

Risks of Untrustworthiness

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Complexity

- “Everything should be made as simple as possible, but no simpler.”
Albert Einstein
- Simplicity is highly praised, but Security is Inherently Complex. Oversimplifying it creates flaws.
- How can we manage complexity?

Security

- Security is a set of end-to-end total-system emergent properties, some of which must be avoided.
- Strength in Depth is desirable, but we have Weakness in Depth.
- Achieving better security is only part of the problem.
- We need Trustworthiness.

Trustworthiness

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- Trustworthiness of S (a system, network, subsystem, enterprise, ...) implies S is worthy of being trusted to satisfy its specified requirements R (for security, reliability, human safety, system survivability despite a realistic range of adversities, ...), with some measures of assurance Q.

Trustworthiness is Holistic 1

- Holistic approaches consider systems and enterprises in their entirety in the context of their environments, lifetimes, and total ranges of uses.
- Trustworthiness involves many end-to-end emergent properties, many of which must be avoided.

Trustworthiness Is Holistic 2

- Trustworthiness is Pervasive. Systems need to satisfy all critical requirements, not just security.
- Trustworthiness is highly multidimensional. It is not a local property, especially for applications. Total-system analysis is needed.

Trustworthiness Is Holistic 3

- Security, reliability, and other critical requirements interact, and can be incompatible.
- Effects of flaws and bugs can propagate widely.
- Application security is easily undermined by poor OS security.
- Outages must be anticipated.

Systems Need Holistic Analysis

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- Energy: future-oriented/
short-sighted optimization
 - Agriculture: natural/industrial
 - Health care: prevention/“cure”
 - Systems: principled/unprincipled

See PGN, Holistic Systems, *ACM SIGSOFT Softw.Eng.Notes*, Nov. 2006

Energy

- Renewable resources (solar, wind, biomass, hybrids) can be viable if considered holistically.
- Fossil fuels are short-sighted, nonenvironmental, nonrenewable, contribute to global warming. Nuclear waste has long life.

Agriculture

- Sustainable agriculture uses natural fertilizers/pest-controls, crop rotations. It is healthful.
- Industrial agriculture causes soil depletion, toxic runoffs, worker and consumer health problems.

Health Care

- Alternative/preventive methods are holistic and environmental.
- “Modern” medicine seeks quick fixes that suppress symptoms rather than eliminating causes. It may be iatrogenic, trigger bacterial mutations, ...

System/Network Development

- Principled system development has many long-term benefits.
- Bad practices include monolithic nondecomposable systems, poor software engineering, sloppy software, unsafe languages, overdependence on patches, and create many problems.

Avoiding System Risks

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- Build constructively trustworthy systems with predictable composability and interoperability.
 - Ted Glaser: “A modular system is one that falls apart easily.”
 - Modularity is not enough; we need encapsulation, compatibility, interoperability, noninterference...

Holistic Analysis Is Needed

- Principled development of trustworthy systems must be demonstrably cost-effective before it can become pervasive. How can this be accomplished?

Principled System Development:

- Holistic approaches to complexity: sound requirements, structured architectures, principles, good software engineering practice, design for trustworthiness, usability and administrability, pervasive assurance analysis, formal methods, and lots more.

Principled System Design

- Management of complexity through constructive architectures that modularly localize what must be trustworthy, such as separation kernels, virtualization, alternative approaches to multiple security levels, and so on.

Principled System Implementation

- Property-preserving refinements
- Sound software engineering
- Sound programming languages
- Invariant design composability
- Proactive code analysis
- End-to-end self-checking

Principled System Assurance

- Pervasive assurance throughout development/use cycles.
- Assured composability, with hierarchical closure as in the Boyer-Moore stack, Robinson-Levitt (PSOS), Rushby-DeLong (new work).
- Assured multilevel security?

Deja Vu All Over Again, Yogi Berra

- Unfortunately, the same types of mistakes (design flaws, software bugs, operational errors) recur.
- There is much to be learned, from many past mistakes. Educational is crucial.
- Various examples follow.

Backup and Recovery Risks 1: Air-Traffic Control Failures

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- LA Palmdale ATC Jul 2006 power
 - Reagan National Apr 2000 power
 - LI NY ATC SW upgrade Jun 1998
 - LA ElToro ATC 104 failures/day
1989 (no previous system saved)
 - 3 NY airports 1991 (on batteries)

Backup and Recovery Risks 2

More total system/backup failures:

- Swedish central train res system
- Washington Metro Blue Line 1997
- SF BART SW upgrades Apr 2006
- Japanese stock exchange Nov 2005

Cases of losses with no backup:

- NY Public library references
- Dutch criminal mgmt system

Propagation Risks 1: Widespread Network Outages

- 1980 ARPANET collapse: router memory errors, weak garbage collection of old status messages, memory overflow in every node
- 1990 AT&T longlines collapse: untested change in recovery code, repeated crashing for half a day.

Propagation Risks 2: Widespread power outages

- Northeast US, Nov 1965
- Lower NY State, Jul 1977, >26 hrs
- Ten Western states, Oct 1984
- Western US, Jul 1996, heat/tree
- Western US/Canada/Baja, Aug 1996
- Northeast, Aug 2003, >2 days

Propagation Risks 3: Power outages in 2006

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- Queens, NY, week-long, wiring
 - Portland, Oregon, October
 - Ems River, Germany, November.
preventive shutdown failed to
consider iterative implications
(N-1), affecting 10 million in 6
countries from Austria to Spain.

Software Flaws 1

- Buffer/stack overflows, missing bounds checks, type mismatches, and other flaws are ubiquitous and keep recurring. This seems rather ridiculous.

Software Flaws 2

- Multics prevented stack overflows.
- Progr. languages are a mixed bag.
- Analysis tools: StackGuard (Cowan), buffer overflow analyzer (Wagner), lint family, Coverity (Engler), Fortify (Chess), MOPS (Chen); Microsoft: Spec#/Boogie, PREfast/PREfix, RaceTrack, ...

Election Systems 1

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- Elections should have end-to-end integrity/reliability/accountability, nonsubvertible audit trails, uncompromised voter privacy, etc.
 - The entire process is vulnerable: registration, voter authentication, authorization, voting, counting, certifying, recounting, etc.

Election Systems 2

- Weakness in depth: every step is a potential weak link.
- All-electronic paperless systems are unauditable, lacking integrity, and subject to errors, fraud, and nontechnological problems, as seen in 2000, 2004, 2006.
- HAVA, EAC, evals: simplistic.

Conclusions 1

- The individual cases may be less important than the fact that we repeatedly see the same types of problems.
- Many common vulnerabilities can be relatively easily avoided with more principled approaches.

Conclusions 2

- Computer development is mostly an incremental process, driven by marketplace forces. But security research and assurance are slow to be adopted, despite vital needs.
- Incentives are needed to make better use of past lessons.

Conclusions 3

- Better trustworthiness is urgently, needed, and should be approached holistically, with composable architectures and principled system developments.
- Development and operation of trustworthy critical systems require massive cultural changes.

A Few Relevant References

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