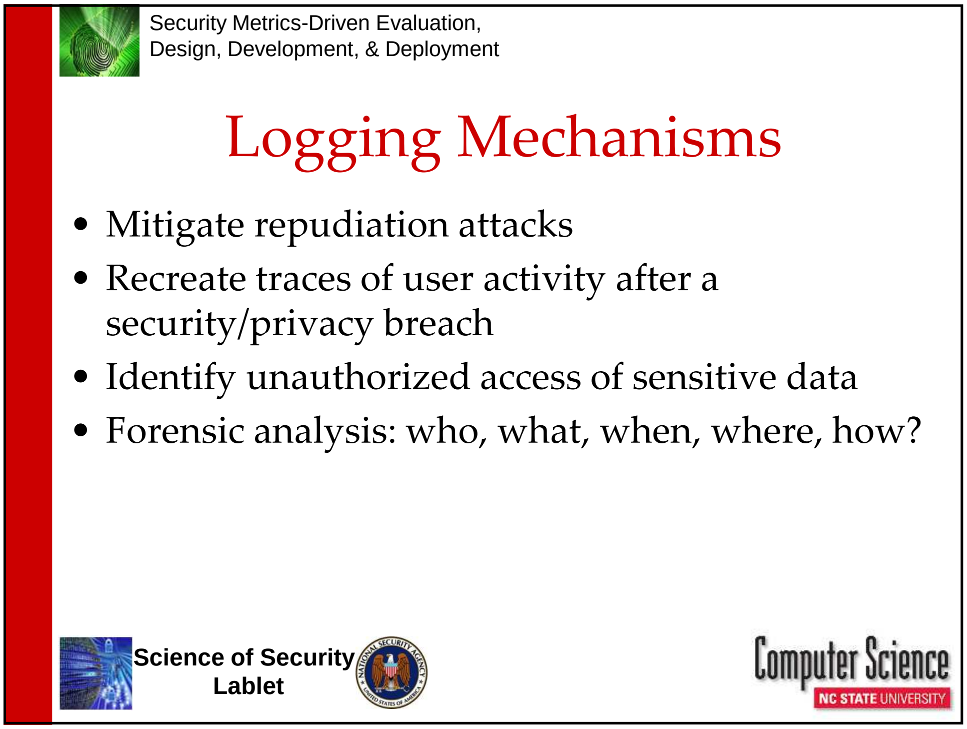

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Logging Mechanisms

- Mitigate repudiation attacks
- Recreate traces of user activity after a security/privacy breach
- Identify unauthorized access of sensitive data
- Forensic analysis: who, what, when, where, how?

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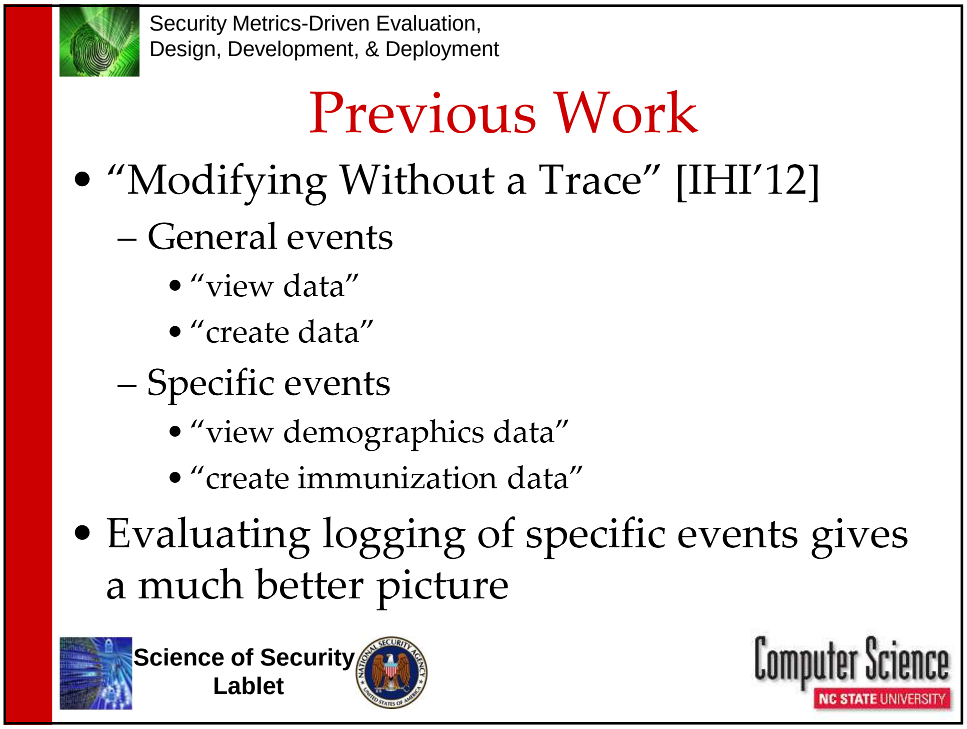

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Previous Work

- “Modifying Without a Trace” [IHI’12]
  - General events
    - “view data”
    - “create data”
  - Specific events
    - “view demographics data”
    - “create immunization data”
- Evaluating logging of specific events gives a much better picture

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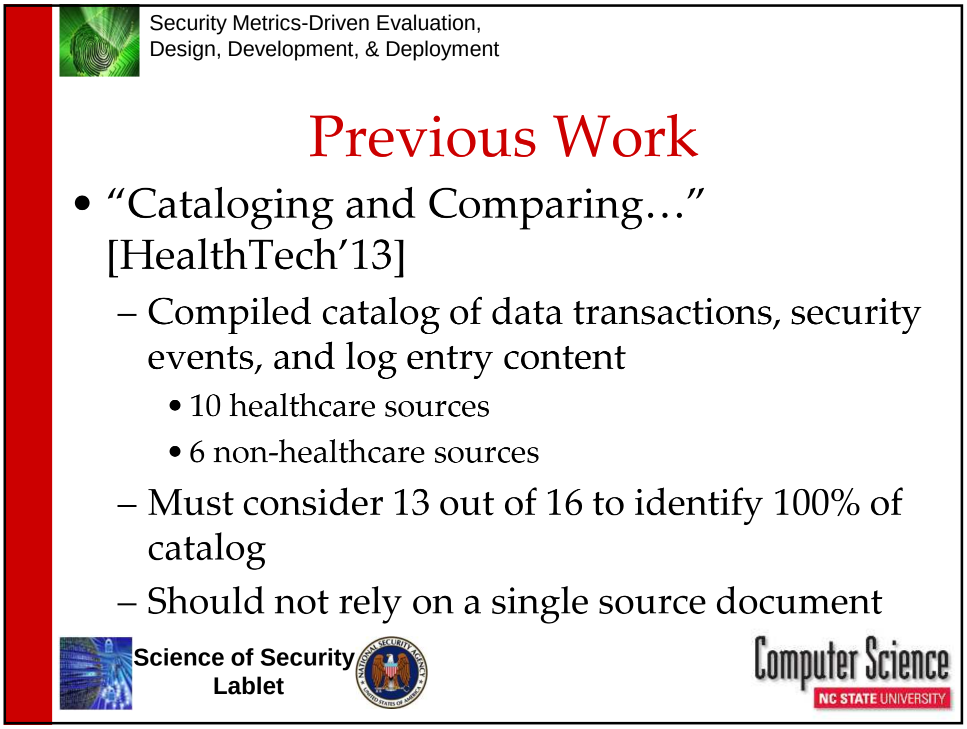

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Previous Work

- “Cataloging and Comparing…” [HealthTech’13]
  - Compiled catalog of data transactions, security events, and log entry content
    - 10 healthcare sources
    - 6 non-healthcare sources
  - Must consider 13 out of 16 to identify 100% of catalog
  - Should not rely on a single source document

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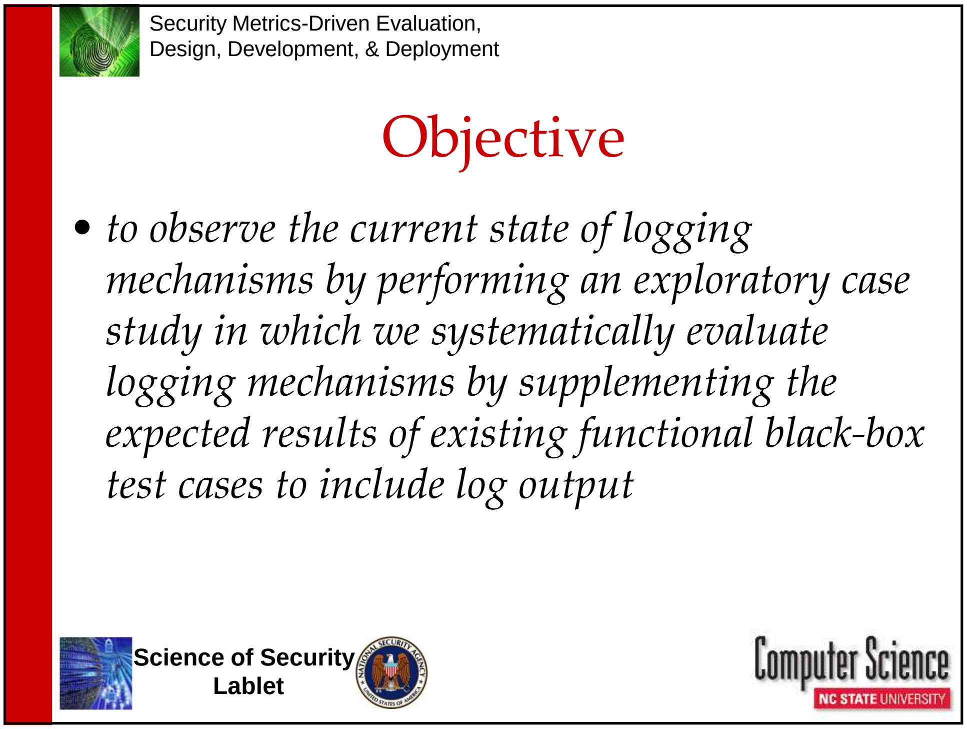
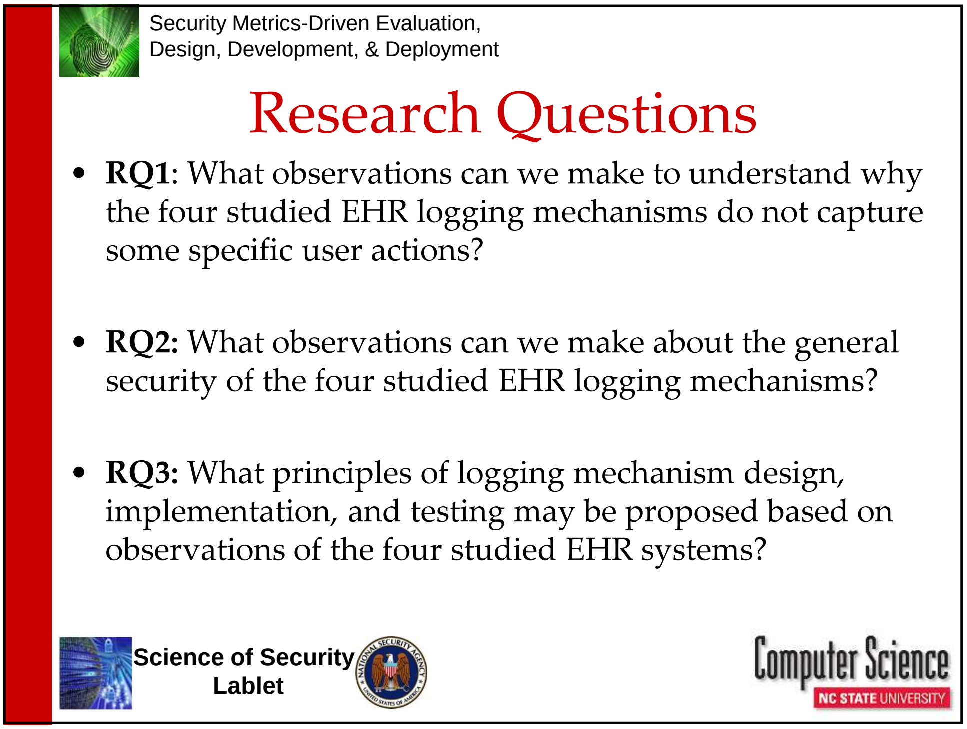


Objective

- *to observe the current state of logging mechanisms by performing an exploratory case study in which we systematically evaluate logging mechanisms by supplementing the expected results of existing functional black-box test cases to include log output*

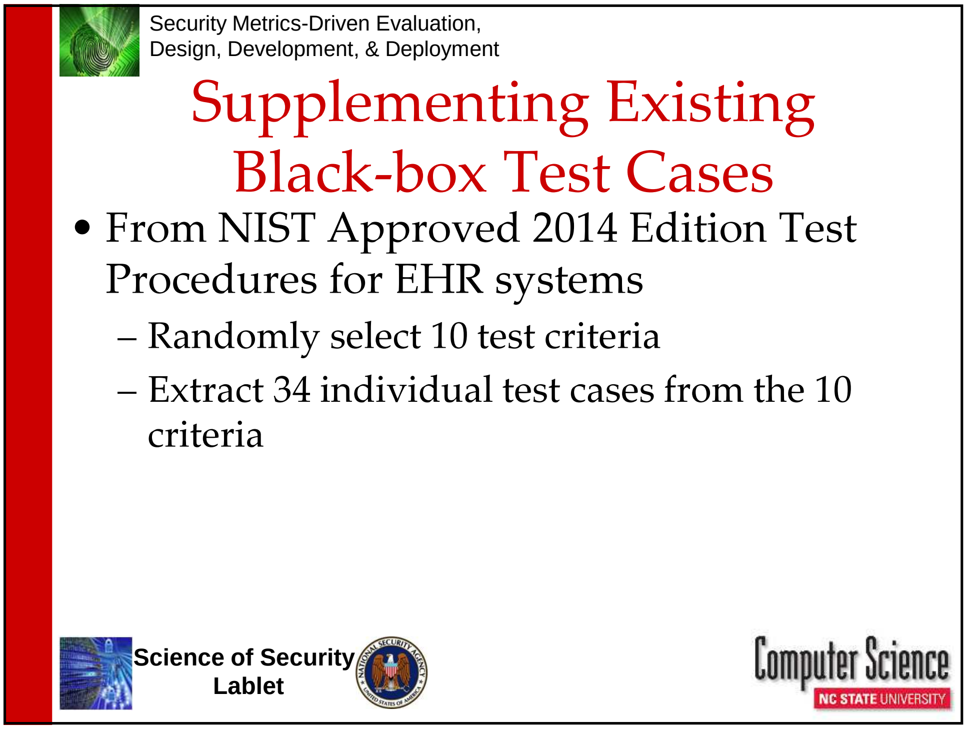


Research Questions

- **RQ1**: What observations can we make to understand why the four studied EHR logging mechanisms do not capture some specific user actions?

- **RQ2:** What observations can we make about the general security of the four studied EHR logging mechanisms?

- **RQ3:** What principles of logging mechanism design, implementation, and testing may be proposed based on observations of the four studied EHR systems?



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Supplementing Existing Black-box Test Cases

- From NIST Approved 2014 Edition Test Procedures for EHR systems
  - Randomly select 10 test criteria
  - Extract 34 individual test cases from the 10 criteria

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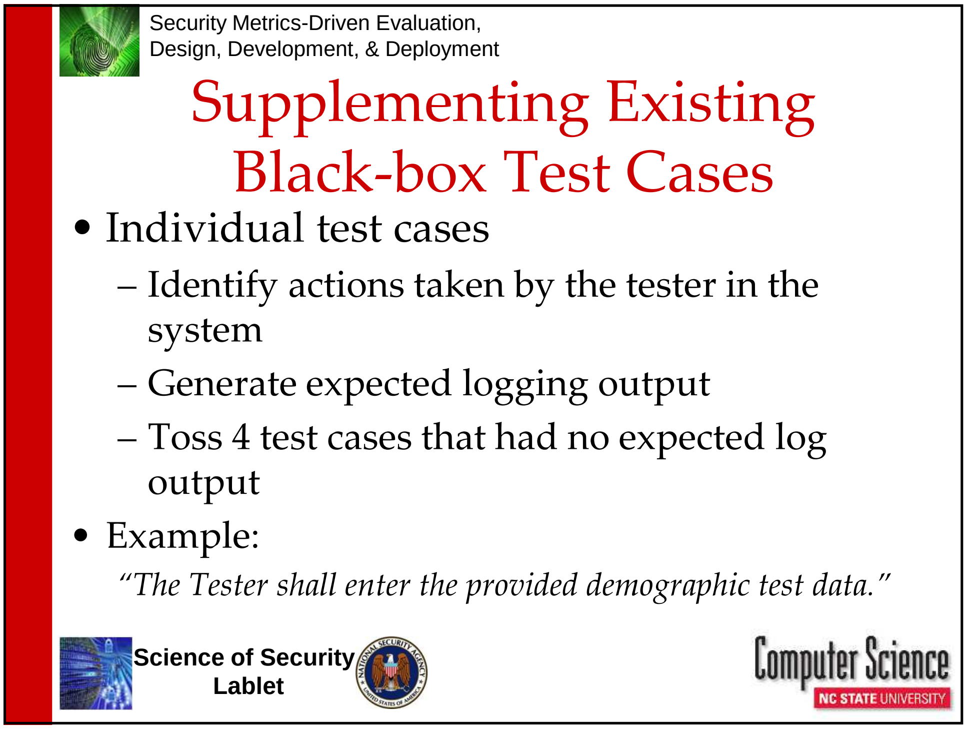

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Supplementing Existing Black-box Test Cases

- Individual test cases
  - Identify actions taken by the tester in the system
  - Generate expected logging output
  - Toss 4 test cases that had no expected log output
- Example:

  "The Tester shall enter the provided demographic test data."

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Supplementing Existing Black-box Test Cases

- Expected log entry content:

  Based on ASTM International E2147-01 Standard Specification for Audit and Disclosure Logs for Use in Health Information Systems

  – Date and time

  – Patient Identification

  – User Identification

  – Type of action

  – Identification of the patient data accessed

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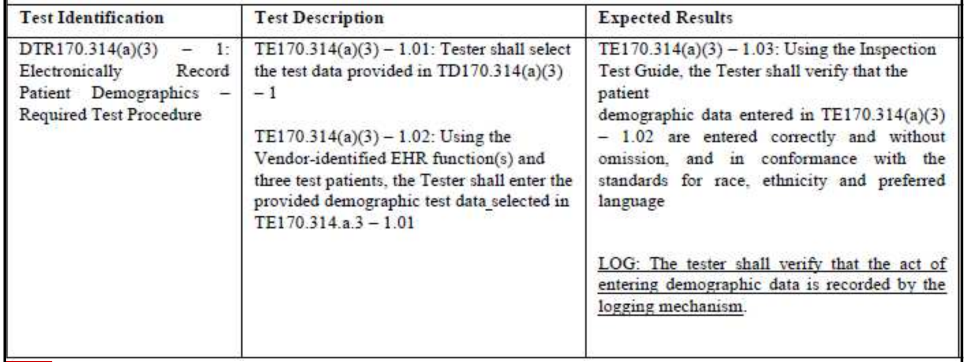
Test Cases Summary

- 30 test cases



Test Identification	Test Description	Expected Results
DTR170.314(a)(3) – 1: Electronically Record Patient Demographics – Required Test Procedure	TE170.314(a)(3) – 1.01: Tester shall select the test data provided in TD170.314(a)(3) – 1 TE170.314(a)(3) – 1.02: Using the Vendor-identified EHR function(s) and three test patients, the Tester shall enter the provided demographic test data selected in TE170.314.a.3 – 1.01	TE170.314(a)(3) – 1.03: Using the Inspection Test Guide, the Tester shall verify that the patient demographic data entered in TE170.314(a)(3) – 1.02 are entered correctly and without omission, and in conformance with the standards for race, ethnicity and preferred language <u>LOG: The tester shall verify that the act of entering demographic data is recorded by the logging mechanism</u>.

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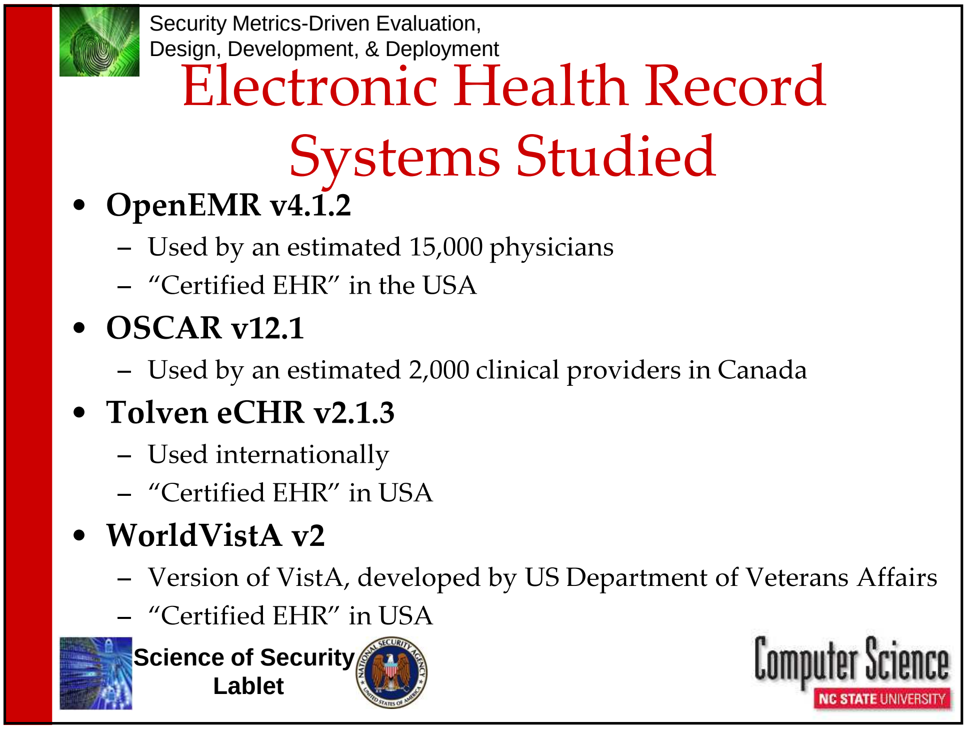

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Electronic Health Record Systems Studied

- **OpenEMR v4.1.2**
  - Used by an estimated 15,000 physicians
  - "Certified EHR" in the USA
- **OSCAR v12.1**
  - Used by an estimated 2,000 clinical providers in Canada
- **Tolven eCHR v2.1.3**
  - Used internationally
  - "Certified EHR" in USA
- **WorldVistA v2**
  - Version of VistA, developed by US Department of Veterans Affairs
  - "Certified EHR" in USA

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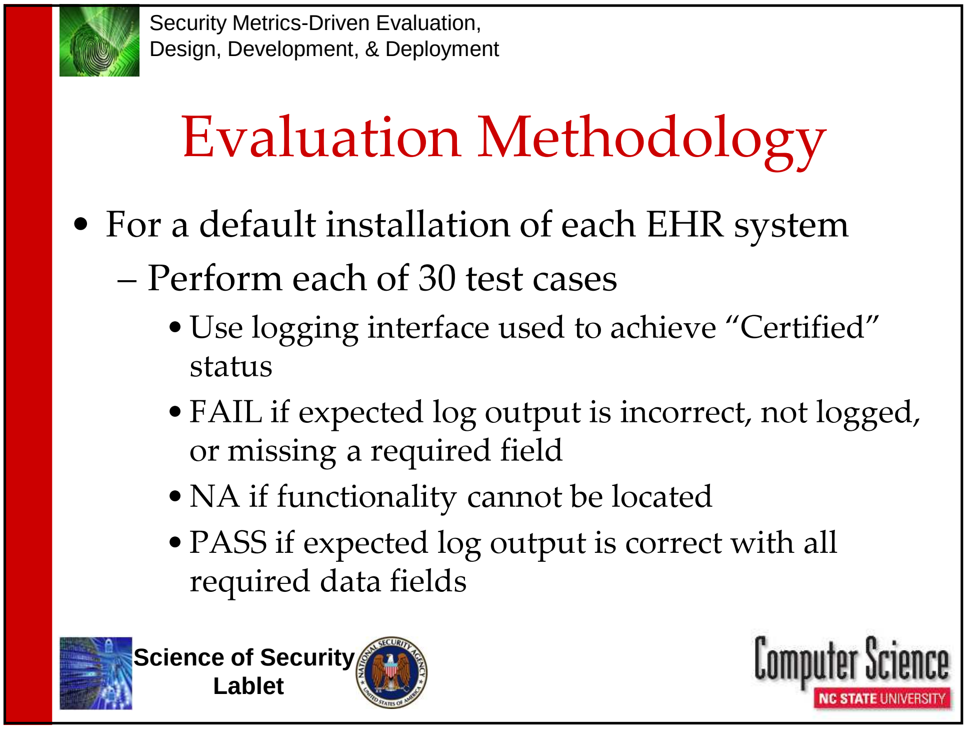

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Evaluation Methodology

- For a default installation of each EHR system
  - Perform each of 30 test cases
    - Use logging interface used to achieve "Certified" status
    - FAIL if expected log output is incorrect, not logged, or missing a required field
    - NA if functionality cannot be located
    - PASS if expected log output is correct with all required data fields

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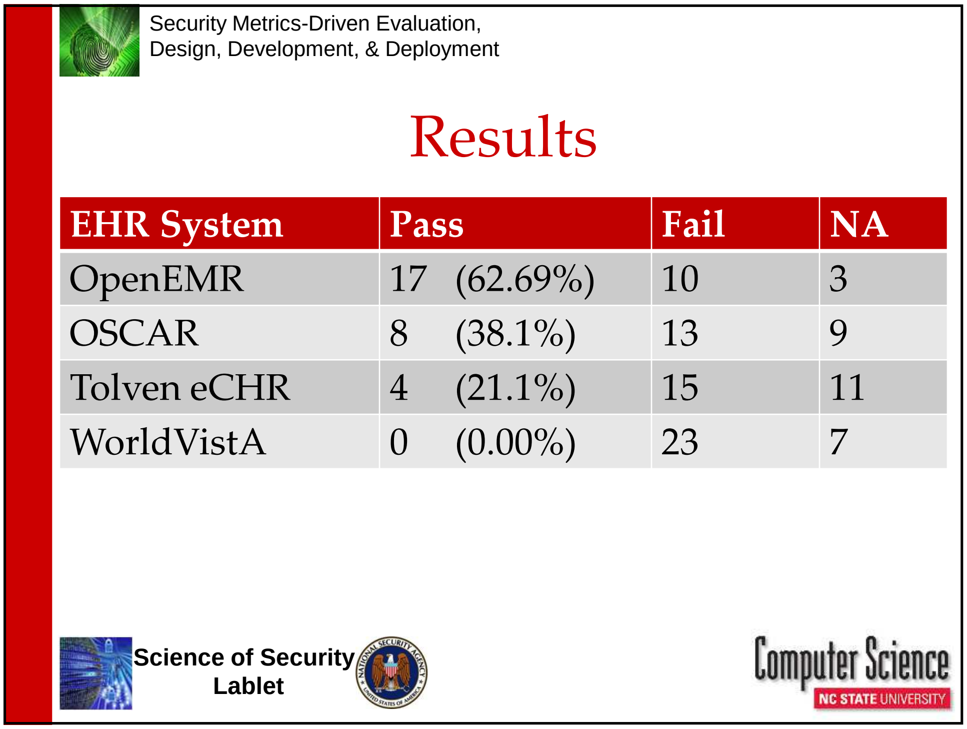

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Results

EHR System	Pass	Fail	NA
OpenEMR	17 (62.69%)	10	3
OSCAR	8 (38.1%)	13	9
Tolven eCHR	4 (21.1%)	15	11
WorldVistA	0 (0.00%)	23	7

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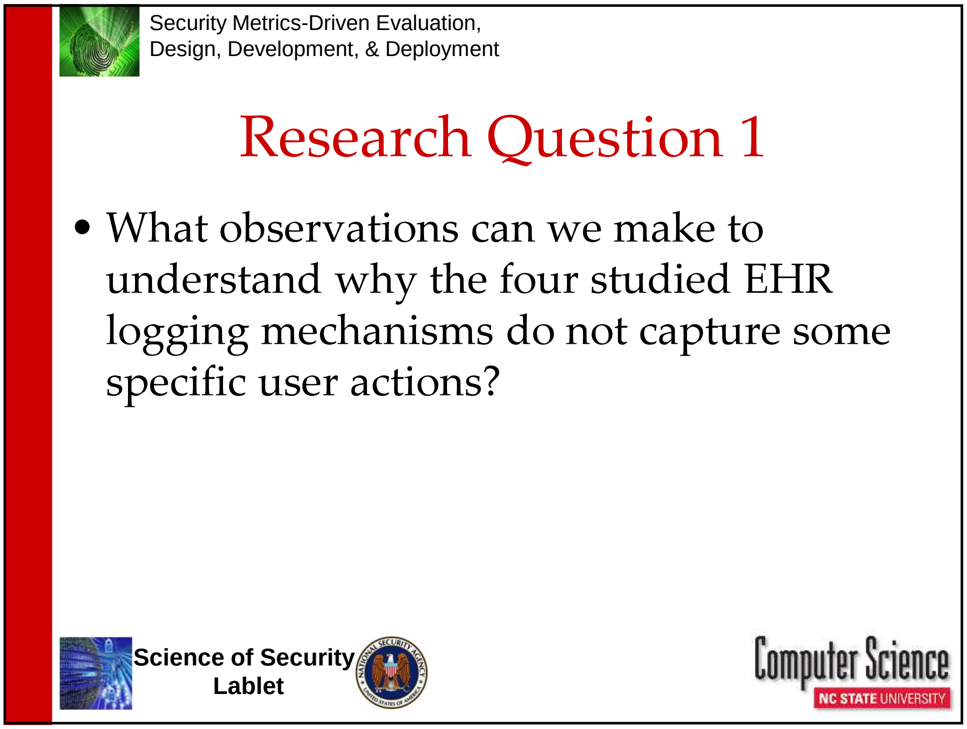

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Research Question 1

- What observations can we make to understand why the four studied EHR logging mechanisms do not capture some specific user actions?

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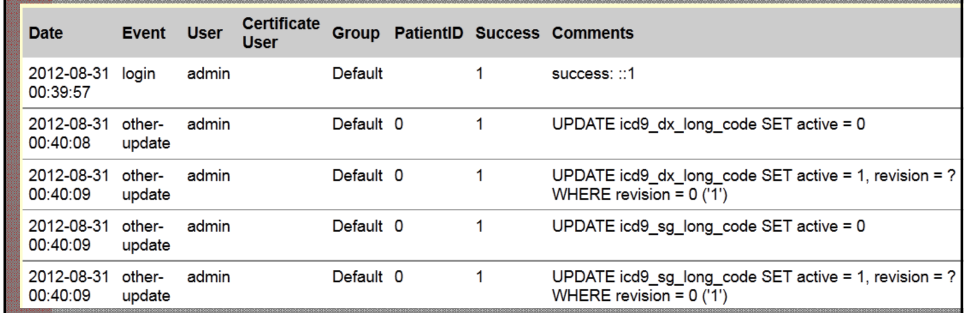
RQ1: OpenEMR



Date	Event	User	Certificate User	Group	PatientID	Success	Comments
2012-08-31 00:39:57	login	admin		Default		1	success: ::1
2012-08-31 00:40:08	other-update	admin		Default	0	1	UPDATE icd9_dx_long_code SET active = 0
2012-08-31 00:40:09	other-update	admin		Default	0	1	UPDATE icd9_dx_long_code SET active = 1, revision = ? WHERE revision = 0 ('1')
2012-08-31 00:40:09	other-update	admin		Default	0	1	UPDATE icd9_sg_long_code SET active = 0
2012-08-31 00:40:09	other-update	admin		Default	0	1	UPDATE icd9_sg_long_code SET active = 1, revision = ? WHERE revision = 0 ('1')

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RQ1: OpenEMR

- Logs SQL queries
- Does not log SELECT queries by default
  - 7 "view" test cases fail

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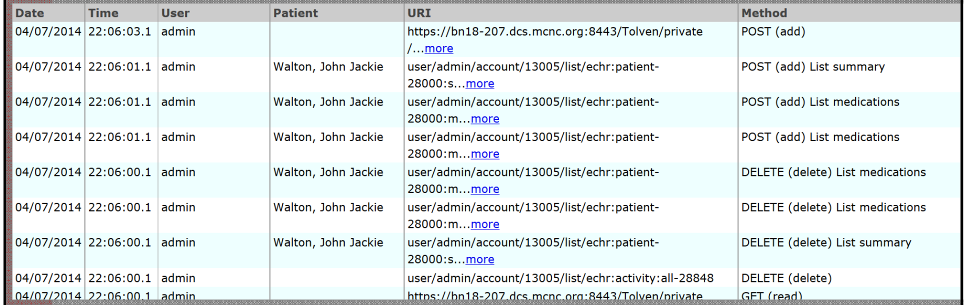
RQ1: Tolven eCHR



Date	Time	User	Patient	URI	Method
04/07/2014	22:06:03.1	admin		https://bn18-207.dcs.mcnc.org:8443/Tolven/private /...more	POST (add)
04/07/2014	22:06:01.1	admin	Walton, John Jackie	user/admin/account/13005/list/echr:patient-28000:s...more	POST (add) List summary
04/07/2014	22:06:01.1	admin	Walton, John Jackie	user/admin/account/13005/list/echr:patient-28000:m...more	POST (add) List medications
04/07/2014	22:06:01.1	admin	Walton, John Jackie	user/admin/account/13005/list/echr:patient-28000:m...more	POST (add) List medications
04/07/2014	22:06:00.1	admin	Walton, John Jackie	user/admin/account/13005/list/echr:patient-28000:m...more	DELETE (delete) List medications
04/07/2014	22:06:00.1	admin	Walton, John Jackie	user/admin/account/13005/list/echr:patient-28000:m...more	DELETE (delete) List medications
04/07/2014	22:06:00.1	admin	Walton, John Jackie	user/admin/account/13005/list/echr:patient-28000:s...more	DELETE (delete) List summary
04/07/2014	22:06:00.1	admin		user/admin/account/13005/list/echr:activity:all-28848	DELETE (delete)
04/07/2014	22:06:00.1	admin		https://bn18-207.dcs.mcnc.org:8443/Tolven/private	GET (read)

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RQ1: Tolven eCHR

- “updates” are recorded as “additions”
  - 4 test cases fail
- Stores additional query parameters in database
  - Must have authorized access to database
  - Not viewable in a black-box evaluation

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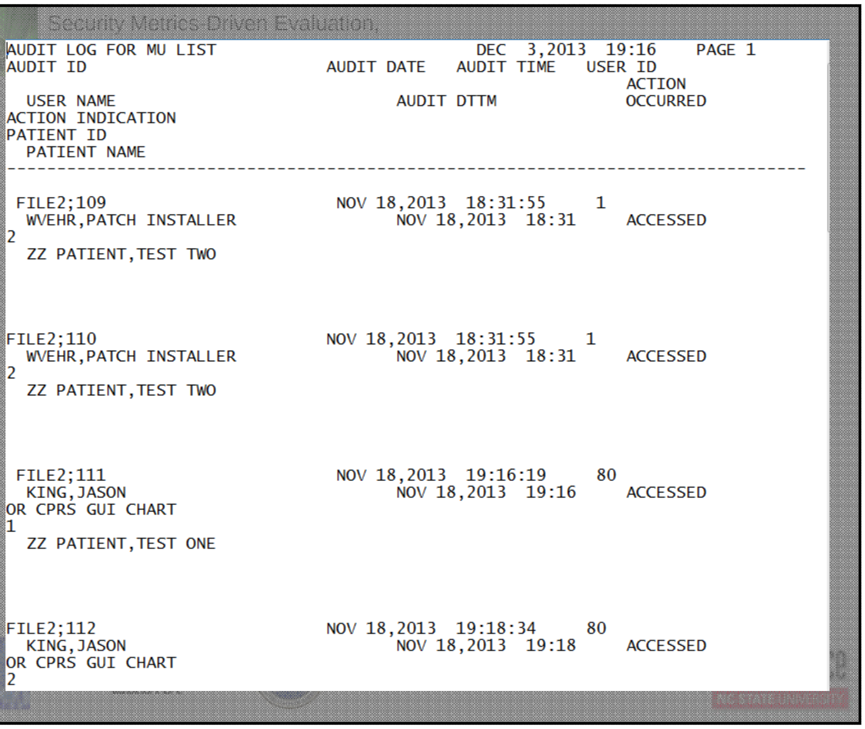

```
AUDIT LOG FOR MU LIST                          DEC  3,2013  19:16     PAGE 1
AUDIT ID                        AUDIT DATE   AUDIT TIME   USER ID
                                                              ACTION
  USER NAME                            AUDIT DTTM             OCCURRED
ACTION INDICATION
PATIENT ID
  PATIENT NAME
--------------------------------------------------------------------------------

 FILE2;109                       NOV 18,2013  18:31:55     1
  WVEHR,PATCH INSTALLER                NOV 18,2013  18:31     ACCESSED
2

  ZZ PATIENT,TEST TWO



FILE2;110                       NOV 18,2013  18:31:55     1
  WVEHR,PATCH INSTALLER                NOV 18,2013  18:31     ACCESSED
2

  ZZ PATIENT,TEST TWO



 FILE2;111                       NOV 18,2013  19:16:19     80
  KING,JASON                           NOV 18,2013  19:16     ACCESSED
OR CPRS GUI CHART
1

  ZZ PATIENT,TEST ONE



FILE2;112                       NOV 18,2013  19:18:34     80
  KING,JASON                           NOV 18,2013  19:18     ACCESSED
OR CPRS GUI CHART
2
```

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RQ1: WorldVistA

- Only data accesses seem to generate log entries
  - No entries indicated “create” “modify” or “delete”
- No human-readable, clear descriptions of event that happened
- 0 passing test cases

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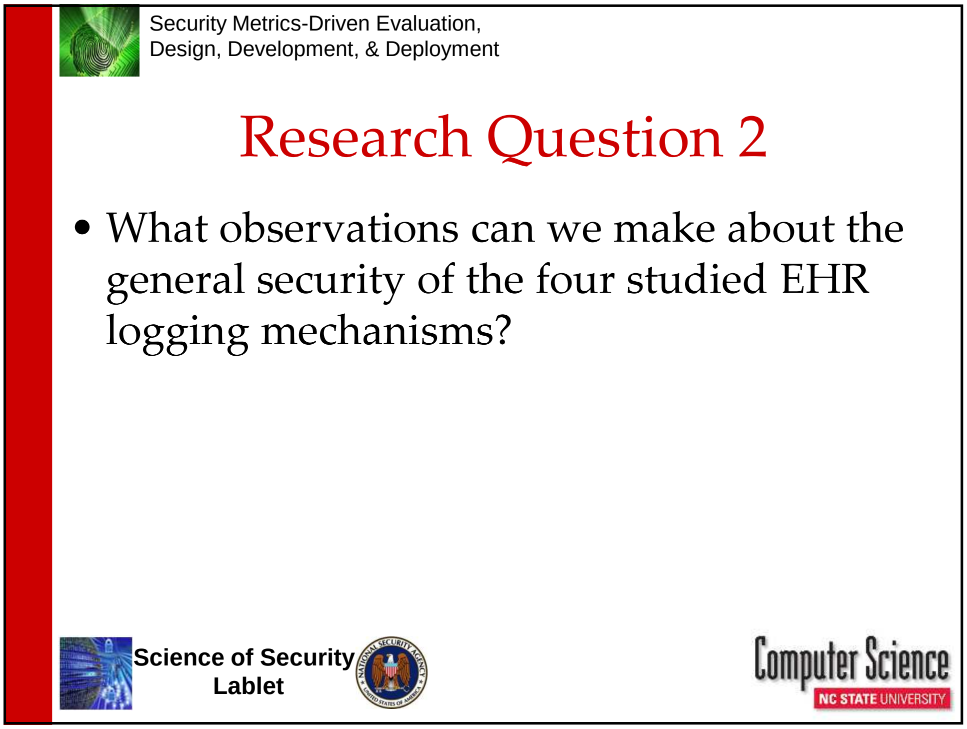

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Research Question 2

- What observations can we make about the general security of the four studied EHR logging mechanisms?

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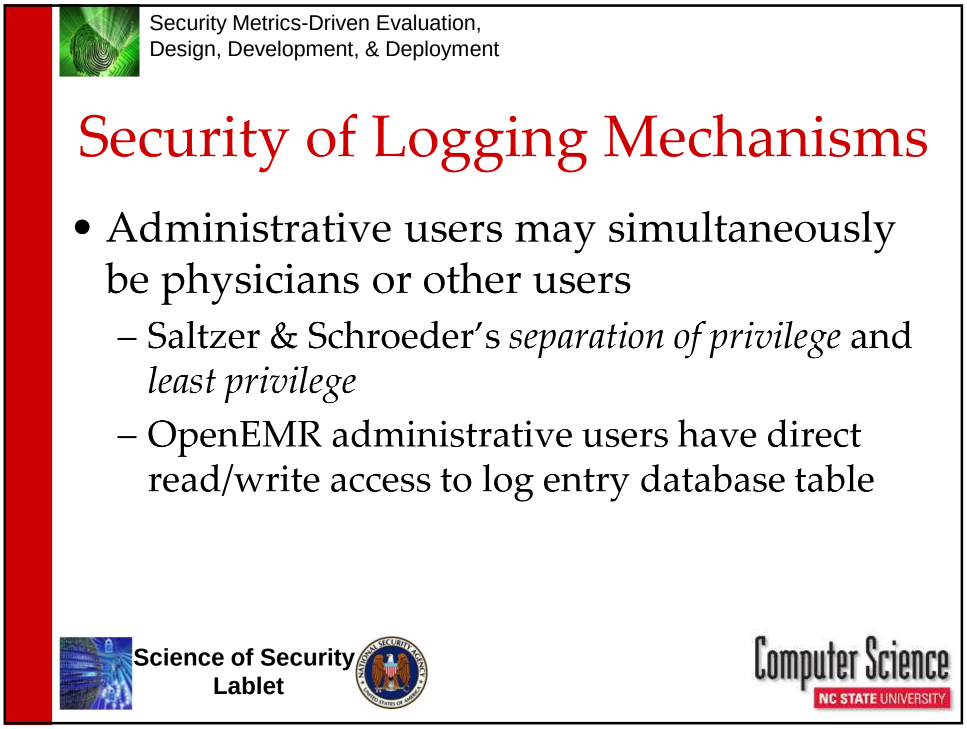

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Security of Logging Mechanisms

- Administrative users may simultaneously be physicians or other users
  - Saltzer & Schroeder's *separation of privilege* and *least privilege*
  - OpenEMR administrative users have direct read/write access to log entry database table

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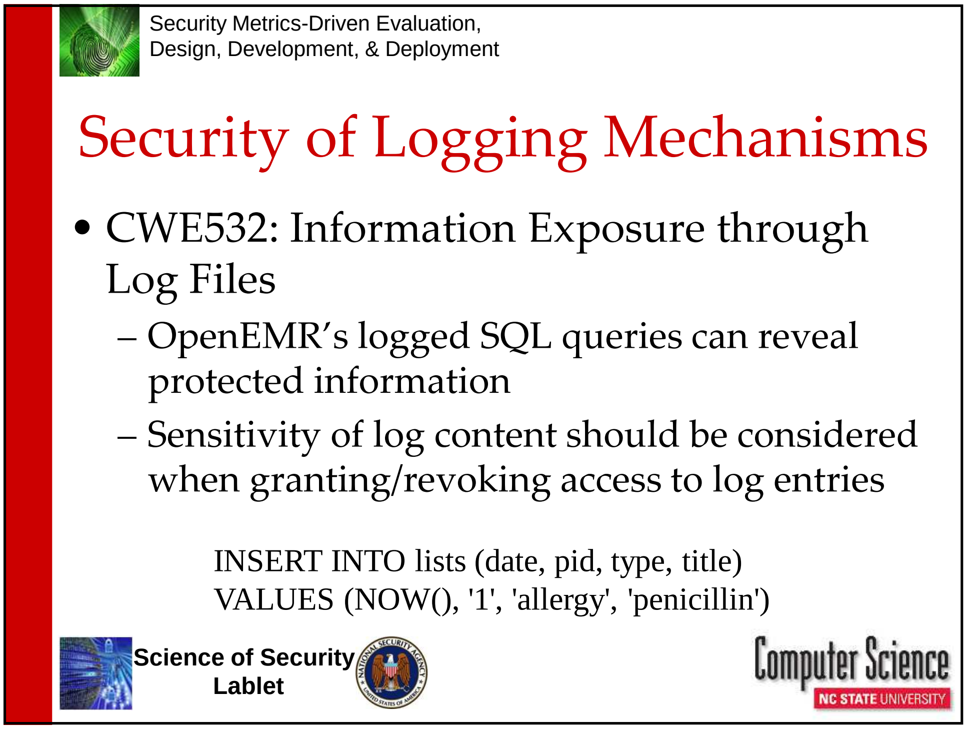
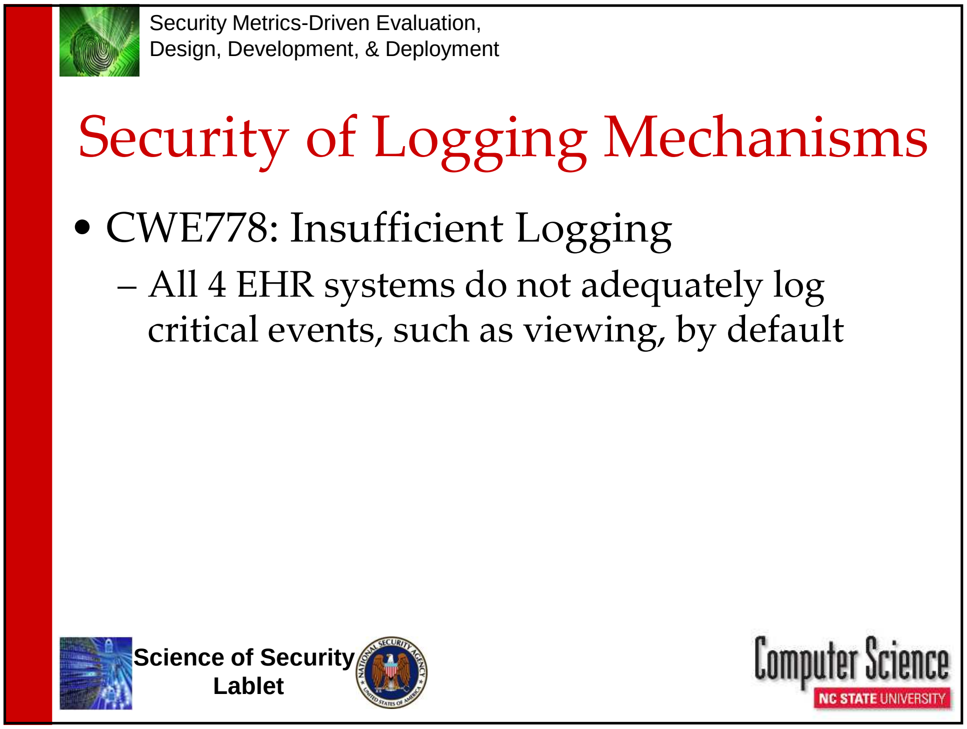


Security of Logging Mechanisms

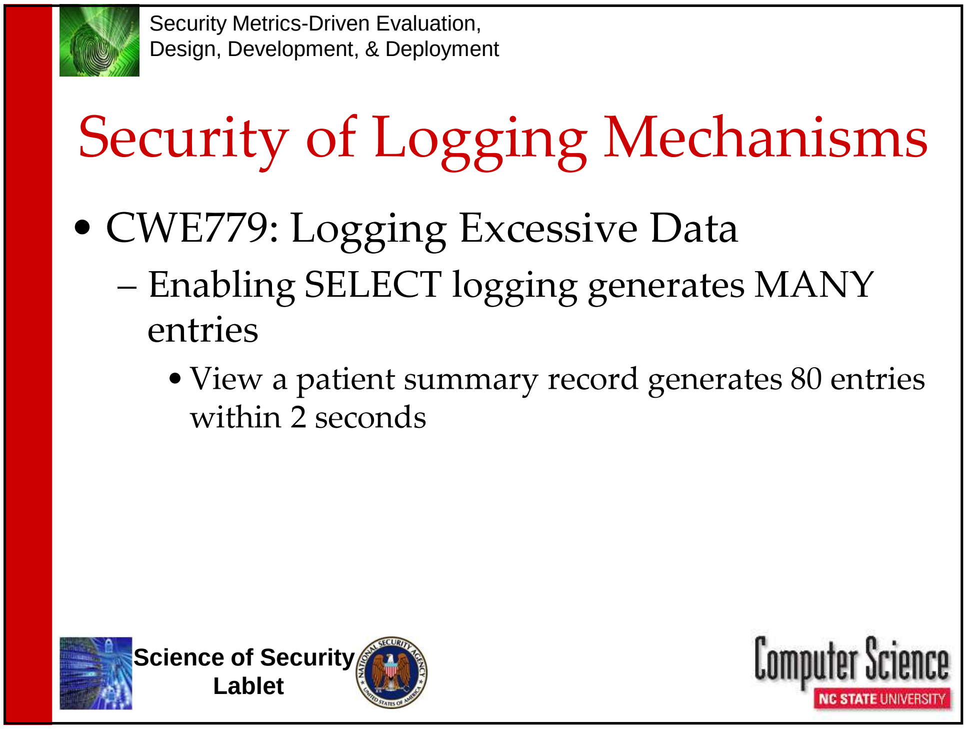
- CWE532: Information Exposure through Log Files
  - – OpenEMR’s logged SQL queries can reveal protected information
  - – Sensitivity of log content should be considered when granting/revoking access to log entries

```
INSERT INTO lists (date, pid, type, title)
VALUES (NOW(), '1', 'allergy', 'penicillin')
```



Security of Logging Mechanisms

- CWE778: Insufficient Logging
  - – All 4 EHR systems do not adequately log critical events, such as viewing, by default



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Security of Logging Mechanisms

- CWE779: Logging Excessive Data
  - Enabling SELECT logging generates MANY entries
    - View a patient summary record generates 80 entries within 2 seconds

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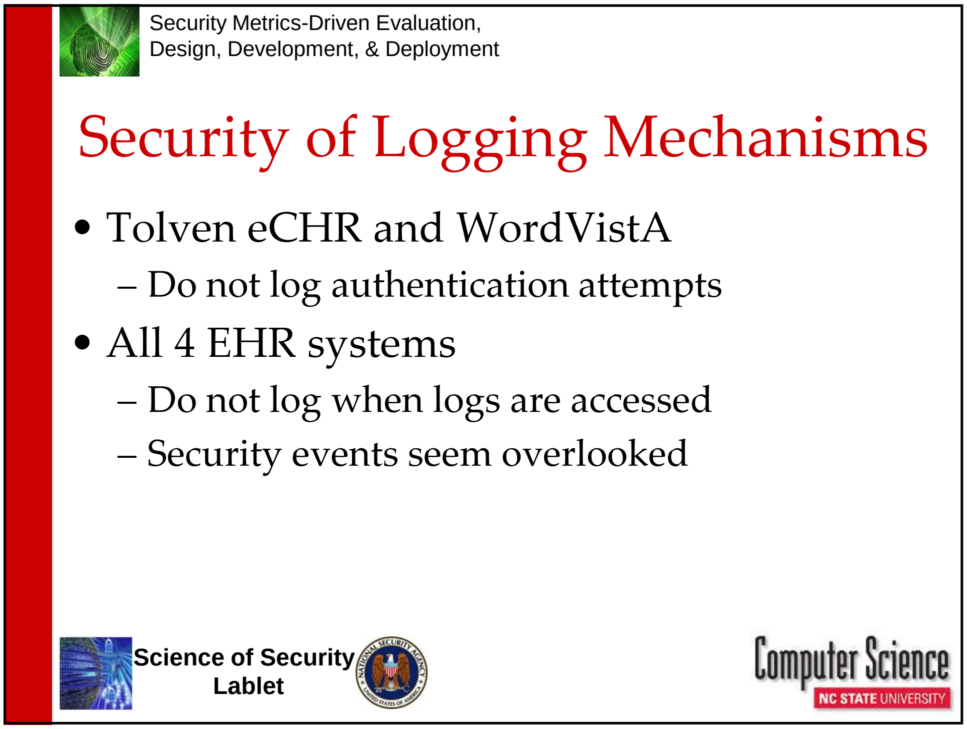

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Security of Logging Mechanisms

- Tolven eCHR and WordVistA
  - Do not log authentication attempts
- All 4 EHR systems
  - Do not log when logs are accessed
  - Security events seem overlooked

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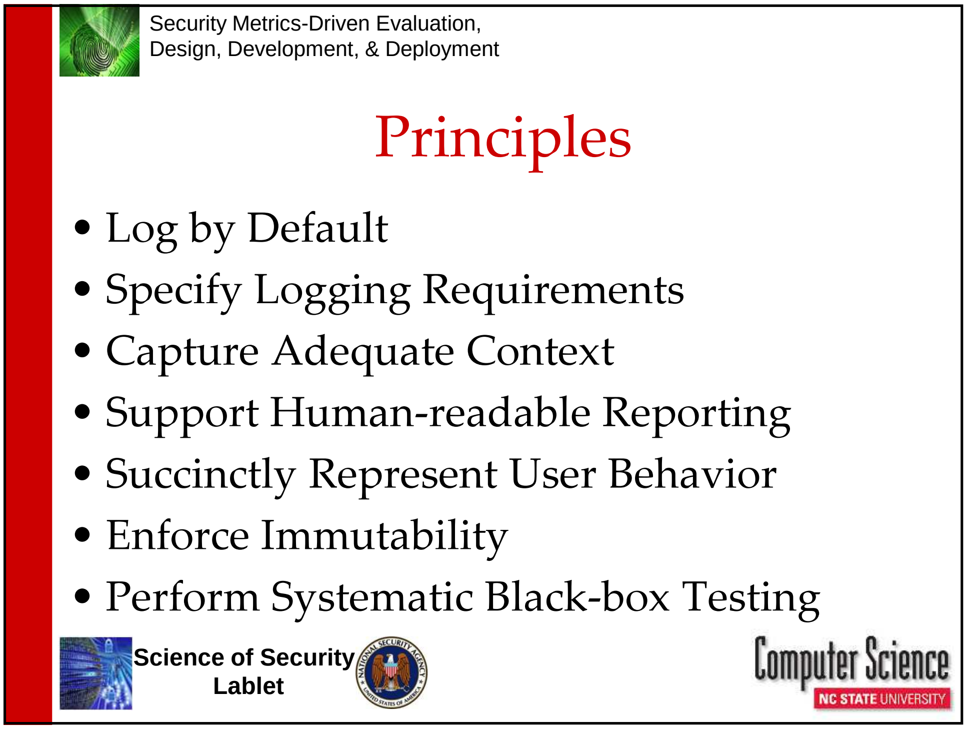

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Principles

- Log by Default
- Specify Logging Requirements
- Capture Adequate Context
- Support Human-readable Reporting
- Succinctly Represent User Behavior
- Enforce Immutability
- Perform Systematic Black-box Testing

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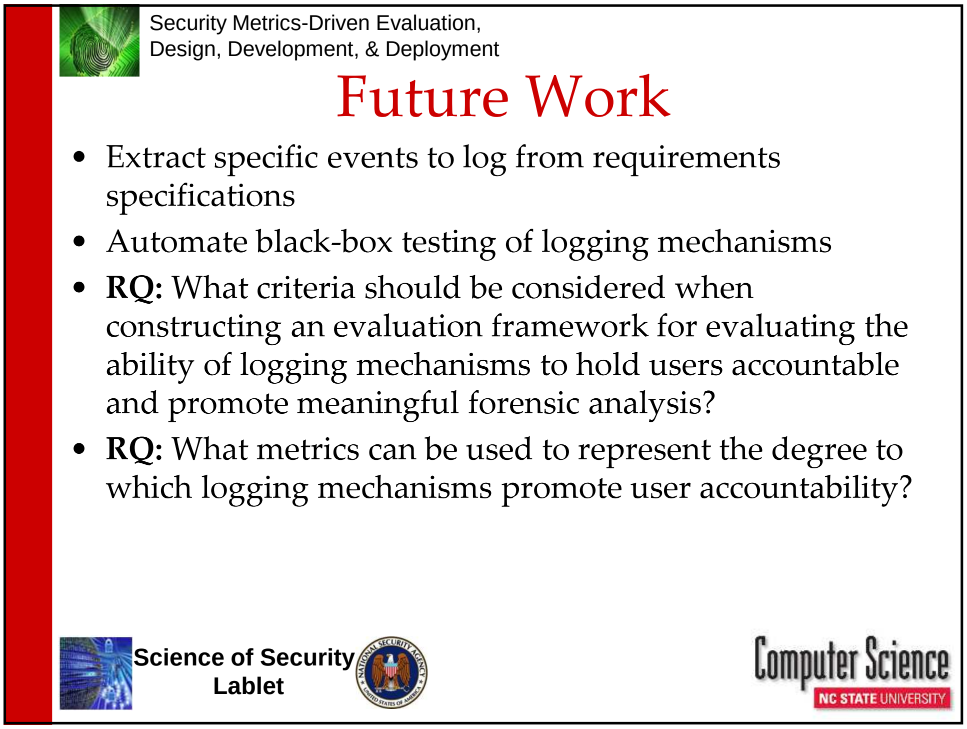

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Future Work

- Extract specific events to log from requirements specifications
- Automate black-box testing of logging mechanisms
- **RQ:** What criteria should be considered when constructing an evaluation framework for evaluating the ability of logging mechanisms to hold users accountable and promote meaningful forensic analysis?
- **RQ:** What metrics can be used to represent the degree to which logging mechanisms promote user accountability?

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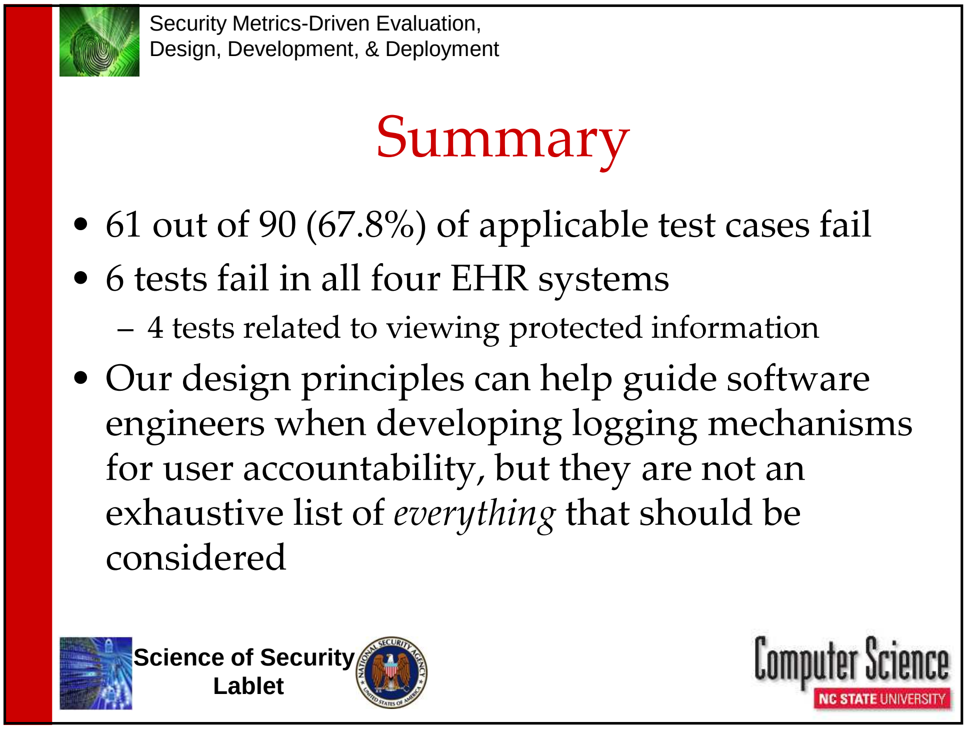

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Summary

- 61 out of 90 (67.8%) of applicable test cases fail
- 6 tests fail in all four EHR systems
  - 4 tests related to viewing protected information
- Our design principles can help guide software engineers when developing logging mechanisms for user accountability, but they are not an exhaustive list of *everything* that should be considered

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