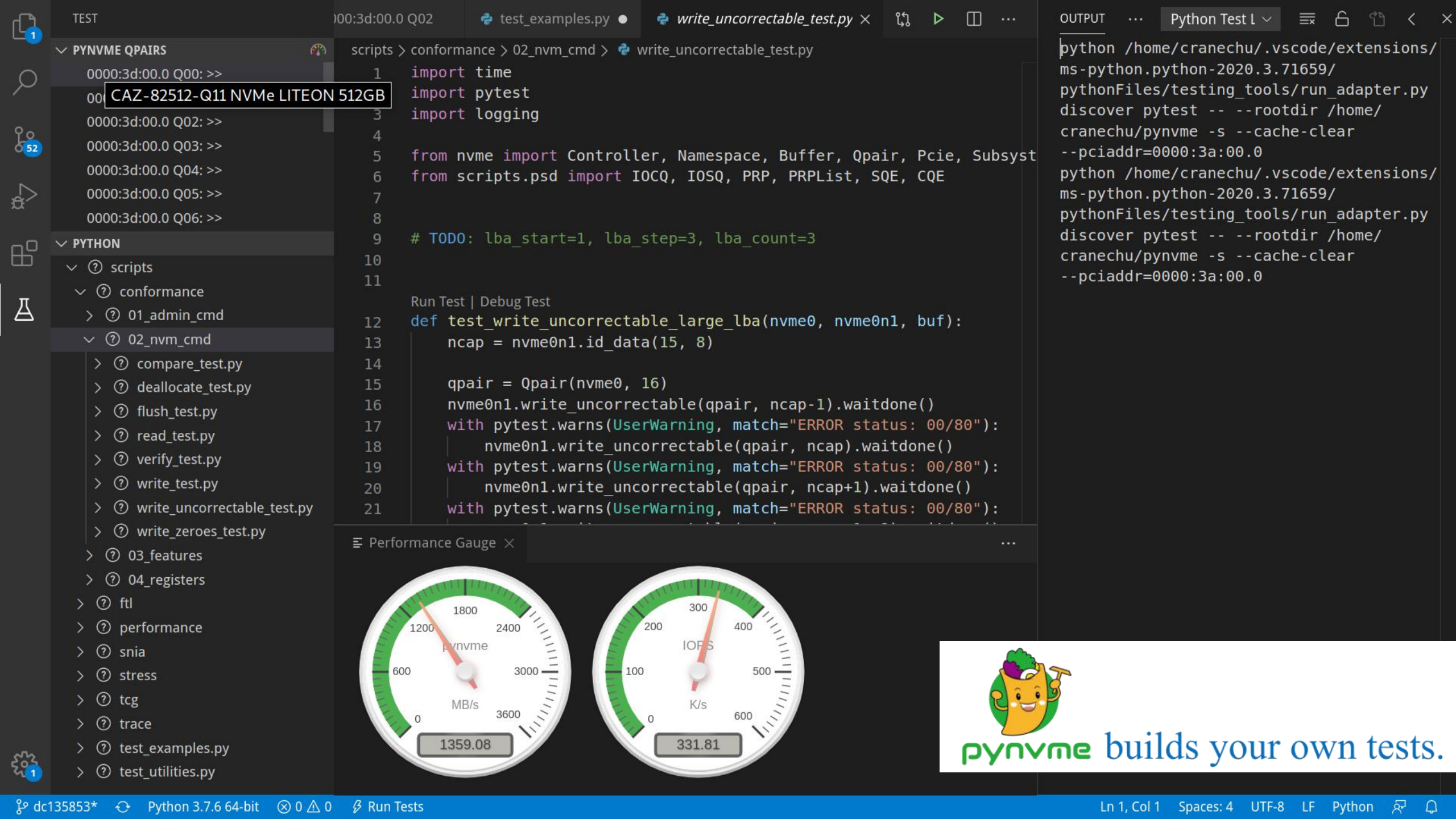
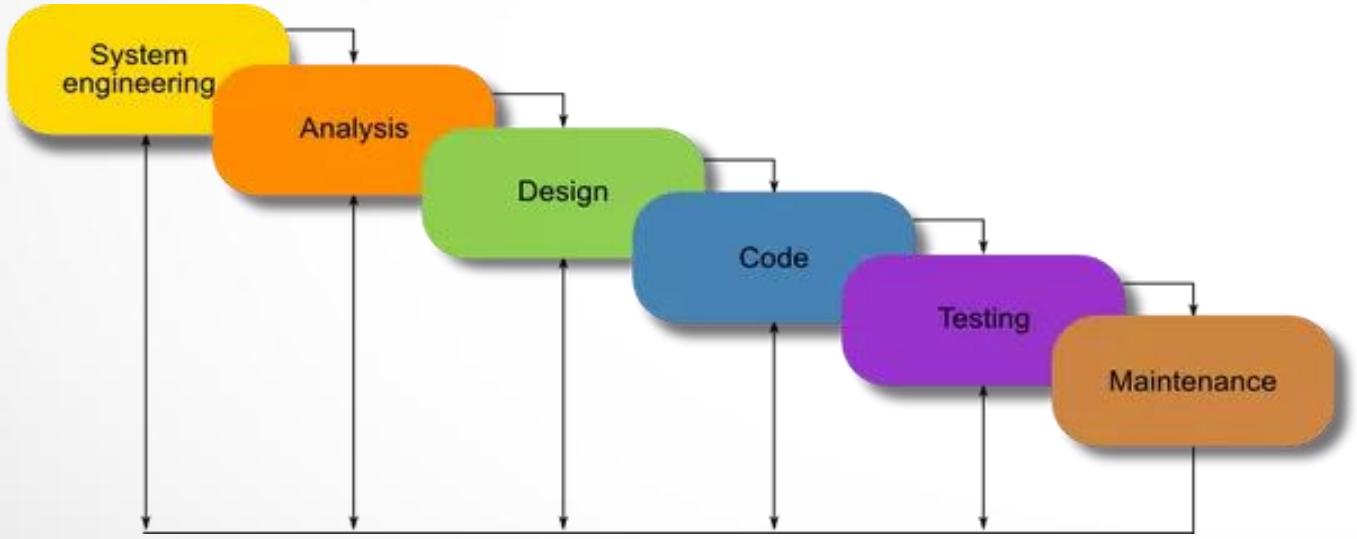
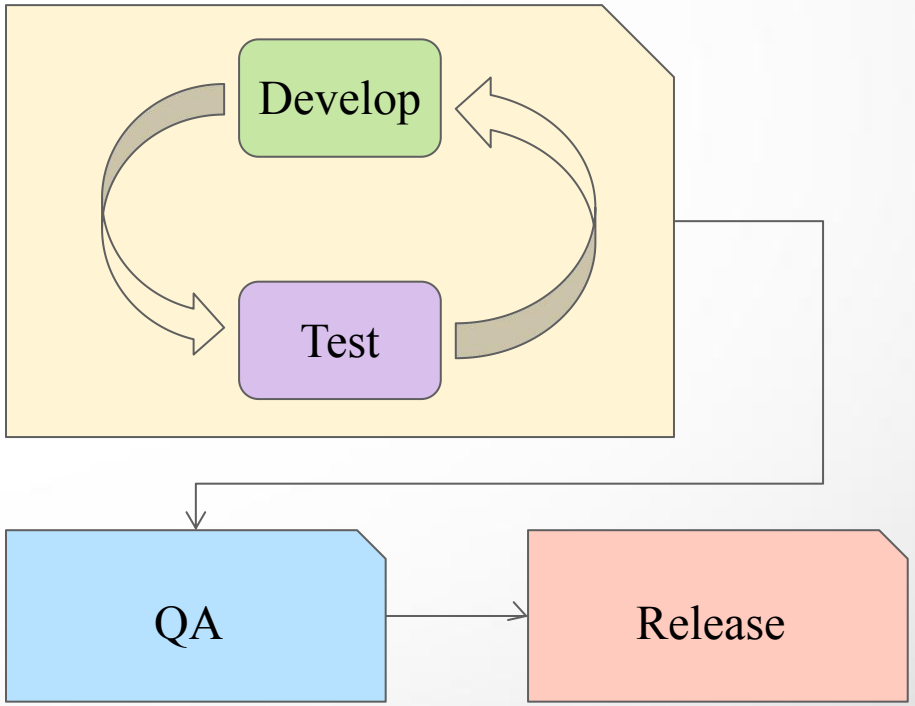

TEST
0000:3d:00.0 Q02
test_examples.py
write_uncorrectable_test.py
OUTPUT
Python Test L
PYNVME QPAIRS
0000:3d:00.0 Q00: >>
CAZ-82512-Q11 NVMe LITEON 512GB
0000:3d:00.0 Q02: >>
0000:3d:00.0 Q03: >>
0000:3d:00.0 Q04: >>
0000:3d:00.0 Q05: >>
0000:3d:00.0 Q06: >>
PYTHON
scripts
conformance
01_admin_cmd
02_nvm_cmd
compare_test.py
deallocate_test.py
flush_test.py
read_test.py
verify_test.py
write_test.py
write_uncorrectable_test.py
write_zeroes_test.py
03_features
04_registers
ftl
performance
snia
stress
tcg
trace
test_examples.py
test_utilities.py
scripts > conformance > 02_nvm_cmd > write_uncorrectable_test.py
import time
import pytest
import logging
from nvme import Controller, Namespace, Buffer, Qpair, Pcie, Subsyst
from scripts.psd import IOCQ, IOSQ, PRP, PRPList, SQE, CQE
# TODO: lba_start=1, lba_step=3, lba_count=3
Run Test | Debug Test
def test_write_uncorrectable_large_lba(nvme0, nvme0n1, buf):
ncap = nvme0n1.id_data(15, 8)
qpair = Qpair(nvme0, 16)
nvme0n1.write_uncorrectable(qpair, ncap-1).waitdone()
with pytest.warns(UserWarning, match="ERROR status: 00/80"):
nvme0n1.write_uncorrectable(qpair, ncap).waitdone()
with pytest.warns(UserWarning, match="ERROR status: 00/80"):
nvme0n1.write_uncorrectable(qpair, ncap+1).waitdone()
with pytest.warns(UserWarning, match="ERROR status: 00/80"):
Performance Gauge
pynvme
MB/s
1359.08
IOPS
K/s
331.81
python /home/cranechu/.vscode/extensions/ms-python.python-2020.3.71659/pythonFiles/testing_tools/run_adapter.py discover pytest -- --rootdir /home/cranechu/pynvme -s --cache-clear --pciaddr=0000:3a:00.0
python /home/cranechu/.vscode/extensions/ms-python.python-2020.3.71659/pythonFiles/testing_tools/run_adapter.py discover pytest -- --rootdir /home/cranechu/pynvme -s --cache-clear --pciaddr=0000:3a:00.0
pynvme builds your own tests.
dc135853*
Python 3.7.6 64-bit
Run Tests
Ln 1, Col 1
Spaces: 4
UTF-8
LF
Python

Test v.s. Quality Assurance

- Develop => QA
- Waterfall



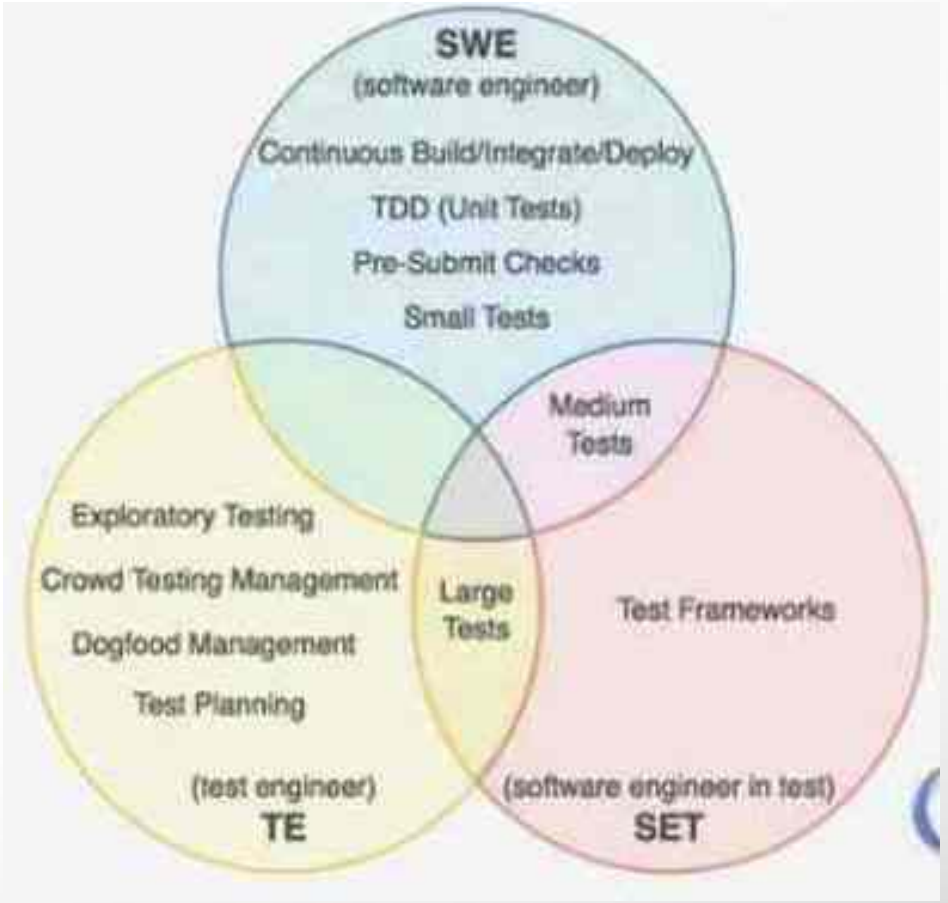
- (Develop+Test) => QA
- Agile



Experience of SSD Firmware Development

- Firmware Engineer & Test Engineer
  - FE develops firmware code
  - TE develops scripts to test firmware code
- test tool (DriveMaster):
  - difficult to develop and maintain
  - form a gap between FE and TE
  - source code is not open

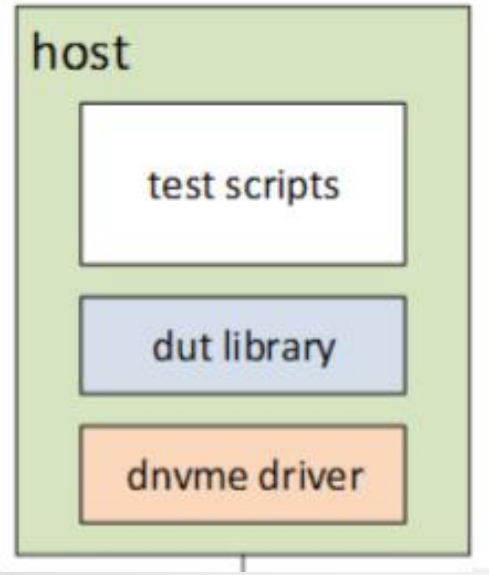
- How Google Tests Software
  - SWE(FE), SET(TE), TE(QA)



Pair programming in CZ-5

Experience in a Startup

- dnvme: @2015
  - wrap with python in userspace
  - functional tests
  - integrited with Jenkins
  - firmware engineers develop scripts
  - PASS IOL test on the first try



- challenges:
  - low performance:
    - IOPS, latency, consistency
    - test efficiency
    - stress tests
  - maintainness: kernel module
  - function coverage: PRP, ...
- dnvme is good at NVMe test, but in-efficient on SSD test.

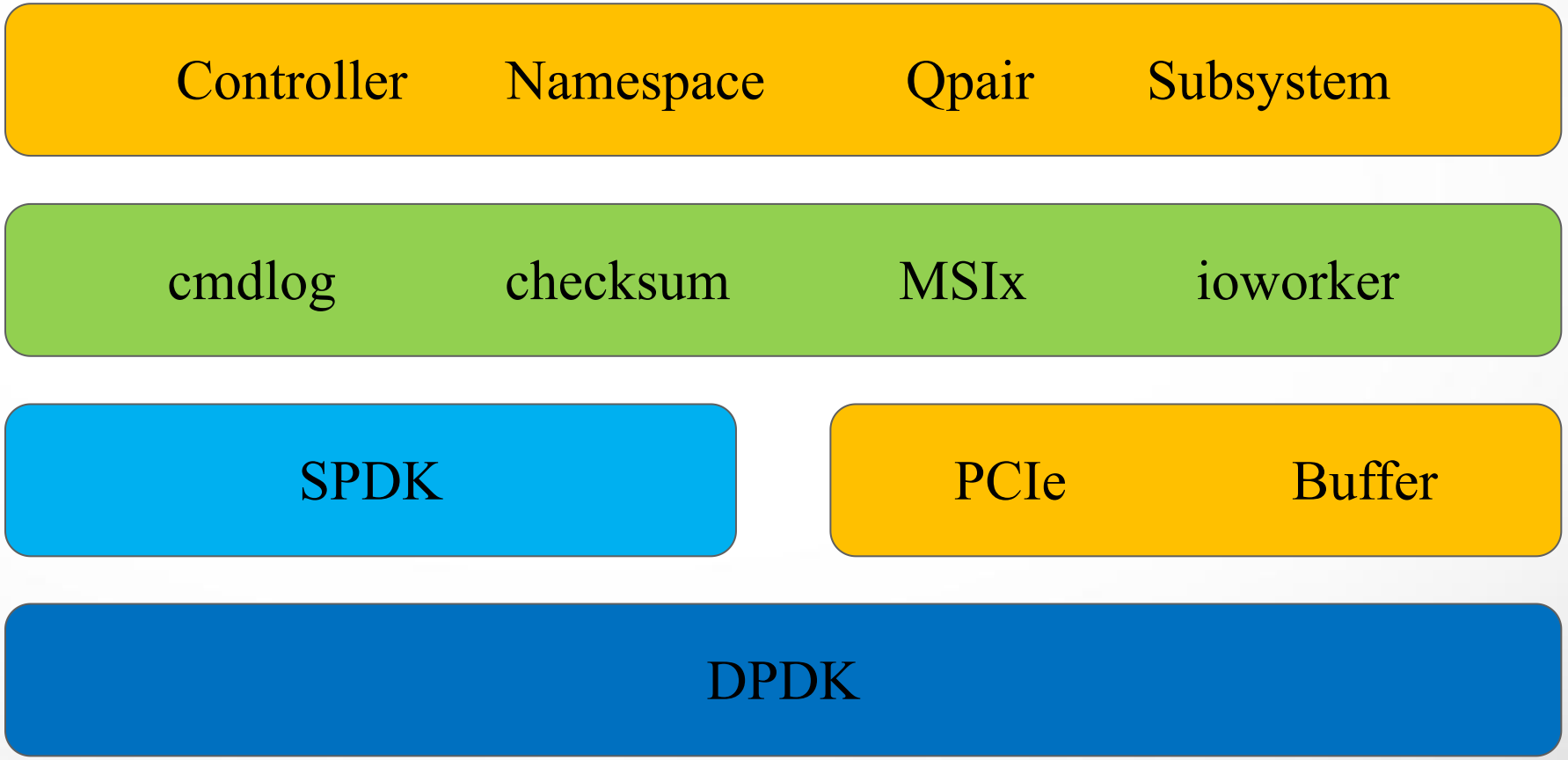
Storage Performance Development Kit

- SPDK is open from 2016
  - super high performance: 10M IOPS
  - user space application
  - based on DPDK environment, which abstracts low-level resources
    - PCIe
    - memory

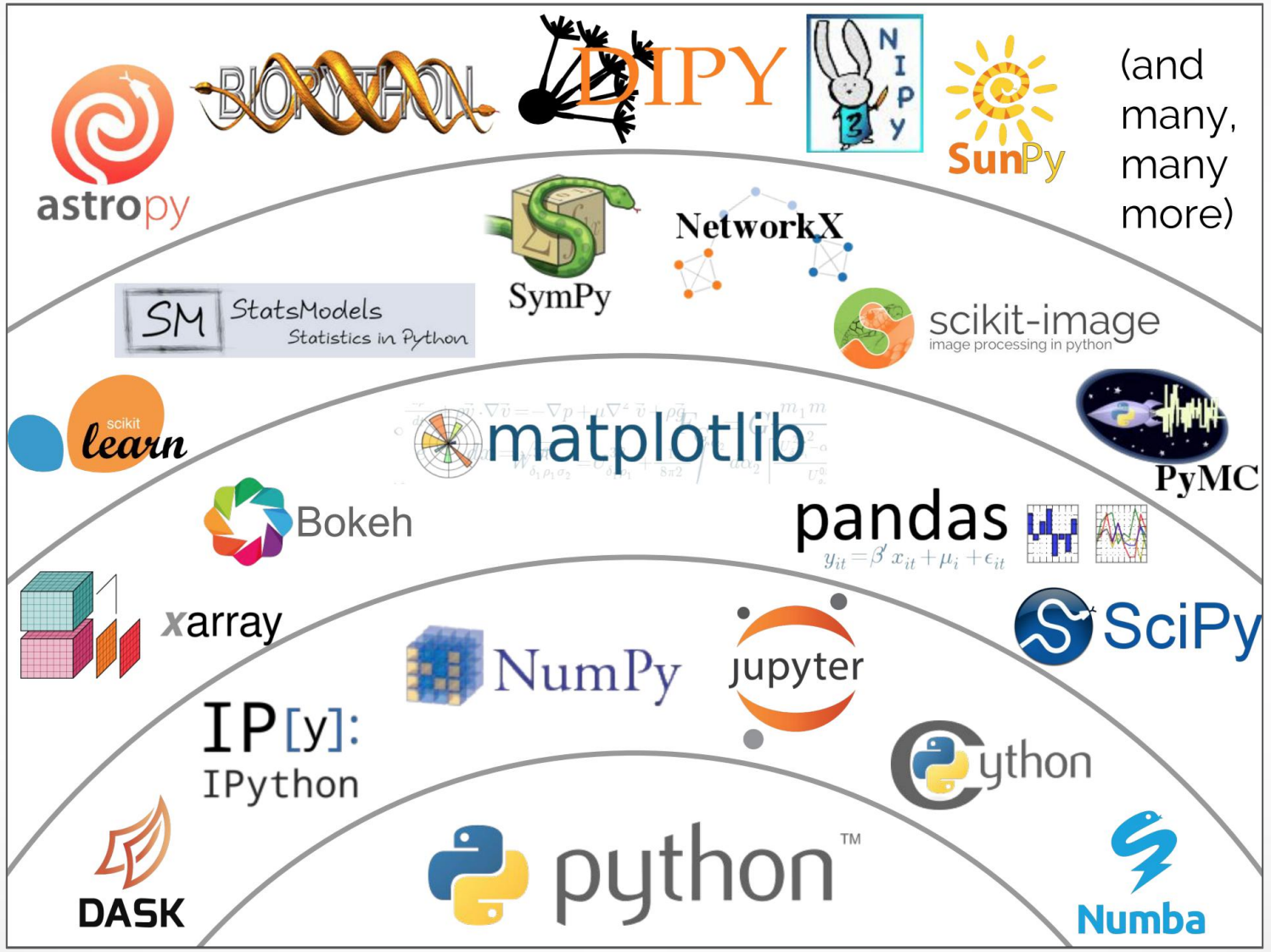
- meet challenges:
  - low performance:
    - IOPS, latency, consistency
    - test efficiency
    - stress tests
  - maintainness: kernel module
  - function coverage: PRP, ...

pynvme: a software-defined SSD test framework

- pynvme abstracts test resources from low to high level, and provides Python API to access all these resources.

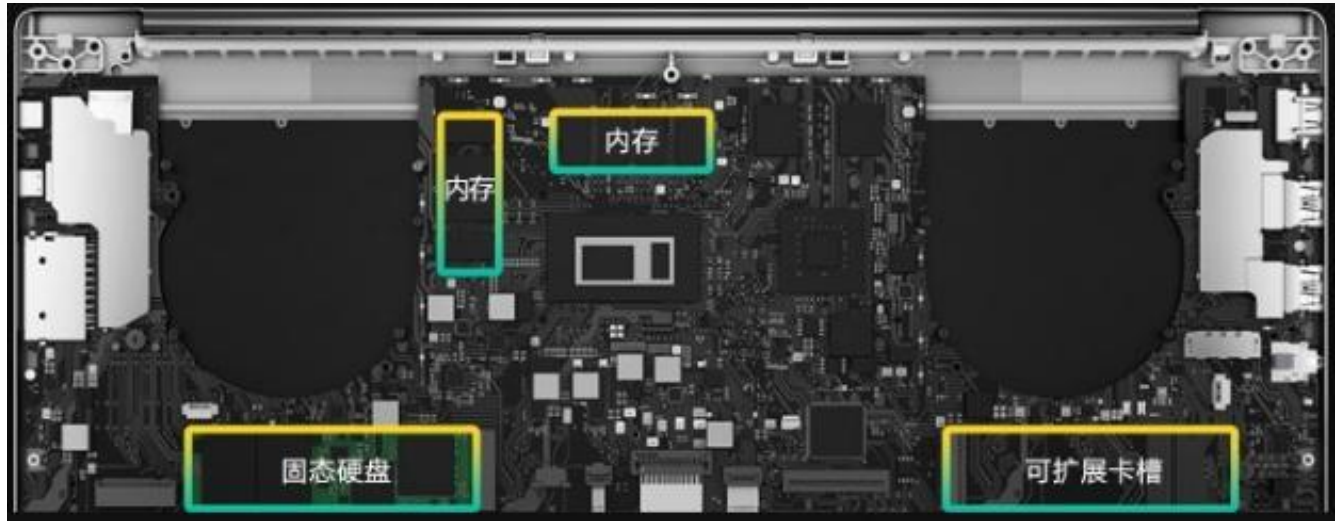


Open to the Ecosystem of Python



Flexible Hardware Configuration

- Single Node
  - laptop
  - workstation
- Mass Deploy
  - server



Test Scripts

```python
import pytest
import nvme as d

import time
import logging


# intuitive, spec, qpair, vscode, debug, cmdlog, assert
def test_hello_world(nvme0, nvme0n1):
    # prepare data buffer and IO queue
    read_buf = d.Buffer(512)
    write_buf = d.Buffer(512)
    write_buf[10:21] = b'hello world'
    qpair = d.Qpair(nvme0, 16)  # create IO SQ/CQ pair, with 16 queue-depth

    # send write and read command
    def write_cb(cdw0, status1):  # command callback function
        nvme0n1.read(qpair, read_buf, 0, 1)
    nvme0n1.write(qpair, write_buf, 0, 1, cb=write_cb)

    # wait commands complete and verify data
    assert read_buf[10:21] != b'hello world'
    qpair.waitdone(2)
    assert read_buf[10:21] == b'hello world'
```

```python
import time
import pytest
import logging

import nvme as d

@pytest.mark.parametrize("repeat", range(10))
def test_quarch_dirty_power_cycle(nvme0, nvme0n1, subsystem, buf, verify, repeat):
    # get the unsafe shutdown count before test
    nvme0.getlogpage(2, buf, 512).waitdone()
    orig_unsafe_count = buf.data(159, 144)
    logging.info("unsafe shutdowns: %d" % orig_unsafe_count)

    # 128K sequential write
    cmdlog_list = [None]*1000
    with nvme0n1.ioworker(io_size=256, lba_random=False,
                          read_percentage=0, lba_start=0,
                          qdepth=1023, time=15,
                          output_cmdlog_list=cmdlog_list):
        # sudden power loss before the ioworker end
        time.sleep(5)
        subsystem.poweroff()

    # power on
    subsystem.poweron()
    subsystem.reset()
```

Test Scripts: dirty power cycle

- PCIe Card Module
- Torridon Interface Kit

- poweroff process
  - poweroff when ioworker is alive
  - remove device from system

- poweron process
  - poweron
  - remove kernel driver
  - rescan device
  - nvme initialization

Test Scripts: 3 ways of sending IO

```python
def test_ioworker_simplified(nvme0n1):
    nvme0n1.ioworker(io_size=2, time=2).start().close()
```

```python
def test_hello_world(nvme0, nvme0n1):
    # prepare data buffer and IO queue
    read_buf = d.Buffer(512)
    write_buf = d.Buffer(512)
    write_buf[10:21] = b'hello world'
    qpair = d.Qpair(nvme0, 16)  # create IO SQ/CQ pair,

    # send write and read command
    def write_cb(cdw0, status1):  # command callback fun
        nvme0n1.read(qpair, read_buf, 0, 1)
    nvme0n1.write(qpair, write_buf, 0, 1, cb=write_cb)

    # wait commands complete and verify data
    assert read_buf[10:21] != b'hello world'
    qpair.waitdone(2)
    assert read_buf[10:21] == b'hello world'
```

```python
def test_send_single_cmd(nvme0):
    cq = IOCQ(nvme0, 1, 10, PRP())
    sq = IOSQ(nvme0, 1, 10, PRP(), cqid=1)

    # first cmd, invalid namespace
    sq[0] = [8] + [0]*15
    sq.tail = 1
    time.sleep(0.1)
    status = (cq[0][3]>>17)&0x7ff
    assert status == 0x000b

    sq.delete()
    cq.delete()
```

Test Scripts: ioworker

Inputs:

- lba_start, lba_step, lba_align
- lba_random
- region_start, region_end
- distribution

- io_size (int, range, list, dict)
- read_percentage, io_percentage
- time, io_count
- qdepth, qprio
- pvalue, ptype
- iops
- ...

Outputs:

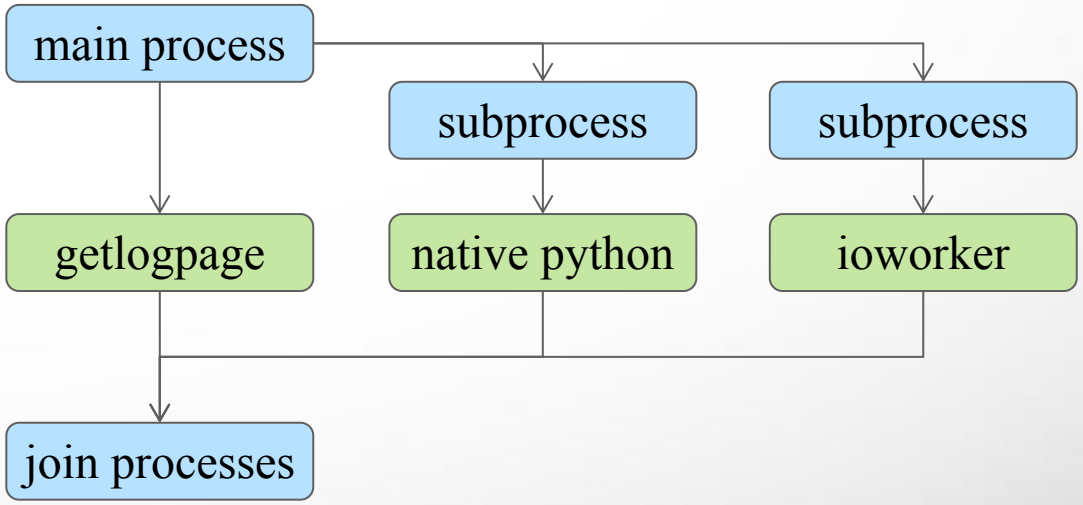
- io_count_read
- io_count_write
- mseconds
- latency_max_us
- latency_average_us
- error
- cpu_usage

- output_io_per_second (optional)
- output_percentile_latency (optional)
- output_cmdlog_list (optional)
- ...

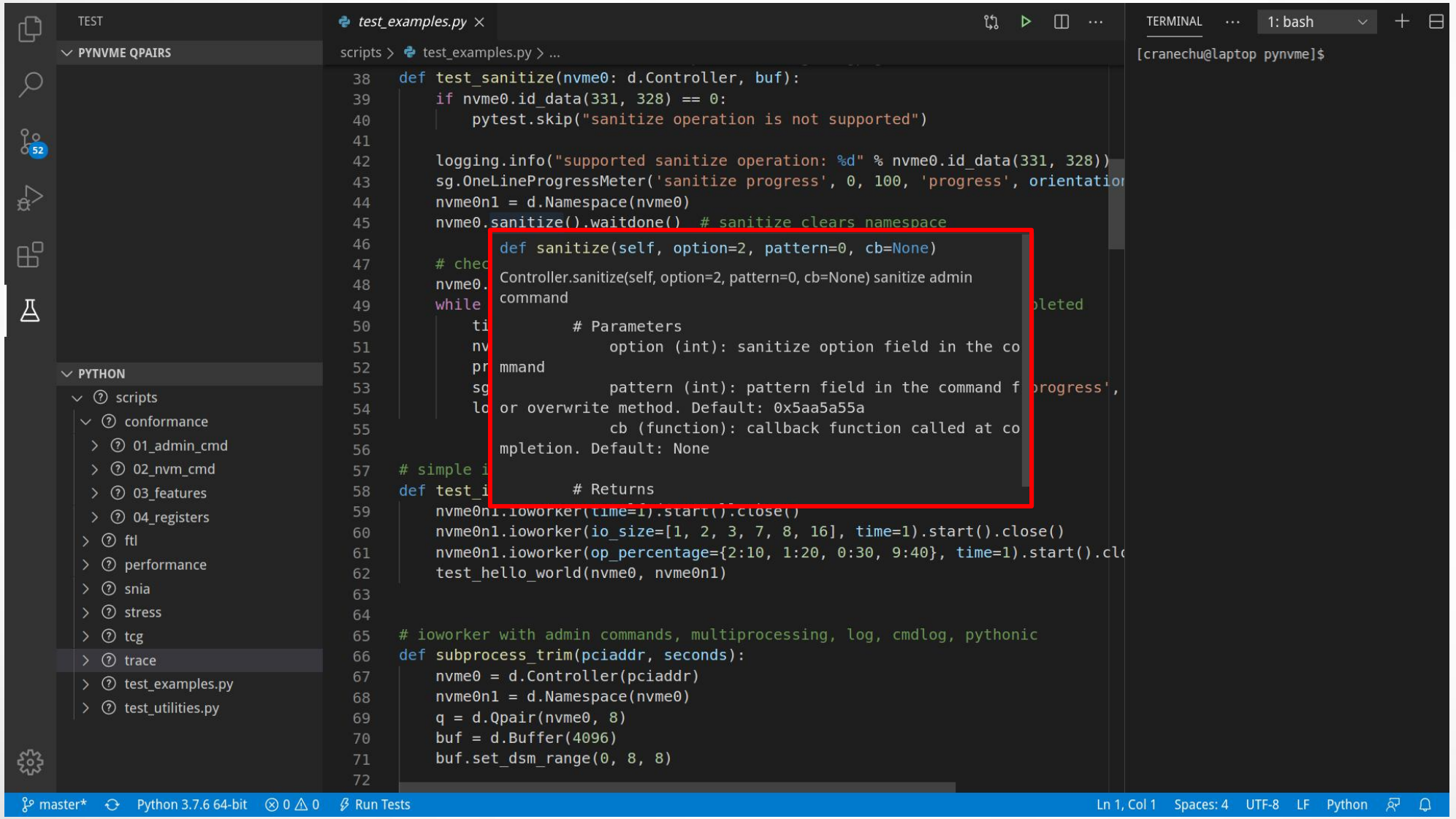
Test Scripts: multiprocessing

```
72  def test_ioworker_with_temperature_and_trim(nvme0, nvme0n1):
73      # start trim process
74      import multiprocessing
75      mp = multiprocessing.get_context("spawn")
76      p = mp.Process(target = subprocess_trim,
77                     args = (nvme0.addr.encode('utf-8'),
78                             300000))
79      p.start()
80
81      # start read/write ioworker and admin commands
82      smart_log = d.Buffer(512, "smart log")
83      with nvme0n1.ioworker(io_size=8, lba_align=16,
84                            lba_random=True, qdepth=16,
85                            read_percentage=67, iops=10000, time=10):
86          for i in range(15):
87              nvme0.getlogpage(0x02, smart_log, 512).waitdone()
88              ktemp = smart_log.data(2, 1)
89
90              from pytemperature import k2c
91              logging.info("temperature: %0.2f degreeC" % k2c(ktemp))
92              time.sleep(1)
93
94      # wait trim process complete
95      p.join()
96
```

```
60  # ioworker with admin commands, multiprocessing, log, cmdlog, pythonic
61  def subprocess_trim(pciaddr, loops):
62      nvme0 = d.Controller(pciaddr)
63      nvme0n1 = d.Namespace(nvme0)
64      q = d.Qpair(nvme0, 8)
65      buf = d.Buffer(4096)
66      buf.set_dsm_range(0, 8, 8)
67
68      # send trim commands
69      for i in range(loops):
70          nvme0n1.dsm(q, buf, 1).waitdone()
71
```

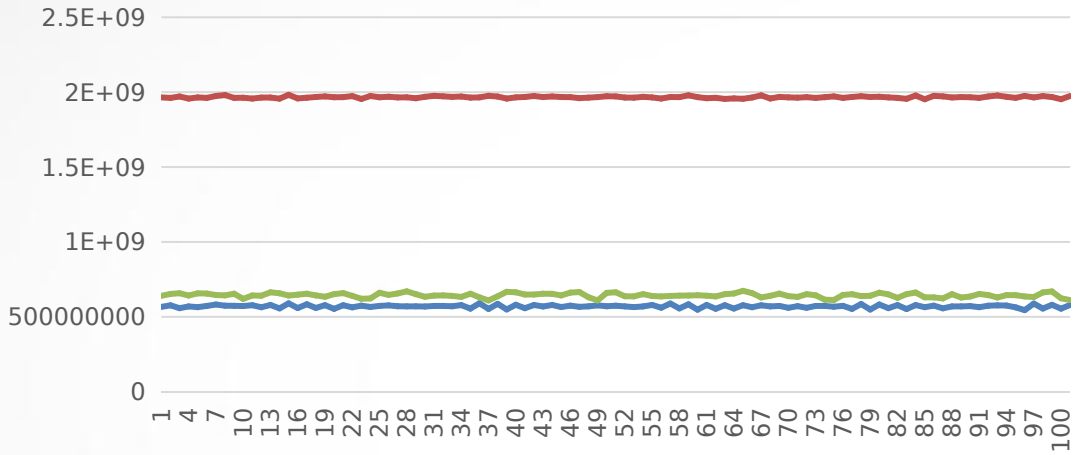


Test Scripts: API document

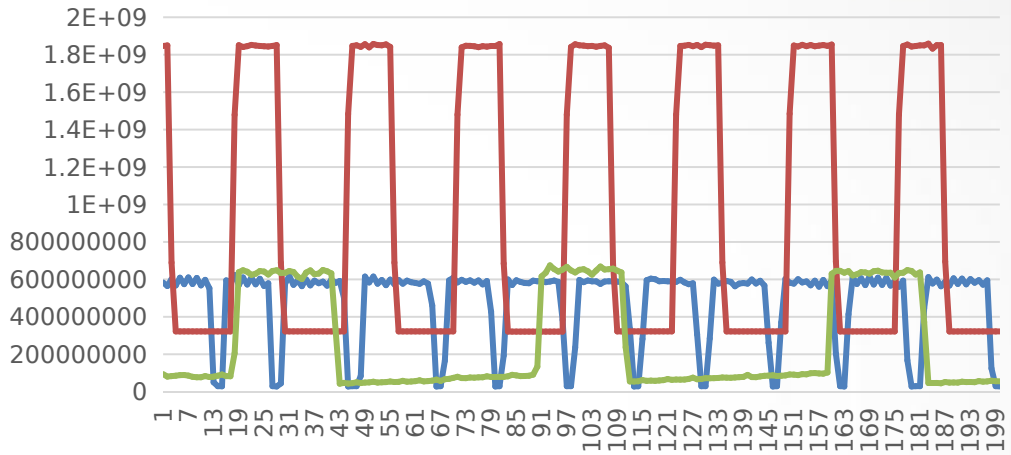


Test Scripts: gallery

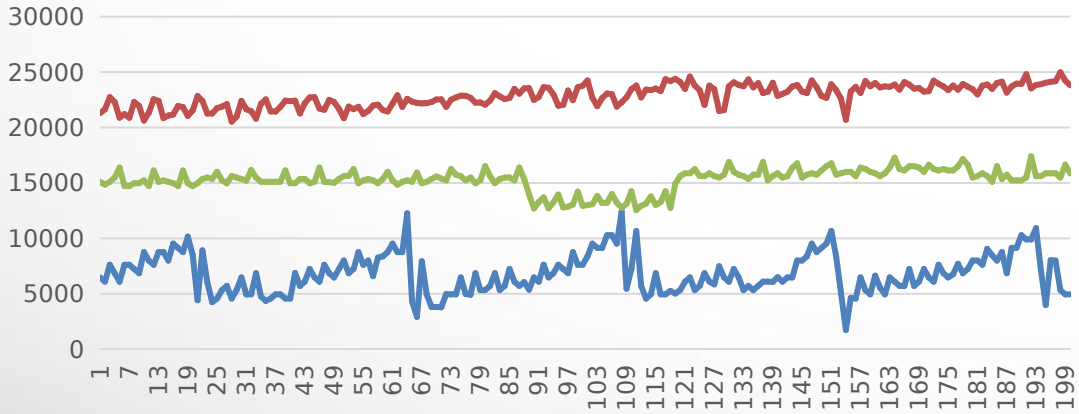
sequential write 1st pass (x: second, y: B/s)



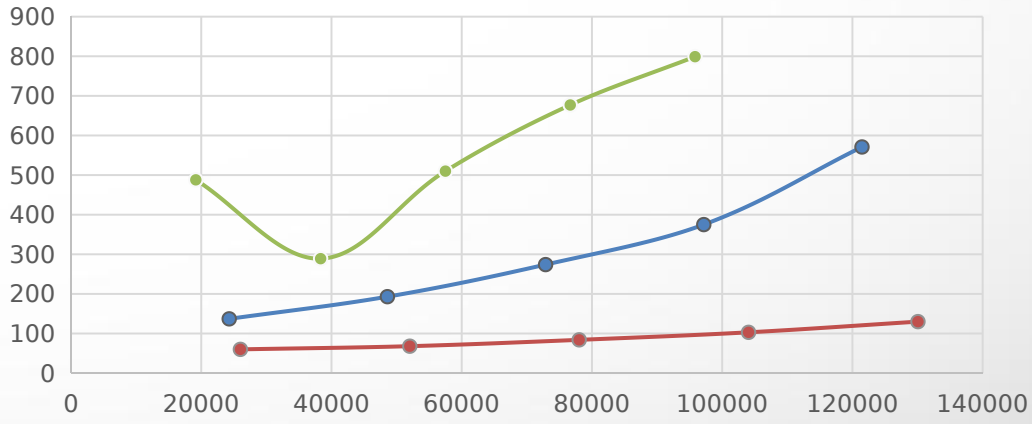
sequential write 3rd pass (x: second, y: B/s)



4K random write (x: second, y: IOPS)



latency against IOPS, 2R1W (x: IOPS, y: us)



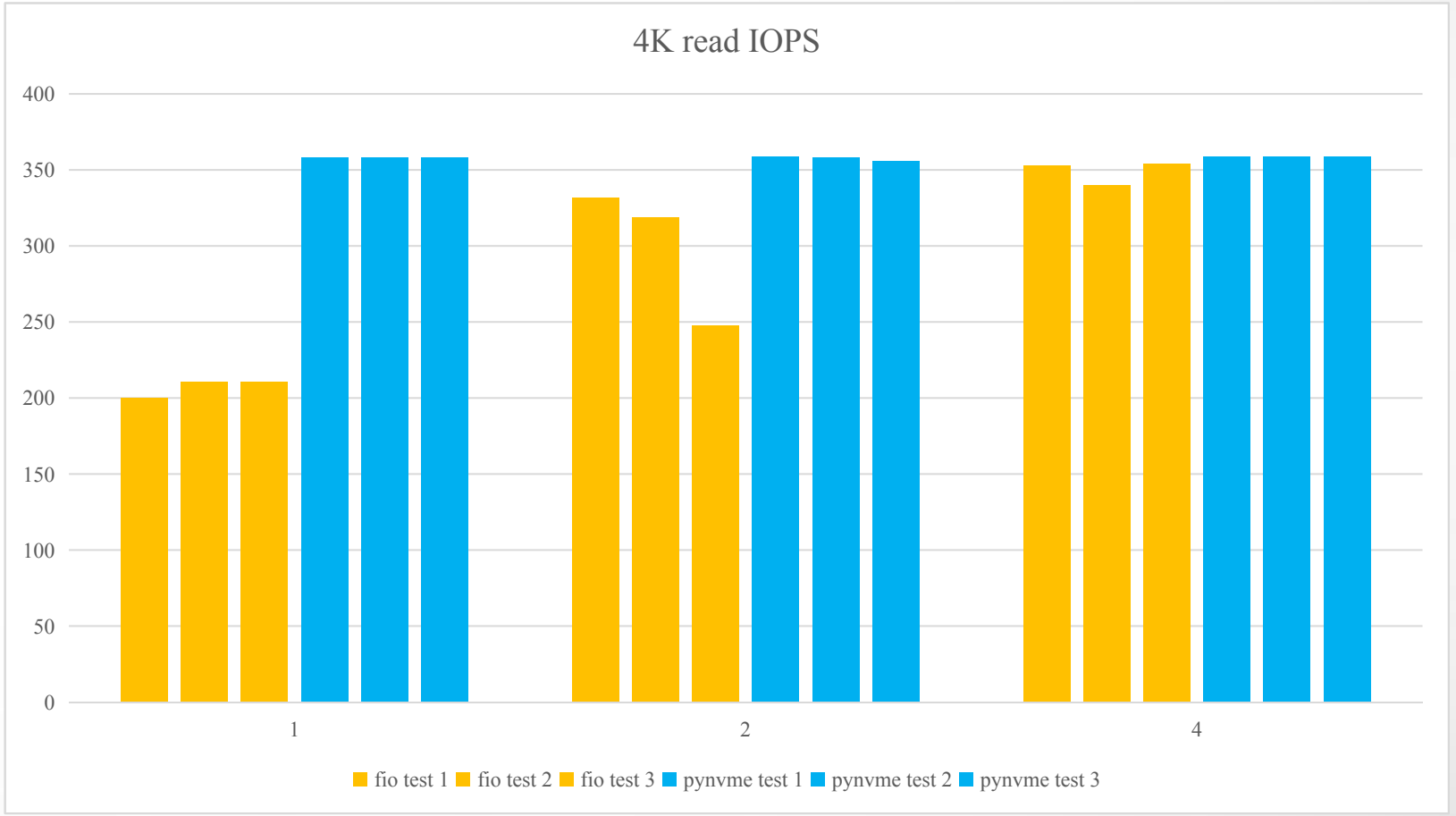
Performance: IOPS compared with FIO

fio (unit: K IOPS)

Q count	1	2	4
test 1	200	332	353
test 2	211	319	340
test 3	211	248	354

pynvme (unit: K IOPS)

Q count	1	2	4
test 1	358	359	359
test 2	358	358	359
test 3	358	356	359



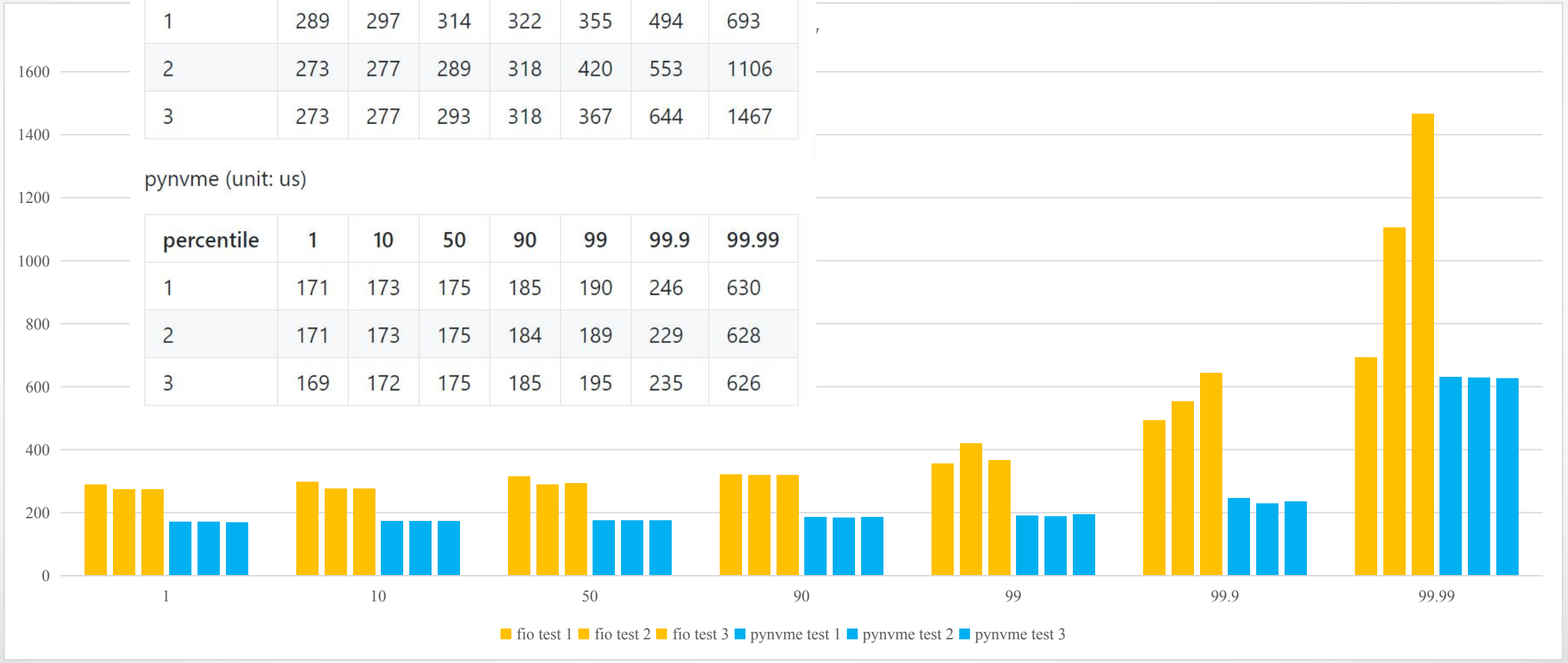
Performance: latency compared with FIO

fio (unit: us)

percentile	1	10	50	90	99	99.9	99.99
1	289	297	314	322	355	494	693
2	273	277	289	318	420	553	1106
3	273	277	293	318	367	644	1467

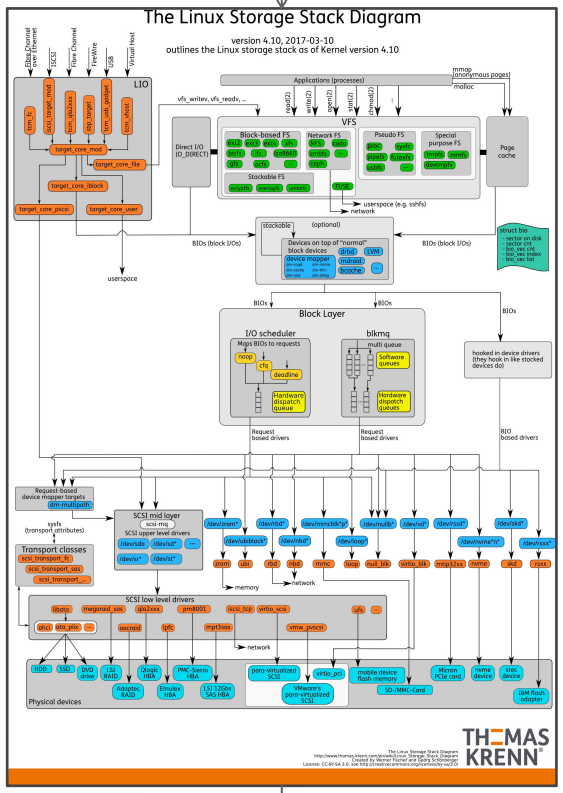
pynvme (unit: us)

percentile	1	10	50	90	99	99.9	99.99
1	171	173	175	185	190	246	630
2	171	173	175	184	189	229	628
3	169	172	175	185	195	235	626



Performance: userspace driver

FIO



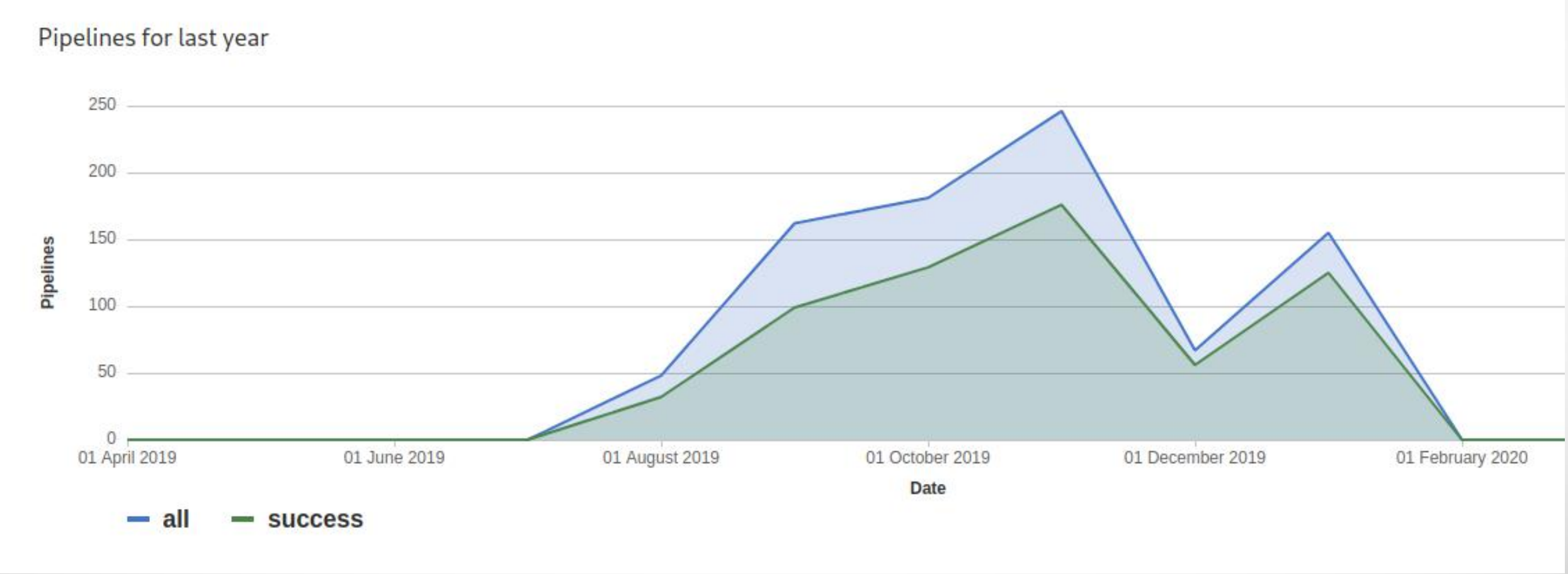
pynvme

NVMe driver
in userspace

DUT

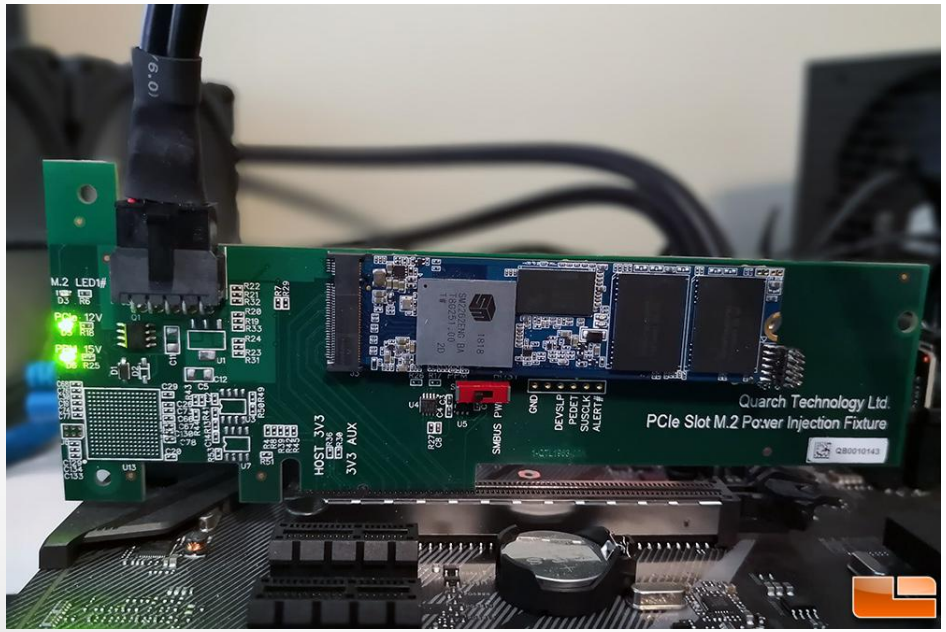
Quality: test of the test infrastructure

- CI in gitlab.com
- ~200 test cases

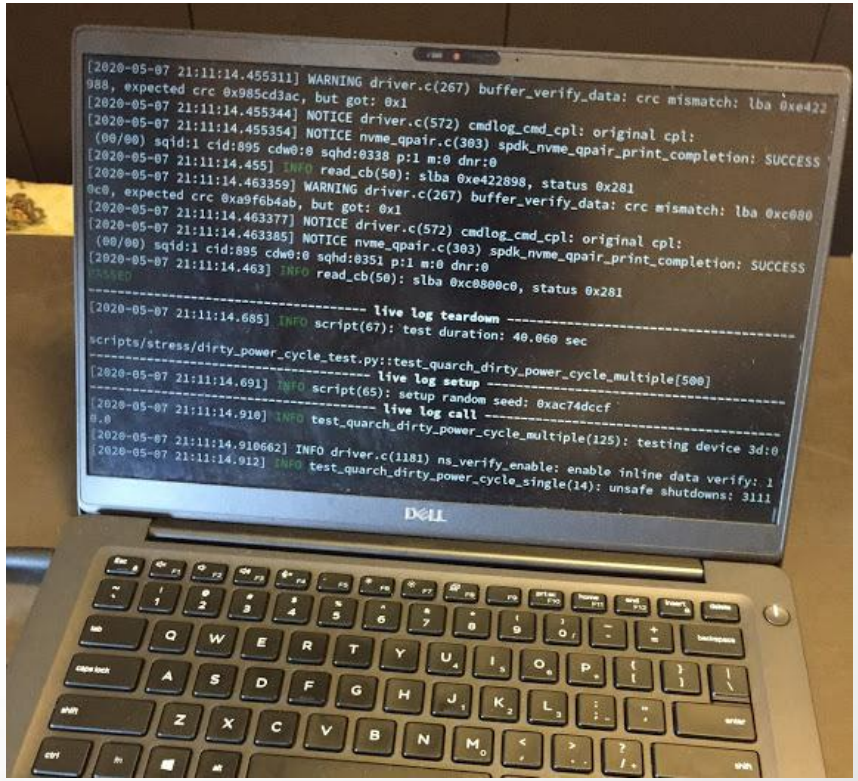


vPower to ON and OFF

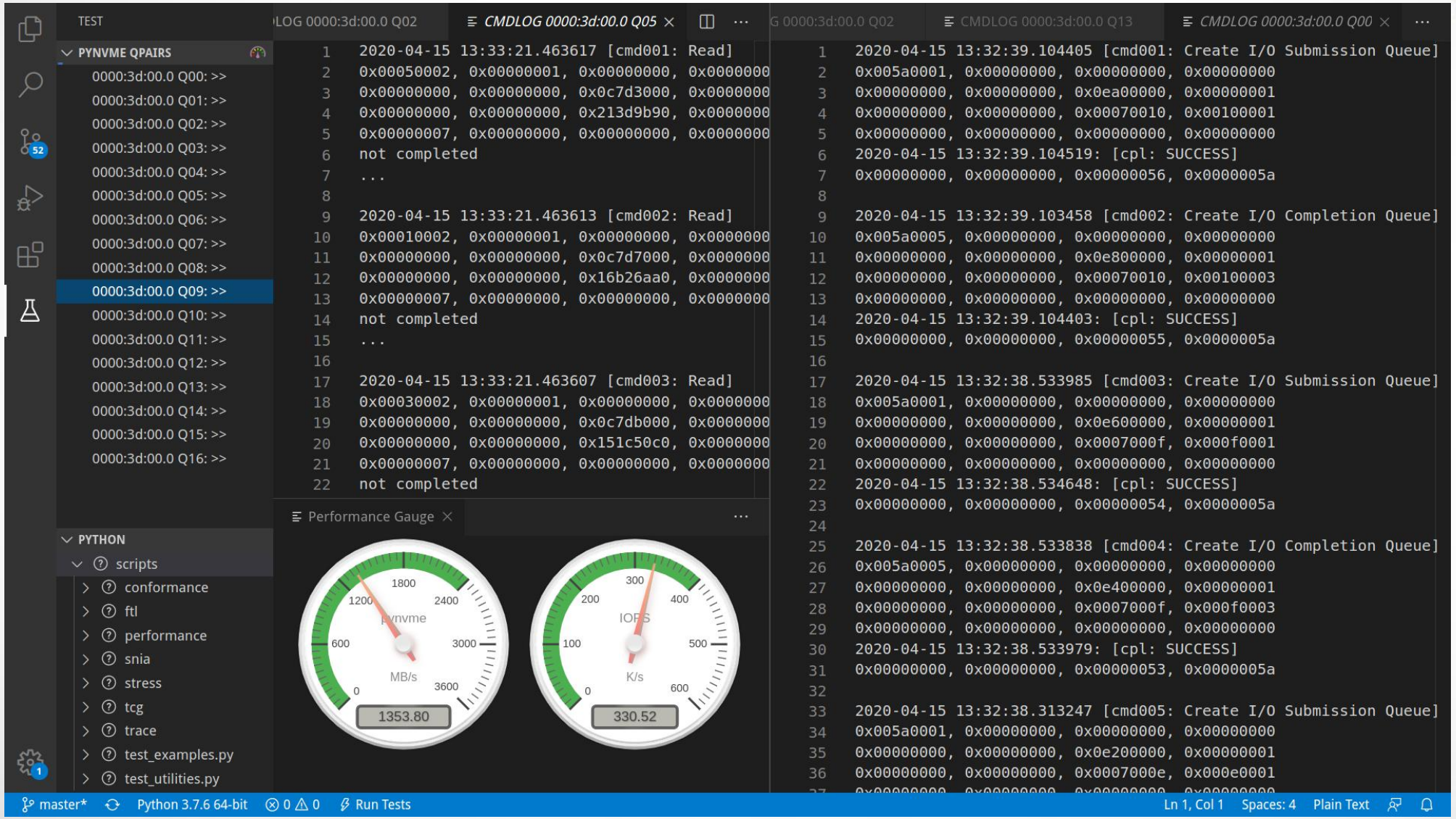
- Usually we need a special hardware box to control the power of SSD



- vPower contorls the power of SSD:
  - power off: enter S3/sleep mode
  - power on: wake up by RTC



vAnalyzer


TEST
PYNVME QPAIRS
0000:3d:00.0 Q00: >>
0000:3d:00.0 Q01: >>
0000:3d:00.0 Q02: >>
0000:3d:00.0 Q03: >>
0000:3d:00.0 Q04: >>
0000:3d:00.0 Q05: >>
0000:3d:00.0 Q06: >>
0000:3d:00.0 Q07: >>
0000:3d:00.0 Q08: >>
0000:3d:00.0 Q09: >>
0000:3d:00.0 Q10: >>
0000:3d:00.0 Q11: >>
0000:3d:00.0 Q12: >>
0000:3d:00.0 Q13: >>
0000:3d:00.0 Q14: >>
0000:3d:00.0 Q15: >>
0000:3d:00.0 Q16: >>
PYTHON
scripts
conformance
ftl
performance
snia
stress
tcg
trace
test_examples.py
test_utilities.py
CMDLOG 0000:3d:00.0 Q05
2020-04-15 13:33:21.463617 [cmd001: Read]
0x00050002, 0x00000001, 0x00000000, 0x0000000
0x00000000, 0x00000000, 0x0c7d3000, 0x0000000
0x00000000, 0x00000000, 0x213d9b90, 0x0000000
0x00000007, 0x00000000, 0x00000000, 0x0000000
not completed
...
2020-04-15 13:33:21.463613 [cmd002: Read]
0x00010002, 0x00000001, 0x00000000, 0x0000000
0x00000000, 0x00000000, 0x0c7d7000, 0x0000000
0x00000000, 0x00000000, 0x16b26aa0, 0x0000000
0x00000007, 0x00000000, 0x00000000, 0x0000000
not completed
...
2020-04-15 13:33:21.463607 [cmd003: Read]
0x00030002, 0x00000001, 0x00000000, 0x0000000
0x00000000, 0x00000000, 0x0c7db000, 0x0000000
0x00000000, 0x00000000, 0x151c50c0, 0x0000000
0x00000007, 0x00000000, 0x00000000, 0x0000000
not completed
Performance Gauge
pynvme
MB/s
1353.80
IOPS
K/s
330.52
CMDLOG 0000:3d:00.0 Q13
CMDLOG 0000:3d:00.0 Q00
2020-04-15 13:32:39.104405 [cmd001: Create I/O Submission Queue]
0x005a0001, 0x00000000, 0x00000000, 0x00000000
0x00000000, 0x00000000, 0x0ea00000, 0x00000001
0x00000000, 0x00000000, 0x00070010, 0x00100001
0x00000000, 0x00000000, 0x00000000, 0x00000000
2020-04-15 13:32:39.104519: [cpl: SUCCESS]
0x00000000, 0x00000000, 0x00000056, 0x0000005a
2020-04-15 13:32:39.103458 [cmd002: Create I/O Completion Queue]
0x005a0005, 0x00000000, 0x00000000, 0x00000000
0x00000000, 0x00000000, 0x0e800000, 0x00000001
0x00000000, 0x00000000, 0x00070010, 0x00100003
0x00000000, 0x00000000, 0x00000000, 0x00000000
2020-04-15 13:32:39.104403: [cpl: SUCCESS]
0x00000000, 0x00000000, 0x00000055, 0x0000005a
2020-04-15 13:32:38.533985 [cmd003: Create I/O Submission Queue]
0x005a0001, 0x00000000, 0x00000000, 0x00000000
0x00000000, 0x00000000, 0x0e600000, 0x00000001
0x00000000, 0x00000000, 0x0007000f, 0x000f0001
0x00000000, 0x00000000, 0x00000000, 0x00000000
2020-04-15 13:32:38.534648: [cpl: SUCCESS]
0x00000000, 0x00000000, 0x00000054, 0x0000005a
2020-04-15 13:32:38.533838 [cmd004: Create I/O Completion Queue]
0x005a0005, 0x00000000, 0x00000000, 0x00000000
0x00000000, 0x00000000, 0x0e400000, 0x00000001
0x00000000, 0x00000000, 0x0007000f, 0x000f0003
0x00000000, 0x00000000, 0x00000000, 0x00000000
2020-04-15 13:32:38.533979: [cpl: SUCCESS]
0x00000000, 0x00000000, 0x00000053, 0x0000005a
2020-04-15 13:32:38.313247 [cmd005: Create I/O Submission Queue]
0x005a0001, 0x00000000, 0x00000000, 0x00000000
0x00000000, 0x00000000, 0x0e200000, 0x00000001
0x00000000, 0x00000000, 0x0007000e, 0x000e0001
master*
Python 3.7.6 64-bit
0 0
Run Tests
Ln 1, Col 1
Spaces: 4
Plain Text

vTracer: IO Recorder and Replayer

Windows 10 Virtual Machine

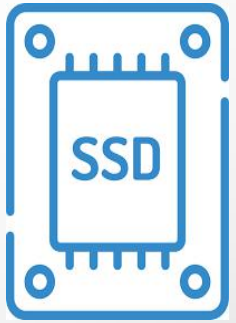
QEMU with pynvme vSSD

Linux

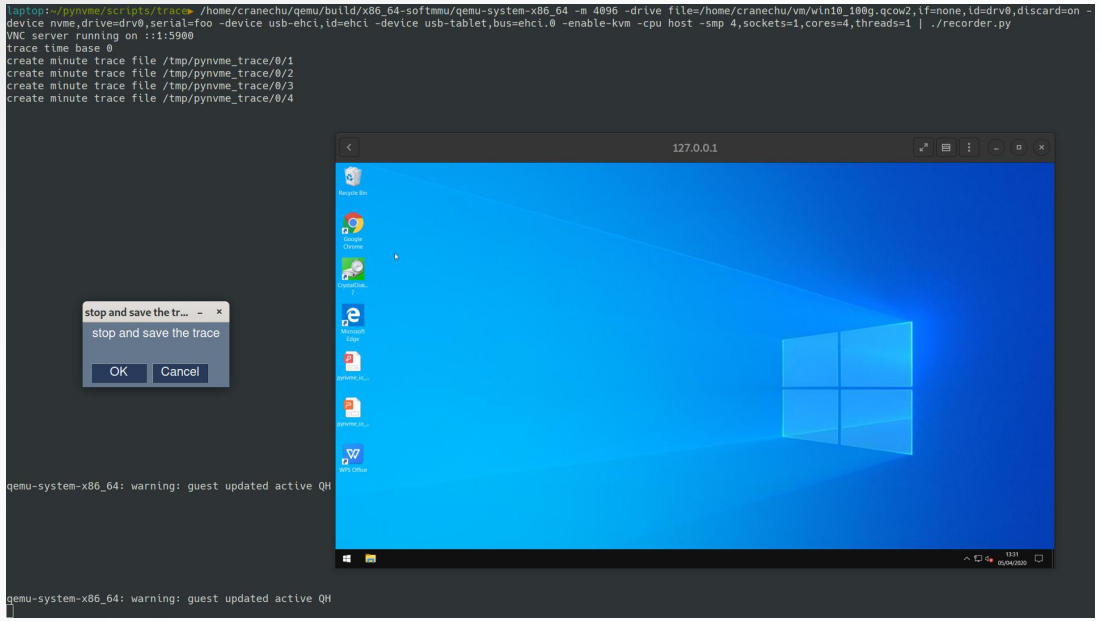
record

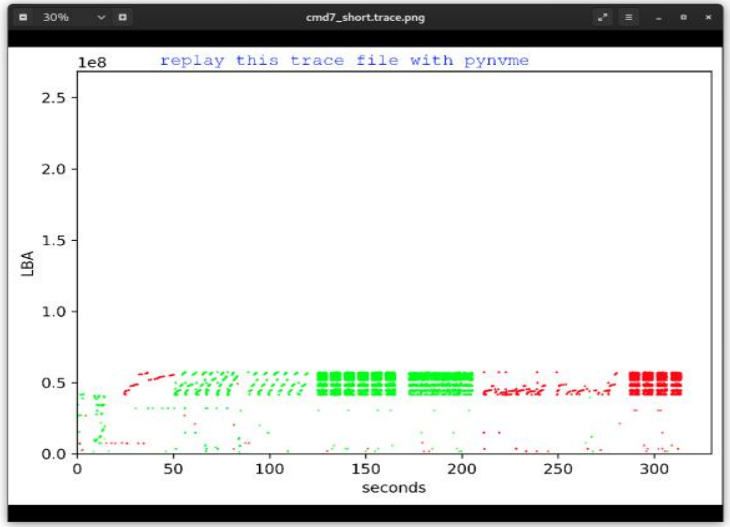
replay

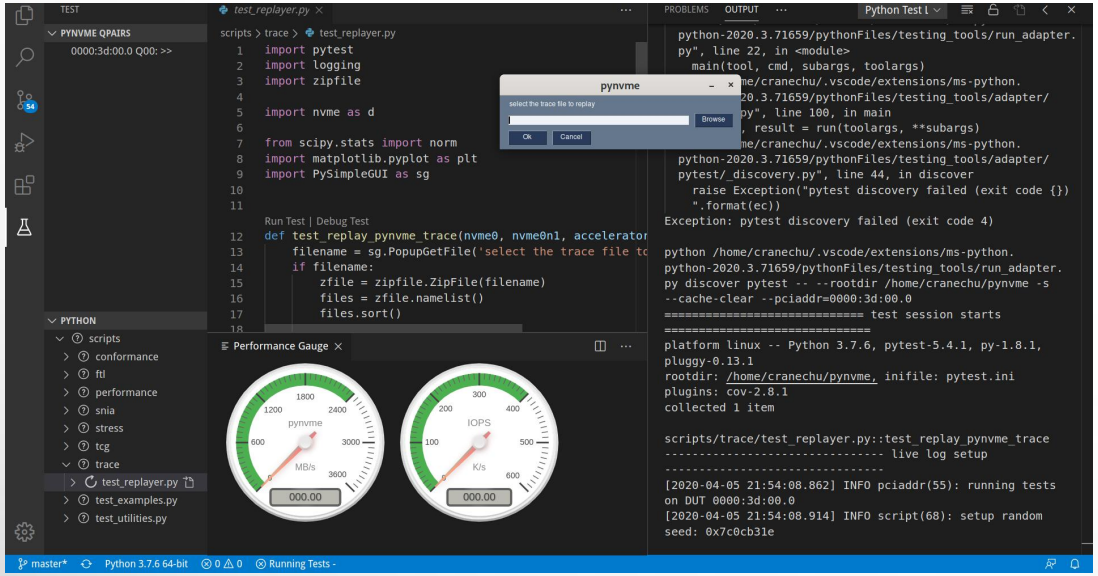
pynvme ioworker

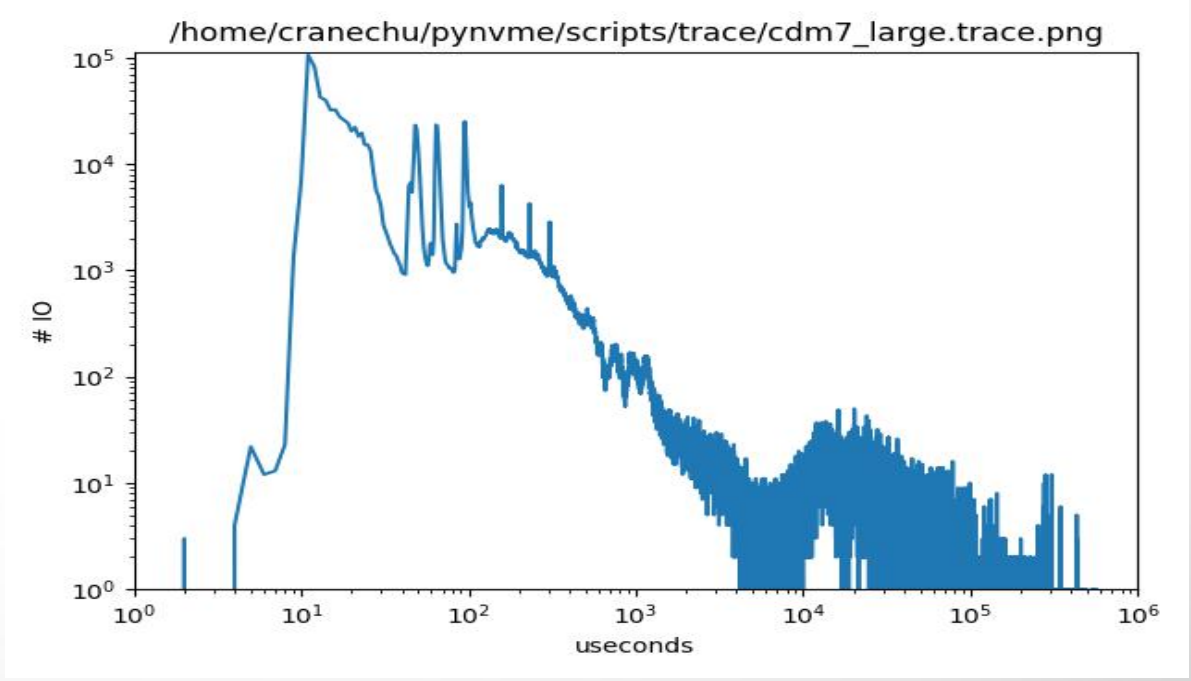


vTracer: Demo

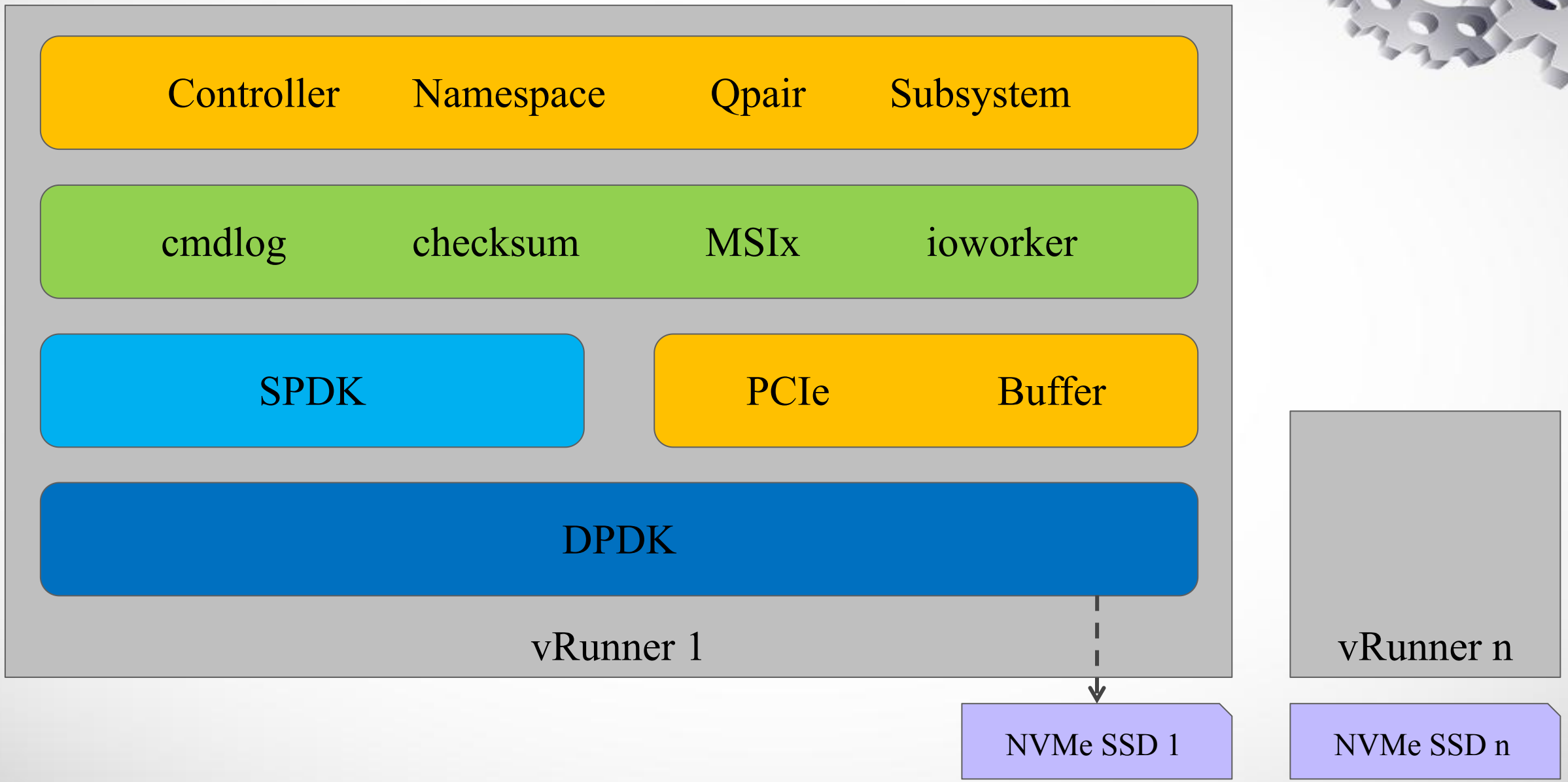








vRunner: Mass Deploy



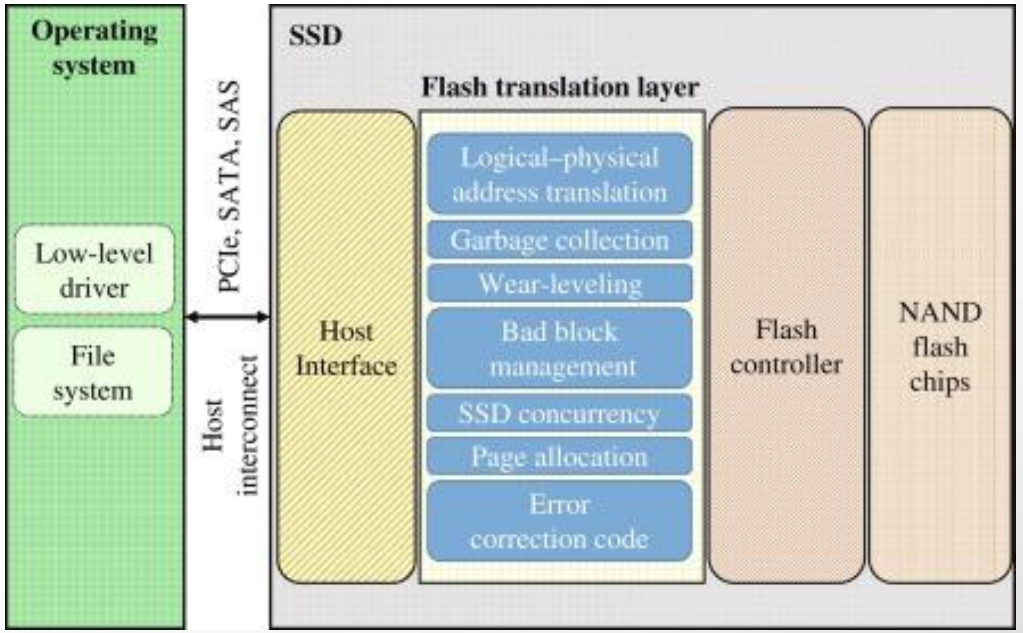
Services

```
5   def test_ioworker_jedec_workload(nvme0n1):
6       distribution = [1000]*5 + [200]*15 + [25]*80
7       iosz_distribution = {1: 4,
8                            2: 1,
9                            3: 1,
10                           4: 1,
11                           5: 1,
12                           6: 1,
13                           7: 1,
14                           8: 67,
15                           16: 10,
16                           32: 7,
17                           64: 3,
18                           128: 3}
19
20      nvme0n1.ioworker(io_size=iosz_distribution,
21                       lba_random=True,
22                       qdepth=128,
23                       distribution = distribution,
24                       read_percentage=0,
25                       ptype=0xbeef, pvalue=100,
26                       time=12*3600).start().close()
```

JEDEC

SNIA

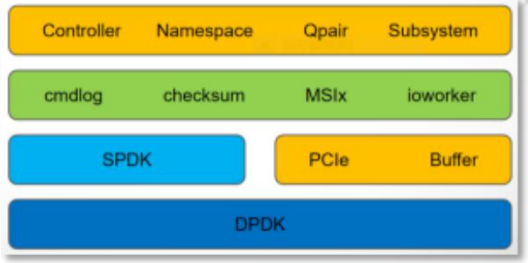
nvm EXPRESS



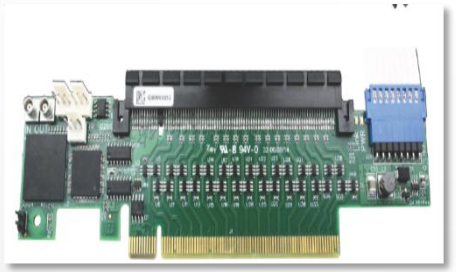
Values

Ecosystem

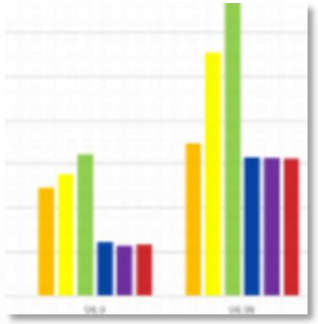
Scripts



Expendability



Hardware



Performance

Service

pynvme builds your own tests.

Thanks!