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Secure Computer Systems

DARPA Cyber Colloquium
Arlington, VA

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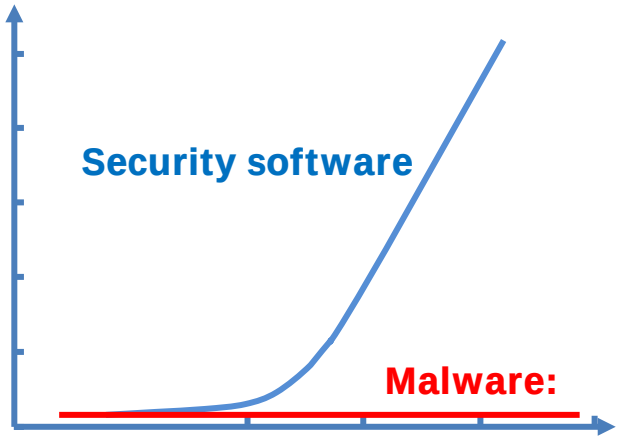
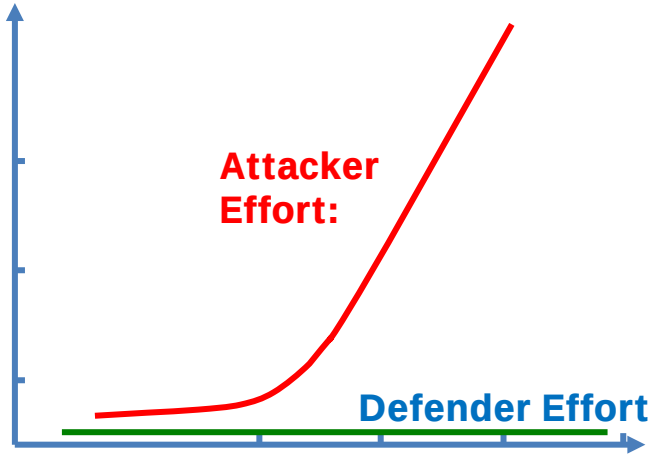
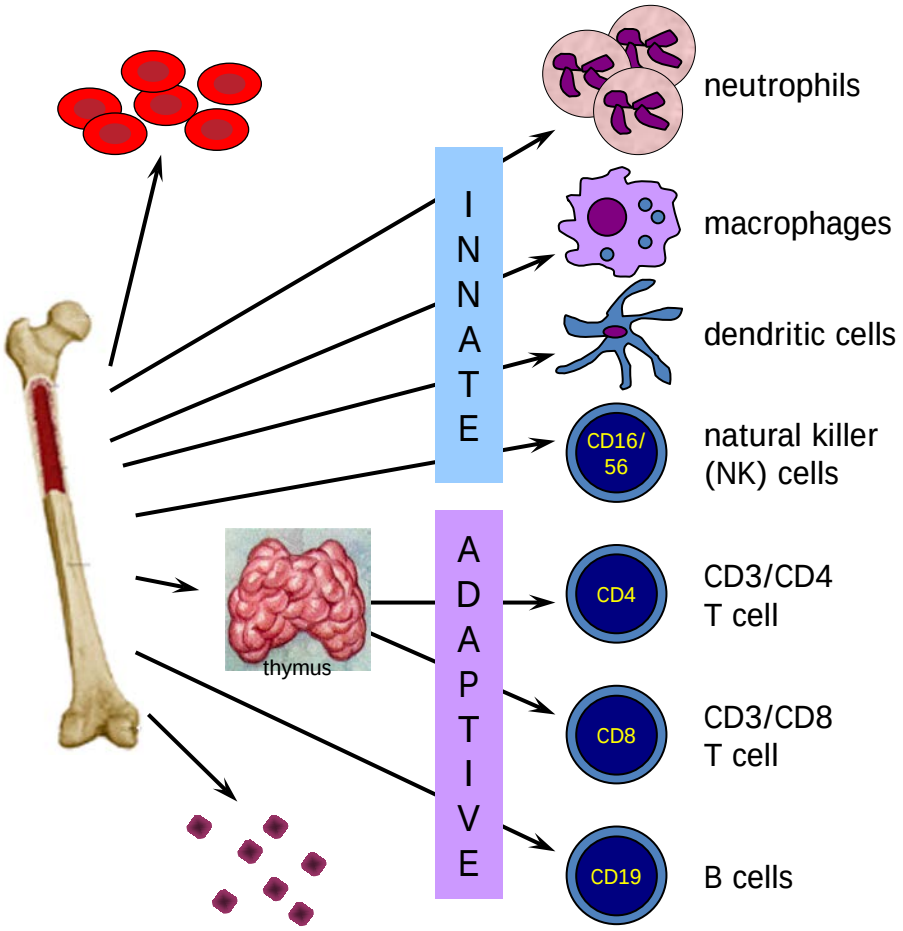
Today's Practice P4: Perimeter Protection, Patch & Pray isn't Convergent with The Threat





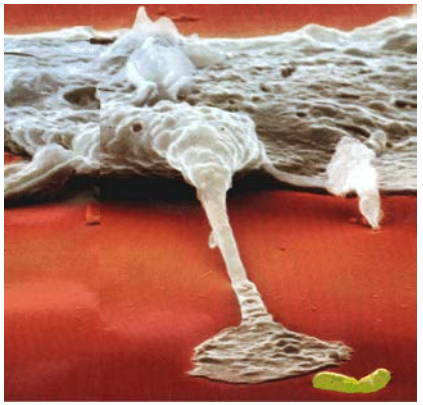
It's about learning from biology and societies how to design secure, adaptive and resilient systems.

Humans Have Two Immune Systems: Innate and Adaptive



Fast, but inflexible, covers fixed sets of pathogen that are always present. Supports the adaptive immune system.

Slower, learns to recognize new sets of pathogens, distinguishes self from non-self, retains memory to guard against future attacks.



At least 20 – 30% of the body's resources are involved in constant surveillance and containment.

Three Big Problems

1. Systems can be easily penetrated

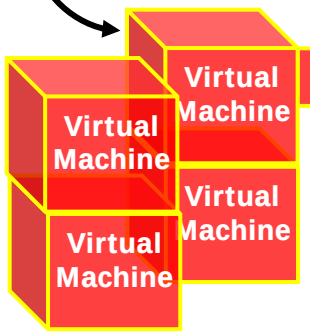
2. Once penetrated, cleanup is prohibitively expensive, time-consuming, and unpredictable

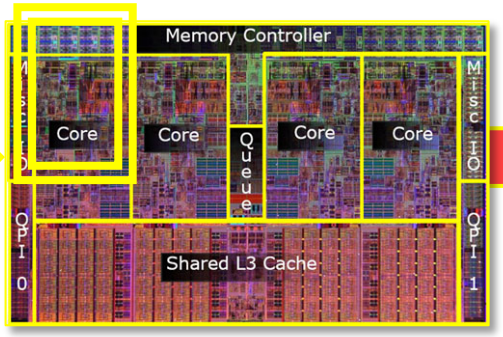
3. If one system can be penetrated, then nearly all of them can

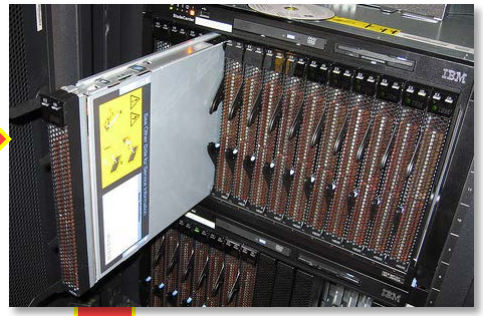
Mission-oriented Resilient Clouds

Using the power of a computational community to protect massively shared computational infrastructure

Your Software Lives Here

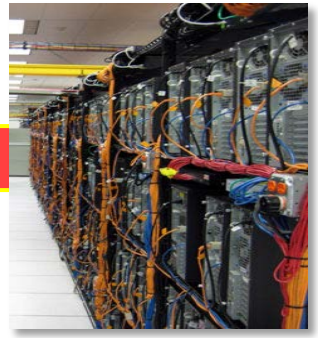






Your Software Lives On A Network with 100K Other Virtual Machines and No Firewalls

Modular Data Center Containers



Blade Server Racks

Blade Server Network

Resilient Clouds: A Community that uses the Network as a *Defensive Amplifier*

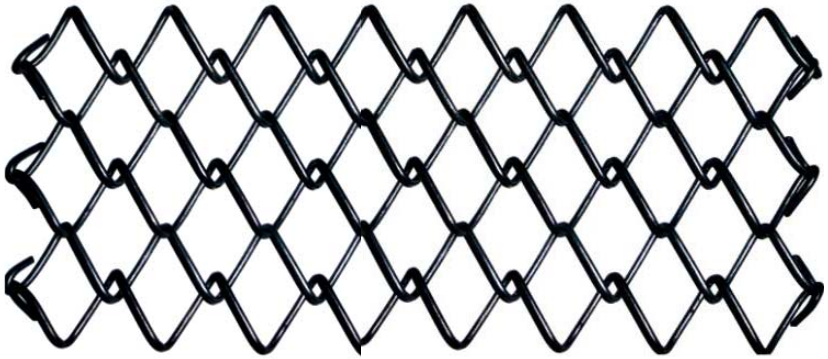
TODAY

Acting as individuals makes the enterprise weaker than the sum of its parts

- "Box" Oriented
- Vulnerable Components
- Static Sitting Duck
- Shared Vulnerabilities
- Implicit Trust is Amplifier

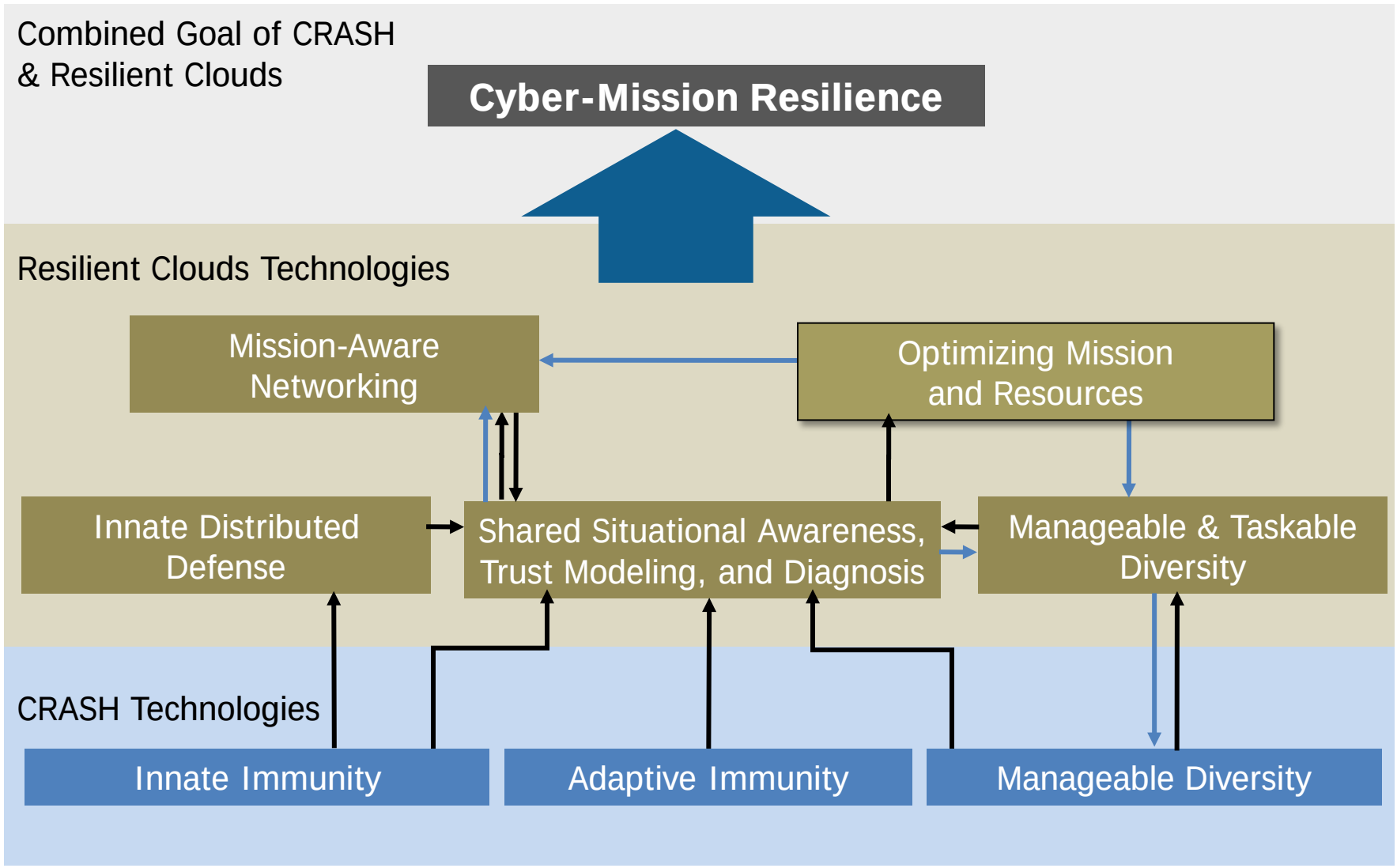
RESILIENT CLOUDS (CRASH++)

Acting as a community makes the enterprise stronger than the sum of its parts



- Mission Optimized
- CRASH-worthy components
- Moving Target
- Resilience through Diversity
- Collective Diagnosis is Damper

Resilient Clouds Technology Areas



For more info see: http://tinyurl.com/68w9wpf

➔ Information flow
➔ Control flow

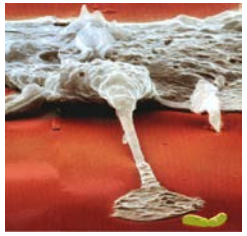
Secure Computer Systems

CRASH

Clean-slate design of **R**esilient, **A**daptive, **S**ecure **H**osts

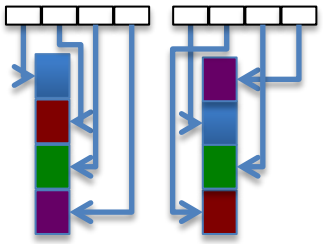
CRASH Applies Biological Principles to Computation

Innate Immunity:
New hardware & operating system architectures
that eliminate all common technical vulnerabilities



Adaptive Immunity
Middleware that:

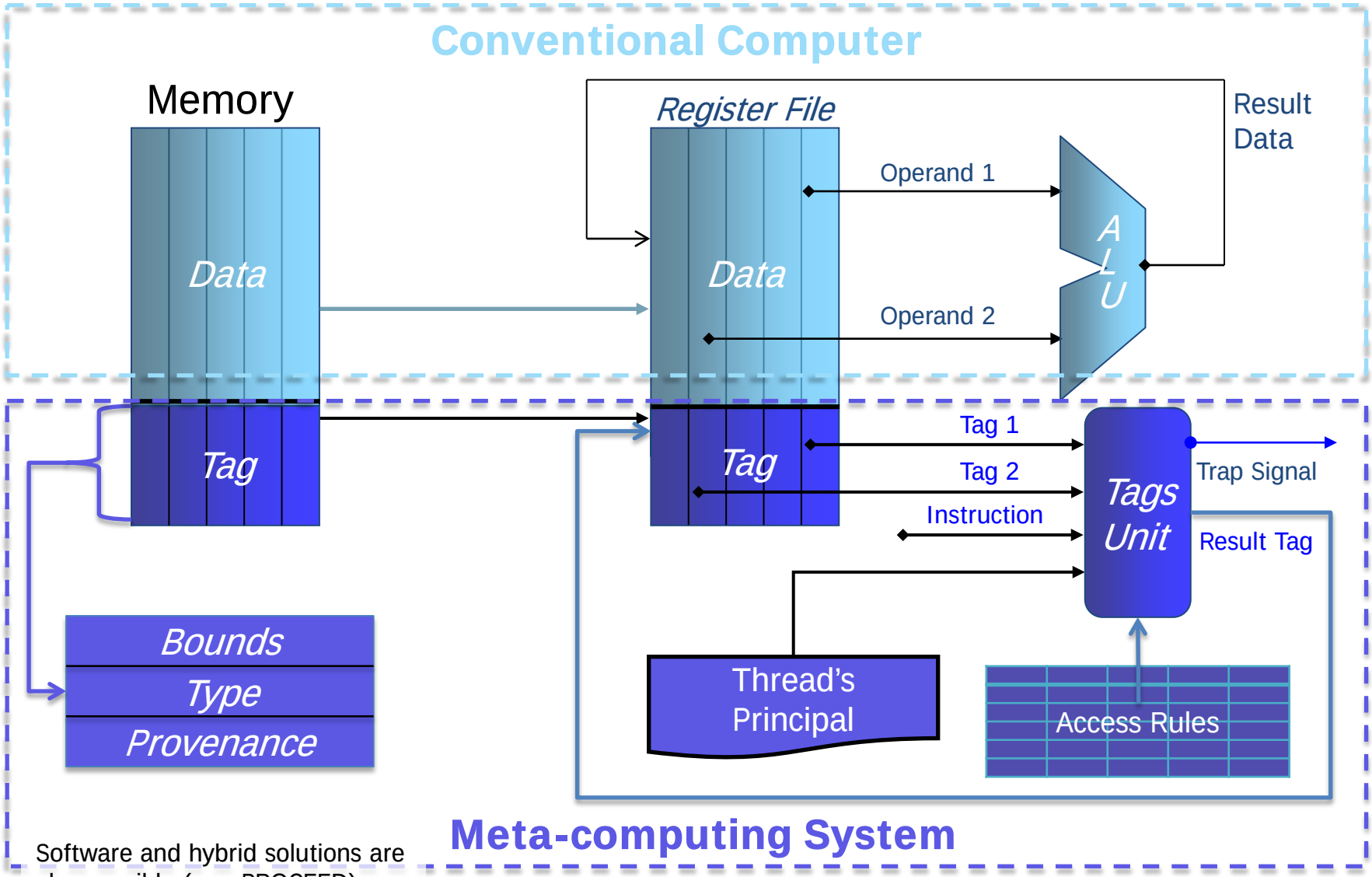
- Diagnoses root causes of vulnerabilities and builds situational assessment
- Quickly adapts & reconfigures
- Learns from previous attacks and gets better at self-protection



Population Diversity
Computational techniques that:

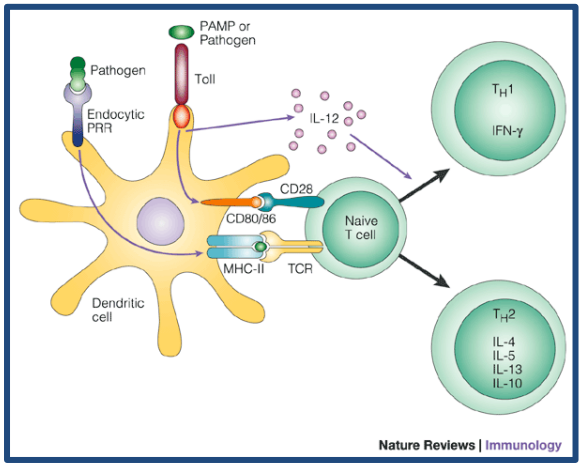
- Increase entropy in time and space
- Make every system unique
- Raise work factor of attacker for each system

Innate Immunity:
An Example Hardware Solution

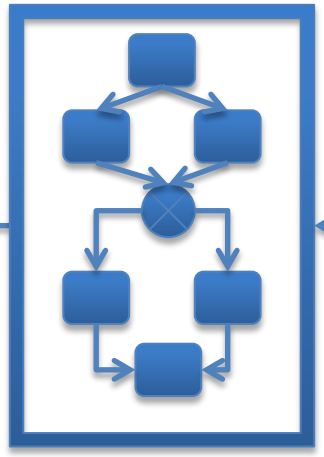


Software and hybrid solutions are also possible (e.g. PROCEED)

Adaptive Immunity

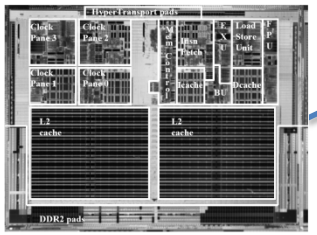


System Model



4. System model is adapted with new attack-specific detector

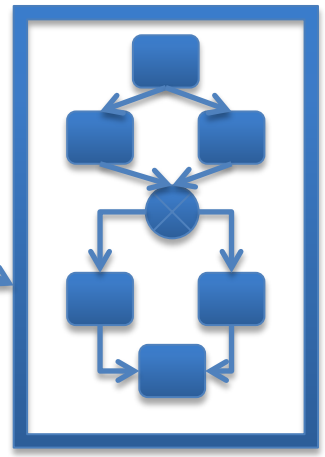
3. System model is used to perform diagnosis (e.g. localization and characterization)



1. Hardware analog of innate immune system detects anomaly

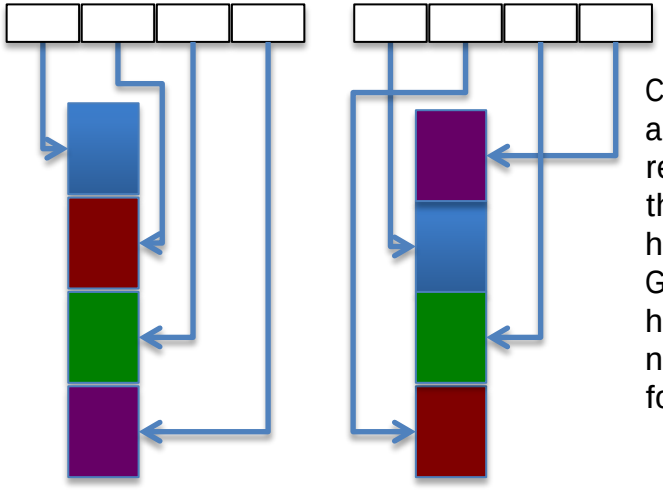
2. Software system analog of adaptive immune system is signaled

5. Adaptive immune system synthesizes plan to get around problem and patch to remove specific vulnerability



Dynamic Diversity Makes a Single Host Different from Moment to Moment

Address Space Randomization



Code and/or data blocks are periodically repositioned in memory so that attacker has to work harder to find a target. Garbage-collected memory has the property inherently, new methods may optimize for increased entropy.

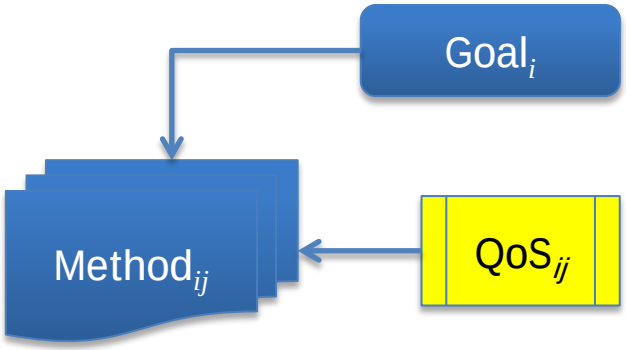
Instruction Set Randomization

Disk	Memory	ICache
Instruction-1	Encrypted-1	Instruction-1
Instruction-2	Encrypted-2	Instruction-2
Instruction-3	Encrypted-3	Instruction-3
Instruction-4	Encrypted-4	Instruction-4
Instruction-5	Injected-1	Encrypted-1
Instruction-6	Injected-2	Encrypted-1
	Encrypted-5	Instruction-5
	Encrypted-6	Instruction-6

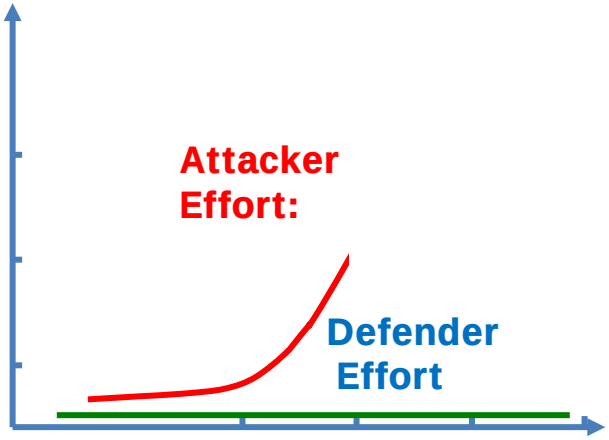
Code is encrypted as it enters memory and Decrypted as it enters the instruction cache (or translation buffer). Injected code in native instruction set is then encrypted and not executable. Encryption key can be varied by process and time.

Functional Redundancy & Decision Theoretic Dispatch

There are multiple methods for achieving each goal ("n-version programming"). Each distinct method has different qualities of service. Method selection is driven both by preferences over QoS and by need for unpredictability.

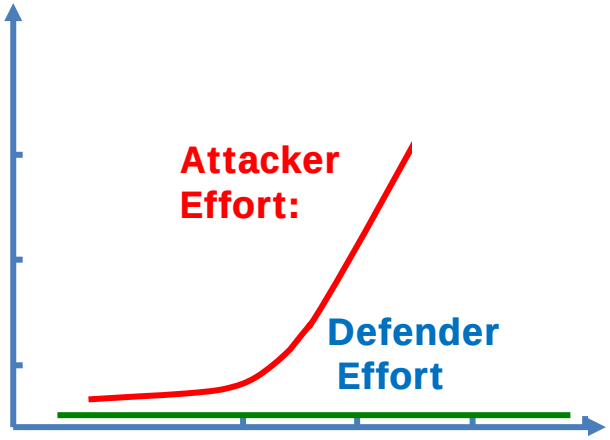


Turn the Tables: Make The Attacker Do The Work



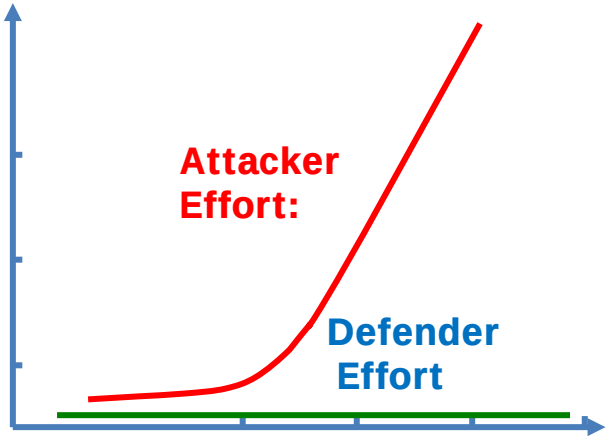
Innate Immunity

- Novel Hardware
- Separation OS's
- Information Flow
- Formal Methods



Adaptive Immunity

- Policy Weaving
- Automatic Patching
- Selective Playback
- Symbiotes

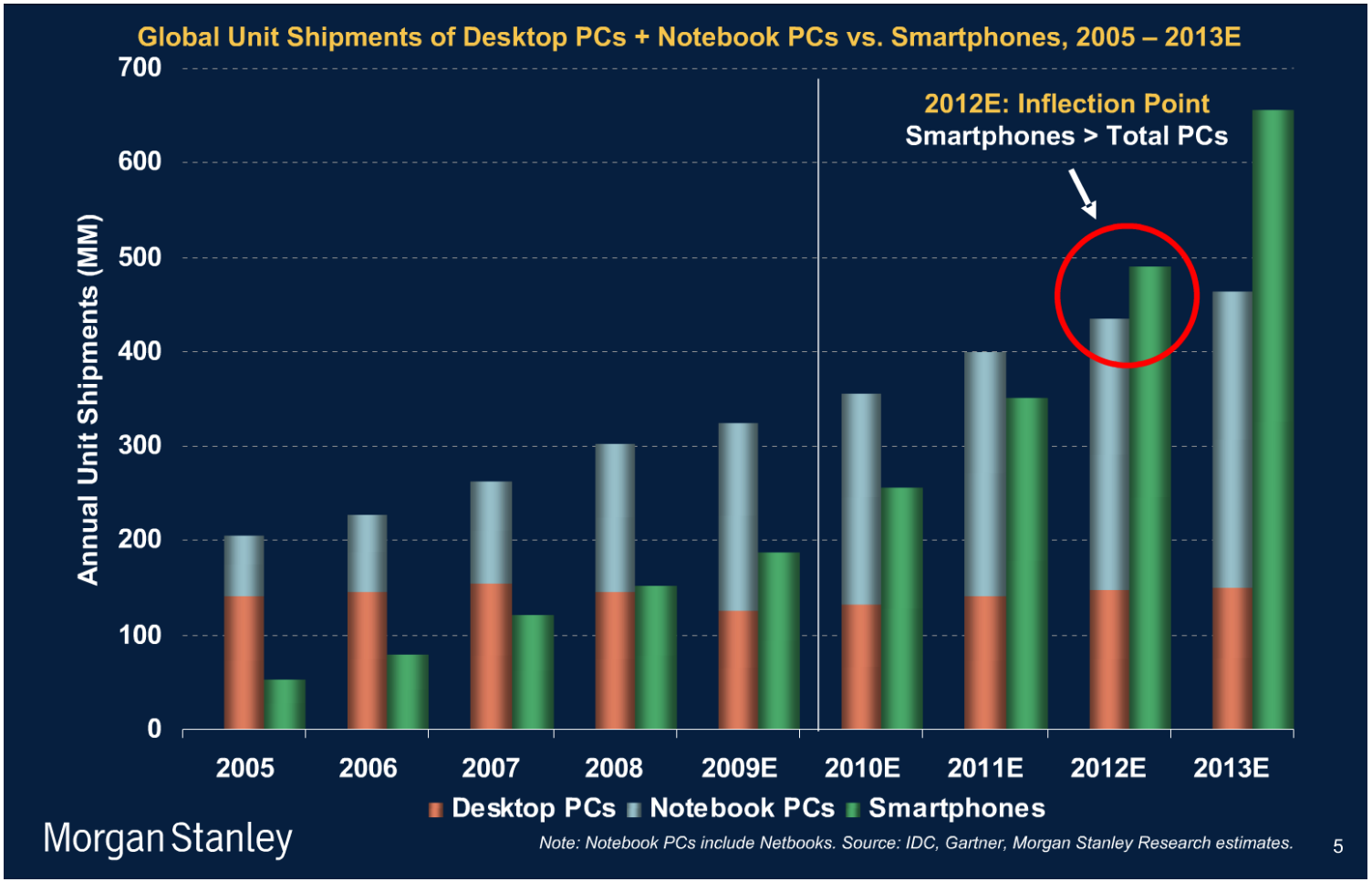


Dynamic Diversity

- Compiler generated Diversity
- Algorithmic Diversity
- Instruction Set Randomization

An opportunity...
Smartphone > PC shipments within 2 years

Implies very rapid, land grab evolution of internet access



Our goal...

...is to get CRASH & MRC technologies into ***your*** machines.

- If you make computers, operating systems, middleware...
- If you use these and can influence the people who make them
- If you think there's a great startup opportunity

- Then we want to talk with you about how to transition our technologies into the real world.
- Contact us at CrashInquiries@darpa.mil