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Failing Gracefully:
Patching & beyond

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Brief Bio

- Founded Cryptography Research, Inc. 11 years ago
  - Focus on mitigating "unsolvable" real-world security problems
- Examples of projects & work by myself and the team at CRI:
  - CryptoFirewall™: Tamper-resistant hardware for securing pay TV services
  - Deep Crack: Hardware to break DES
  - DPA & countermeasures: >1 billion smartcards made annually have DPA countermeasures patented by CRI
  - SPDC™: Renewable security for optical disc formats
  - SSL v3.0 / TLS v1.0
- Designs secure >>$100B of commerce annually

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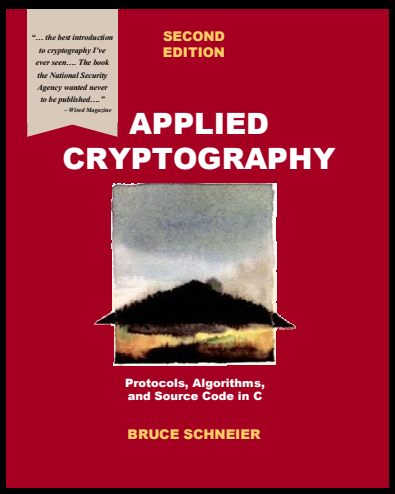
We've spent ages seeking to "achieve" security…

Optimism is fading…



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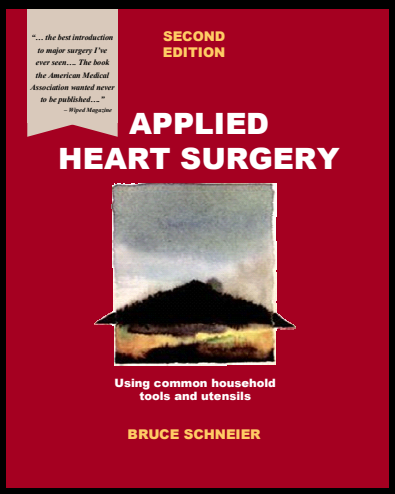

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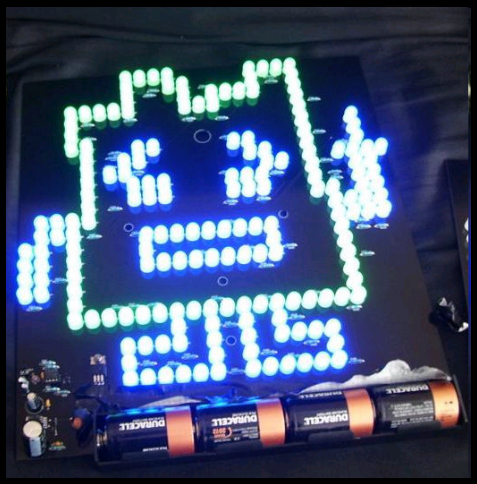
The world is filled with **scary things**!

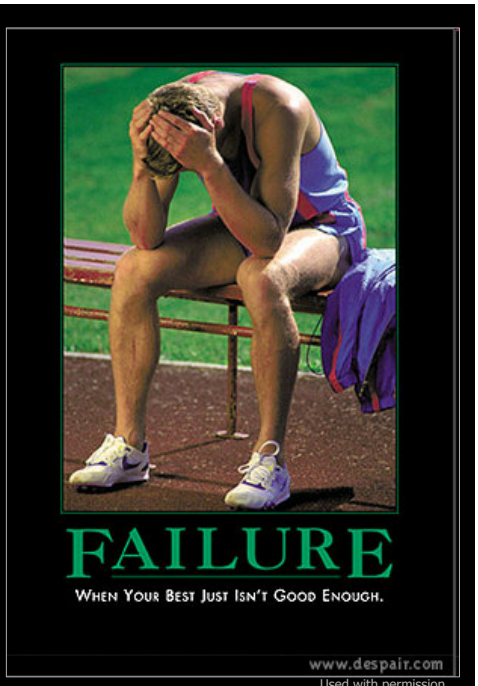


What if it's all hopeless?

What if we're doomed to an eternity of

Patches

and other coping mechanisms?



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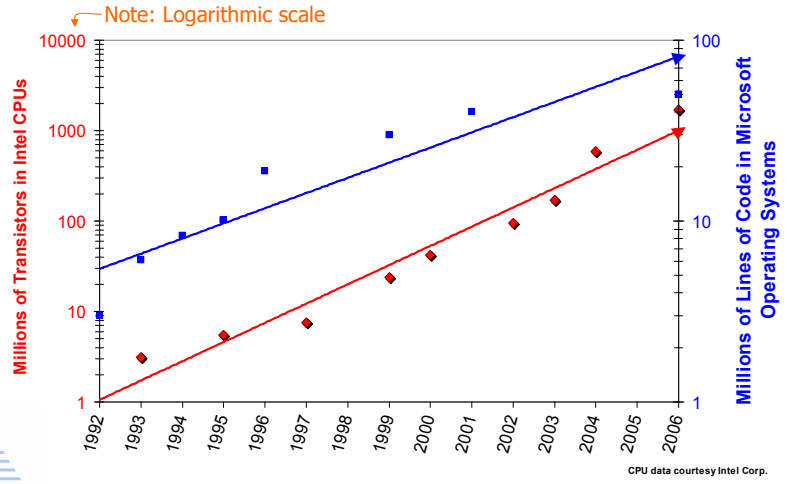
Growth in complexity



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Moore's Law overwhelms everything

- Tools can help buy some time:
  - Safer programming languages
  - Code scanning tools
  - Better APIs/libraries
  - Additional layers of abstraction
  - Run-time detection
  - Stack monitoring/canaries
- Certifications can also buy time:
  - Good ones help weed out the worst products and encourage good engineering
  - Bad ones drive away experienced engineers who are allergic to paperwork and detract from the real problems
  - Complexity of products is overwhelming evaluators

- Tools & certifications help by a *constant factor*
  - Addresses X% of the bugs
  - Which means there are still some bugs – and complexity inevitably catches up again…

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Three coping strategies…
(Besides prayer, magic, or unlimited security budgets)

- Three strategies I'll examine:
  - On-line updates
  - Piggybacking strategies
  - Redundancy-based security architectures

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The Microsoft approach

- Windows has security bugs
  - Microsoft is trying hard: Density of bugs is decreasing
  - But complexity of Windows (other ring 0 code) is increasing
- Windows-based PCs could not survive on the Internet without updates
  - Infrastructure is "worth" targeting [even if only for ego]
  - Eventually an unstoppable exploit would arrive
- Windows would be unusable without Microsoft Update

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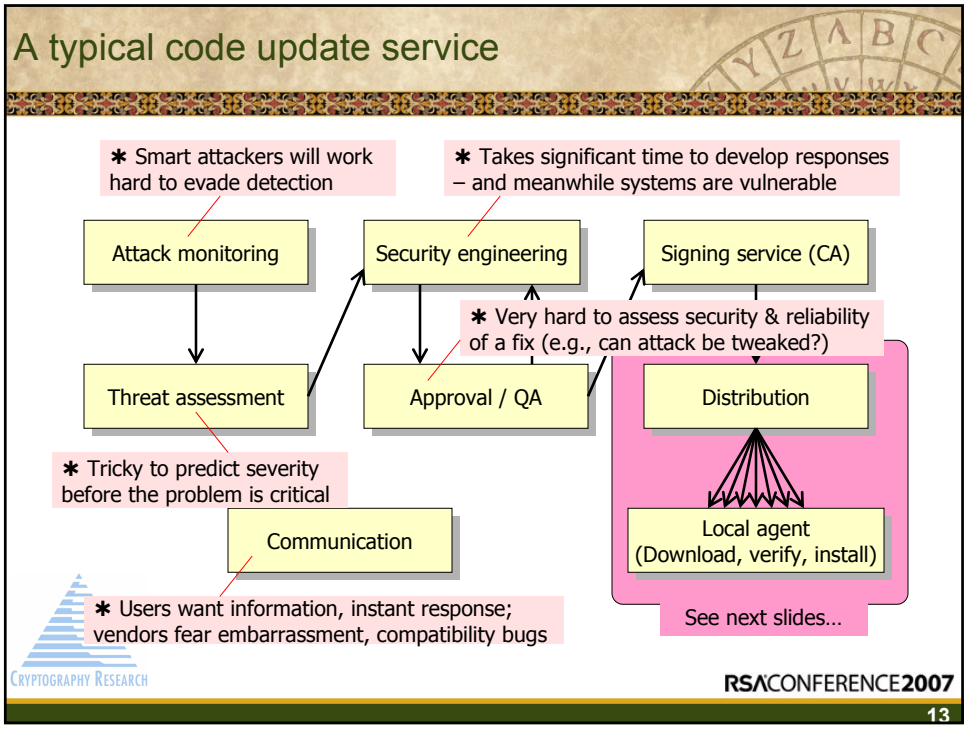
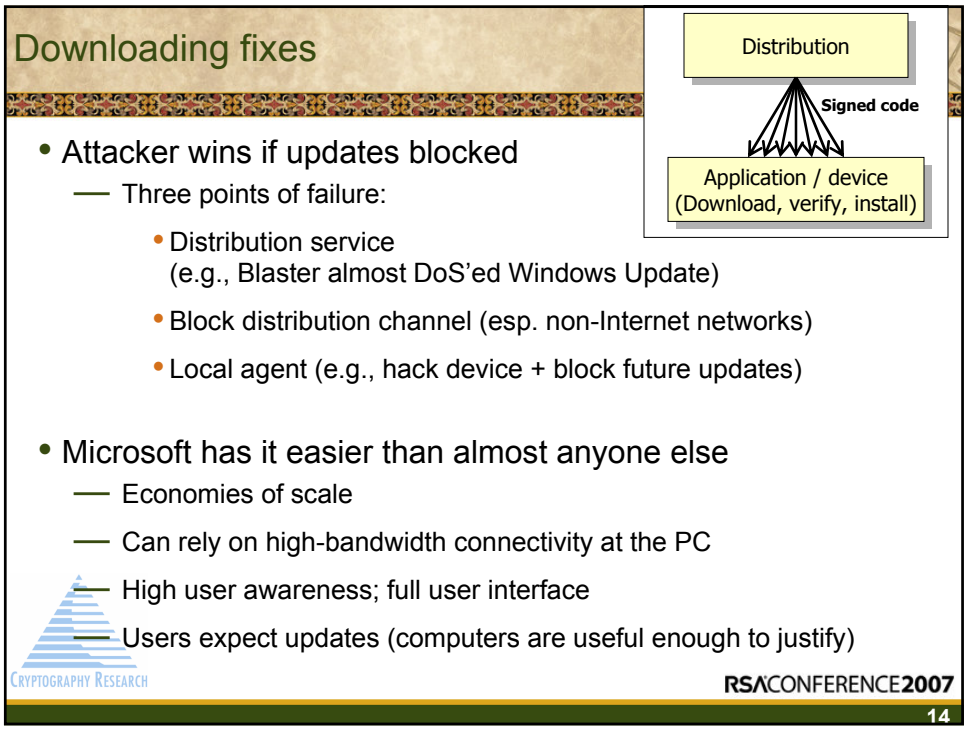
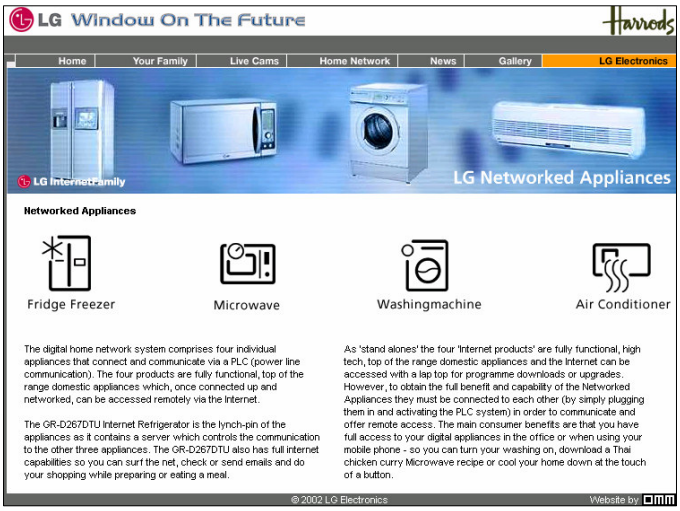




Beyond Windows & anti-virus applications: Fixing bugs



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Beyond Windows + anti-virus applications

- Problem gets much harder
  - Limited user interface
  - Network connectivity may be expensive or unavailable
  - User expectation: Reliability (not frequent changes)
  - Product usage model does not provide convenient alternative recovery channels

User may be cooperative:

- Routers
- Firewalls
- Mobile phones
- Security Cameras
- Printers
- GPS Navigation
- VoIP phones
- Printer consumables

... or adversarial:

- Video game systems
- Pay TV decoders
- Media players
- Home Ent. Systems
- Payment cards
- ID cards/tokens

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More problems (1 of 2)

- Problem: Malicious code can disable update downloader
  - Attacker goal: block the update & prevent users from noticing
    - Viruses often try this against anti-virus software
  - Strategy for devices: Update-at-boot
    - Boot flash checks over the network for updates
    - Before running other code, boot flash hardware disables writes to itself until reboot
  - Strategy for PCs:
    - Race to get the patch out before exploit
    - Force attacker to rewrite/modify a lot of (uniquely randomized) code
    - Leverage flexible user interface & user awareness

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More problems (2 of 2)

- Problem: Denial-of-service on servers
  - Attacker wins if the update service is DoS'ed
  - Solution: Multiple DNS queries/IP addresses, updateable connection strategies (e.g., Java code), big pipes, priority for authenticated devices (if privacy permits)
- Problem: Patches can cause compatibility issues
  - No good solution.
    - Patches are hard to write, hard to test, and frequently cause trouble
    - Users hate them for good reason

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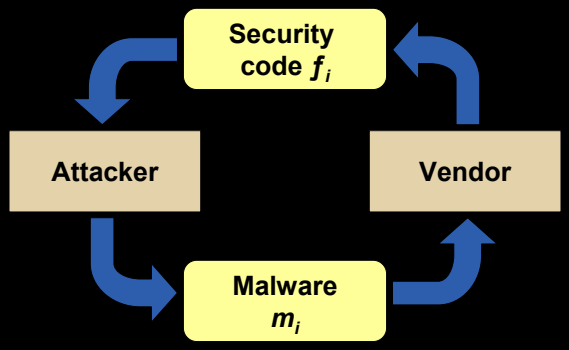
Summary of 21st Century O/S Security



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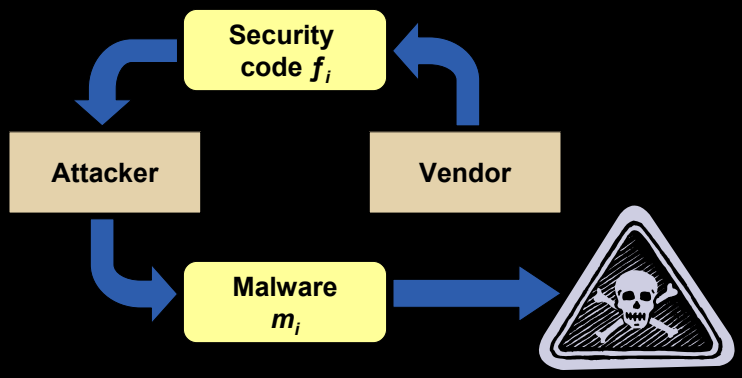
Exponential complexity growth in the environment
Users' data forms the battlefield

Summary of 21st Century O/S Security

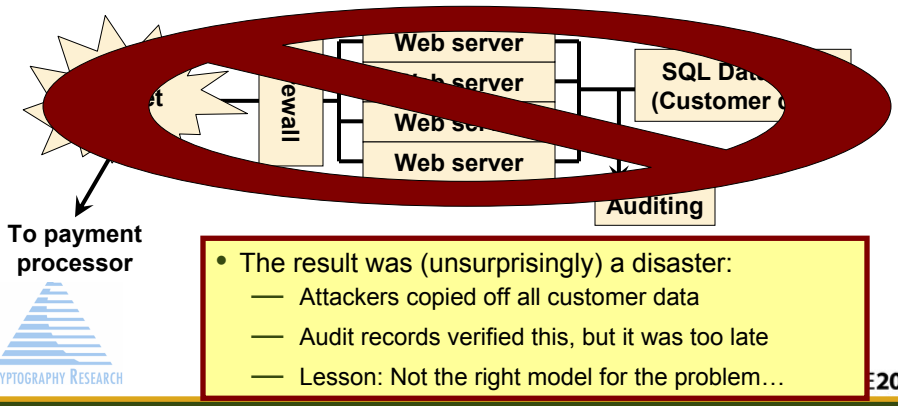


But on the bright side…

It's often less ghastly than the alternative.

Case study: Merchant e-commerce credit card database

- Running separate high-security servers for customer data is expensive and cumbersome
  - Approach: Allow web servers to access customer & payment data, but have a comprehensive audit system + stay current on patches
  - Significantly reduced costs!



- The result was (unsurprisingly) a disaster:
  - Attackers copied off all customer data
  - Audit records verified this, but it was too late
  - Lesson: Not the right model for the problem…

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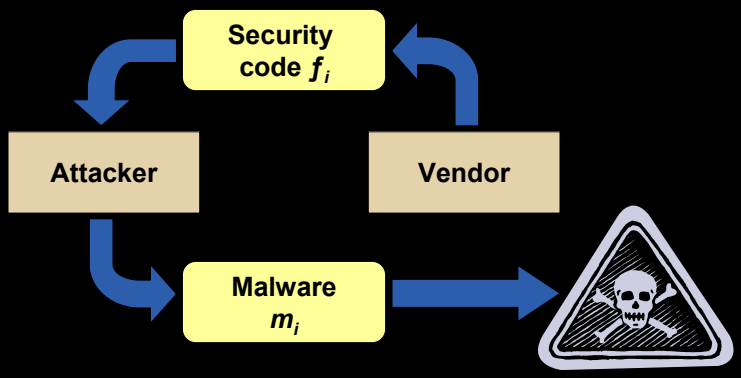
Summary of 21st Century O/S Security



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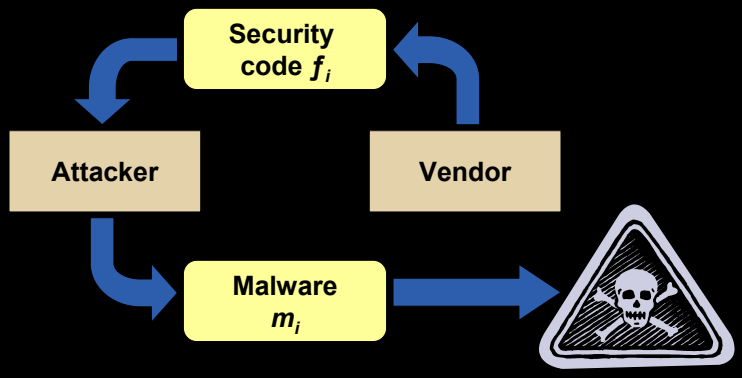
Summary of 21st Century O/S Security



But on the bright side…

(but not always)

It's often ^ less ghastly than the alternative.

Making the problem "less bad"

- Lots of practical issues we'd like to mitigate…
  - Do multiple vendors make device? Provides source data?
  - Are there multiple versions of target devices?
  - Bandwidth limitations? Backward compatibility issues?
  - How is customer service handled?
  - Do vendors support their devices indefinitely?
  - Will users ever miss patches? Have NVRAM bit errors? …

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Piggybacking

- Many devices' normal role is to process data
  - Can include security updates as part of this data
  - Bundling with beneficial data enables security updates in adversarial models (e.g. piracy situations)

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Case study: Piracy from academy screeners

- Academy members need to see movies so they can vote on them for academy awards
  - Problem: Virtually every movie was getting pirated
  - Much too expensive & difficult to try to make movies uncopyable
- Solution: Piggybacked forensic marking data
  - Unique identifying marks in each original enable copies to be traced
- Adding a back-channel solved the problem
  - Russell Sprague went to jail; Carmine Caridi kicked out of Academy
  - Today, screeners are rarely pirated and sources get shut off quickly
  - Very successful: problem is self-limiting

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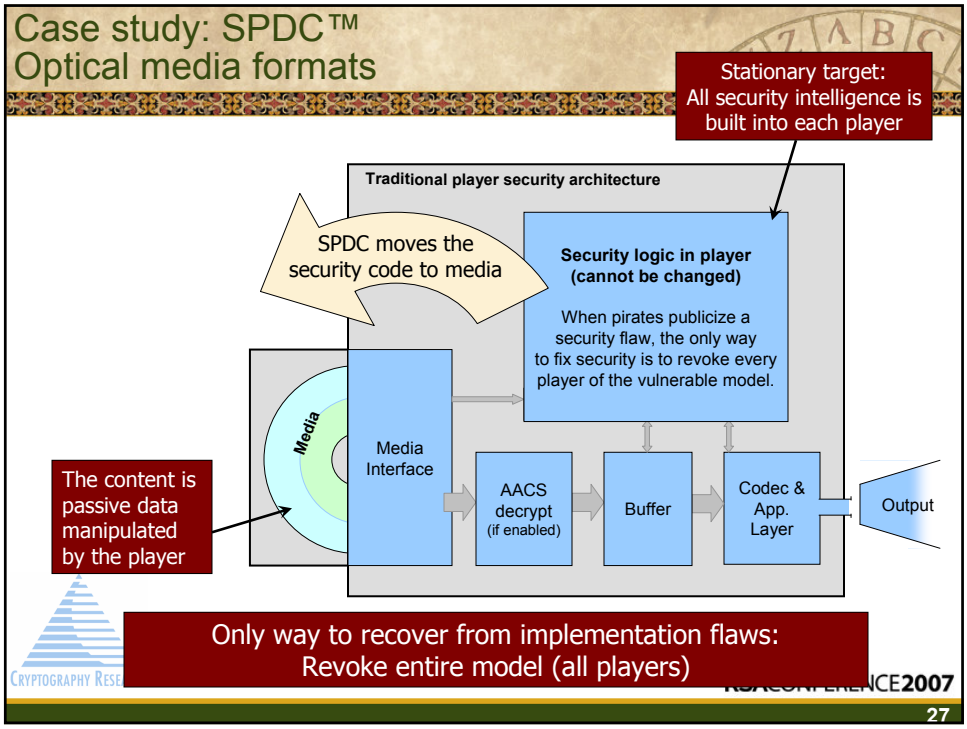
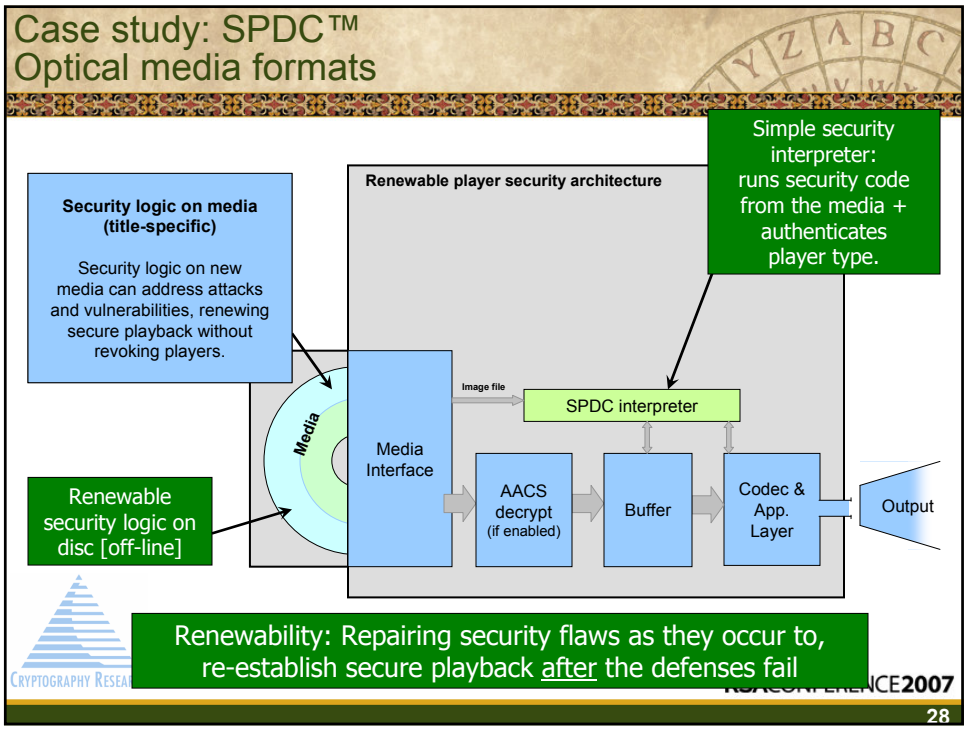
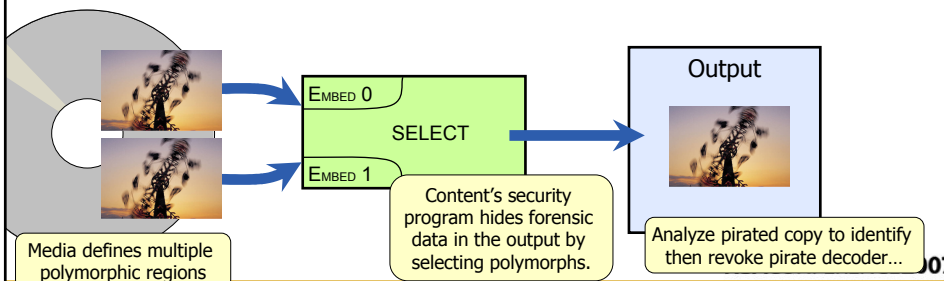




Case study: SPDC™ Optical media formats

Provided by reprogrammability

- Risk management requires knowledge and control.
- Forensic marking: Knowing what went wrong.
  - Player can allow content program to modify the output
    - Modifications may be unique to player, output devices, user, keys.
  - Addresses anonymity of piracy
    - No impact on privacy of users who don't redistribute copies.



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Complexity is going to keep increasing.

Harnessing it to improve security…

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Hardware architectures

- Fully-featured CPUs (such as those in smart cards) are fiendishly difficult to secure from tampering
  - Software bugs
  - External monitoring attacks
  - Invasive attacks
  - ...
- A tiny oversight… and the whole thing collapses
- A better general approach is required

  … especially as complexity increases…

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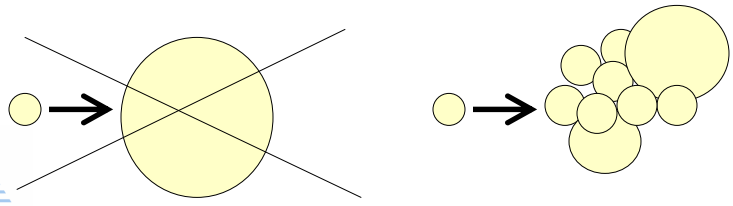
CPU designs, software…

- Every 18 months we can pack twice the functionality into the same die area
- What we shouldn't do:
  - Make our existing systems more complex
  - Spend all of the circuitry on the usual stuff (pipelining, L2 caches, …)



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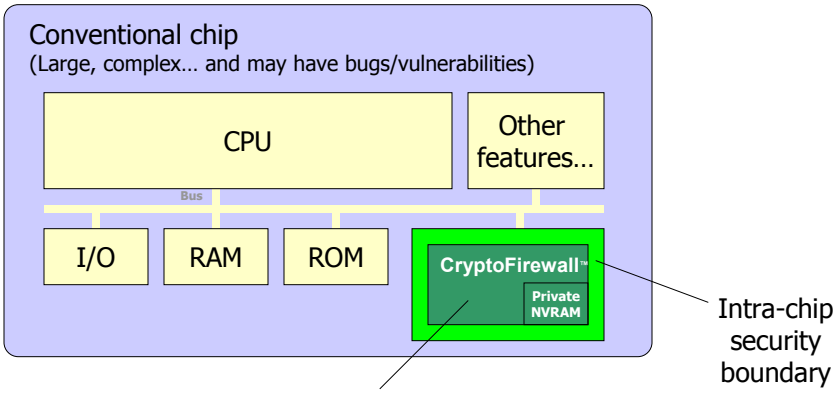
A Specific Example: Architecture for Tamper Resistance



Stand-alone high-security core
- Internal algorithms, keys, countermeasures…
- Assumes the rest of the chip is hostile

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Architecture Elements

- Well-defined intra-chip hardware trust boundary
  - Secure even if the CPU malicious
  - Special modes (test, personalization) protected w/ strong crypto
- Strict state management
  - Hardware state well defined, minimized
  - Cryptographic hash of state at every clock cycle of the computation
- One purpose: Address tamper resistance/security
  - Information leakage: SPA / DPA / Timing
  - Glitching: Error handling and response
  - Protocol attacks: Rigid command set in hardware; strong crypto
  - Invasive attacks / Reverse engineering: Entropic array
  - Emulation: Netlist design tools
  - All software assumed malicious (CPU only performs untrusted tasks)

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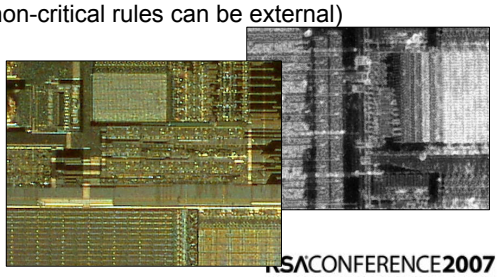
Special-purpose security peripherals

- Complements or replaces CPU-based enforcement mechanisms
  - Pay TV: Derivation of decryption keys
  - Mobile phones: Validation of subsidy lock
  - Payments: Security of balances & audit data
  - Printers: Authentication of consumables
  - PCs: Key management, policy enforcement, crypto

  (Support tasks and enforcement of non-critical rules can be external)



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(Background: Pay TV piracy)

- Canadians can't legally buy U.S. pay TV services
  - Willing to pay more than U.S. subscribers do (~$60/month)
  - Pirates have made a fortune breaking U.S. systems
    - Competition among pirates is fierce: attacks spread fast
    - International: Legal measures are of limited effectiveness
    - Attacks spill into the U.S. market
      - Direct losses (box subsidies) to operator
      - Indirect losses (lost revenue) content owners + operator
  - Similar dynamic elsewhere (e.g., UK expats in Germany)
- Result: Extreme pressure on the technical systems
  - Pirates willing to invest from past profits in new attacks
  - Early systems (VideoCipher II+) failed horribly

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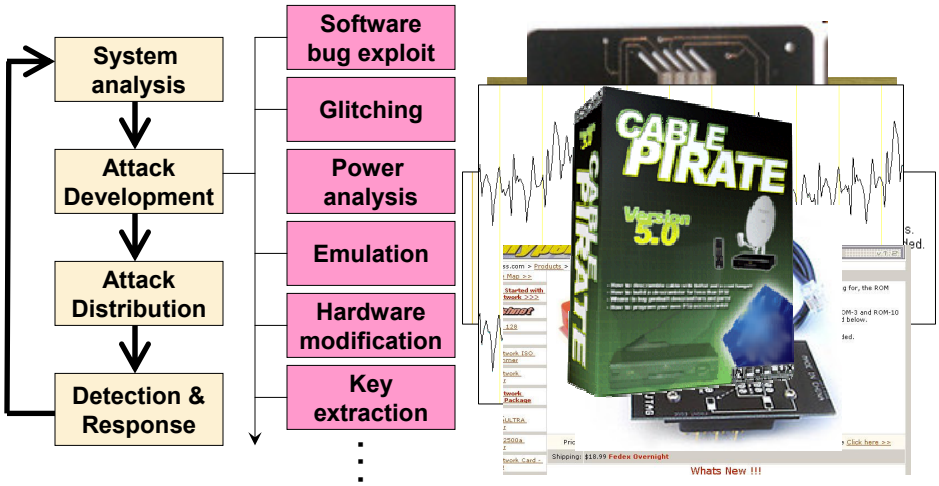
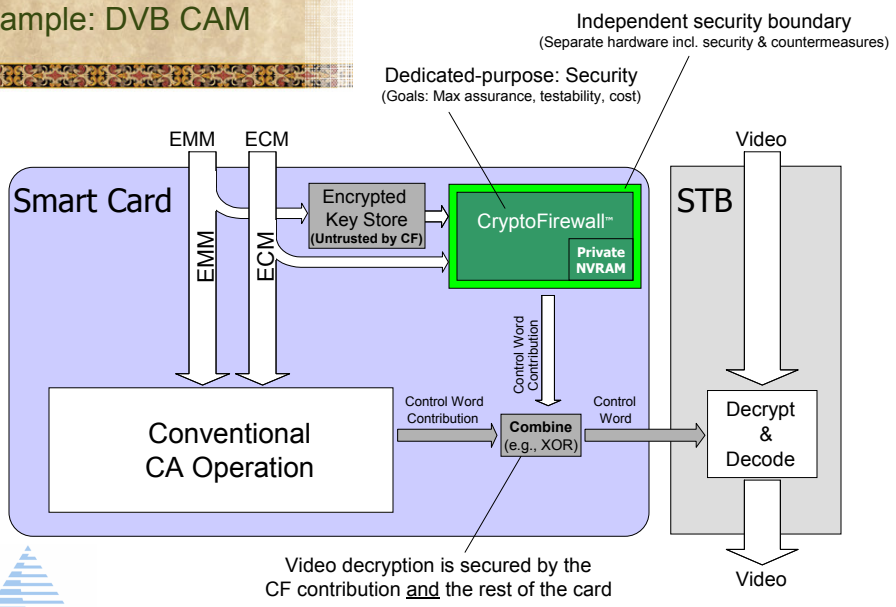
Case study: Pay TV piracy



- Natural selection favors the most devastating attacks

Example: DVB CAM



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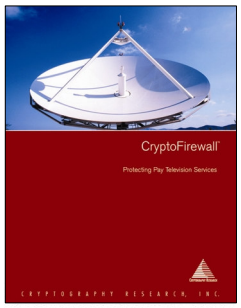
Combines multiple strategies

- Hardware updates
  - Deployment part of new security module or other chip
- Security updates (patching; keys + software)
  - Piggybacked with programming data
- Redundancy-based architecture
  - Independent security elements reinforce
- So far so good:
  - Security: No news = good news…



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More problems that could benefit from extra dedicated/redundant hardware

- Key management
  - Keys, passwords can be stored on separate processing engines
    - Encrypt & swap to main (untrusted) CPU as needed
- Secure input
  - Separate processing engines can handle keyboard, mouse…
- Secure display
  - Separate processing engines can control aspects of the delay (e.g., secure overlay)
- Secure storage
  - Disk encryption, file system security, etc. can also be handled separately

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Caveat: Inter-related failure modes

- Problem: Failure modes be inter-related
  - Assume independence: P(fail) = P(fail1) * P(fail2)
  - Linear collapse model: T(fail) = T(fail1) + T(fail2)
  - Simultaneous collapse model: T(fail) = max(T(fail1), T(fail2))
- Case study with cryptographic secret sharing
  - CA root key stored in physical tokens
    - Goal: Avoid single modes of failure
    - After key created, audit done to verify policies
  - Key shares were in the same type of hardware
    - With the same type of battery
  - The risk was identified, but it not fixed
    - The master key was nearly lost due to battery failures

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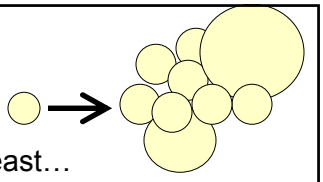
A more general approach: Micro CPUs



- A better way to invest the Moore's Law feast…
  - Add independent isolated execution areas
    - Computing areas are a resource for applications & OSes
    - Taking the "cell" microprocessor philosophy to the next level
  - Completely independent hardware
    - Separate processing capabilities
    - Separate internal RAM (even a few KB can be very useful)
    - Separate key management
    - Fully independent operation (e.g., no timing dependencies)
  - Communicates with the main CPU
    - Main CPU can perform support tasks (e.g., paging)
    - Software running on each micro-CPU should assume that the main CPU and its siblings are malicious

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Example: Network security

- The main CPU should not be responsible for network security
  - Too complex – numerous applications, configuration settings, drivers… A single bad ring 0 driver and it all falls down
  - … But users won't lug physical firewalls everywhere
- Solution:
  - Add a separate processing engine for firewall/VPN functionality
  - Sits between the main CPU and the network ports
    - The main CPU can't receive or transmit unauthorized data

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Network security

- Look forward 10 years:
  - If Moore's Law continues, we'll have 1000 times as much computing hardware in 15 years…
  - We could have dozens of independent processing engines for network security – 1% would be enough for security
    - Each could handle different network security tasks (e.g., firewalling, decryption, etc.)
  - Example: Run many VPNs all at once
    - Data would pass from one to the next…
    - Use products from multiple security vendors…
    - **Add more code & security improves!**

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Conclusion;

- Future of security depends on our ability to cope with complexity
  - Patching strategies are grisly, but better than total collapse
  - But this doesn't lead to trustworthy systems…
- Hope in the gloom:
  - Use complexity to add depth and resiliency
  - Layers can fail but the system survives

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Questions?…

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