An Attacker Looks At Docker

Approaching Multi-Container Applications

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My Background

- Ph.D. Computer Science – Mississippi State University
- Academia
  - NSA CAE – Research, Education, Cyber Operations – MSU
  - Industrial Control Systems – Human-Machine Interfaces
  - Research & Education - Reverse Engineering & Malware Attribution
- Private
  - Director of Cyber Operations – HORNE Cyber
  - Computer Network Operations – CNO/CNE/CAN
  - Penetration testing, red teaming, application security
  - Operational security of testing engagements

Intentions

- …to make a strong point about the relationship between an attacker's skill set (and its development over time) vs. developer trends.
  - How to leverage what you already know
  - How to look at learning new technologies moving forward
- …to provide a hacker experienced in exploitation and post-exploitation of **networks of systems** an exposure to applications composed of **multiple containers**
  - Exploring application internals
- …with concrete Docker examples that leverage common practices (those in tutorials and intuitive/naïve usage)
- Inspiration concept/approach –
  HD Moore/Valsmith DEF CON 15 *Tactical Exploitation*
- Target audience – Attackers – Pentest, Red Team, CNE, CNO

Prior Art in Docker

- David Mortman, *Docker, Docker, Give Me the News, I Got a Bad Case of Securing you*, DEF CON 23
  - Underlying implementation and architecture
- Aaron Grattafiori, *Understanding and Hardening Linux Containers,* DEF CON 23
  - Kernel capabilities and advice for low-level security
- Docker documentation
  - Current state: a lack of “default on”
- Anthony Bettini, *Vulnerability Exploitation in Docker Containers*, Black Hat Europe 2015
  - Platform vulnerabilities
- Michael Cherney and Sagie Dulce, *Well, That Escalated Quickly! How Abusing Docker API Led to Remote Code Execution, Same Origin Bypass and Persistence in The Hypervisor via Shadow Containers*, Black Hat USA 2017
  - Targeting developers

Containerization & Docker

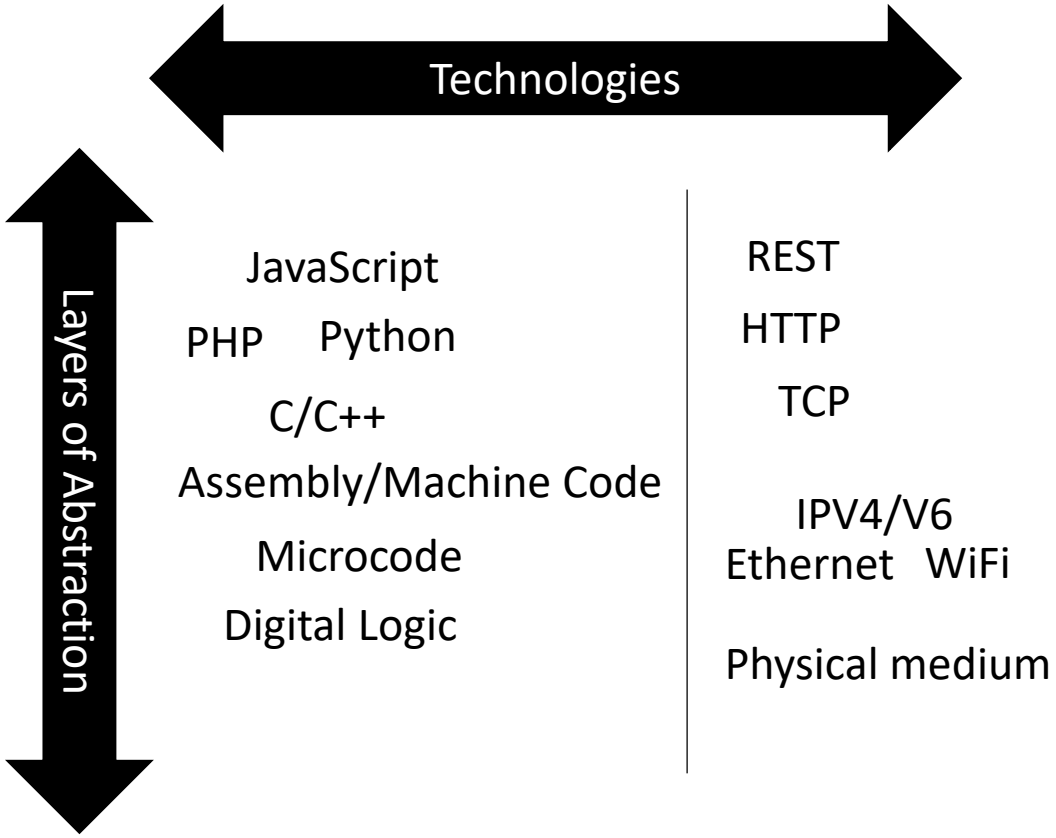
- Operating-system-level virtualization
- As an attacker, you're almost certainly already aware of hardware/platform virtualization
- "Lighter" virtualization
  - Shared kernel
  - Multiple user-space
    - Filesystems
    - Libraries
    - Networks
- Docker – Images, Containers, high level composition into applications
  - Development
  - Deployment

Vulnerabilities & Layers of Abstraction

- Vulnerability Life Cycle
  - Doesn't begin with discovery
  - Begins with a *mistake*
- *Everything* is an abstraction on top of physical properties of silicon
- Vulnerabilities are often a result of not understanding the layer(s) underneath you. Examples:
  - Web application vulnerabilities
  - Memory corruption and memory models
- …or the "magic box" itself is broken

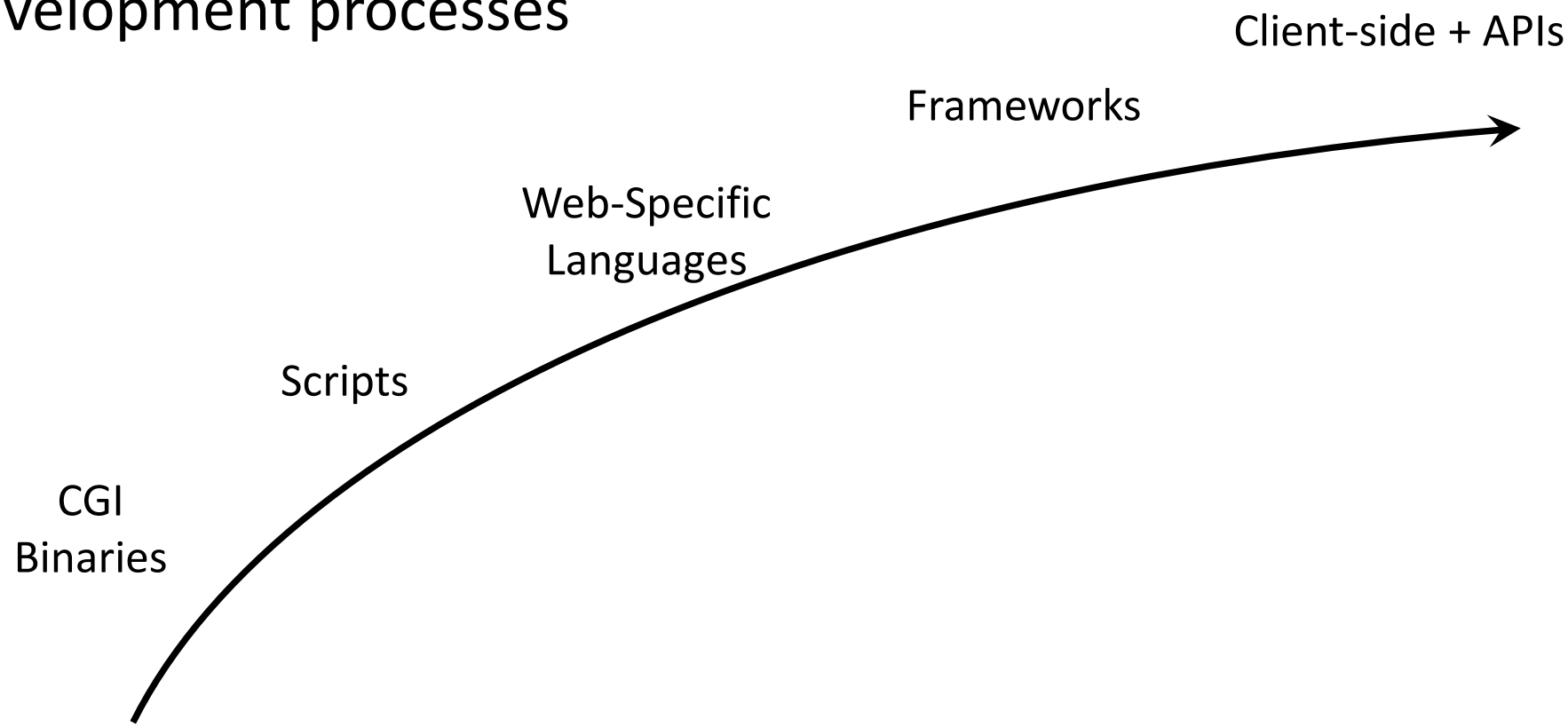
How Does a Hacker Keep Up?

- For your target, you don't get to dictate the attack surface and underlying environment:
  - Language
  - Protocols
  - Platforms & Frameworks
- Two dimensions of gap in skills
  - Layers of abstraction
  - Specifics of technology (above)

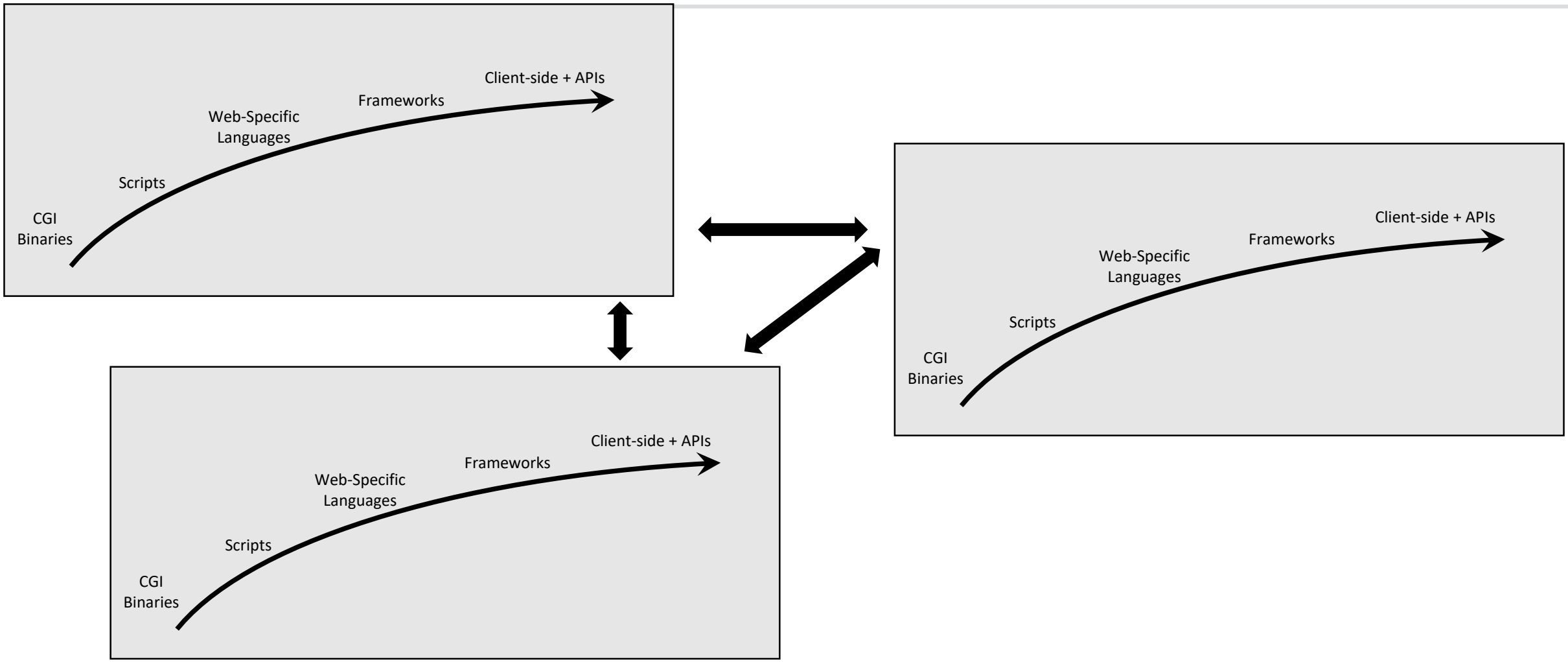


Movement and Abstraction in Development

- From lowest to highest-level abstraction in web application development processes



Next-Level Abstraction - Containerization



Mindset after you learn “Hello World”…

What can I build with these language constructs?

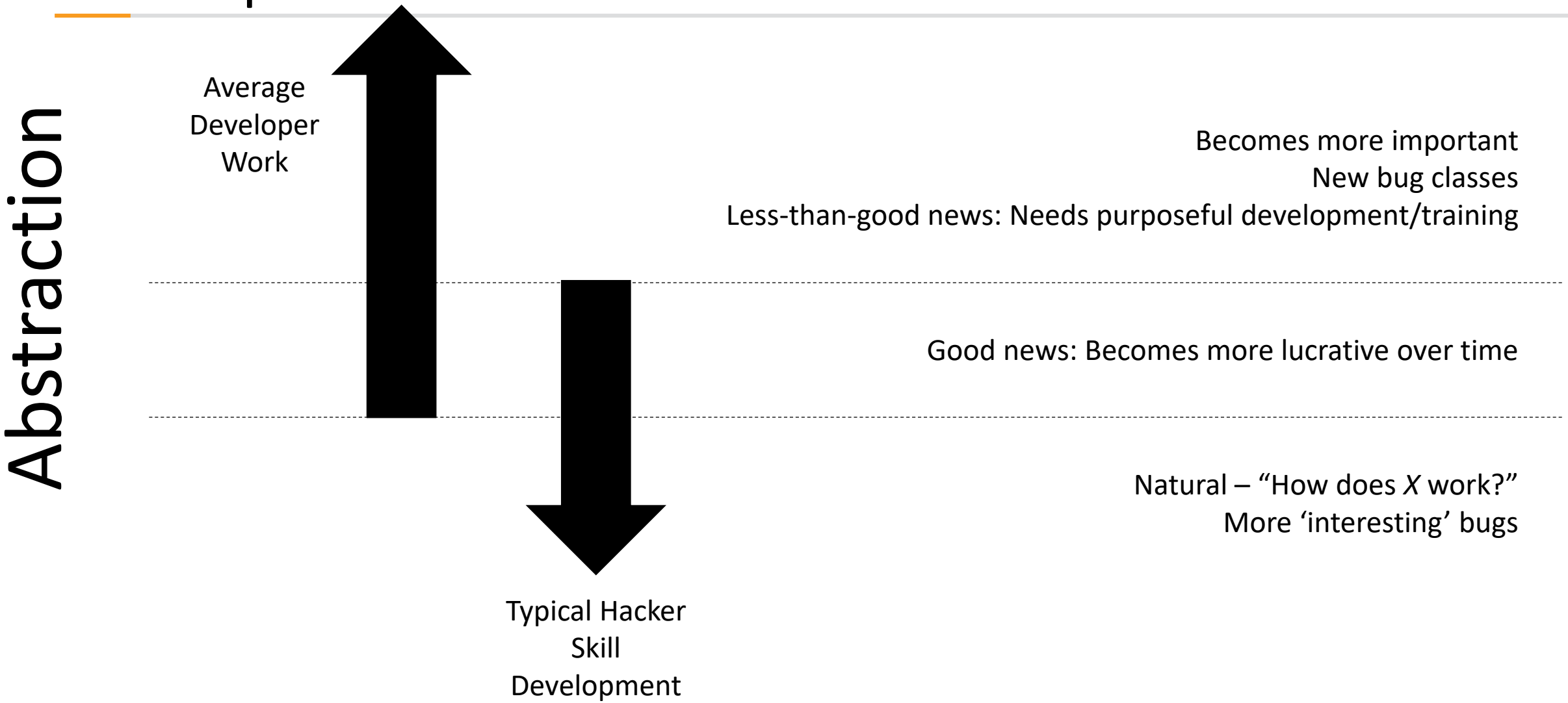
vs

How does “Hello World” work?

Movement and Abstraction for Hackers

- As an individual or small team you'll approach and become familiar with an increasingly large number of software projects
  - …with more developers than an average CNE/CNA team
- Abstraction allows for more efficient development
  - Higher level technologies
  - Layers that "take care" of things for you
  - Lower-prerequisites for developers
  - Building block containers of mixed-technology software combined to make an application VS writing it in a monolithic style at a lower level
- What does this mean?

Movement and Abstraction for Developers vs. Hackers



Application to Attacking Application Internals

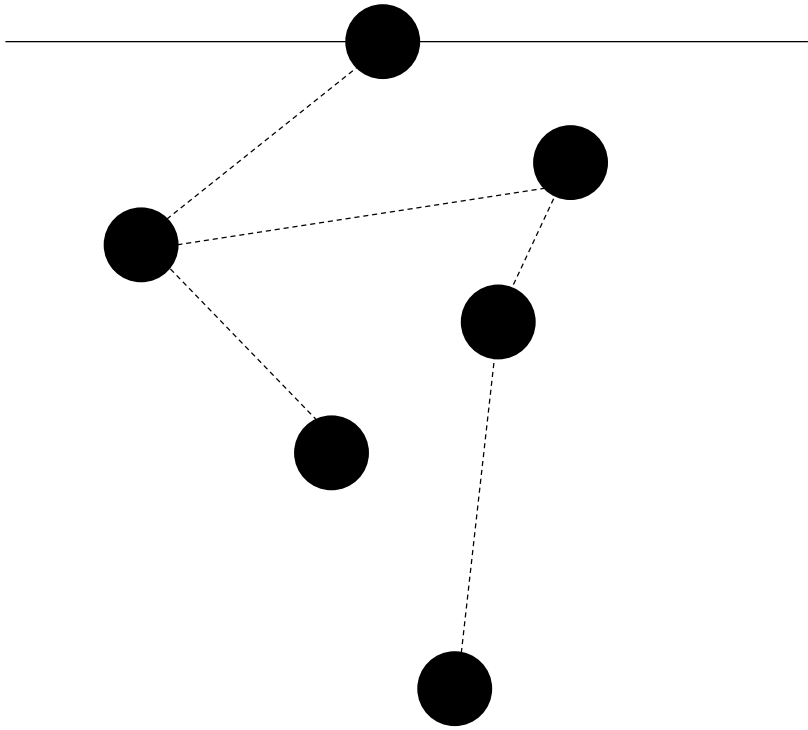
- Control over execution – opportunity to turn code against itself
  - Ex. – Malware analysis, ROP, Web API's, CSRF
- Skillset – Penetration tester vs. Application security expert
  - External vs. internal application attack surface
- Penetration tests less-often involve new "creative" control over execution in monolithic binary applications
- Pentester training gap
  - Basic understanding of memory corruption – introductory and conceptual
  - Targeted on understanding tool use
  - Not sufficient to target modern applications/environments
  - vs. motivated, funded, organized attackers that have developed talent

A Useful Shift for Attackers

- Containerization allows for the design of applications that are composed of many independent single-purpose services.
- Democratizing post-exploitation manipulation and instrumentation
  - Observing and instrumenting program flow/data
    - Monolithic - Language/platform-specific knowledge/tools
    - Multi-container – Leveraging system/network-level post-exploitation and sniffing tools

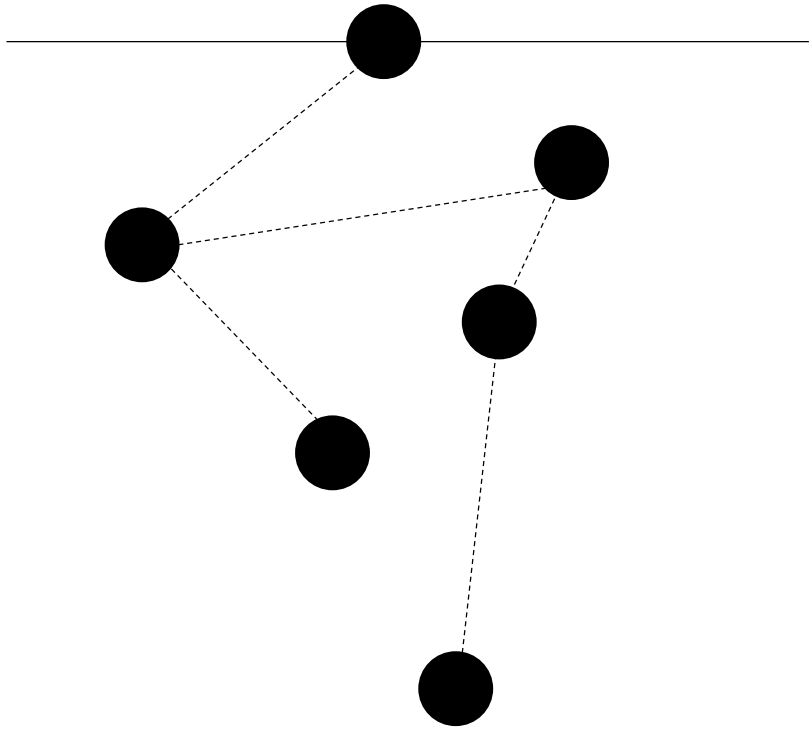
Taking Advantage of Abstraction

- Organization-wide attack
  - Progression/change of compromising connected systems
- Multi-container applications have their own networks (possibly shared with other applications)
  - The test of an application becomes a microcosm of an organization-wide test
  - The same would happen with traditional virtualization, but it'll be more common with containers: light and easy



Taking Advantage of Abstraction

- Exploitation of multi-container attack surface will begin with specific software in one container
- Post-initial-exploitation, access to an internal network of the *rest* of the containers, services, data, and protocols.
- Leveraged by the usual tools you already have familiarity with as a penetration tester.
- Analogous to hooking/examination/instrumentation of monolithic application



Docker as a Target Application Platform

- Monolithic container applications
  - Ease of deployment
- Multi-container applications
- Docker container networks
  - Default shared between containers
  - Configurations define which ports are “published” or shared to the outside world through the host.
  - Inside the network, containers may freely scan/connect/probe

Basic Exploration of Docker Container Applications

Quick connectivity check from one container to another, without the target container being explicitly configured to allow the connection

Implications

- Access through conventional exploits place attackers into an internal network with opportunity to pivot
- Familiar territory for attackers with system/network-level attack experience
- Limits: “Living off the land” is more challenging due to minimalistic images
- Learn to identify – You may not realize you’re inside of a Docker container network until you’ve exploited the external attack surface of it.

Exploitation and Post-Exploitation of a Multi-Container Application

Externally, with Kali & Metasploit:

Leveraging an older Joomla in the Docker Hub repositories

Pivoting to manipulation of multi-container voting application (from Docker tutorials)

Take-Aways

- Existing offense skills become useful at a lower relative position of abstraction relative to newer applications.
  - Developers are moving up, the new “low level” moves up
- Important to update yourself. Work “up” the stack as well.
  - New development practices such as multi-container application composition
  - Chase a trendy technology and look at the attack surface
- Containerization represents an opportunity for attackers to leverage existing network/system-level knowledge to explore the internals of applications that are composed of multiple containers.
  - Your existing skills are moving “down” the stack relative to where applications are being developed, and you can take advantage of it.

Discussion & Contact Information

Whitepaper available in conference materials, with more references and resources.

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