Artwork: Giacomo Marchesi

A Research Agenda for Scientific Foundations of Security

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2½ years ago…

NSF/IARPA/NSA Workshop on the *Science of Security*

http://sos.cs.virginia.edu/

Philosophical Questions
(Usually Not Worth Discussing*)

Is there science in computer system security?

Yes, but of course there should be more.

Alchemy (700-~1660)

Well-defined, testable goal (turn lead into gold)

Established theory (four elements: earth, fire, water, air)

Methodical experiments and lab techniques (Jabir ibn Hayyan in 8th century)

Wrong and unsuccessful…but led to modern chemistry.

Realistic Goal?

Can we be a ***real*** science like physics or chemistry?

Unlikely – humans will always be a factor in security.

How far can we get without modeling humans?

How far can we get with simple models of human capabilities and behavior?

Some Questions a Science of Security Should Be Able to Answer

Resilience: Given a system P and an attack class A, is there a way to:

- **Prove** that P is not vulnerable to any attack in A?
- **Construct** a system P' that behaves *similarly* to P except is not vulnerable to any attack in A?

Establishing Improvement

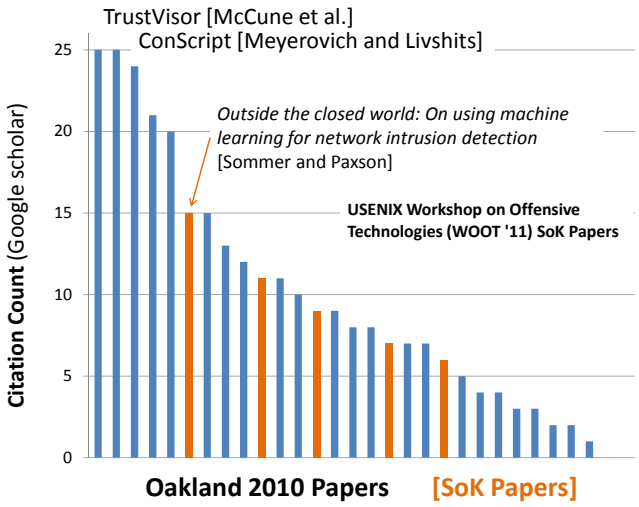
How can we determine if a system Q is "more secure" than system P?

Meaning of "Science"

Systematization of Knowledge
- Ad hoc point solutions vs. general understanding
- Repeating failures of the past with each new platform, type of vulnerability

Scientific Method
- Process of hypothesis testing and experiments
- Building abstractions and models, theorems

Universal Laws
- Widely applicable
- Make strong, quantitative predictions



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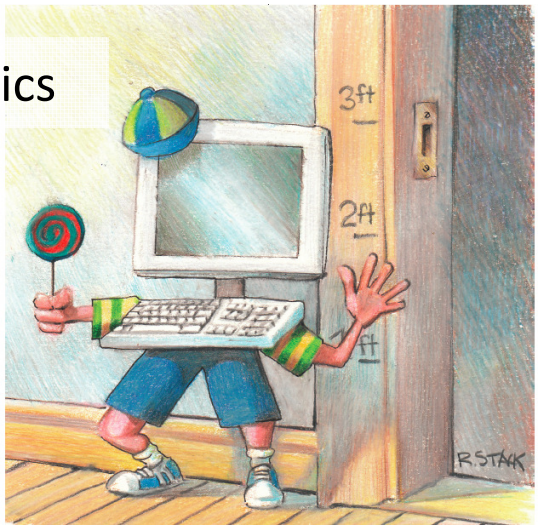
Experimentation

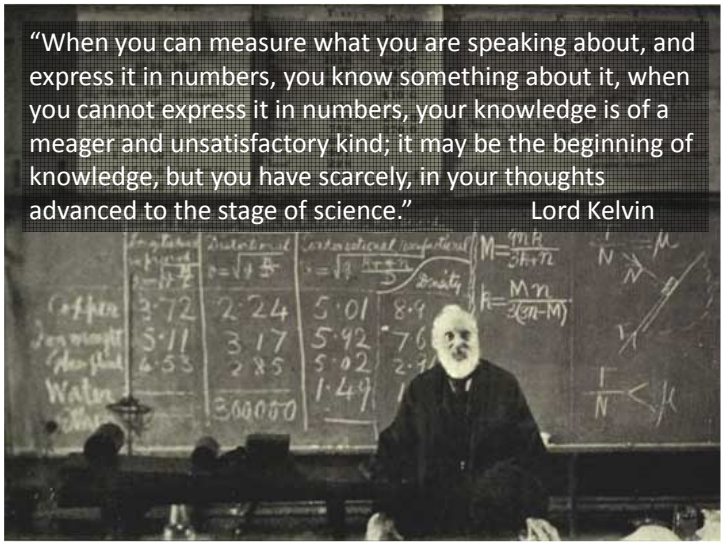
Security experiments require **adversary models**

Need to improve adversary models
- Coalesce knowledge of real adversaries
- Canonical attacker models (c.f., crypto)

Design for ~~**reproducibility**~~
meaningfulness and robustness

Metrics





Large increases in cost with questionable increases in performance can be tolerated only in race horses and [computer security].

Lord Kelvin

Metrics: Promising Approaches?

Comparative metrics
Attack Surface [Howard; Manadhata & Wing, TSE May 2011]

Experimental metrics
more systematic "red team" approaches

Economic metrics
Active research community; WEIS

Epidemiological metrics
model spread over network, but need assumptions

Entropy/Computational complexity metrics
Define attacker search space; automated diversity

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Formal Methods and Security

Lots of progress in reasoning about **correctness**

Systems fail when attackers find ways to **violate assumptions** used in proof

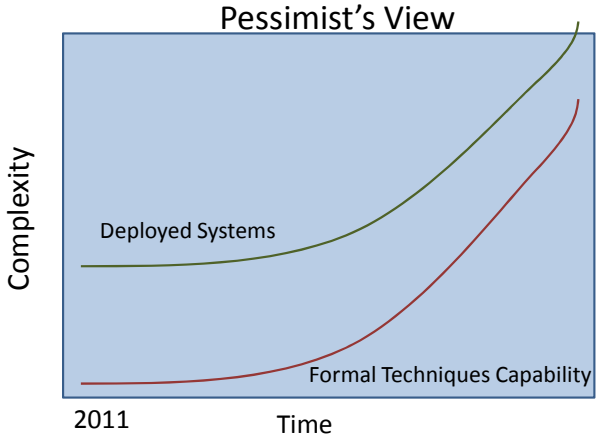
- Need formal methods that make assumptions explicit in a useful way
- Combining formal methods with enforcement mechanisms that enforce assumption

Degabriele, Paterson, and Watson. *Provable Security in the Real World.* [in IEEE S&P Magazine SoS issue]

(Loosely) Due to Fred Chang

Formal Methods vs. Complexity

Pessimist's View



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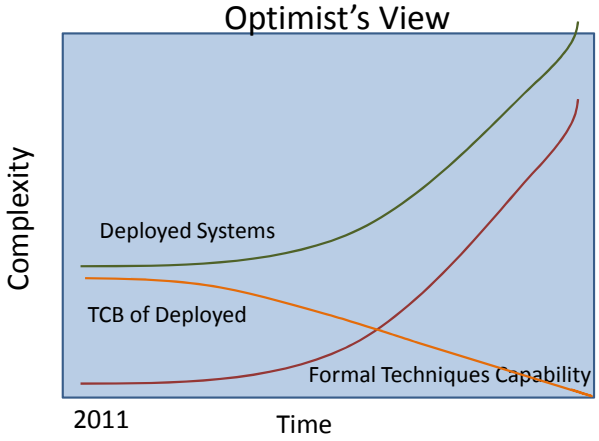
Formal Methods vs. Complexity

Optimist's View



Formal Methods Approaches

Refinement: Can we develop refinement approaches (design → ... → implementation) that **preserve security properties** the way they are used to preserve correctness properties now?

Program analysis: What security properties can be established by dynamic and static analysis?

How can computability limits be overcome using hybrid analysis, system architectures, or restricted programming languages?

Summary

Systematization of Knowledge

Valuable and achievable: need the right incentives for community

Scientific Method

Progress in useful models; big challenges in constructing security experiments

Universal Laws

Uncertainty if such laws exist; long way to go for meaningful quantification.

"In science there is only physics; all the rest is stamp collecting." Lord Kelvin

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