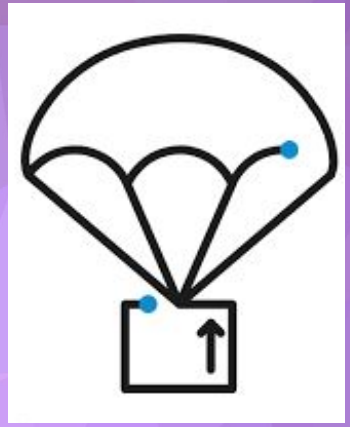


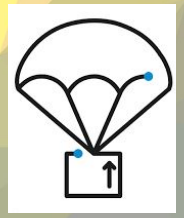
Deep Dive: TUF

Trishank Karthik Kuppusamy, Datadog

Justin Cappos, NYU

NYU TANDON SCHOOL OF ENGINEERING

Kubecon North America 2018



Repository compromise

Software updates

- Experts agree: software updates the most security practice (USENIX SOUPS 2015)
- Updates fix security vulns
- However, important problem is often neglected...

"...no one can hack my mind": Comparing Expert and Non-Expert Security Practices

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Sunny Consolvo
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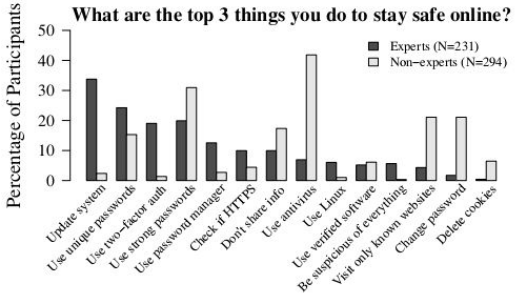
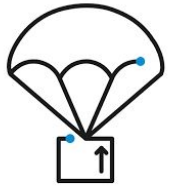


Figure 1: Security measures mentioned by at least 5% of each group. While most experts said they keep their system updated and use two-factor authentication to stay safe online, non-experts emphasized using antivirus software and using strong passwords.

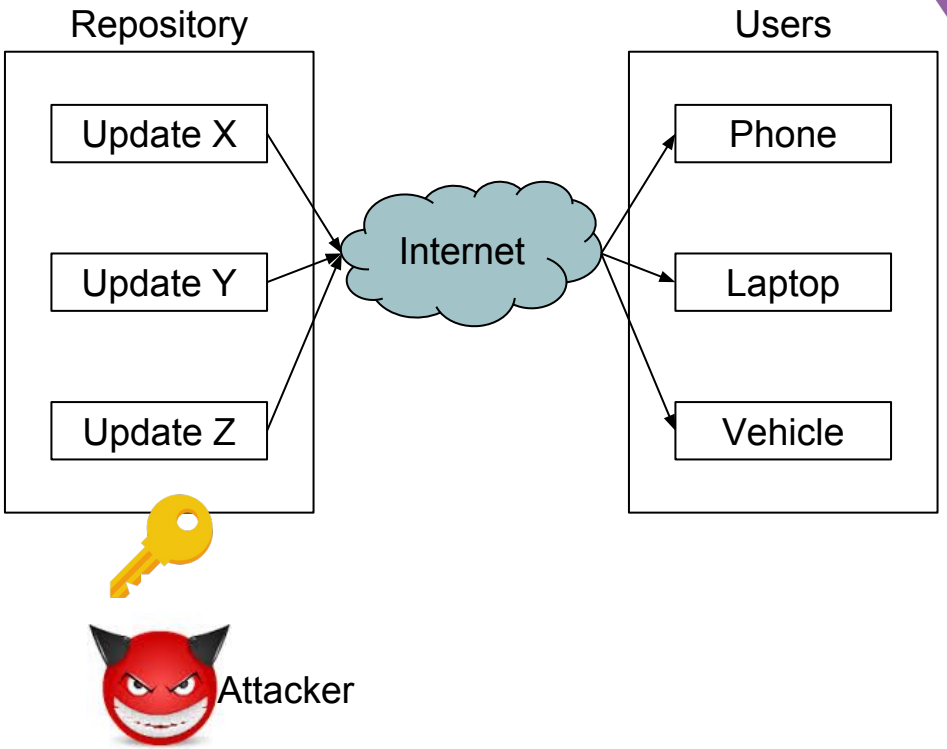
Repository compromise

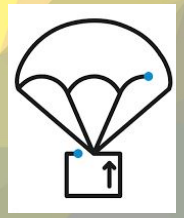
- Examples:
  - Microsoft Windows Update (2012): **Flame** malware targeted Iran nuclear efforts
  - **South Korea** cyberattack (2013): >$750M USD in economic damage
  - **NotPetya** (2017): infected multinational corporations
- Compromise **millions** of devices



Goal: compromise-resilience

- Only question of when, not if
- Cannot prevent compromise
- But must severely limit impact





The Update Framework (TUF)

What is on a repository?

- Repository contains packages + metadata

What is on a repository?

- Repository contains packages + metadata
- *Package*
  - Smallest unit of update
  - Software application or library

Package

What is on a repository?

- Repository contains packages + metadata
- *Package*
  - Smallest unit of update
  - Software application or library
- *Metadata*
  - Cryptographic hashes, file sizes, version numbers, etc.
  - About packages, or other metadata files

The Update Framework (TUF): secure software updates

- **Authenticity** and **integrity**—
  even if repository compromised

- Design principles
  - Separation of duties
  - Threshold signatures
  - Explicit & implicit
  - revocation of keys
  - Minimizing risk using
  - offline keys
  - Selective delegation of trust
  - Diversity of hashing + signing algorithms

- (CCS 2010)

- https://theupdateframework.com

Survivable Key Compromise in Software Update Systems

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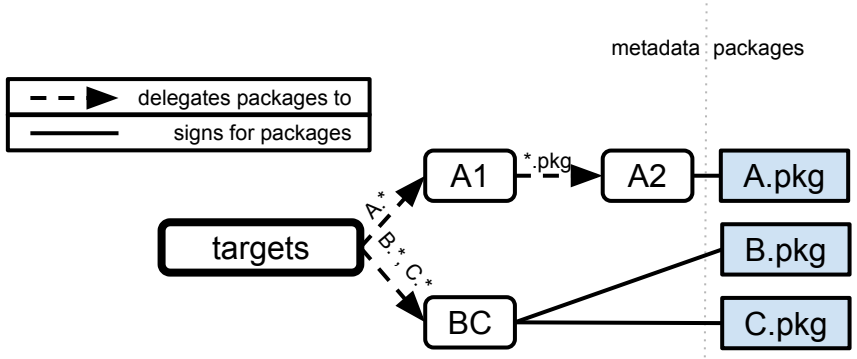
arma@mit.edu

Separation of duties

Design principles:

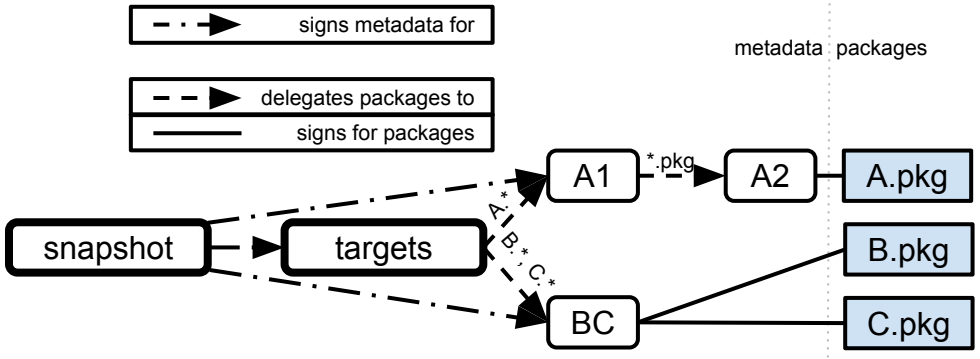
1. **Separation of duties**
   (i.e., don’t put all your eggs in one basket).

The targets role



Role	Purpose
targets	Indicates metadata such as the cryptographic hashes and file sizes of packages. May delegate this responsibility to other, custom-made roles.

The snapshot role



Role	Purpose
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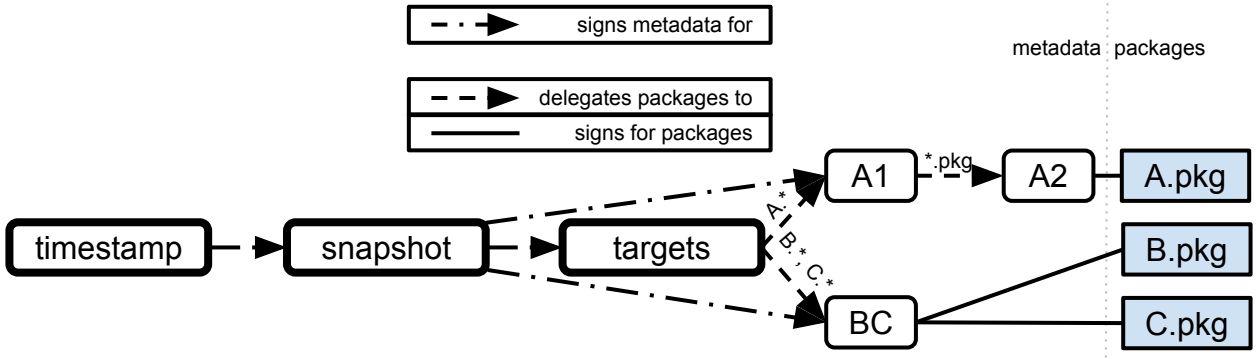
snapshot	Indicates which packages have been released at the same time by the repository.

The timestamp role



Role	Purpose
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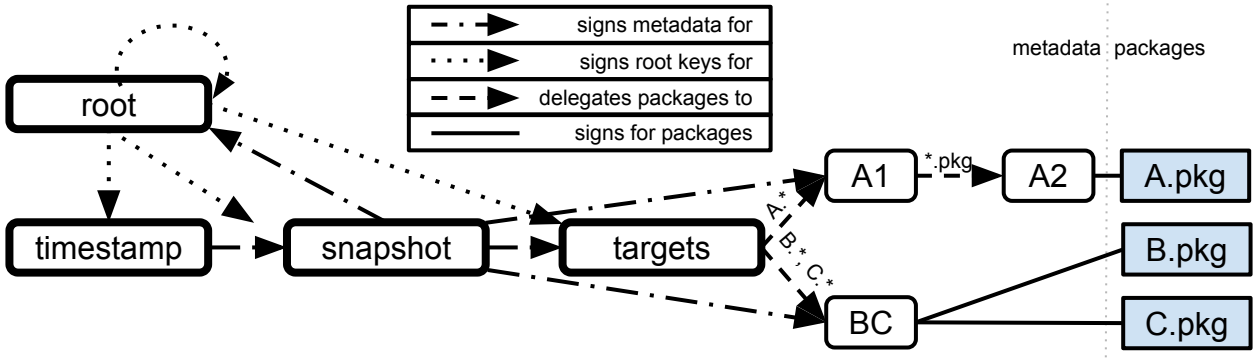
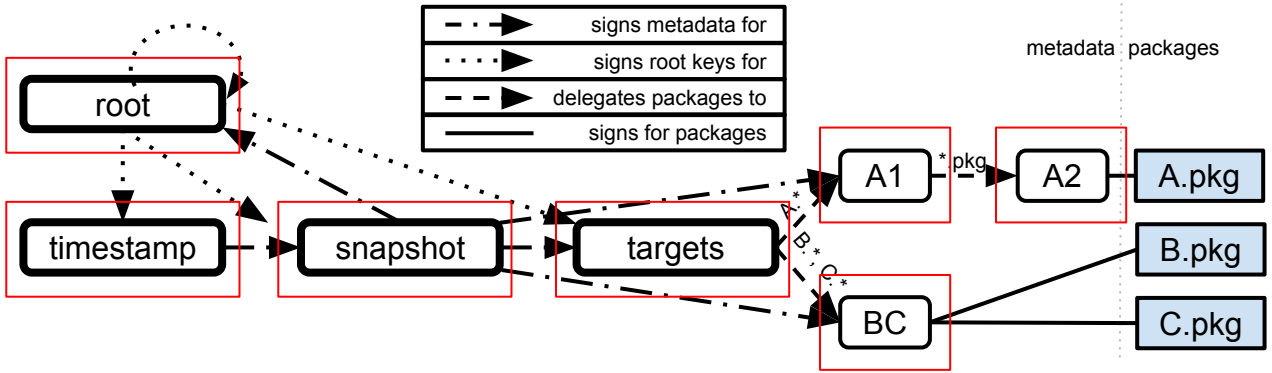
timestamp	Indicates whether there is any new metadata or package on the repository.

The root role



Role	Purpose
targets	Indicates metadata such as the cryptographic hashes and file sizes of packages. May delegate this responsibility to other, custom-made roles.
snapshot	Indicates which packages have been released at the same time by the repository.
timestamp	Indicates whether there is any new metadata or package on the repository.
root	Serves as the certificate authority for the repository. Distributes and revokes the public keys used to verify the root, timestamp, snapshot, and targets role metadata.

Separation of duties



Design principles:

1. **Separation of duties**
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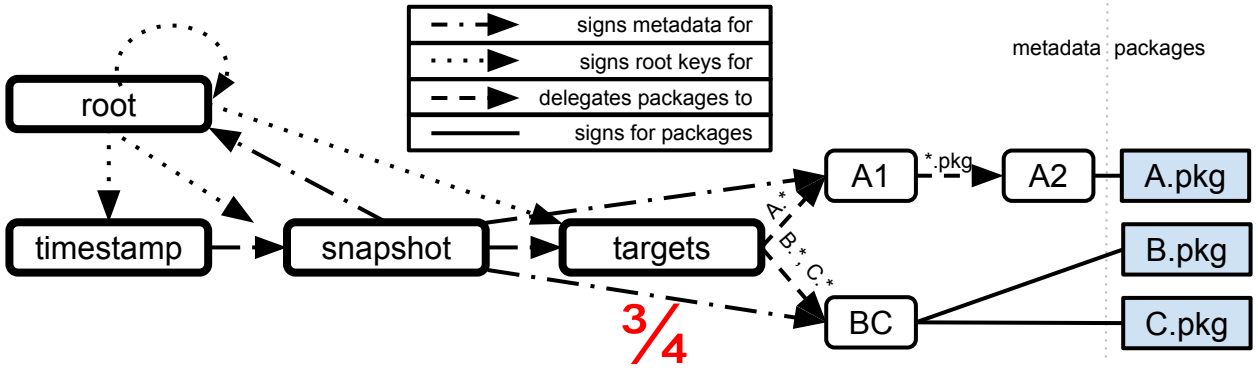
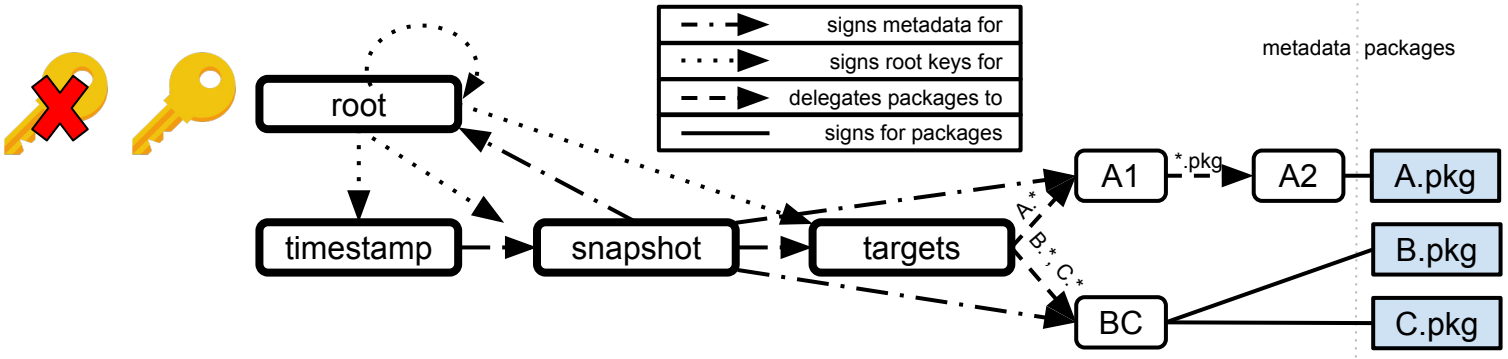
Threshold signatures



Design principles:

1. Separation of duties.
2. **Threshold signatures**
   (i.e., like the two-man rule to launch nuclear missiles)**.**

Explicit & implicit revocation of keys



Design principles:

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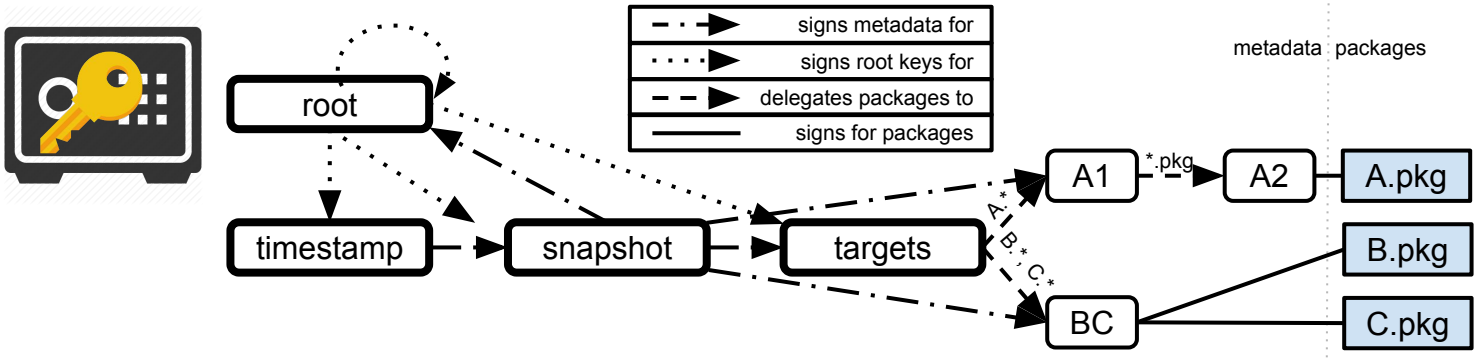
Minimizing risk with offline keys

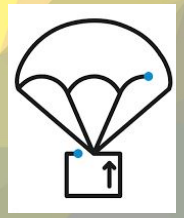


Design principles:

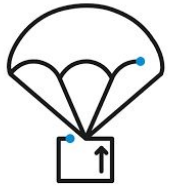
1. Separation of duties.
2. Threshold signatures.
3. Explicit and implicit revocation of keys.
4. **Minimized risk through use of offline keys**
   (i.e., don't put keys to the kingdom under the carpet)**.**

Diversity of cryptographic algorithms

- **Hedge** your **bets**
- Can’t break TUF unless you **break them all**
- No need to depend on just SHA-2 or SHA-3, RSA or Ed25519
- Can even try **post-quantum crypto** at the same time



How TUF Has (and Does) Evolve



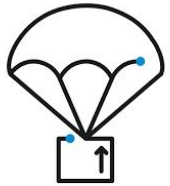
TUF Standardization Process (TAPs)

- TAP 3 -- multi-role signatures over unequal quorums
- TAP 4 -- multi-repository consensus
- TAP 5 -- split repository location across URLs [draft]
- TAP 6 -- version numbers in root metadata
- ~~TAP 7 -- TUF conformance testing [rejected]~~
- TAP 8 -- Key rotation / self revocation [draft]
- TAP 9 -- Mandated metadata signing scheme
- TAP 10 -- Remove native compression support

Future TAPs

- Clearer versioning support
- Wireline formats
- Partially signed threshold metadata
- Supply chain security integration

Discuss with us, then submit (TAP 1/2)



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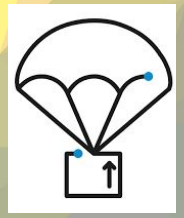
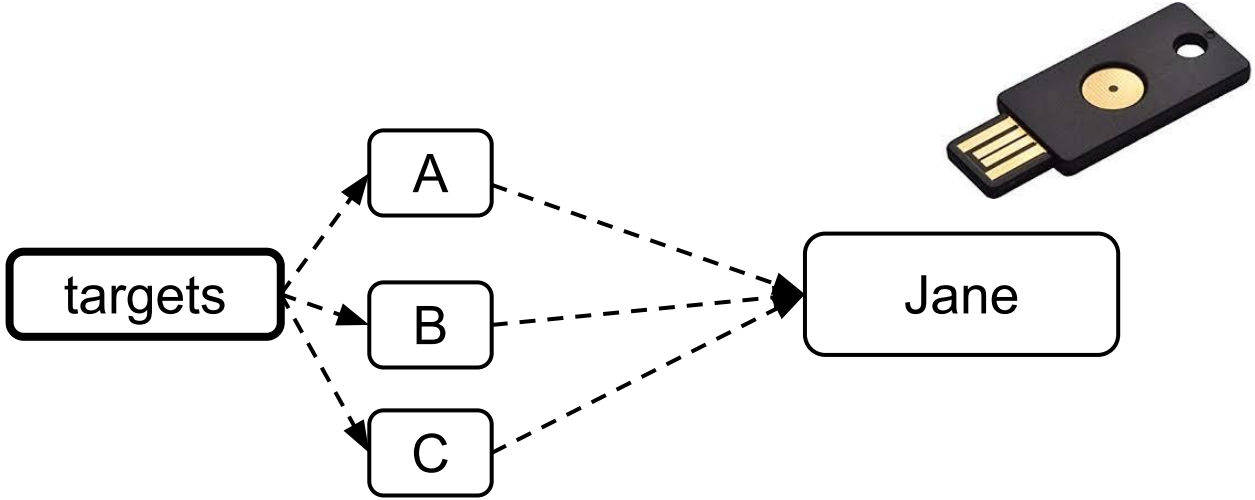
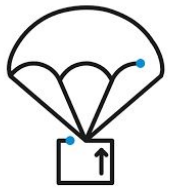


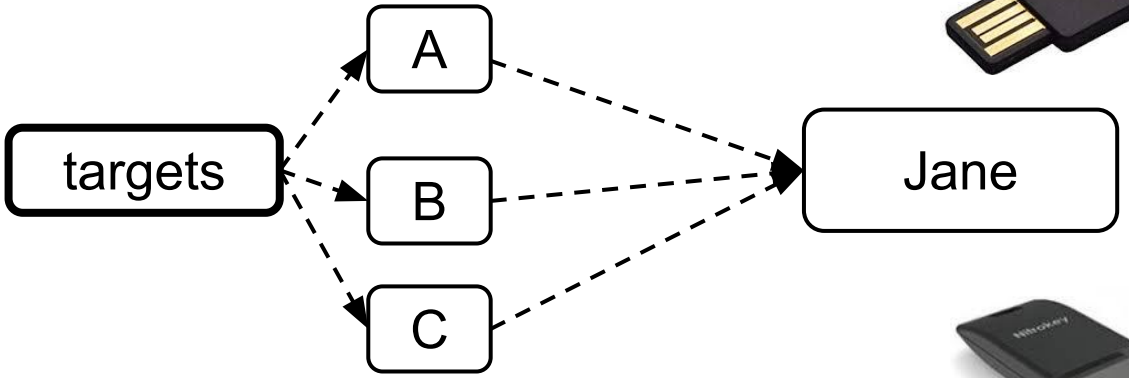
TAP 8:
Key Rotation and Self Revocation

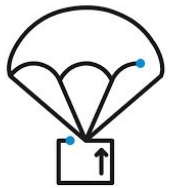
TAP 8: Key rotation / self revocation





TAP 8: Key rotation / self revocation





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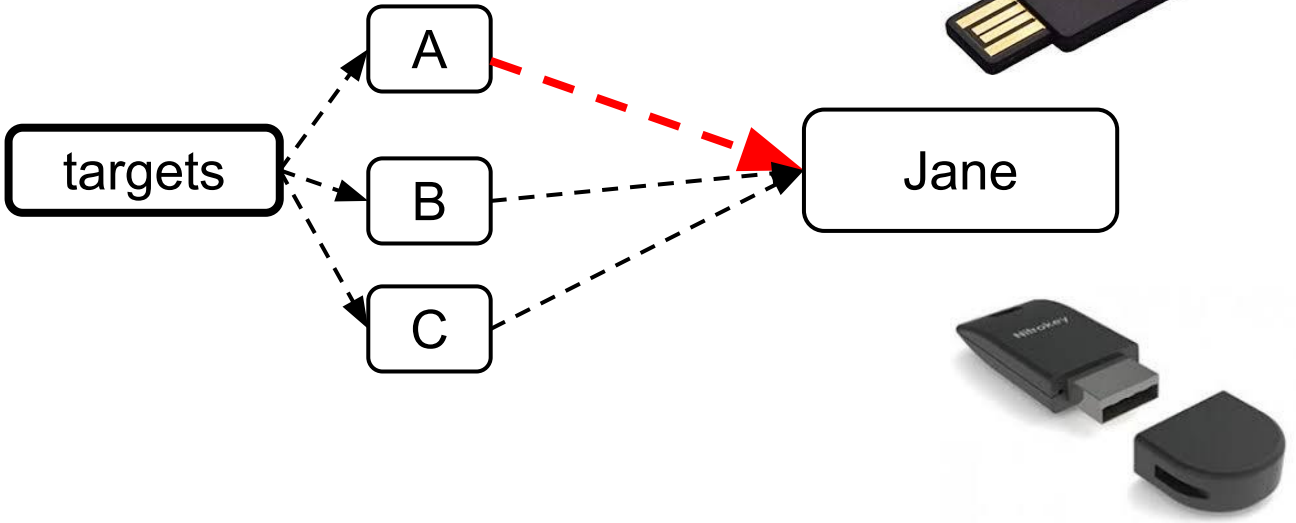

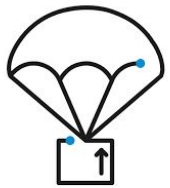

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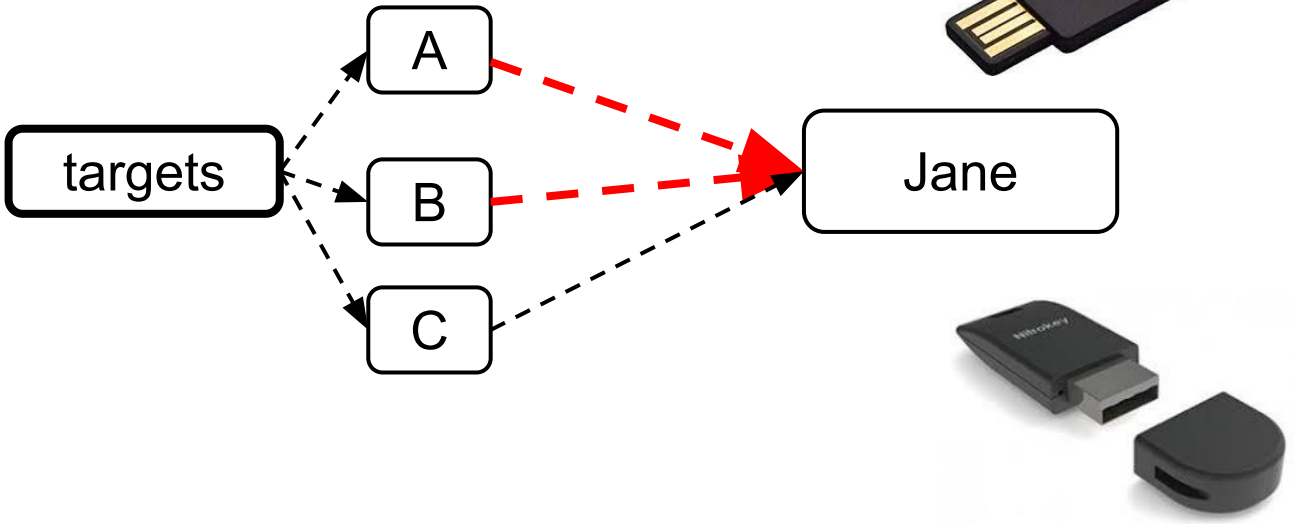

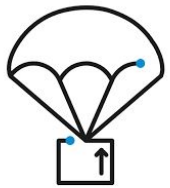

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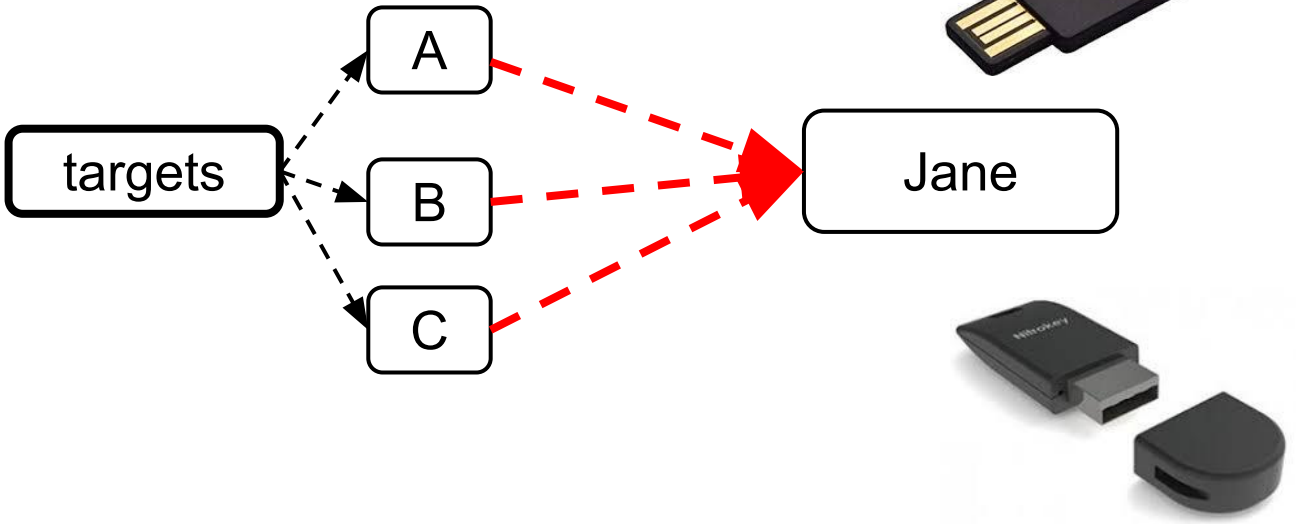

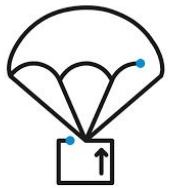

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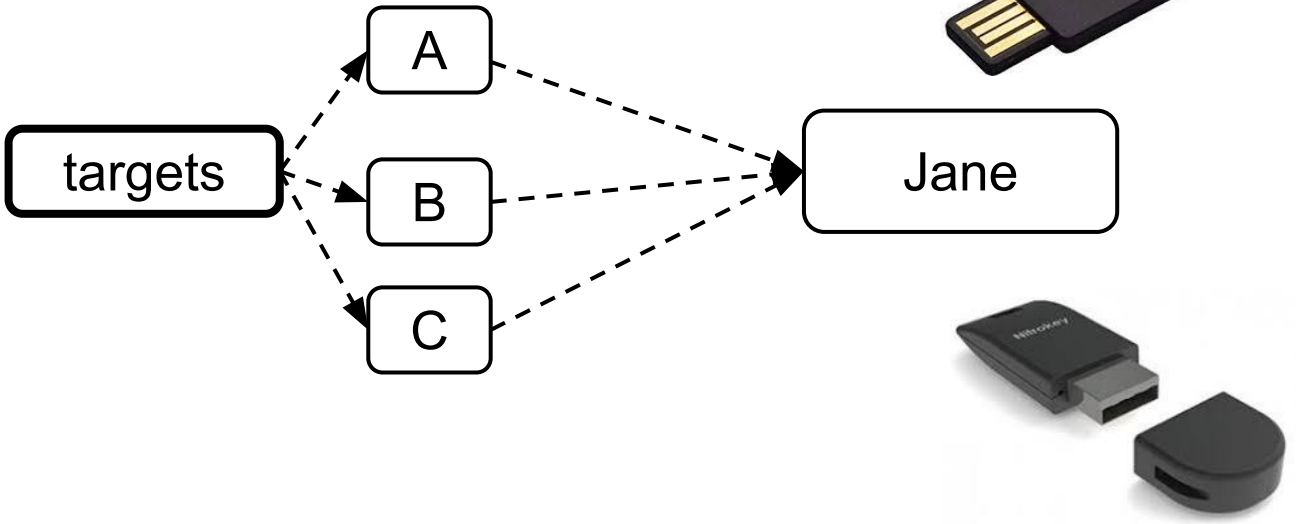

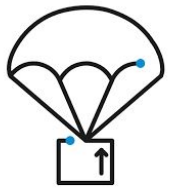

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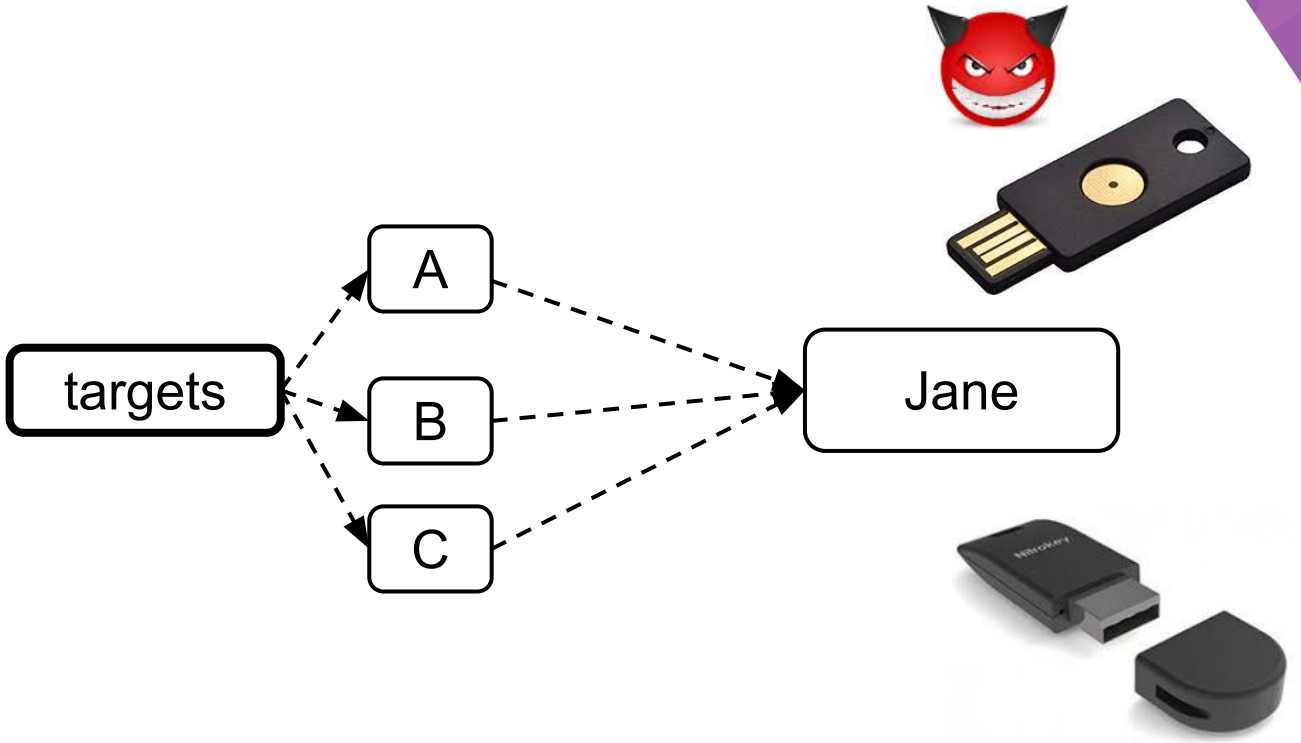

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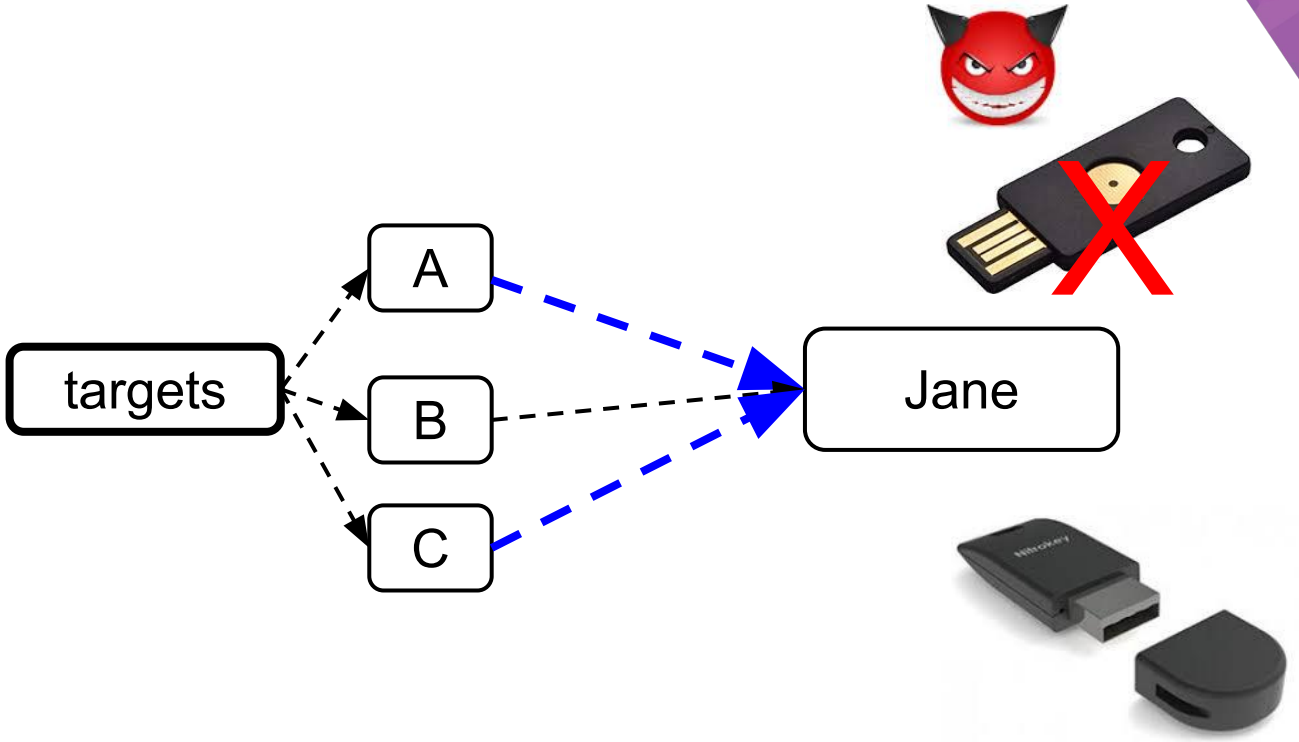

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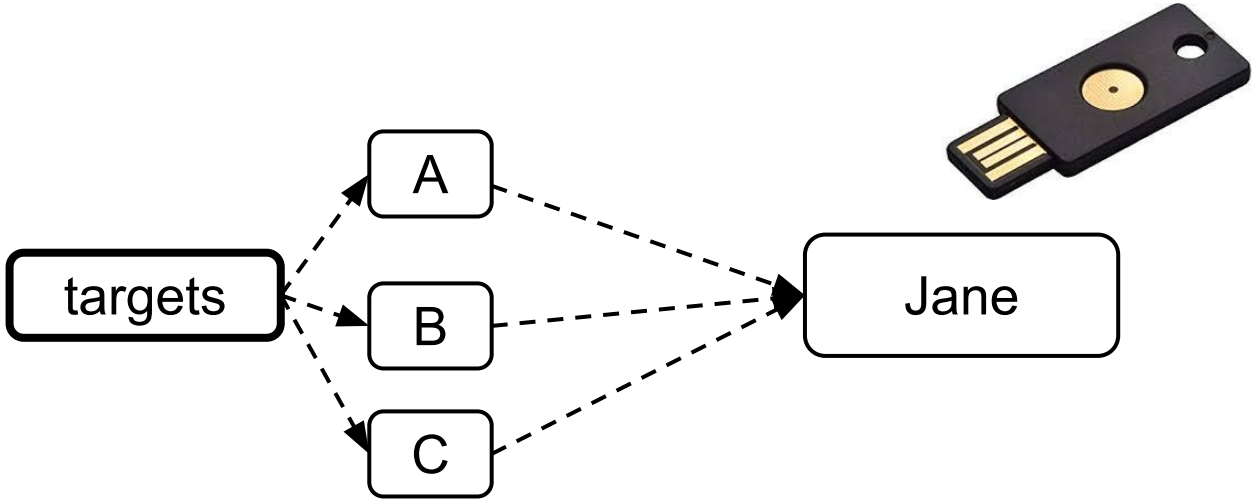

Solution: self rotation / revocation

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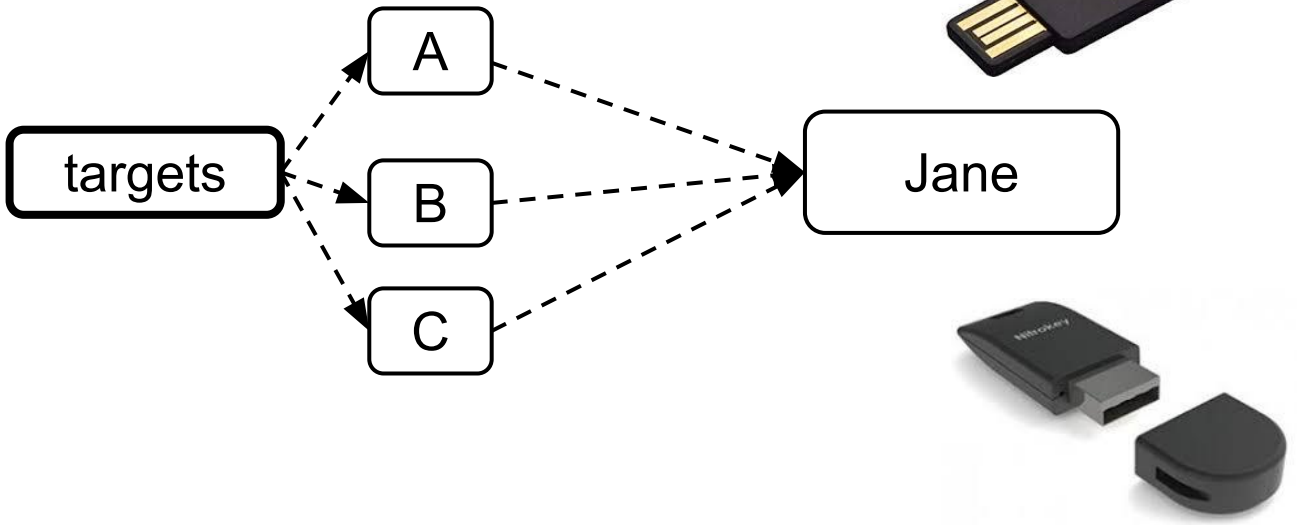

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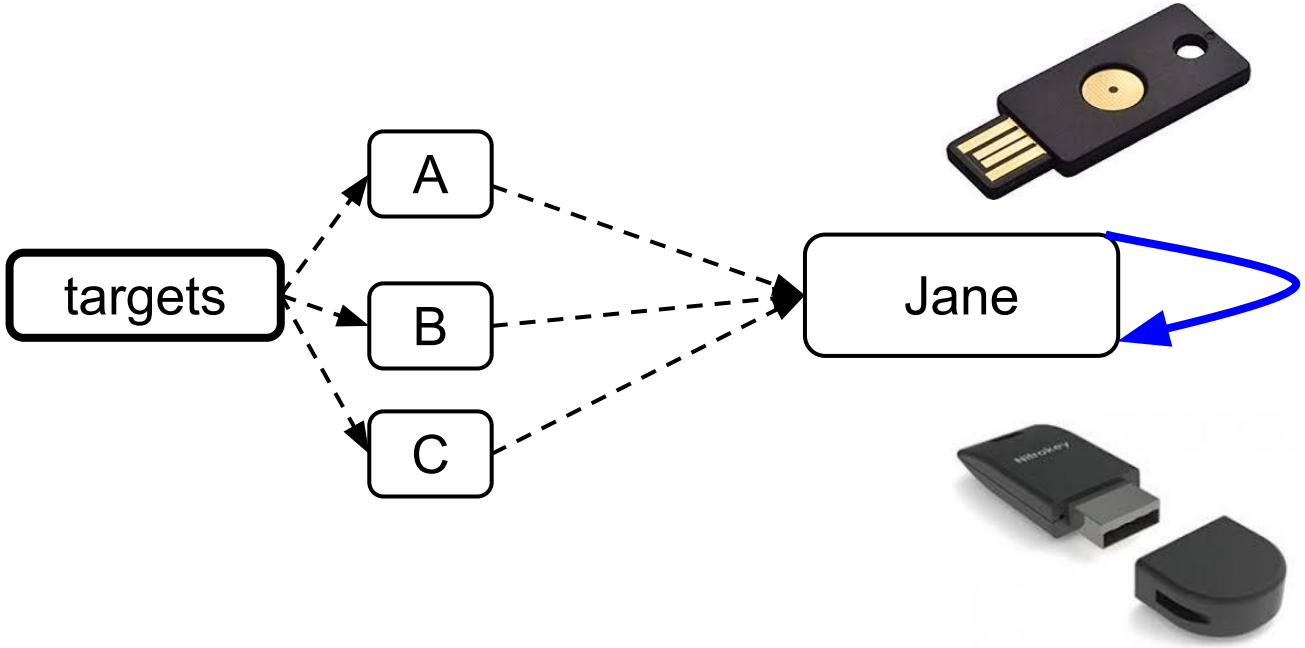

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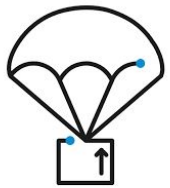

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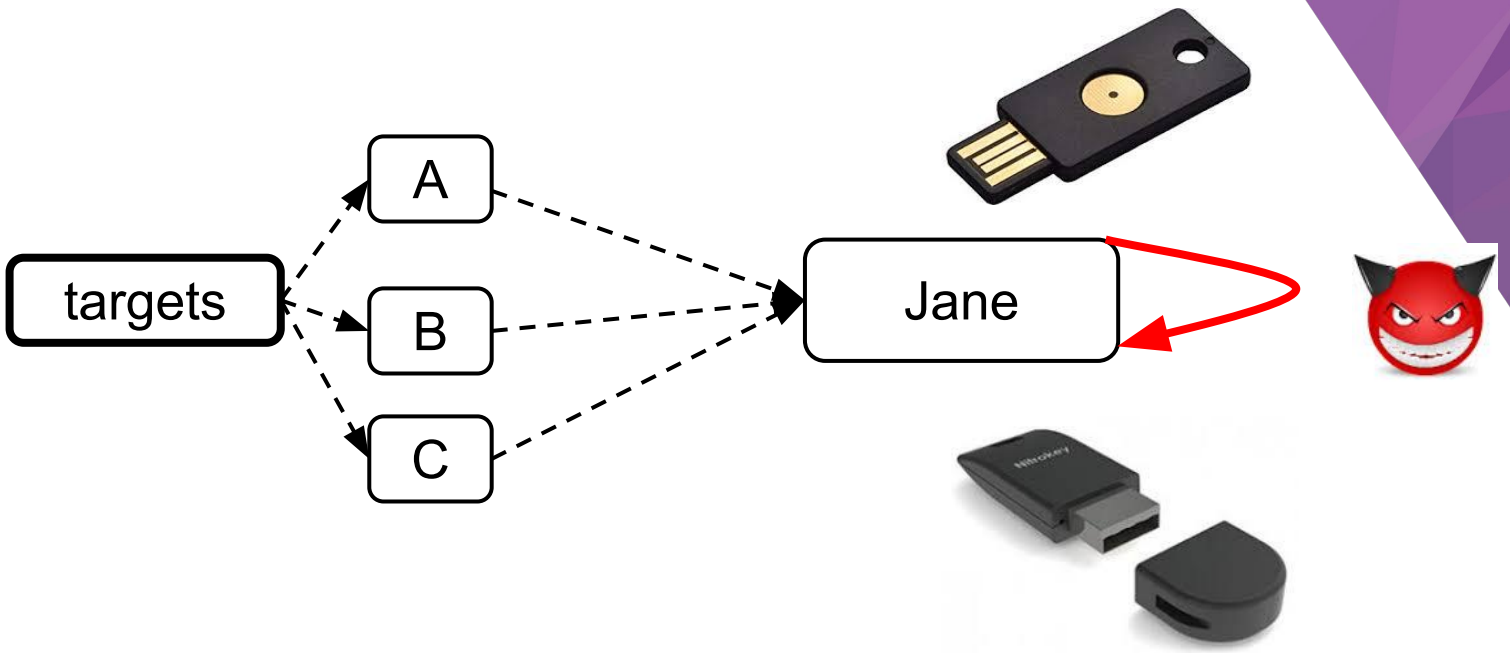

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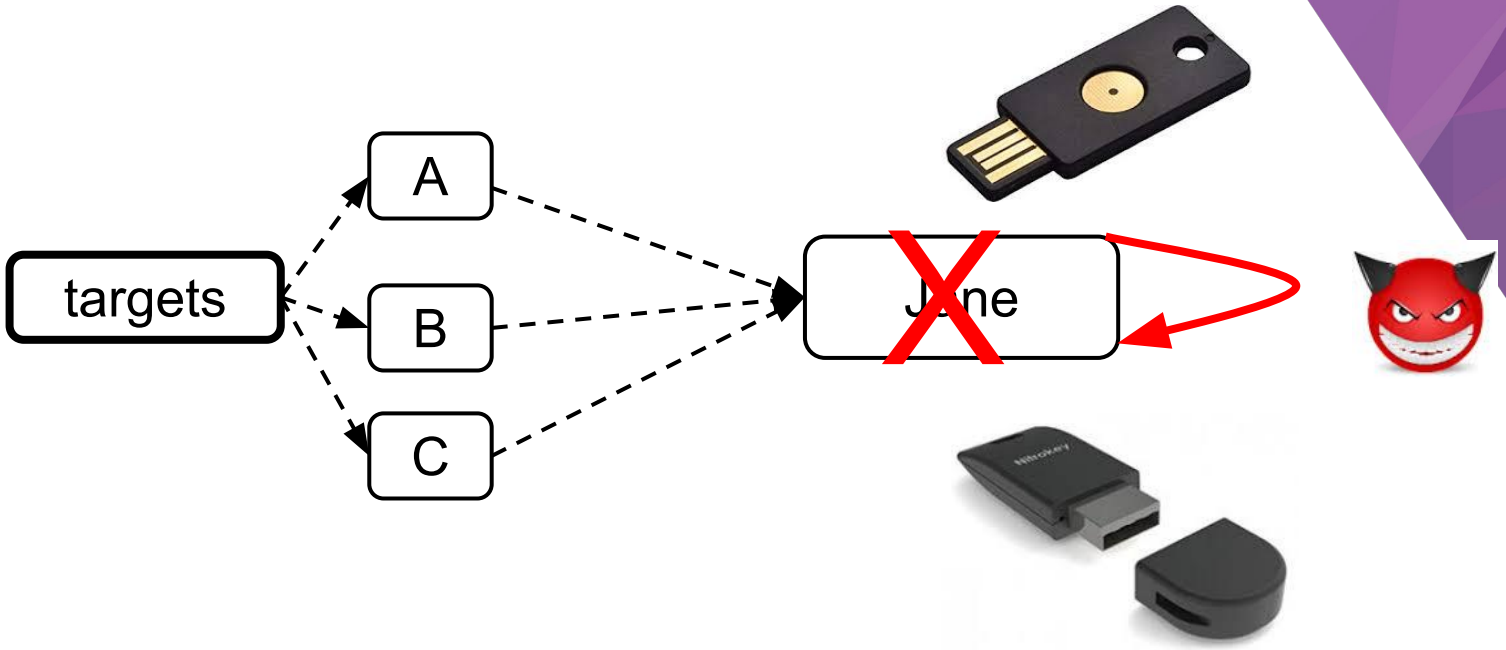

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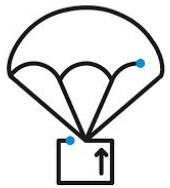

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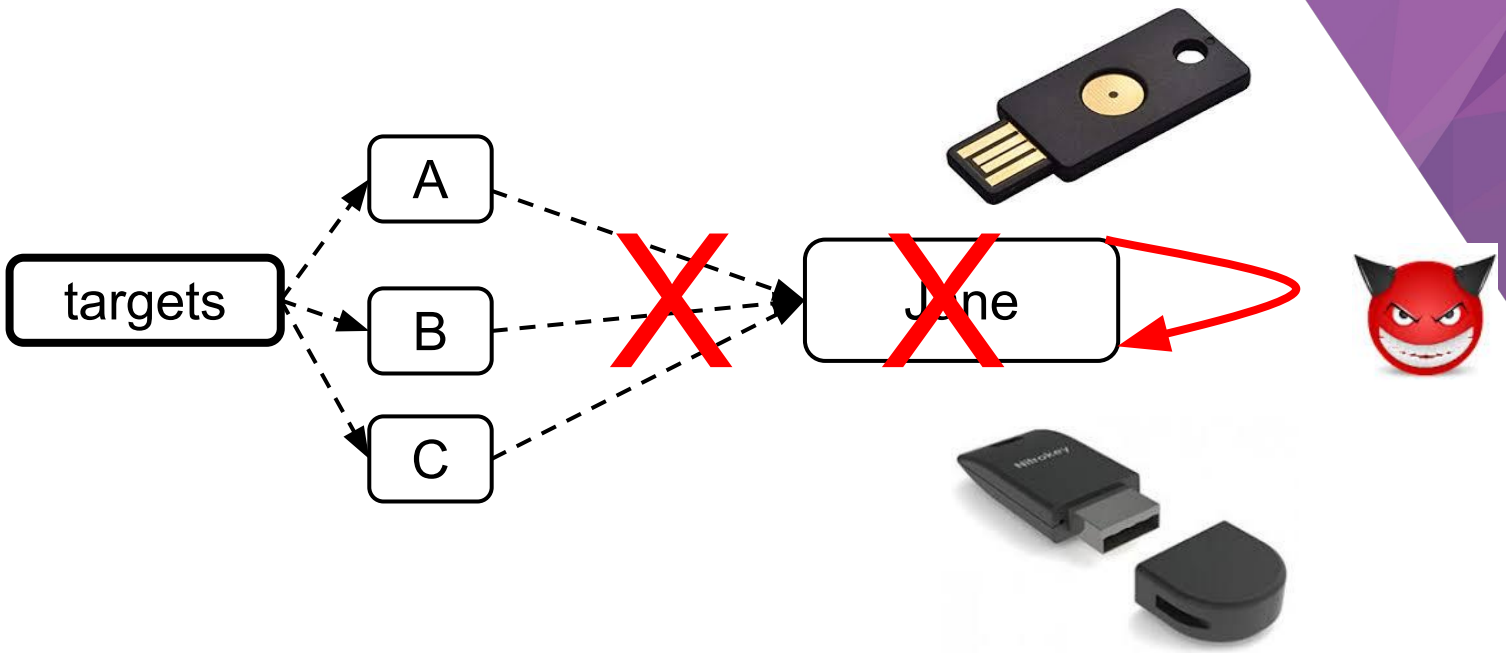
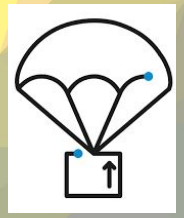


Solution: self rotation / revocation

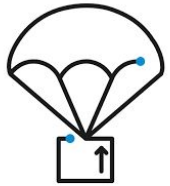
TAP 8: Key rotation / self revocation

Self-managing project use case
Also very cloud-native relevant
Immediately rotate / revoke

- Hannes Mehnert, Justin Cappos, Marina Moore

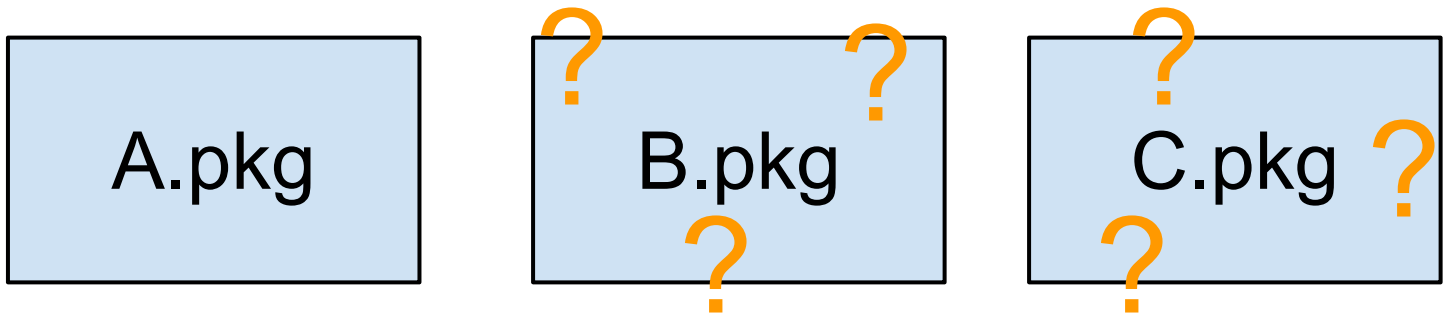


TAP 5:
Split repository location across URLs



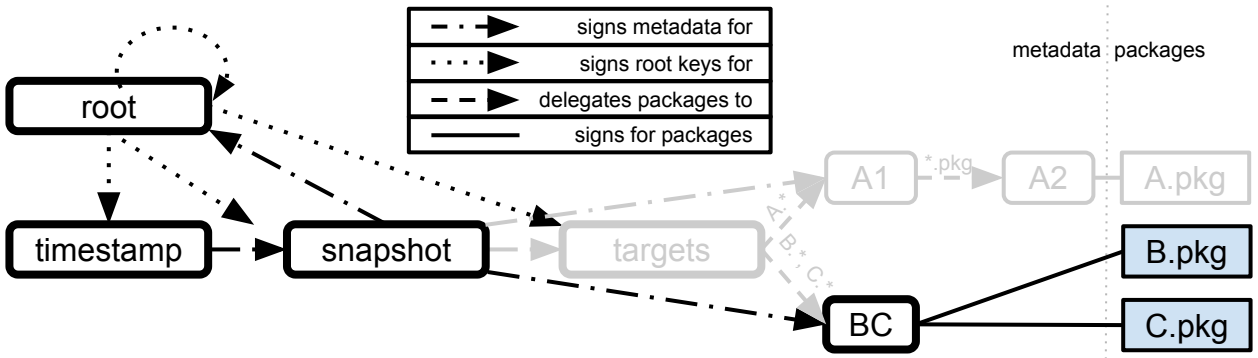
TAP 5: Split repository location across URLs

- Problem: How do you partially trust a repo?
  - What if you need A, but the repo contains other packages?



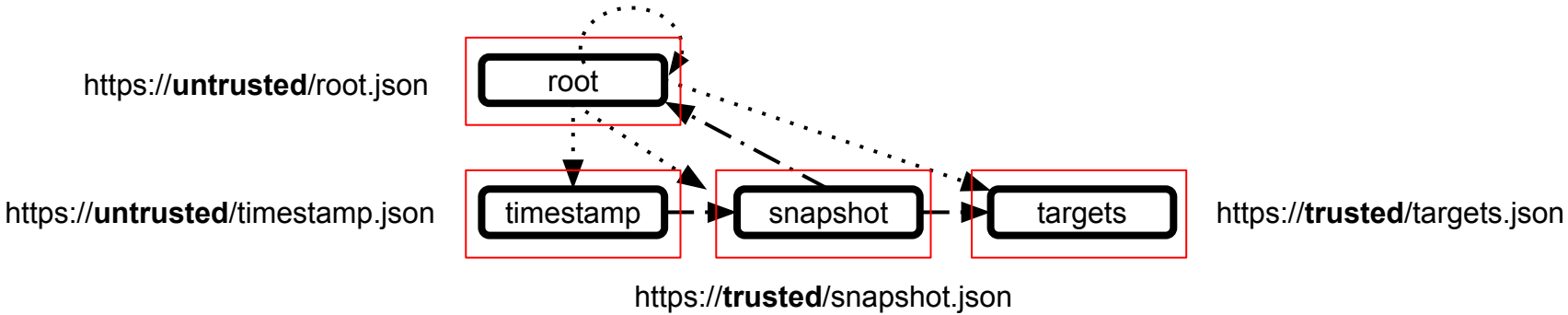
TAP 5: Restricting trust to a single project (example)

- Cloud-native use case
- Can **control what** enterprise **users see** on a repository
- Example: trust **only** this image on Quay



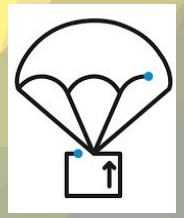
TAP 5: Trusting a mirror only for online metadata (example)

- Alternative Cloud-native use case
- Running Docker Hub in **adversarial** environments
- Potentially hostile server trusted **only** for **timeliness** and **consistency** of images



TAP 5: Split repository location across URLs

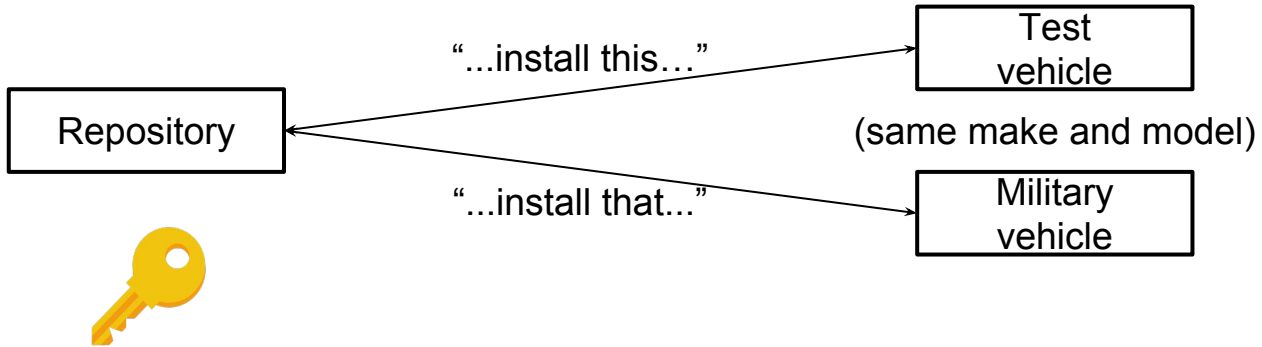
- Came out of discussions with **CoreOS**
  - Evan Cordell, Jake Moshenko

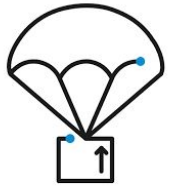


TAP 4:
Multi-repository consensus

Scenario: Repository controls what updates are applied

Question: Should the repository sign this info with a key on the repo or a key kept offline?



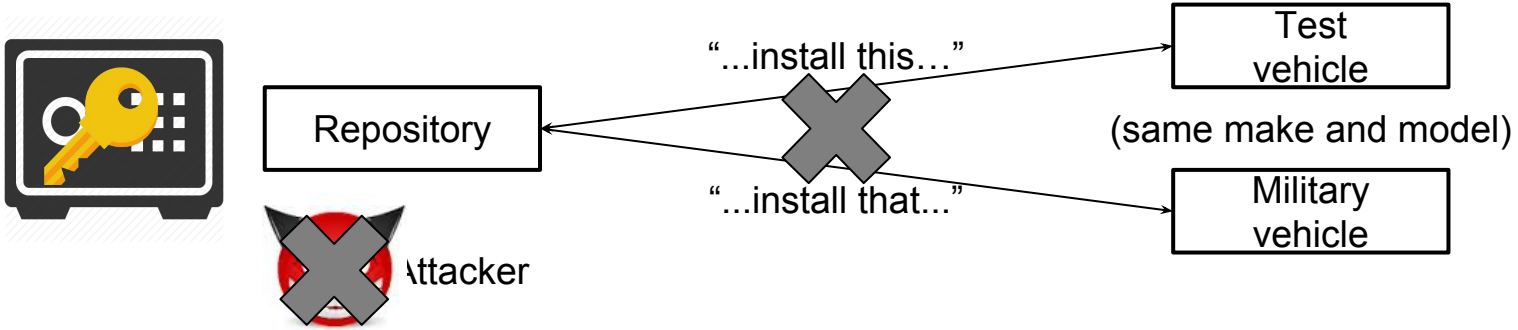


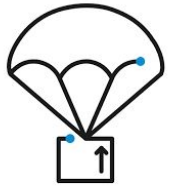
Online key: Flexible but insecure

- Use **online** keys to sign all metadata
- **Pro: on-demand customization**
  - Easy to install different updates on vehicles of same make and model
  - Can instantly blacklist only buggy updates
- **Con: no compromise-resilience**
  - Attackers cannot tamper with metadata without being detected

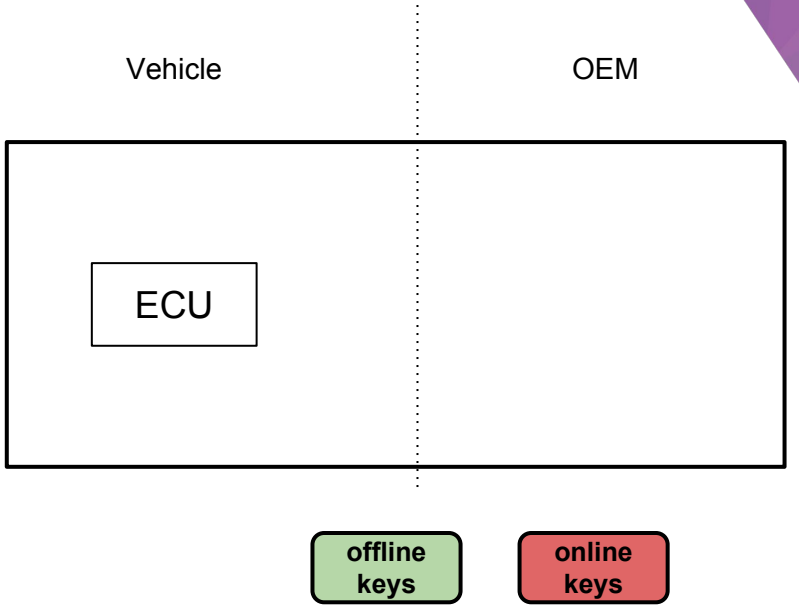
Offline key: Secure but inflexible

- Use **offline** keys to sign all metadata
- **Pro: compromise-resilient**
  - Attackers cannot tamper with metadata without being detected
- **Con: no on-demand customization**
  - Difficult to install different updates on vehicles of same make and model
  - Cannot instantly blacklist only buggy updates



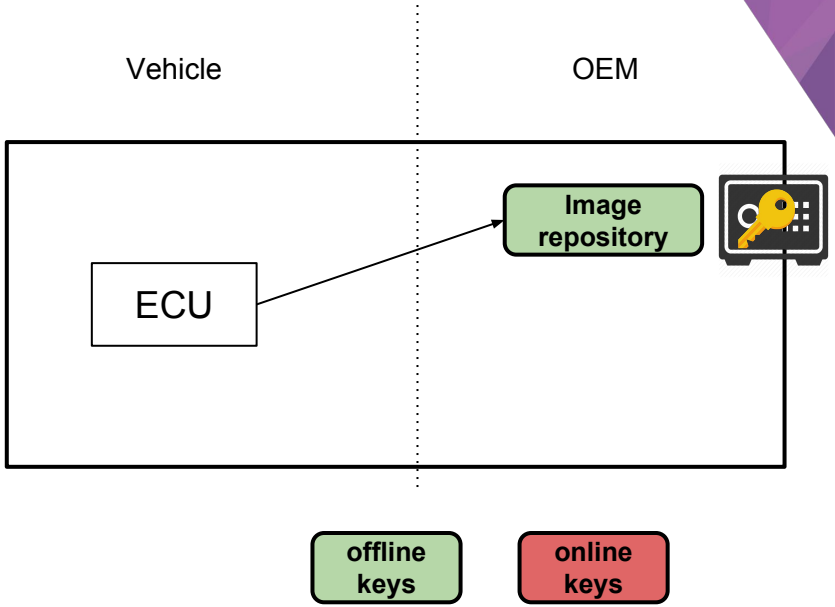


Solution: Use two repositories



Solution: Use two repositories

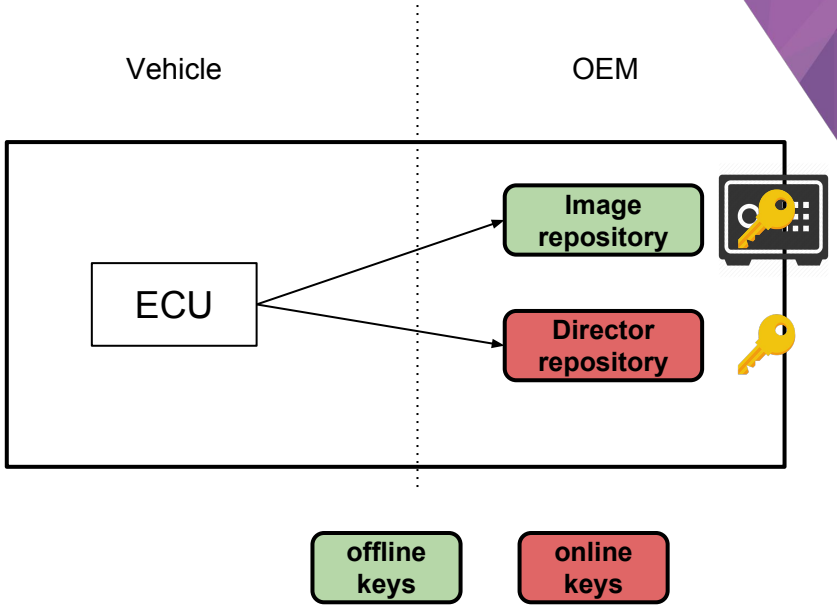
- Image repository
  - Uses **offline** keys
  - Provides signed metadata about all available updates for **all ECUs** on **all vehicles**



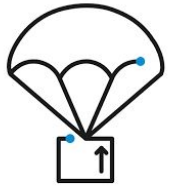
TAP 4: Multi-repository consensus

Solution: Use two repositories

- Image repository
  - Uses offline keys
  - Provides signed metadata about all available updates for all ECUs on all vehicles
- **Director repository**
  - Uses **online** keys
  - Signs metadata about **which updates** should be installed on **which ECUs** on a vehicle



Cloud native relevance: Nation state attackers



TAP 4: Multi-repository consensus

Strong involvement from automakers [Uptane]

- Work closely with vendors, OEMs, etc.
- Many top suppliers / vendors adopted Uptane in future cars!
  - ~12-35% of cars on US roads
- Automotive Grade Linux
- IEEE / ISTO standardization
  - Vibrant community
  - Dozens of institutions

AUTOMOTIVE GRADE LINUX

POPULAR SCIENCE

WANT MORE?

TECHNOLOGY

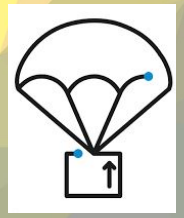
The year's most important innovations in security

A botnet vaccine, a harder drive, and 3-D bag scanner.

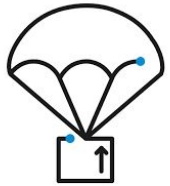
By Kelsey D. Atherton and Rachel Feltman October 17, 2017

This article is a segment of 2017's Best of What's New list. For the complete tabulation of the year's most transformative products and discoveries, head right this way.

Cloud Native help from CoreOS (Evan Cordell and Jake Moshenko)

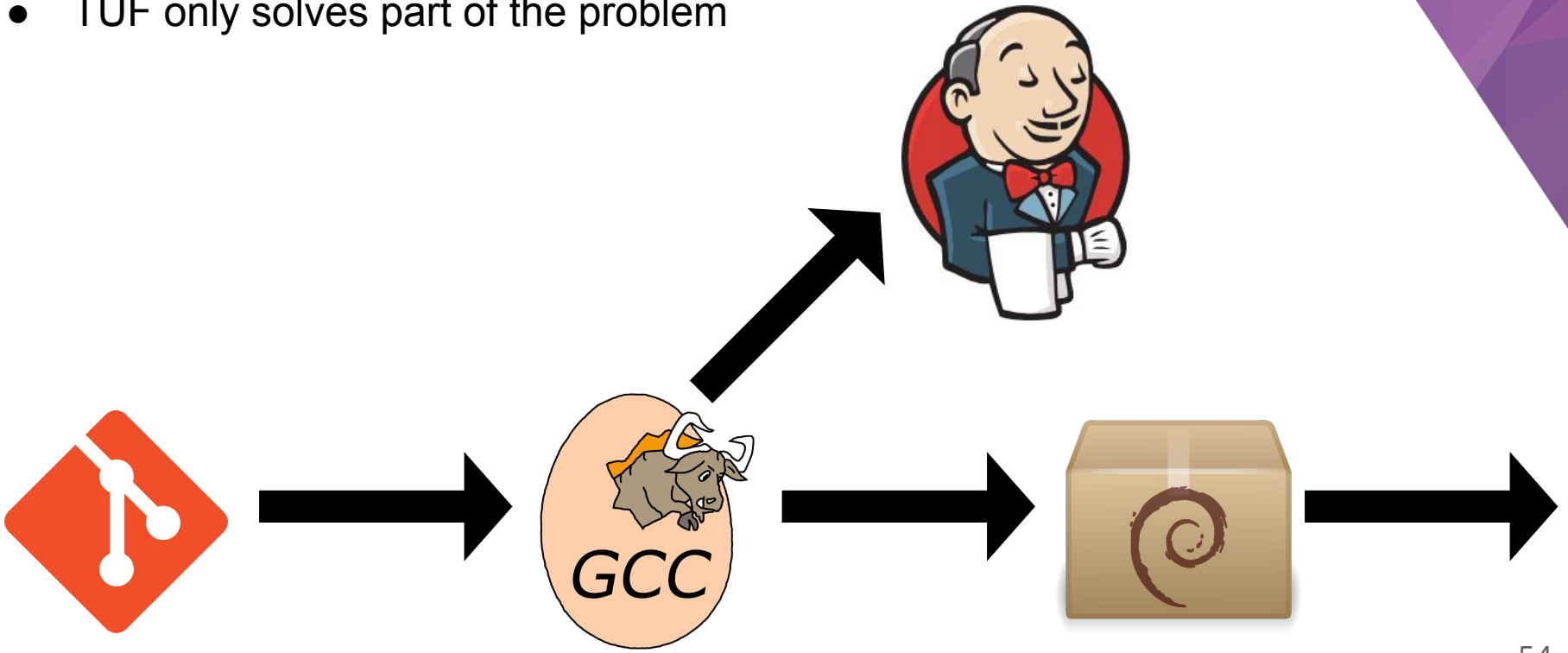


Supply Chain Security with TUF and in-toto



Supply chain security with in-toto

- TUF only solves part of the problem



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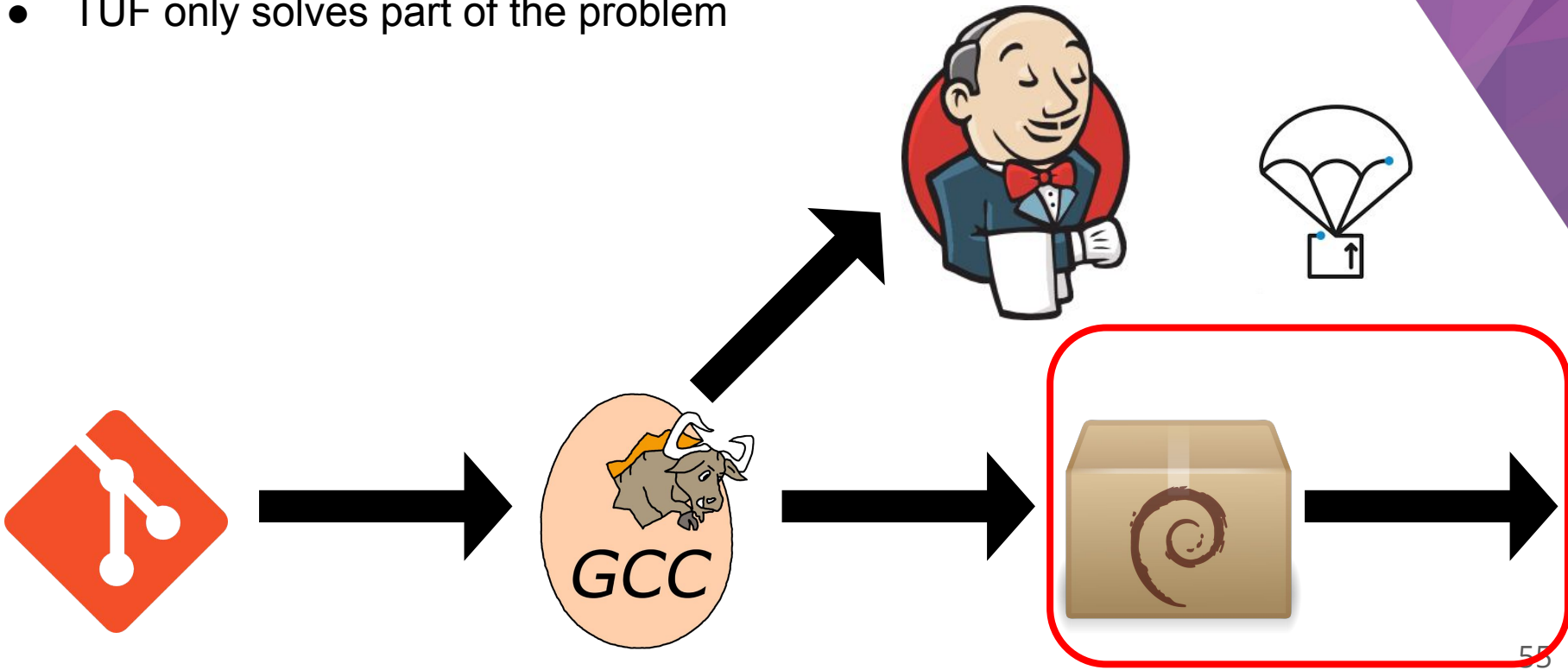
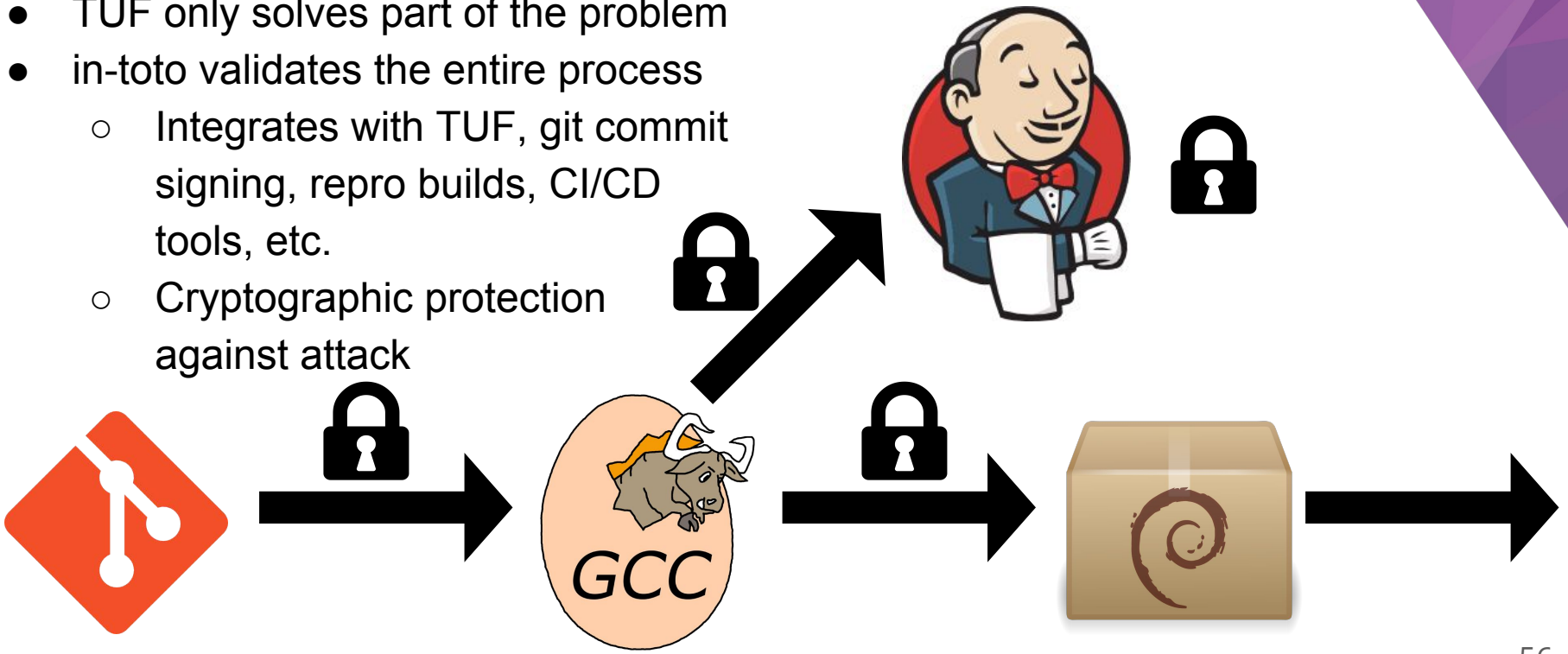
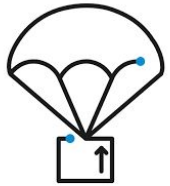


Supply chain security with in-toto

- TUF only solves part of the problem
- in-toto validates the entire process
  - Integrates with TUF, git commit signing, repro builds, CI/CD tools, etc.
  - Cryptographic protection against attack





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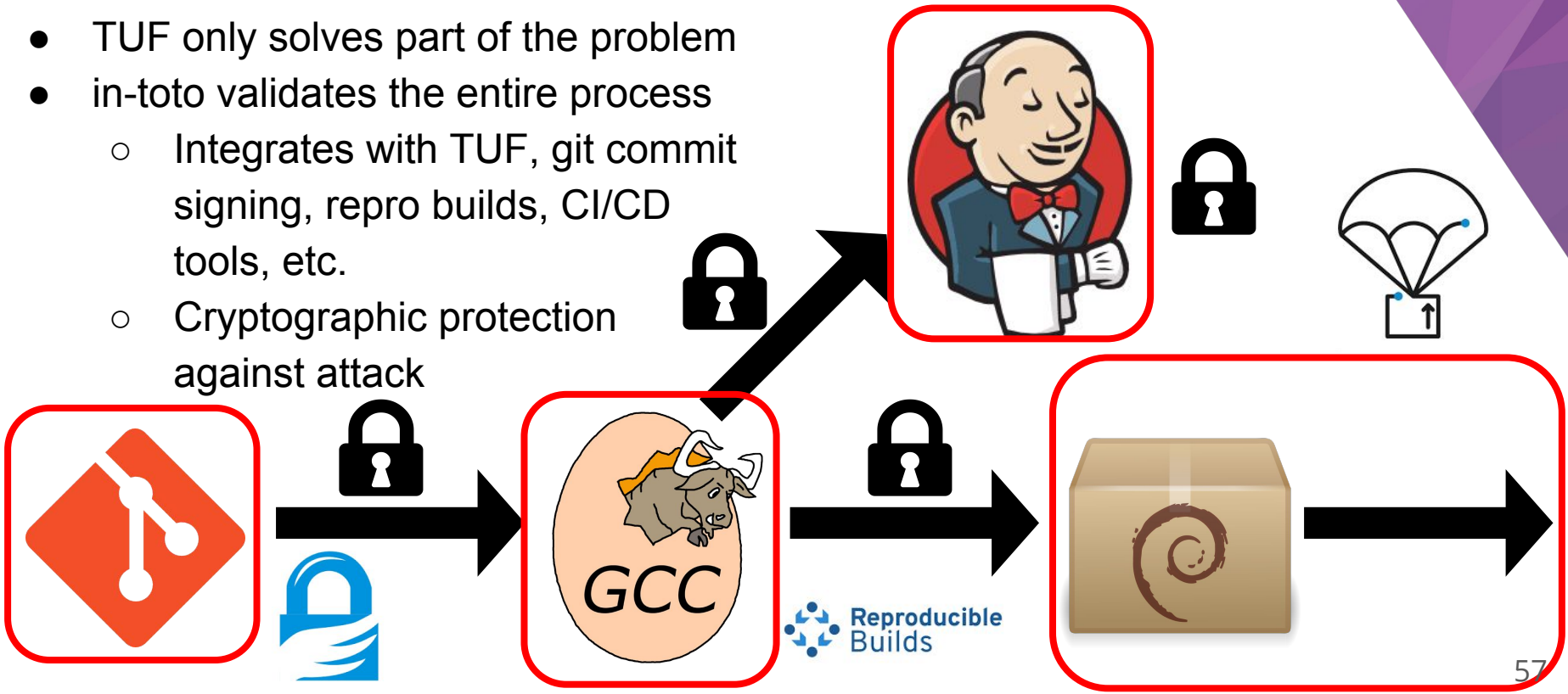

Supply chain security with in-toto

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Supply chain security with in-toto

kubernetes

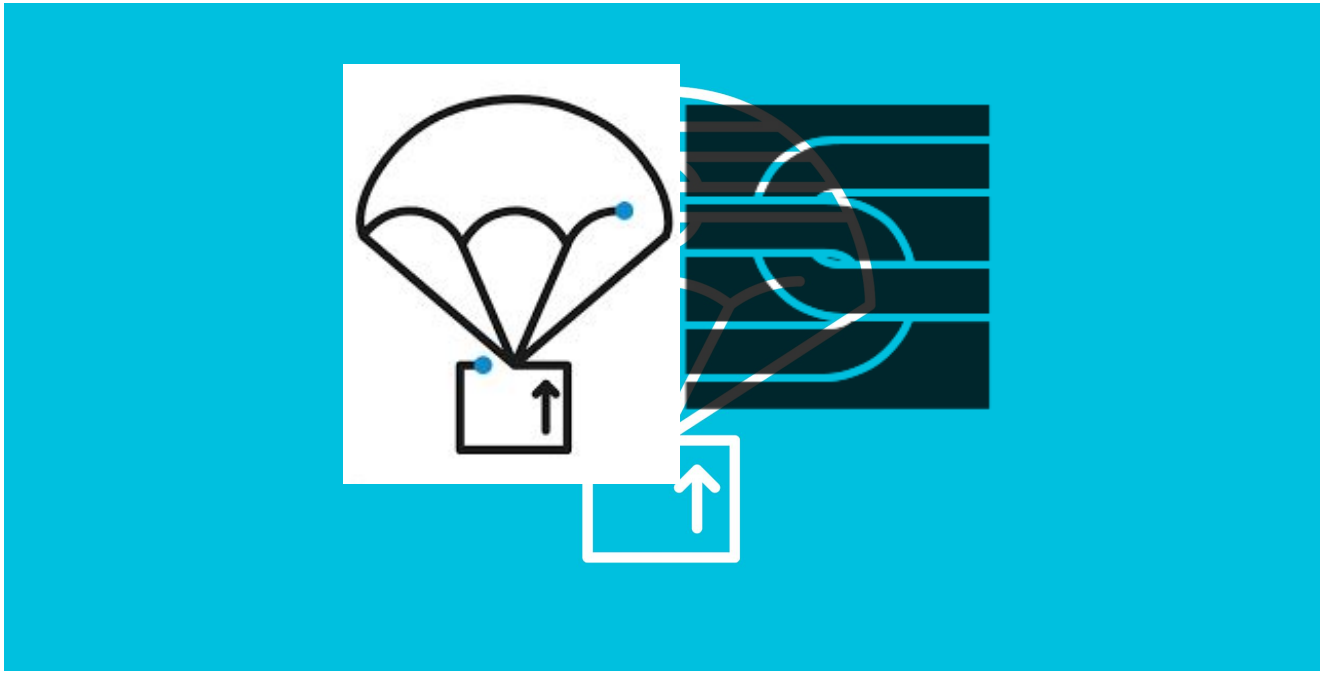
controlplane

DATADOG

debian

reproducible-builds.org

Why TUF + in-toto

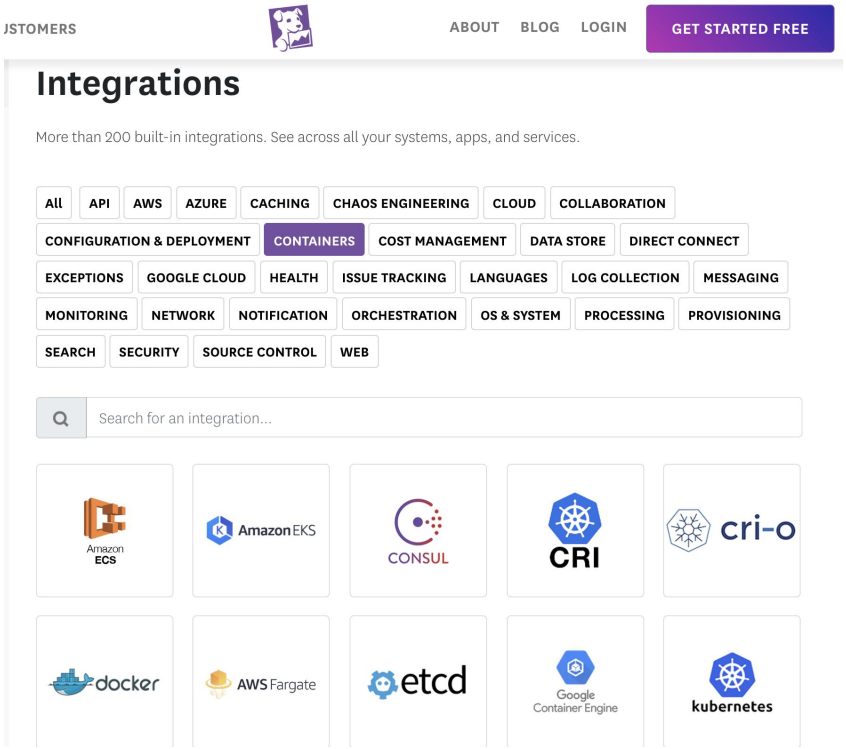


TUF and in-toto in practice:

Datadog
Agent
Integrations

Datadog, Agent, and Agent integrations

- 3 pillars of **Datadog** monitoring
  - Infrastructure metrics
  - App performance
  - Logs
- **Agent**
  - Collects events and metrics
- **Agent integrations**
  - Add-ons / plug-ins
  - > 100 and counting

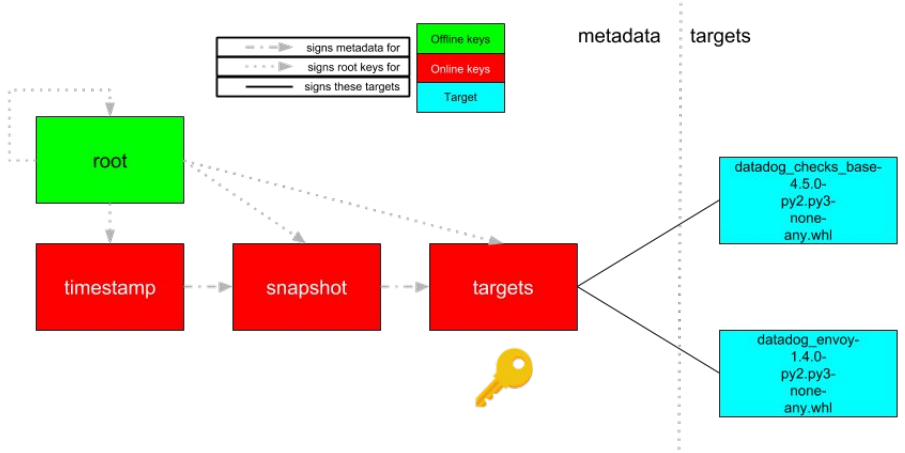


Decoupling integrations from Agent release cycle

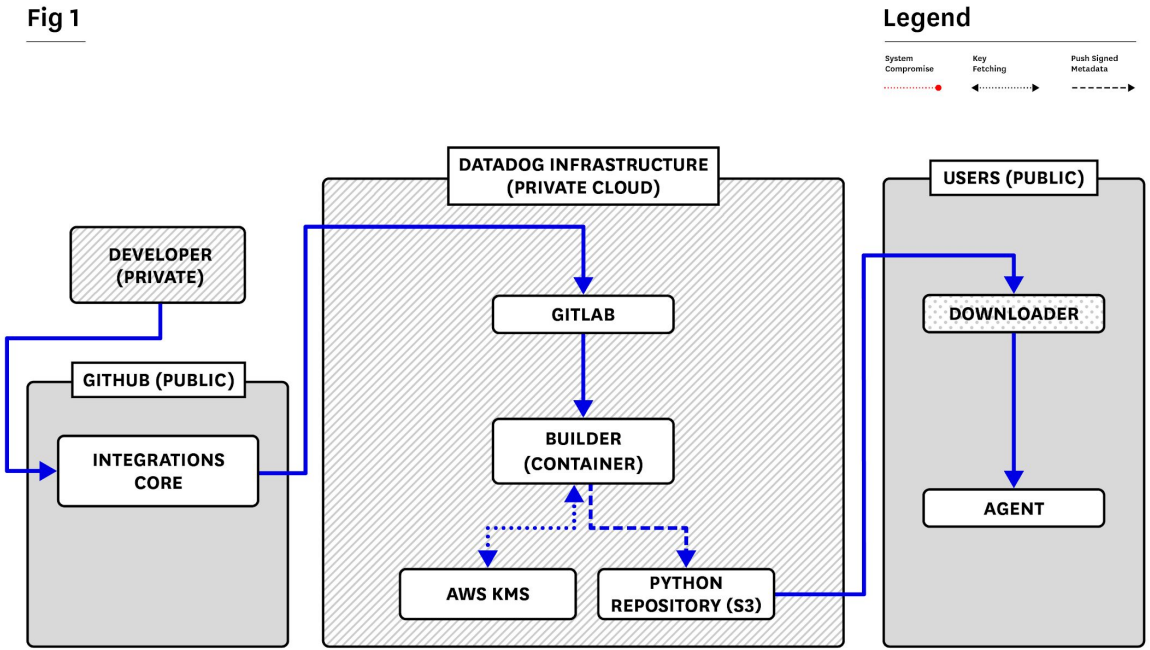
- **Agent**
  - 6-week release cycle
- **Agent integrations**
  - Latest versions bundled with the Agent every 6 weeks
  - But we also want to publish new versions *independently* of the Agent
  - So customers can beta-test immediately

State-of-the-art: CI/CD

- **CI/CD**
  - Continuous integration / continuous deployment
- **Pros**
  - Faster deployments
  - Clean build environments
  - More secure handling of code-signing keys

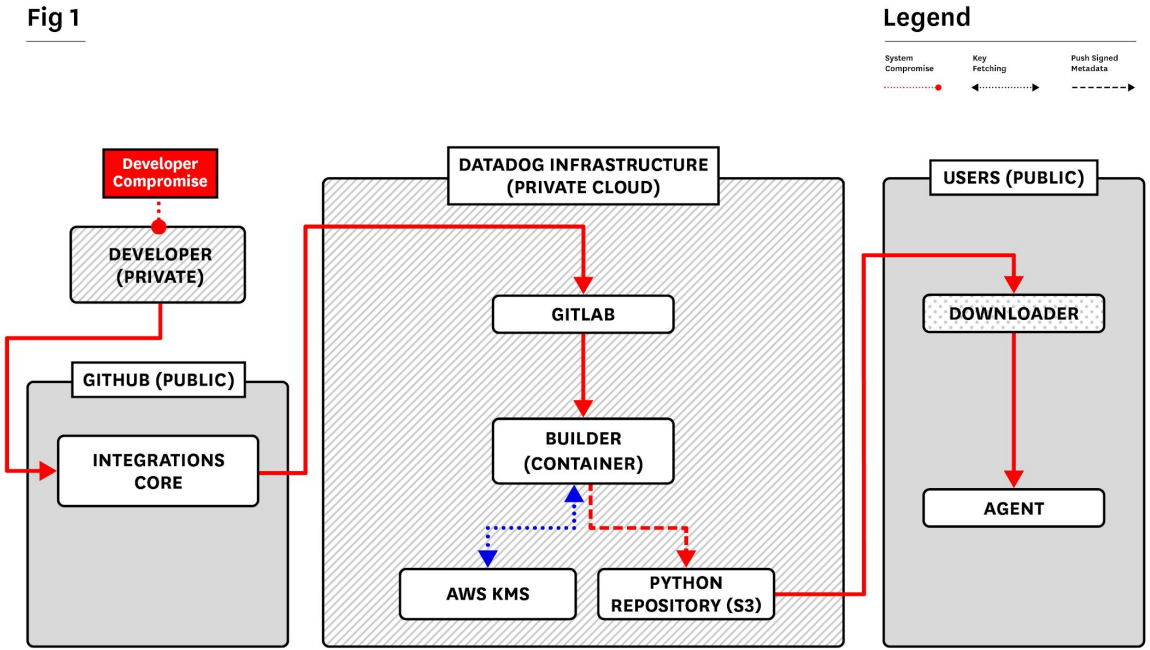


State-of-the-art: what can go wrong?



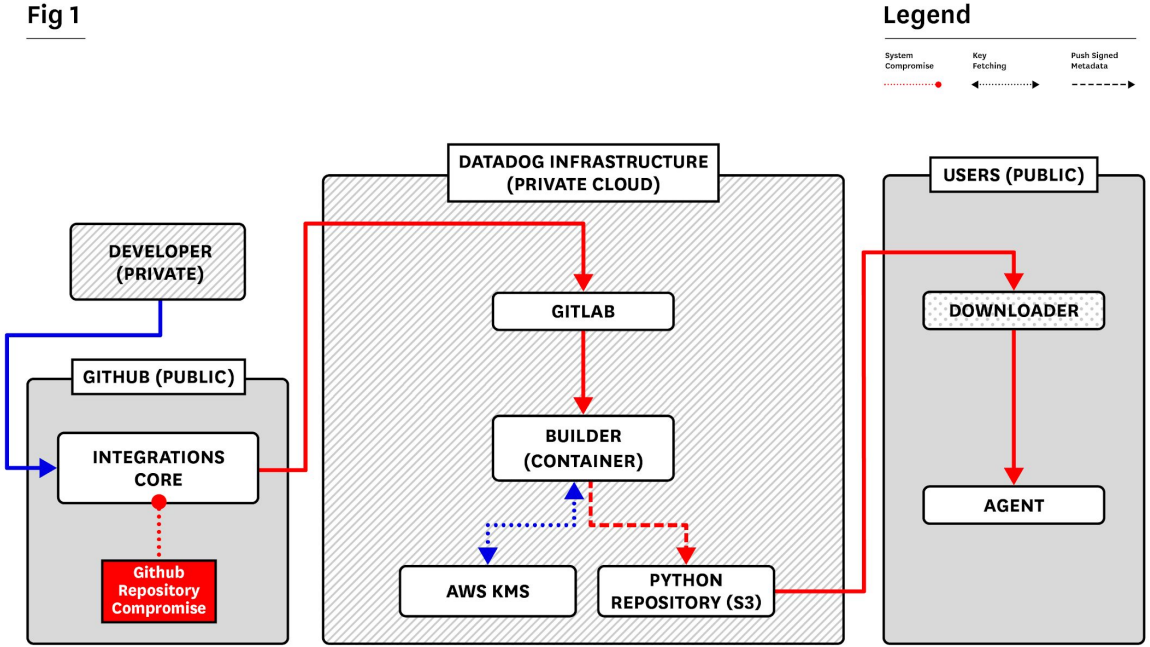
State-of-the-art: developer key compromise

Fig 1



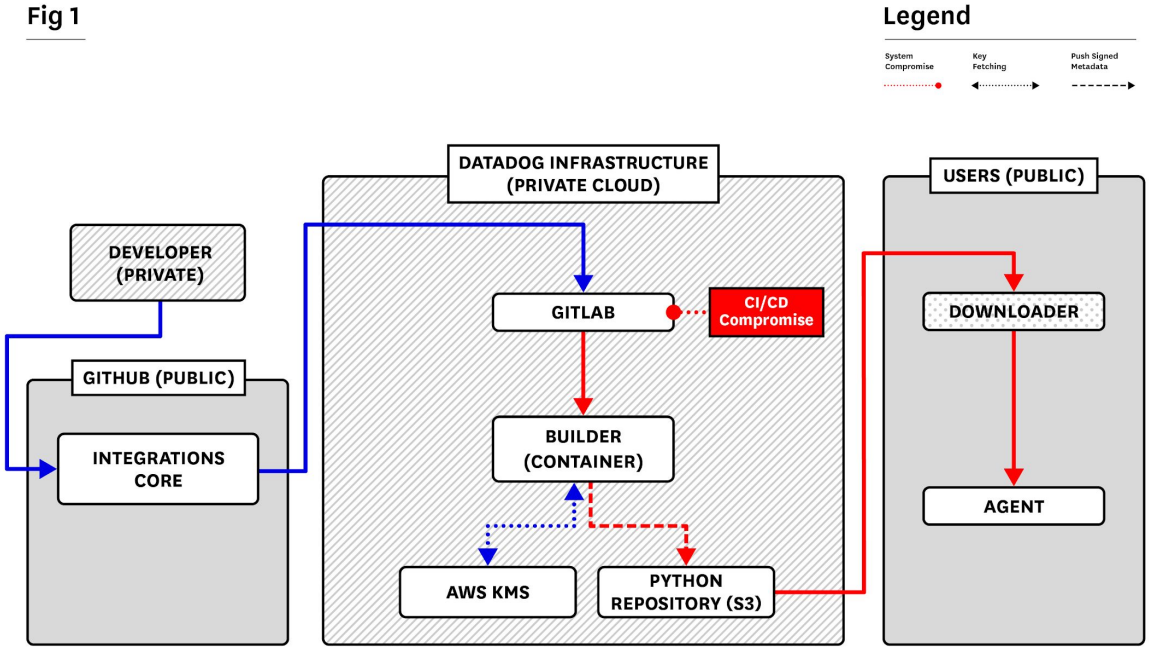
State-of-the-art: VCS repository compromise

Fig 1

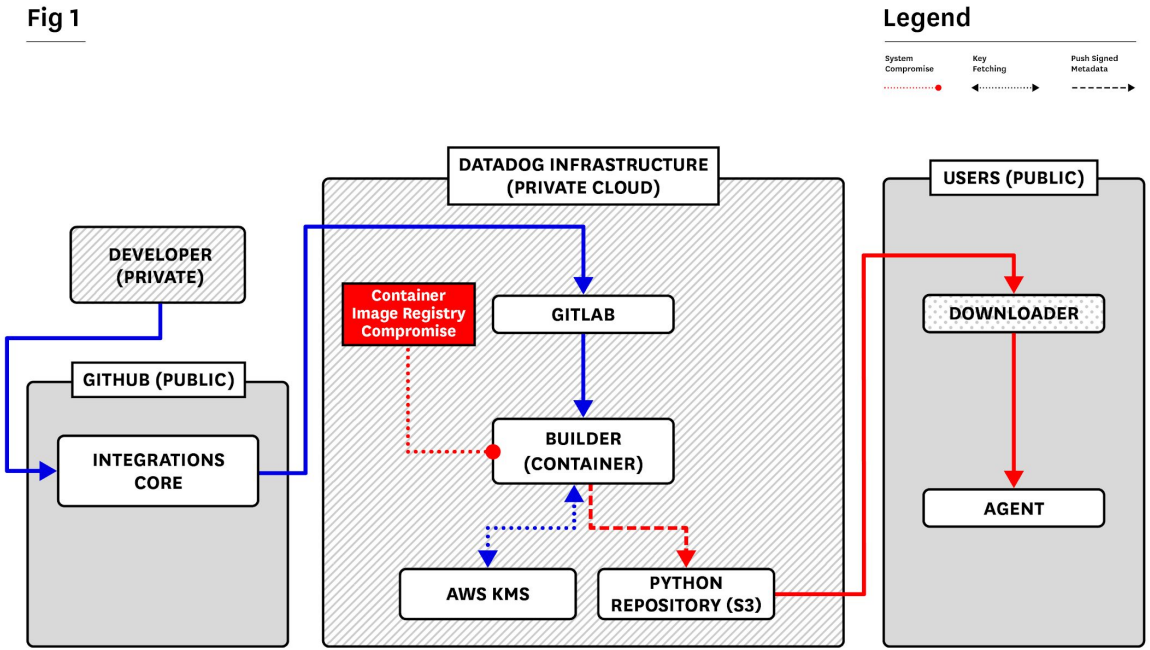


State-of-the-art: CI/CD system compromise

Fig 1

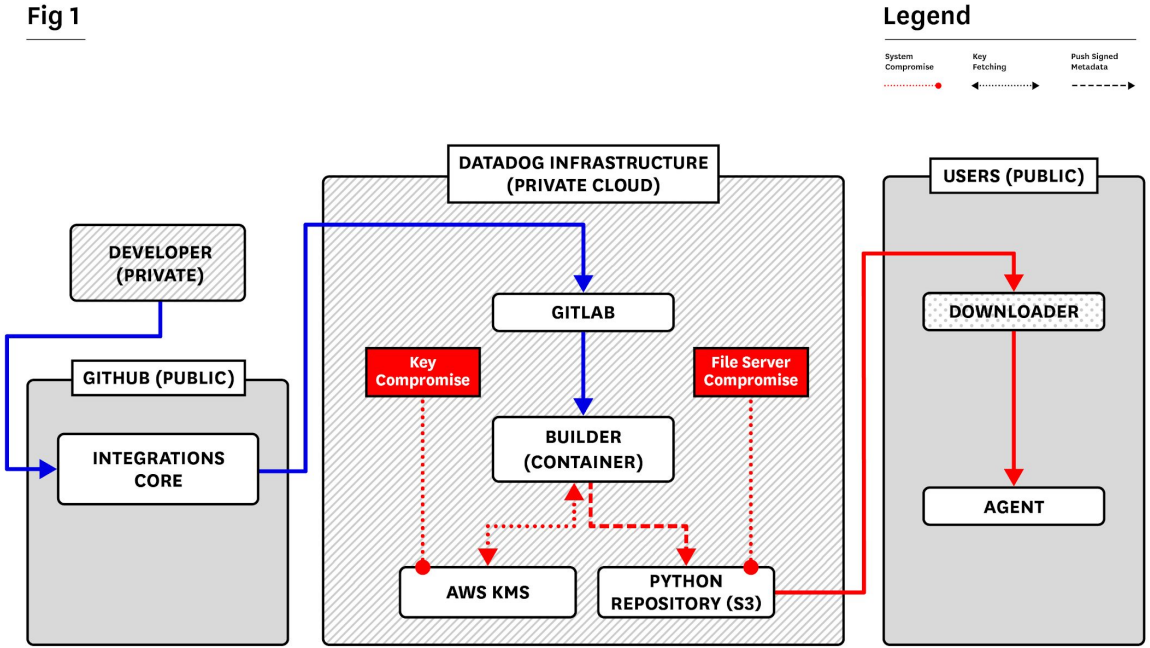


State-of-the-art: container image registry compromise



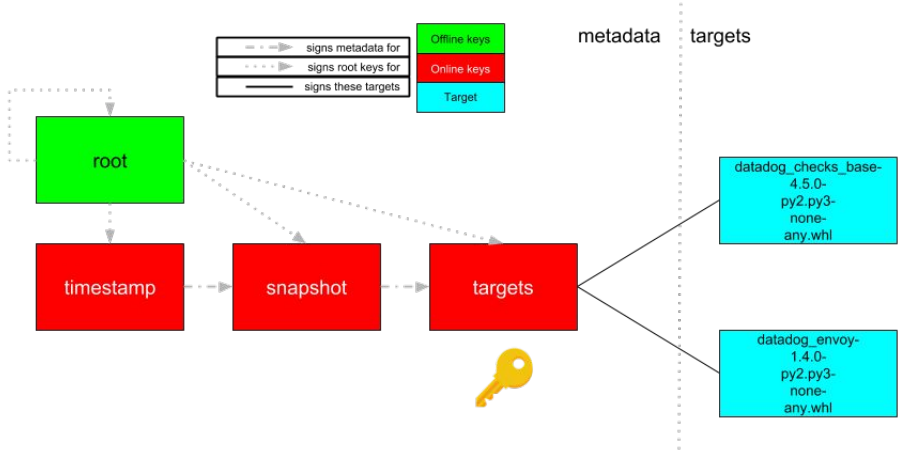
State-of-the-art: key + file server compromise

Fig 1



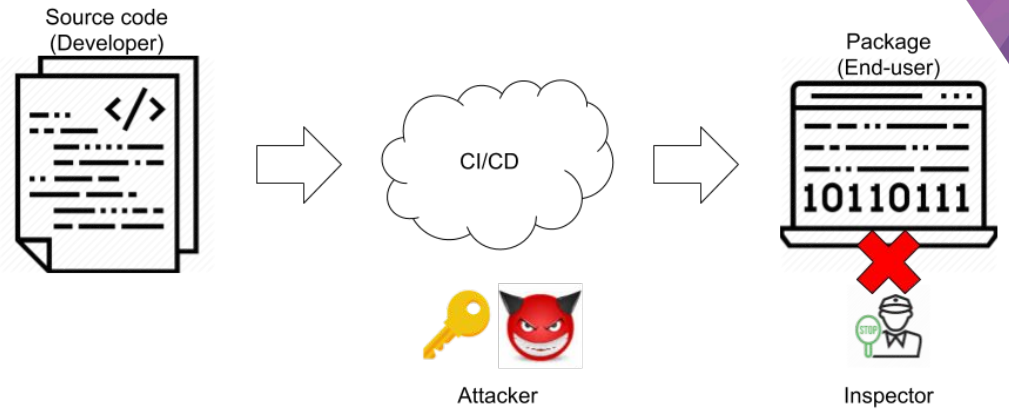
State-of-the-art: no compromise-resilience

- CI/CD
  - Continuous integration / continuous deployment
- Pros
  - Faster deployments
  - Clean build environments
  - More secure handling of code-signing keys
- **Cons**
  - **No compromise-resilience**



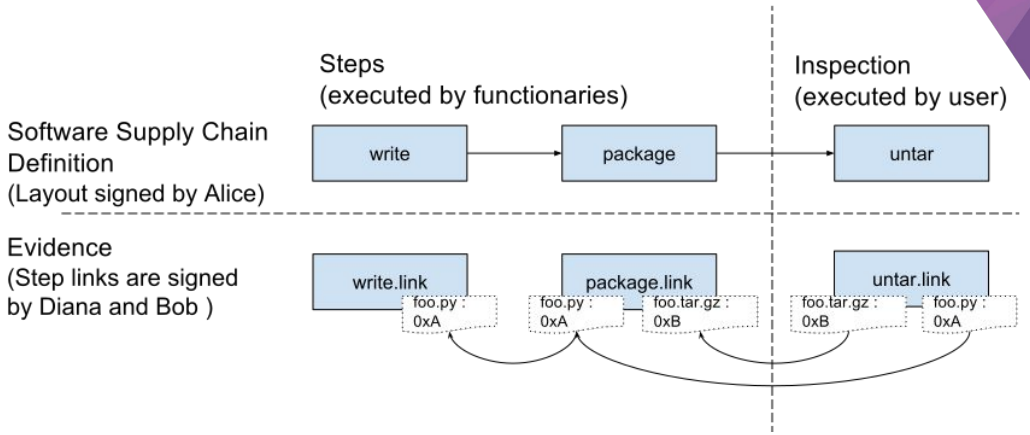
Key idea: tamper-evident CI/CD

- **Tamper-evident**
  - *x* <=> source code
  - *f* <=> authentic CI/CD pipeline
  - *y* <=> package
  - Does *y* = *f(x)*?
- **Compromise-resilience**
  - End-users download *x*, *f*, and *y*
  - If *y* ≠ *f(x)*, then reject *y*



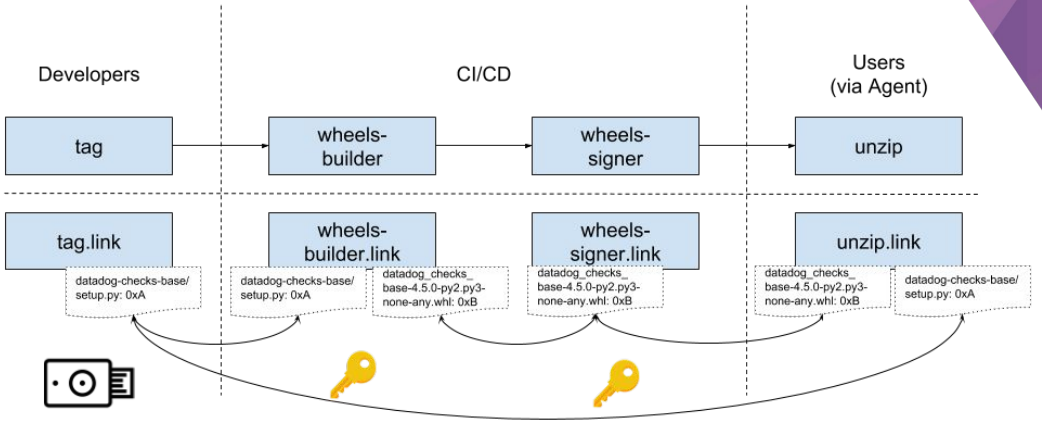
in-toto: software supply chain integrity

- Pipeline = series of **steps**
  - Every step produces signed link / attestation: “I got this input, and produced that output.”
- **Inspection**
  - Verify whether each step followed pipeline
- Provides **E2E verification** of entire supply chain
- https://in-toto.io



Datadog Agent integrations software supply chain

1. **tag**
   - Developer outputs source code
2. **wheels-builder**
   - Container must receive same source code as in “tag”
   - (Container builds wheels)
   - Container outputs wheels
3. **wheels-signer**
   - Container must receive same wheels as in “wheels-builder”

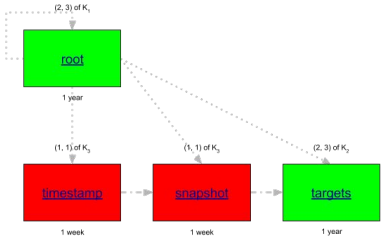


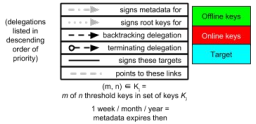
TUF + in-toto = tamper-evident CI/CD

- Offline keys (administrators)
- Semi-offline keys (developers)
- Online keys (CI/CD)

TUF + in-toto = tamper-evident CI/CD

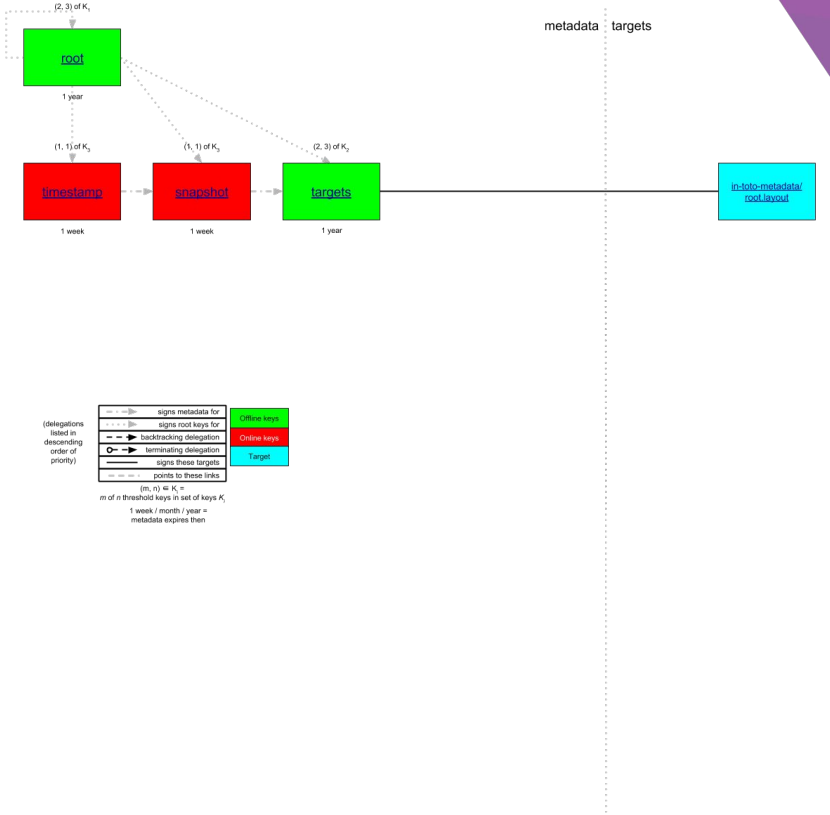
- **Offline** keys (administrators)
  - **TUF root of trust**
- Semi-offline keys (developers)
- Online keys (CI/CD)





TUF + in-toto = tamper-evident CI/CD

- **Offline** keys (administrators)
  - TUF root of trust
  - **in-toto software supply chain**

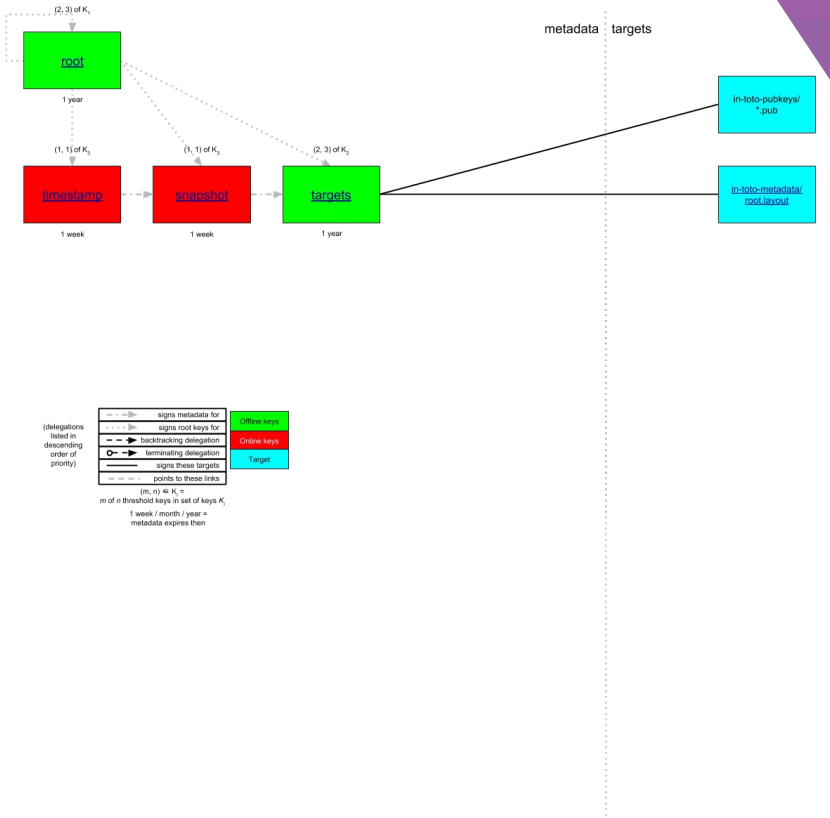


- **Semi-offline** keys (developers)
  - **Python source code**

- Online keys (CI/CD)

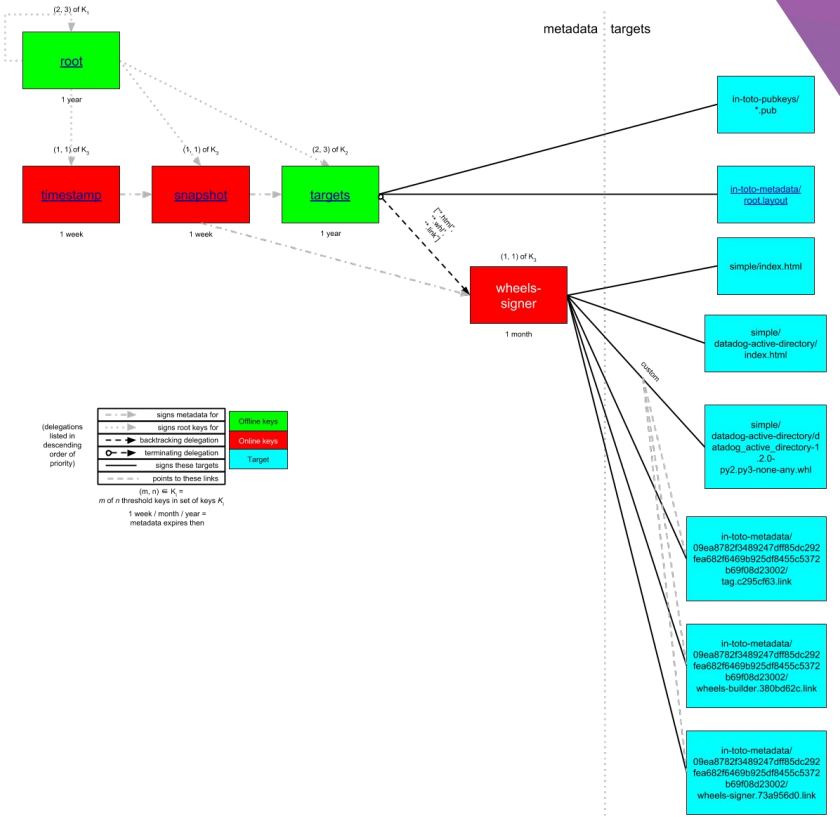
TUF + in-toto = tamper-evident CI/CD

- **Offline** keys (administrators)
  - TUF root of trust
  - in-toto software supply chain
  - **Public keys for in-toto software supply chain**
- Semi-offline keys (developers)
  - Python source code
- Online keys (CI/CD)



TUF + in-toto = tamper-evident CI/CD

- Offline keys (administrators)
  - TUF root of trust
  - in-toto software supply chain
  - Public keys for in-toto software supply chain
- Semi-offline keys (developers)
  - Python source code
- **Online** keys (CI/CD)
  - **in-toto links**
  - **Packages (universal Python wheels)**



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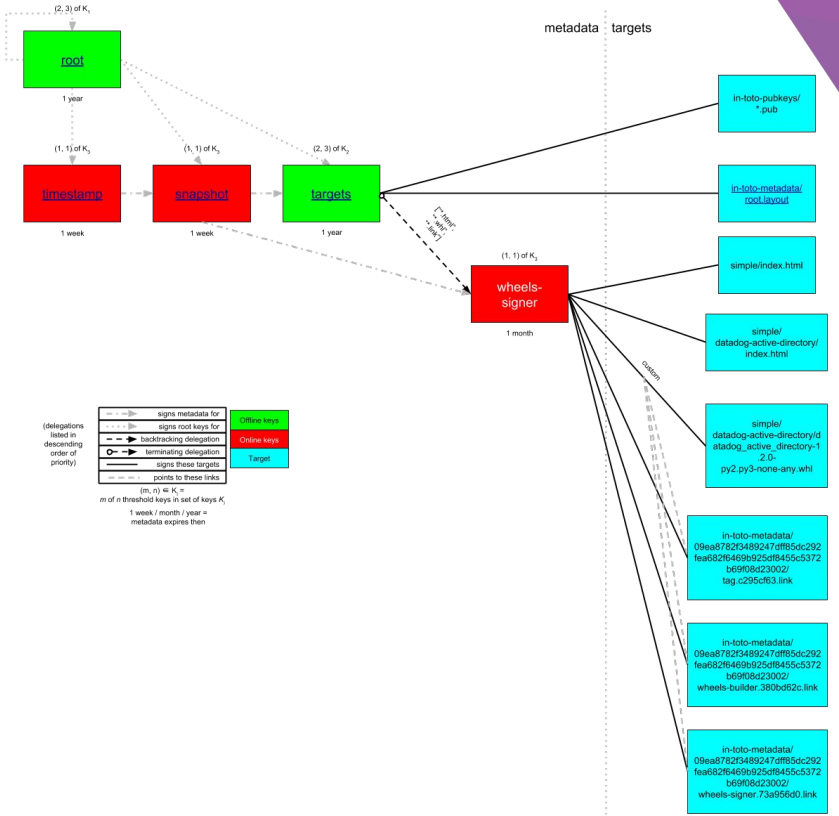
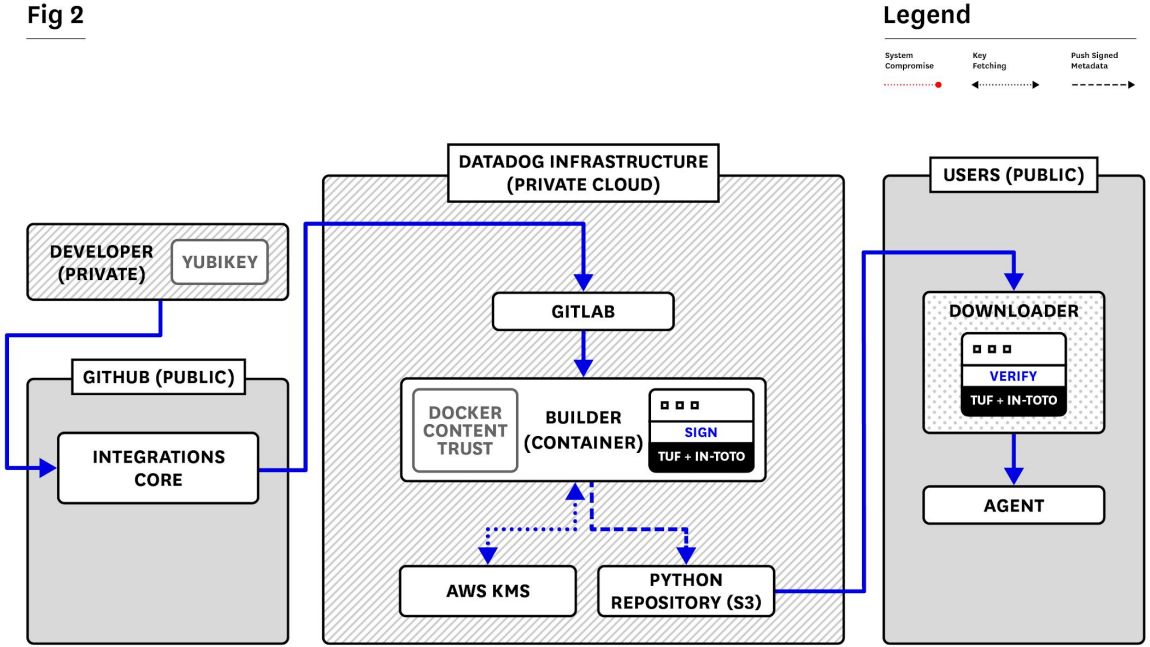
  - in-toto links
  - Packages (universal Python wheels)



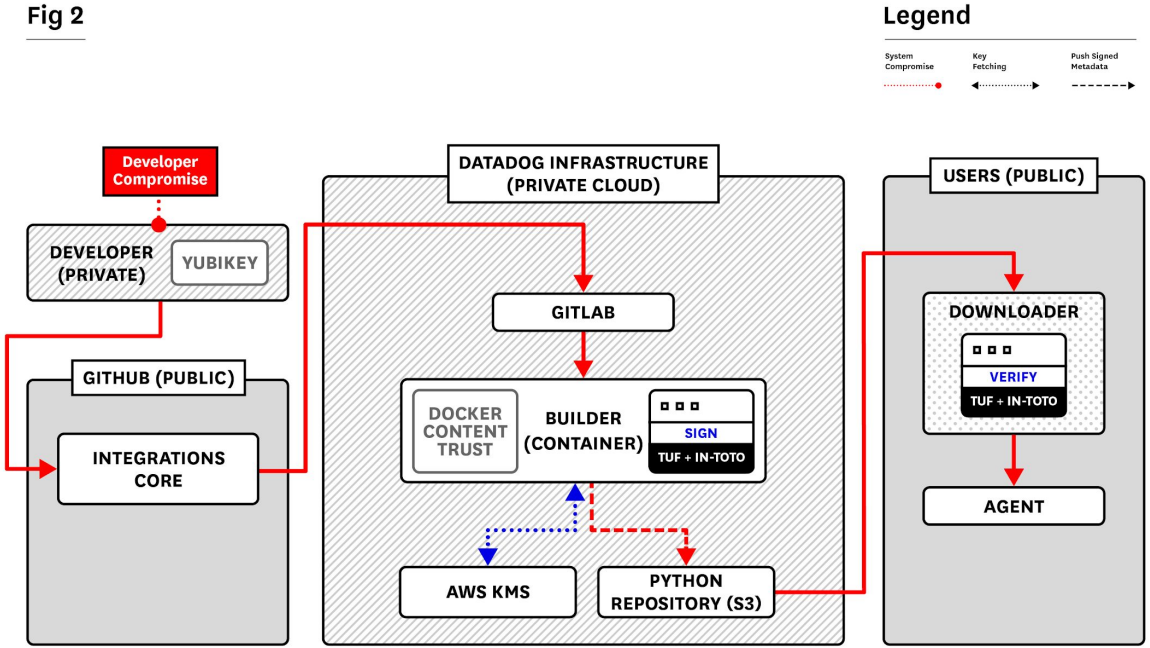
TUF + in-toto: what can go wrong?

Fig 2



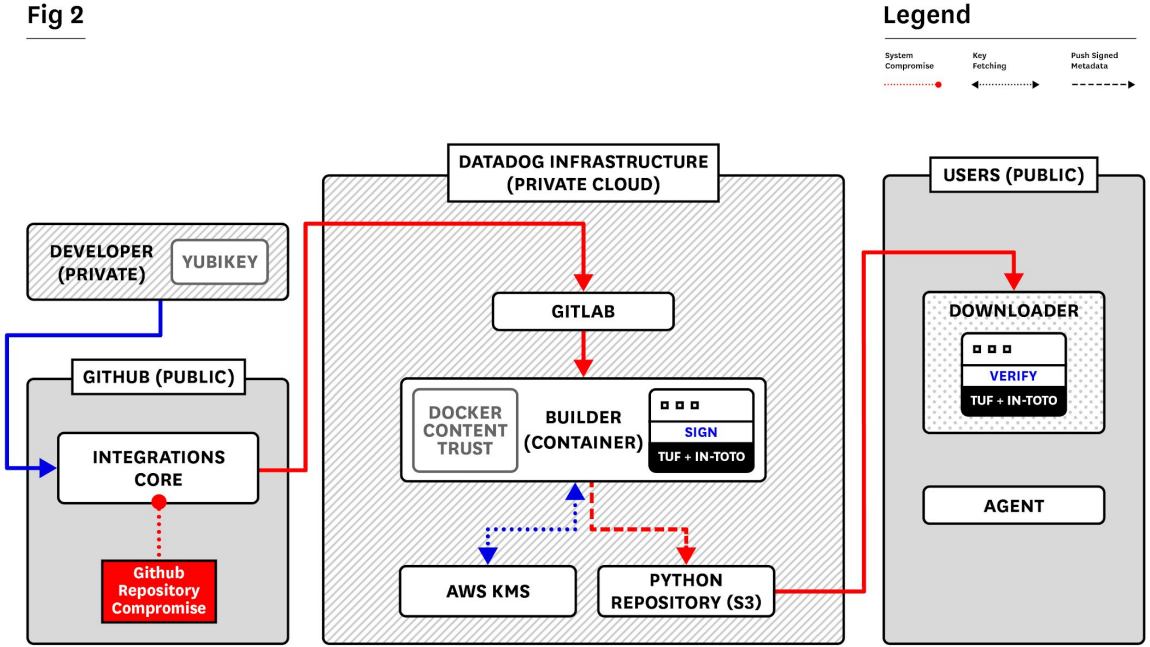
TUF + in-toto: developer key compromise

Fig 2



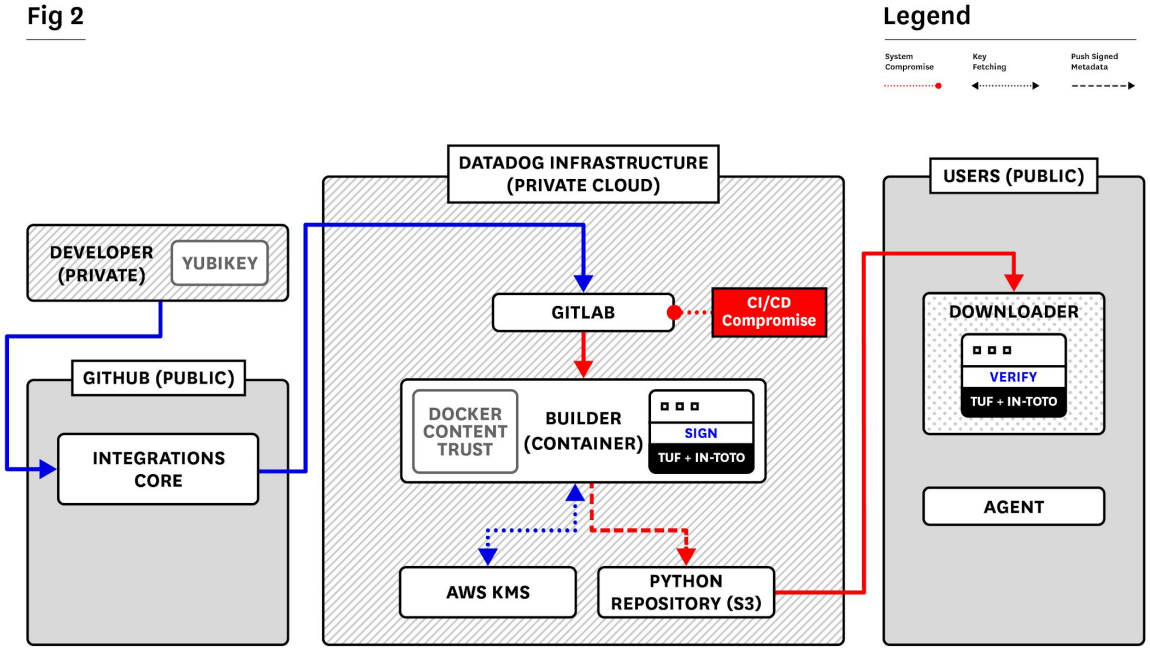
TUF + in-toto: VCS repository compromise

Fig 2



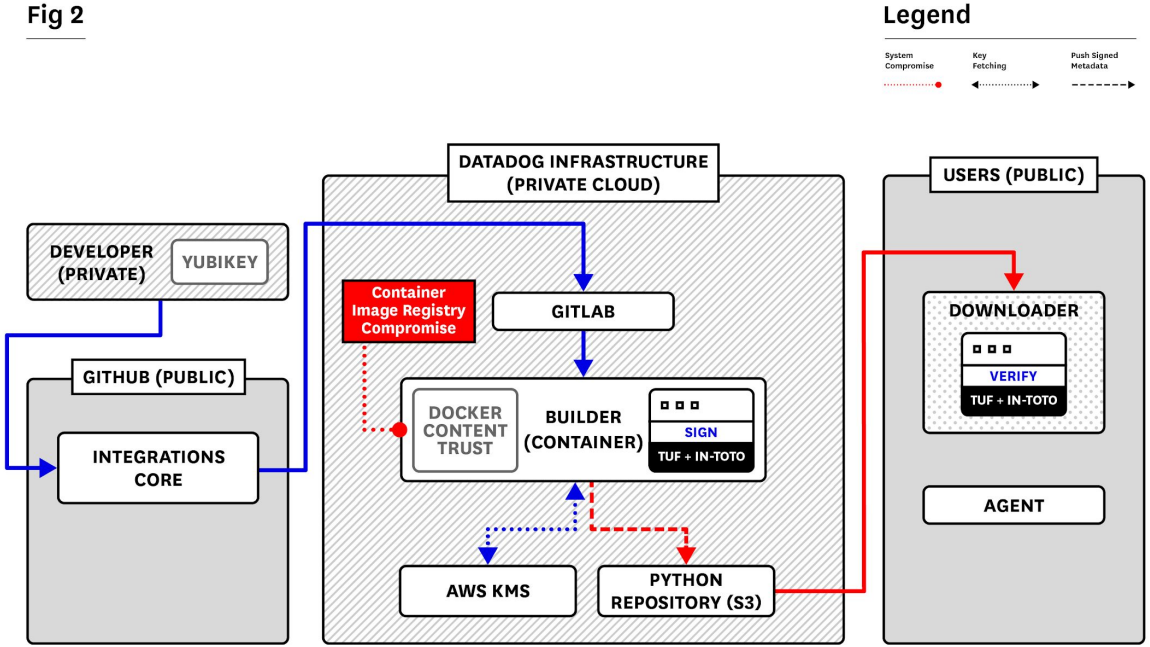
TUF + in-toto: CI/CD system compromise

Fig 2



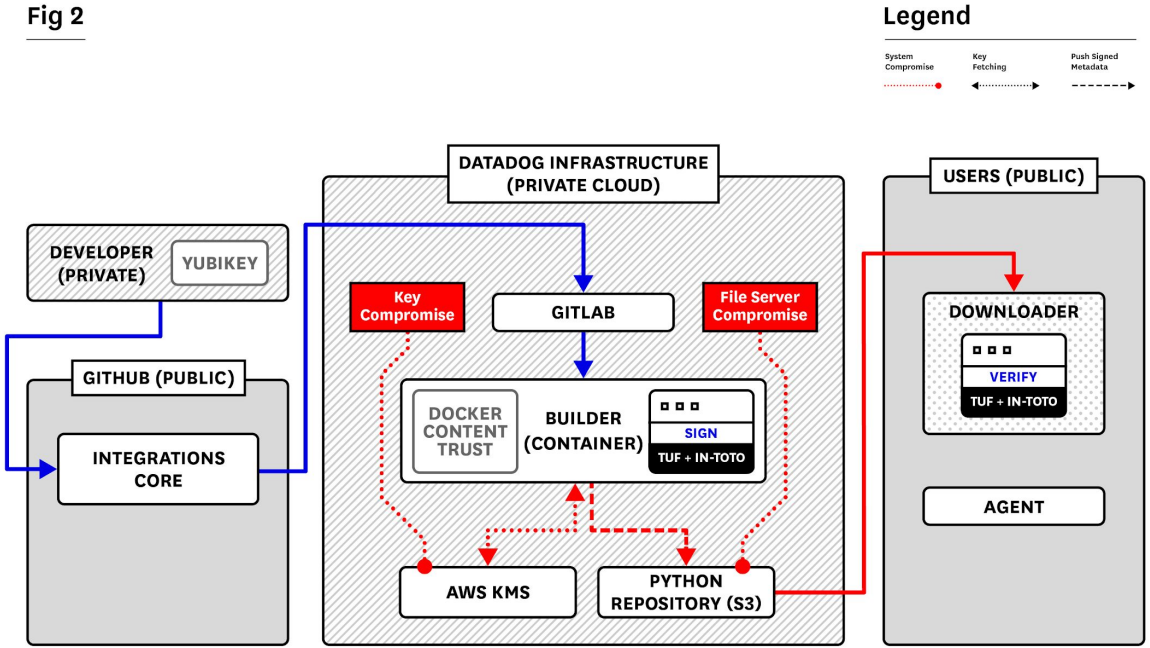
TUF + in-toto: container image registry compromise

Fig 2



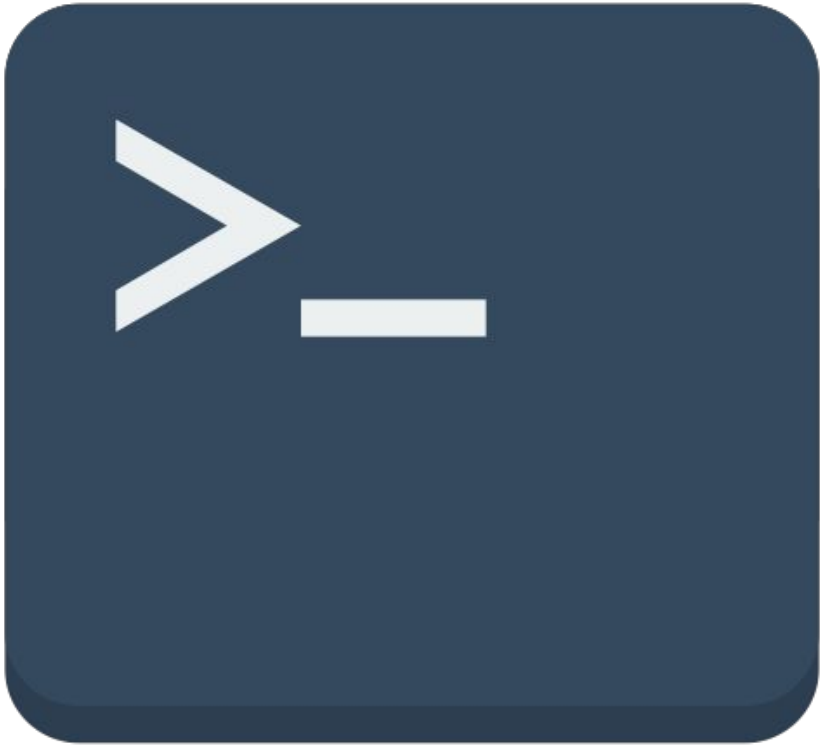
TUF + in-toto: key + file server compromise

Fig 2



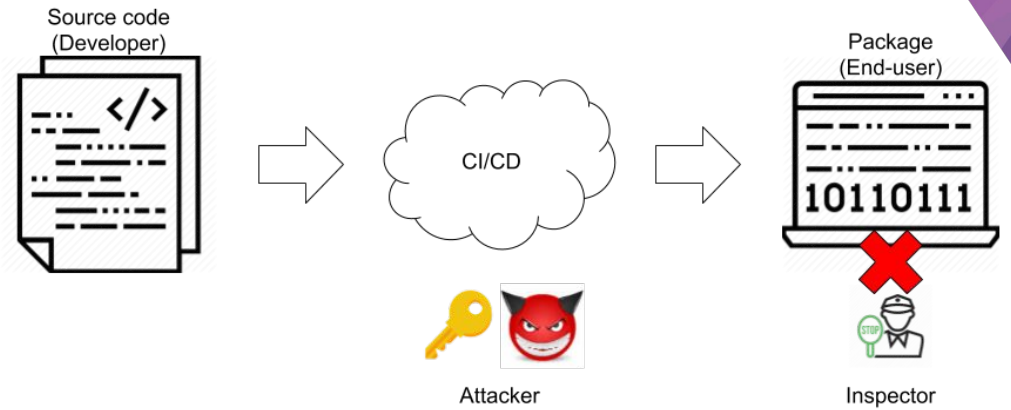
DATADOG

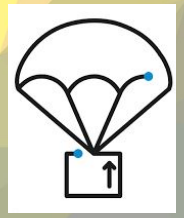
Live demo of production



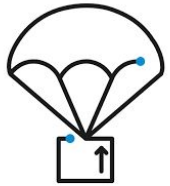
Takeaway: TUF + in-toto = tamper-evident CI/CD

- Tamper-evident
  - *x* <=> source code
  - *f* <=> authentic CI/CD pipeline
  - *y* <=> package
  - Does *y* = *f(x)*?
- Compromise-resilience
  - End-users download *x*, *f*, and *y*
  - If *y* ≠ *f(x)*, then reject *y*
- Industry-first
  - Datadog Agent 6.8.0



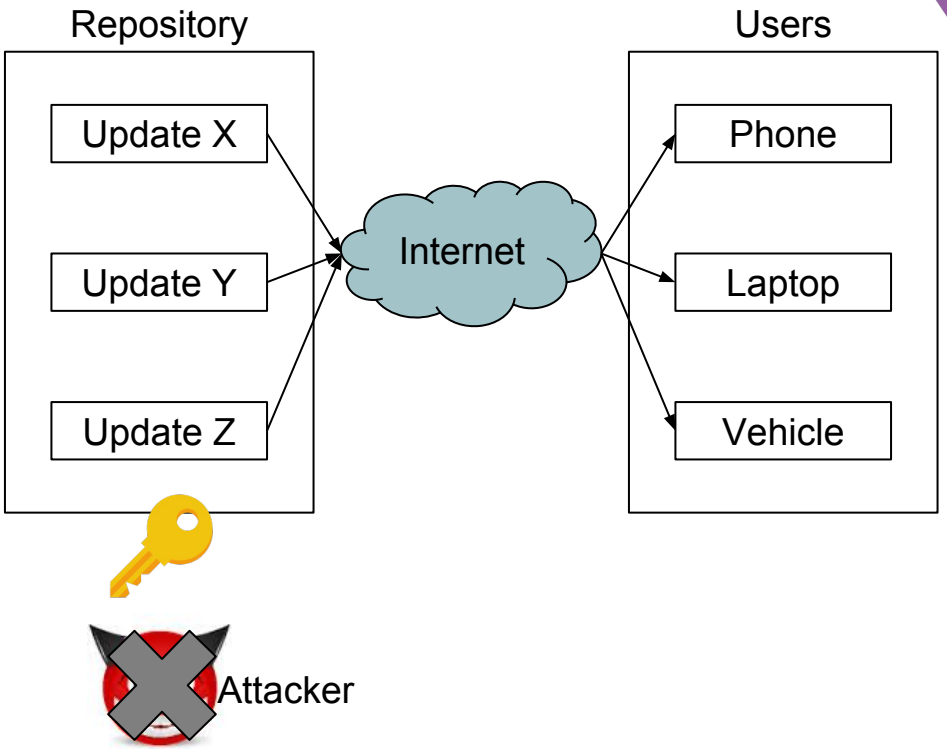


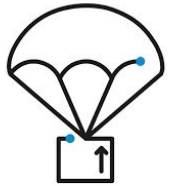
Conclusions



Takeaway: TUF = compromise-resilience

- Only question of when, not if
- Cannot prevent compromise
- But must severely limit impact
- Use TUF





TUF: selected integrations & deployments

docker

AUTOMOTIVE GRADE LINUX

CLOUDFLARE

Advanced Telematic SYSTEMS

CoreOS

Flynn

DigitalOcean

DATADOG

Uptane

IBM

vmware

Microsoft

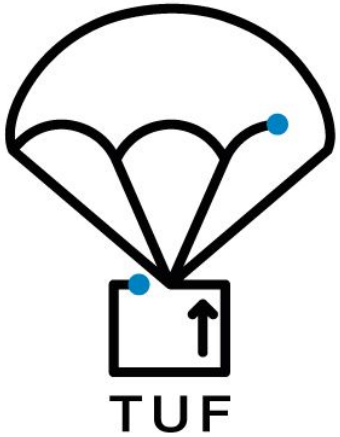
OTAinfo
SECURED OVER THE AIR INFORMATION TRANSFER

Acknowledgements

- **Datadog**
  - Andrew Becherer, Douglas DePerry, Agent-Integrations, Agent-Core
- **NYU**
  - Sebastien Awwad, Justin Cappos, Lois Anne DeLong, Vladimir Diaz, Lukas Puhringer, Santiago Torres-Arias
- **Docker**
  - Nathan McCauley, Diogo Monica, David Lawrence, Justin Cormack
- **CoreOS**
  - Evan Cordell, Jacob Moshenko
- **Uptane**
  - Uptane Alliance

Q & A

- Thanks for your time!
- TUF: https://theupdateframework.com
- in-toto: https://in-toto.io/
- Email: trishank@datadog.com [DataDog, TUF]
- Email: jcappos@nyu.edu [TUF, in-toto]
- Yubikey: https://github.com/DataDog/yubikey



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