Ensuring your DAGs work before going to production

Airflow Summit 2020

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GO DATA DRIVEN

About me

- Background in Software Engineering (Haagse Hogeschool) and Computer Science (University of Leiden)

- Data Engineer at GoDataDriven last 4,5 years

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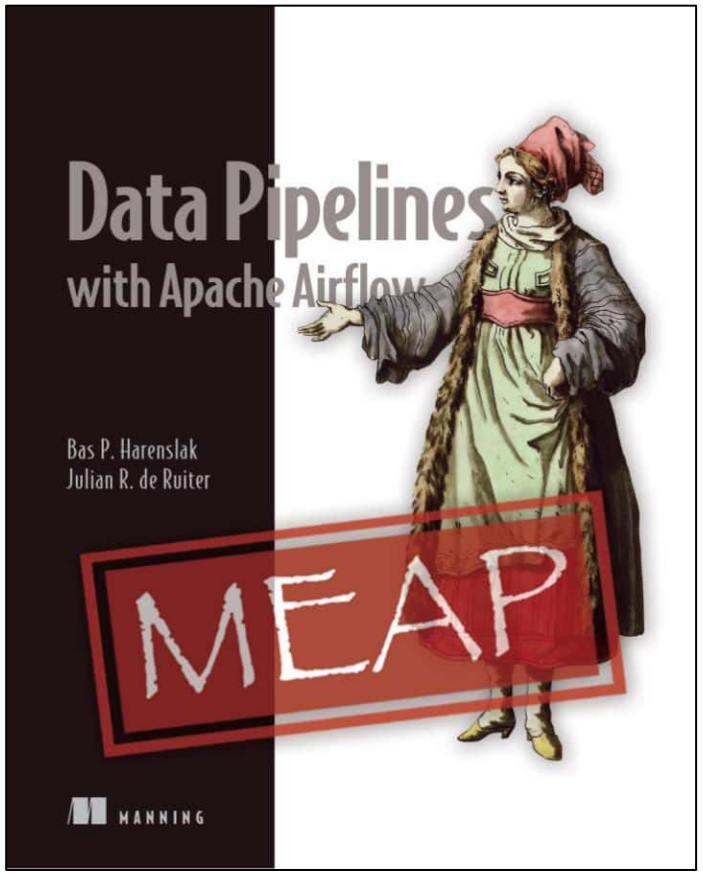
About me

- Apache Airflow committer
- (Co-)author of Manning's
  "Data Pipelines with Apache Airflow"
- First 10 chapters available in preview, new chapters added on a regular basis
- https://www.manning.com/books/data-pipelines-with-apache-airflow



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Ensuring your DAGs work before going to production

1. Unit testing
2. Testing in Python with pytest
3. Mocking
4. Using fake external systems
5. Debugging

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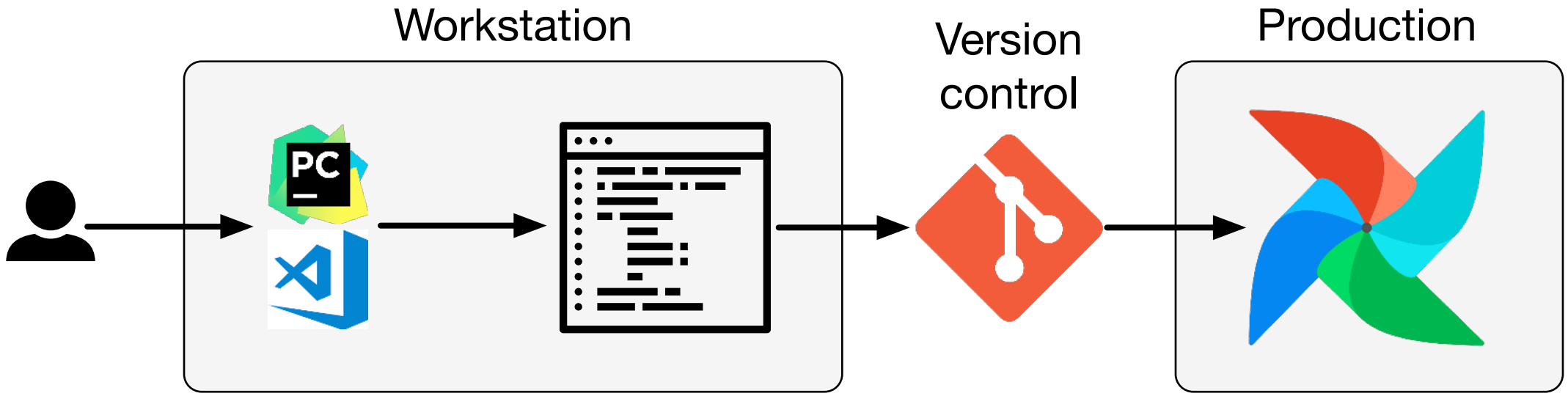
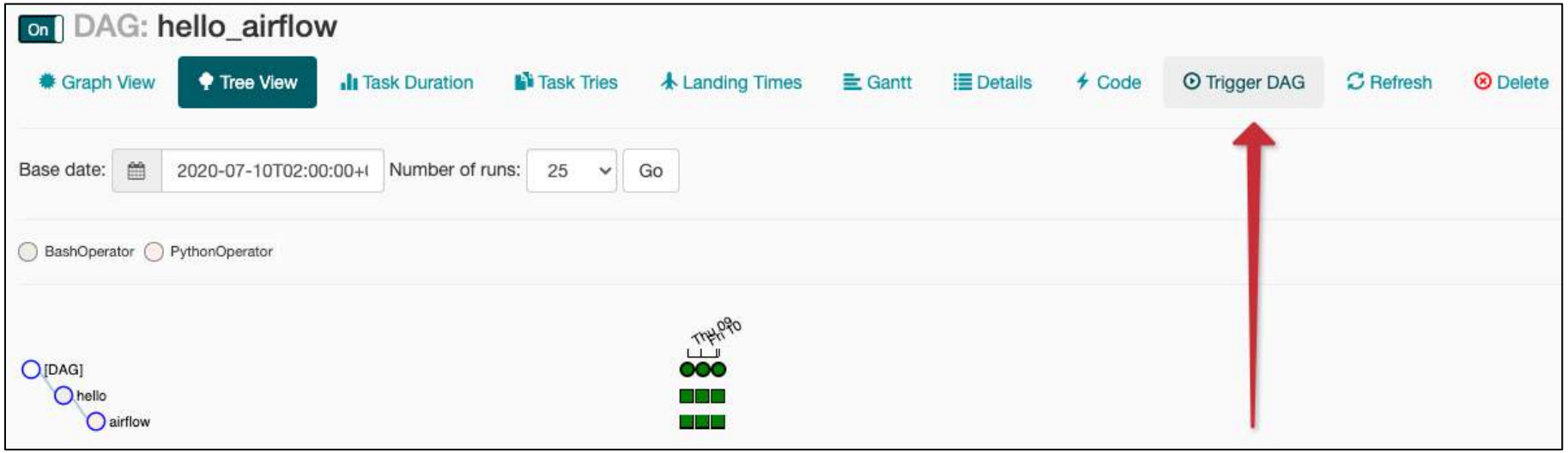
Typical very first deployment and test





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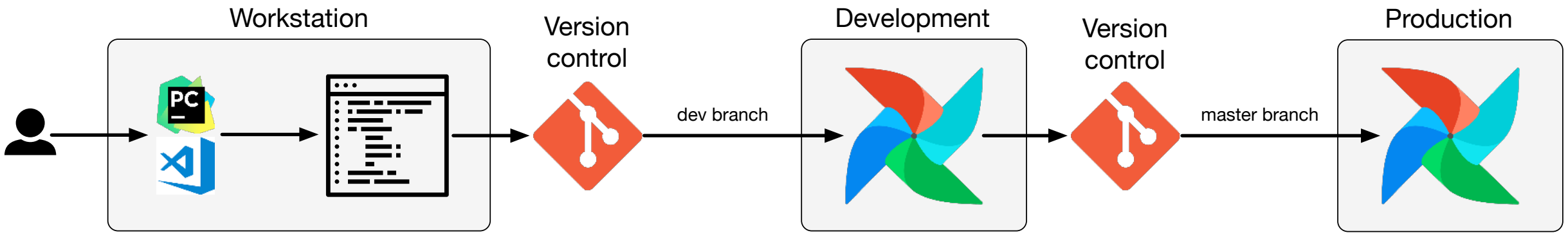
Second deployment



Development:

Production:

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“Testing Airflow is hard”

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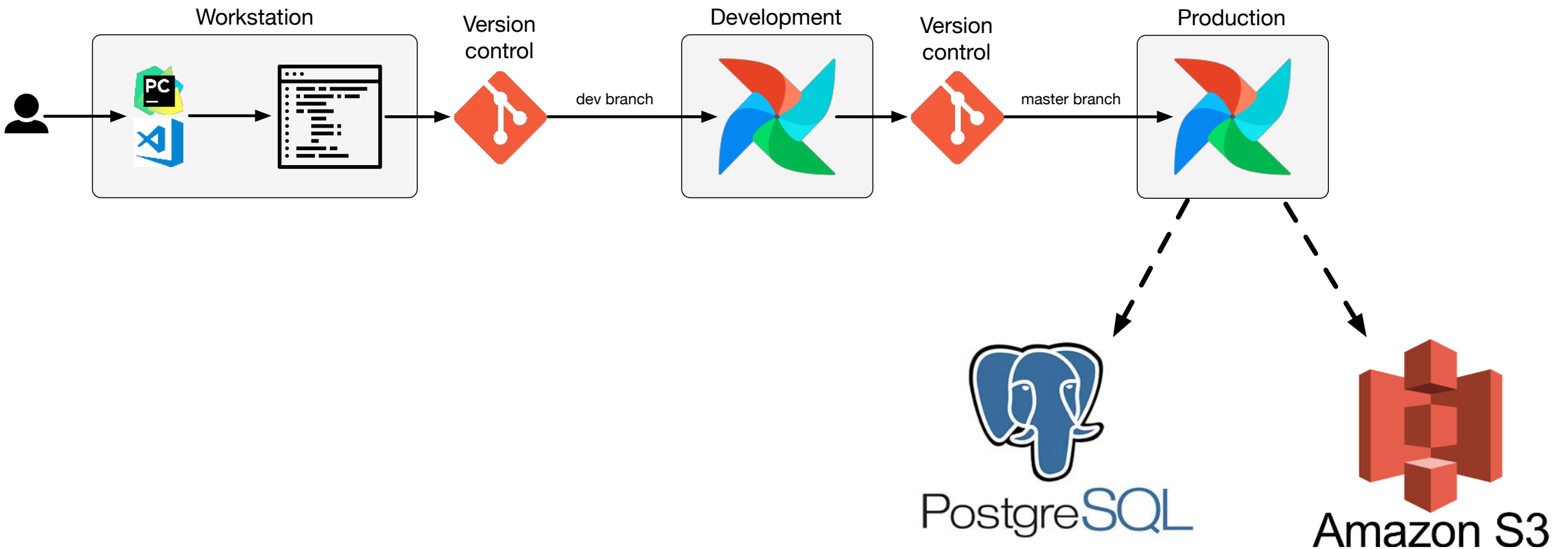
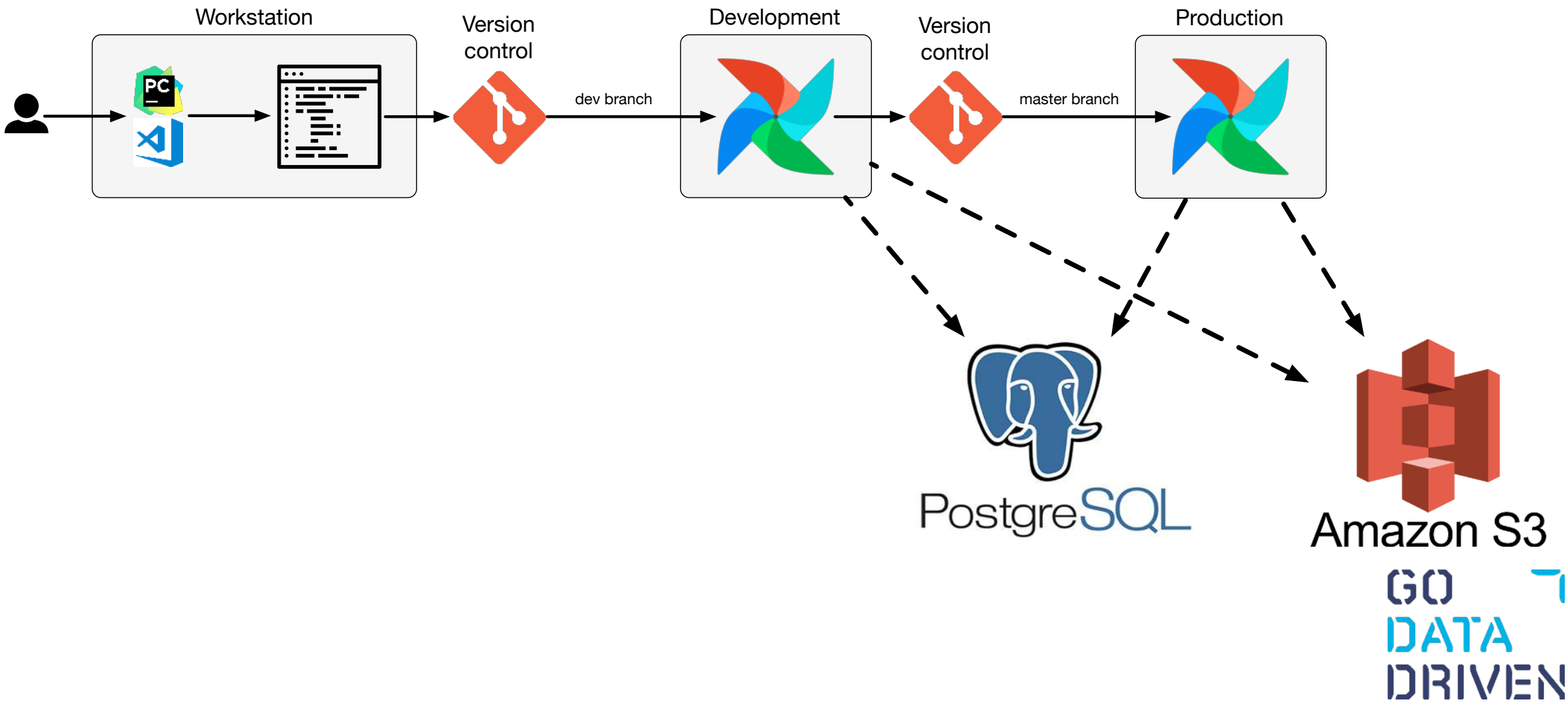
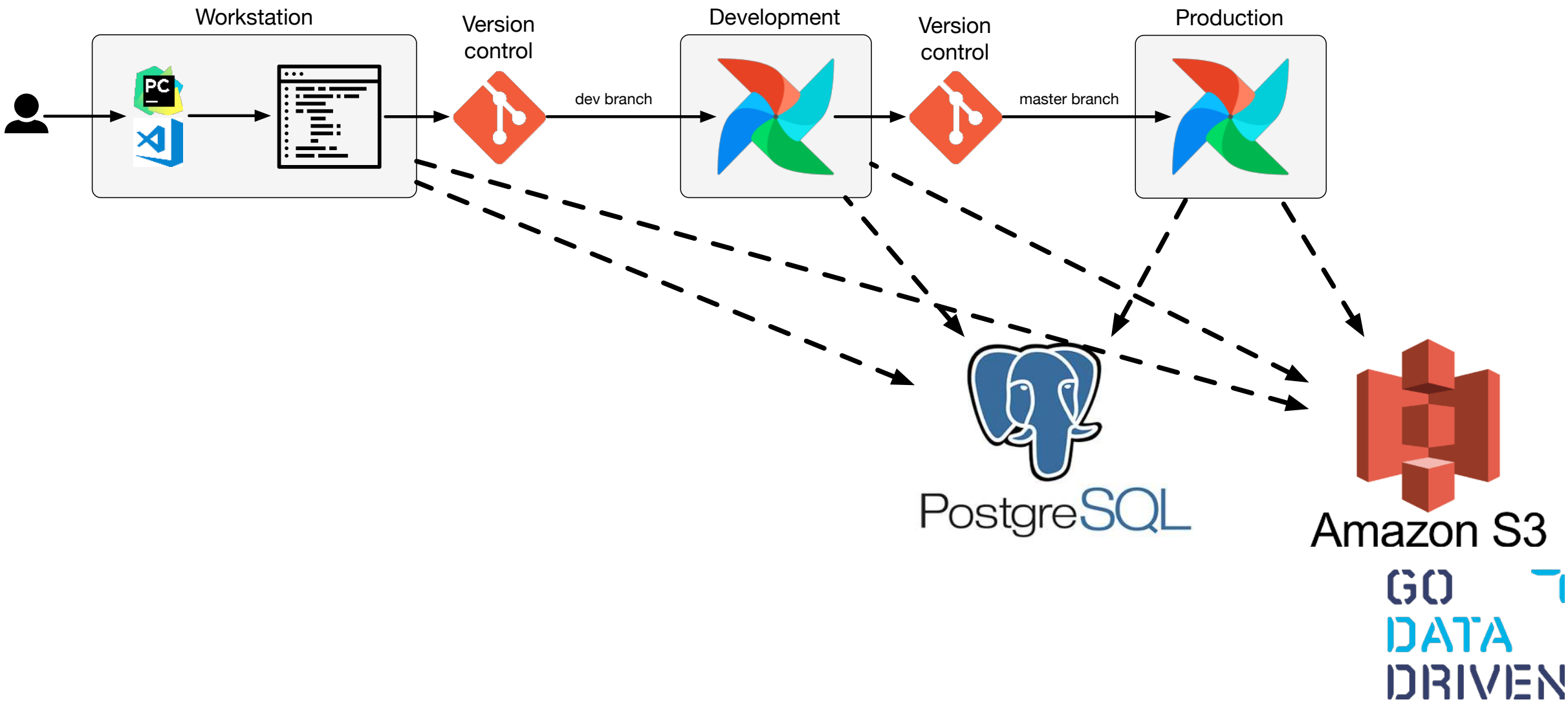
Testing Airflow is hard



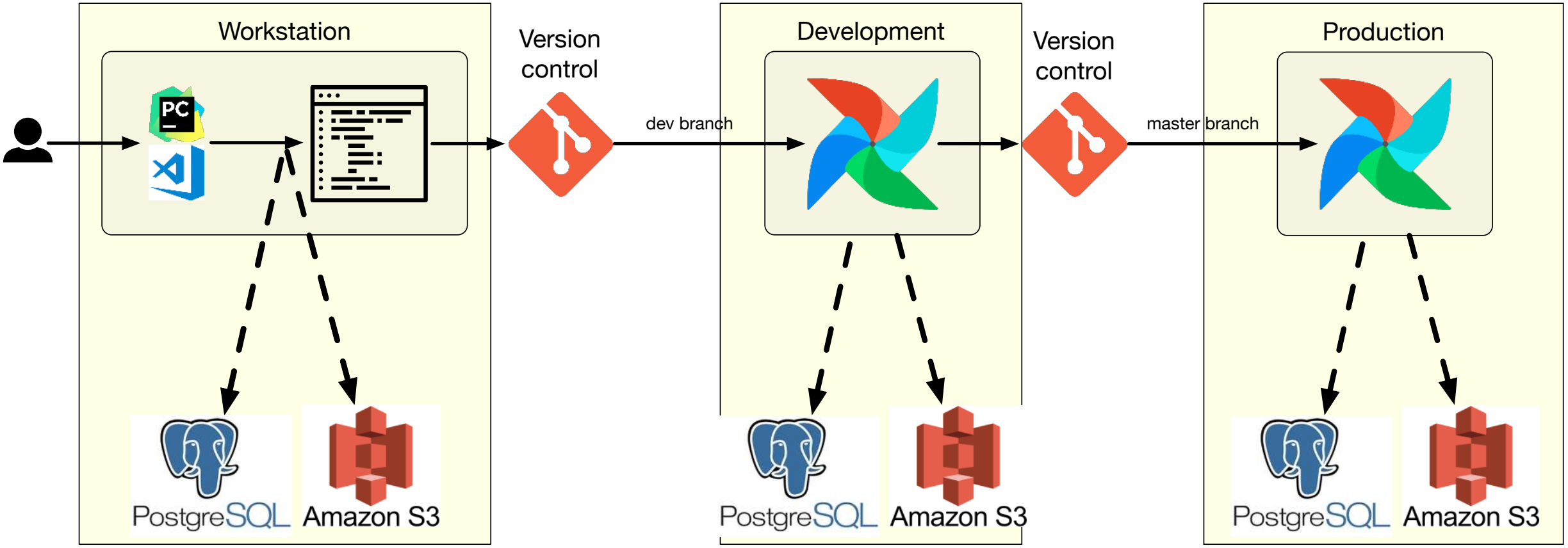
Testing Airflow is hard



Testing Airflow is hard



Testing Airflow is hard



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Unit testing

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What is a unit test?

```
def count_lines_in_postgres_table(table_name):
    # SELECT COUNT(*) FROM table_name...
```

```
result = count_lines_in_postgres_table("foobar")
```

```
assert result == 5
```

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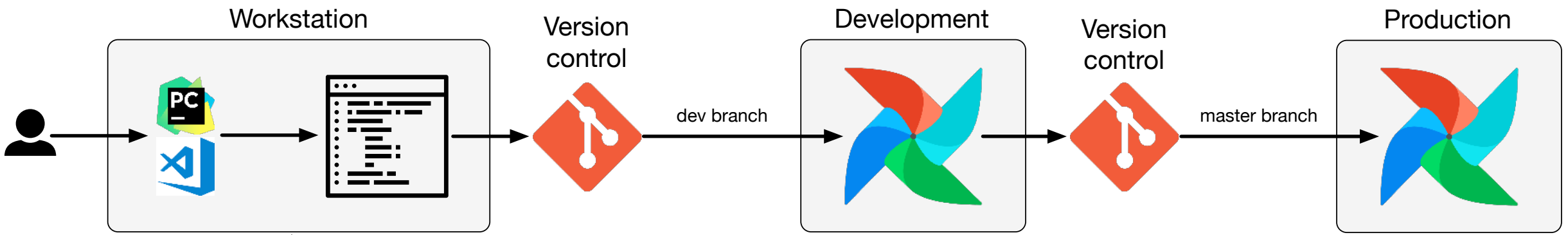
What is a unit test?




```
def count_lines_in_postgres_table(table_name):
    # SELECT COUNT(*) FROM table_name...

result = count_lines_in_postgres_table("foobar")

assert result == 5
```

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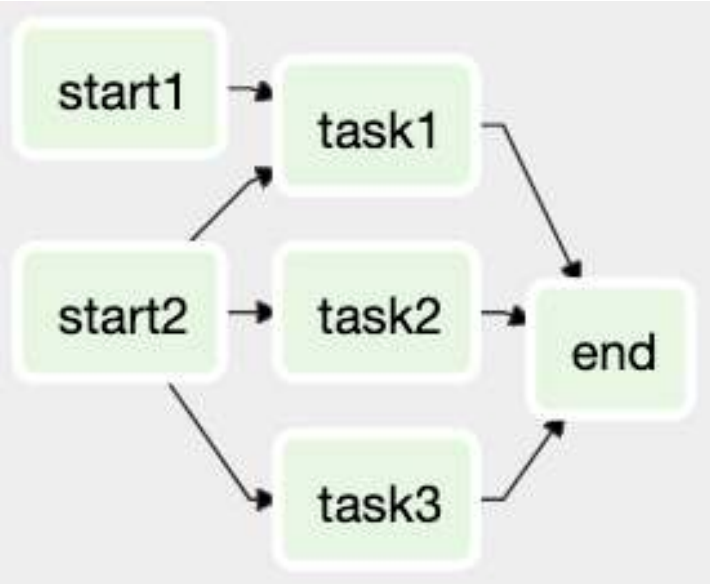
Unit testing and Airflow



- A DAG consists of one or more tasks, represented as “Operators”

- We can test Operators as a whole
- Or callable functions (e.g. when using PythonOperator)
- Or underlying code (e.g. custom hooks/operators)

- Does *not* validate “integration” of multiple tasks

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So how do I unit test an operator?

- “It depends”

- Example test for PythonOperator:

```
def test_python_operator():
    test = PythonOperator(task_id="test", python_callable=lambda: "testme")
    result = test.execute(context={})
    assert result == "testme"
```

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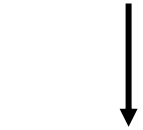
So how do I unit test an operator? (2)

- “It depends”

- Example test for BashOperator:

“it depends”



```
def test_bash_operator():
    test = BashOperator(task_id="test", bash_command="echo testme", xcom_push=True)
    result = test.execute(context={})
    assert result == "testme"
```

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So how do I unit test an operator? (3)

- It depends:

```
class BaseOperator():
    # …

    def execute(self, context):
        raise NotImplementedError()
```

- Note `context` is a required argument, hence the "`context={}`".

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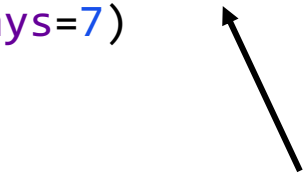
How do I test with context?

- If you need one single, fixed, thing from the context:

```
def next_week(**context):
    return context["execution_date"] + datetime.timedelta(days=7)


def test_python_operator():
    test = PythonOperator(task_id="test", python_callable=next_week, provide_context=True)
    testdate = datetime.datetime(2020, 1, 1)
    result = test.execute(context={"execution_date": testdate})
    assert result == testdate + datetime.timedelta(days=7)
```



provide the context yourself

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Testing with pytest

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pytest

- Default testing package in Python in unittest

- Why 3rd party library pytest?
  - Because nice features (e.g. fixtures)

- https://pytest.org
- pip install pytest

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pytest vs unittest example

pytest

```python
@pytest.fixture
def a():
    return 1


@pytest.fixture
def b():
    return 2


def test_sum(a, b):
    assert sum([a, b]) == 3
```

unittest

```python
class TestWithUnittest(unittest.TestCase):
    def setUp(self):
        self.a = 1
        self.b = 2

    def test_sum(self):
        self.assertEqual(sum([self.a, self.b]), 3)
```

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pytest vs unittest example (2)

```python
@pytest.fixture
def a():
    return 1

@pytest.fixture
def b():
    return 2

@pytest.fixture
def c():
    return 3

def test_sum_ab(a, b):
    assert sum([a, b]) == 3

def test_sum_ac(a, c):
    assert sum([a, c]) == 4
```

```python
class TestWithUnittest(unittest.TestCase):
    def setUp(self):
        self.a = 1
        self.b = 2
        self.c = 3

    def test_sum_ab(self):
        self.assertEqual(sum([self.a, self.b]), 3)

    def test_sum_ac(self):
        self.assertEqual(sum([self.a, self.c]), 4)
```

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pytest fixture scopes

- Scope of fixtures can be:
  - Function (default)
  - Class
  - Module
  - Package
  - Session

- Especially useful to define when (not) to re-use variables

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pytest fixture scopes example

```python
@pytest.fixture(scope="module")
def a():
    return [1]


@pytest.fixture
def c():
    return [2]


class TestBla:
    def test_something(self, a):
        a.append(1)
        assert sum(a) == 2

    def test_something_ac(self, a, c):
        assert sum(a + c) == 3
```

Initialized ***once*** per module!

failure

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pytest fixture scopes

- Module scope is especially useful for “expensive” things
  - e.g. database clients

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pytest built-in fixtures

- capfd
- capfdbinary
- caplog
- capsys
- capsysbinary
- cache
- doctest_namespace
- monkeypatch
- pytestconfig
- record_property
- record_testsuite_property
- recwarn
- request
- testdir
- tmp_path
- tmp_path_factory
- tmpdir
- tmpdir_factory

https://docs.pytest.org/en/stable/fixture.html#fixtures

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pytest tmpdir fixture

```python
def test_writing_to_disk(tmpdir):
    tmpfile = tmpdir.join("hello.txt")

    task = BashOperator(task_id="test", bash_command=f"echo 'hello' > {tmpfile}")
    task.execute(context={})

    assert len(tmpdir.listdir()) == 1
    assert tmpfile.read().replace("\n", "") == "hello"
```

Define tmp file path

Run BashOperator

Write “hello” to tmpfile

Assertions

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Enough pytest – show me Airflow!

- One useful pytest plugin: pytest-helpers-namespace
  - `pip install pytest-helpers-namespace`

```
import datetime

import pytest
from airflow.models import DAG

pytest_plugins = ["helpers_namespace"]
```

- If you need the “full” context, you will need a DAG:

```
@pytest.fixture
def test_dag():
    """Airflow DAG for testing."""
    return DAG(
        "test_dag",
        start_date=datetime.datetime(2020, 1, 1),
        schedule_interval=datetime.timedelta(days=1),
    )
```

```
@pytest.helpers.register
def run_task(task, dag):
    """Run an Airflow task."""
    dag.clear()
    task.run(start_date=dag.start_date, end_date=dag.start_date)
```

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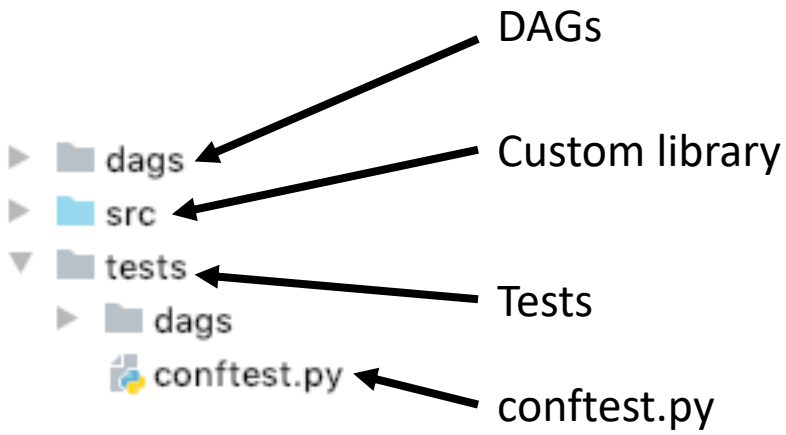
Place this script in a conftest.py

- Pytest will auto-discover anything in /tests prefixed with `test_/Test`
- And automagically read everything defined in `conftest.py`
- ”per-directory configuration”



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Running a task with DAG

```
def test_bash_operator_tmpdir(test_dag, tmpdir):
    tmpfile = tmpdir.join("hello.txt")

    task = BashOperator(task_id="test", bash_command=f"echo 'hello' > {tmpfile}", dag=test_dag)
    pytest.helpers.run_task(task=task, dag=test_dag)

    assert len(tmpdir.listdir()) == 1
    assert tmpfile.read().replace("\n", "") == "hello"
```

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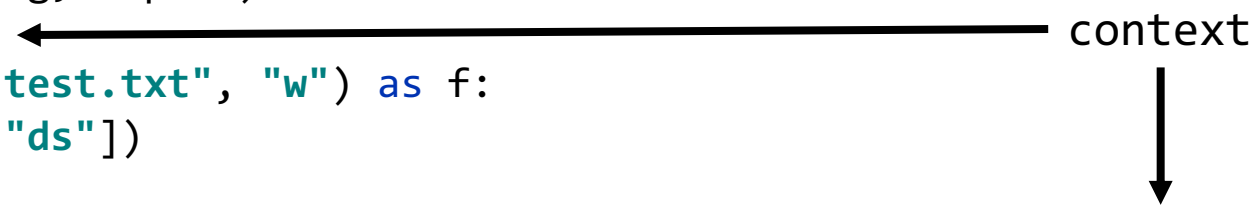
Running a task with full context

```
def test_full_context(test_dag, tmpdir):
    def do_magic(**context):
        with open(tmpdir / "test.txt", "w") as f:
            f.write(context["ds"])

    task = PythonOperator(task_id="test", python_callable=do_magic, provide_context=True, dag=test_dag)
    pytest.helpers.run_task(task=task, dag=test_dag)

    with open(tmpdir / "test.txt", "r") as f:
        assert f.readlines()[0] == test_dag.start_date.strftime("%Y-%m-%d")
```



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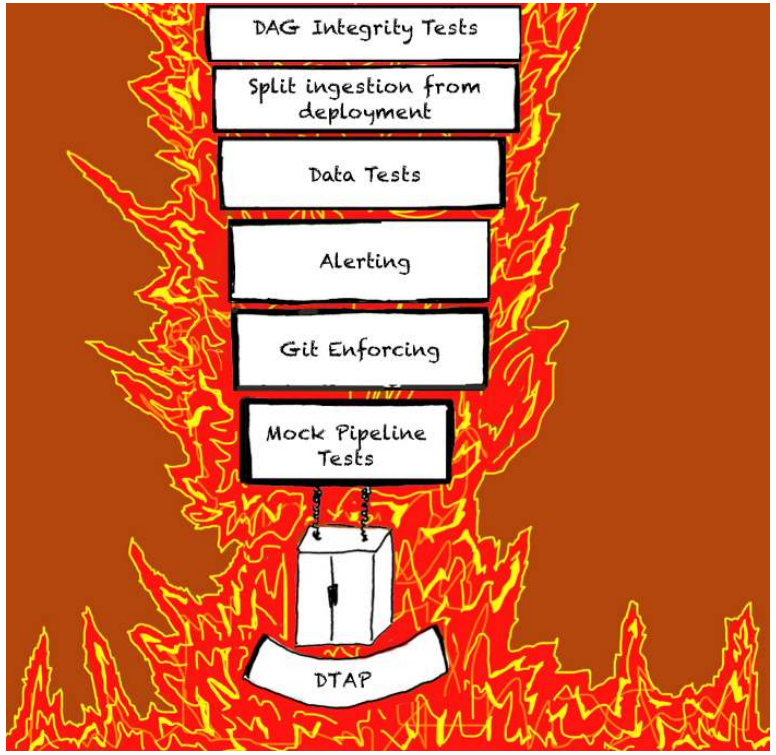
The “DAG integrity test”

- Asserts the validity of DAG objects, i.e. “can Python instantiate this DAG”
- Plus, test for cycles
- https://medium.com/wbaa/datas-inferno-7-circles-of-data-testing-hell-with-airflow-cef4adff58d8



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“Hello world” of checking DAG correctness

- `python your_dag.py`

- Does it take long?
- Does it produce many logs?
- Does it make connections to external systems?
- Etc…

- *Anything in the global scope must be avoided!*

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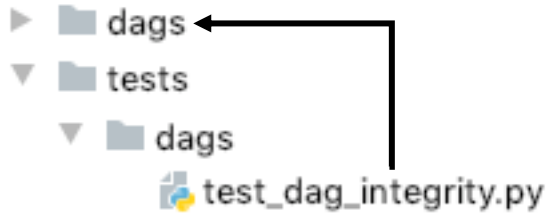
The “DAG integrity test”




```python
import glob
from os import path

import pytest
from airflow import models as airflow_models

DAG_PATHS = glob.glob(path.join(path.dirname(__file__), "..", "..", "dags", "*.py"))


@pytest.mark.parametrize("dag_path", DAG_PATHS)
def test_dag_integrity(dag_path):
    """Import DAG files and check for a valid DAG instance."""
    dag_name = path.basename(dag_path)
    module = _import_file(dag_name, dag_path)

    # Validate if there is at least 1 DAG object in the file
    dag_objects = [var for var in vars(module).values() if isinstance(var, airflow_models.DAG)]
    assert dag_objects

    # For every DAG object, test for cycles
    for dag in dag_objects:
        dag.test_cycle()


def _import_file(module_name, module_path):
    import importlib.util

    spec = importlib.util.spec_from_file_location(module_name, str(module_path))
    module = importlib.util.module_from_spec(spec)
    spec.loader.exec_module(module)
    return module
```

For every DAG file

Assert if valid DAG object

Test for cycles

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The “DAG integrity test”

```
task1 = DummyOperator(task_id="task1", dag=dag)
task2 = DummyOperator(task_id="task2", dag=dag)

task1 >> task2 >> task1
```

```
airflow.exceptions.AirflowDagCycleException: Cycle detected in DAG. Faulty task: task2 to task1
```

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Mocking

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Mocking – what and why?

- Provide “canned” responses, typically to fake calls to external systems
- For example – to test a function processing an API call, provide it a fake result to validate the processing part.
- Within Airflow – we can use mocking to e.g. provide a Connection object, so we don’t need a metastore for testing.
- Sometimes requires digging in internal code.

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Mocking example

- Let’s consider an external API (something not maintained by ourselves):

- https://api.sunrise-sunset.org/json?lat=52.370216&lng=4.895168&formatted=0
- Returns sunrise and sunset times of the given location (Amsterdam city centre):


```
{
  "results": {
    "sunrise": "2020-07-12T03:34:14+00:00",
    "sunset": "2020-07-12T19:58:09+00:00",
    "solar_noon": "2020-07-12T11:46:12+00:00",
    "day_length": 59035,
    "civil_twilight_begin": "2020-07-12T02:47:34+00:00",
    "civil_twilight_end": "2020-07-12T20:44:49+00:00",
    "nautical_twilight_begin": "2020-07-12T01:37:06+00:00",
    "nautical_twilight_end": "2020-07-12T21:55:17+00:00",
    "astronomical_twilight_begin": "1970-01-01T00:00:01+00:00",
    "astronomical_twilight_end": "1970-01-01T00:00:01+00:00"
  },
  "status": "OK"
}
```


Sunrise/sunset times on the date of making this call

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Mocking example

Test definition

Mock BaseHook.get_connection()

Fake Connection response

```python
from datetime import datetime

import pytest
from airflow.hooks.base_hook import BaseHook
from airflow.models import Connection
from airflow.operators.http_operator import SimpleHttpOperator


def test_simple_http_operator(test_dag, mocker):
    mocker.patch.object(
        BaseHook,
        "get_connection",
        return_value=Connection(schema="https", host="api.sunrise-sunset.org")
    )

    def _check_light(sunset_sunrise_response):
        results = sunset_sunrise_response.json()["results"]
        sunrise = datetime.strptime(results["sunrise"][:-6], "%Y-%m-%dT%H:%M:%S")
        sunset = datetime.strptime(results["sunset"][:-6], "%Y-%m-%dT%H:%M:%S")

        if sunrise < datetime.utcnow() < sunset:
            print("It is light!")
        else:
            print("It is dark!")

        return True

    is_it_light = SimpleHttpOperator(
        task_id="is_it_light",
        http_conn_id="my_http_conn",
        endpoint="json",
        method="GET",
        data={"lat": "52.370216", "lng": "4.895168", "formatted": "0"},
        response_check=_check_light,
        dag=test_dag,
    )

    pytest.helpers.run_task(task=is_it_light, dag=test_dag)
```

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Mocking and pytest

- Unittest comes with a built-in mocking package (`from unittest import mock`)
- While you can use this in pytest
- A convenient plugin is pytest-mock, which makes it available as a fixture
- `pip install pytest-mock`

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How to mock the ”unmockable”?

- Some systems cannot be mocked
- Cloud services for example don’t always provide a mocking library

- Three options:
  1. Mock and assert calls to the external systems
  2. Run a Dockerized version of the external system (e.g. PostgreSQL)
  3. Run a development version of the external system (e.g. Google Cloud Storage)

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Mock and assert calls to external systems

```python
def test_simple_http_operator_no_external_call(test_dag, mocker):
    mocker.patch.object(
        BaseHook, "get_connection", return_value=Connection(schema="https", host="api.sunrise-sunset.org")
    )
    mock_run = mocker.patch.object(HttpHook, "run")

    is_it_light = SimpleHttpOperator(
        task_id="is_it_light",
        http_conn_id="my_http_conn",
        endpoint="json",
        method="GET",
        data={"lat": "52.370216", "lng": "4.895168", "date": "{{ ds }}", "formatted": "0"},
        dag=test_dag,
    )

    pytest.helpers.run_task(task=is_it_light, dag=test_dag)
    mock_run.assert_called_once()
    assert mock_run.call_args_list[0][0][1] == {
        "lat": "52.370216",
        "lng": "4.895168",
        "date": test_dag.start_date.strftime("%Y-%m-%d"),
        "formatted": "0",
    }
```

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Faking external systems

Testing with Docker

- We can run external systems for the duration of our tests in Docker
- Note: a Docker image of your desired system must exist (which is not the case for e.g. Google Cloud Storage)

- One option: create a Docker Compose for your tests
- Alternative option: use `pytest_docker_tools` plugin

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pytest_docker_tools

- `pip install pytest_docker_tools`
- Small wrapper around your Docker client (so Docker must be installed!)
- Provide access to Docker SDK with a set of pytest fixtures

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pytest_docker_tools

- Say we implemented a “PostgresToLocalOperator”, which runs a PostgreSQL query and writes the result to a local file.

- We need:
  - PostgreSQL database
  - Some location to write to locally
  - Data in the database to download

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pytest_docker_tools – create database

```
from pytest_docker_tools import container, fetch


postgres_image = fetch(repository="postgres:11.1-alpine")

postgres = container(
    image="{postgres_image.id}",
    environment={
        "POSTGRES_USER": "secretuser",
        "POSTGRES_PASSWORD": "secretpassword",
    },
    ports={"5432/tcp": None},
    volumes={
        path.join(path.dirname(__file__), "postgres-init.sql"): {
            "bind": "/docker-entrypoint-initdb.d/postgres-init.sql"
        }
    },
)
```

Defines Docker image

Defines Docker container (very similar to docker run …)

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pytest_docker_tools – initialize database

postgres-init.sql:

```
SET search_path TO public;
CREATE TABLE dummy (
    id integer,
    name character varying(255)
);
INSERT INTO dummy (id,name) VALUES (1, 'dummy1');
INSERT INTO dummy (id,name) VALUES (2, 'dummy2');
INSERT INTO dummy (id,name) VALUES (3, 'dummy3');
```

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pytest_docker_tools – the actual test

Mock Postgres connection

Reference to Postgres container

Call the operator

Check results

```python
def test_postgres_to_local_operator(test_dag, mocker, tmpdir, postgres):
    mocker.patch.object(
        PostgresHook,
        "get_connection",
        return_value=Connection(
            host="localhost",
            conn_type="postgres",
            login=postgres_credentials.username,
            password=postgres_credentials.password,
            port=postgres.ports["5432/tcp"][0],
        ),
    )

    output_path = str(tmpdir / "pg_dump")
    task = PostgresToLocalOperator(
        task_id="test",
        postgres_conn_id="postgres",
        pg_query="SELECT * FROM dummy",
        local_path=output_path,
        dag=test_dag,
    )
    pytest.helpers.run_task(task=task, dag=test_dag)

    # Assert if output file exists
    output_file = Path(output_path)
    assert output_file.is_file()

    # Assert file contents, should be the same as in postgres-init.sql
    expected = [
        {"id": 1, "name": "dummy1"},
        {"id": 2, "name": "dummy2"},
        {"id": 3, "name": "dummy3"},
    ]
    with open(output_file, "r") as f:
        assert json.load(f) == expected
```

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Debugging

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airflow test

- `airflow test [dag id] [task id] [execution date]`
- E.g. “airflow test mydag mytask 2020-01-01”

- Running a single task from the command line, for a given execution date

- No state recorded in metastore

“airflow task test” in Airflow 2.0

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Debugging Airflow code

- Set breakpoints in your IDE locally:

```
task = PostgresToLocalOperator(
    task_id="test",
    postgres_conn_id="postgres",
    pg_query="SELECT * FROM dummy",
    local_path=output_path,
    dag=test_dag,
)
pytest.helpers.run_task(task=task, dag=test_dag)

# Assert if output file exists
output_file = Path(output_path)
assert output_file.is_file()
```

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Debugging in production

- Try to avoid
- But if you must;
- (i)Python DeBugger: (i)pdb

```
import ipdb
ipdb.set_trace()
```

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Debugging in production (2)

Python Debugger Cheatsheet

Getting started

start pdb from within a script:
import pdb;pdb.set_trace()
start pdb from the commandline:
python -m pdb <file.py>

Basics

h(elp)	print available commands
h(elp) ***command***	print help about *command*
q(uit)	quit debugger

Examine

p(rint) ***expr***	print the value of *expr*
pp ***expr***	pretty-print the value of *expr*
w(here)	print current position (including stack trace)
l(ist)	list 11 lines of code around the current line
l(ist) ***first*****,** ***last***	list from *first* to *last* line number
a(rgs)	print the args of the current function

Movement

<ENTER>	repeat the last command
n(ext)	execute the current statement (step over)
s(tep)	execute and step into function
r(eturn)	continue execution until the current function returns
c(ontinue)	continue execution until a breakpoint is encountered
u(p)	move one level up in the stack trace
d(own)	move one level down in the stack trace

Breakpoints

b(reak)	show all breakpoints
b(reak) ***lineno***	set a breakpoint at *lineno*
b(reak) ***func***	set a breakpoint at the first line of a *func*

Manipulation

!*stmt* treat *stmt* as a Python statement instead of a pdb command

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airflow test

- airflow test [dag_id] [task_id] [execution_date]

“airflow tasks test” in Airflow 2.0

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DebugExecutor

- https://airflow.apache.org/docs/stable/executor/debug.html

- Add to your DAG script:

```
if __name__ == "__main__":
    dag.clear(reset_dag_runs=True)
    dag.run()
```

- export `AIRFLOW__CORE__EXECUTOR=DebugExecutor`
- And run with python your_dag.py
- ***Warning***: will run ALL runs from configured start_date!

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Coming in Airflow 2.0: airflow dags test

- Complete CLI was rewritten in Airflow 2.0
- Can run a DAG using the DebugExecutor *without* editing the DAG

```
airflow dags test dag_id execution_date
```

- Executes all tasks in the order they're defined in

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Final words

- Airflow operators can be tested (run) by simply calling them
- If you want the context, you need a DAG (or explicitly provide it yourself)
- Mocking is useful for e.g. avoiding metastore calls
- Docker can be useful for running systems temporarily during a test
- “airflow test” can be helpful for debugging

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Final words (2)

- Talk is recorded
- Code is available at https://github.com/godatadriven/airflow-testing-examples
- @basph on Airflow Slack

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