



Toward Information Protection Science

Keynote

Colombian National Computer Security
Conference

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Dr. Fred Cohen

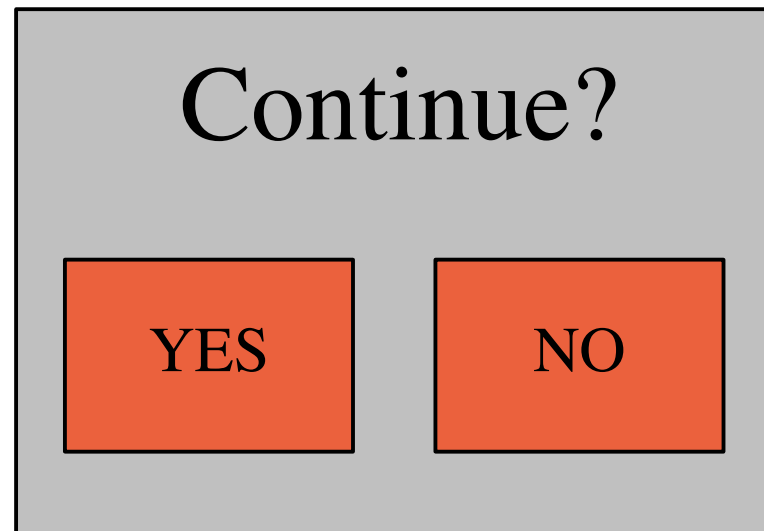
President - California Sciences Institute

CEO – Fred Cohen & Associates



Outline

- Introduction – the basics and the need
- Science as a social activity
- A different physics – an attempt at a theory
- The future





Your speaker

- CEO - Fred Cohen & Associates / **President CalSci**
 - Enterprise information protection architecture
 - Digital forensics for (usually high-valued) legal cases
 - **501(c)3 research and educational institution**
 - **M.S. Advanced Investigation / Ph.D. Digital Forensics**
- B.S. EE (C-MU '77), M.S. Info Sci (Pitt '81), Ph.D. EE (USC '86)
- >30 years of information protection R&D, design, engineering, testing, implementation, operation, etc.
- >20 years since first digital forensics case
- POST certified instructor in digital forensics, Guest lecturer FLETC, PMTS Sandia National Labs, etc.
- >>100 peer reviewed publications, many conference talks, ...



- Science is about causality
 - **A scientific theory:**
 - $C \rightarrow^M E$: Cause(C) produces Effect (E) via mechanism M
- The scientific method
 - **Identifies the criteria for rejecting (or accepting, for now) a scientific theory**
 - Hypothesize $C \rightarrow^M E$
 - Perform experiments to refute
 - Failure to refute \rightarrow confirmation
 - Enough confirmations and hypothesis becomes theory
 - One refutation and theory becomes refuted (wrong)
 - **But it may still be useful for limited cases**



Example science

- Hypothesis: The World is flat
- Experiment: Keep sailing West
 - See if you come back from the East
 - Lots of them didn't come back... confirmed
 - So many didn't come back → scientific theory
 - One made it around...
- Refutation – the theory was refuted (wrong)
 - But it may still be useful for limited cases
 - Do you account for the curvature of the Earth when you design a building?
 - Or do you assume the Earth is flat?



A problem with science

- Scientists are people too
 - People make mistakes → Science makes mistakes
 - Science corrects big mistakes and does it slowly
 - When someone notices “something wrong”
 - When the wrong thing is important enough to someone
 - Scientists will check it out, refute the old, propose new
 - Old workable science is still useful ($F=ma$)
 - People lie → science examines refutation carefully
 - Confirmation not so much – because it's not surprising
 - A new result that's important will get checked out
 - Once you lie in science - nobody will likely believe you again – and your old work will be largely discounted

- Is digital forensics important enough to care?
 - It sends people to jail / kills / frees them
 - It forms a framework for the legitimacy of the courts – and civil society
 - The social contract fails if science does not aide justice
- Is information protection important enough?
 - We have created a highly dependent society
 - Advanced society may literally collapse without properly functioning information technology
- I think it's important enough, so I care... do you?



But suppose we don't care?

- Without a reliable $C \rightarrow^m E$ model
 - We make a lot of mistakes (which happens anyway)
 - Those mistakes don't get corrected
 - They may be replaced by other mistakes
- How's that working out for you?
 - We pay too much and get too little
 - Snake oil sales prosper in the marketplace
 - We still do ridiculous things we did 25 years ago
 - Change your password how often?
- A scientific approach may help us get to “right”



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Continue?

YES NO



Some simple questions

- What is the definition of risk?
 - What are its units?
 - What is the standard of measurement?
 - Is it an absolute quantity?
- What can we do to it?
 - Transfer: Is there any benefit to the shell game?
 - Reduction: By how much and with what method?
 - Avoidance: What are the units of reward?
 - Acceptance: Only if we know what it is...
 - ARE THOSE THE ONLY THINGS TO DO?



Consensus: Digital Forensics

- The “scientific community” in digital forensics lacks consensus even around the very basic notions
- Compared to the consensus on human activity producing global climate change (86% or more) the basic notions of digital forensics are not at consensus levels:
 - Digital evidence is made of bit sequences.
 - You can observe bits without altering them.
 - You can duplicate bits without removing them.
 - Digital evidence is trace evidence



Challenge!!!

- There are only about 500 peer reviewed articles on digital forensics in the literature
 - Terminology is not widely agreed or uniformly applied – lots “made up”
 - Testability, validation, and scientific principles have not been widely addressed
 - The small corpus of published results limits the scientific basis for statements
 - Claims w/out supporting experiments common.
- “The State of the Science of Digital Evidence Examination” - 2011 IFIP DF conference



Consensus: Info. Protection

- We have some reasonably consistent words
 - Most CISSPs use many of the same words
 - Although they don't mean exactly the same things
 - There are 10,000+ peer reviewed articles
 - ~5 real journals (outside of cryptography)
 - Scores of peer reviewed conferences
 - Testability, validation, and scientific principles have not been widely addressed
 - Claims w/out supporting experiments common
 - Lots of long-term mistakes and rote approaches
 - Words are not consistently enforced in publications
 - No standard wordings (like there are in psychology)



Info Pro Big Problems

- There are almost no scientific experiments
 - No widely used theory of measurement
 - Almost no useful metrics
 - Progress in the attack graph with time (units?)
 - Almost no scientifically valid experiments
 - We don't even have a physics...
- A big part of the problem:
 - We have a purely mathematical basis
 - It ignores the people and processes
- A big part of the solution:
 - Social sciences integrated with artificial sciences



Another social problem

- Science is about refutation
 - When you say something, expect a challenge
 - On a rational and relevant basis
 - If you can't answer the challenge, you're refuted
 - Sort of – for now...
- But decision-makers in this space don't like it
 - Example: risk aggregation in large-scale systems
 - Example: computer viruses vs. trusted systems
 - Example: security theater vs. measurable basis
- We could use some executives who seek refutation rather than “yes – you're right”



And another critical issue

- Information protection involves people
 - As a field we don't seem to apply the human research areas to our work very often or well
 - Sociology, psychology, social psychology, etc.
 - Behavioral models and cognitive limitations
 - Decision-making methodologies and metrics
 - Without addressing the human aspects, we are destined to fail to meet our protection objectives
- A saying of mine
 - The “hard” sciences are the easy sciences
 - The “soft” sciences are the hard sciences

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Continue?

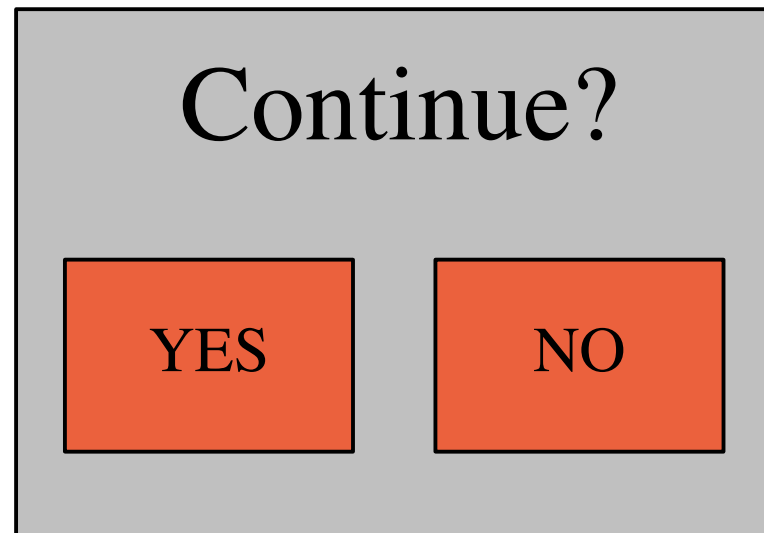
YES

NO



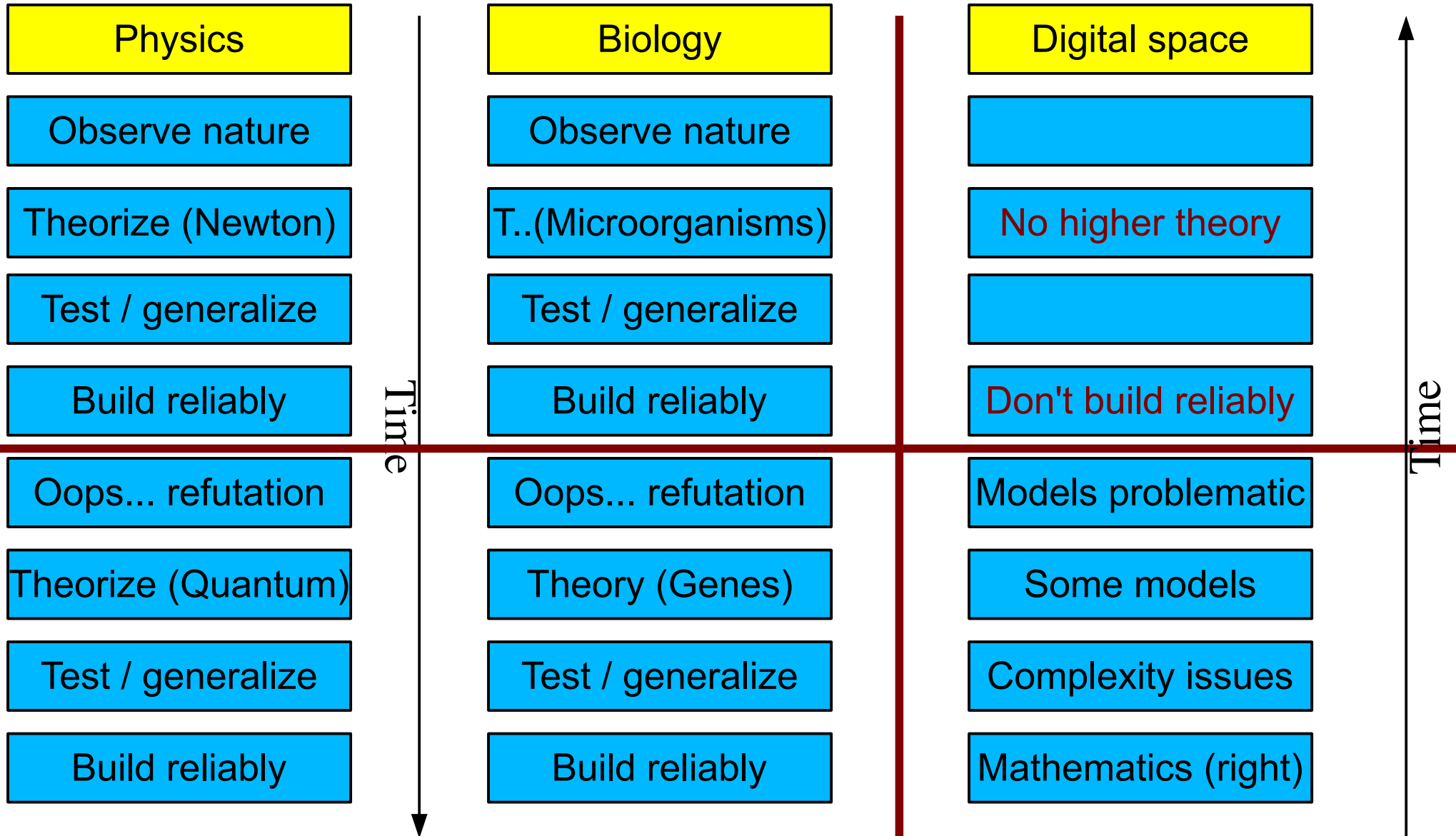
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How did some sciences form?



You can't build reliable bridges using only quantum theory
 You can't reliably cure diseases using only genetic theory

- Mathematics

- Keep building from the bottom
- Hope to construct our way out of it
- Complexity issues

- Archeology

- NSF approach to DF
- Requires a physics
- Problematic for reliable results

- Engineering

- Build and test
- Find and fix
- Requires a physics
- Bridges are falling

- Social sciences

- Statistics: Causality is too complex / unknown
 - P(x) problematic
 - Measure what? How?



Notions of a new approach

- Information physics
 - We may want a “physics of digital information” level to reduce complexity and allow composition based on physics properties
- Social sciences
 - We may want a “behavioral science” area to address the human and social factors associated with protection
- Fusion (**IRB decision is involved**)
 - Example: Deception experiments from ~2000
 - Human and group dynamics taken into account
 - Measured progress in attack graphs with time
 - Differential effects of 3 types of “deceptions”



Transfer vs. Trace

- **Natural world** forensics
 - **Transfer** is the scientific basis for trace evidence
 - When physical objects come into contact, each leaves part of itself with the other(s) (Locard misquote)
 - Scientific theory: Objects: Contact \rightarrow Transfer Traces
 - Traces found on objects are consistent with transfer from physical contact with other objects
- There is **no transfer in digital evidence**:
 - The scientific basis for evidence acceptance in the **natural world does not apply**
- But there are still **traces** (product of execution)
 - Scientific theory: FSM \rightarrow Execute Traces



A different physics?

- Some basic physics of the digital world:
 - Digital data is entirely sequences of bits
 - The atomic unit is the “bit”
 - Nothing smaller (finite granularity)
 - No longer dealing with the digital evidence
 - Smaller than a bit it's physical evidence
 - Finite bit granularity → finite time granularity
 - Bits can only store traces (of time) at finite granularity (a finite bit sequence)
- Normal space: infinite granularity space/time
- Digital space: finite granularity space/time



Finite granularity issues

- Finite granularity → time is a partial ordering
 - A before B ($A < B$), A after B ($A > B$), Can't tell ($A \approx B$)
 - Traces as recorded are subject to Δt
 - What is the Δt for your traces / time stamps?
 - Is the claim a sequence of events?
 - Don't know Δt → don't know the sequence!
- Precision vs. accuracy
 - Trace time stamps are subject to delays, etc.
 - They look precise (2010-11-02 03:34:54.455)
 - But often aren't as accurate (off by 9 hours)
 - Mixed granularity misleading as to sequences
 - Some Windows time stamps at 1-day granularity



Convergence vs. divergence

- FSMs have “perfect” forward predictability
 - Given an FSM, initial state, and input sequence, all state and output sequences are precisely defined
 - Many FSMs and input sequences produce identical output sequences
 - Digital space “converges” with time
 - Traces do not uniquely identify causes!
 - $C \rightarrow^m E \not\Rightarrow E \rightarrow C$ – Effect does not imply (unique) cause!
- Normal space (physics) admits to only one past but many possible futures: $E \rightarrow C$ unique!!!
 - Normal space “diverges” with time!
 - Effect implies unique cause



Convergence details...

- Digital space converges with time
 - FSM: $(I, O, S, m: \{I \times S\} \rightarrow \{O, S'\})$ IF $|I| > (|O| + |S|)$ THEN $\exists (i, i') \in I: \exists (o) \in O, \exists (s) \in S, i \rightarrow (o, s)$ and $i' \rightarrow (o, s)$
 - Also note that $h(O) \leq h(I+S)$ (Shannon's h)
 - Normal space diverges with time (2nd law of thermodynamics)
 - Digital space converges with time
- You can't normally identify I^n from traces T
 - $T: |T| < |I^n|, \exists (i, i') \in I^n: \exists (t) \in T, i \rightarrow (t)$ and $i' \rightarrow (t)$
 - In digital space, history is not uniquely determined by the present



Latent nature and tools

- Bits (and DFE) are (normally) latent in nature
 - Bits can't be directly observed with human senses
 - The bits must be observed through tools
 - How do we understand and trust the tools?
 - Most tools are computer programs (sequences of bits interpreted by FSMs)
 - How do we assess and present tool reliability?
 - A scientific methodology to evaluate tools?
 - No methodology → regardless of what the tools tell us, we don't know how to interpret it
 - What is the basis for trusting your tools?
 - In most cases, no basis is provided
 - Do you know the scientific principals and methods?



How do we know?

- How do we calibrate and test tools?
 - Calibration → validation with known samples
 - What known samples are right for the matter?
 - What is the “right” answer and how do we tell?
 - Testing involves software verification
 - Mathematical proofs
 - Tests against error models
 - A theory of measurement is needed:
 - What does the tool measure? How does it do it?
 - Do I need / can I use the same tool to test it?
 - Can I use a tool that doesn't reveal mechanisms producing its outputs?



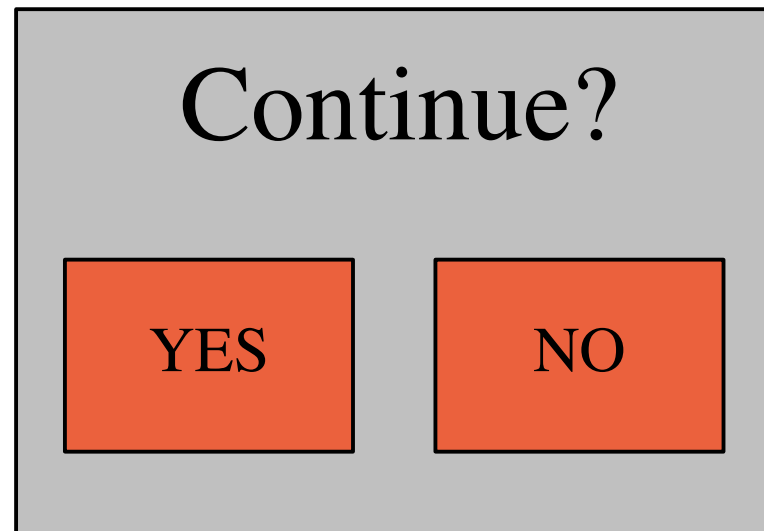
Differences in physics ...

- There are many more examples of differences between the physics of digital information and the physics of the natural world.
- For details see:
 - F. Cohen, “Digital Forensic Evidence Examination - 3rd ed.”, ASP Press, 2011



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An engineering discipline

- An approach to building reliable protection
 - A science base that produces methodologies, scientific theories along with limitations, measurement methods, defined language and usage, and experimental basis for showing properties of components and composites.
 - A set of well tested tools and techniques for analysis and construction of mechanisms with known properties and identified limitations not requiring expertise in the lowest level of minutia.
 - A global feedback mechanism for improvement over time, including a rich set of peer reviewed publications, professional standards, and strong educational base with common real knowledge



- The social part of science...
 - Here I am – trying to convince you
 - If I do, you will try to convince others
 - In the marketplace of ideas, mindshare wins
 - For a while... until failures force abandonment
 - Refutation is king
 - The “meme”s that survive are more “fit”
 - In the environmental niches they live in
 - Evolution is not optimization
 - But refutation pushes us out of our gravity wells
- I would love to discuss your research...



Thank You



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