Deep Dive: TUF

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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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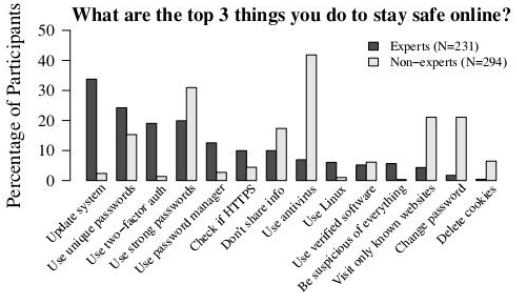

Figure 1: Security measures mentioned by at least 5% of each group. While most experts said they keep their system updated and use two-factor authentication to stay safe online, non-experts emphasized using antivirus software and using strong passwords.

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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

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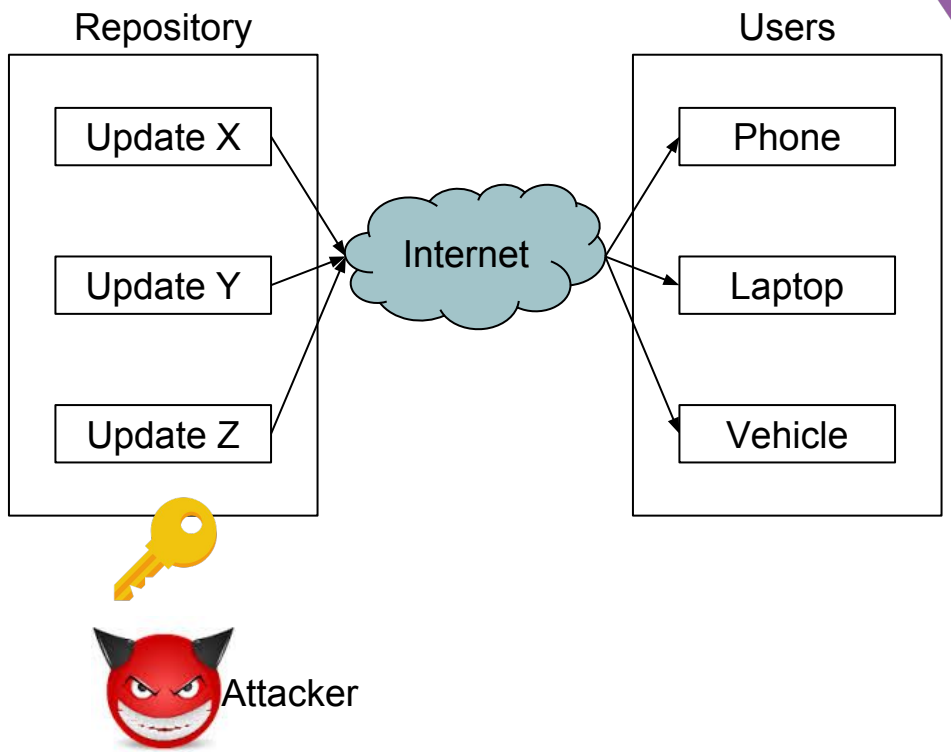
Goal: compromise-resilience

- 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

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- *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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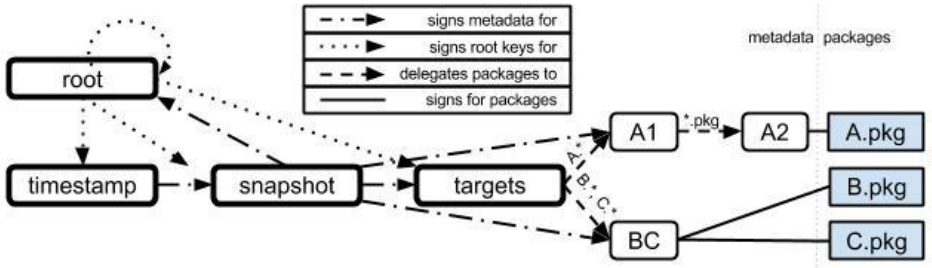
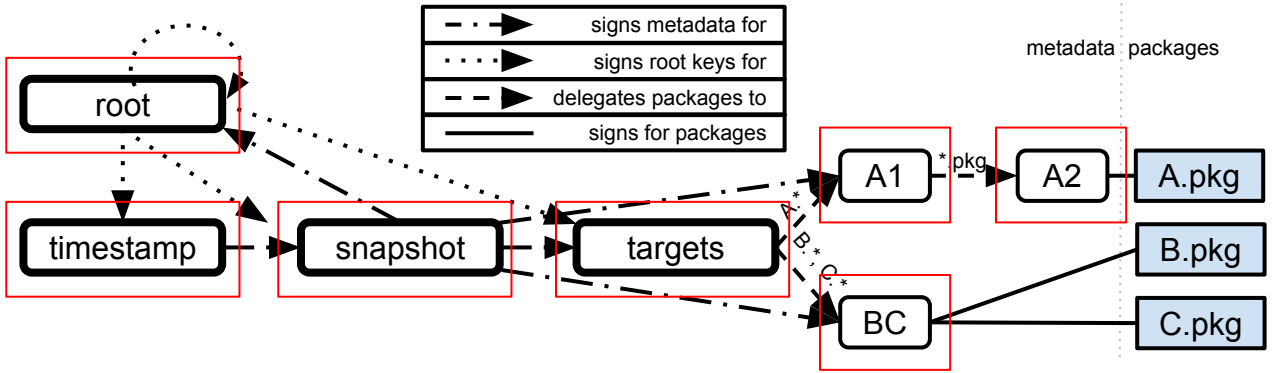


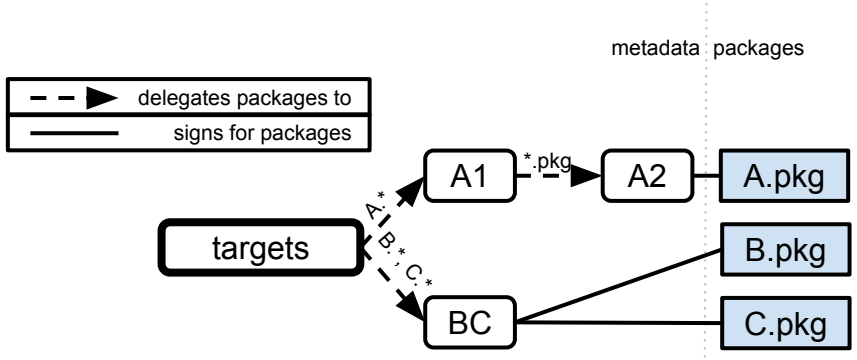
Separation of duties



Design principles:

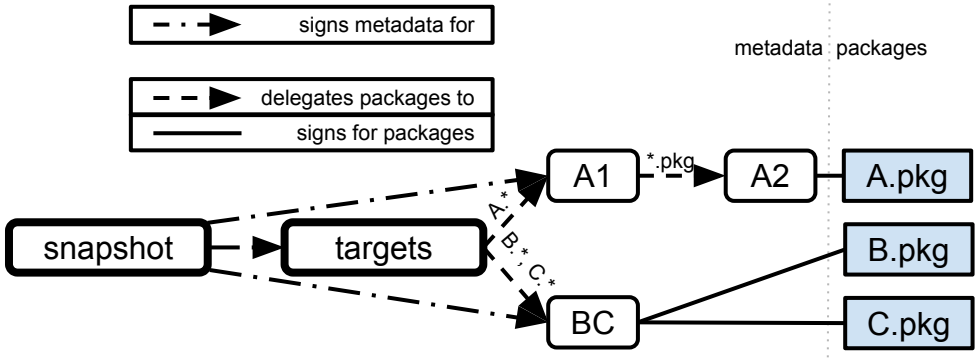
1. **Separation of duties**
   (i.e., don't put all your eggs in one basket).

The targets role



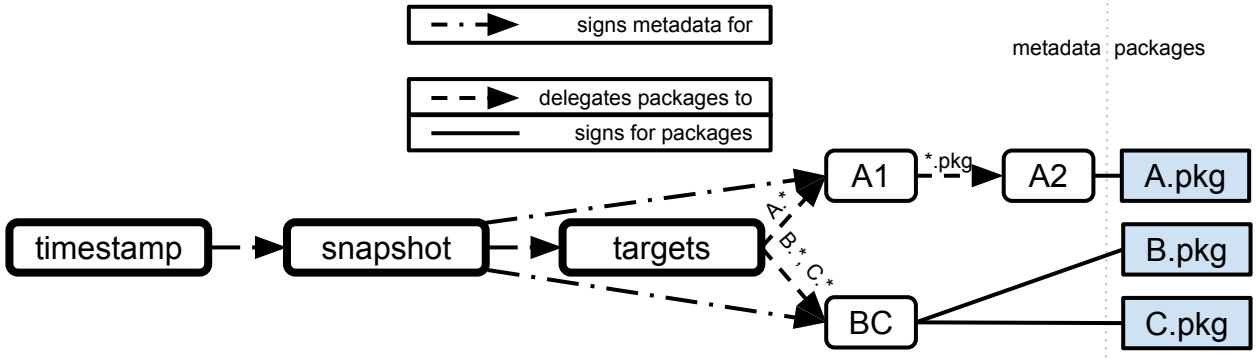
Role	Purpose
targets	Indicates metadata such as the cryptographic hashes and file sizes of packages. May delegate this responsibility to other, custom-made roles.

The snapshot role



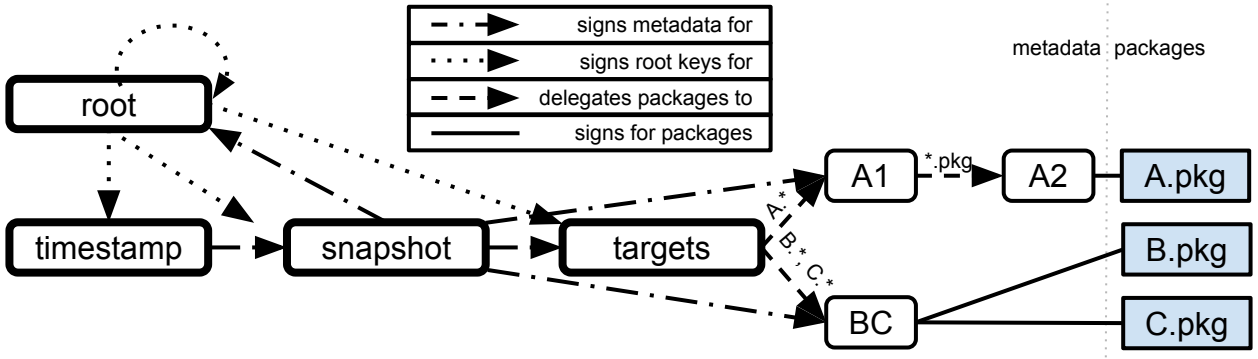
Role	Purpose
targets	Indicates metadata such as the cryptographic hashes and file sizes of packages. May delegate this responsibility to other, custom-made roles.
snapshot	Indicates which packages have been released at the same time by the repository.

The timestamp role



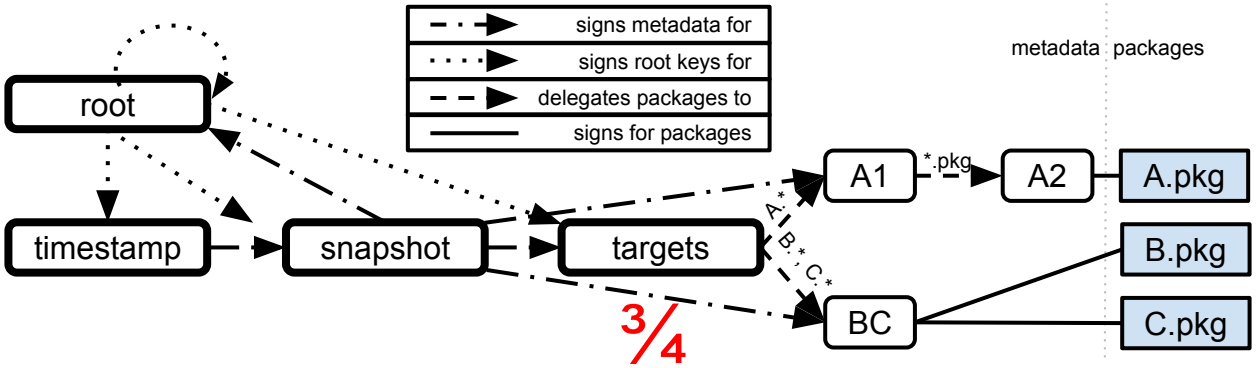
Role	Purpose
targets	Indicates metadata such as the cryptographic hashes and file sizes of packages. May delegate this responsibility to other, custom-made roles.
snapshot	Indicates which packages have been released at the same time by the repository.
timestamp	Indicates whether there is any new metadata or package on the repository.

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.

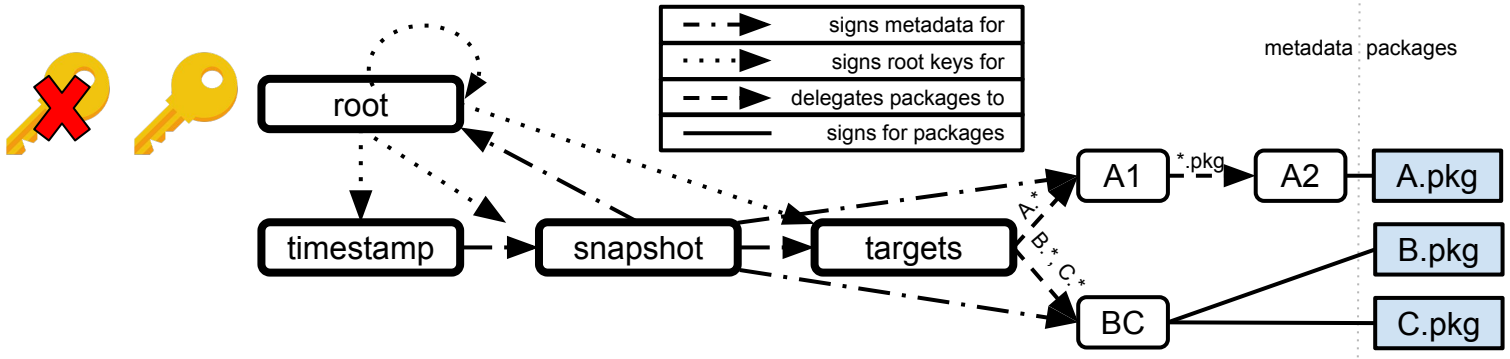
Threshold signatures



Design principles:

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

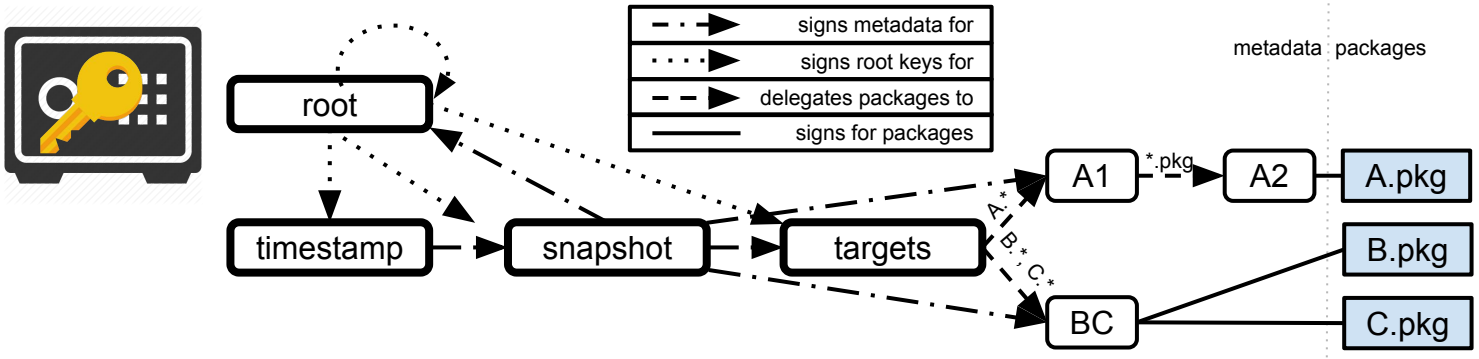
Explicit & implicit revocation of keys



Design principles:

1. Separation of duties.
2. Threshold signatures.
3. **Explicit and implicit revocation of keys.**

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)**.**

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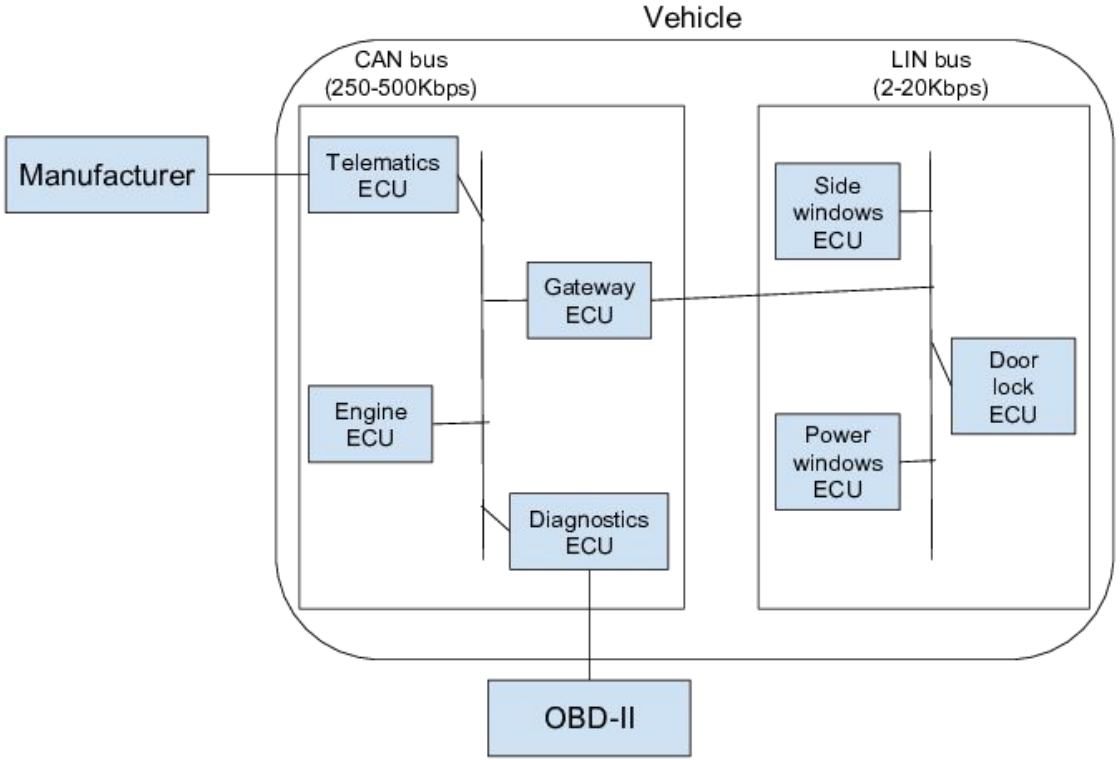
Diversity of cryptographic algorithms

- **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

TUF in practice:

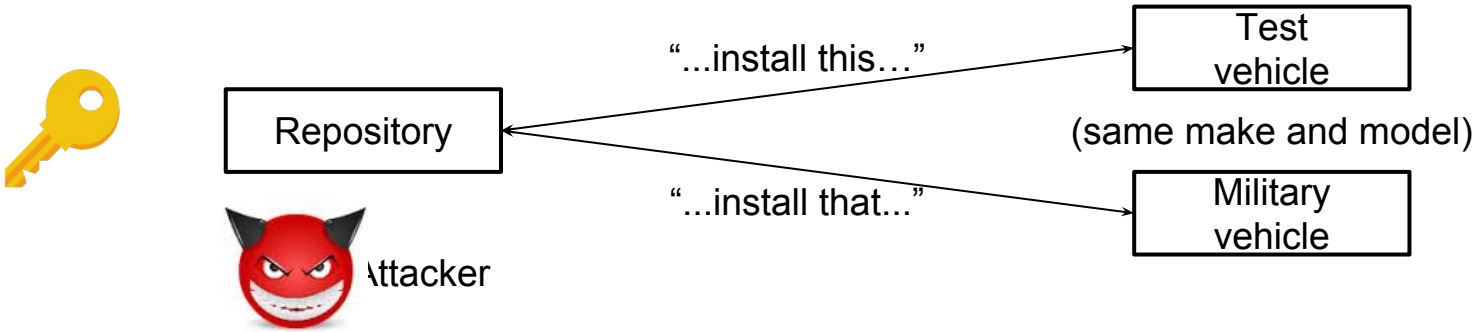
Securing Software Updates for Automobiles

Vehicles and ECUs



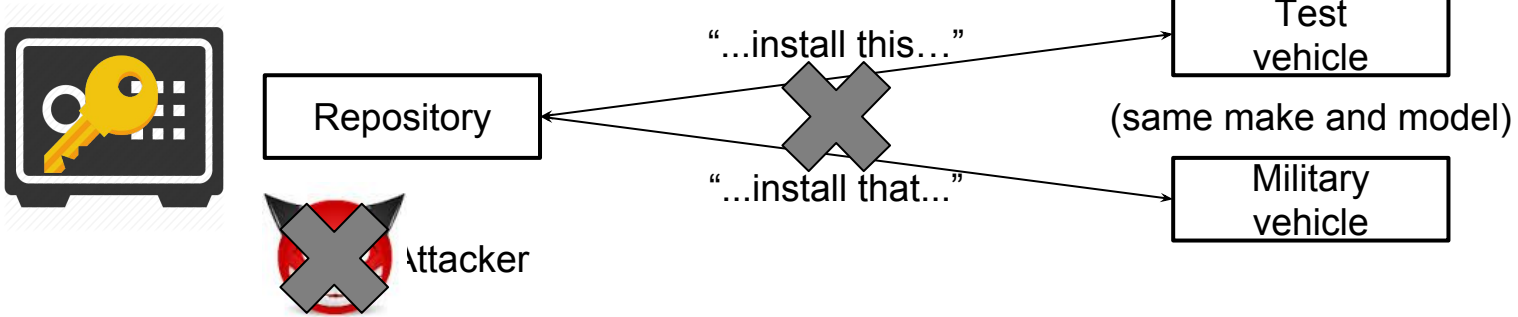
Customizability…

- 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



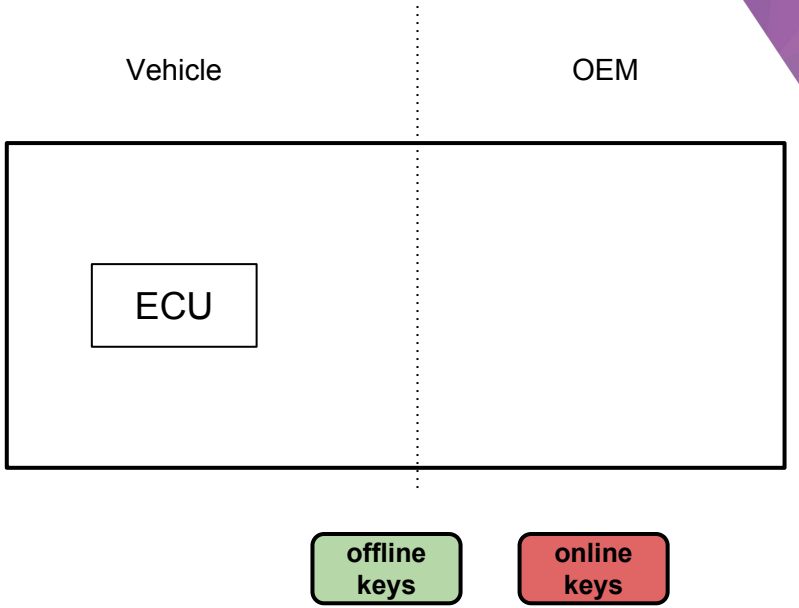
...or security?

- 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



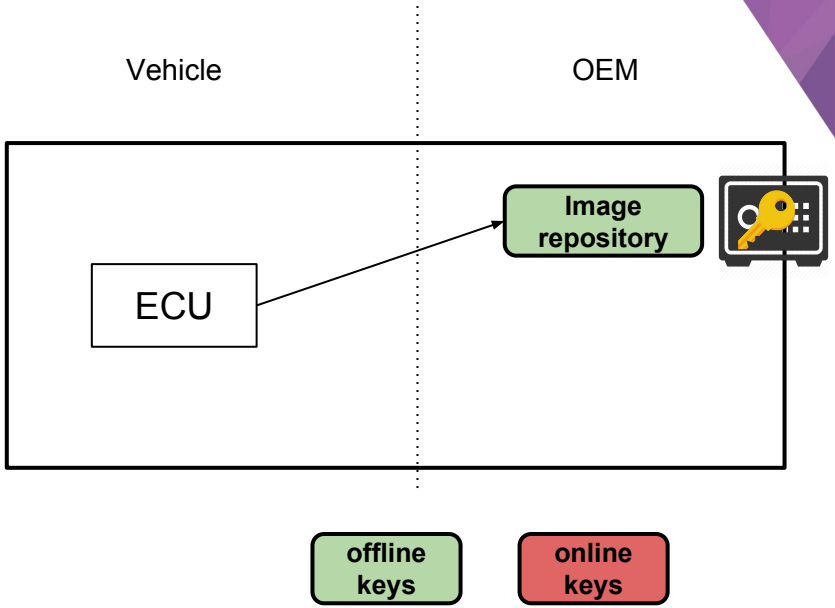
Key idea

- What if there are **two** repositories?



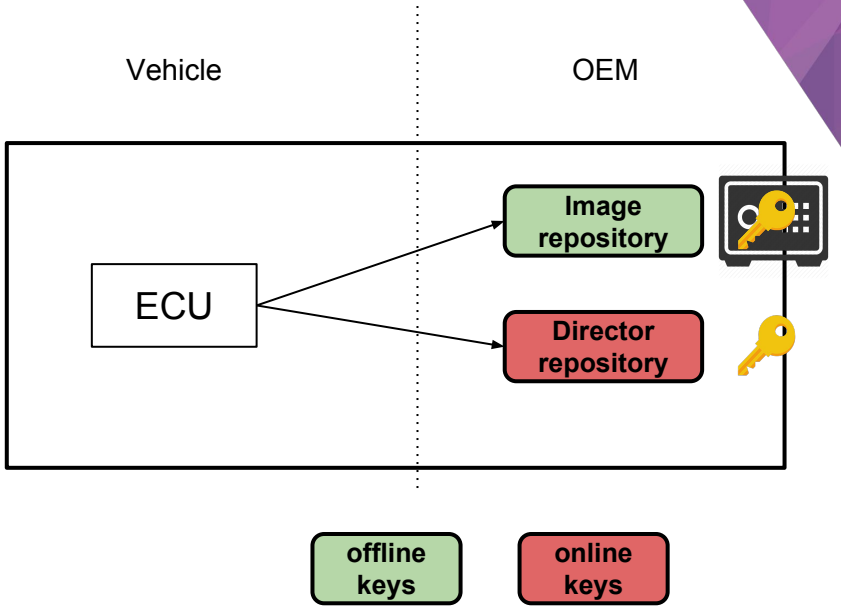
Key idea: image repository

- What if there are two repositories?
- **Image repository**
  - Uses **offline** keys
  - Provides signed metadata about all available updates for **all ECUs** on **all vehicles**



Key idea: director repository

- What if there are 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



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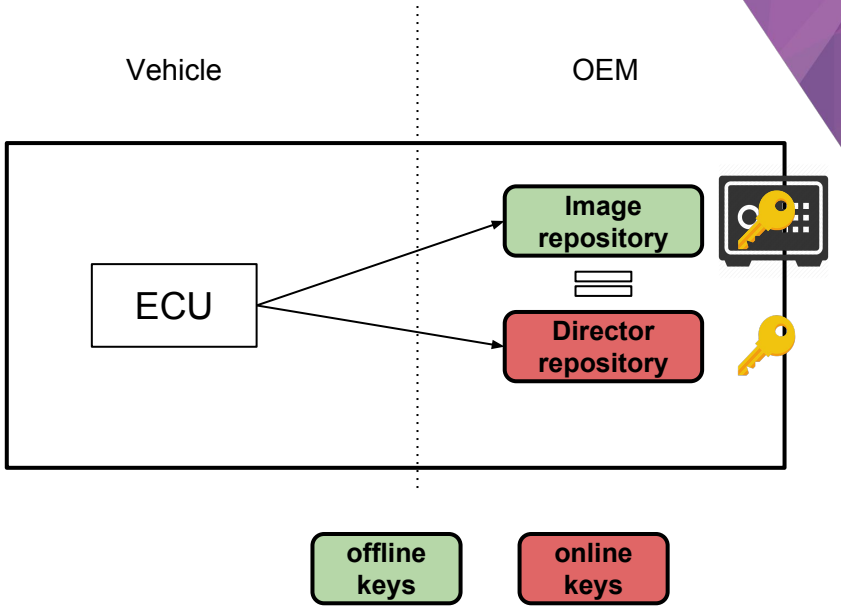
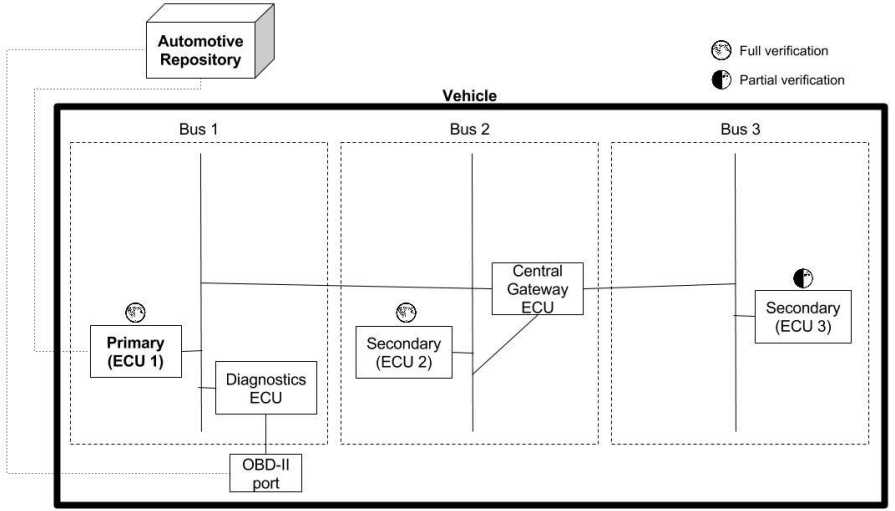
Key idea: security & customizability

- A vehicle would ensure that installation instructions from the **director** repository **match** updates from the **image** repository.
- Using both repositories provides **both** on-demand **customization** of vehicles & **compromise-resilience**.



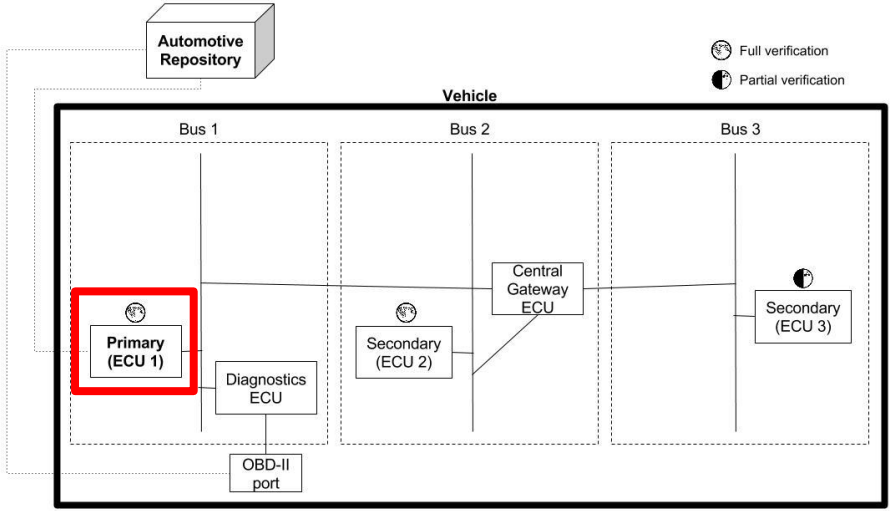
Primaries and secondaries

- **Two** types of ECUs, because:
  - Some ECUs are more / less **powerful** than others.
  - Few ECUs have network **connection** to outside world.
  - ECUs should not **download** metadata independently of each other.



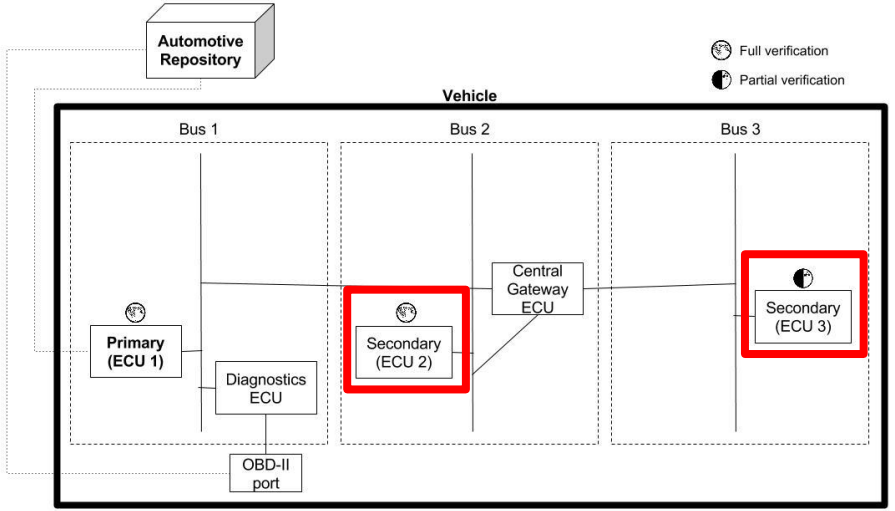
Primaries

- A **primary** downloads, verifies, distributes metadata + images to secondaries.



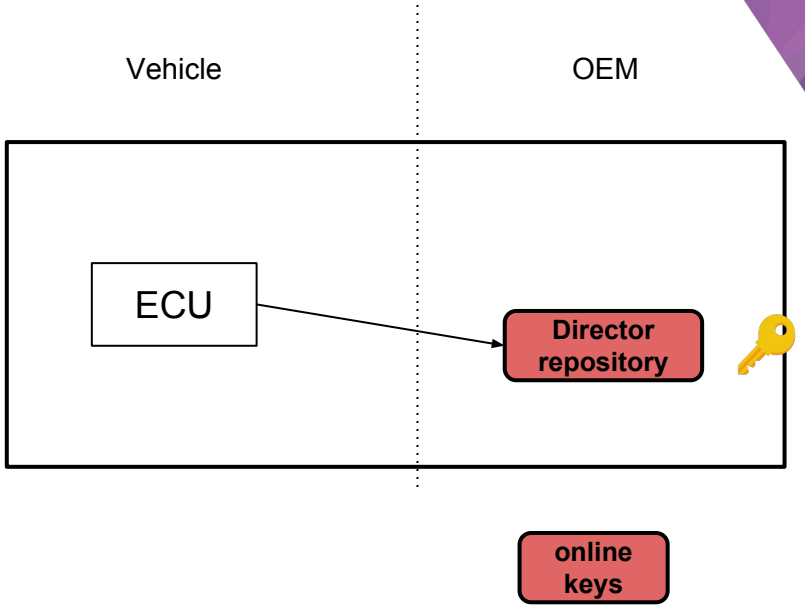
Secondaries

- A **secondary** verifies both the metadata & image distributed by a primary, before updating to that image.



Partial verification

- Checking **only** metadata from the **director** repository.
- Involves checking only **one signature** on **one metadata file**.



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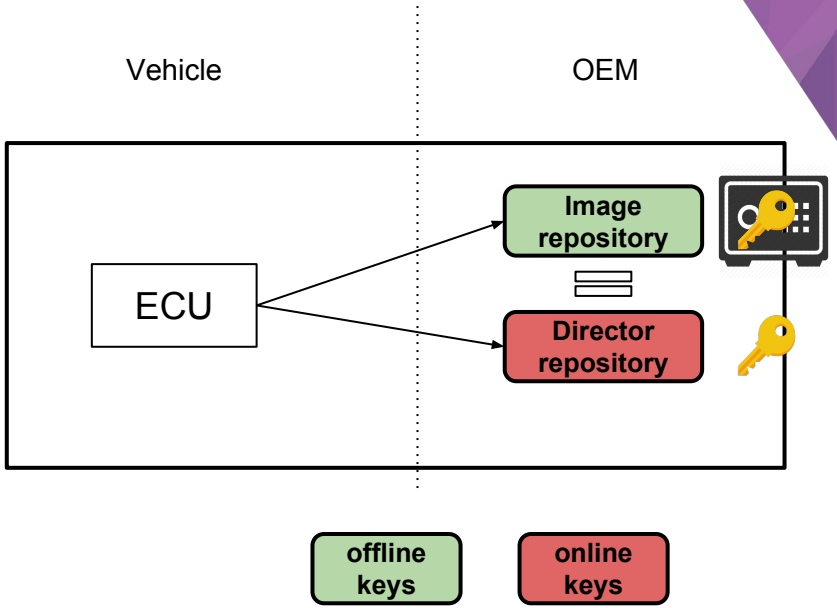
Full verification

- Checking that metadata about updates chosen by the **director** repository **match** metadata about the same updates on the **image** repository.
- Involves checking **many signatures** on **many metadata files** from both repositories.



Partial vs full verification

Increasing difficulty for attackers

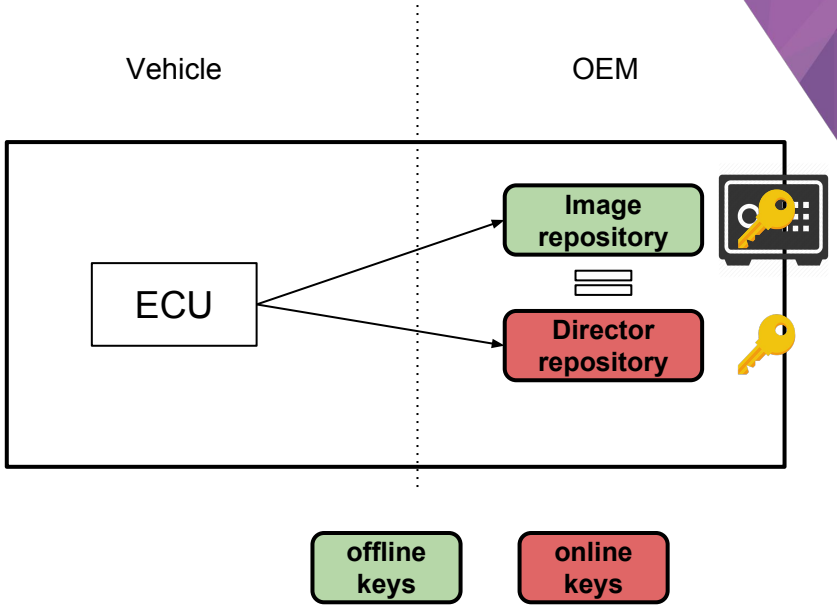
Greater compromise-resilience

	MitM outside / inside vehicle	MitM + director repository compromise	
		Primaries not compromised	Primaries compromised
Partial verification	Cannot cause ECUs to fail to interoperate	Can cause ECUs to fail to interoperate	Can install malware
Full verification			Cannot install malware

Mild	Serious	Critical

Takeaway: security & customizability

- Uptane provides **both** on-demand customization of vehicles & compromise-resilience.

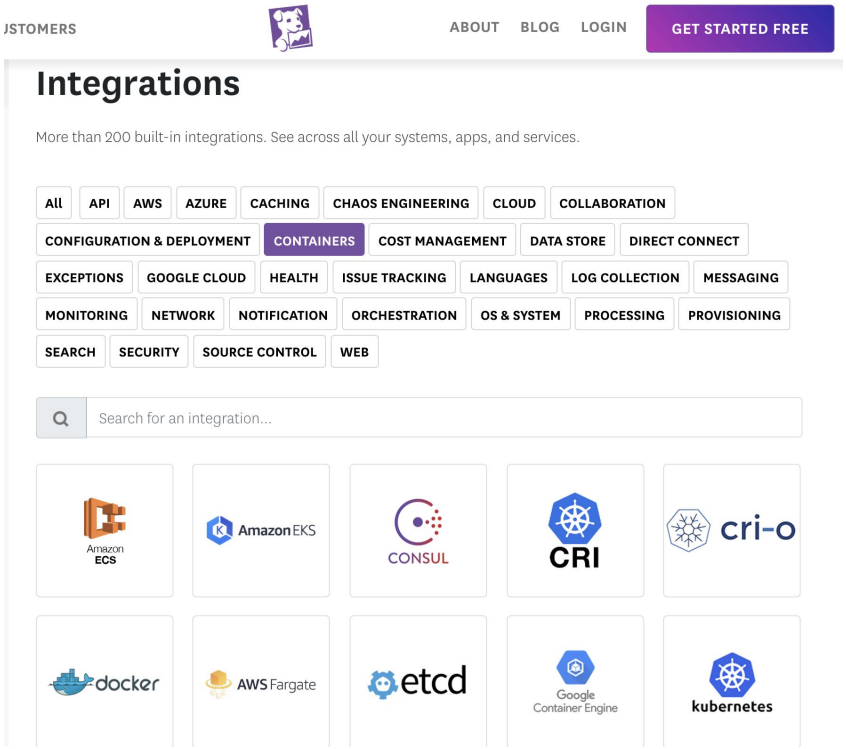


TUF in practice:

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

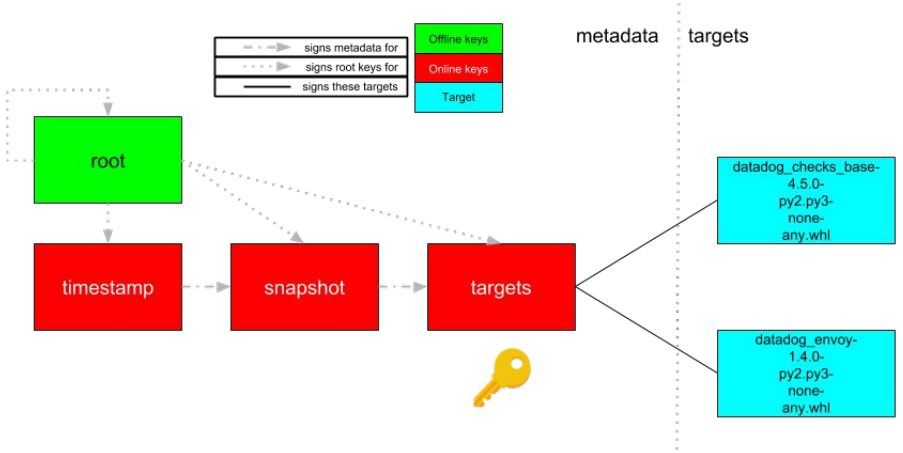


Decoupling integrations from Agent release cycle

- **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

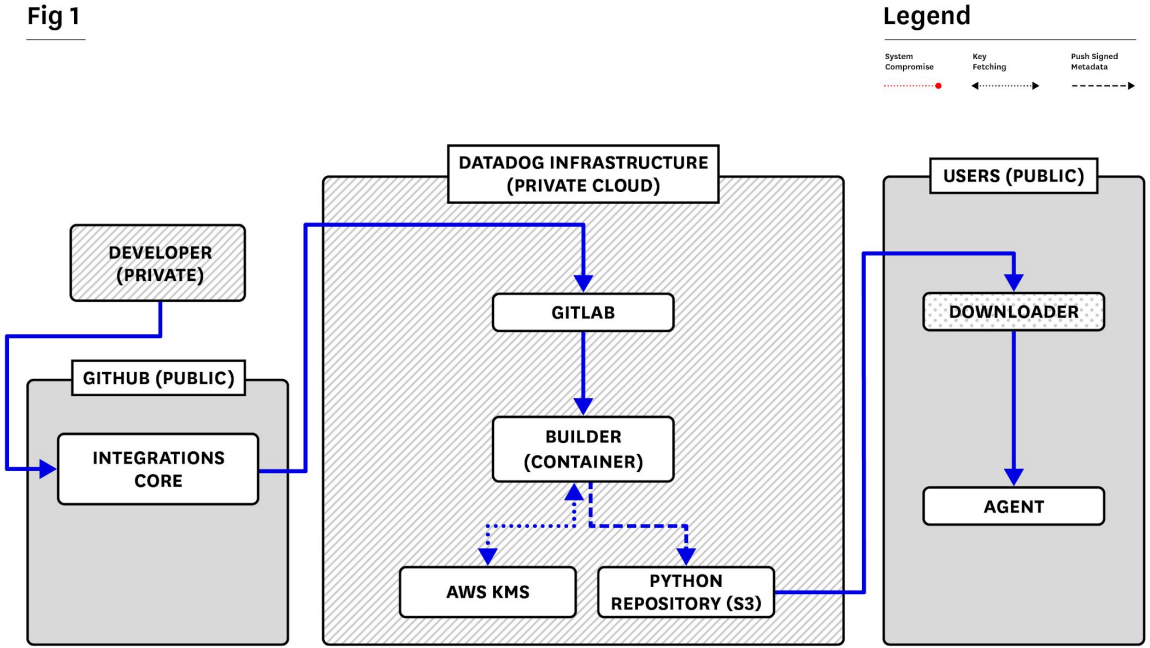
State-of-the-art: CI/CD

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



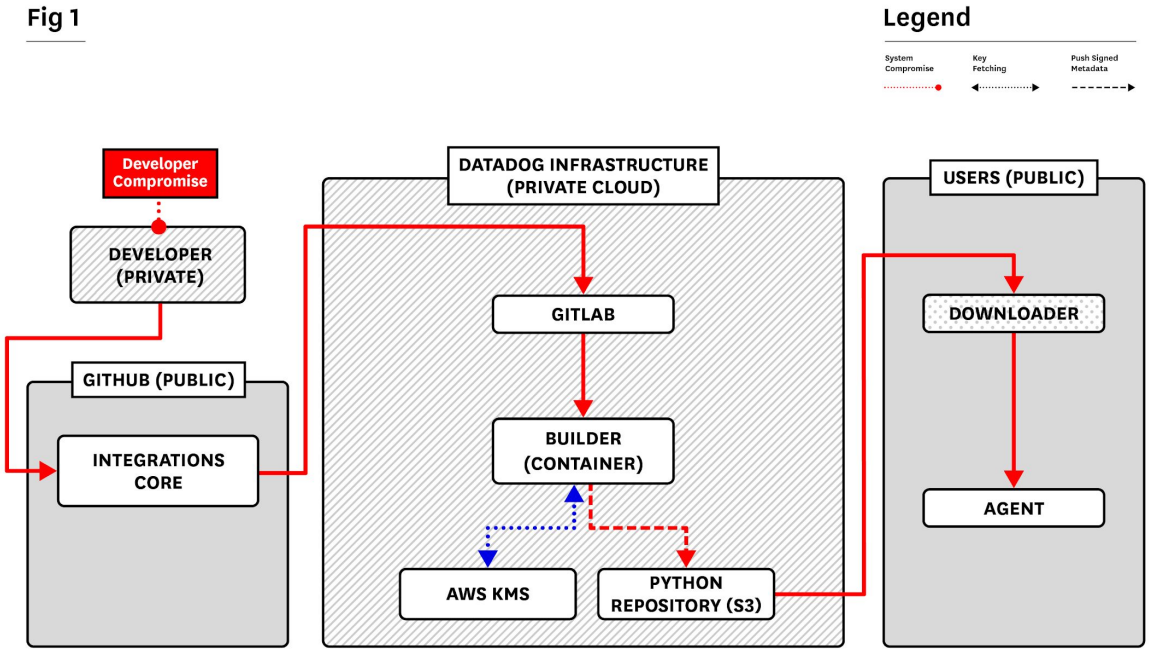
State-of-the-art: what can go wrong?

Fig 1



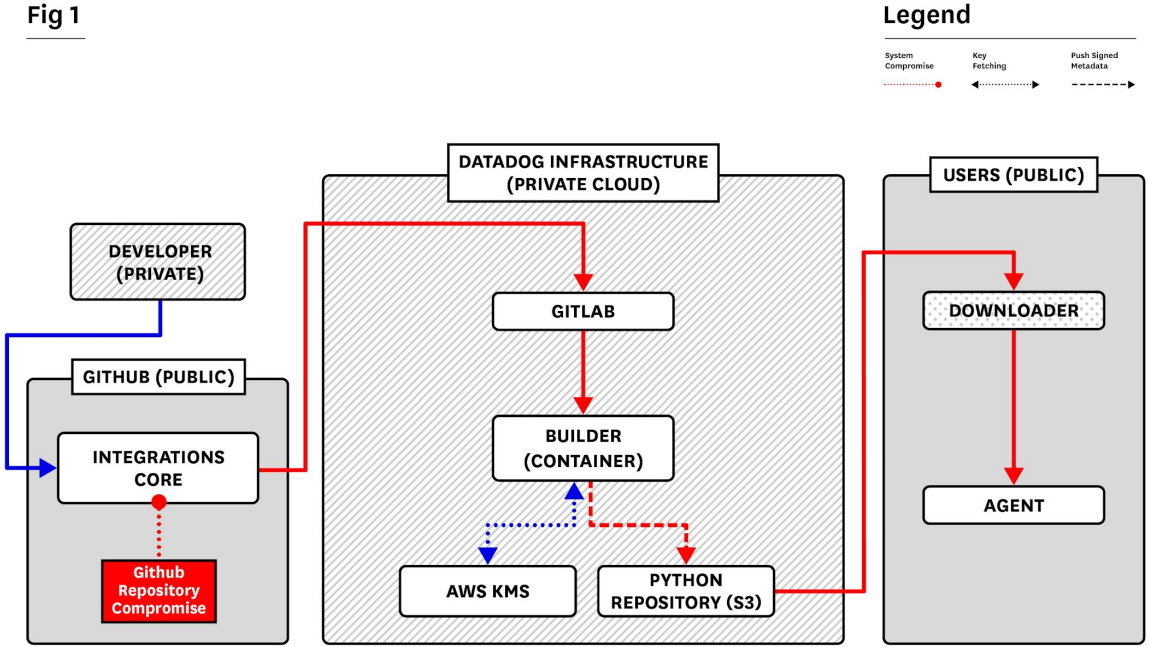
State-of-the-art: developer key compromise

Fig 1



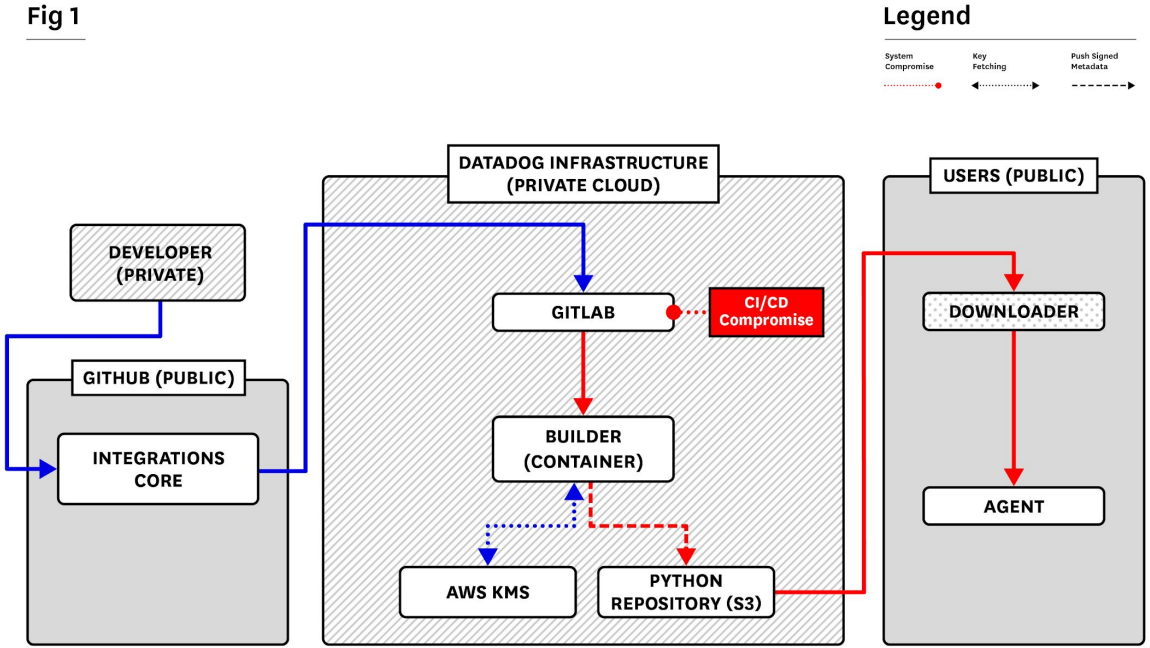
State-of-the-art: VCS repository compromise

Fig 1



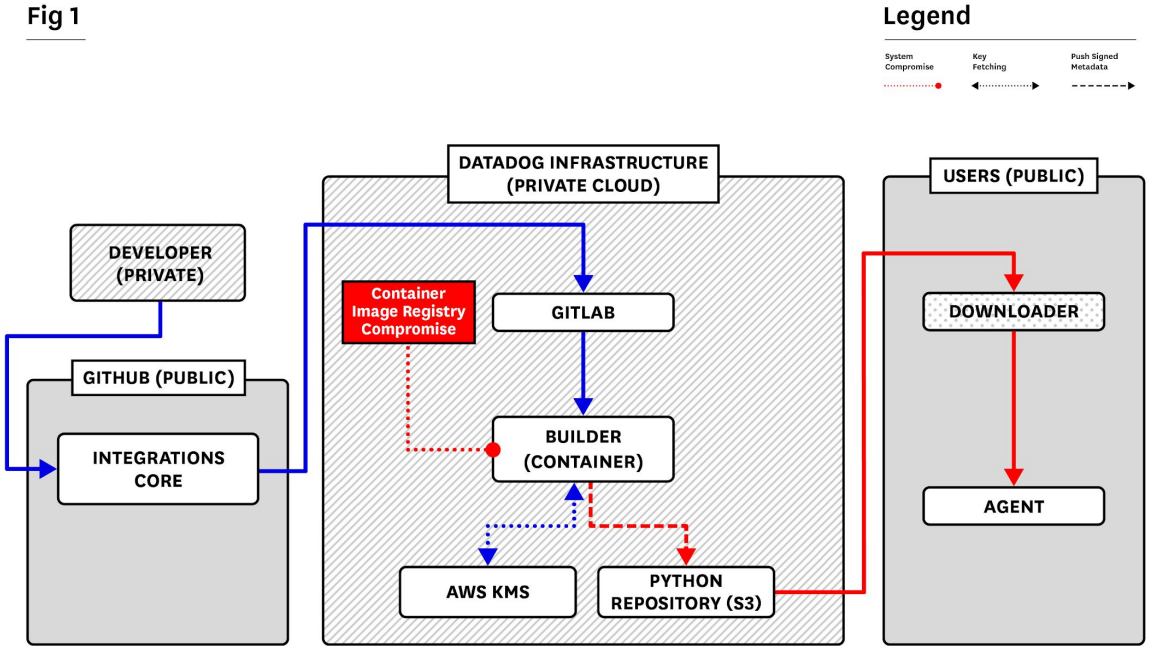
State-of-the-art: CI/CD system compromise

Fig 1



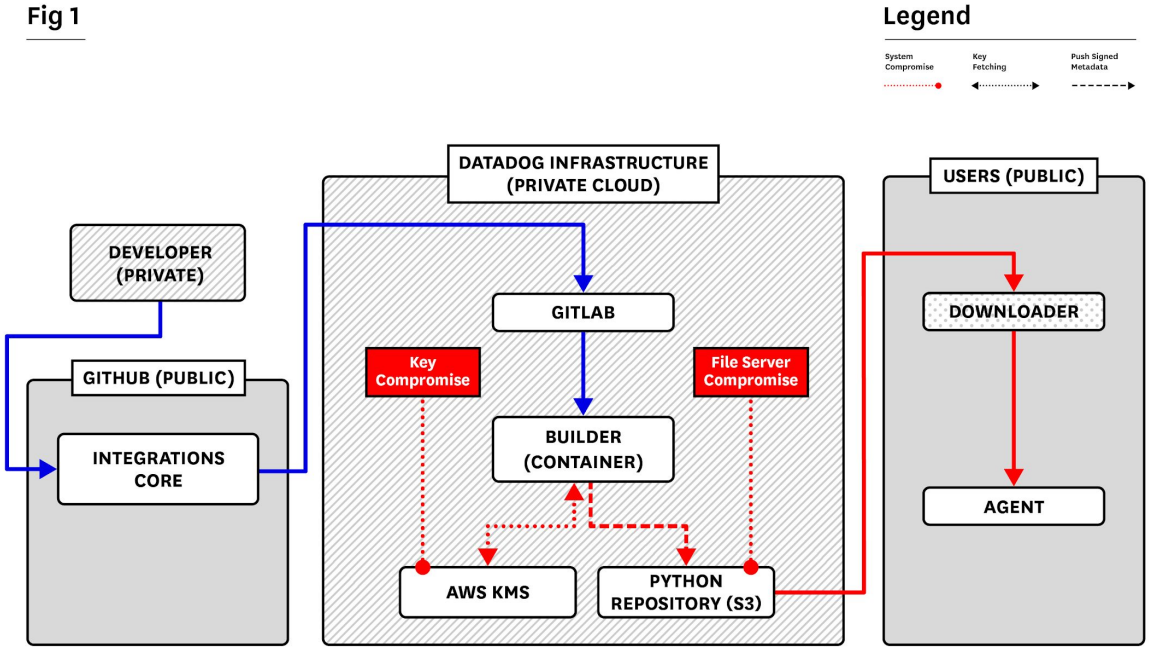
State-of-the-art: container image registry compromise

Fig 1



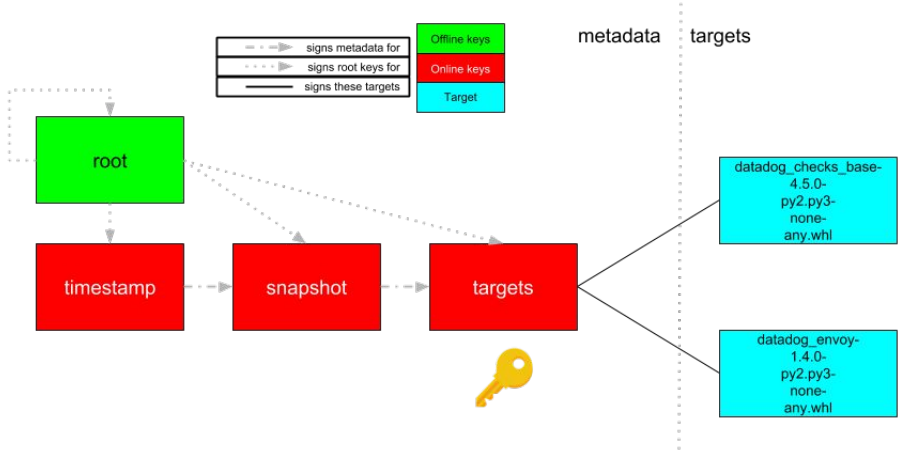
State-of-the-art: key + file server compromise

Fig 1



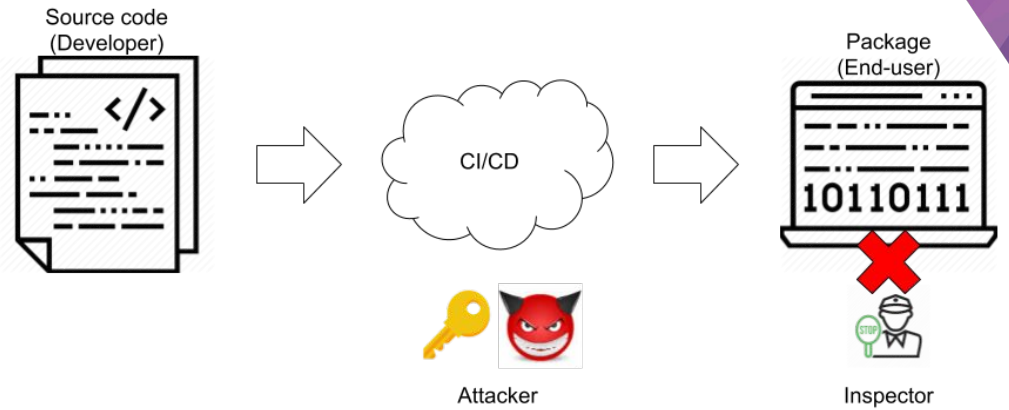
State-of-the-art: no compromise-resilience

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



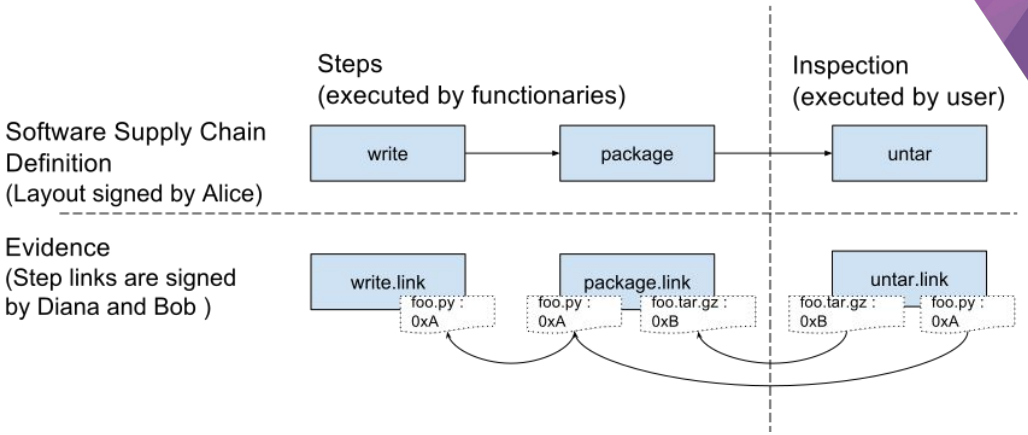
Key idea: tamper-evident CI/CD

- **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

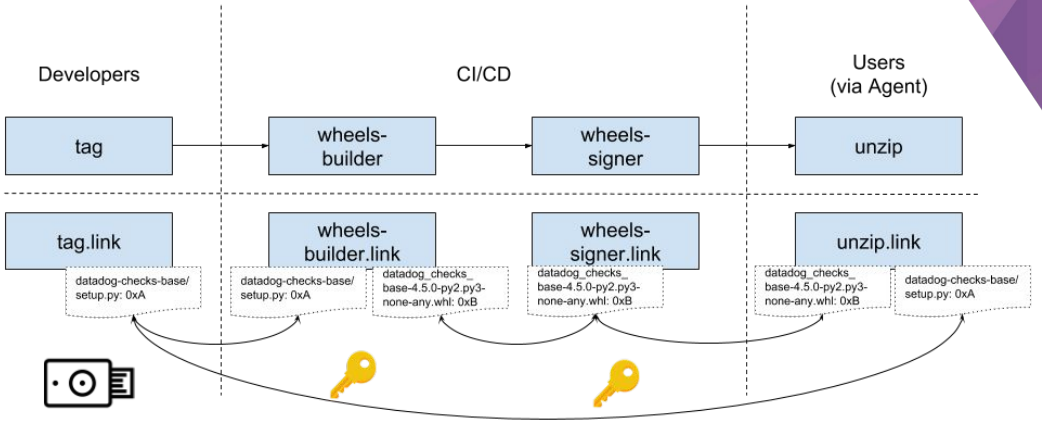


Datadog Agent integrations software supply chain

1. **tag**
   - Developer outputs source code

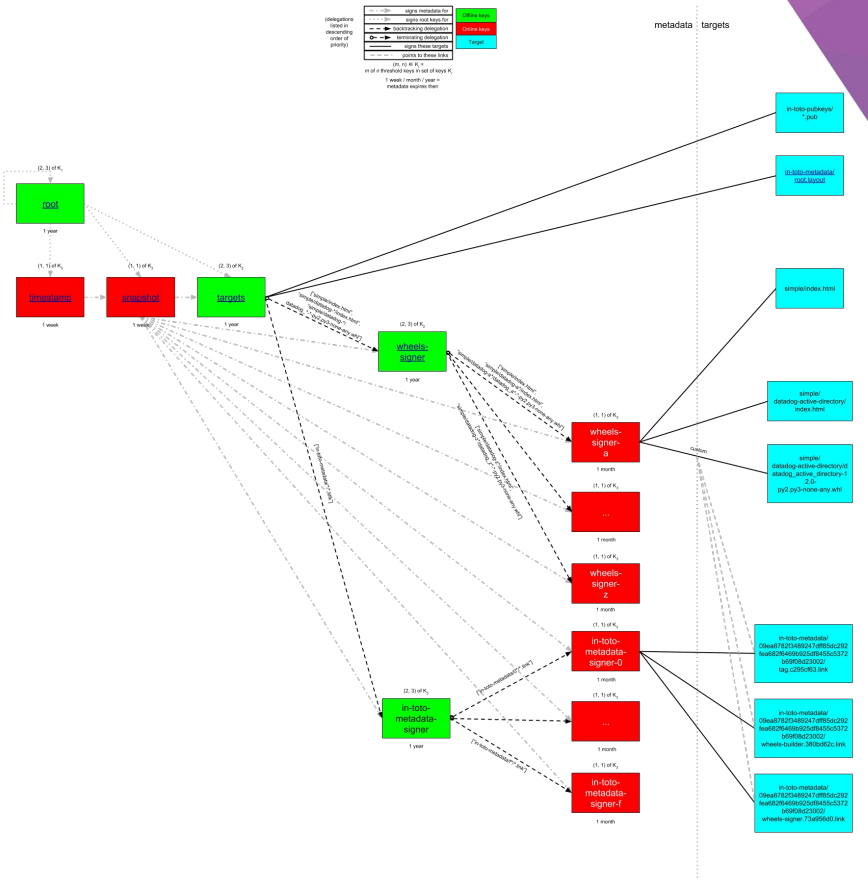
2. **wheels-builder**
   - Container must receive same source code as in “tag”
   - (Container builds wheels)
   - Container outputs wheels

3. **wheels-signer**
   - Container must receive same wheels as in “wheels-builder”



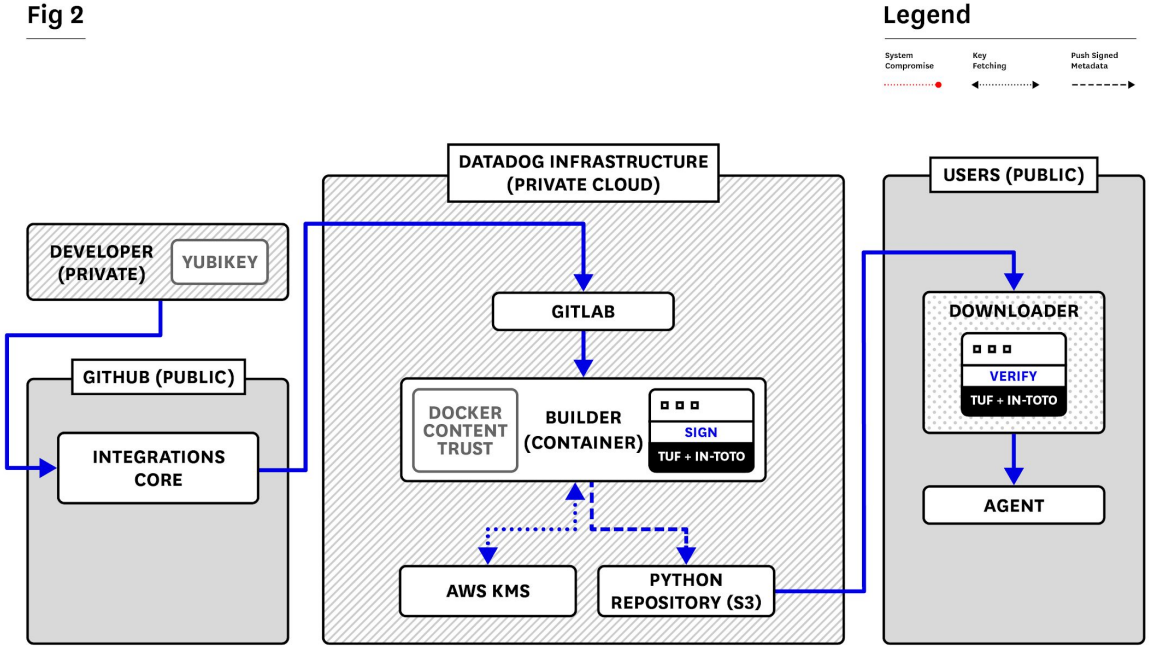
TUF + in-toto = tamper-evident CI/CD

- **Offline** keys (administrators)
  - 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)



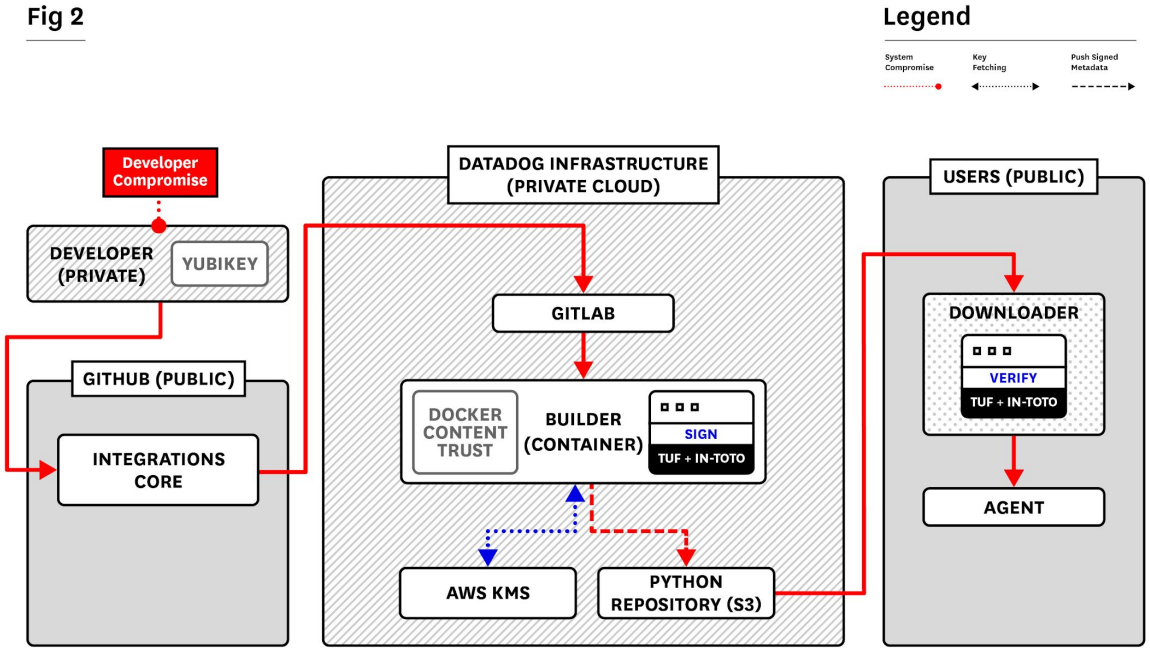
TUF + in-toto: what can go wrong?

Fig 2



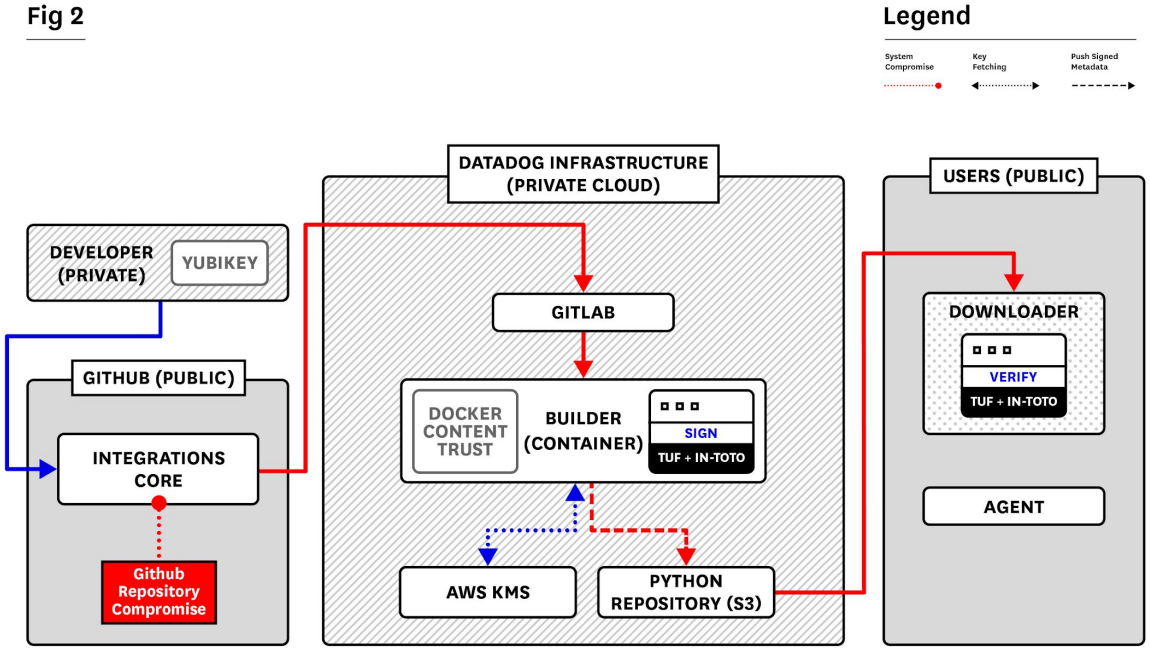
TUF + in-toto: developer key compromise

Fig 2



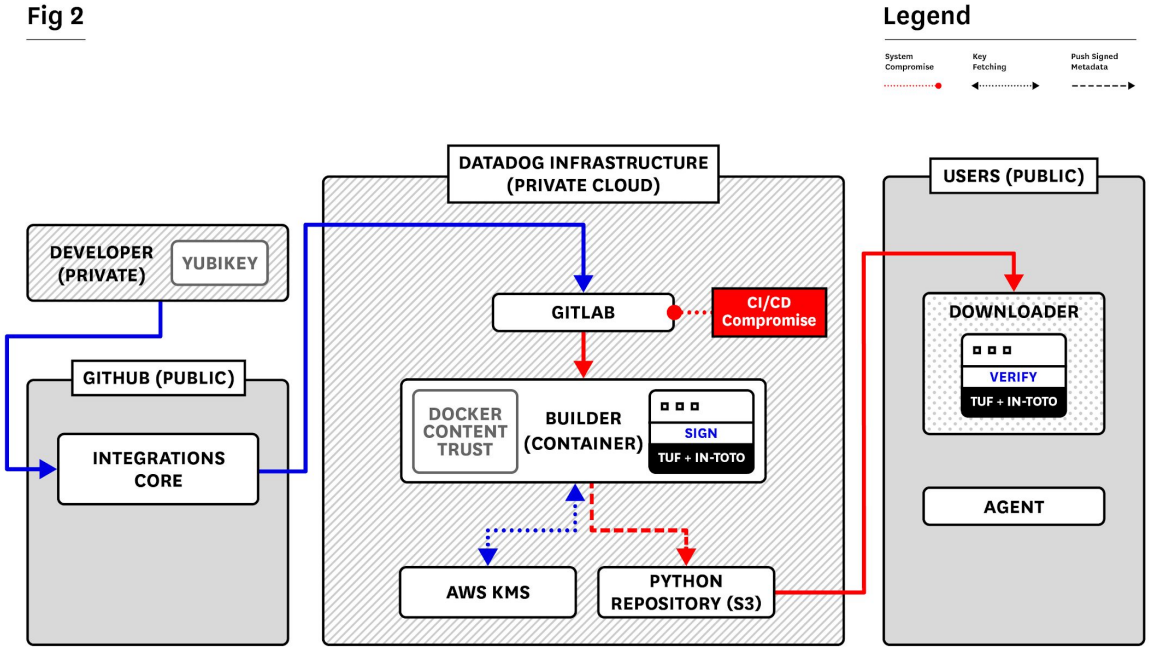
TUF + in-toto: VCS repository compromise

Fig 2



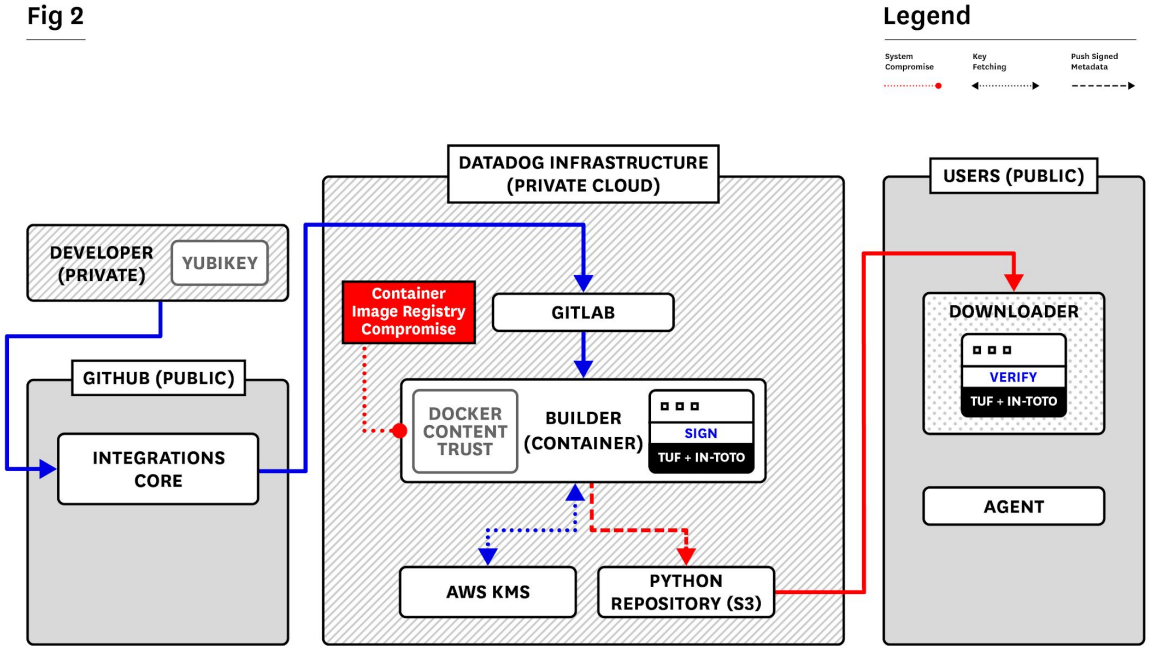
TUF + in-toto: CI/CD system compromise

Fig 2



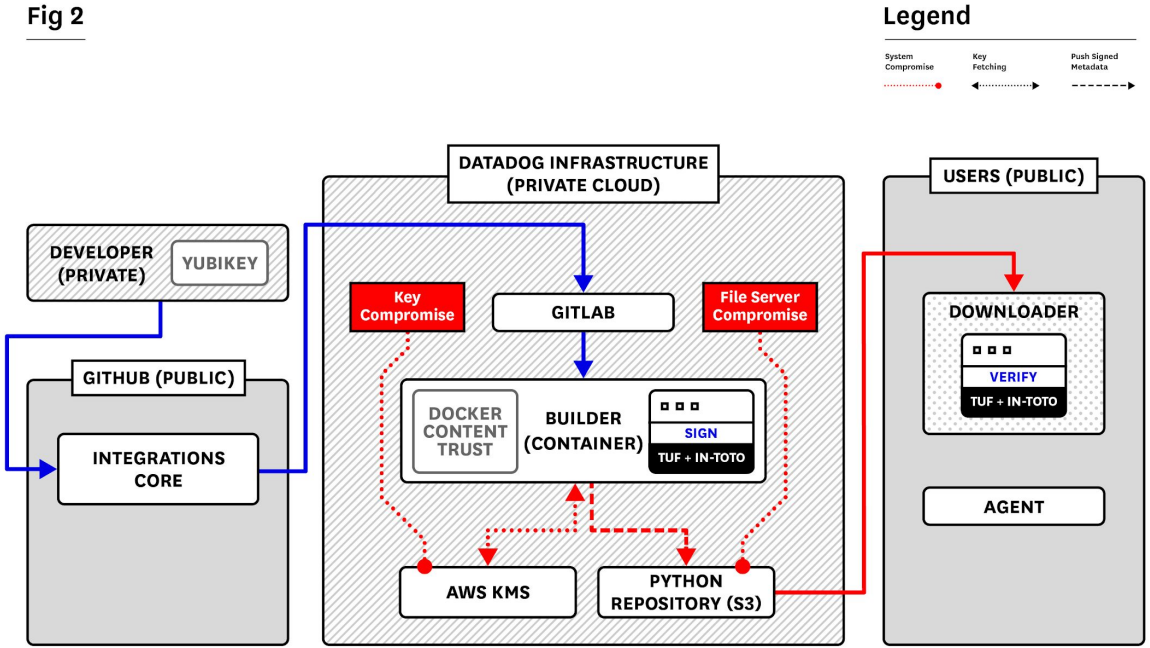
TUF + in-toto: container image registry compromise

Fig 2



TUF + in-toto: key + file server compromise

Fig 2



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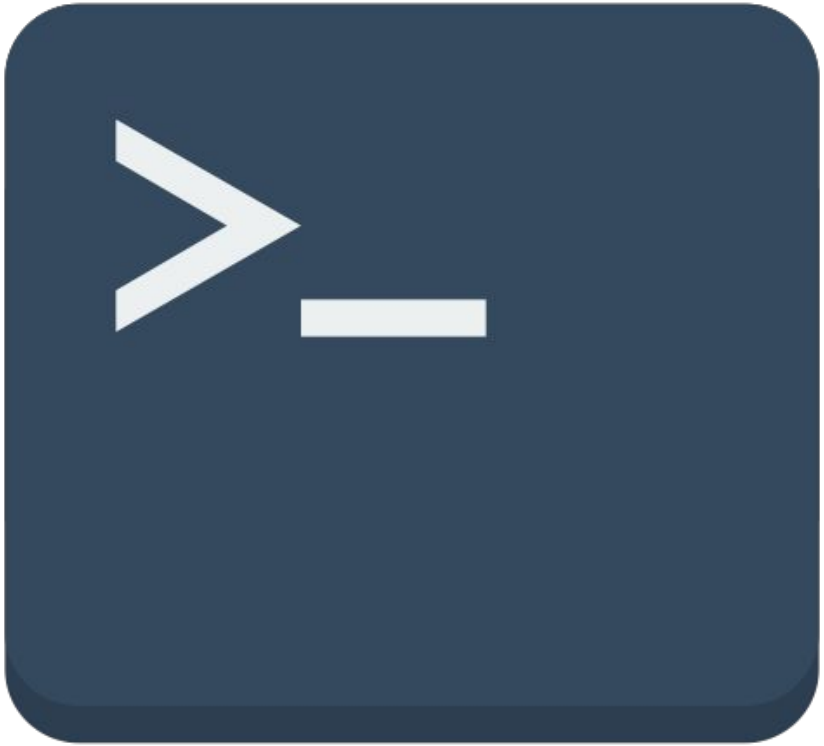
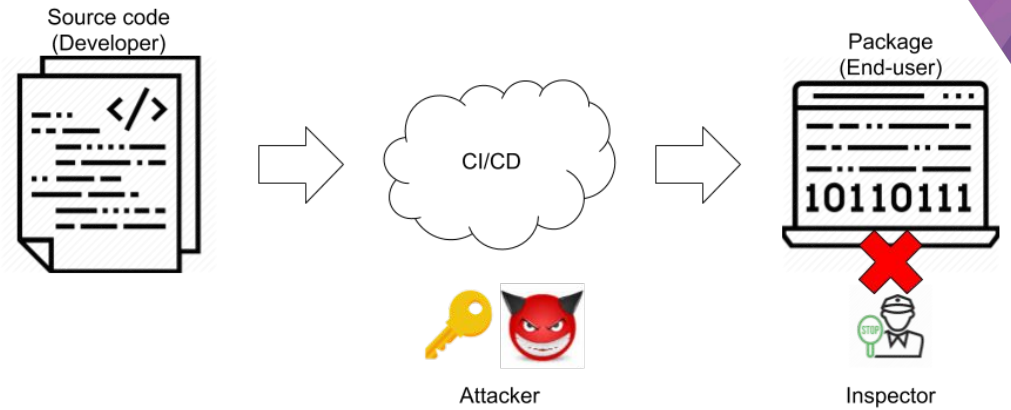
Live demo of production



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

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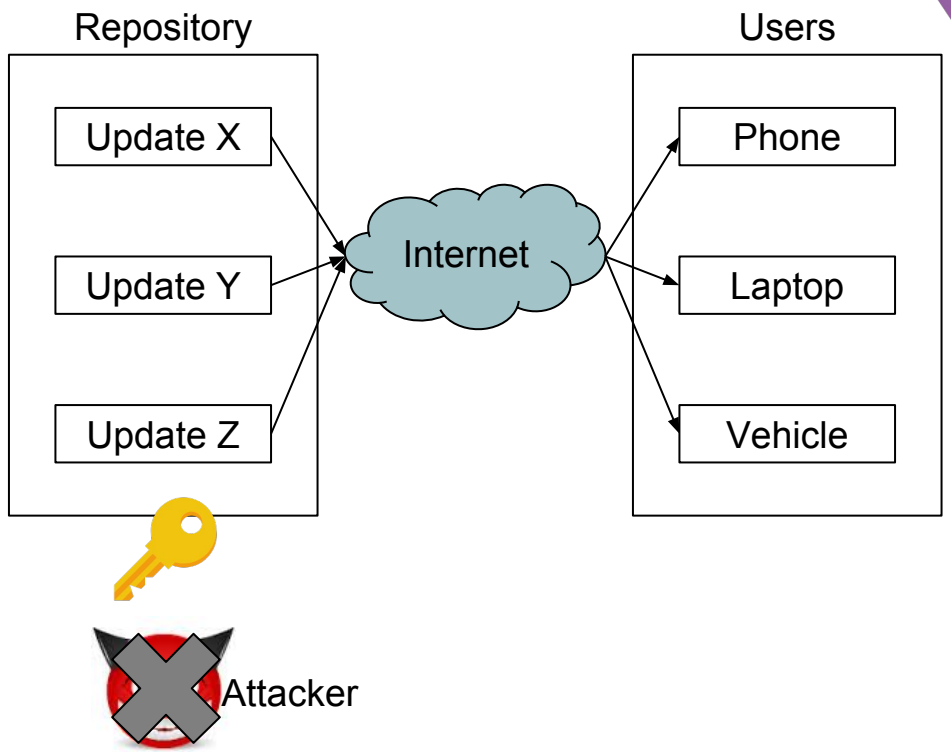
Takeaway: TUF = compromise-resilience

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



TUF: integrations & deployments

Microsoft

CLOUDFLARE

docker

Advanced Telematic SYSTEMS

CoreOS

DATADOG

Flynn

DigitalOcean

LEAR CORPORATION

IBM

vmware

OTAinfo
SECURED OVER THE AIR INFORMATION TRANSFER

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- **CoreOS**
  - Evan Cordell, Jacob Moshenko
- **Uptane**
  - Russ Bielawski, Akan Brown, Meghan Caiazzo, Sam Lauzon, John Liming, Cameron Mott, André Weimerskirch

Q & A

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