ArmoredSoftware: Trusting the Cloud Commons

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Background Projects

- Trusted Research Platform (DoD with Galois)
  - modeling SVP architecture and access control
  - capturing system design
- Verified TPM (Battelle)
  - verified substantial TPM 1.2 subset
  - verified simple attestation and migration protocols
- Verified vTPM (DoD with Kestrel)
  - verifying SVP vTPM infrastructure
  - capturing SVP vTPM system design
- ACHILLES (DARPA with Adventium Labs)
  - imagining malice in embedded systems
  - assessing and appraising runtime environment and applications

Clouds and Trust

- The promises of "the cloud" are substantial
  - reduced hardware and software costs
  - reduced resource consumption
  - improved availability and reliability
- The promises of "the cloud" complicate assurance
  - not under the desk
  - ambiguous and changing runtime environment
  - unknown and unknowable actors in the same environment
- Is trust possible in "the cloud" environment?
  - unambiguous identification
  - confirmation of uninhibited execution
  - direct or trusted indirect observation of good behavior

How Might ArmoredSoftware Help?

- Estimating likelihood of client software or host system compromise
- Appraising cloud applications without sacrificing anonymity or performance
- Guiding migration from untrusted to trusted infrastructure
- Implementing mission specific appraisal monitoring multiple applications
- Aggregating trust information from cloud components to enhance decision making
- Providing architectural support ensuring long-term cloud-based resource availability

Ultimate Goal

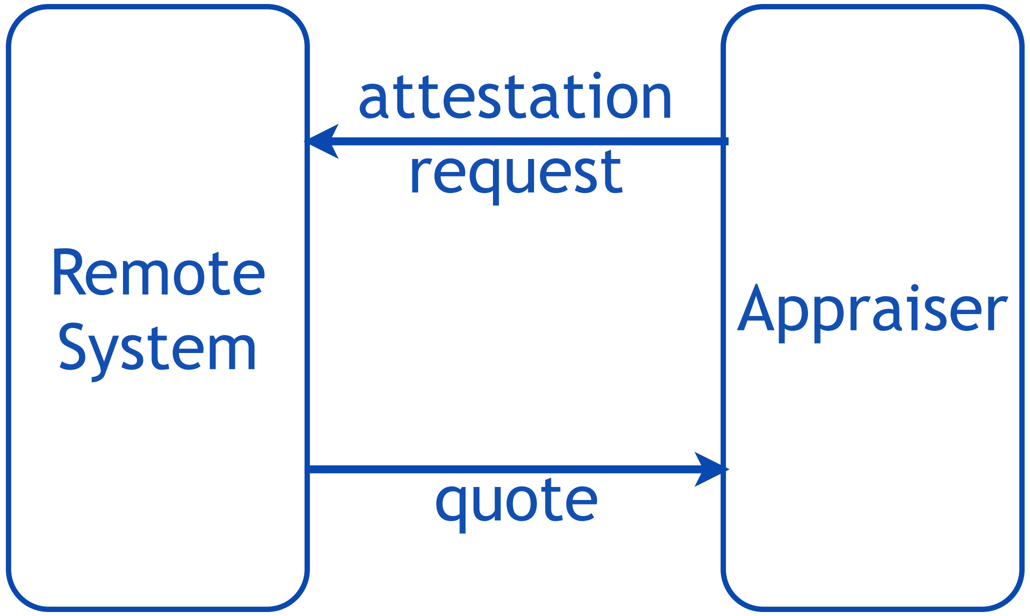
Provide new capabilities that help overcome barriers to cloud acceptance by industry and government, specifically DoD

ArmoredSoftware Features

- Establishes trust among cloud components
  - trust among cohorts of processes
  - trust among processes and environment
- Promotes informed decision making
  - data confidentiality can be confirmed
  - execution and data integrity can be confirmed
- Autonomous run-time response and reconfiguration
  - responds to attack, failure, reconfiguration, and repair
  - response varies based on measurement
- Lightweight integration with existing cloud
  - targeting Xen, OpenStack, and Linux
  - user-space measurement and attestation

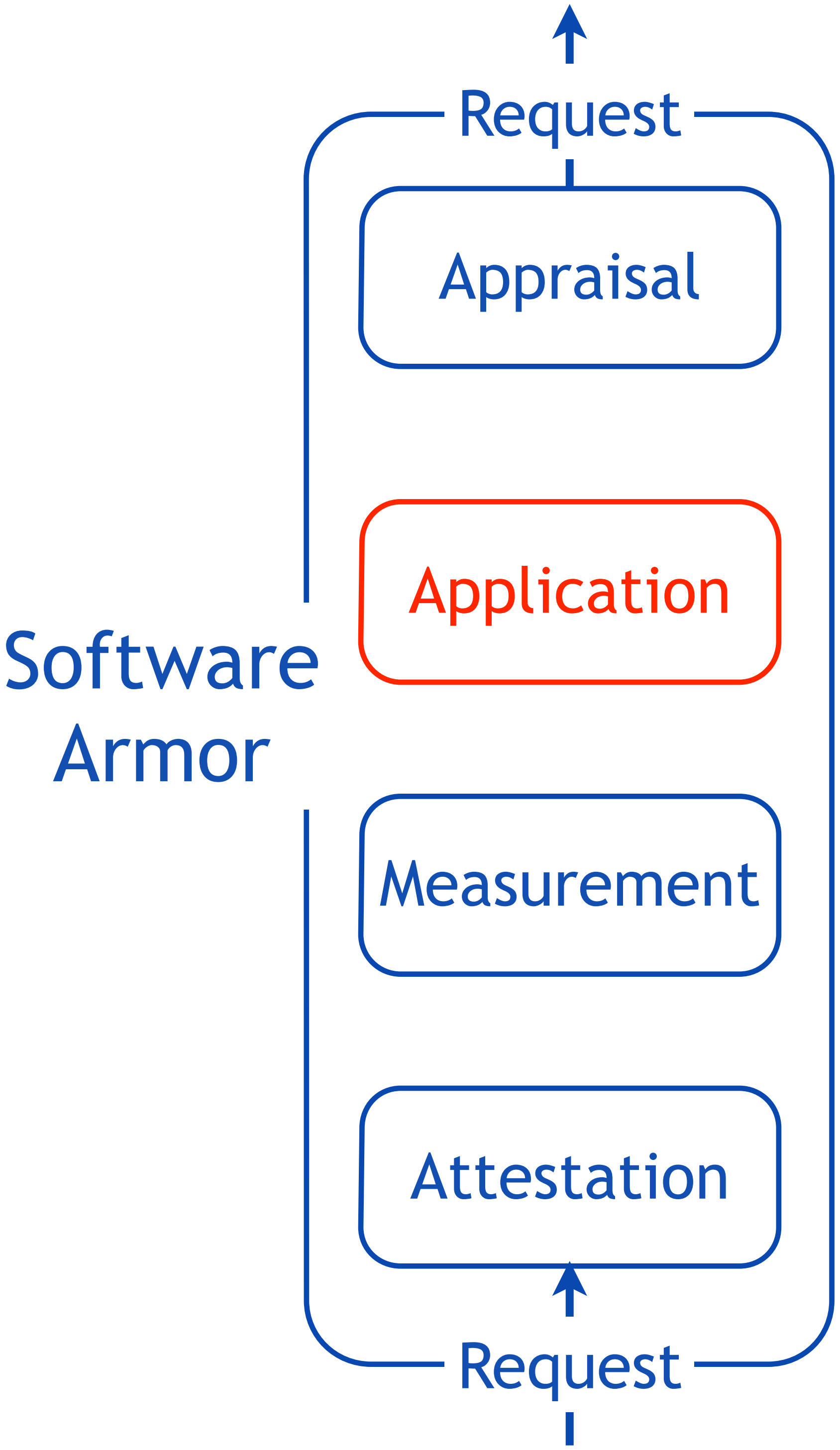
Based on Remote Attestation

- Appraiser requests a quote
  - specifies what information is needed
  - includes a nonce for freshness
- Remote system gathers evidence
  - measures executing software
  - gathers historical evidence
- Remote system generates quote
  - evidence describing system
  - the original nonce
  - cryptographic signature
- Appraiser assesses quote
  - correct boot process
  - correct parts
  - evidence integrity and identity



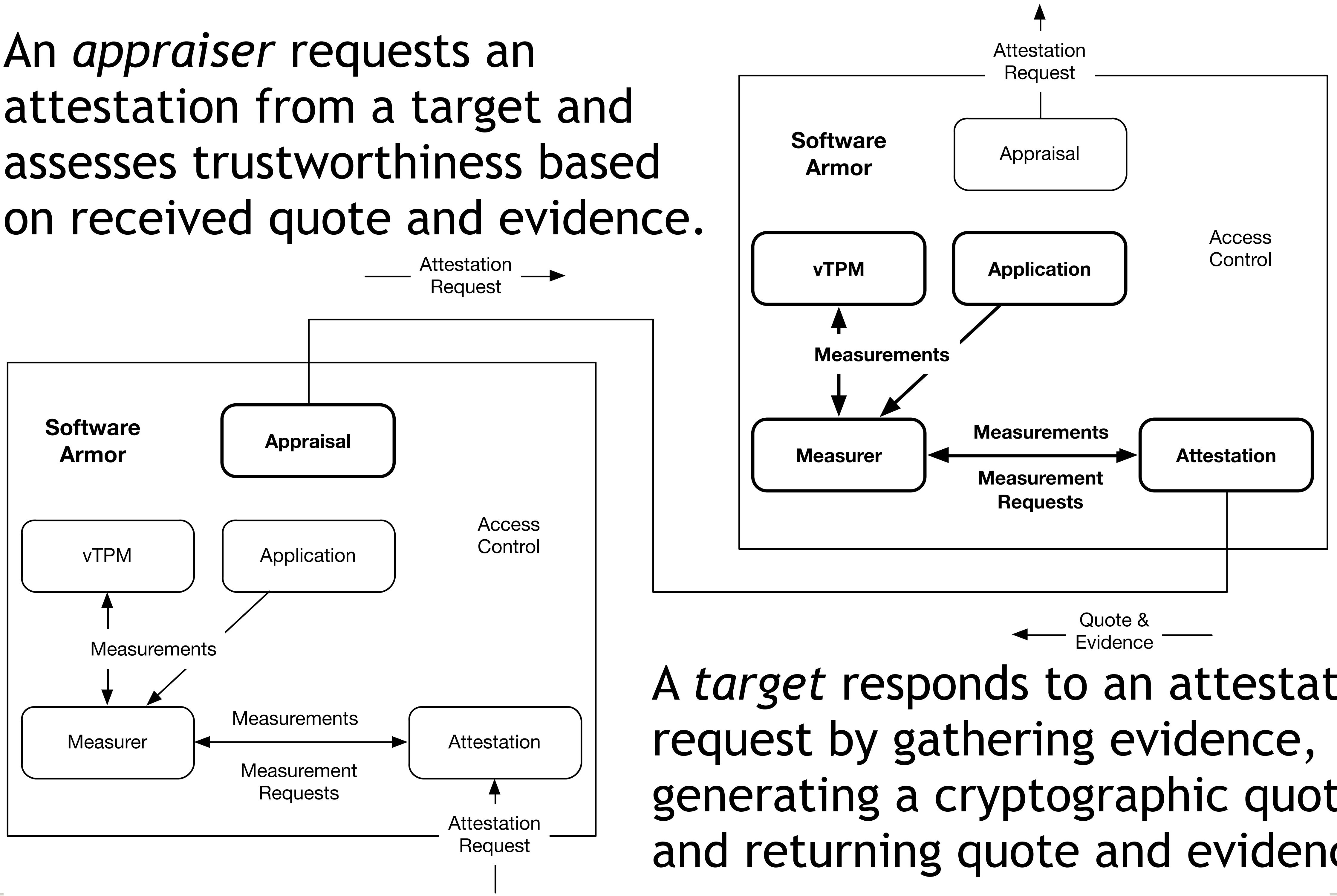
Armor Component Architecture

- Focused on user-space applications
- Protects the application from the cloud infrastructure and environment
- Provides attestations to cloud infrastructure and environment
- High-assurance, lightweight infrastructure
- Influenced by the *Trusted Research Platform* and *Principles of Remote*



Attestation in ArmoredSoftware

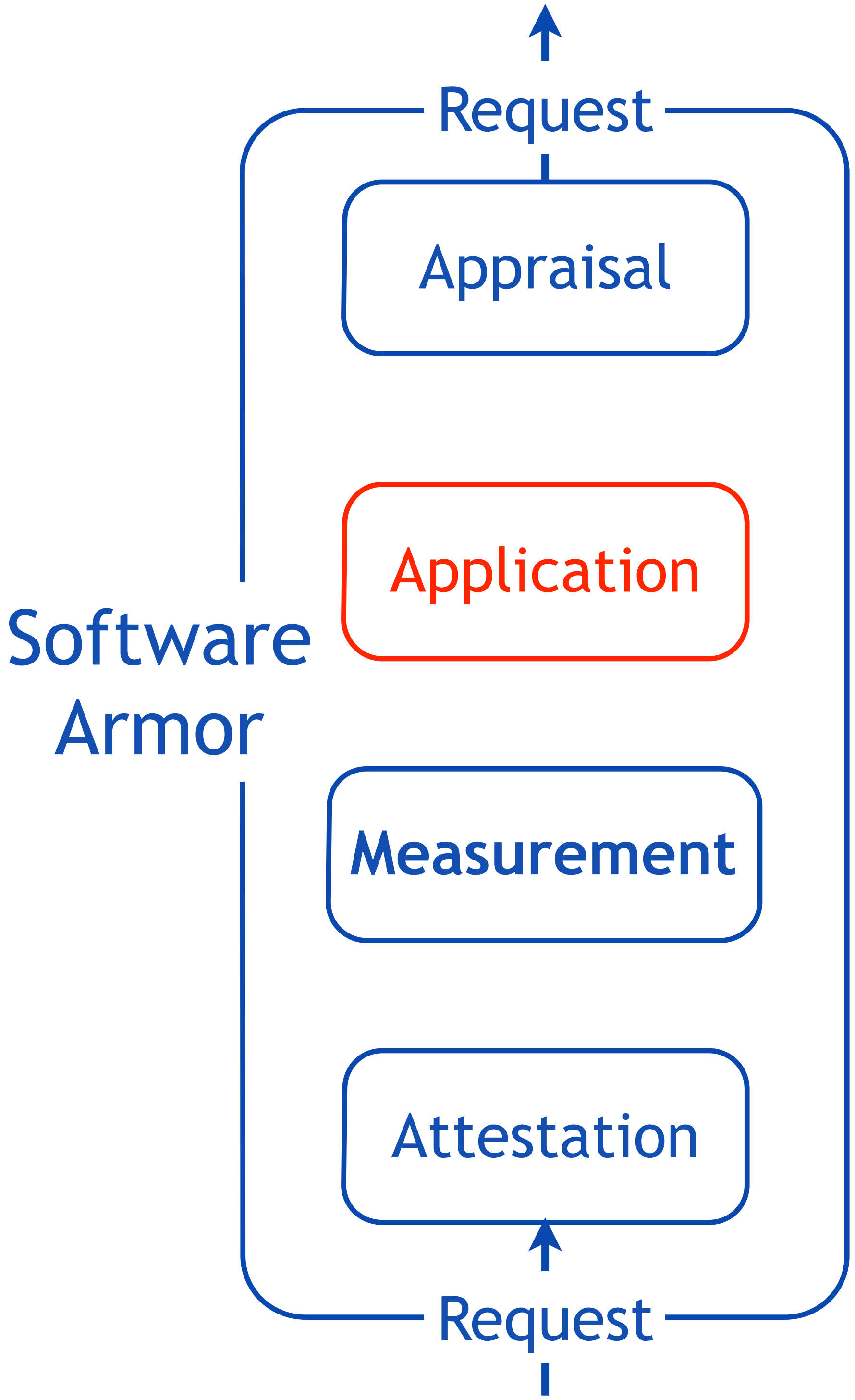
An *appraiser* requests an attestation from a target and assesses trustworthiness based on received quote and evidence.



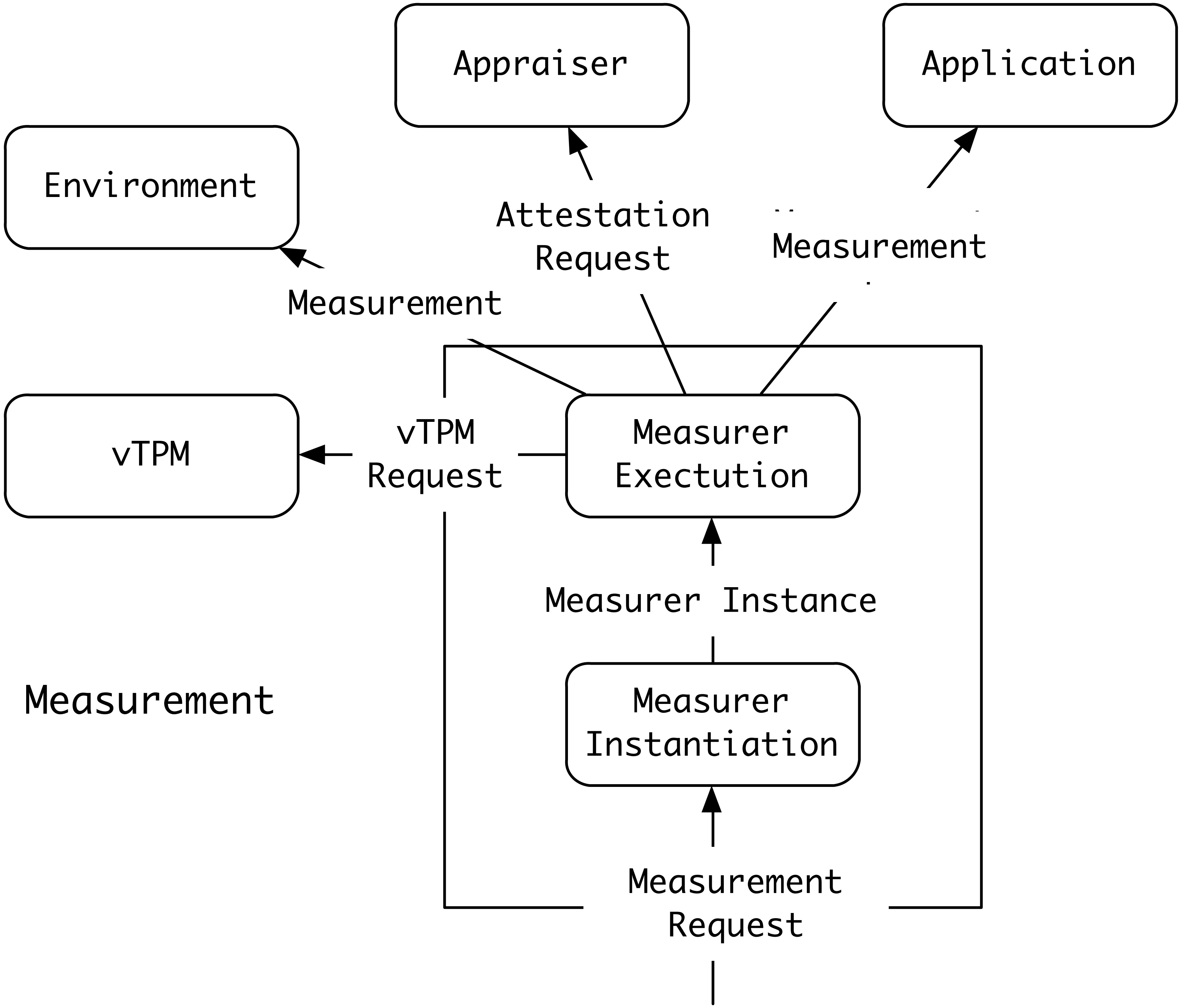
A *target* responds to an attestation request by gathering evidence, generating a cryptographic quote, and returning quote and evidence.

Measurement

- Gathers information
  - Configuration and boot information
  - Runtime information
- Armor measures and is measured
  - measures itself and its application for others
  - requests measurements from environment
- Target classes include:
  - Hosted languages (Java)
  - Compiled code (C,C++)
  - Operational environment



Measurement



Appraiser

Application

Environment

Attestation Request

Measurement

Measurement

vTPM

vTPM Request

Measurer Exectution

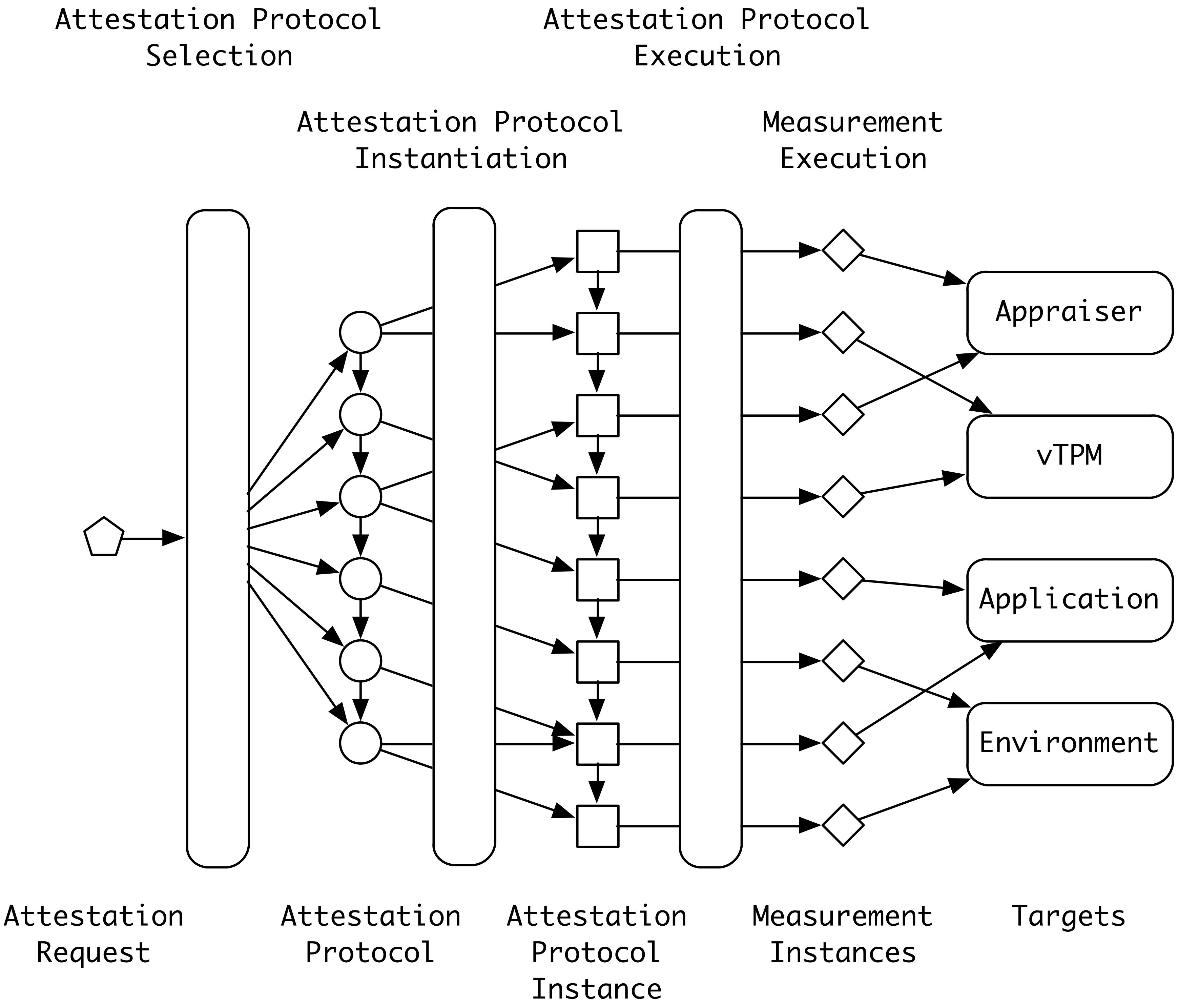
Measurer Instance

Measurement

Measurer Instantiation

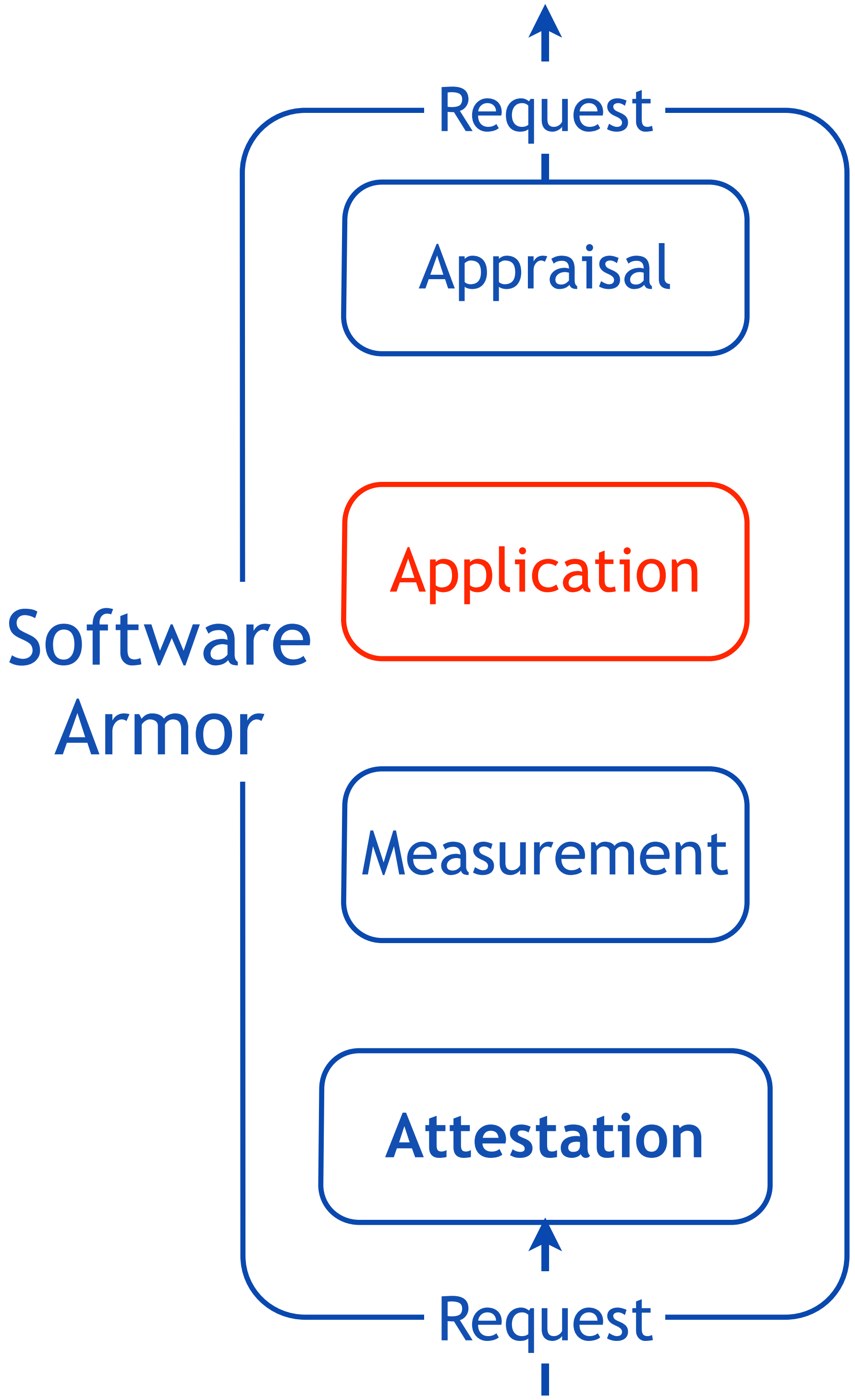
Measurement Request

Detecting Evidence of Malice

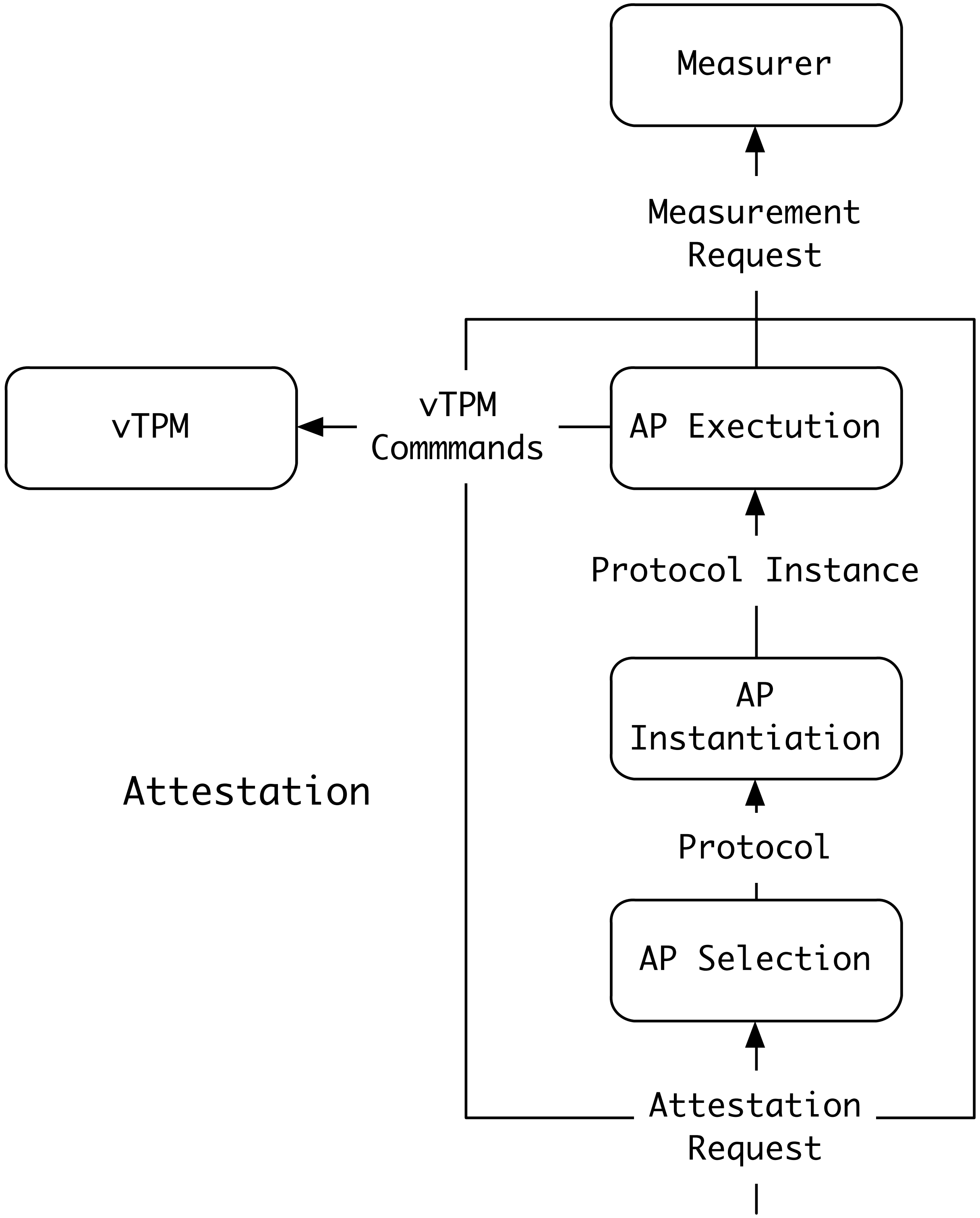

Attestation Protocol Selection
Attestation Protocol Execution
Attestation Protocol Instantiation
Measurement Execution
Appraiser
vTPM
Application
Environment
Attestation Request
Attestation Protocol
Attestation Protocol Instance
Measurement Instances
Targets

Attestation

- Responds to attestation requests
  - receives attestation requests
  - obtains measurement information
  - high-integrity response
- Armor reports on its state
  - application boot and runtime state
  - armor boot and runtime state
- Protocols implement responses
  - invokes measurement
  - vTPM provides assurance
  - vTPM manages measurements
  - complex interactions among Armor elements and environment

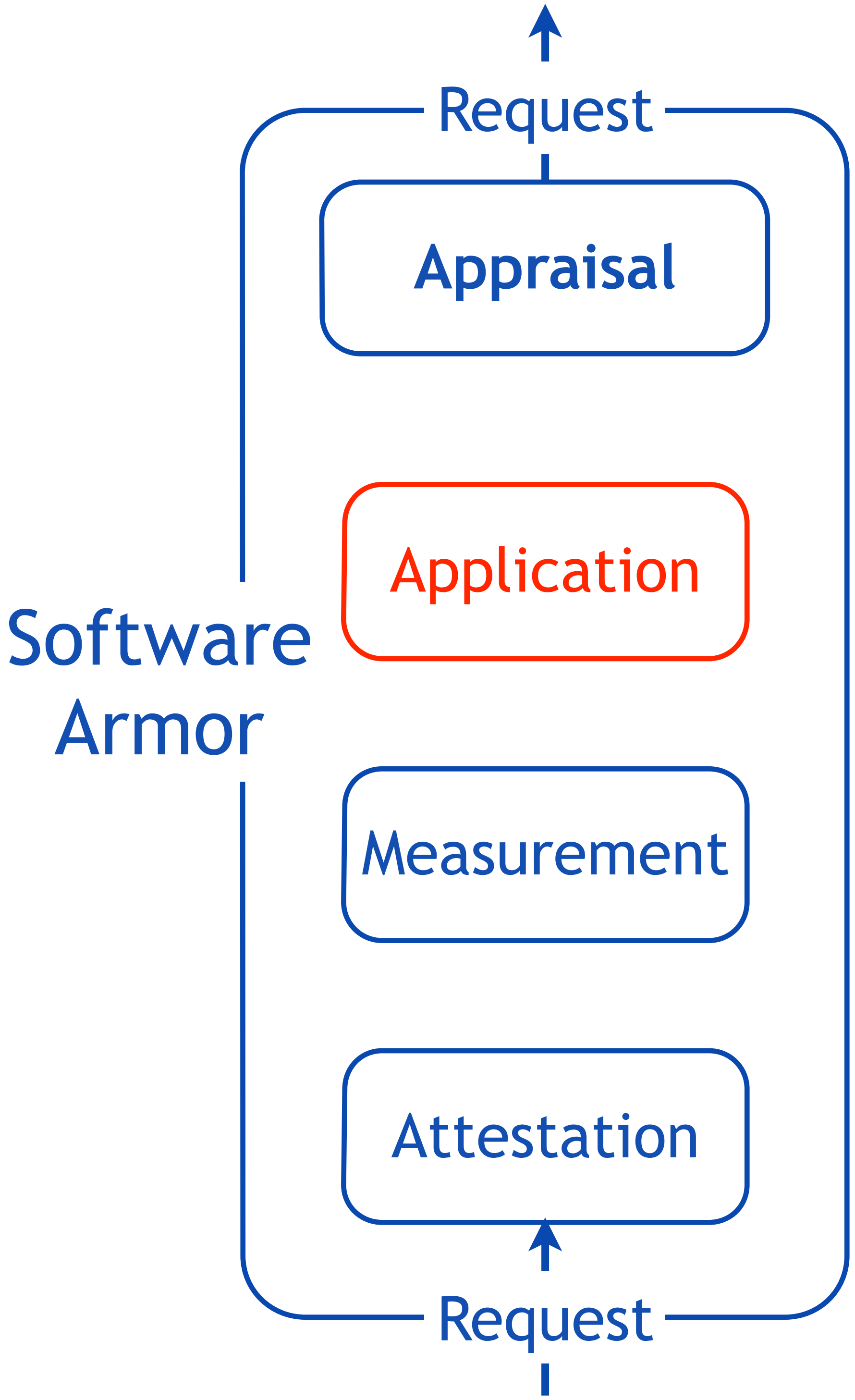


Attestation



Appraisal

- Assesses environment
  - sends attestation requests
  - determines measurement integrity
  - calculates salient properties
- Armor appraises its environment
  - requests information
  - assesses information
  - determines response as appropriate
- Responses include
  - information reporting
  - migration
  - reconfiguration in the current environment



TPM Inside

- Provides and Protects Roots of Trust
  - Storage Root Key (SRK) - root of trust for storage
  - Endorsement Key (EK) - root of trust for reporting
- Quote generation
  - high integrity quotes - $(\{|RS|\}_{AIK^{-1}}$, SML, $\{|n,PCR_{0\text{-}m}|\}_{AIK^{-1}})$
  - high integrity evidence - $(\langle E,n\rangle$, $\{|\#E,PCR,n|\}_{AIK^{-1}})$
- Sealing data to state
  - $\{D,PCR\}_K$ will not decrypt unless PCRs = current PCRs
  - data is safe even in the presence of malicious machine
- Binding data to TPMs and machines
  - $(\{K^{-1}\}_{SRK},K)$ - $\{D\}_K$ cannot be decrypted unless SRK is installed
  - $(\{J^{-1}\}_K,J)$ - $\{D\}_j$ cannot be decrypted unless K and SRK are installed

vTPM & Trust Infrastructure

- Focus on light and mobile
  - easy migration among cloud infrastructure
  - lightweight, minimal implementation
  - decentralized, lightweight construction
- Abstract DSL for Trust
  - specifies high-level (v)TPM-based protocols
  - abstracts communication details and components
  - interpretable and verifiable with precise semantics
- Appropriately verified core infrastructure
  - vTPM ecosystem including creation and management
  - protocol execution across VMs
- Moving towards automated synthesis

Research & Development Plan

- Develop measurement capabilities
  - hosted languages measurers (Java)
  - traditional languages measurers (C, C++)
  - environment measurers (Xen,OS)
- Develop attestation capabilities
  - attestation protocols
  - protocol instantiation
- Develop appraisal framework
  - flexible, user configurable appraisal protocols
  - establishment of Armor trustworthiness
- Develop lightweight, mobile vTPM infrastructure
  - vTPM management with support for mobile roots of trust
  - appropriately strong argument for correctness

Research & Development Plan

- Automated synthesis and verification
  - DSL for protocol specification
  - synthesis of executable components
  - artifact verification across components
- Demonstrations
  - initially simple demonstration applications demonstrating
  - cloud-based "big data" environment demonstration
  - federated trust demonstrations
  - *demonstrations as discovered/directed*
- Scale up and roll out
  - full integration with Xen, OpenStack, Linux
  - installation management and packaging

Current Status

- Experimental environment up and running
  - eight node development cloud - Xen, OpenStack
  - five node experimental cloud - Xen, OpenStack
- Simple measurement prototyping
  - gathering information from hosted language execution
  - triggered by external attestation agent
- Inter-VM communication techniques established
  - using Cloud Haskell on industry standard mechanisms
  - TCP/IP based communication and shared page communication
  - integrating XSM into development infrastructure
- Planning initial demonstrations Fall 2014

Outreach

- Talking with potential commercial users
  - Cisco - OpenStack integration
  - Google - Trust infrastructure
  - BATS - Trust infrastructure
- Application examples
  - cloud-based data enclave
  - migration from danger
  - what are good use cases for secure cloud?
- Contacts
  - Perry Alexander - alex@ittc.ku.edu
  - website - http://armoredsoftware.github.io
  - sources - http://github.com/armoredsoftware

References

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People

- Institutions
  - KU Information and Telecommunication Technology Center
  - Southern Cross Engineering
- KU People
  - Dr. Perry Alexander, PI
  - Dr. Prasad Kulkarni, Dr. Andy Gill, Co-PI
  - Leon Searl, Technical Staff
  - Justin Dawson, Jason Gevargizian, Adam Petz, Paul Kline, students
- Southern Cross Engineering People
  - Edward Bishop, Ciro-Coelho