real-time passive volatile memory inspection inside virtual machines

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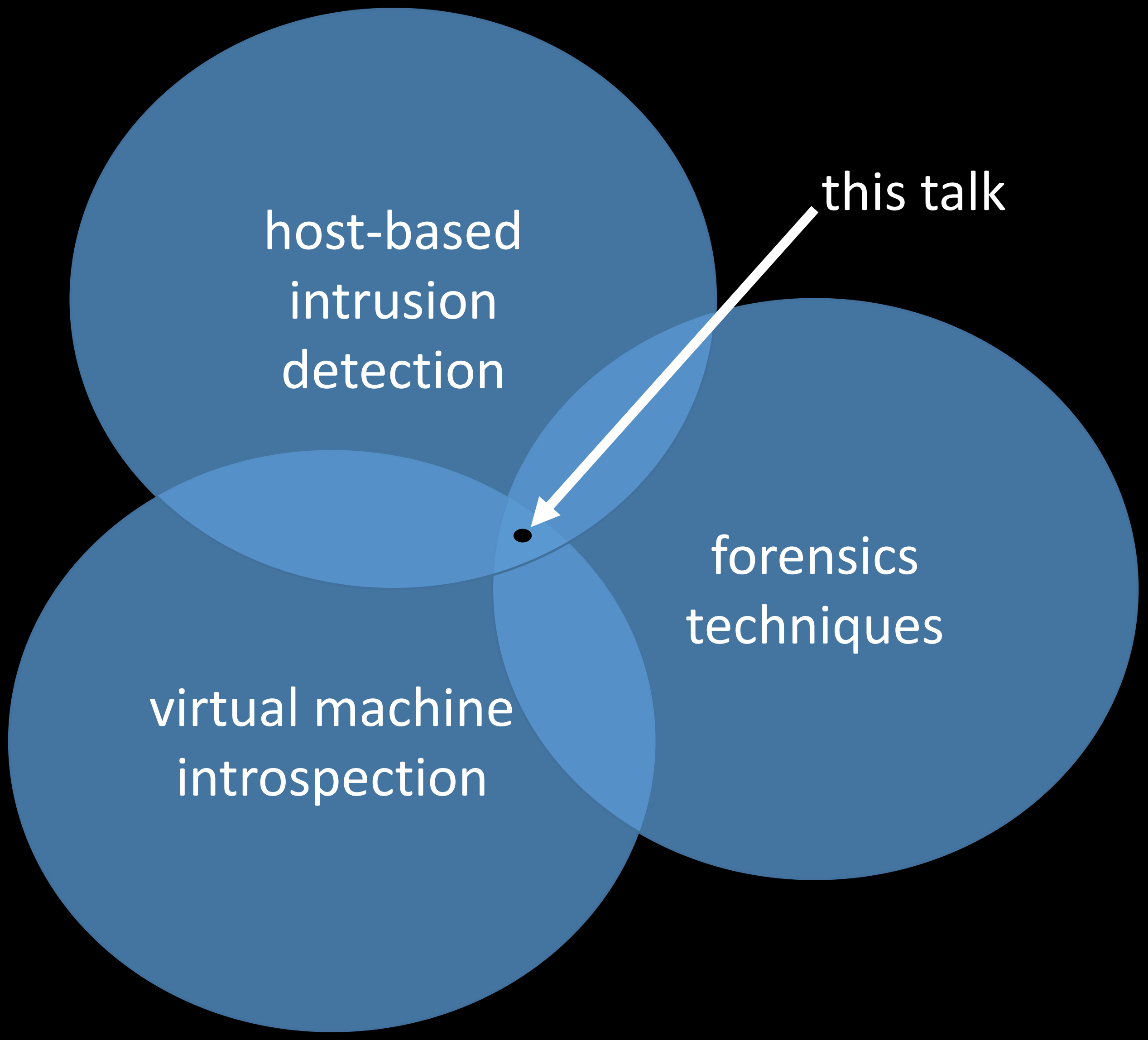
who am I?

- John Williams
  - security consultant @ Ernst & Young (emerging technologies)
  - embedded SW engineer (safety critical systems)
  - computer engineering @ University of Washington

- research interests
  - defensive security technologies
  - embedded security
  - trusted computing

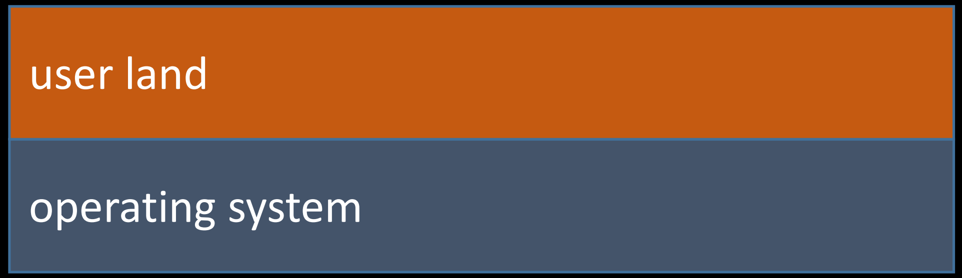
talk roadmap

- motivations for research
- introduce memminer
- gaps in run-time protection
- steps to building a solution to address problem
- live demo of memminer



motivations for research

- looking at security of virtualized hosts
  - they’re everywhere: cloud, mobile, desktop, etc.
  - opportunity for different methods of protection
- memory-based rootkits on the rise
  - may never touch a disk
  - kernel of host cannot really be trusted



- trusting the data used for analysis
  - providing greater assurance
  - trusted hw is around the corner

what is memminer?

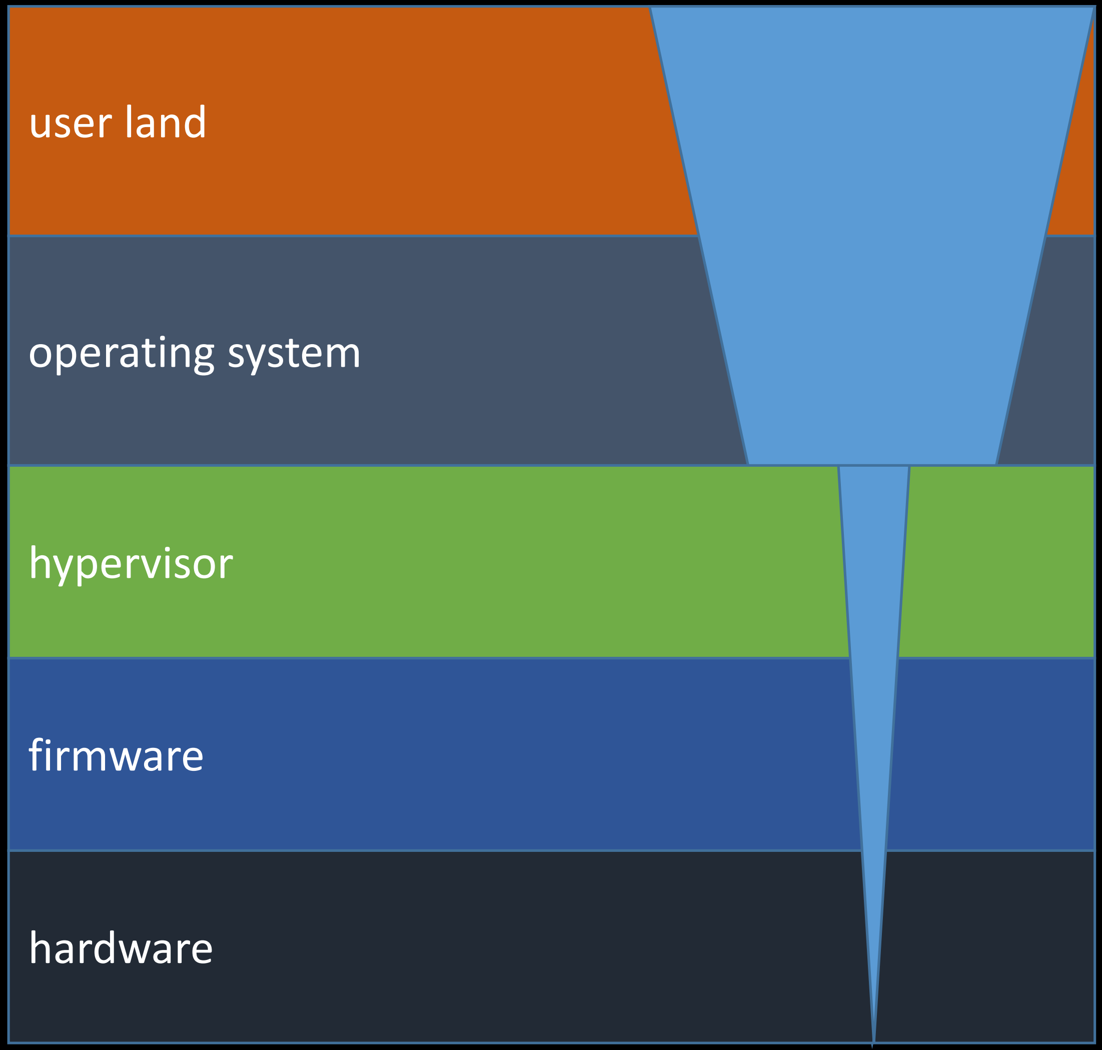
- agentless security indicator collection for virtual machines
  - monitors indicators that pose red flags in a system
  - provides standard output
  - logging of data over time for analysis
- somewhat hypervisor and guest system agnostic
- provides basis for executing response behaviors at VM level
- differs from existing solutions because it’s agentless

how does memminer work?

- memminer sits at hypervisor level and peeks into host using libvmi
- leverages rekall to track specific indicators that may be hidden from host (requires minimal knowledge of host)
- monitors indicators that may pose red flags in a system
  - (e.g. ssdt, apihooks, etc.)
- converts data to standard format (cybox)
- logs data over time into mongodb for independent tracking and longitudinal analysis

system attack surfaces

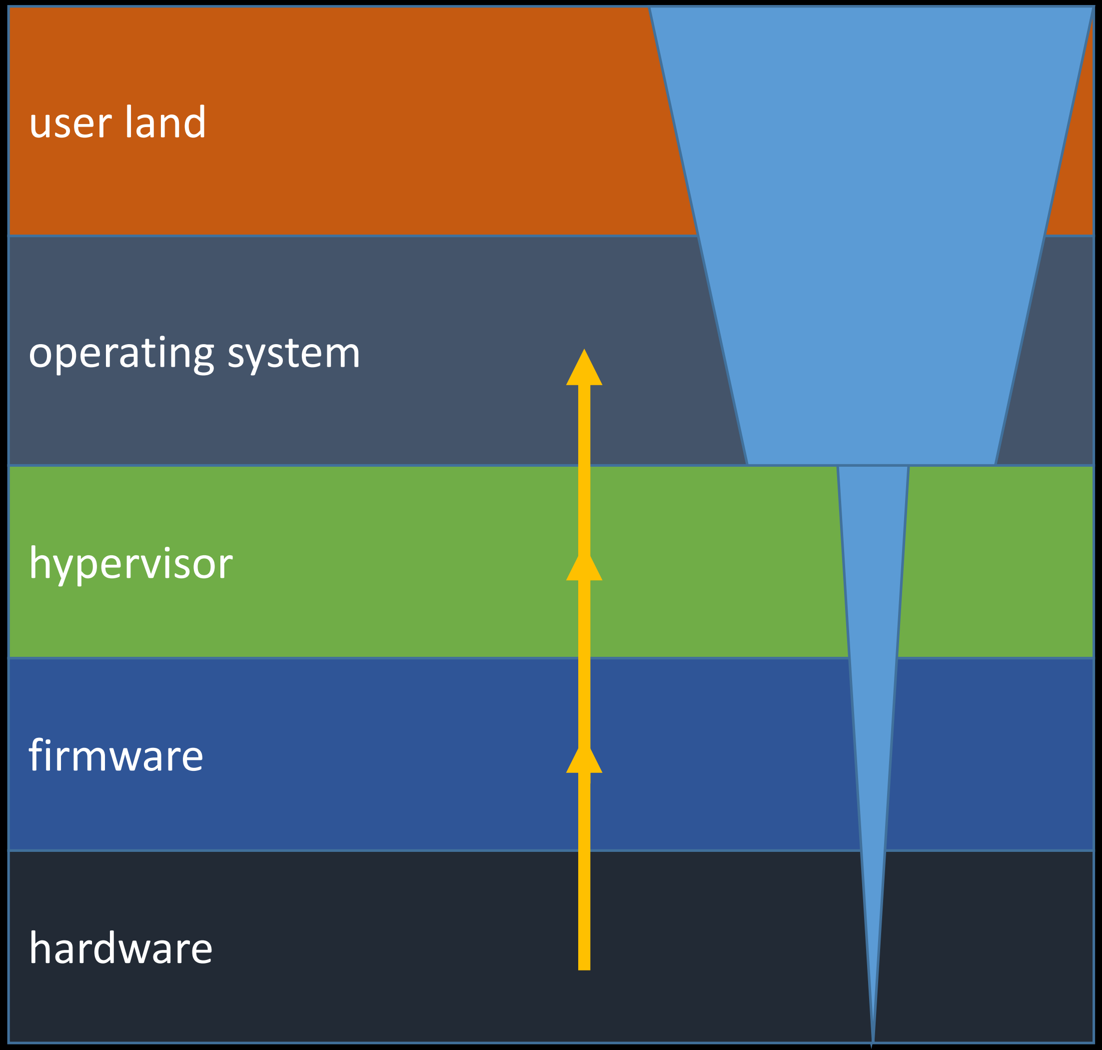
- modern operating systems have very high attack surface
- hypervisors have much smaller attack surface in comparison
  - much more trustworthy but neither can be fully trusted (i.e. hardened)



boot protections

- trusted boot for boot protections
  - Mechanisms for securing and authenticating the boot process

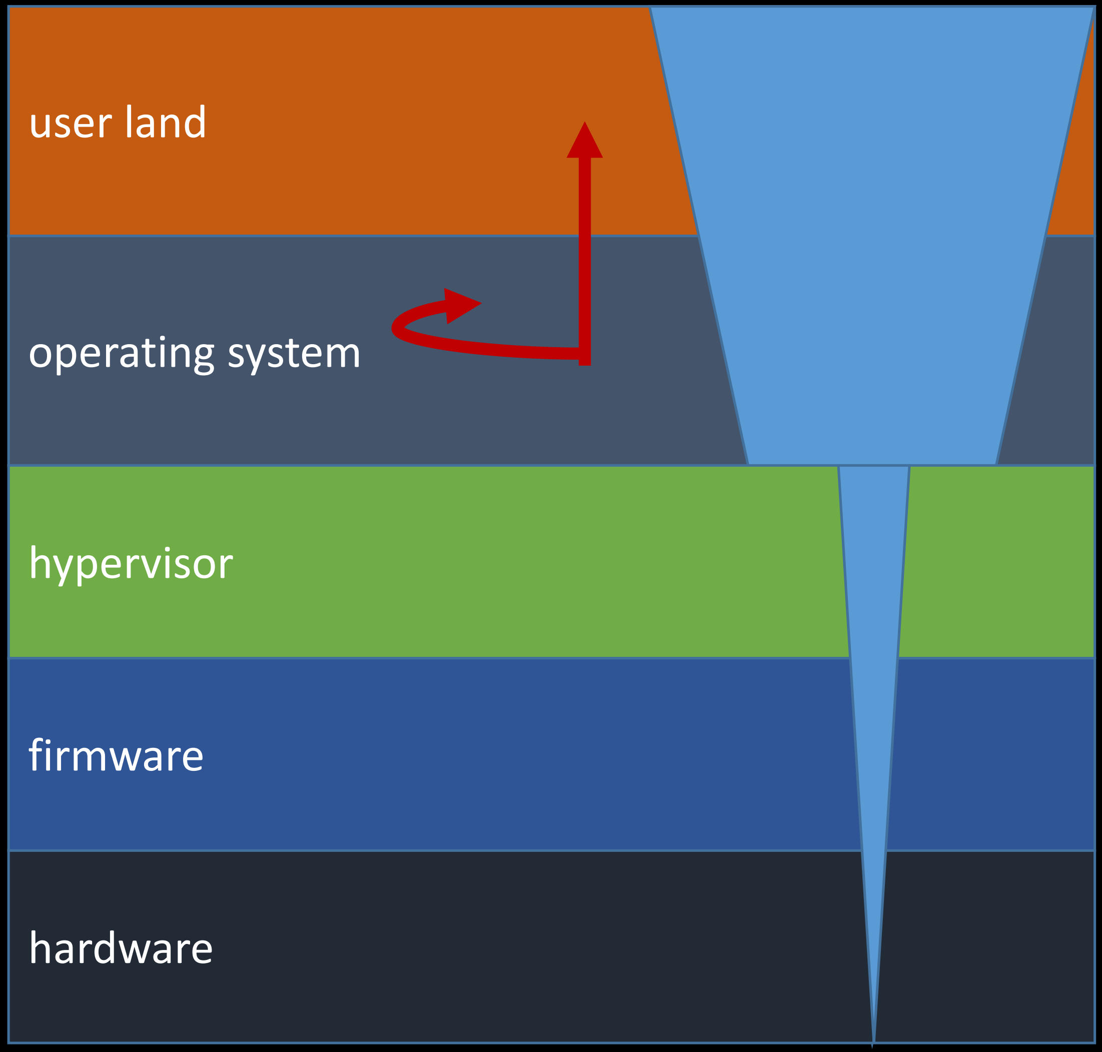
- examples
  - trusted execution extensions
  - UEFI



runtime protections

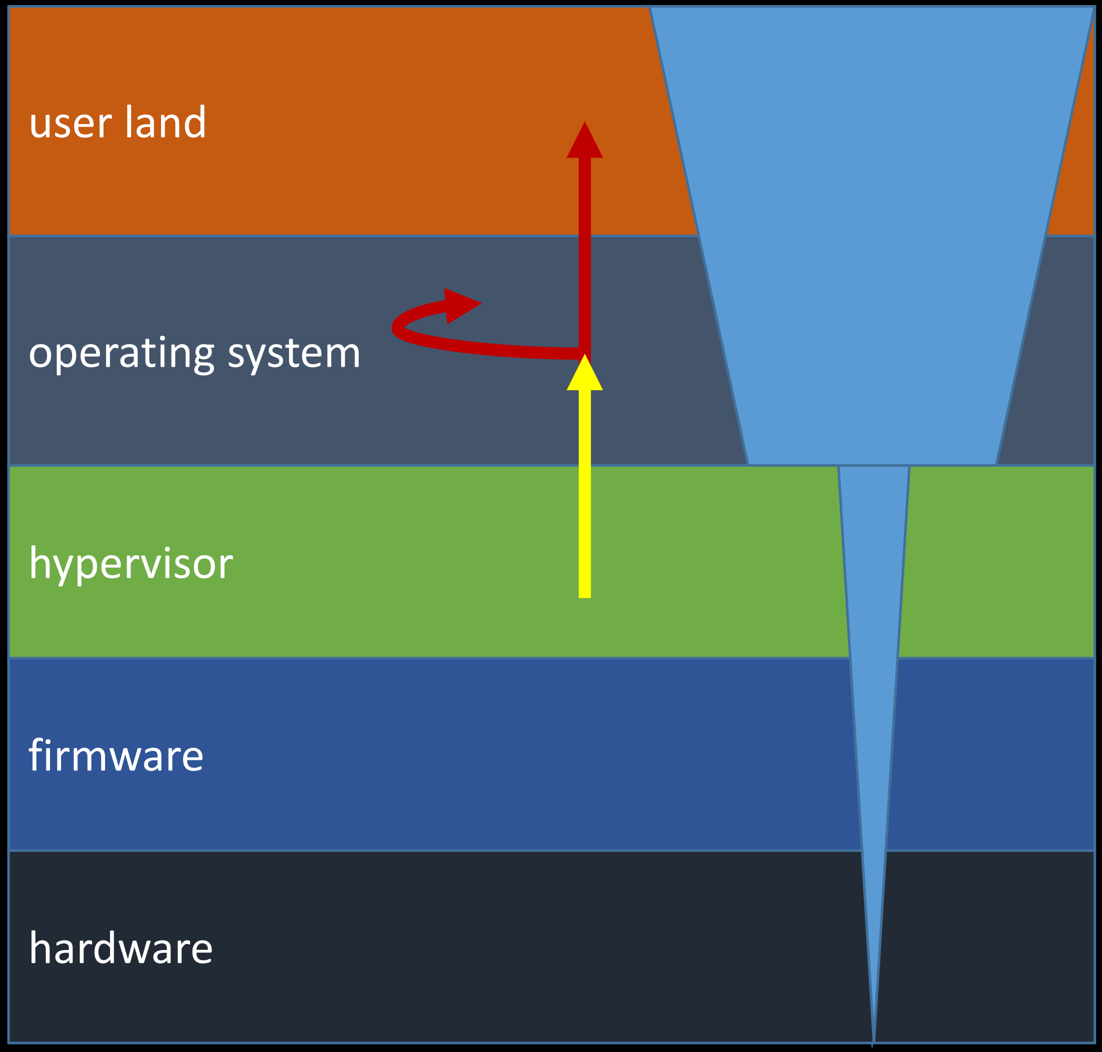
- “in-the-box” methodology is deficient
  - relies on kernel to protect itself
  - huge attack surface provides rootkits many options for specifically evading agents

- Ultimately is a cat-and-mouse game
  - example: PatchGuard bypassing



runtime protection gaps

- trusted boot doesn’t provide ongoing runtime protection
- complex code will have complex problems
  - e.g. third party driver loading
- what can we do to support the runtime protection of the guest?



gap scenarios considered

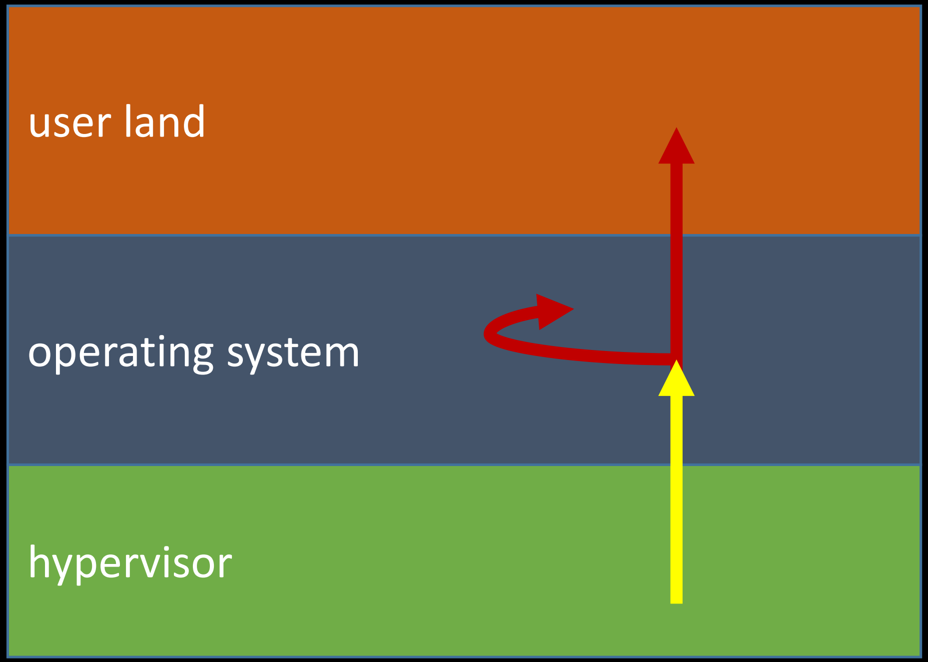
- controlled guest
  - has some sort of traditional agent
  - possibly has an anti-malware solution

- uncontrolled guest
  - no agent or other security controls
  - example: unmanaged VPS

functional goals

- support controlled guest
  - complement agent to enhance integrity
  - provide rudimentary rootkit detection
  - validate guest defenses

- monitor uncontrolled guest
  - develop of a truly agentless HIDS
  - provide indicators from within guest
  - look for modified structures
  - some of the things anti-malware does

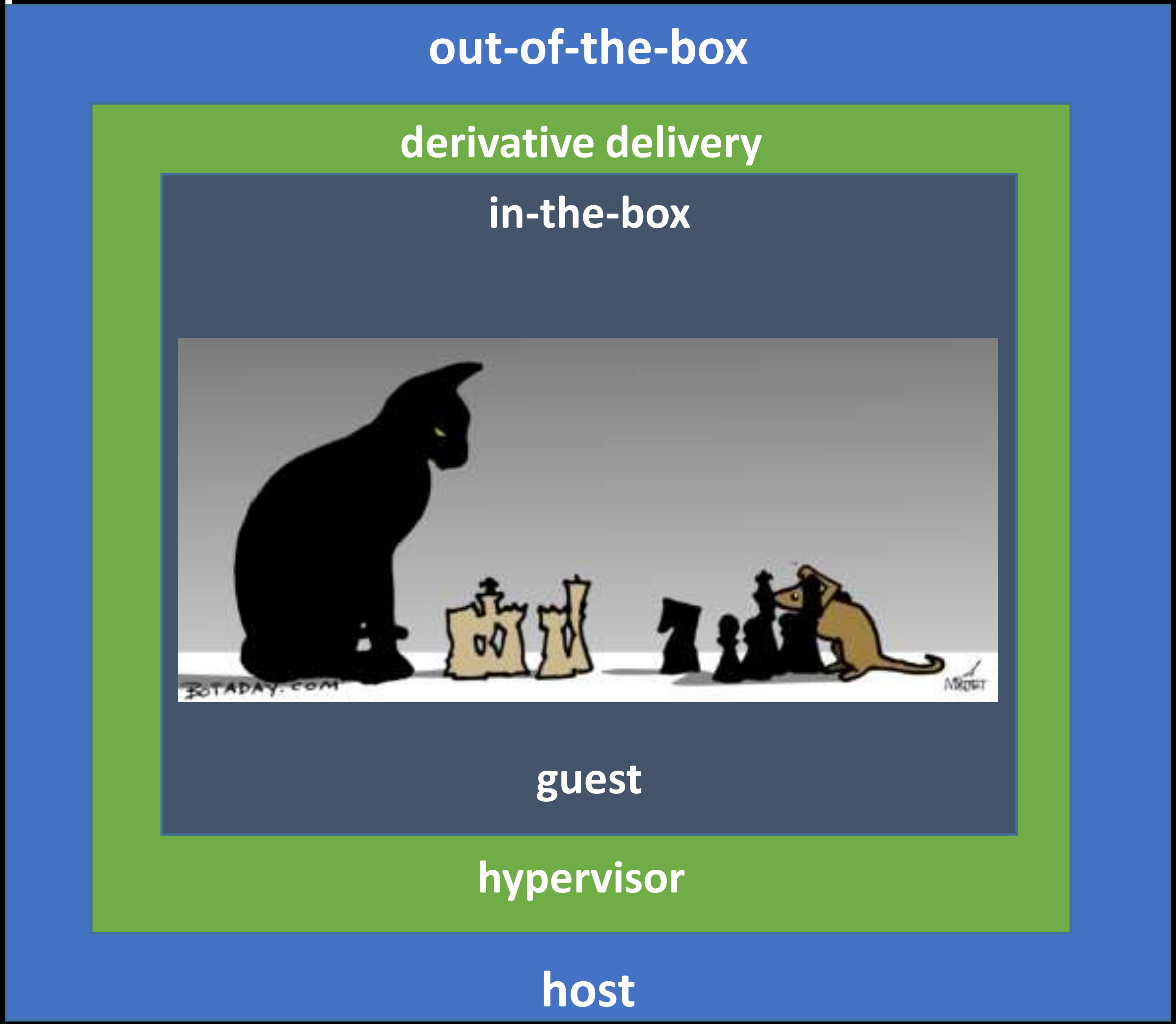


tool landscape

- all perform in-the-box data collection
  - cuckoo
    - automated malware analysis
  - ossec
    - host-based intrusion detection
  - google rapid response
    - incident response
- existing products support VMware
  - trend micro

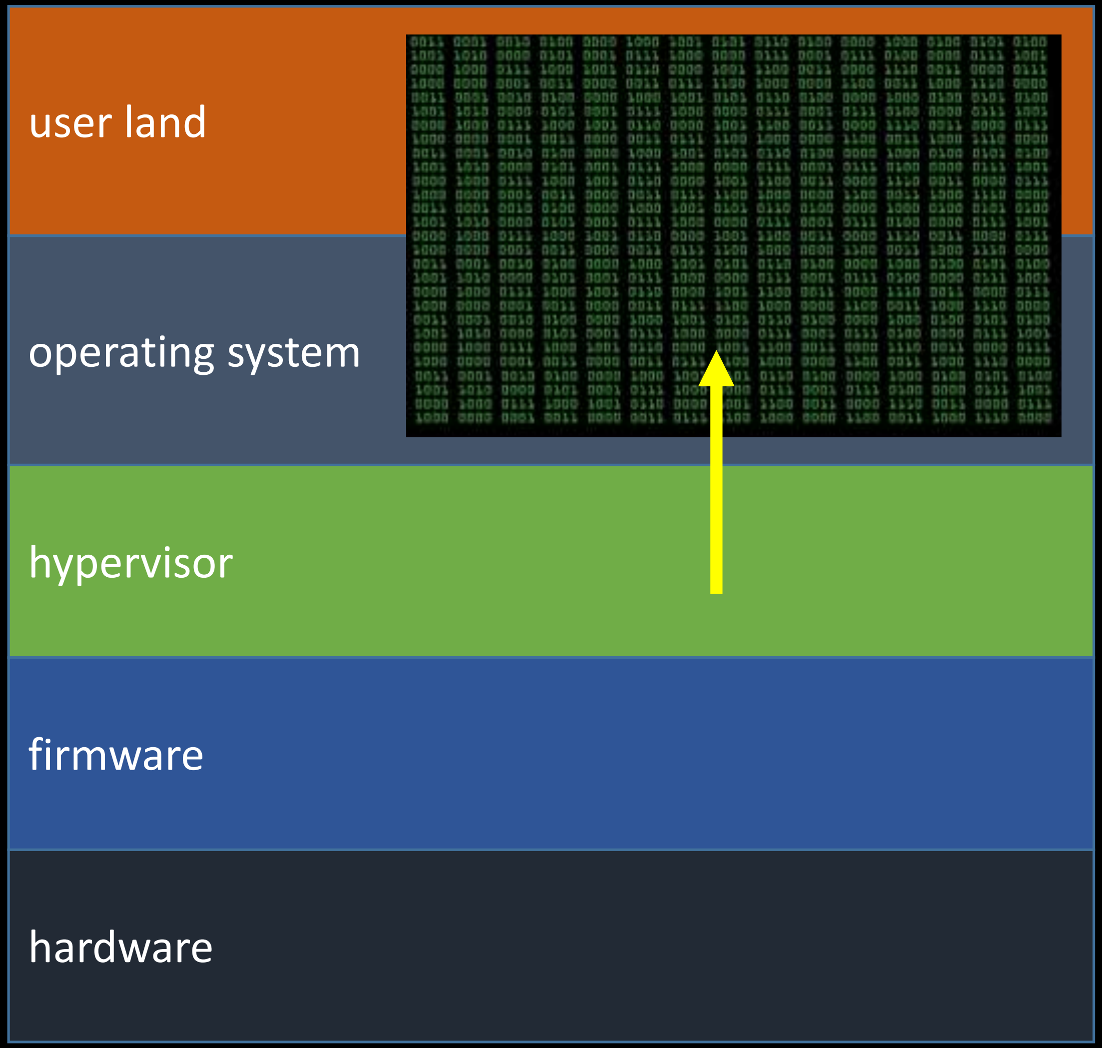
outside guest protection

- “derivative delivery” is specialized
  - integration into hypervisor
  - interposition → modification/feedback
- “out-of-the-box” methodology
  - isolation → integrity
  - inspection → full visibility



out-of-the-box analysis

- benefits of properties
  - isolation provides integrity
  - Inspection provides full visibility
  - control → response
- implementation challenges
  - semantic gap
  - user/performance impact
  - what to do with data

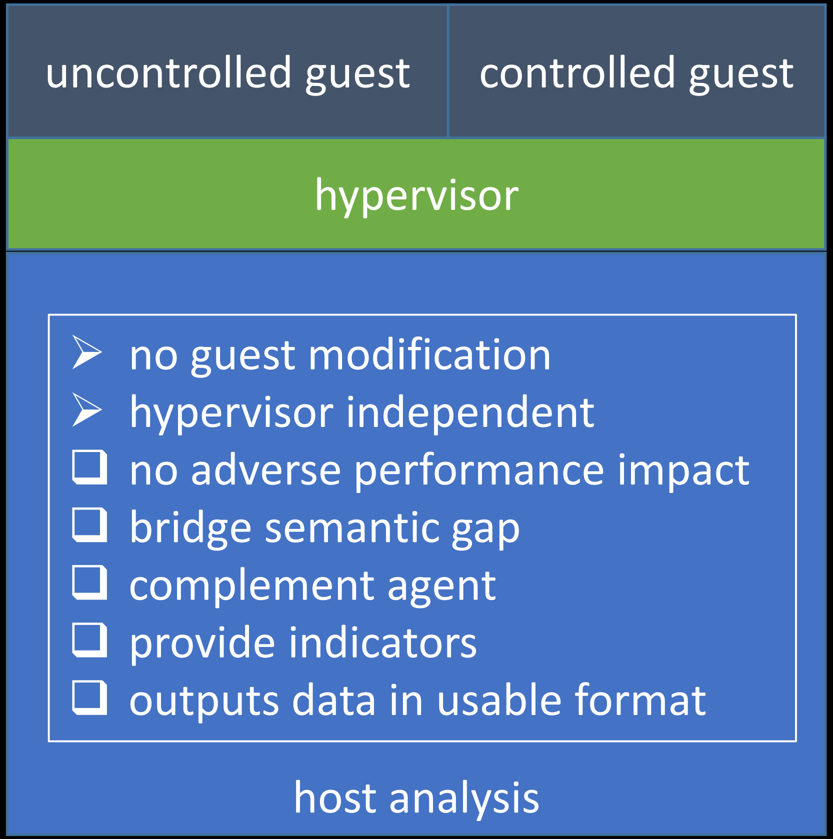


solution components preview

- functional and user requirements
- memminer solution components
  - Libvmi + vmifs
  - Rekall
  - CyBox

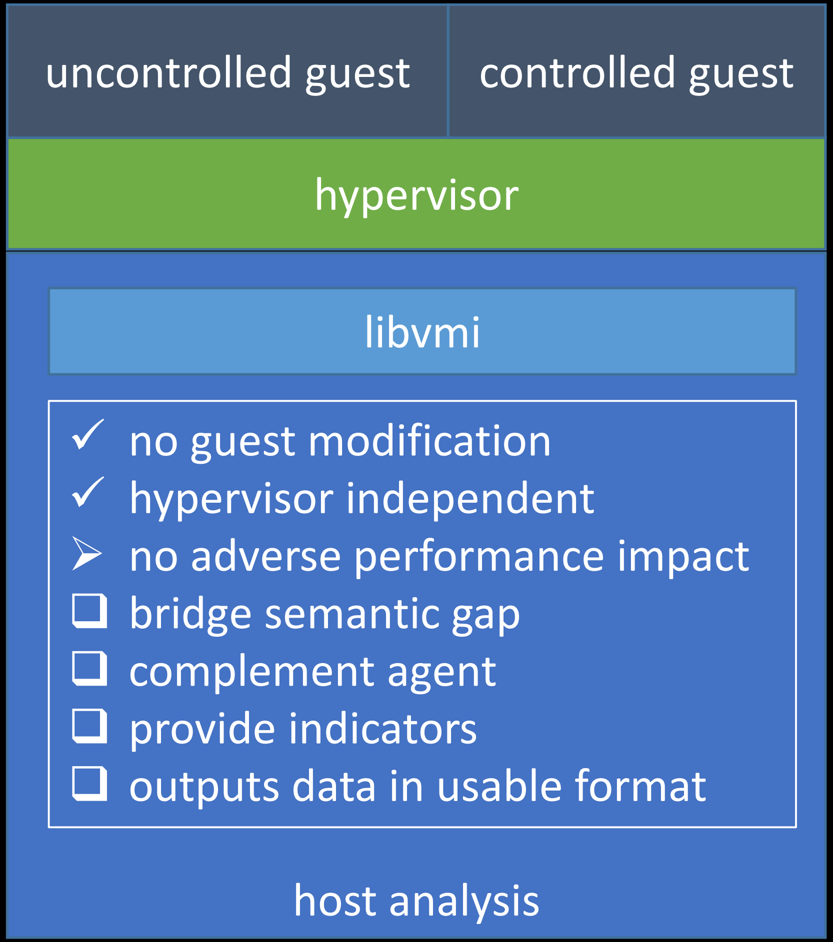
user requirements

- no guest modification
- hypervisor independent
- no adverse performance impact
- outputs data in usable format



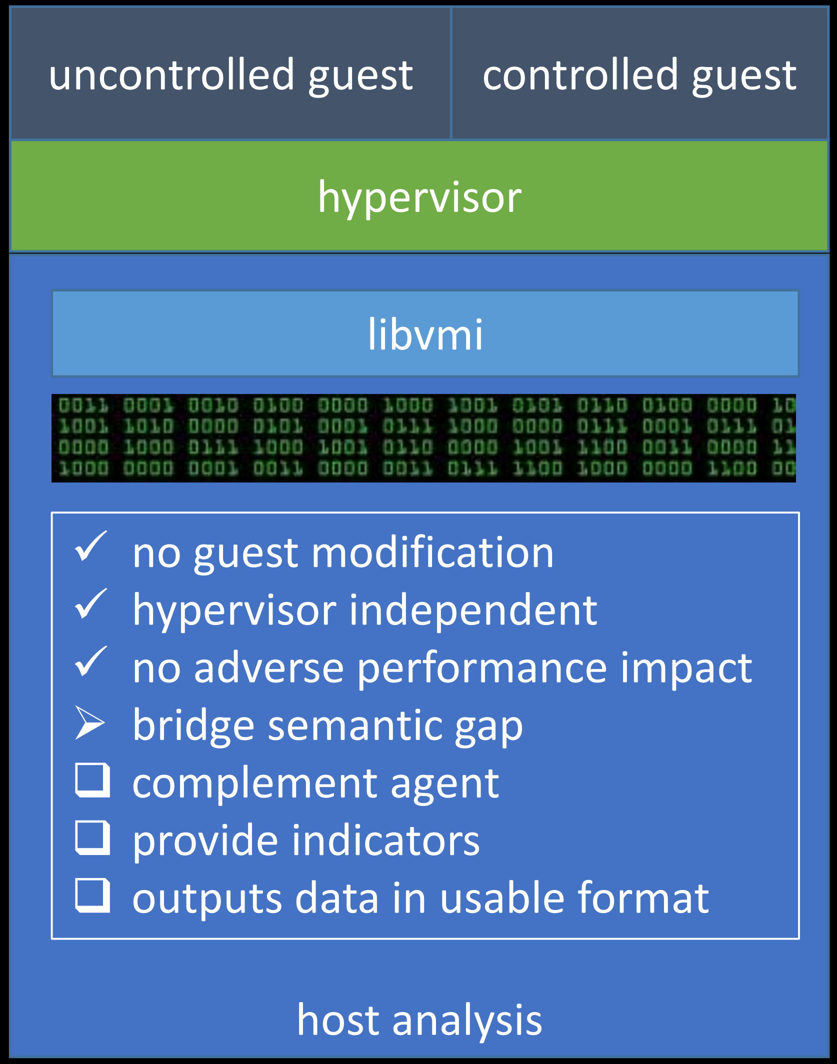
performance impact

- problem: introspect with minimal interference
  - how we access memory is important
  - full memory snapshots are costly
  - don’t want to pause the host
    - memory coherency
- solution: libvmi (virtual machine introspection)
  - direct memory access
  - shm-snapshot provides coherency
  - designed to work across different hypervisors
  - however, requires hypervisor support
  - also provides abstracted control



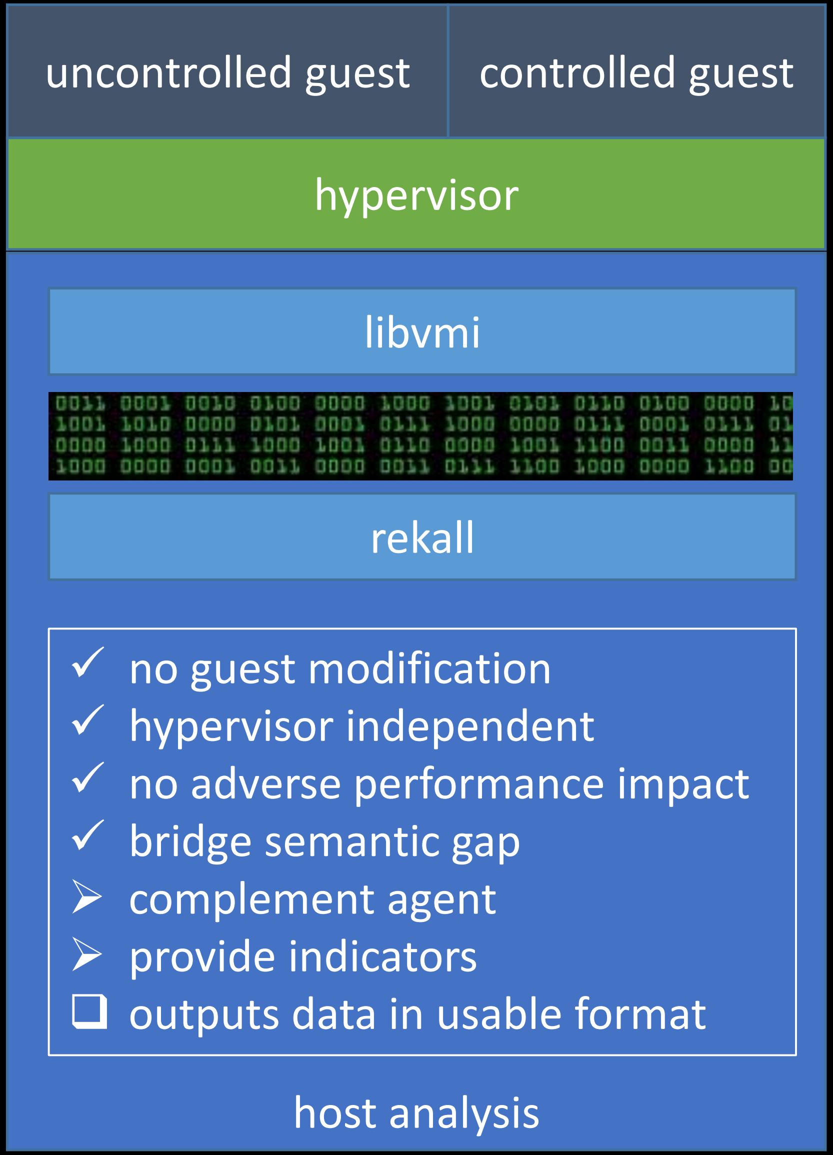
bridging the semantic gap

- problem: bridging the OS semantic gap
  - inherent if we can’t query kernel
  - complex problem, system-dependent
  - we don’t want to have to tailor each install
- solution: forensic analysis tools
  - designed to bridge the semantic gap in raw memory dump
  - actively being developed



forensics tools

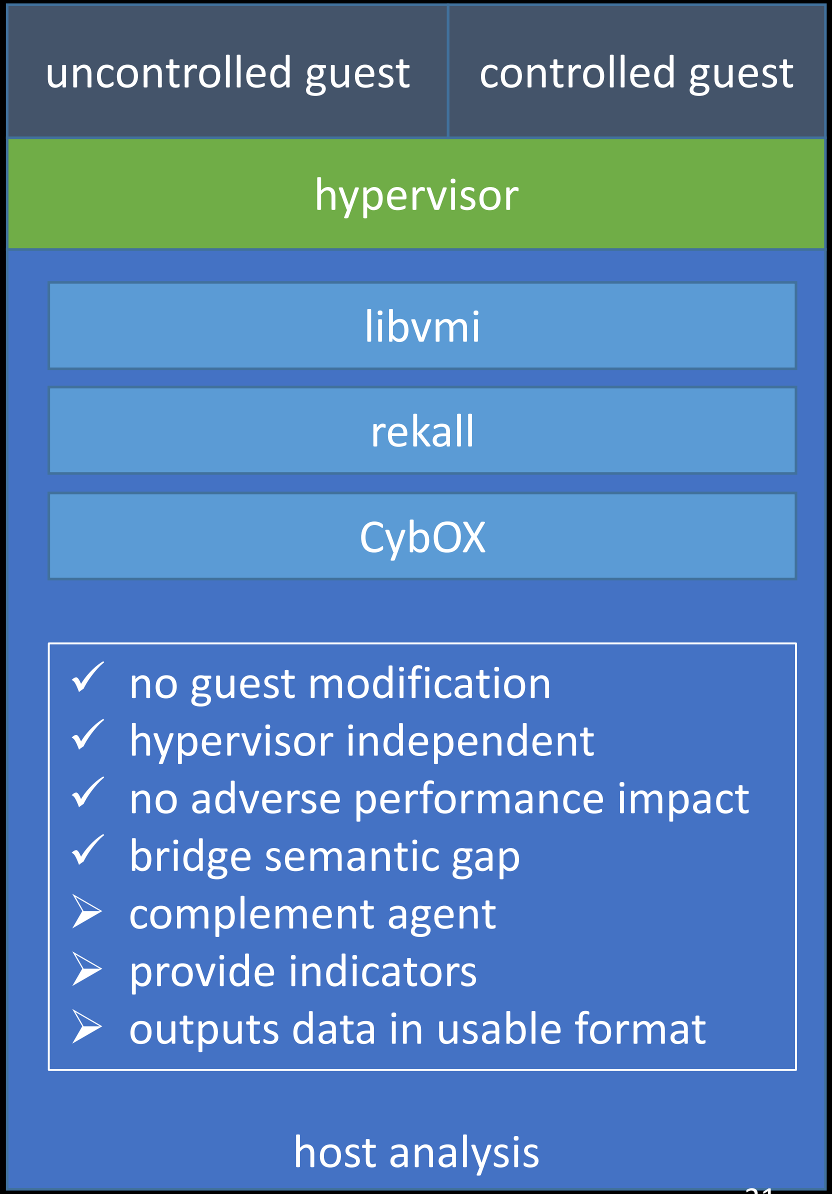
- designed for malware hunting
  - random information dumping
  - lie detection (psxview)
  - raw socket detection
  - integrity checking (process dumping)
  - heuristic scanning, yara
- limitations
  - not designed for speed
  - not compact or hardened
- capable tools
  - volatility
  - rekall



usable output

- problem: need to output structured data
  - malware red flags
    - ssdt, apihooks, etc.
  - operational system data
    - what's normally collected by HIDS
    - longitudinal analysis

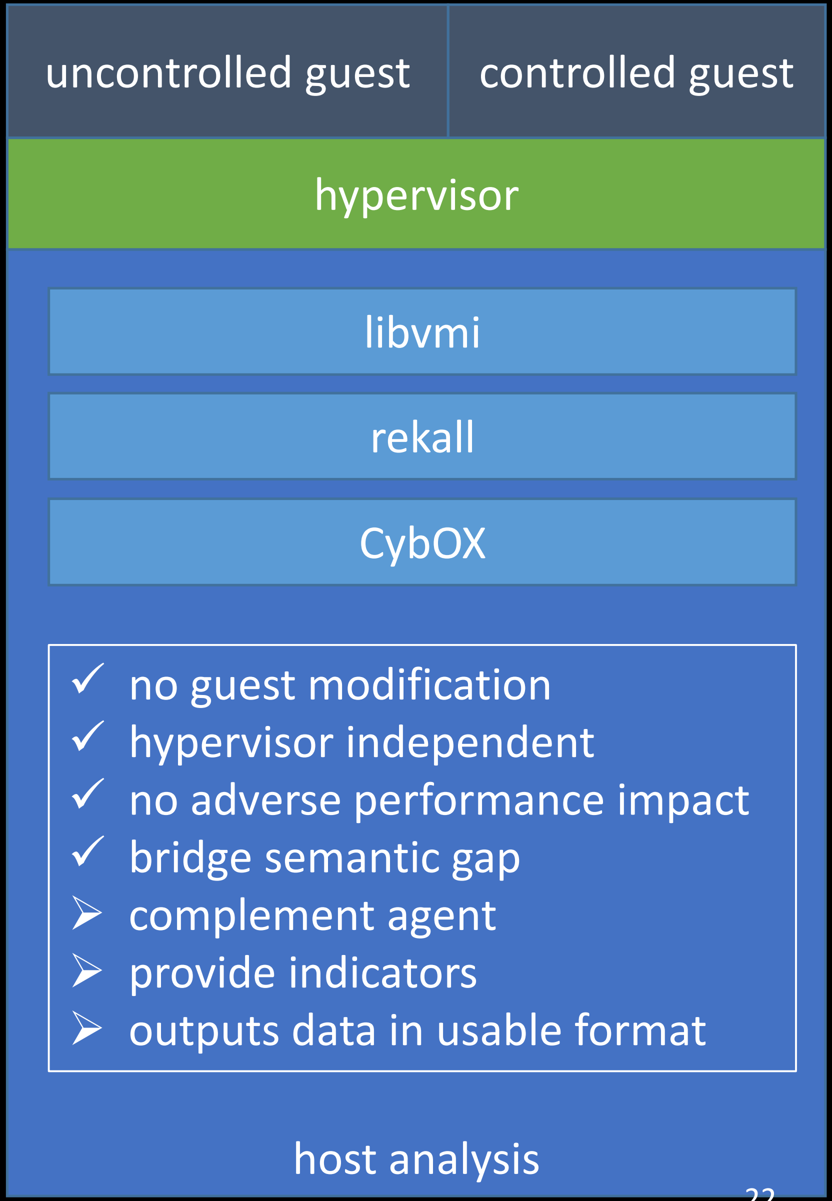
- solution: CybOX
  - Cyber observables expression
    - Objects and relationships (e.g. Process, File, DNS Cache)
    - https://cybox.mitre.org/
  - standardized – composability



integration opportunities

- Create an “agentless” agent
  - hypervisor-level agent representing host
  - ossec-hids
  - google rapid response

- support rootkit detection
  - signature-based
  - heuristic/behavioral based
  - cross-view based
  - integrity-based



Demo

- windows 7 machine
- monitoring process/service lists, ssdt
- output data into mongodb

how can this be evaded

- timing attacks
  - presence of VM and can point toward monitoring
- functional evasion
  - i.e. detection and avoidance
- Functional modification
  - i.e. modifying target code
  - DKOM (direct kernel object modification)
- VMM exploitation, firmware exploitation
- attack the tools

limitations of

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- Increasing attack surface
- not incredibly lightweight
- some assembly required
- only gives you main memory
- limited by hypervisor support
  - xen, qemu+kvm supported by libvmi

benefits of memminer

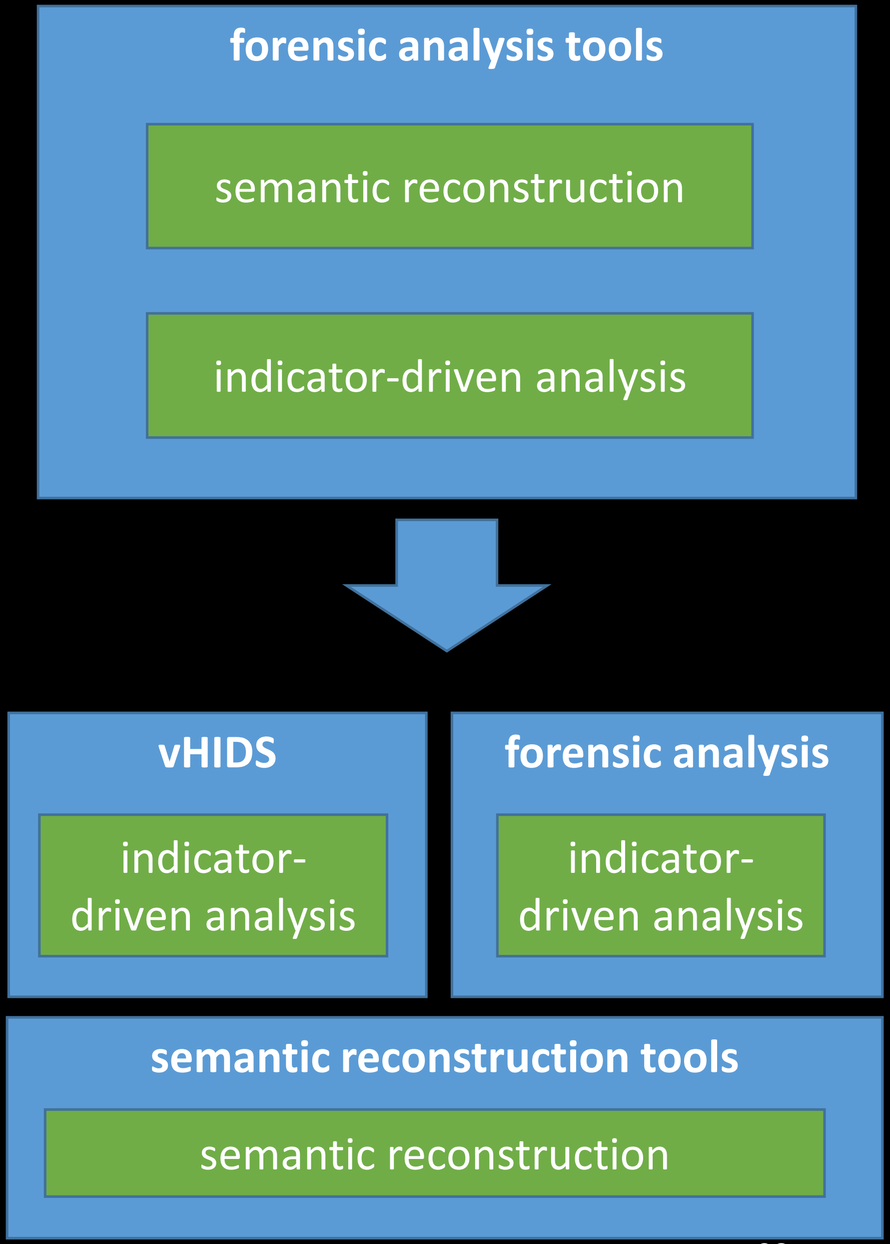
- uses same tools that are being used for forensic analysis
- rekall is under active development
- many options for leveraging things
  - periodically integrity check your favorite process
  - pause machine on bad things

next steps

- better support for guest memory access APIs
- minimize solution
- integrate with something

what do we need ultimately

- semantic reconstruction tools
  - high-performance
  - lightweight
  - composable
- forensic analysis tools
  - easily scriptable
  - based on semantically reconstructed data
- virtual host-based IDS
- ultimately afforded
  - self-protection with isolation
  - self-healing through modification



Questions?

- https://goo.gl/LdItuD
- https://github.com/johnwwil/memminer

- Contact me: johnwwil[at]u.washington.edu