Introduction to Docker caching

INTRODUCTION TO DOCKER

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Docker build

Downloading and unzipping a file using the Docker instructions.

```
RUN curl http://example.com/example_folder.zip
RUN unzip example_folder.zip
```

Will change the file system and add:

```
/example_folder.zip
/example_folder/
    example_file1
    example_file2
```

It is these changes that are stored in the image.

Docker instructions are linked to File system changes

Each instruction in the Dockerfile is linked to the changes it made in the image file system.

```
FROM docker.io/library/ubuntu
 => Gives us a file system to start from with all files needed to run Ubuntu
```

```
COPY /pipeline/ /pipeline/
 => Creates the /pipeline/ folder
 => Copies multiple files in the /pipeline/ folder
```

```
RUN apt-get install -y python3
 => Add python3 to /var/lib/
```

Docker layers

- Docker layer: All changes caused by a single Dockerfile instruction.
- Docker image: All layers created during a build

--> Docker image: All changes to the file system by all Dockerfile instructions.

While building a Dockerfile, Docker tells us which layer it is working on:

```
=> [1/3] FROM docker.io/library/ubuntu
=> [2/3] RUN apt-get update
=> [3/3] RUN apt-get install -y python3
```

Docker caching

Consecutive builds are much faster because Docker re-uses layers that haven't changed.

Re-running a build:

```
=> [1/3] FROM docker.io/library/ubuntu
=> CACHED [2/3] RUN apt-get update
=> CACHED [3/3] RUN apt-get install -y python3
```

Re-running a build but with changes:

```
=> [1/3] FROM docker.io/library/ubuntu
=> CACHED [2/3] RUN apt-get update
=> [3/3] RUN apt-get install -y R
```

Understanding Docker caching

When layers are cached helps us understand why sometimes images don't change after a rebuild.

- Docker can't know when a new version of python3 is released.
- Docker will use cached layers because the instructions are identical to previous builds.

```
=> [1/3] FROM docker.io/library/ubuntu
=> CACHED [2/3] RUN apt-get update
=> CACHED [3/3] RUN apt-get install -y python3
```

Understanding Docker caching

Helps us write Dockerfiles that build faster because not all layers need to be rebuilt.

In the following Dockerfile all instructions need to be rebuild if the pipeline.py file is changed:

```
FROM ubuntu
COPY /app/pipeline.py /app/pipeline.py
RUN apt-get update
RUN apt-get install -y python3
```

```
 => [1/4] FROM docker.io/library/ubuntu
 => [2/4] COPY /app/pipeline.py /app/pipeline.py
 => [3/4] RUN apt-get update
 => [4/4] RUN apt-get install -y python3
```

Understanding Docker caching

Helps us write Dockerfiles that build faster because not all layers need to be rebuilt.

In the following Dockerfile, only the COPY instruction will need to be re-run.

```
FROM ubuntu
RUN apt-get update
RUN apt-get install -y python3
COPY /app/pipeline.py /app/pipeline.py
```

```
 => [1/4] FROM docker.io/library/ubuntu
 => CACHED [2/4] RUN apt-get update
 => CACHED [3/4] RUN apt-get install -y python3
 => [4/4] COPY /app/pipeline.py /app/pipeline.py
```

Let's practice!

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Changing users and working directory

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Dockerfile instruction interaction

FROM, RUN, and COPY interact through the file system.

```
COPY /projects/pipeline_v3/start.sh /app/start.sh
RUN /app/start.sh
```

Some influence other instructions directly:

- `WORKDIR` : Changes the working directory for all following instructions
- `USER` : Changes the user for all following instructions

WORKDIR - Changing the working directory

Starting all paths at the root of the file system:

```
COPY /projects/pipeline_v3/ /app/
```

Becomes cluttered when working with long paths:

```
COPY /projects/pipeline_v3/ /home/my_user_with_a_long_name/work/projects/app/
```

Alternatively, use WORKDIR:

```
WORKDIR /home/my_user_with_a_long_name/work/projects/
```

```
COPY /projects/pipeline_v3/ app/
```

RUN in the current working directory

Instead of using the full path for every command:

```
RUN /home/repl/projects/pipeline/init.sh
RUN /home/repl/projects/pipeline/start.sh
```

Set the WORKDIR:

```
WORKDIR /home/repl/projects/pipeline/
RUN ./init.sh
RUN ./start.sh
```

Changing the startup behavior with WORKDIR

Instead of using the full path:

```
CMD /home/repl/projects/pipeline/start.sh
```

Set the WORKDIR:

```
WORKDIR /home/repl/projects/pipeline/
CMD start.sh
```

Overriding command will also be run in WORKDIR:

```
docker run -it pipeline_image start.sh
```

Linux permissions

- Permissions are assigned to users.
- Root is a special user with all permissions.

Best practice

- Use root to create new users with permissions for specific tasks.
- Stop using root.

Changing the user in an image

Best practice: Don't run everything as root

Ubuntu -> root by default

```
FROM ubuntu          --> Root user by default
RUN apt-get update   --> Run as root
```

USER Dockerfile instruction:

```
FROM ubuntu          --> Root user by default
USER repl            --> Changes the user to repl
RUN apt-get update   --> Run as repl
```

Changing the user in a container

Dockerfile setting the user to repl:

```
FROM ubuntu          --> Root user by default
USER repl            --> Changes the user to repl
RUN apt-get update   --> Run as repl
```

Will also start containers with the repl user:

```
docker run -it ubuntu bash
repl@container: whoami
repl
```

Summary

Usage	Dockerfile Instruction
Change the current working directory	WORKDIR <path>
Change the current user	USER <user-name>

Time for practice!

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Variables in Dockerfiles

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Variables with the ARG instruction

Create variables in a Dockerfile

```
ARG <var_name>=<var_value>
```

For example `ARG path=/home/repl`

To use in the Dockerfile

```
$path
```

For example `COPY /local/path $path`

Use-cases for the ARG instruction

Setting the Python version

```
FROM ubuntu
ARG python_version=3.9.7-1+bionic1
RUN apt-get install python3=$python_version
RUN apt-get install python3-dev=$python_version
```

Configuring a folder

```
FROM ubuntu
ARG project_folder=/projects/pipeline_v3
COPY /local/project/files $project_folder
COPY /local/project/test_files $project_folder/tests
```

Setting ARG variables at build time

```
FROM ubuntu
ARG project_folder=/projects/pipeline_v3
COPY /local/project/files $project_folder
COPY /local/project/test_files $project_folder/tests
```

Setting a variable in the build command

```
docker build --build-arg project_folder=/repl/pipeline .
```

ARG is overwritten, and files end up in:

```
COPY /local/project/files /repl/pipeline
COPY /local/project/test_files /repl/pipeline/tests
```

Variables with ENV

Create variables in a Dockerfile

```
ENV <var_name>=<var_value>
```

For example `ENV DB_USER=pipeline_user`

To use in the Dockerfile or at runtime

```
$DB_USER
```

For example `CMD psql -U $DB_USER`

Use-cases for the ENV instruction

Setting a directory to be used at runtime

```
ENV DATA_DIR=/usr/local/var/postgres
```

```
ENV MODE production
```

Setting or replacing a variable at runtime

```
docker run --env <key>=<value> <image-name>
```

```
docker run --env POSTGRES_USER=test_db --env POSTGRES_PASSWORD=test_db postgres
```

[1] https://hub.docker.com/_/postgres

Secrets in variables are not secure

`docker history <image-name>`

```
ARG DB_PASSWORD=example_password
```

Will show in `docker history`:

```
IMAGE          CREATED        CREATED BY                                      SIZE      ...
cd338027297f   2 months ago   ARG DB_PASSWORD=example_password    0B          ...
```

Summary

Usage	Dockerfile Instruction
Create a variable accessible only during the build	ARG <name>=<value>
Create a variable	ENV <name>=<value>

Usage	Shell Command
Override an ARG in docker build	docker build --build-arg <name>=<value>
Override an ENV in docker run	docker run --env <name>=<value> <image-name>
See the instructions used to create an image	docker history <image-name>

Let's practice!

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Creating Secure Docker Images

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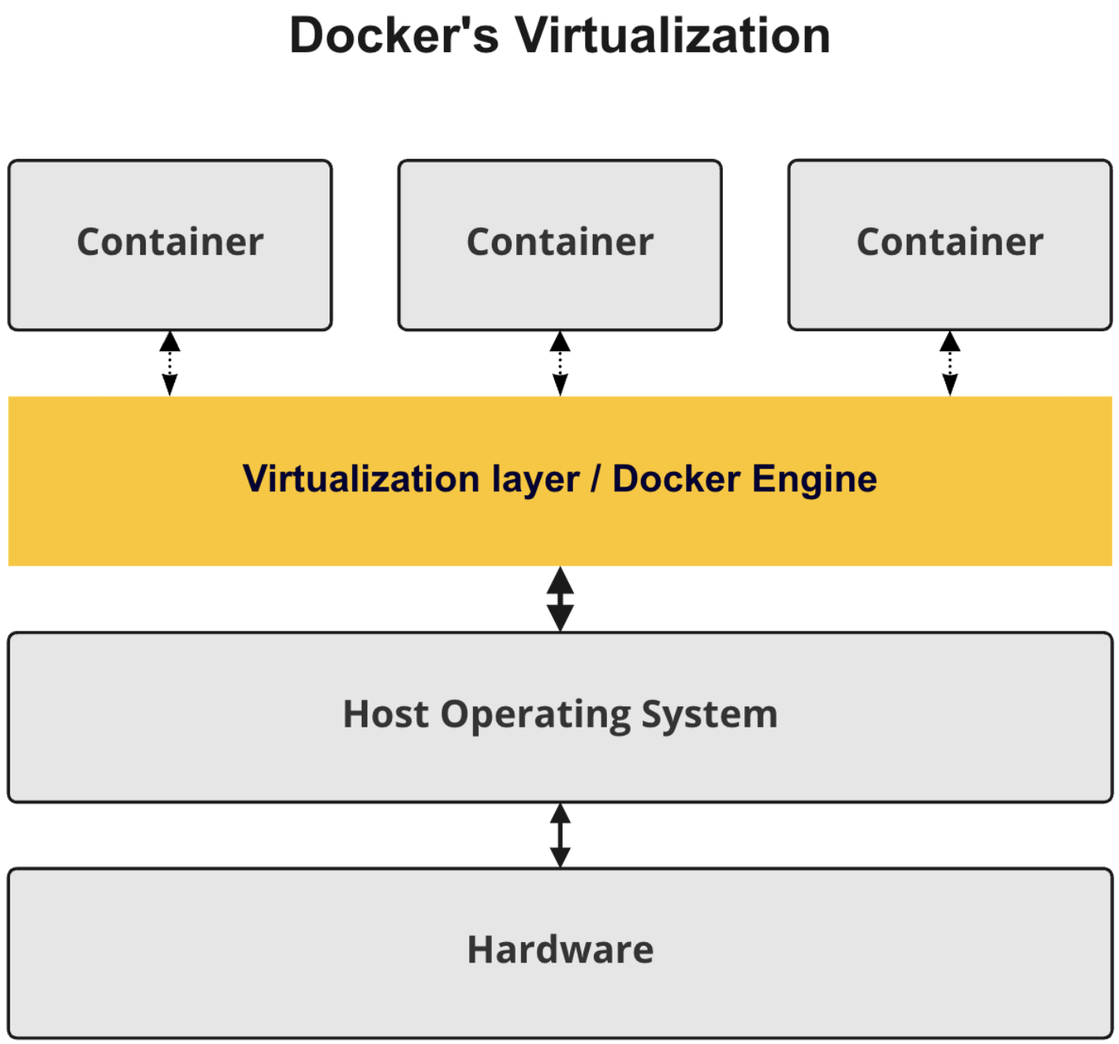
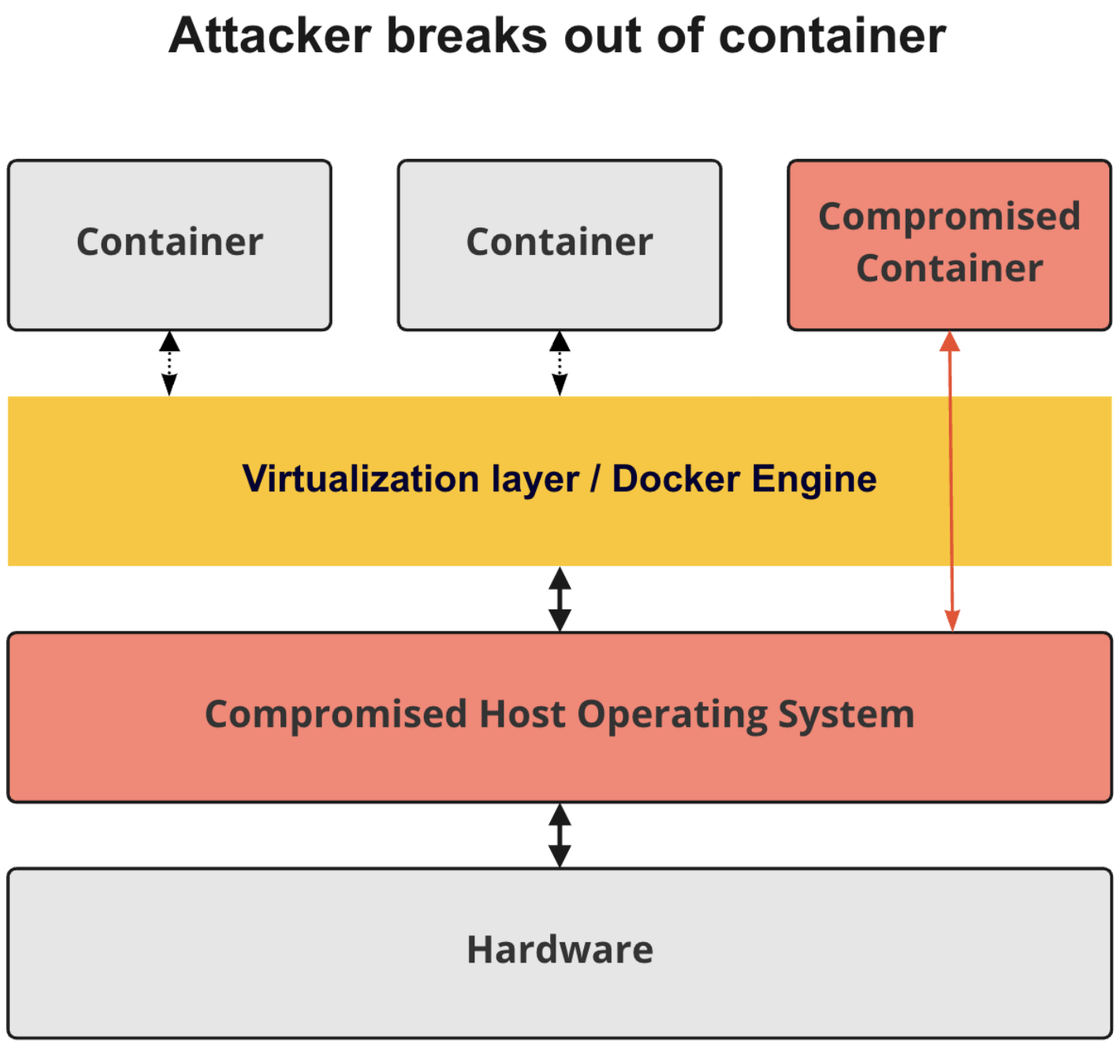
Inherent Security





Making secure images

Attackers can exceptionally break out of a container.

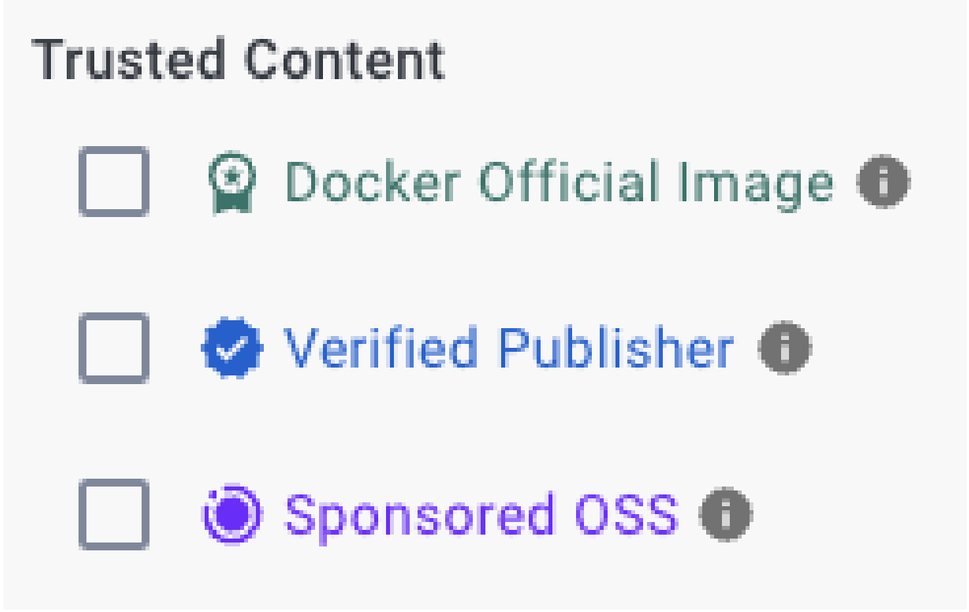
Additional security measures can lower this risk

Becomes especially important once exposing running containers to the Internet.

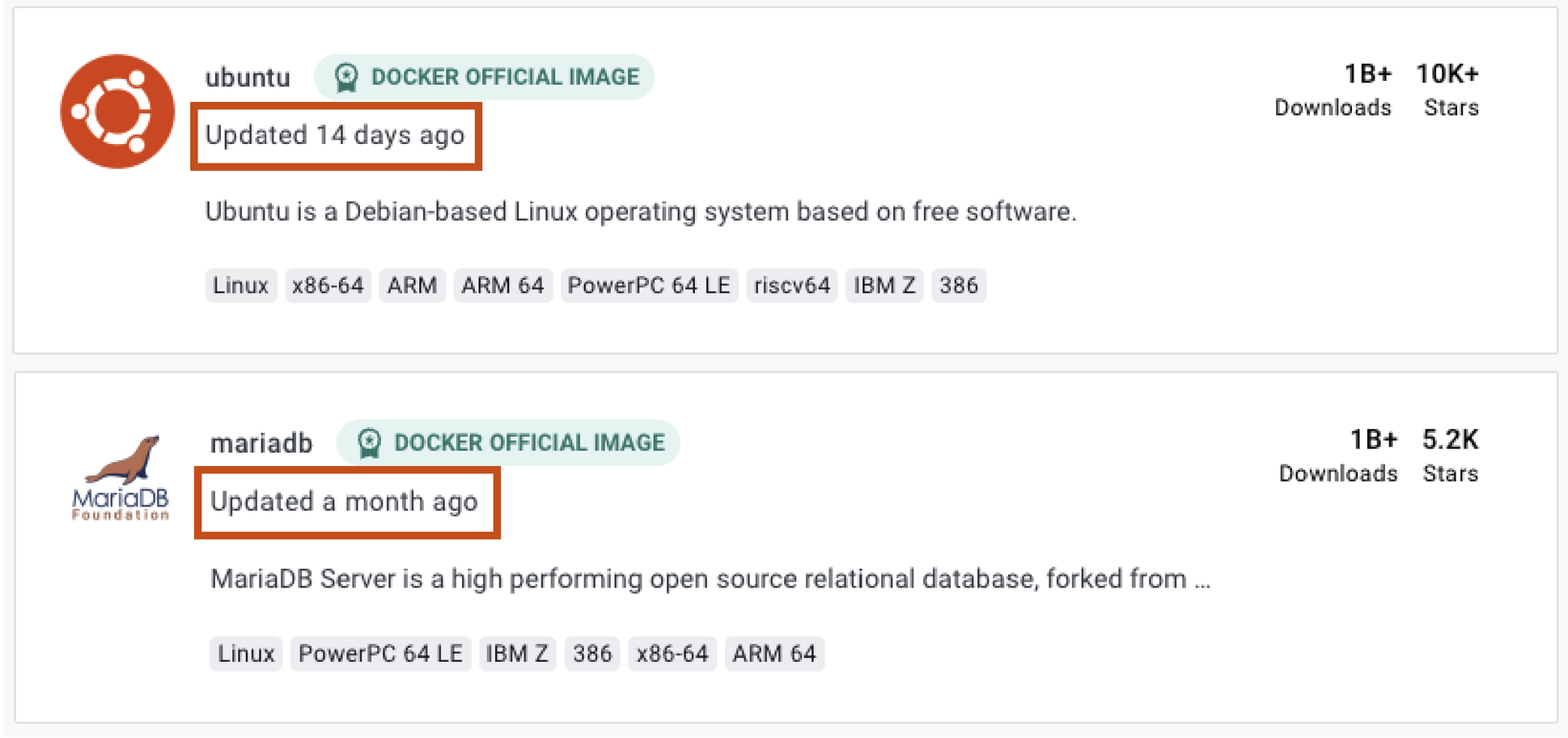
Images from a trusted source

Creating secure images -> Start with an image from a trusted source

Docker Hub filters:



Keep software up-to-date



Keep images minimal

Adding unnecessary packages reduces security

Ubuntu with:

- Python2.7
- Python3.11
- Java default-jre
- Java openjdk-11
- Java openjdk-8
- Airflow
- Our pipeline application

Installing only essential packages improves security

Ubuntu with:

- Python3.11
- Our pipeline application

Don't run applications as root

Allowing root access to an image defeats keeping the image up-to-date and minimal.

Instead, make containers start as a user with fewer permissions:

```
FROM ubuntu # User is set to root by default.
RUN apt-get update
RUN apt-get install python3
USER repl # We switch the user after installing what we need for our use-case.
CMD python3 pipeline.py
```

Let's practice!

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