SSDExplorer:
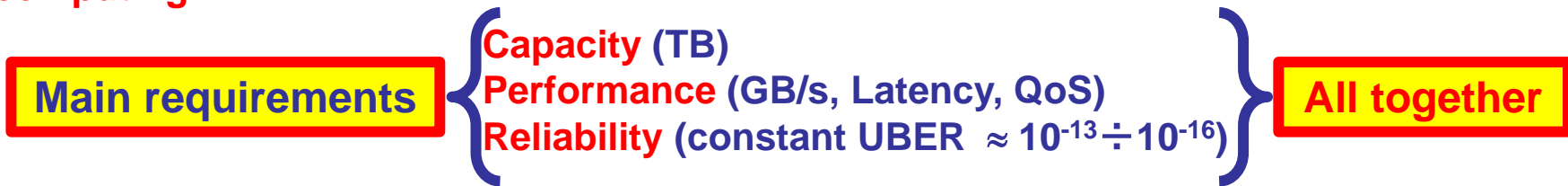# A virtual platform for SSD simulation

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Solid State Drives

Solid State Drives (SSDs) are becoming popular, driven by the relentless growth of **cloud computing**, high performance **gaming**, high-end embedded systems and **portable computing**:

Main requirements {
Capacity (TB)
Performance (GB/s, Latency, QoS)
Reliability (constant UBER $\approx 10^{-13} \div 10^{-16}$)
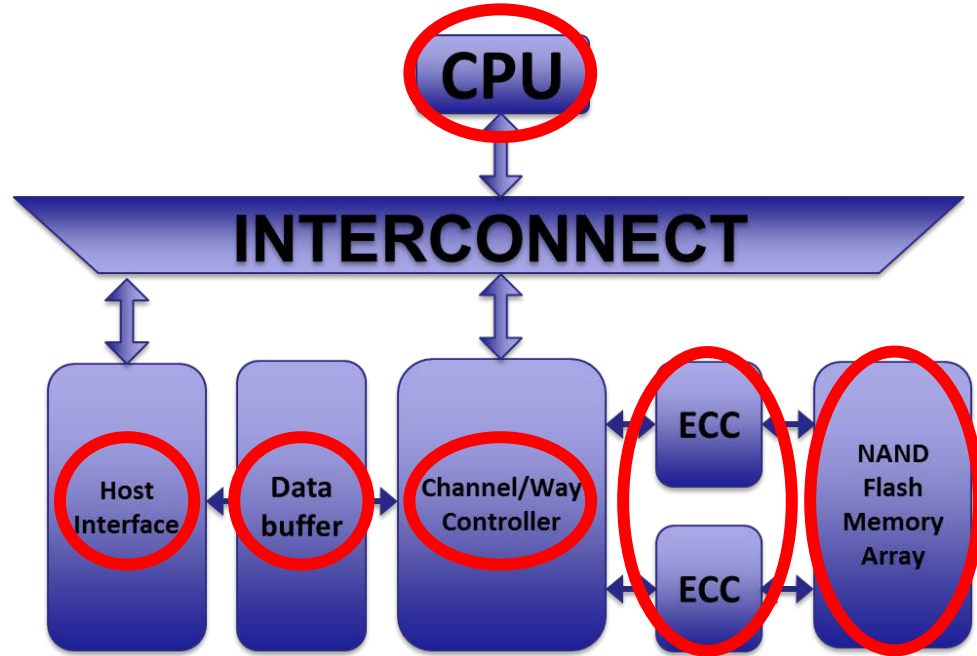} **All together**

As a consequence the complexity of solid state disks is steadily growing up thus exposing a lot of challenges during the design phase…

SSD Design Challenges

- **How to HANDLE the incoming commands and data?**
- **How to CACHE data?**
- **How to PROCESS commands?**
- **How to DISPATCH commands?**
- **How to ENCODE/DECODE data**
- **How to STORE data?**

…An SSD is a complex device and exhibits a lot of degrees of freedom and non-trivial design tradeoffs…
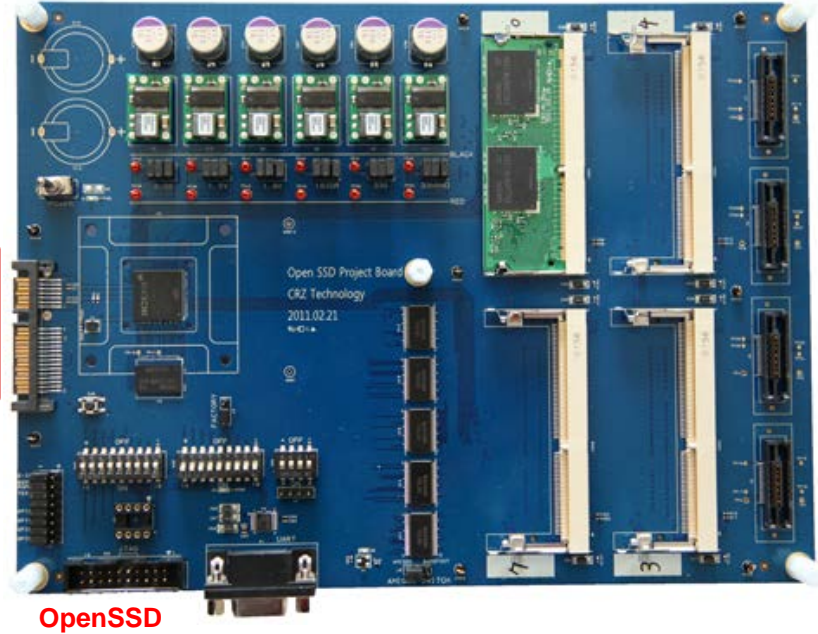
SSD Hardware prototyping

- **Idea…**
  - **During the design phase <u>make use of *SSD hardware prototyping* platforms</u>**
  - **BlueSSD**
  - **OpenSSD**

  They have been developed with a *hardware-oriented* mindset.
  TARGET: high accuracy

PROS:
- **High accuracy**
- **Real device characterization**

CONS:
- **Lack of intrinsic flexibility**
- **Cost**

OpenSSD

…What if the SSD architecture changes??...

THE WHOLE PLATFORM HAS TO BE REIMPLEMENTED
Time to market ↑↑ → $ $ $ ↑↑↑

3

SSD Software prototyping

- **BETTER Idea…**
  - **During the design phase make use of SSD *simulation/emulation platforms***
  - **VSSIM**
  - **DiskSim**

> **They have been developed with a *software-oriented* mindset.**
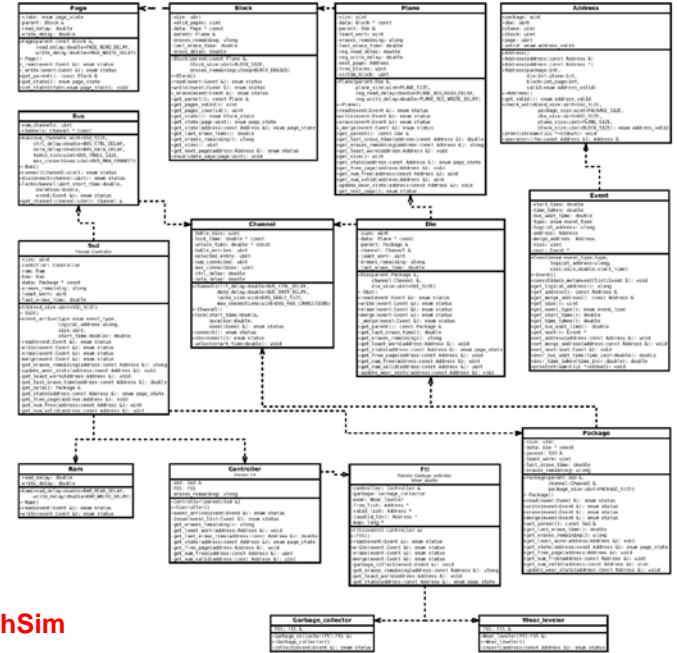> **Target: fast steady state evaluation of SSD's performance in a host environment**

PROS:
- **High simulation speed**
- **Firmware testing**

CONS:
- **Abstract simulation models**
- **Rough Accuracy**

FlashSim

Abstract simulation models???
- **The SSD is seen as a software module of the system as a whole**
- **The Firmware is spread among all the simulator code**

SSD Software prototyping

Moreover: The lack of intrinsic accuracy induces a <u>performance misalignment</u> with respect to real devices…

…Let's take an example…

They can accurately model only simple kinds of operations… but overall they may incur in large performance deviations…

Our approach…
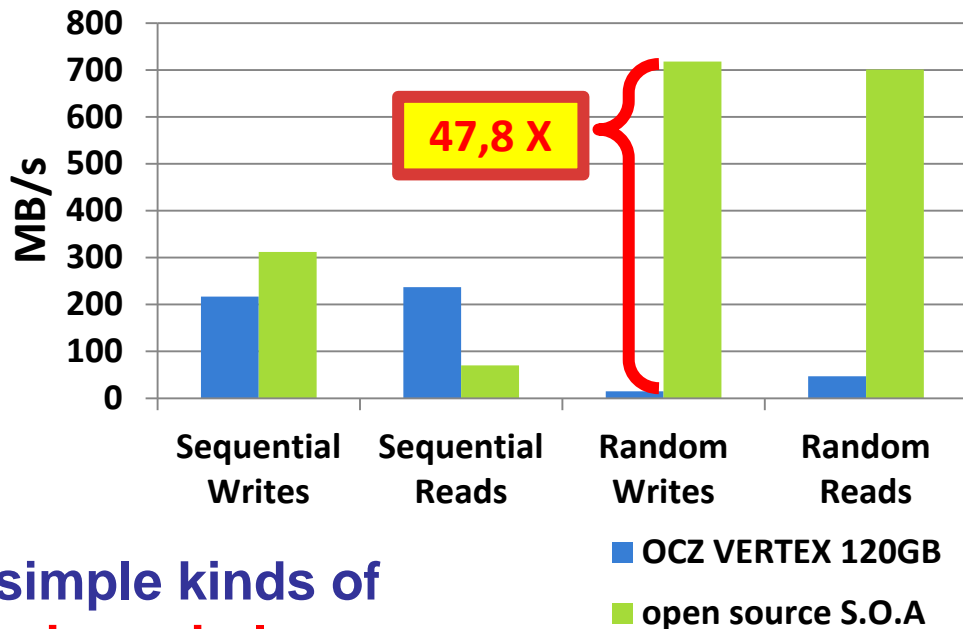
SSDExplorer: A Virtual Platform for SSD Simulation

Main objectives are:

- Modeling of all components of an SSD platform
- Offer a RAD tool (Rapid Application Development) for the SSD design space exploration
- Accounting for the performance implications of the Flash Translation Layer (FTL) without requiring its full implementation…
- … without preventing its actual implementation
- Offer a wear-out aware SSD framework able to explore the disk performance…

SSDExplorer at a glance

Component	DiskSim*	VSSIM**	SSDExplorer
Host interface	✓		✓
Host Protocol	✓	✓	✓
DDR buffer			✓
SSD-Core controller			✓
SSD Channel controller	✓	✓	✓
Interconnect Bus			✓
ECC			✓
NAND Flash	✓	✓	✓

*The DiskSim simulation environment version 4.0," 2008. [Online]. Available:http://www.pdl.cmu.edu/PDL-FTP/DriveChar/CMU-PDL-08-101.pdf

**Jinsoo Yoo; Youjip Won; Joongwoo Hwang; Sooyong Kang; Jongmoo Choi; Sungroh Yoon; Jaehyuk Cha, "VSSIM: Virtual machine based SSD simulator," *Mass Storage Systems and Technologies (MSST), 2013 IEEE 29th Symposium on* , vol., no., pp.1,14, 6-10 May 2013

SSDExplorer: simulation paradigm

SSDExplorer is able to simulate a wide variety of SSD architecture in a very fast way thanks to a offline/online simulation approach.
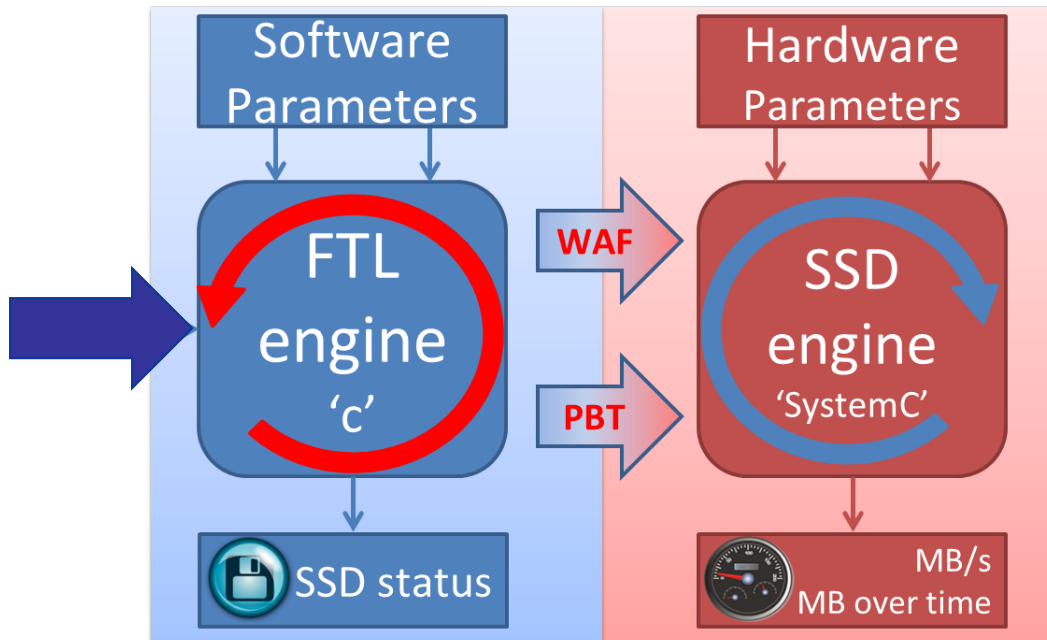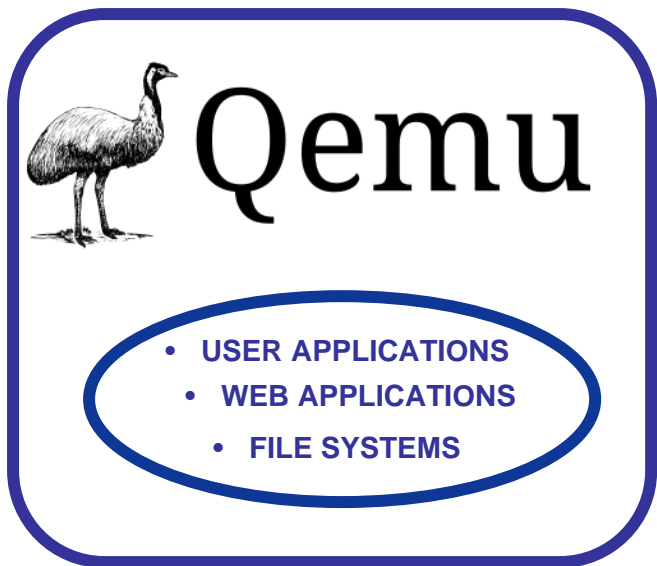
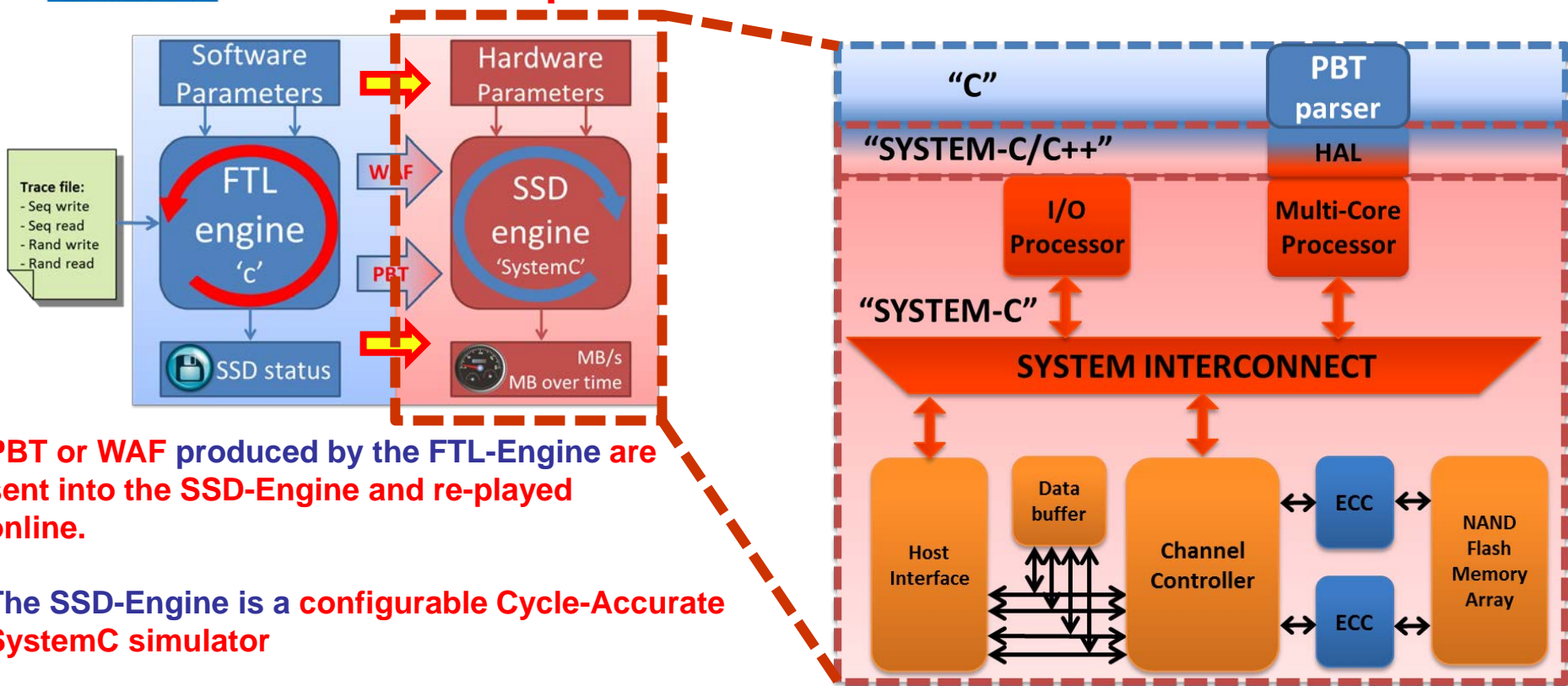**The FTL is executed offline** by the **FTL-Engine.**

FTL-Engine features:
- **Completely written in 'C'**
- **API-Based (anyone can write its own FTL)**
- **Very high simulation speed (100s of transactions per second)**

Trace file:
- Seq write
- Seq read
- Rand write
- Rand read

Software Parameters

Hardware Parameters

FTL engine 'c'

SSD engine 'SystemC'

WAF

PBT

SSD status

MB/s MB over time
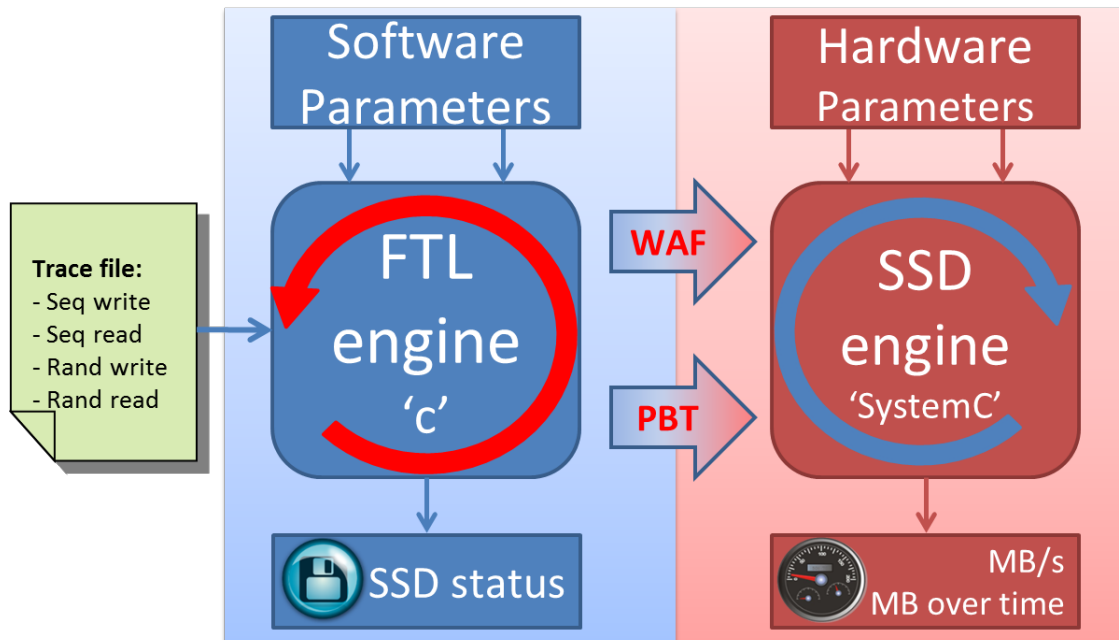
SSDExplorer & QEMU

SSDExplorer: simulator architecture

PBT or WAF produced by the FTL-Engine are sent into the SSD-Engine and re-played online.

The SSD-Engine is a configurable Cycle-Accurate SystemC simulator

SSDExplorer: SSD engine
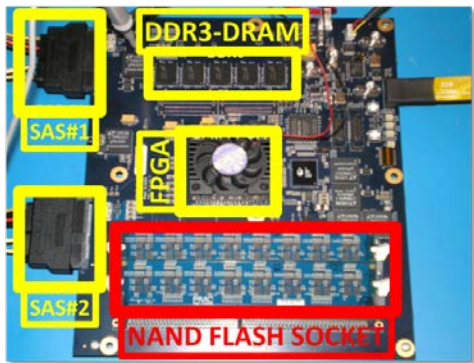
SSD engine inputs:
- Channels/Targets
- Host interface protocol
- Command submission queues
- SSD controller scheduler
- **ECC**
- **Bit Error Rate curves**
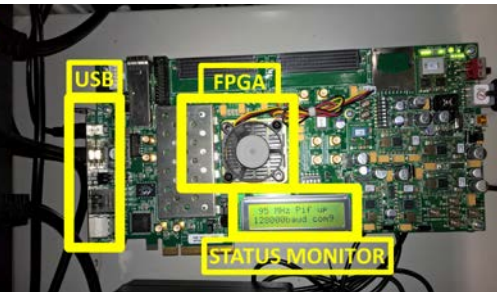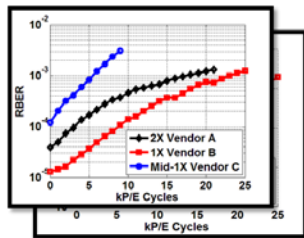- DDR buffer protocol
- NAND flash memories timings
- …
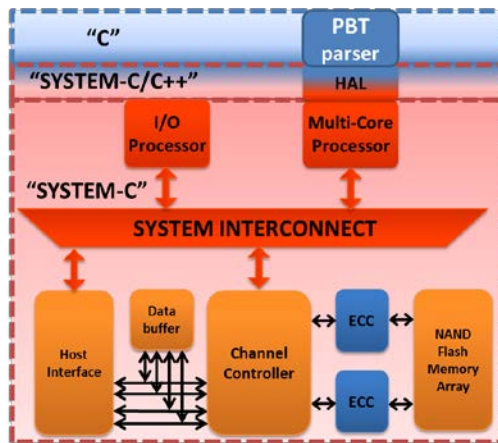
SSD engine output:
- IOPS
- Latency distributions
- N° of active targets
- NAND flash I/O bus usage
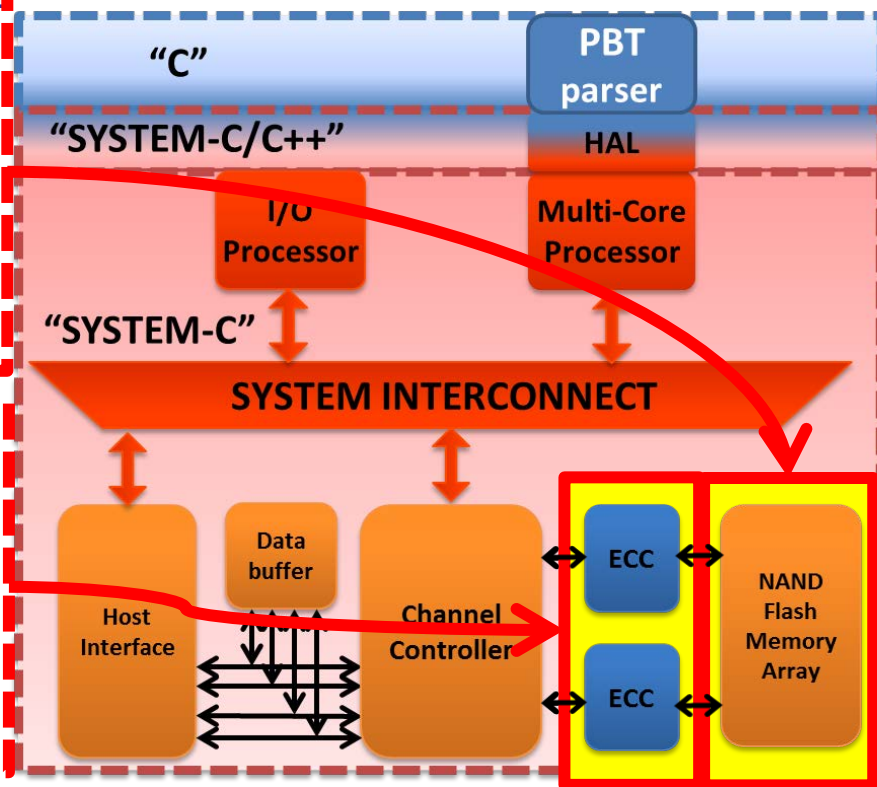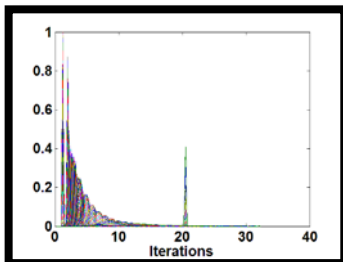- Internal queues exploitation
- …

SSD Engine: CO-simulation

NAND flash characterization board:
- **NAND flash timing**
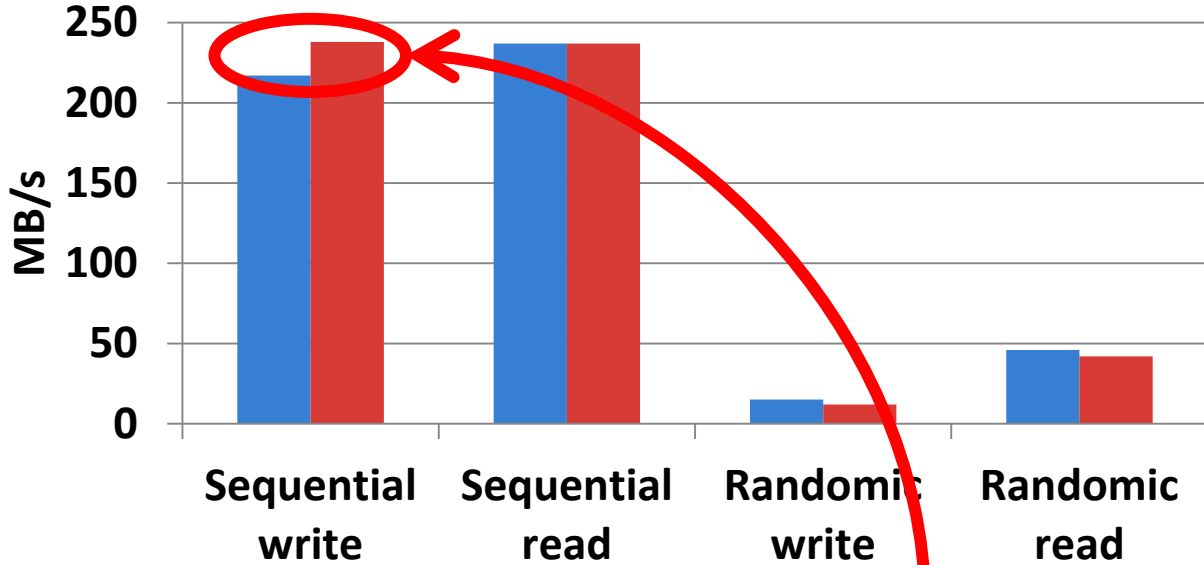- **BER**
- **Percent of uncorrectable pages**

LDPC characterization board:
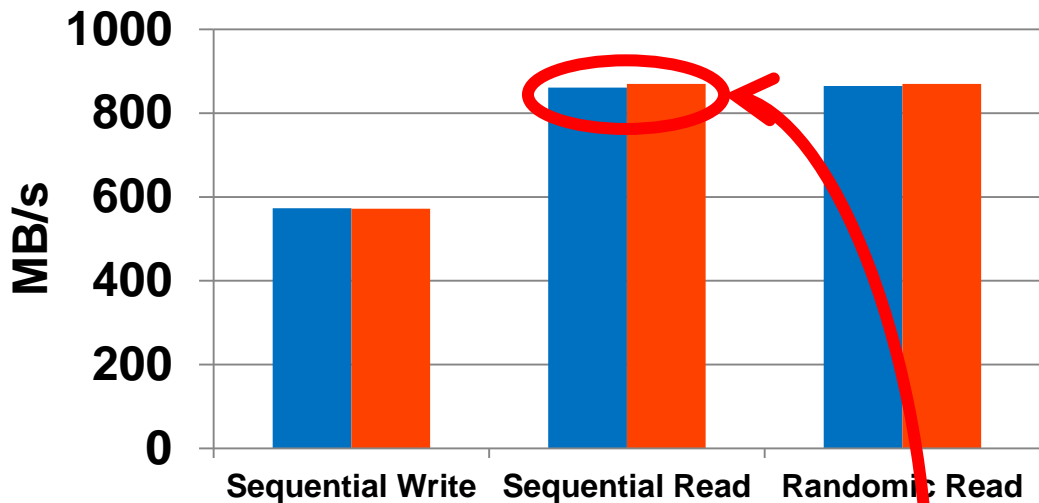- **Iteration distribution**
- **Enc/Dec timings**

SSDExplorer validation (1)

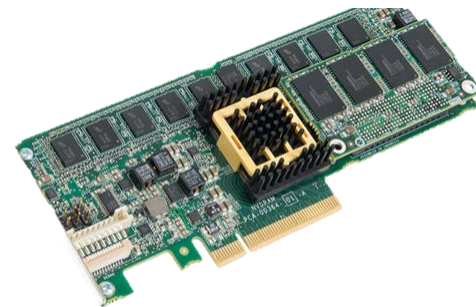**SSDExplorer is able to ACCURATELY track the performance of a real disk with a MAXIMUM offset of about 8% (Sequential Write)**

SSDExplorer validation (2)

MB/s

Chart legend:
- **PMC-SIERRA FLASHTEC NVRAM 512GB** (blue)
- **SSDExplorer 512GB** (orange)

Chart categories: Sequential Write, Sequential Read, Randomic Read

Y-axis: 0, 200, 400, 600, 800, 1000

SSDExplorer is able to ACCURATELY track the performance of a real disk with a MAXIMUM offset of about 1% (Sequential Read)

Meet us at PMC-Sierra booth for a SSDExplorer live demo

From Simulators "as a Tool"…

The last question is… How can I use SSDExplorer?

- **Previously mentioned SSD simulation tools:**
  - **Spreads across thousand of files**
  - **Hard to install**
  - **Hard to modify**
  - **Host machine-dependent**
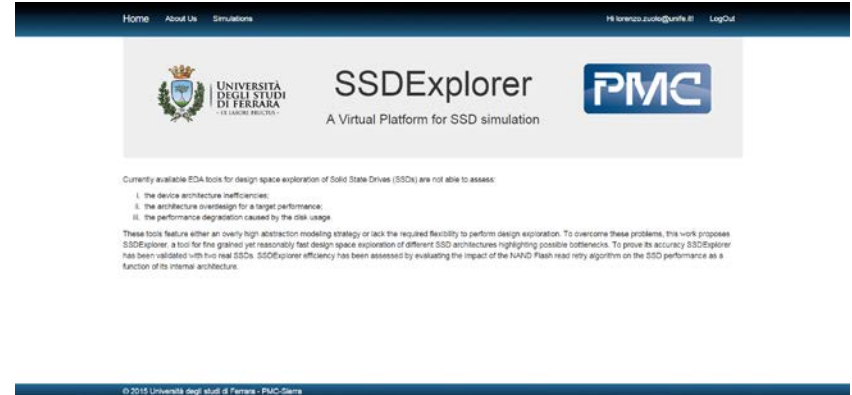 - **Not scalable**
  - **Burden on the host machine**

- **Moreover, the user interface is usually provided through a command prompt**

To Simulators "as a Service"

The last question is… How can I use SSDExplorer?

- **SSDExplorer is a flexible, easy to use, CLOUD WEB SERVICE**
- **Users can access to the tool directly from a web browser (PC/smartphone)**
- **Simulations can be scheduled in just few clicks**

  - **No installation problems**
  - **No burdens on the host machine**
  - **Scalable**
  - **Flexible**
  - **Secure**
  - **Persistent**
  - **Easy to use**
  - **MOBILE**

https://ssdexplorer.azurewebsites.net

Conclusions

- **The SSDExplorer simulation framework is a tool able to connect and explore in the same environment all the design steps of a SSD including:**
  - Error recovery flow evaluation
  - FTL/WAF policy assessment
  - Host behavior and real workload simulation
  - Multi channel/target architecture exploration

Thank you!

Meet us at PMC-Sierra booth for a SSDExplorer live demo