

# Protecting your organization against attacks via the build system

Louis Jacomet - Gradle Inc.

@ljacomet



A decorative background element consisting of a complex network of thin blue lines forming various geometric shapes like hexagons and cubes, resembling a digital circuit or a molecular structure.

# Louis Jacomet

Gradle, Inc.

Senior Lead Software Engineer

**Support Team** at Gradle Build Tool





# Gradle

Since 2008, our mission is to improve developer productivity





# Gradle Build Tool

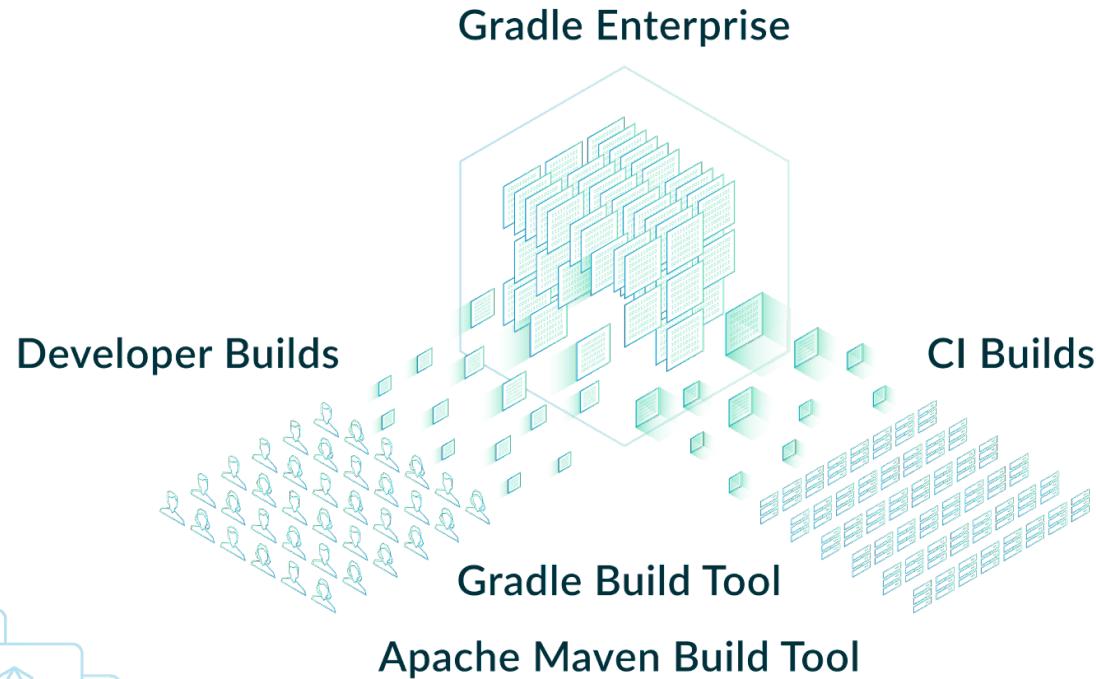
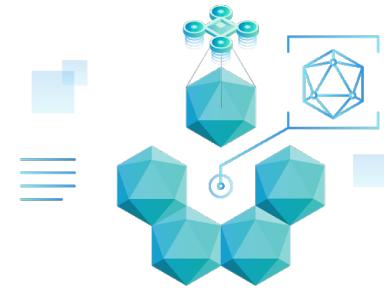
Outil de construction de logiciels publié sous la license [Apache](#)

C'est un des 20 projets open source les plus populaires d'après [TechCrunch](#) avec près de 30 millions de téléchargements mensuels.





# Gradle Enterprise



# Build scans

Gradle Enterprise    ✓ example-build build 19 Oct 2021 01:14:12 CEST

- Summary
- Console log
- Timeline**
- Performance
- Tests
- Projects
- Dependencies
- Build dependencies
- Plugins
- Switches
- Infrastructure

55 tasks executed in 4 projects in 1.799s, with 9 avoided tasks saving 5.667s

Initialization & configuration    Execution

:app:testClasses    1.037s    0.000s    org.gradle.api.DefaultTask

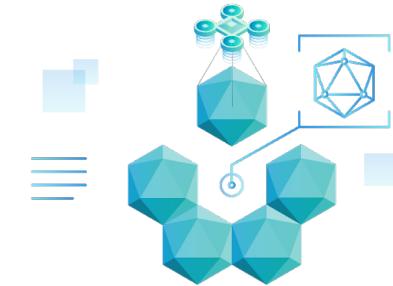
:app:test    1.038s    0.754s

:list:check  
:list:build  
:app:check  
:app:build

Path :app:test  
Type org.gradle.api.tasks.testing.Test

This task is on the critical path.

Started after 1.037s  
Duration > 0.754s



## Gradle & Maven build speed challenge





# Supply chain attacks are no longer an hypothesis

**targets the tools,  
without the developers being aware.**

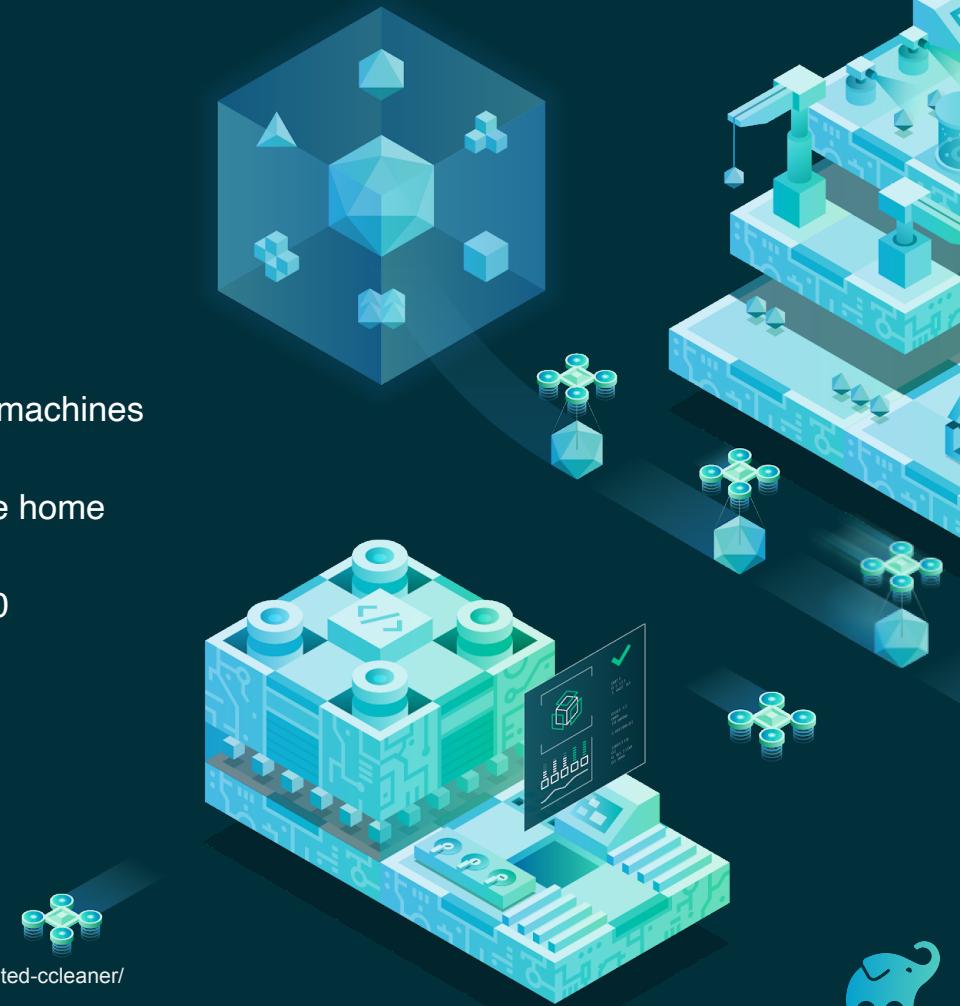
**scale out**

**suspected to be issued from Nation State Actors.**



# CCleaner/Asus in 2018

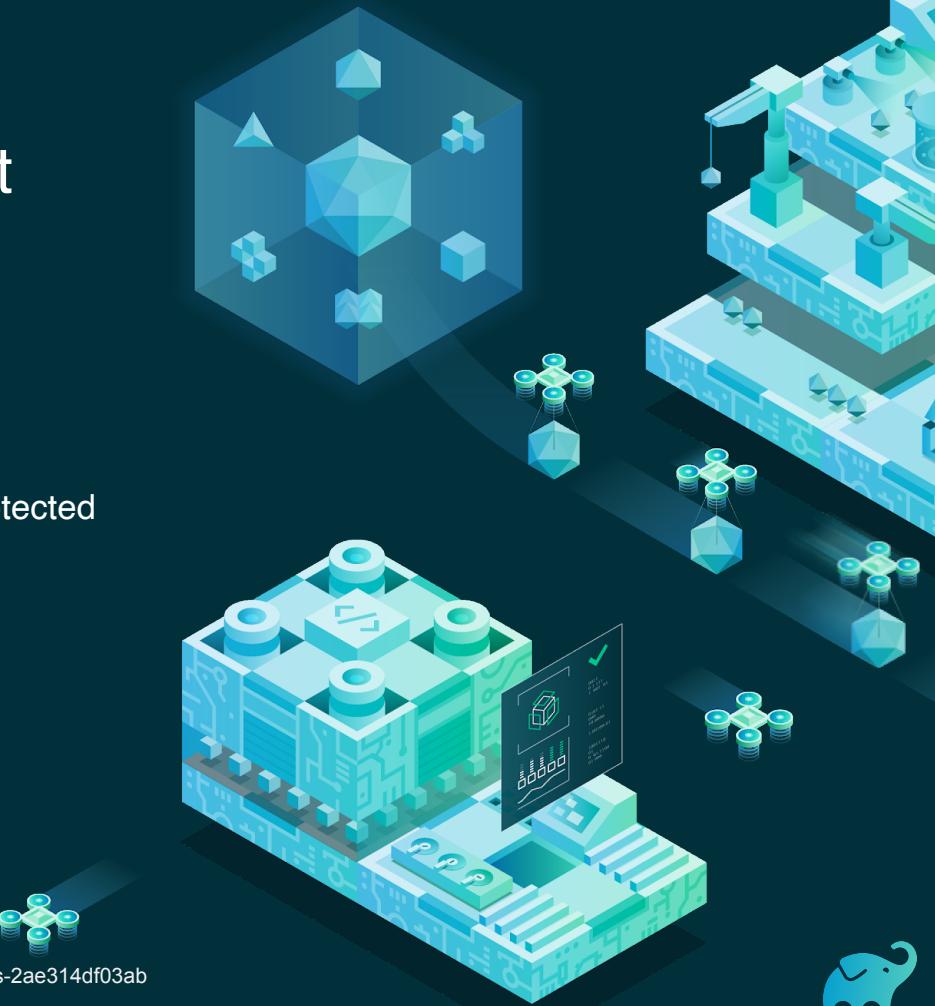
- Hacked into (auto) update systems
- Tool update installed a backdoor (ShadowPad) on machines
- Downloaded 2.27 million times, 1.65 millions phone home
- Follow-up attack against high value targets, only 40



<https://www.wired.com/story/inside-the-unnerving-supply-chain-attack-that-corrupted-ccleaner/>

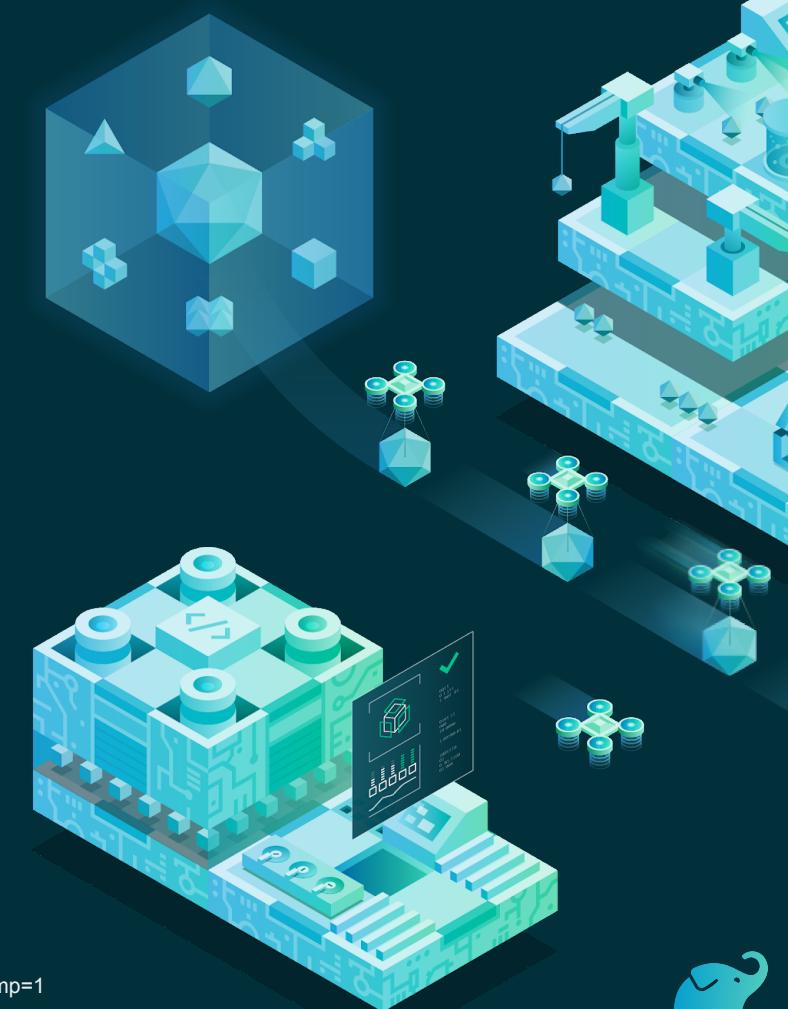
# Homebrew - 30 minutes from nobody to a commit

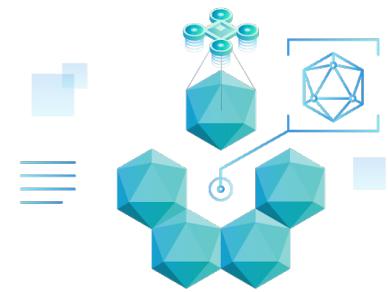
- Case study by Eric Holmes in 2018
- Found a leaked GitHub key on CI
- Committed to the main repo
- Profit Responsible disclosure and get the project protected



# SolarWinds in 2020

- SolarWinds provides system management software
- Hackers inserted a backdoor into the Orion system
- Software update propagated the hack to customers from March until December
- Through the backdoor, customers of customers could be reached





“hackers don't attack individual devices or networks directly, but rather **the companies that distribute the code used by their targets**

<https://www.wired.com/story/supply-chain-hackers-videogames-asus-ccleaner/#>





# Dependency trust is a risk

Package managers cannot guarantee that all packages are **malware-free**.

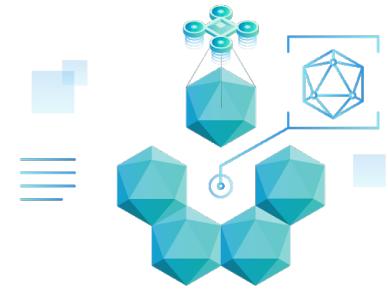




23% of all security advisories against JS projects  
refer to **intentionally malicious packages**

Jonathan Leitschuh, analyzing [Npmjs advisories](#)





“Maintainers of the RubyGems package repository have yanked **18 malicious versions of 11 Ruby libraries** that contained a backdoor mechanism and were caught inserting **code that launched hidden cryptocurrency mining operations** inside other people's Ruby projects.

<https://www.zdnet.com/article/backdoor-code-found-in-11-ruby-libraries/>



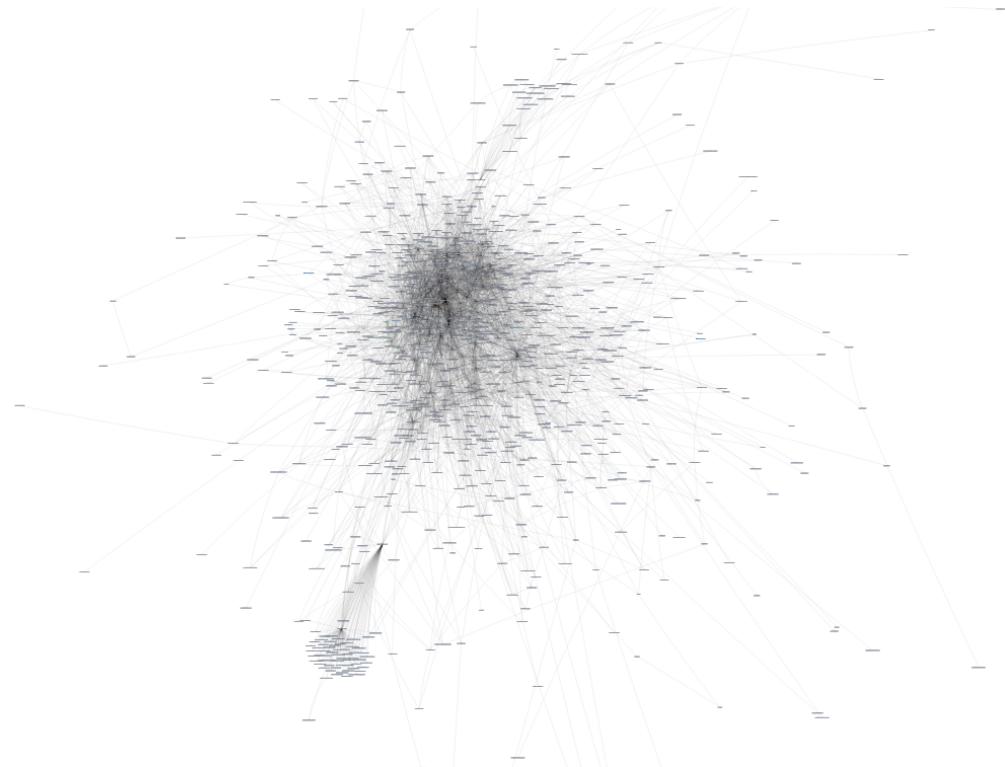


“When installing an average npm package, a user implicitly **trusts around 80 other packages** due to transitive dependencies.

<https://blog.acolyer.org/2019/09/30/small-world-with-high-risks/>



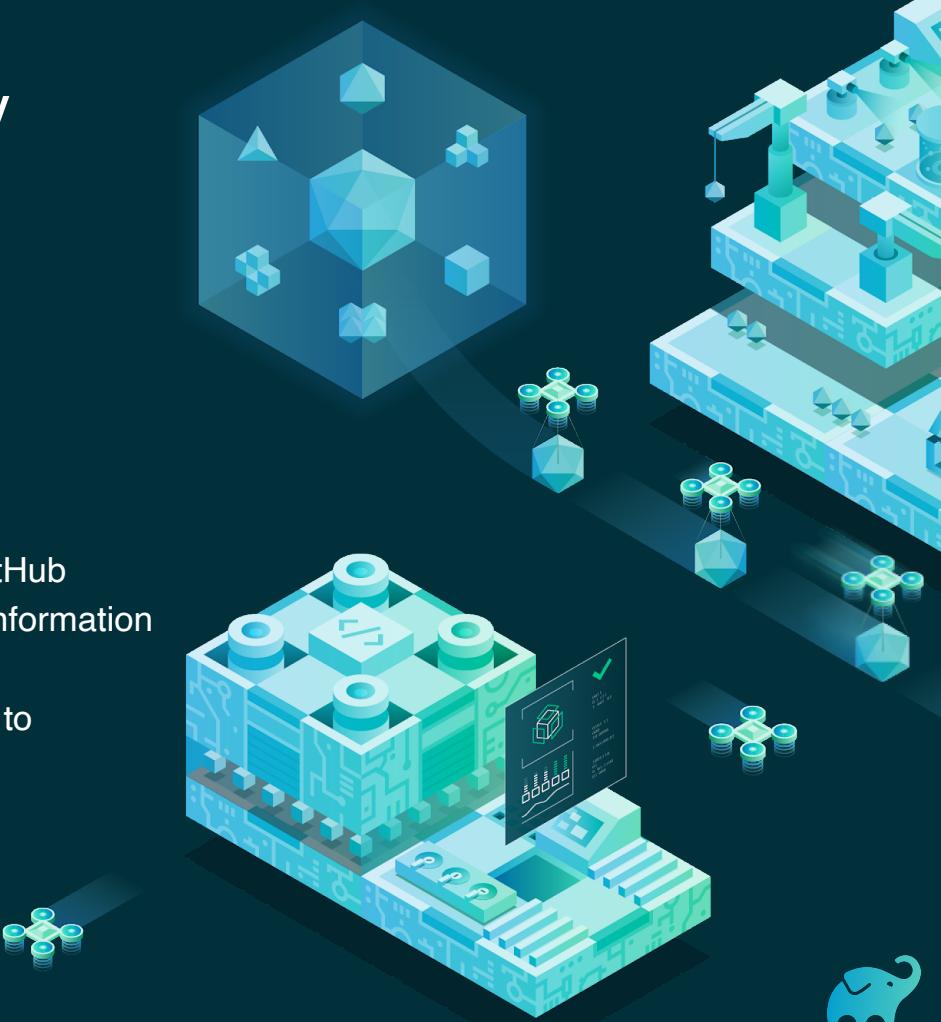
# Real world dependency graph (Java)



# A confusing dependency in 2018

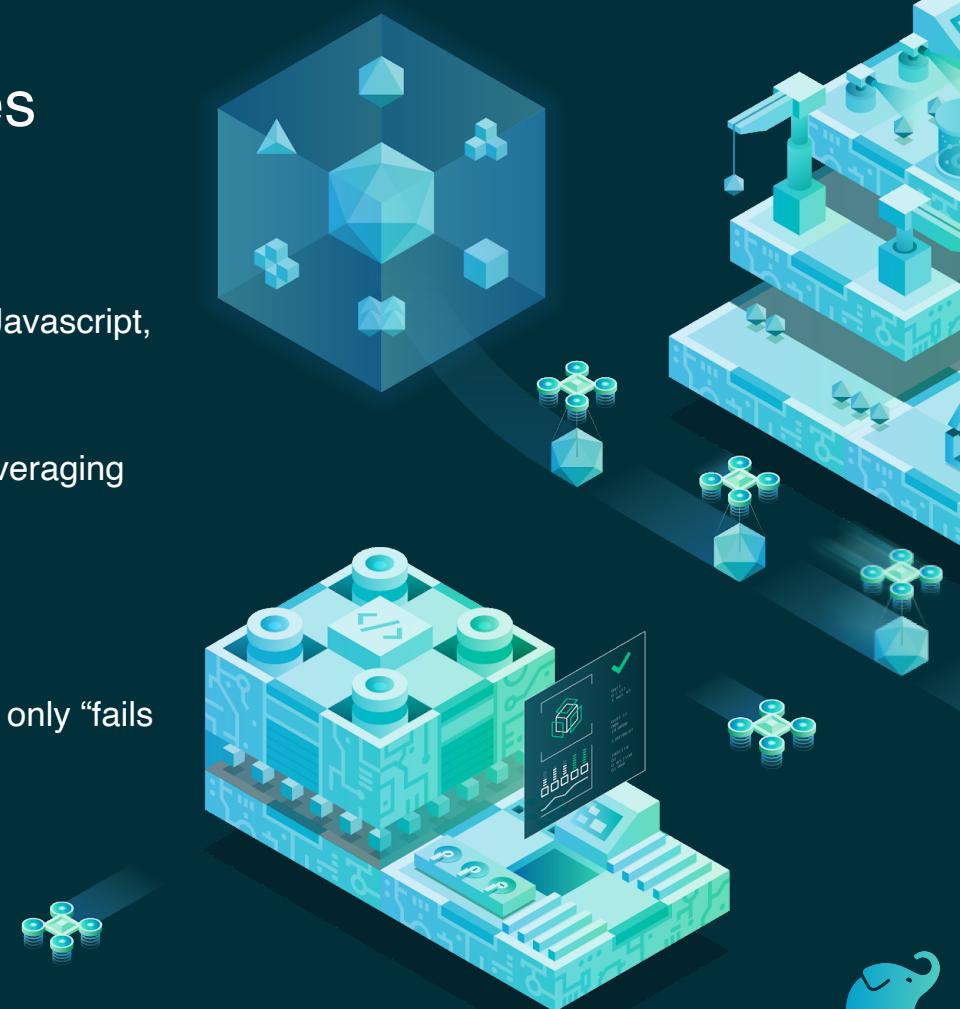
- Android library for audio recording
  - Thousands of stars on GitHub
  - Available through JitPack
- Version that ends up on the app is different
  - Executed code does not match the code on GitHub
  - Attempts network calls, sharing phone model information
- Jitpack version was shadowed by another deployed to JCenter

<https://blog.autsoft.hu/a-confusing-dependency/>



# Confusing dependencies at scale in 2020

- Alex Birsan extracted internal package names for Javascript, Python and Ruby
- Then he deployed a malicious package to each, leveraging DNS queries to exfiltrate information
- Got hits from very large companies
- All of these mean *remote code execution*, even if it only “fails a build”





# JVM Application building: Potential attack vectors

- New code
- CI infrastructure
- Dependencies
- Remote repositories
- Plugins (via plugin portal or Maven Central)
- Gradle/Maven distribution (and wrapper)
- Build cache / external services





# New code and CI infrastructure





# Compromising OSS developer machines

- 01 Submit a PR with compromised code (direct code, upgrade a **plugin** in the build, introduce a new one, upgrade the wrapper, edit a build script, ...)
- 02 Developer checks out the code locally and runs **test**
- 03 Bitcoin all the things!



# How to: compromise CI infrastructure

## 7 successful checks

[Hide all checks](#)

	<b>CI Status</b> — master branch success since 2019-10-28T15:24:33.392Z	<a href="#">Details</a>
	<b>Compile All (Quick Feedback - Linux Only)</b> — TeamCity build finished	<a href="#">Details</a>
	<b>DCO</b> Successful in 2s — DCO	<a href="#">Details</a>
	<b>Performance Regression Test Coordinator - Linux (Ready for Merge)</b> — Te...	<a href="#">Details</a>
	<b>Quick Feedback (Trigger) (Check)</b> — TeamCity build finished	<a href="#">Details</a>
	<b>Quick Feedback - Linux Only (Trigger) (Check)</b> — TeamCity build finished	<a href="#">Details</a>
	<b>Sanity Check (Quick Feedback - Linux Only)</b> — TeamCity build finished	<a href="#">Details</a>

- ◆ Create a pull request
- ◆ Automatically build on CI (private or public farm)
- ◆ **Bitcoin all the things!**



# How to: compromise CI infrastructure

## 7 successful checks

[Hide all checks](#)

	<b>CI Status</b> — master branch success since 2019-10-28T15:24:33.392Z	<a href="#">Details</a>
	<b>Compile All (Quick Feedback - Linux Only)</b> — TeamCity build finished	<a href="#">Details</a>
	<b>DCO</b> Successful in 2s — DCO	<a href="#">Details</a>
	<b>Performance Regression Test Coordinator - Linux (Ready for Merge)</b> — Te...	<a href="#">Details</a>
	<b>Quick Feedback (Trigger) (Check)</b> — TeamCity build finished	<a href="#">Details</a>
	<b>Quick Feedback - Linux Only (Trigger) (Check)</b> — TeamCity build finished	<a href="#">Details</a>
	<b>Sanity Check (Quick Feedback - Linux Only)</b> — TeamCity build finished	<a href="#">Details</a>

- ◆ Create a pull request
- ◆ Automatically build on CI (private or public farm)
- ◆ **Implant malware for infection**





# Never “try out” PRs

- Analyse the change
  - Look at code,
  - **all files**
- Don’t try directly on CI
  - Or even locally!
- Be particularly picky on “obfuscated” upgrades
  - versions
  - binaries





# Pull request acceptance

- Use CLAs (reduces the risks)
- Perform light background verification of the author
- Review first and when you think it's ok
  - Check out the code
  - Test it
- Use **isolated, disposable** build agents
  - Locally as well!



# Signing your commits

Git lets anyone use anyone's identity  
Signing proves your identity

Important for legal too (who contributed what)

Commits on Oct 28, 2019

Merge pull request #11154 from gradle/wolfs/incremental/test-nested-d...	Verified		cea987d	
wolfs committed 1 hour ago ✓				
Merge branch 'release'	Verified		zee1fde	
jjohannes committed 2 hours ago ✓				
Increase timeout in integration test	Verified		ecbc992	
jjohannes committed 2 hours ago ✓				
Set 'org.gradle.workers.max' to 'maxParallelForks' on CI (#11158)	Verified		c4e9590	
jjohannes committed 2 hours ago				
Remove broken import	Verified		11a6ce6	
jjohannes committed 3 hours ago				
Remove unused utility test configurations (#11155)	Verified		8e21b80	
jjohannes committed 3 hours ago				
Add test for nested domain object containers as input	Verified		4f0a3a1	
wolfs committed 4 hours ago ✓				
Merge branch 'release'	Verified		6798612	
ljacomet committed 5 hours ago ●				
Increase integration test timeout	Verified		54ab5c1	
ljacomet committed 5 hours ago ●				



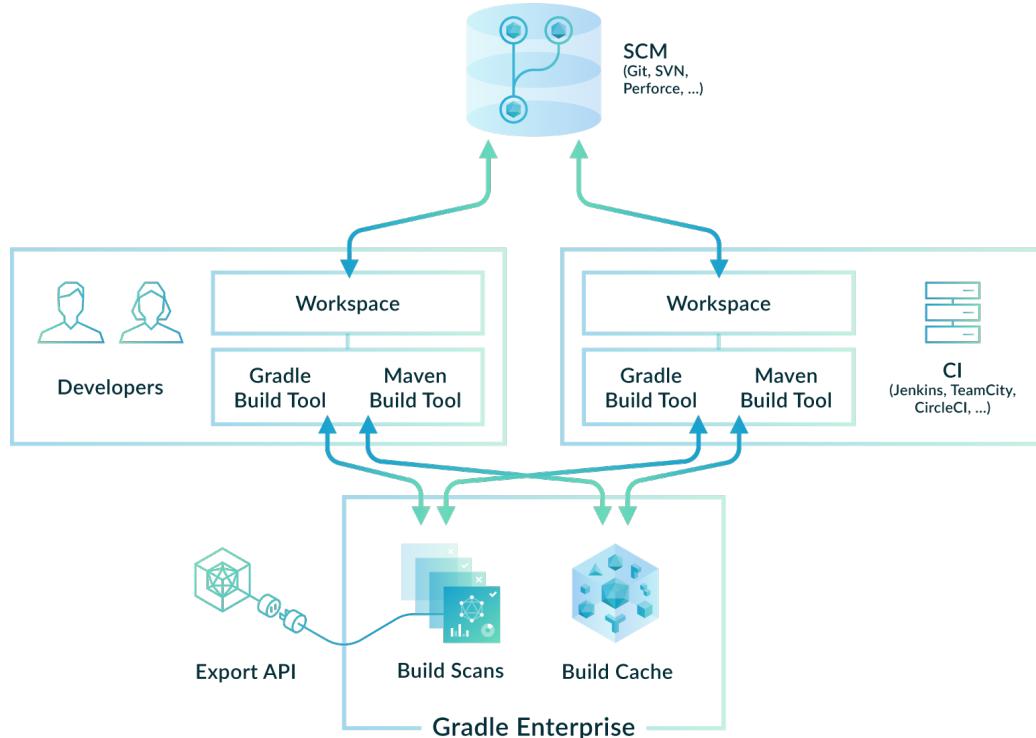
# Improving CI security

**Disposable containers** are a good idea for security, however:

- They are **bad for performance** (extra downloads, no Gradle daemon, build bootstrapping, ...)
- A single **vulnerability** in a container may be enough to **gain access to the host**



# Mitigating performance issues





# Mitigating performance issues

The **build cache** makes it possible to **reuse task outputs** from different build agents.

Needs **secure** connection between nodes.

Doesn't deal with **dependency downloads**

The later can be handled by **copying or sharing** a dependency cache (Gradle 6.2)





# Dependencies, plugins and repositories





# Our Commons: Maven Central / JCenter

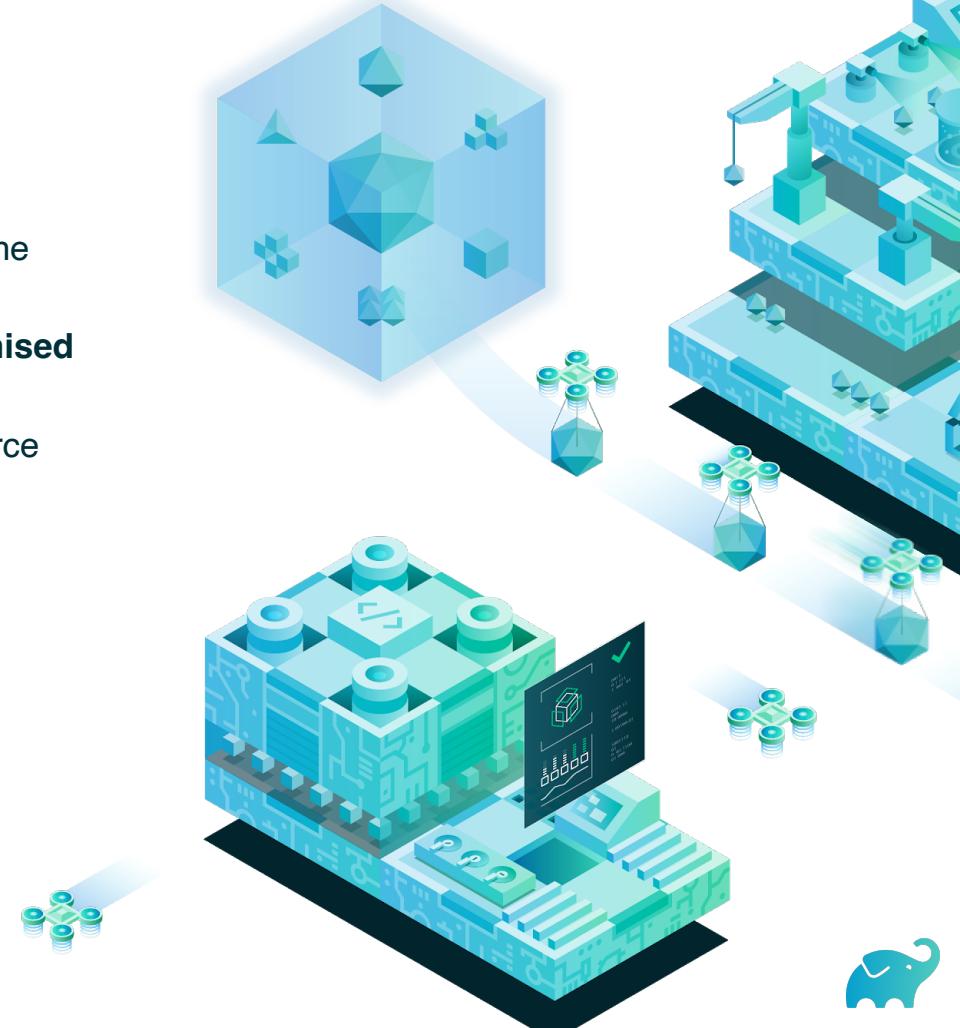
Contains millions of artifacts, mostly published as **convenience binaries**, together with:

- ◆ MD5 checksums → **unsafe for a while**
- ◆ SHA1 checksums → **really no longer safe**
- ◆ ASC signatures → **not always safe**



# Checksums

- A checksum guarantees the **integrity** of the artifact (if it's safe...)
- Repository checksums **may be compromised** too!
  - Use checksums from a different source (website)
  - Publish checksums separately on a different machine!
- Gradle 6 publishes **SHA256** and **SHA512**





There are **broken checksums** on Maven Central.  
JCenter computes SHA1/MD5 **on demand**.

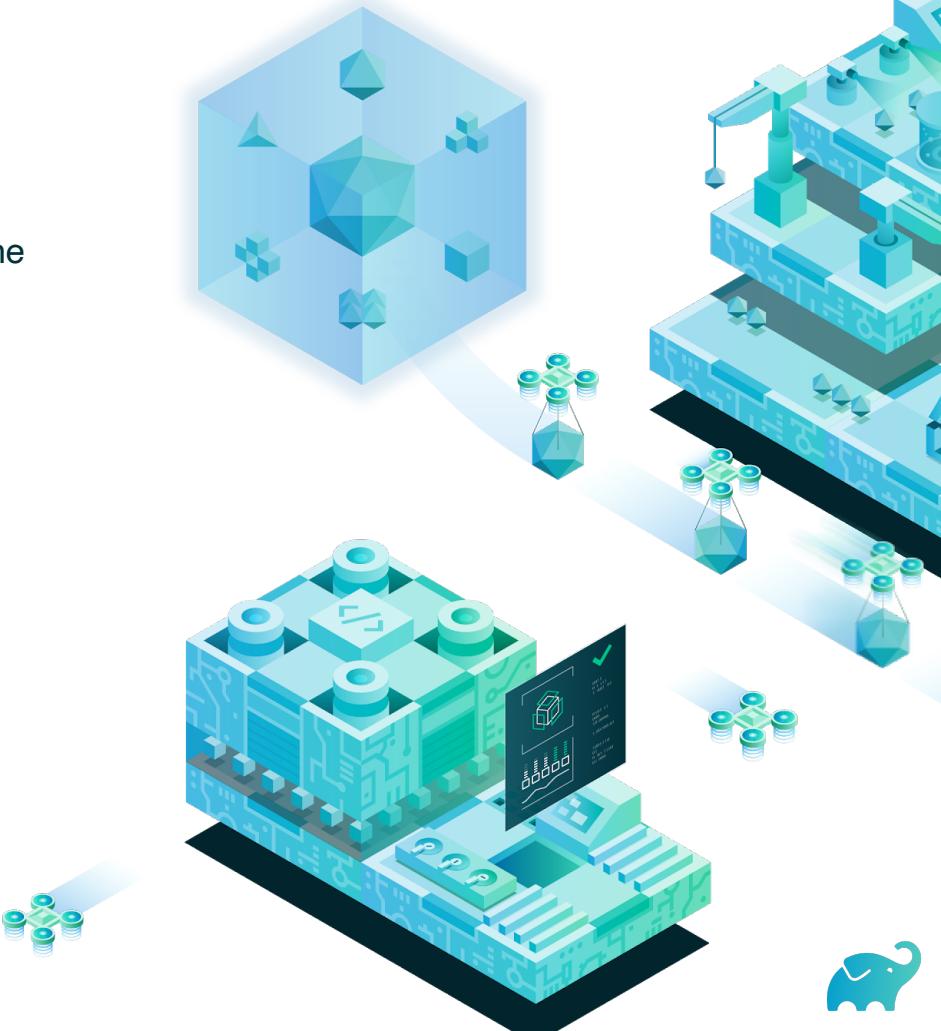


# Signatures

- A signature guarantees the **origin** of the artifact (if private key didn't leak)
- Commonly uses PGP
- Harder for casual developers to check

But:

- Keys sometimes lost
- Malicious authors can sign too



# Verifying dependencies with Gradle

```
<?xml version="1.0" encoding="UTF-8"?>
<verification-metadata xmlns="https://schema.gradle.org/dependency-verification"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="https://schema.gradle.org/dependency-verification https://schema.gradle.org/dependency-verification.xsd">
    <configuration>
        <verify-metadata>false</verify-metadata>
        <verify-signatures>true</verify-signatures>
        <trusted-artifacts>
            <trust group="gradle" name="gradle"/>
            <!-- TAPI tests use a lot of different versions of the Tooling API -->
            <trust group="org.gradle" name="gradle-tooling-api"/>
            <trust group="net.[.]rubbygrapefruit" name="native-platform.*" version=".*snapshot.*" regex="true"/>
            <trust file=".*javadoc[.]jar" regex="true"/>
            <trust file=".*sources[.]jar" regex="true"/>
        </trusted-artifacts>
        <ignored-keys>
            <ignored-key id="74dafdfd6dae2441" reason="Key couldn't be downloaded from any key server"/>
        </ignored-keys>
        <trusted-keys>
            <trusted-key id="019082bc00e0324e2aef4cf00d3b328562a119a7" group="org.openjdk.jmh"/>
            <trusted-key id="0785b3eff60b1b1bea94e0bb7c25280eaed63eb5" group="org.apache.httpcomponents"/>
            <trusted-key id="07e20f0103d9dfc697c490d0368557390486f2c5" group="org.awaitility"/>
            <trusted-key id="08f0aab4d0c1a4bdde340765b341db020fcba6ab" group="org.bouncycastle"/>
            <trusted-key id="160a7a9cf46221a56b06ad64461a804f2609fd89" group="com.[.]githhub[.]shyiko($|([.]*))" regex="true"/>
            <trusted-key id="19beab2d799c020f17c69126b16698a4adfd4d638" group="org.checkerframework" name="checker-qual"/>
            <trusted-key id="1fa868a348719e88b6ddde24c03ef1d7d692bcff" group="org.scala-lang"/>
            <trusted-key id="21f0942275ea159a501d375328852008a47bb995" group="^com[.]google($|([.]*))" regex="true"/>
            <trusted-key id="2db4f1ef0fa761ecc4ea935c86fdc7e2a11262cb">
                <trusting group="commons-codec"/>
                <trusting group="org.apache.commons"/>
            </trusted-key>
        </trusted-keys>
    </configuration>
</verification-metadata>
```

- ◆ **Supported in Gradle core -**  
Requires Gradle 6.2
- ◆ **Can check plugins** in addition to regular dependencies
- ◆ **Supports checking metadata -**  
pom.xml, .module, ...
- ◆ Can be **checksum** or **signature** based
- ◆ Generate file for updates, validating results (Gradle 7.4)



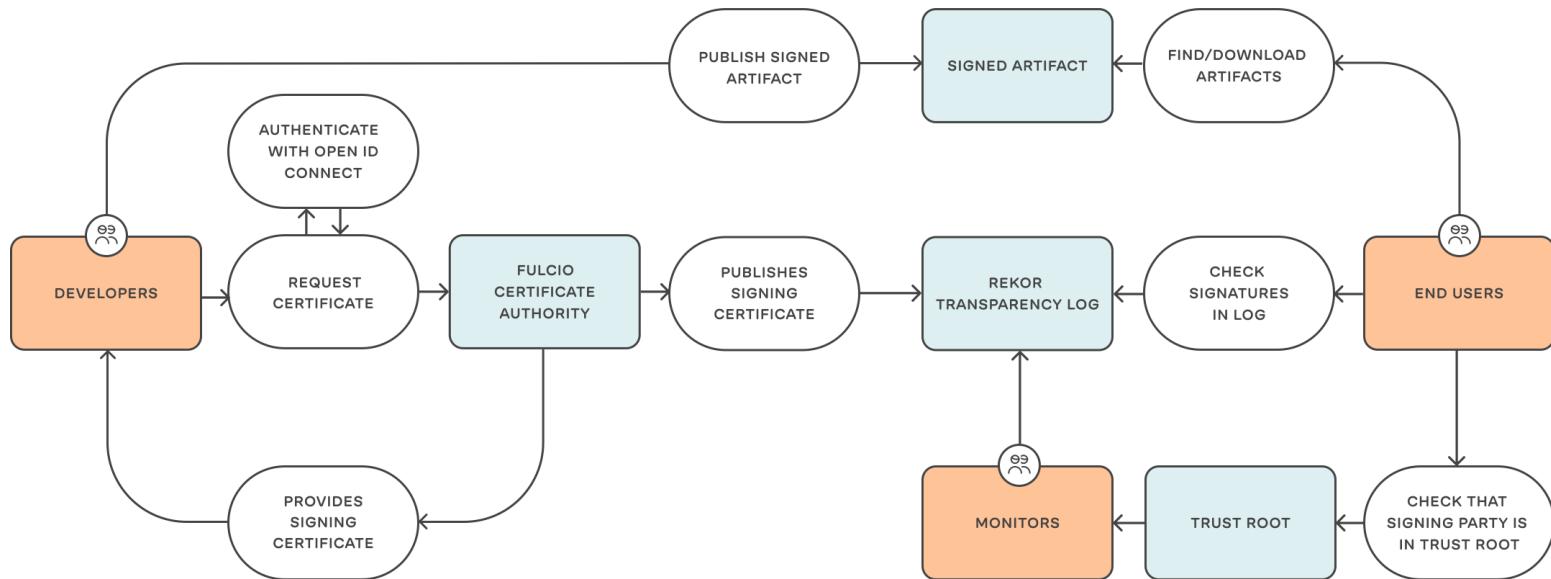
# Verification in Maven



- <https://www.simplify4u.org/pgpverify-maven-plugin/>
- Supports plugins
- Supports checking metadata - pom.xml

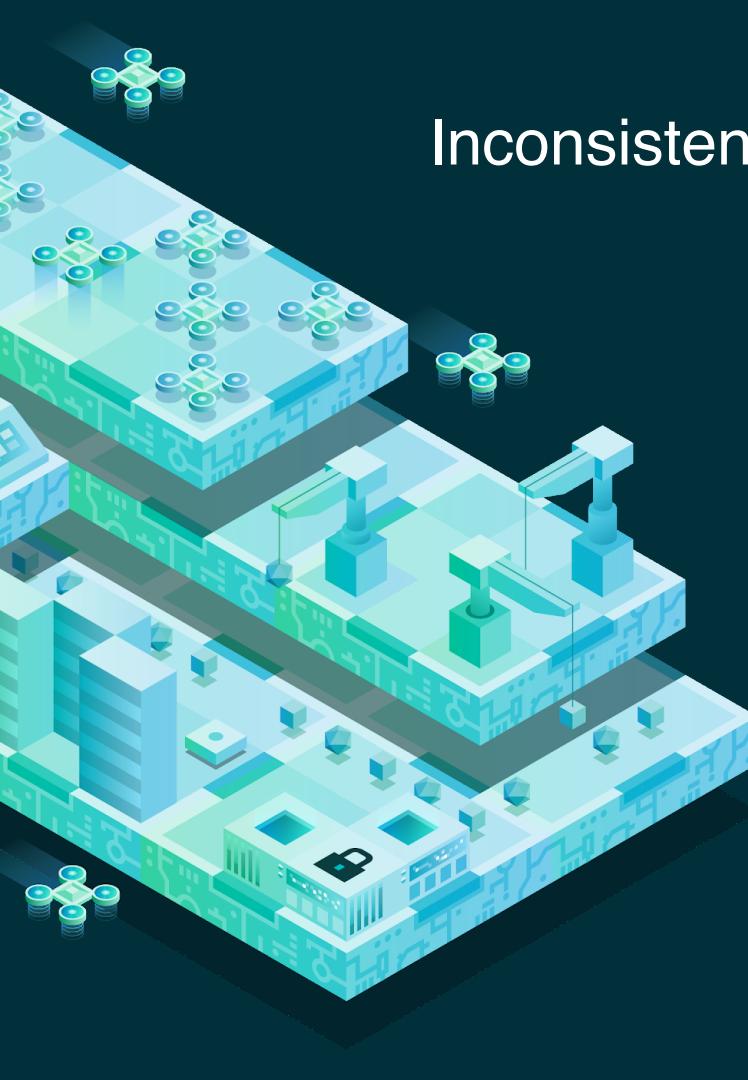


# The sigstore initiative



<https://www.sigstore.dev/>





# Inconsistent repositories

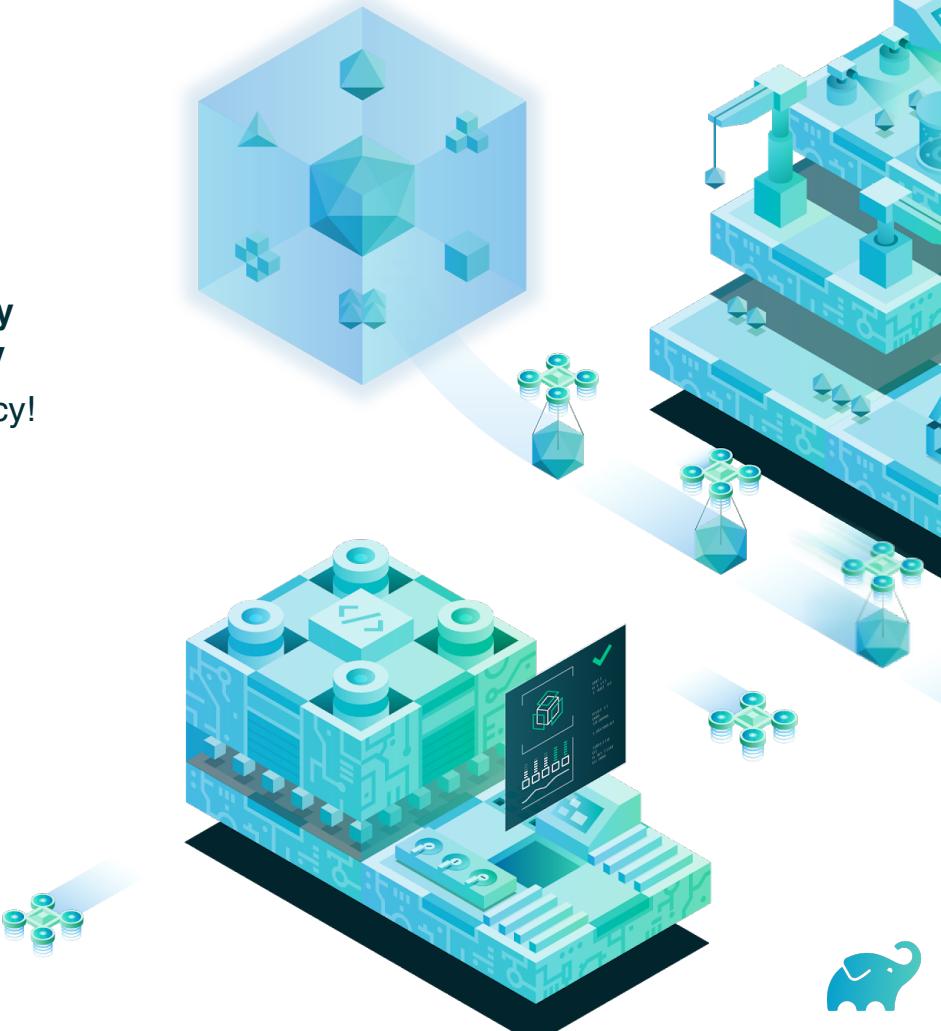
Different repositories may contain different **artifacts** or **metadata** for a single release!

*Gradle's own dependency verification file has entries with multiple checksums for the same file*



# Malicious repositories

Bintray had a vulnerability which **allowed any user to publish dependencies on any GAV coordinates**, shadowing any real dependency!

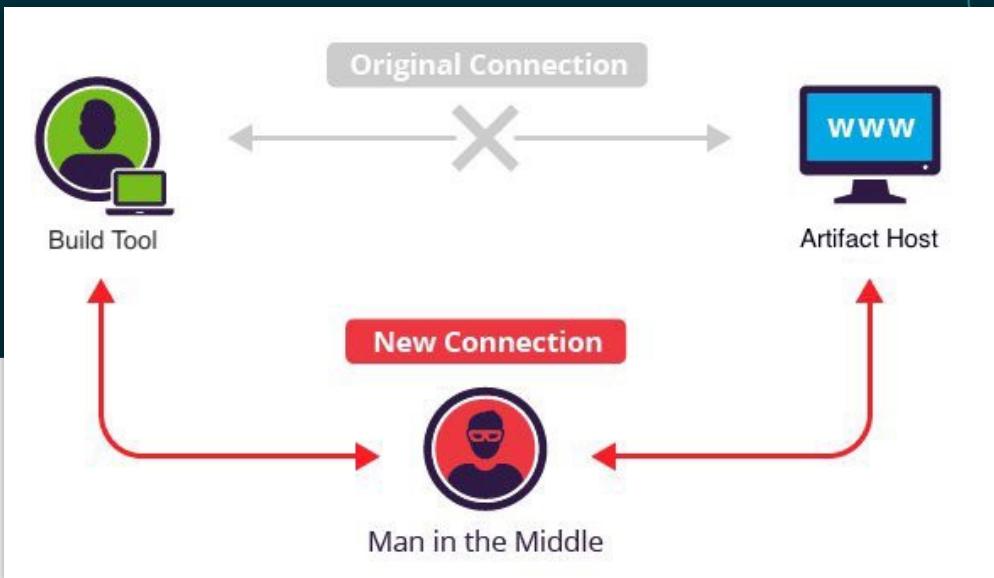


## Man In The Middle Attack

25% of Maven Central downloads are still using HTTP

Gradle deprecates HTTP downloads and decommissions HTTP-based services (**denied** on January 15th, 2020)

Also look at <https://github.com/spring-io/nohttp>

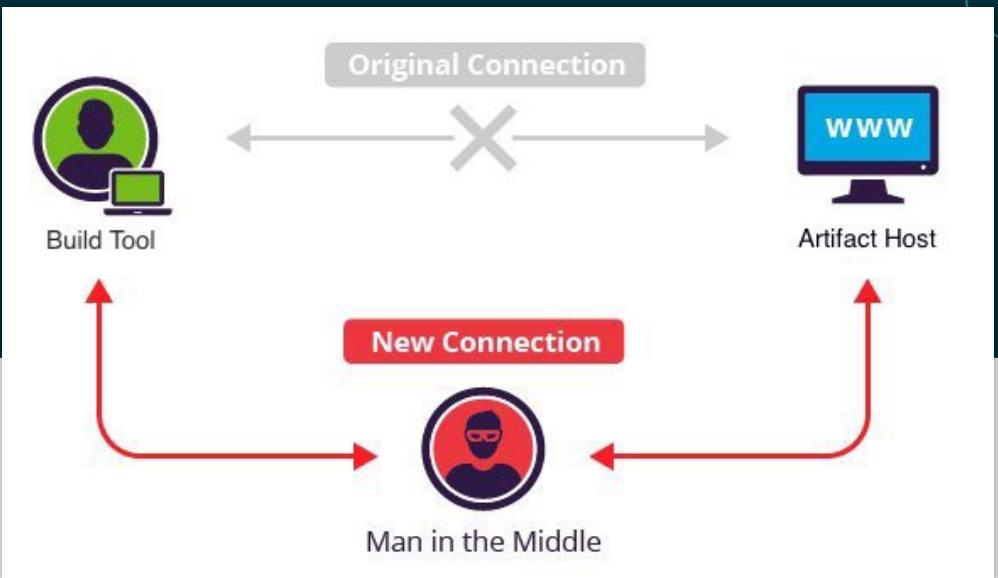


# Man in The Middle Attack

25% of Maven Central downloads are still using HTTP

Gradle deprecates HTTP downloads and decommissions HTTP-based services (**denied** on January 15th, 2020)

Also look at <https://github.com/spring-io/nohttp>





# GitHub package registry

GitHub offers **custom packages publications**, effectively allowing anyone to publish any module on a **GitHub Maven repository**.

Trusting the source becomes extremely important!

(Currently requires a token to access)

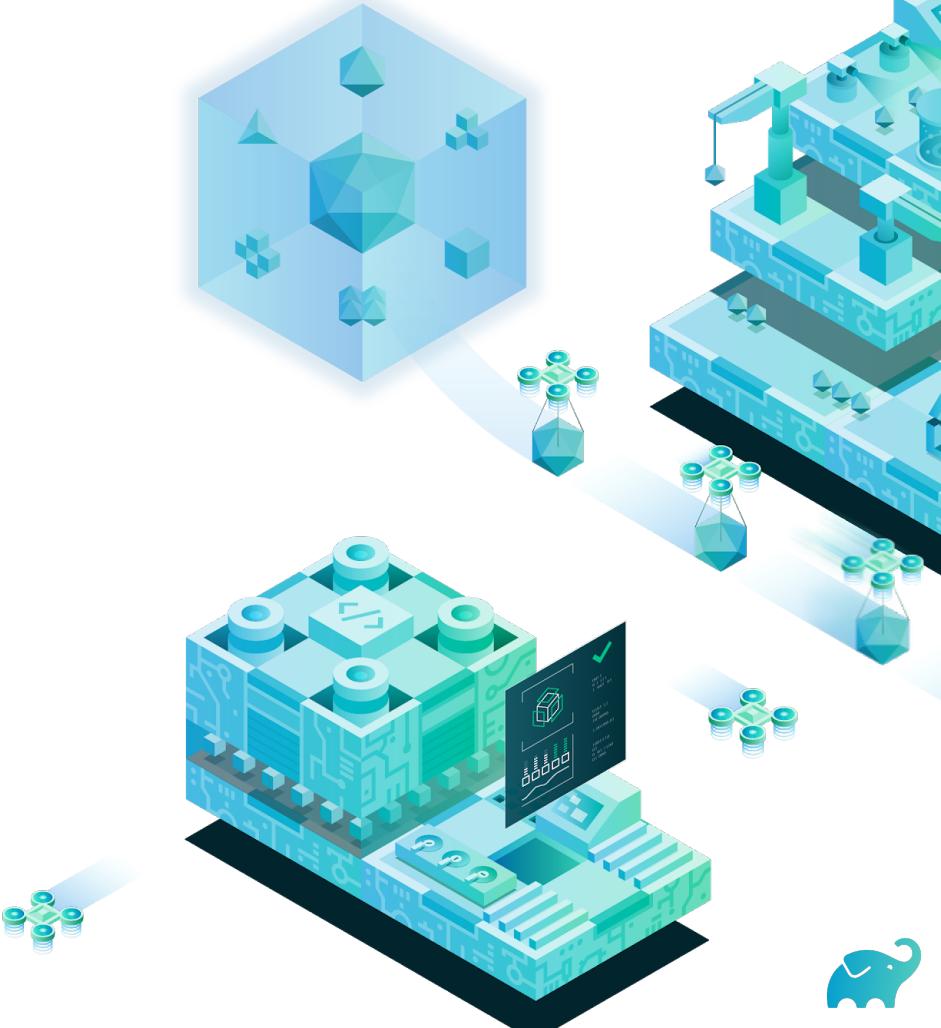


# JitPack

Coordinates based on GitHub or DNS claims

Could be shadowed on another repository

Be careful!



# Repository filtering with Gradle

```
repositories {  
    jcenter {  
        content {  
            includeGroup("junit")  
            includeGroup("com.google.guava")  
        }  
    }  
    maven {  
        name = "myCompanyRepo"  
        content {  
            includeGroupByRegex("com\\.mycompany\\..*")  
        }  
    }  
}
```

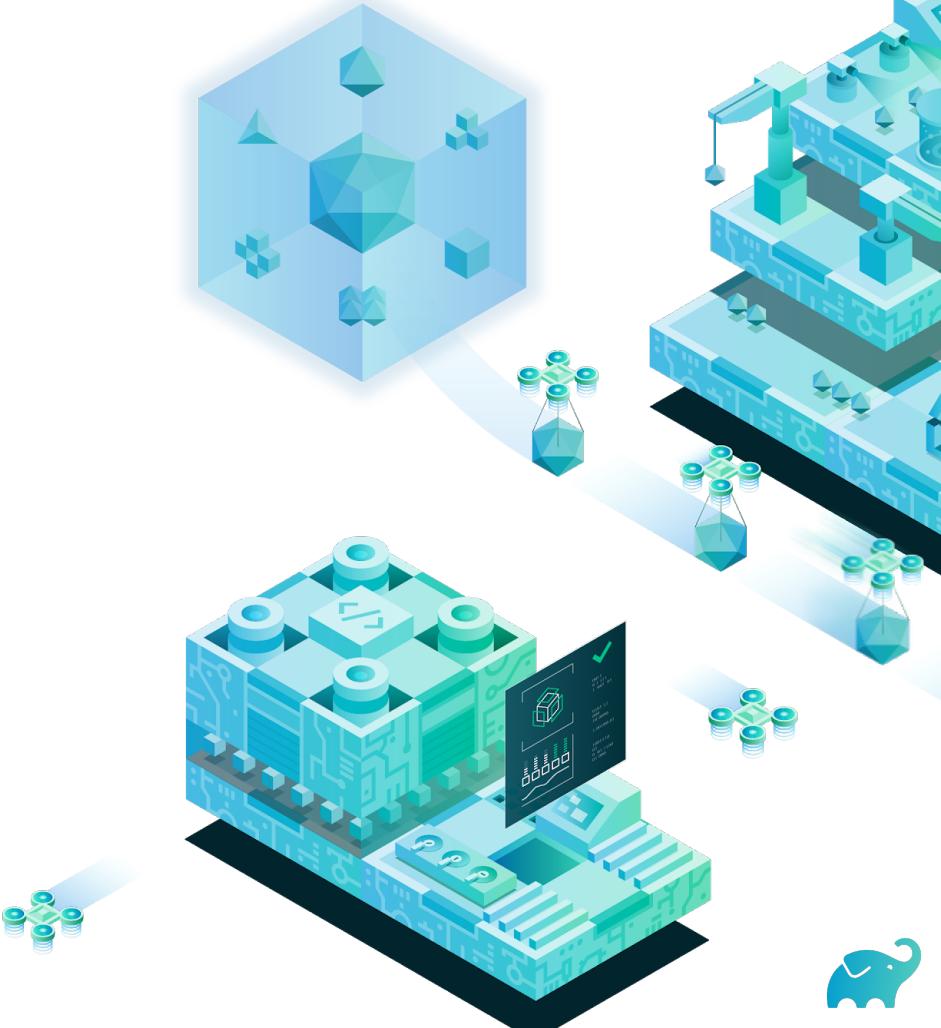
- **Know where your dependencies come from** - Precisely tell Gradle what repository contains what dependency
- **Avoid leaking details about your organization** - Avoids pinging external repositories for your internal coordinates!
- **Avoids ordering issues** - Repositories can be listed in any order if they are mutually exclusive
- **Improves performance** - No unnecessary lookups



# Dealing with vulnerable dependencies

Dependency lifecycle **doesn't end at publication:**

- Bugs are discovered
- Vulnerabilities are discovered
- Bad metadata is published



# Using rich versions in Gradle

```
dependencies {  
    implementation("org.apache.commons:commons-compress") {  
        version {  
            strictly("[1.0, 2.0[")  
            prefer("1.19")  
        }  
    }  
}
```

```
dependencies {  
    constraints {  
        implementation("org.apache.commons:commons-compress") {  
            version {  
                reject("1.15", "1.16", "1.17", "1.18")  
            }  
            because("Versions 1.15-1.18 have a CVE")  
        }  
    }  
}
```

Can be added dynamically

- ◆ **Rich versions** - Allows more accurate model of why a dependency is needed
- ◆ **Graph wide** - Opinions of transitive dependencies matter
- ◆ **Allows enriching the graph with new constraints** - Consumers can tell something about transitives
- ◆ **Component metadata rules** - For amending existing metadata



# Tooling



# Gradle wrapper checksum verification

## Gradle distribution and wrapper JAR checksum reference

This page lists the SHA-256 checksums for all Gradle distributions and `gradle-wrapper.jar` files for your reference. See how to [verify downloaded Gradle distributions](#) and [wrapper JARs](#) in the Gradle documentation.

### ↳ v5.6.3

Binary-only (-bin) ZIP Checksum:

```
60a6d8f687e3e7a4bc901cc6bc3db190efae0f02f0cc697e323e0f9336f224a3
```

Complete (-all) ZIP Checksum:

```
342f8e75a8879fa9192163fa8d932b9f6383ea00c1918a478f0f51e11e004b60
```

Wrapper JAR Checksum:

```
3dc39ad650d40f6c029bd8ff605c6d95865d657dbfdeacdb079db0ddffffedf9f
```

In `gradle-wrapper.properties`:

```
distributionSha256Sum=371cb9fbbebe9880d147f59bab36d61eee122854ef8c9ee1ecf12b82368bcf10
```

- ◆ **Gradle wrapper will verify distribution checksums** - On every invocation
- ◆ **But you need to manually check the wrapper checksum itself** - To avoid a compromised wrapper!
- ◆ **Expected checksum is checked in** - Using a compromised distribution requires access to the source repository



# Gradle wrapper GitHub action



## Gradle Wrapper Validation Action

This action validates the checksums of [Gradle Wrapper](#) JAR files present in the source tree and fails if unknown Gradle Wrapper JAR files are found.

### The Gradle Wrapper Problem in Open Source

The `gradle-wrapper.jar` is a binary blob of executable code that is checked into nearly [2.8 Million GitHub Repositories](#).

Searching across GitHub you can find many pull requests (PRs) with helpful titles like 'Update to Gradle xxx'. Many of these PRs are contributed by individuals outside of the organization maintaining the project.

Many maintainers are incredibly grateful for these kinds of contributions as it takes an item off of their backlog. We assume that most maintainers do not consider the security implications of accepting the Gradle Wrapper binary from external contributors. There is a certain amount of blind trust open source maintainers have. Further compounding the issue is that maintainers are most often greeted in these PRs with a diff to the `gradle-wrapper.jar` that looks like this.

- ◆ **GitHub action** - To be added to your workflow
- ◆ **Validates the wrapper JAR checksum itself** - To avoid a compromised wrapper!





# A word about 3rd-party distributions

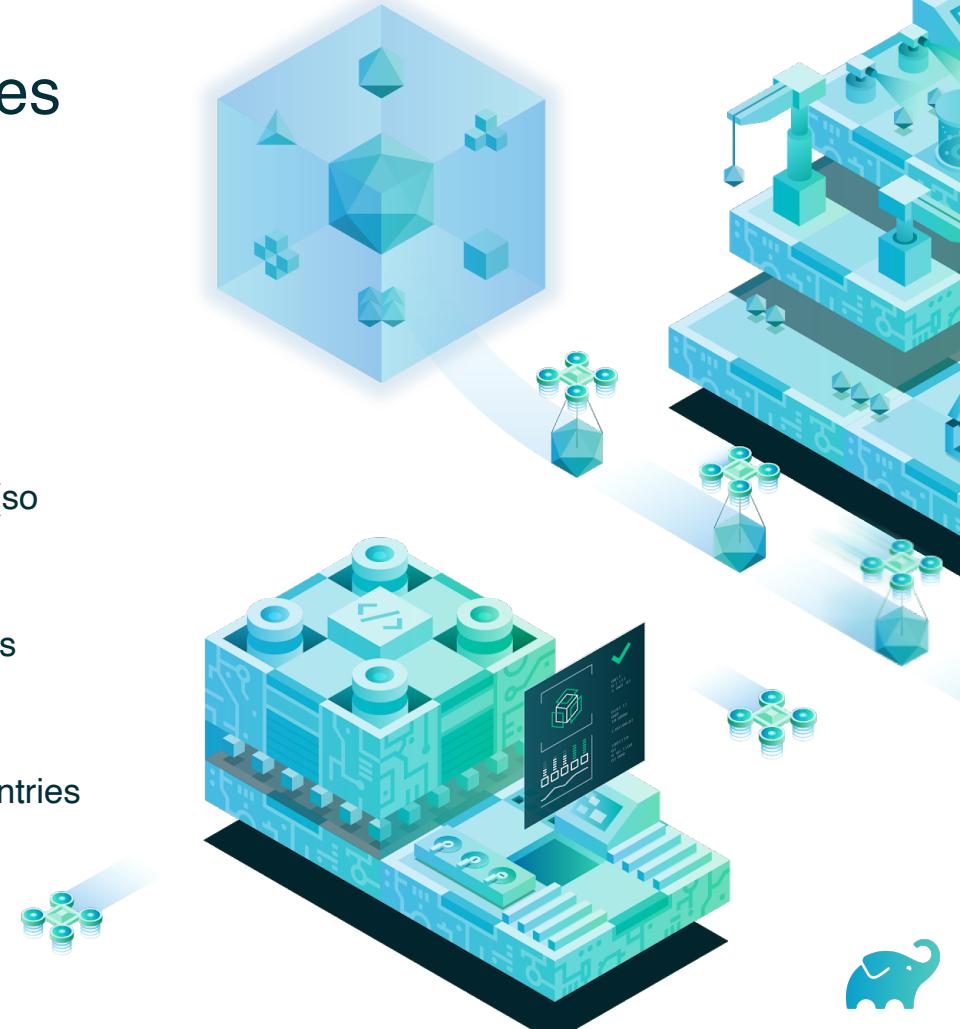
- Gradle “official” Docker image is **not** endorsed by Gradle
- Debian and other distributions are **not** official Gradle releases
  - They use **different dependencies**
  - They build their own!
  - But they pretend to be Gradle (same version number)
- Please always prefer official releases (and Gradle wrapper if possible!)



# Abusing external services

Using Gradle build cache as an example:

- Requires **write access** to the cache (so compromised machine or malicious employee)
- Write **custom client** to write malicious output to the cache for a known key (SHA1)
- Clients will download compromised entries





# Reproducible builds

Any release should be reproducible **byte to byte**

In practice many things can go wrong:

- Dynamic dependencies (ranges, 1.+ , latest, ...)
- Undeclared inputs
- Timestamps/debug symbols/absolute paths/...
- Dependencies removed from remote repositories
- Compiler bugs
- etc

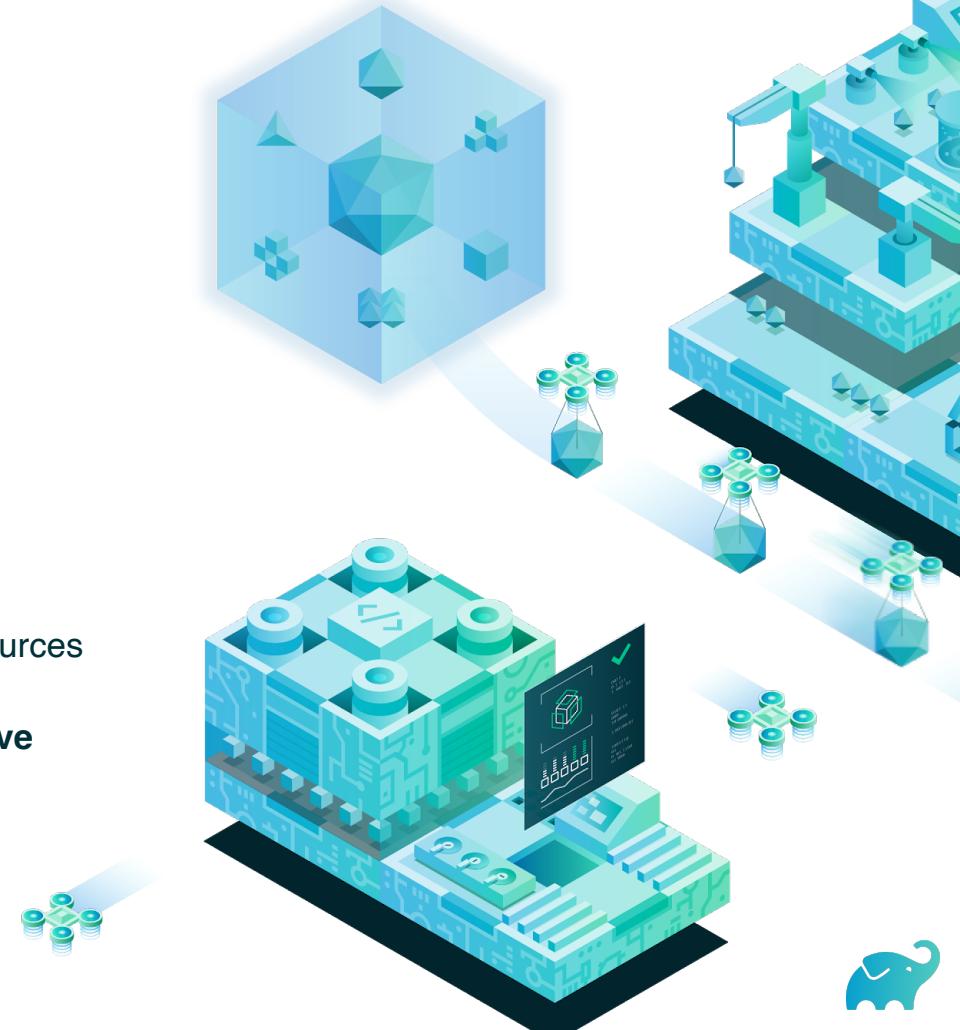


# Different approaches to reproducibility

The *Apache Software Foundation™* way:

- Only **sources** matter
- Binaries (zip, jar, ...) on Central or dist.apache.org are convenience
- Trusting requires you to build from sources

Bootstrapping problem: what about **transitive dependencies**?

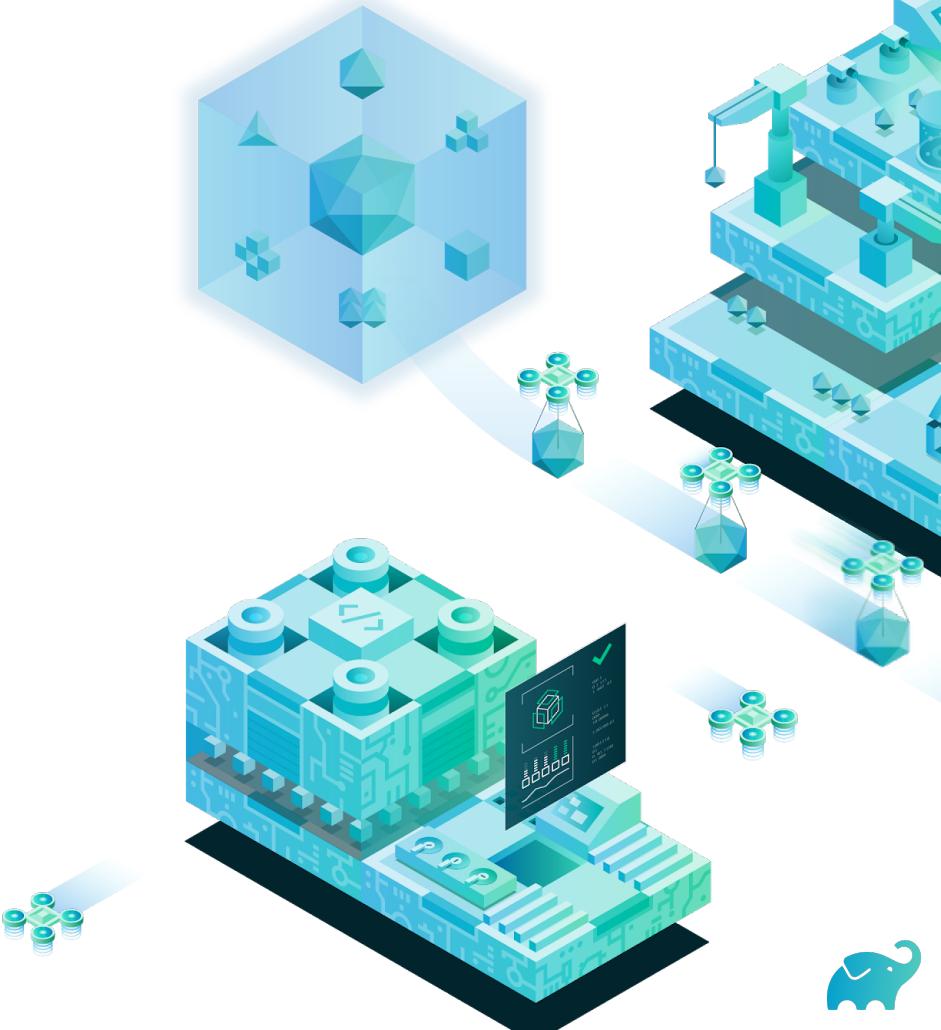


# Different approaches to reproducibility

The *Google* way:

- Only **sources** matter
- No binaries, ever
- Single mono-repository

What about reuse?



# We have to make compromises

If multiple organizations can build the same binaries, byte to byte, from the same sources:

- Reinforces trust
- Improves build quality
- Makes it harder to compromise

A set of best practices:

See <https://reproducible-builds.org/>

- ◆ **Dependency locking** - Make sure you can reuse the same versions later
- ◆ **Checksum verification** - Binaries will not be compromised
- ◆ **Reproducible archives** - Avoid timestamps, consistent ordering of archive entries, ...





# Thank you!

Gradle: <https://www.gradle.org>

@ljacomet



# References

- ◆ [Small world with high risks: a study of security threats in the npm ecosystem](#)
- ◆ [Want to take over the Java ecosystem? All you need is a MITM!](#)
- ◆ [The NPM package that walked away with all your passwords](#)
- ◆ [A Post-Mortem of the Malicious event-stream backdoor](#)
- ◆ [Backdoor code found in 11 Ruby libraries](#)
- ◆ [ESlint Postmortem for Malicious Packages Published on July 12th, 2018](#)
- ◆ [Inside the Unnerving CCleaner Supply Chain Attack](#)
- ◆ <https://blog.autsoft.hu/a-confusing-dependency/>
- ◆ <https://www.techtarget.com/whatis/feature/SolarWinds-hack-explained-Everything-you-need-to-know?amp=1>
- ◆ <https://medium.com/@alex.birsan/dependency-confusion-4a5d60fec610>

