



"This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 644080."



SAFURE

SAFety and secURity by



METRICS: a Measurement Environment for Time Critical Systems

*Sylvain Girbal, Thales Research & Technology
HiPEAC 18, Manchester, 22nd-24th January 2018*

dEsign for interconnected mixed-critical cyber-physical systems

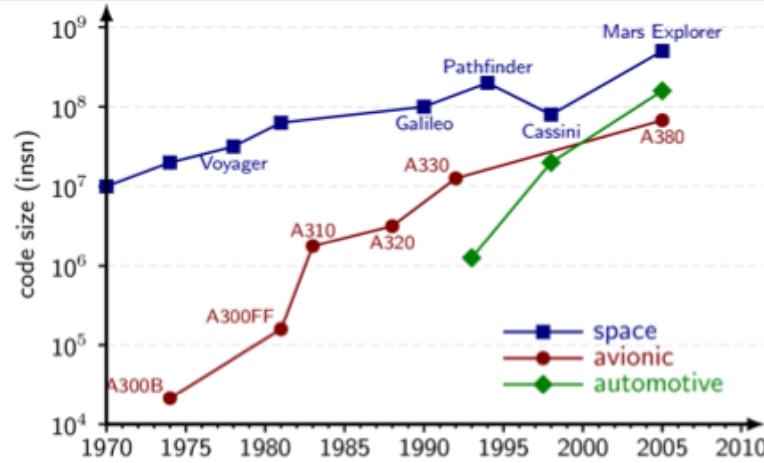
Safety-Critical & Time-Critical Context

Performance Requirements

- Exponential increase of performance requirements
- Unsustainable with classical single-core embedded solutions
- Multi-core architectures → promising candidate with regards to Size, Weight and Power (SWaP)
- Multi-core are oriented toward the consumer electronic market

Compliance with regulation standards → Certification

- Spatial partitioning:** No application or task should be able to access / **alter** the **data** of another application or task.
- Time partitioning:** No application or task should be able to **delay** another application or task.



How to ensure a sufficient level of **time determinism** with multi-core COTS architectures?

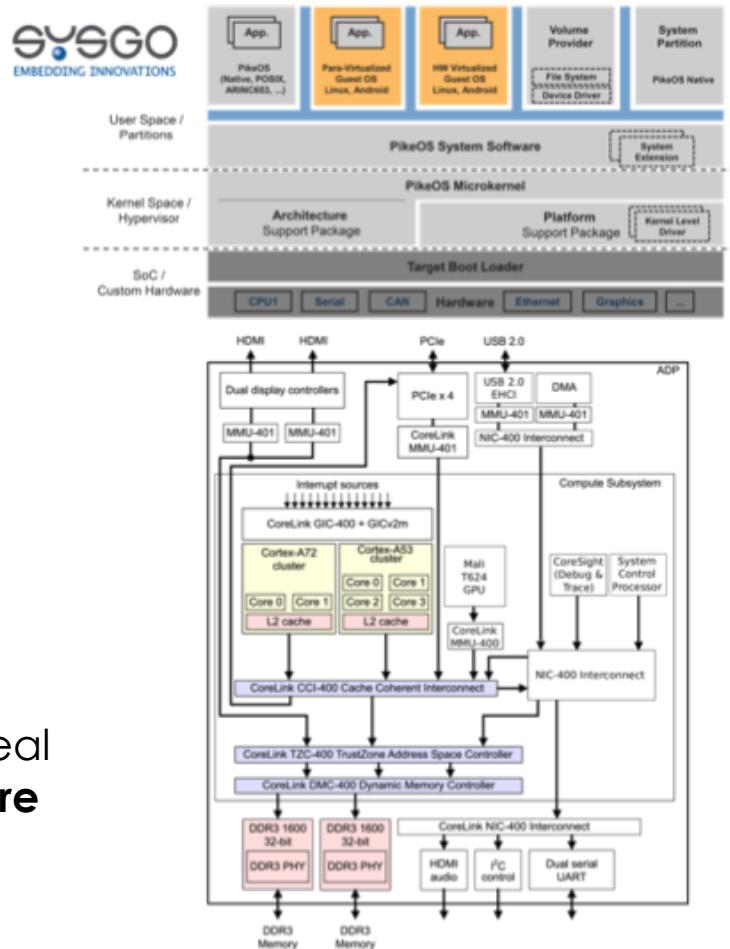
Target Architecture & Environment

PikeOS RTOS from SYSGO AG

- Real-Time Operating System
- Separation Micro-Kernel
- Partitioned Environment
- Virtualization

ARM Juno BOARD

- A hi-performance bi-core out-of-order ARM-v8 Cortex A72 core cluster
- A more predictive quad-core in-order ARM-v8 Cortex A53 core cluster
- Multi-core COTS not specifically designed for real time systems with a large set of **shared hardware resources**



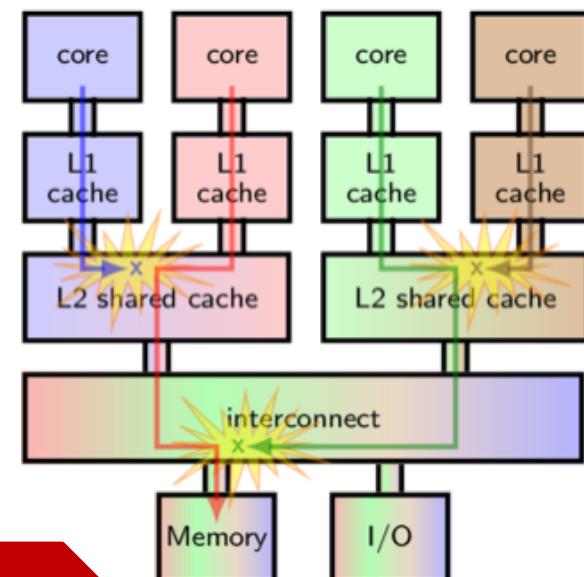
The Challenge of Timing Interferences

Using multi-core COTS in Safety Critical Systems

- Successfully faces the exponential increase of performance requirements
- But focuses on **best-effort** performance, not on **worst-case** performance

The problem: inter-core timing interferences

- Multi-core → shared hardware resources
- Concurrent accesses to these resources are involving some **arbitration mechanisms** at hardware level
- Hardware contention is introducing unpredictable **timing interference** appearing as extra time delays
- Breaking the **time isolation** principles



How to measure **timing interferences** in real systems?
Can we **correlate** with **hardware resource** accesses?

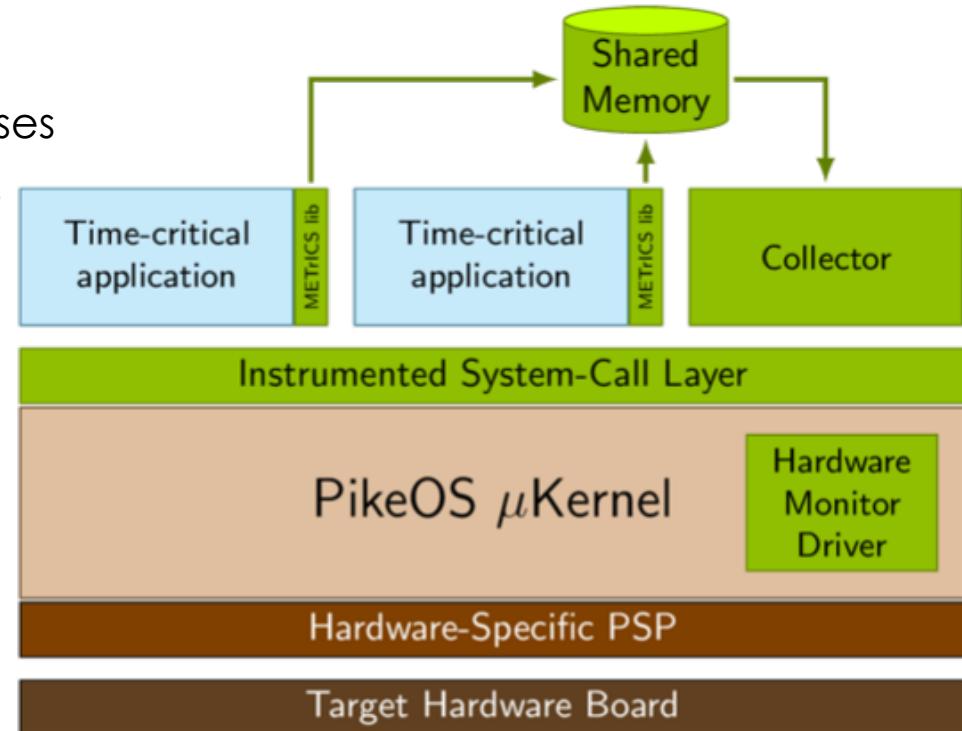
METRICS: a Measurement Environment for Time Critical Systems

Features

- Running on top of the PikeOS RTOS
- Providing accurate measurement of timing and hardware resource accesses
- Rely on hardware time base & performance monitor counters
- Minimizing timing intrusiveness
- Ability to observe timing interference

Software Architecture

- Driver
- Library
- Collector
- SHM
- Instrumented Syscalls



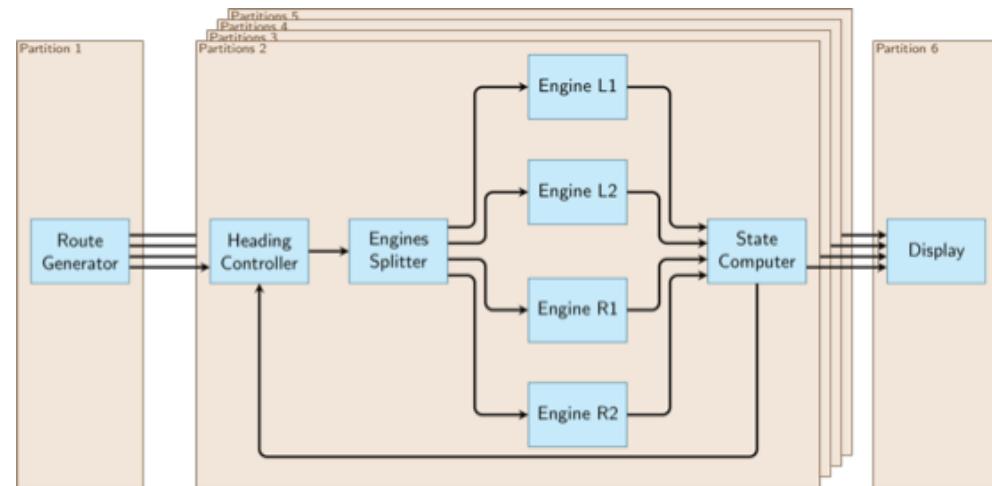
Driving Example: Drone Swarm Application

Description

- Control-command application guiding a set of 4 quadri-copters along a pre-set track

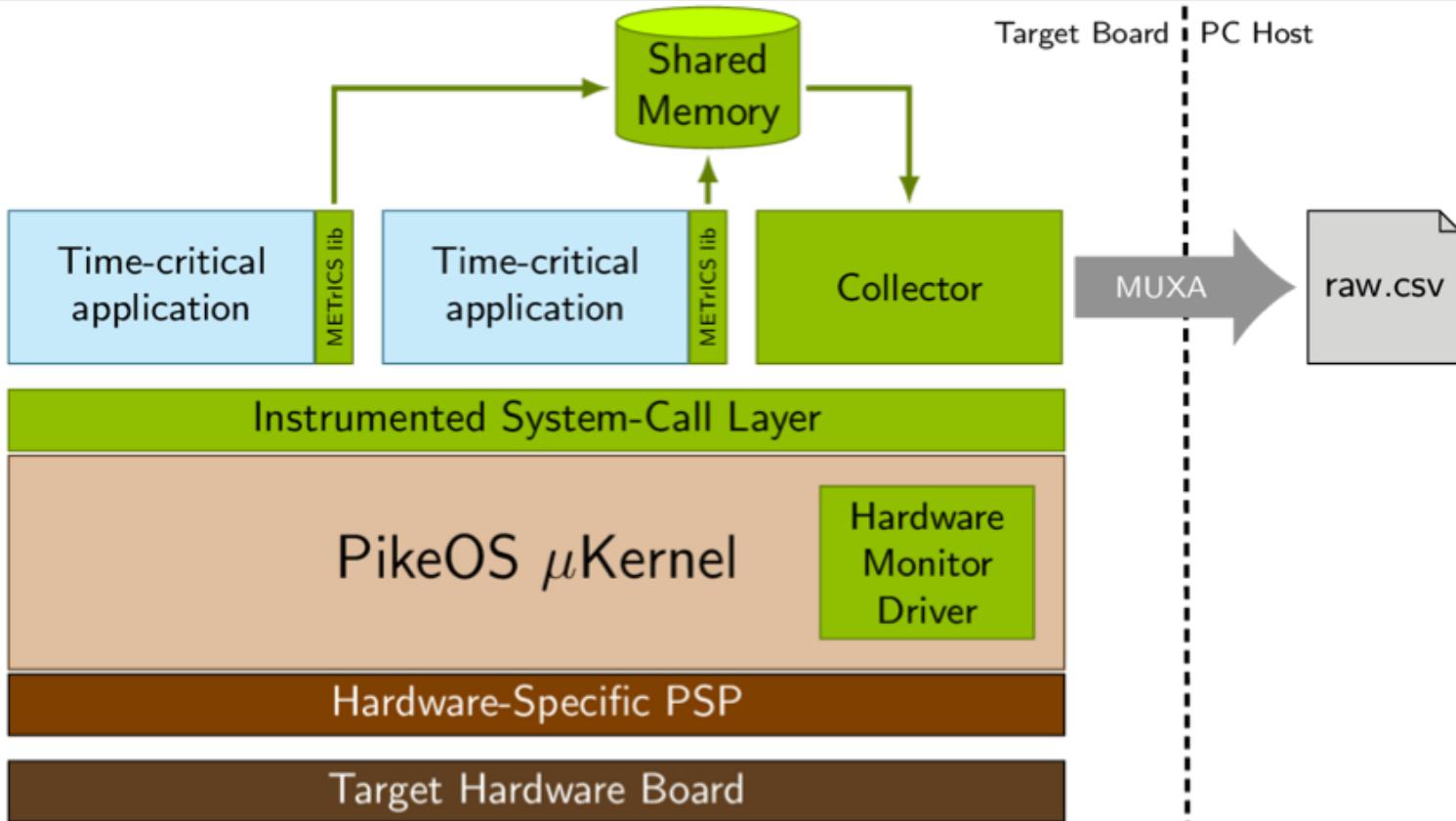
Software Architecture

- Route Generator
- Drone Control (x4)
 - Kinematic model of a drone
 - Controlling velocity and heading
 - Dynamic model controlling DC motors
- Display



How is this particular deployment sensitive to **timing interferences**?

Collecting raw performance data with METRICS



Collecting raw performance data with METRICS

```
jlerhun : minicom - Konsole
File Edit View Bookmarks Settings Help
[ 29.910] x[m]:y[m]:theta[deg] 166: 10: 17 150: 9: -27 124: 12: 47 88: 27: -57
[ 30.110] x[m]:y[m]:theta[deg] 168: 10: 17 151: 8: -27 125: 14: 47 89: 25: -57
[ 30.310] x[m]:y[m]:theta[deg] 170: 11: 17 153: 7: -27 126: 15: 47 91: 23: -57
[ 30.510] x[m]:y[m]:theta[deg] 171: 11: 17 155: 6: -27 128: 17: 47 92: 22: -57
[ 30.710] x[m]:y[m]:theta[deg] 173: 12: 0 157: 6: 7 129: 18: 47 93: 20: -57
[ 30.910] x[m]:y[m]:theta[deg] 175: 11: -11 159: 7: 30 130: 20: 47 94: 18: -57
[ 31.110] x[m]:y[m]:theta[deg] 177: 11: -13 160: 8: 35 132: 21: 47 95: 17: -57
[ 31.310] x[m]:y[m]:theta[deg] 179: 10: -13 162: 9: 33 133: 22: 47 96: 15: -57
[ 31.510] x[m]:y[m]:theta[deg] 181: 10: -12 164: 10: 32 135: 24: 47 97: 13: -57
[ 31.710] x[m]:y[m]:theta[deg] 183: 10: -12 166: 11: 32 136: 25: 47 98: 12: -57
[ 31.910] x[m]:y[m]:theta[deg] 185: 9: -12 167: 12: 32 137: 27: 47 99: 10: -57
[ 32.110] x[m]:y[m]:theta[deg] 187: 9: -12 169: 13: 32 139: 28: 47 100: 8: -57
[ 32.310] x[m]:y[m]:theta[deg] 189: 8: -12 171: 14: 32 140: 30: 47 101: 7: -57
[ 32.510] x[m]:y[m]:theta[deg] 191: 8: -12 172: 15: 32 141: 31: 47 102: 5: -57
[ 32.710] x[m]:y[m]:theta[deg] 193: 8: 5 174: 16: 32 143: 32: -1 104: 4: 3
MONITORING collector Data dump triggered!
SCHED_BOOT collector back to booting mode
SCHED_BOOT collector Will send data through muxa:metrics.
SCHED_BOOT collector Communication use handshake mechanisms
SCHED_BOOT collector CORE 0: total=21866, saved=300. Sending data...!CORE=0,total=21866,count=300
0x09f03004;0;0x8500000f;69039666030;0;0;0;1537687018;2897053611;1586778003;479058620;121503542;121558541;19650
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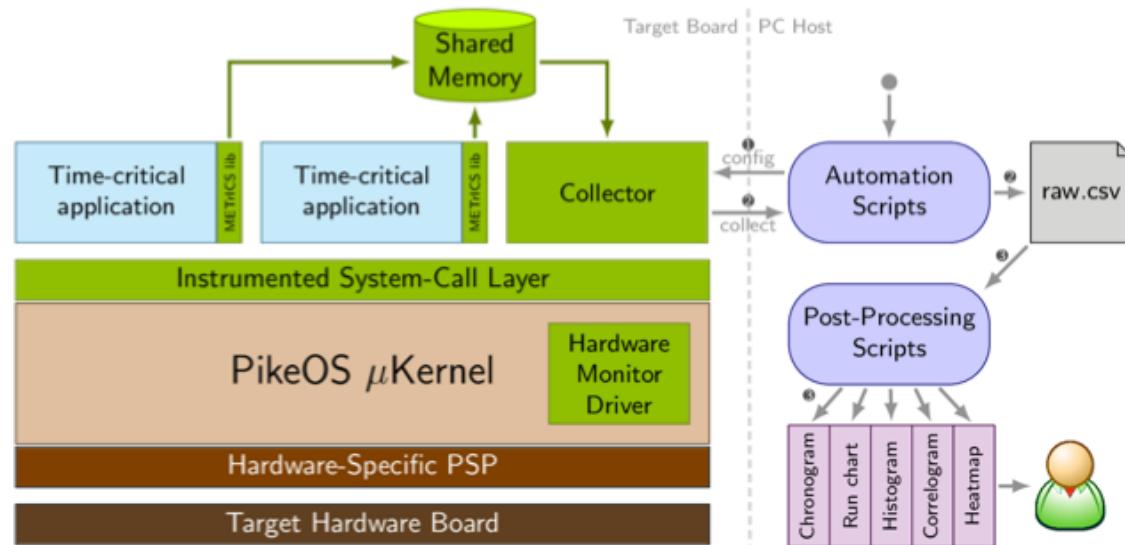
Configurations & METRICS Automation

Application deployments	4
Single-core, AMP, SMP, Hybrid	
Buffer size	3
Fitting in L1, Fitting in L2, Not Fitting	
Cache Policies	2
Flushing / Not Flushing between time partitions	
Hardware Counter Selection	
6 selected among 41 pre-selected	C_41^6
Number of runs	1000
For statistical significance	
TOTAL RUNS	108 Billion

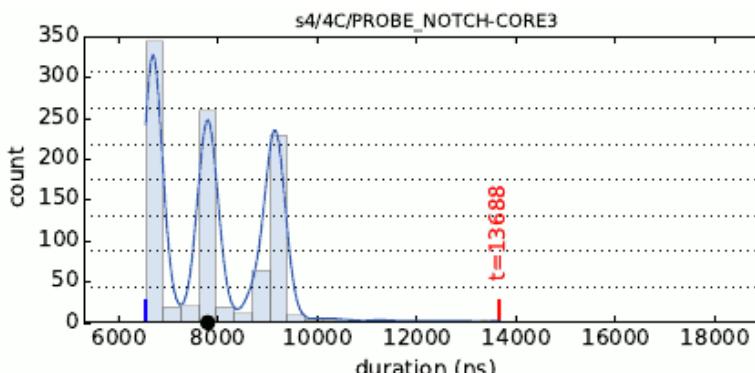
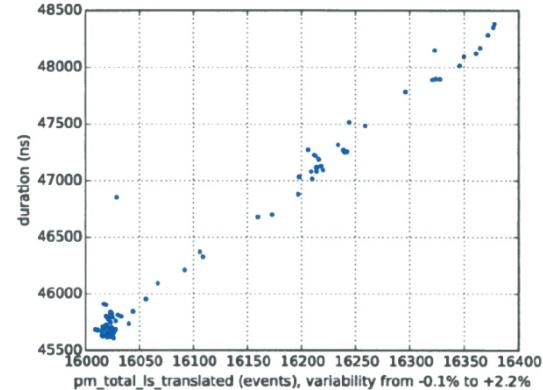
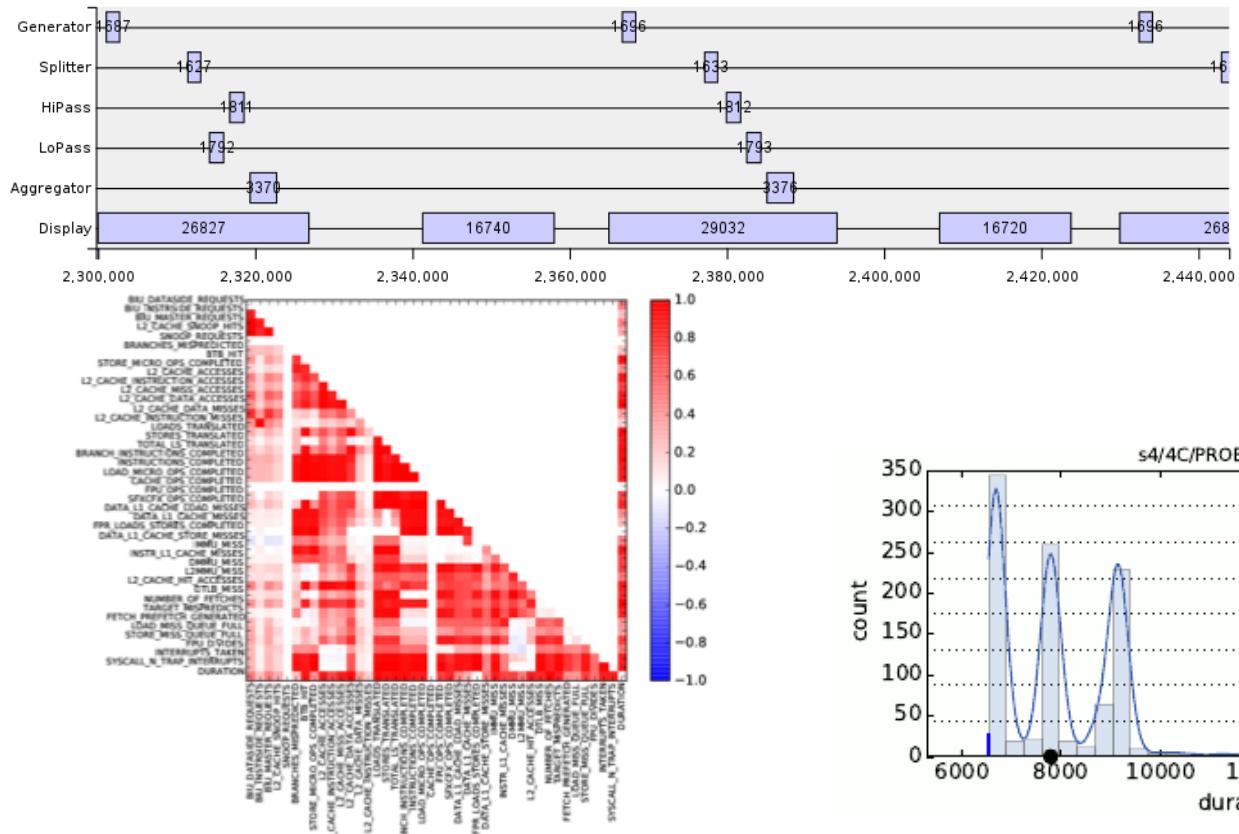
- Need to **reduce the Design Space**
- **Automation** necessary

Studying correlation between counters

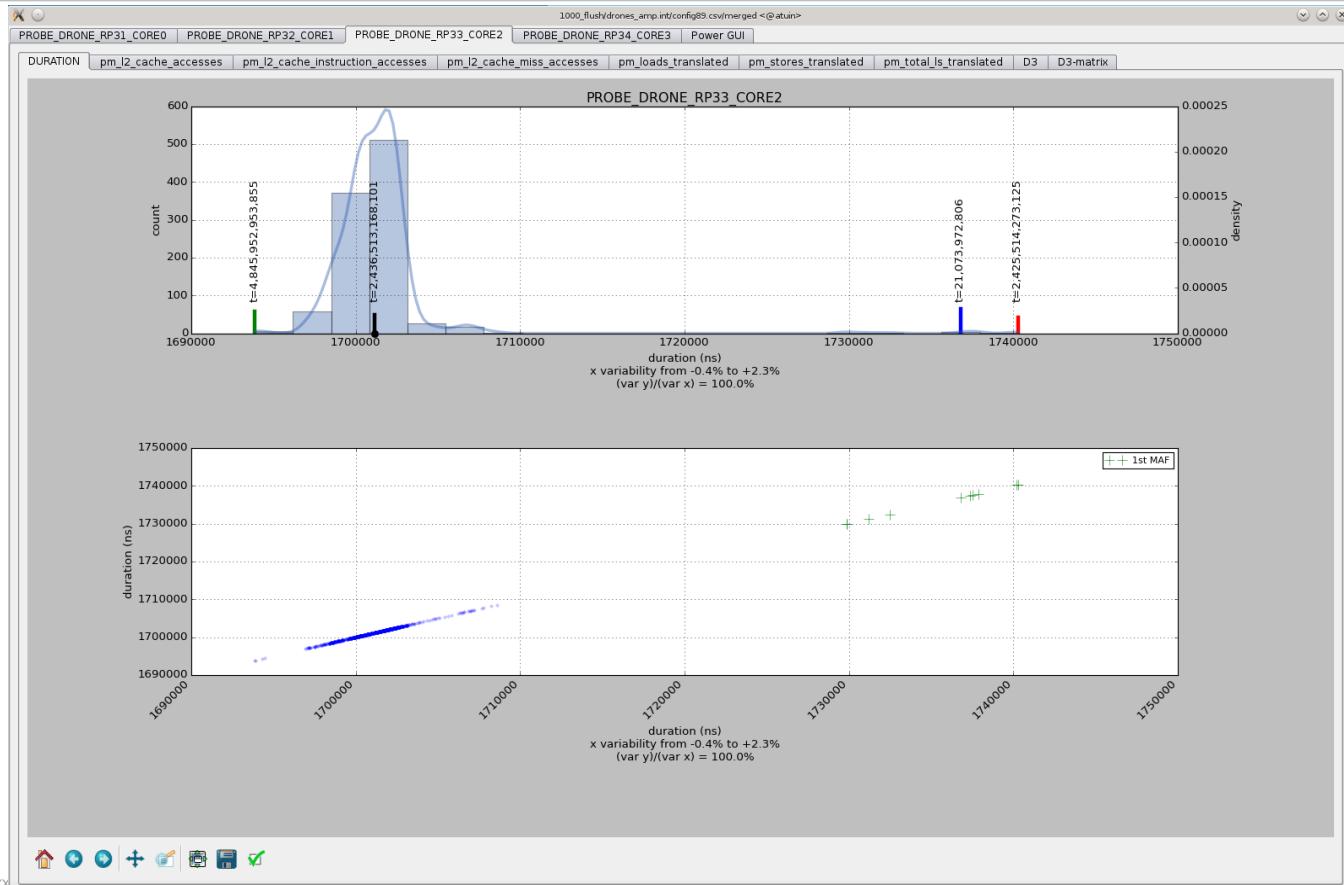
- More than 100GB of raw data
- Around 14 days of runtime



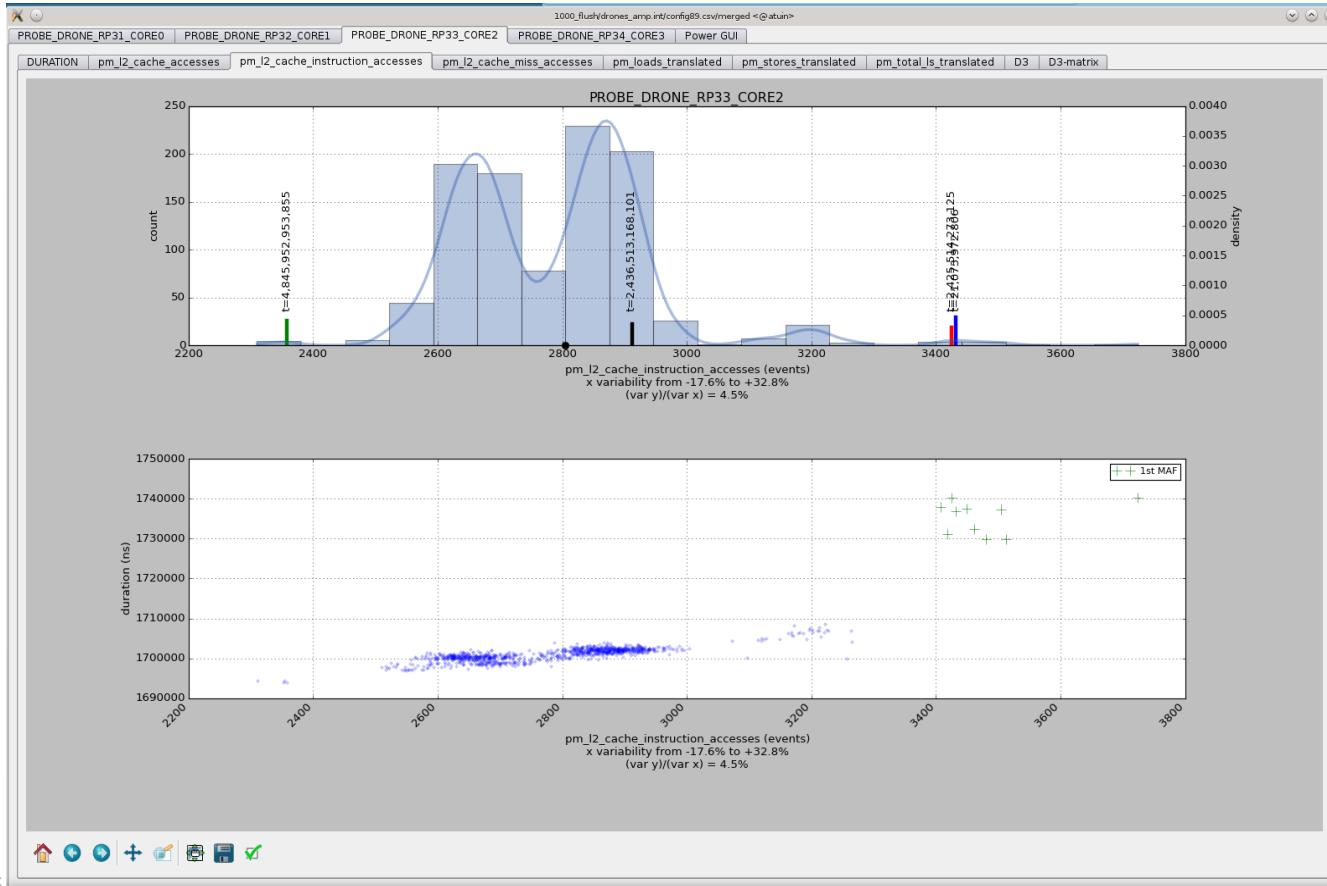
Rendering performance data collected with METRICS



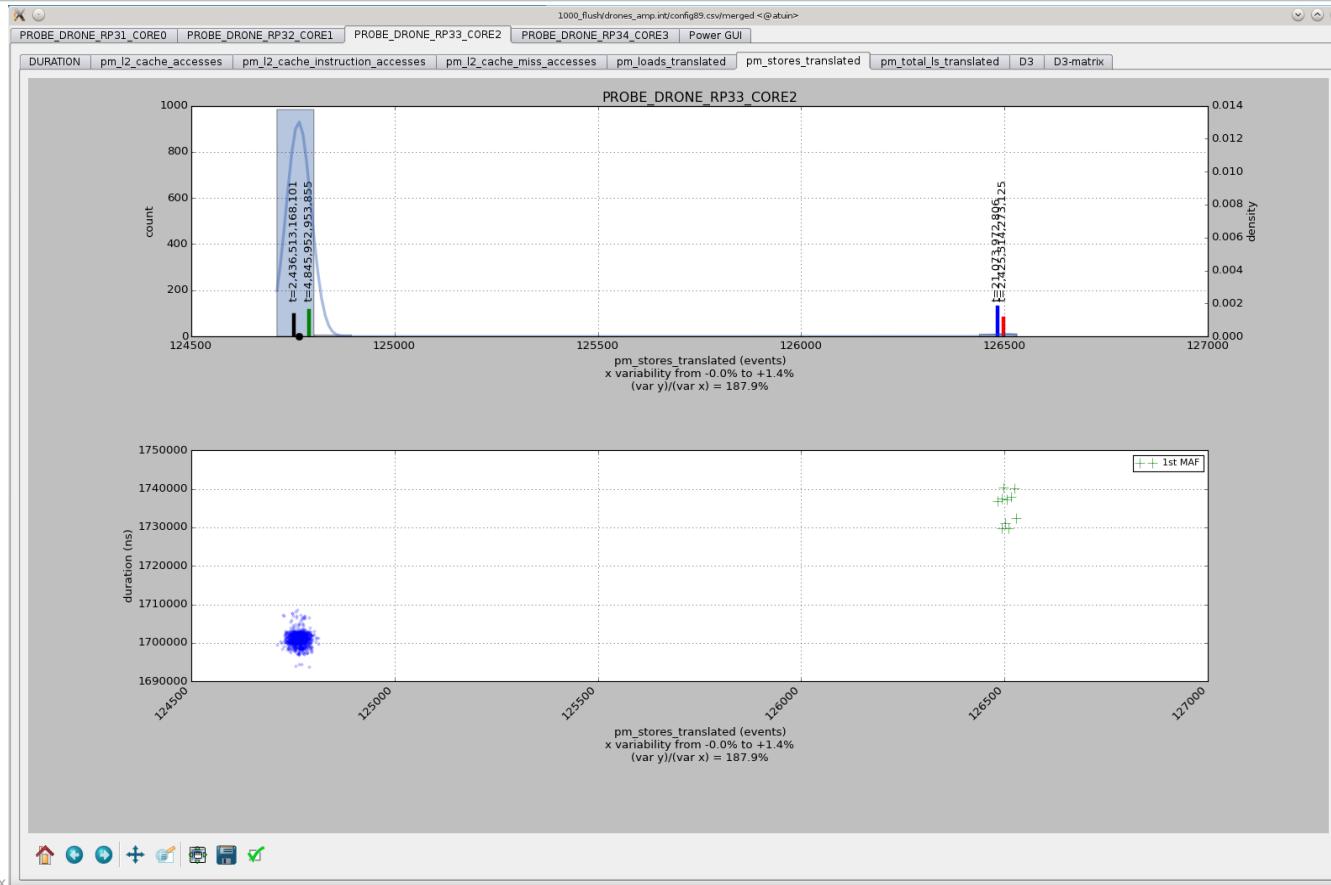
Timing Histograms



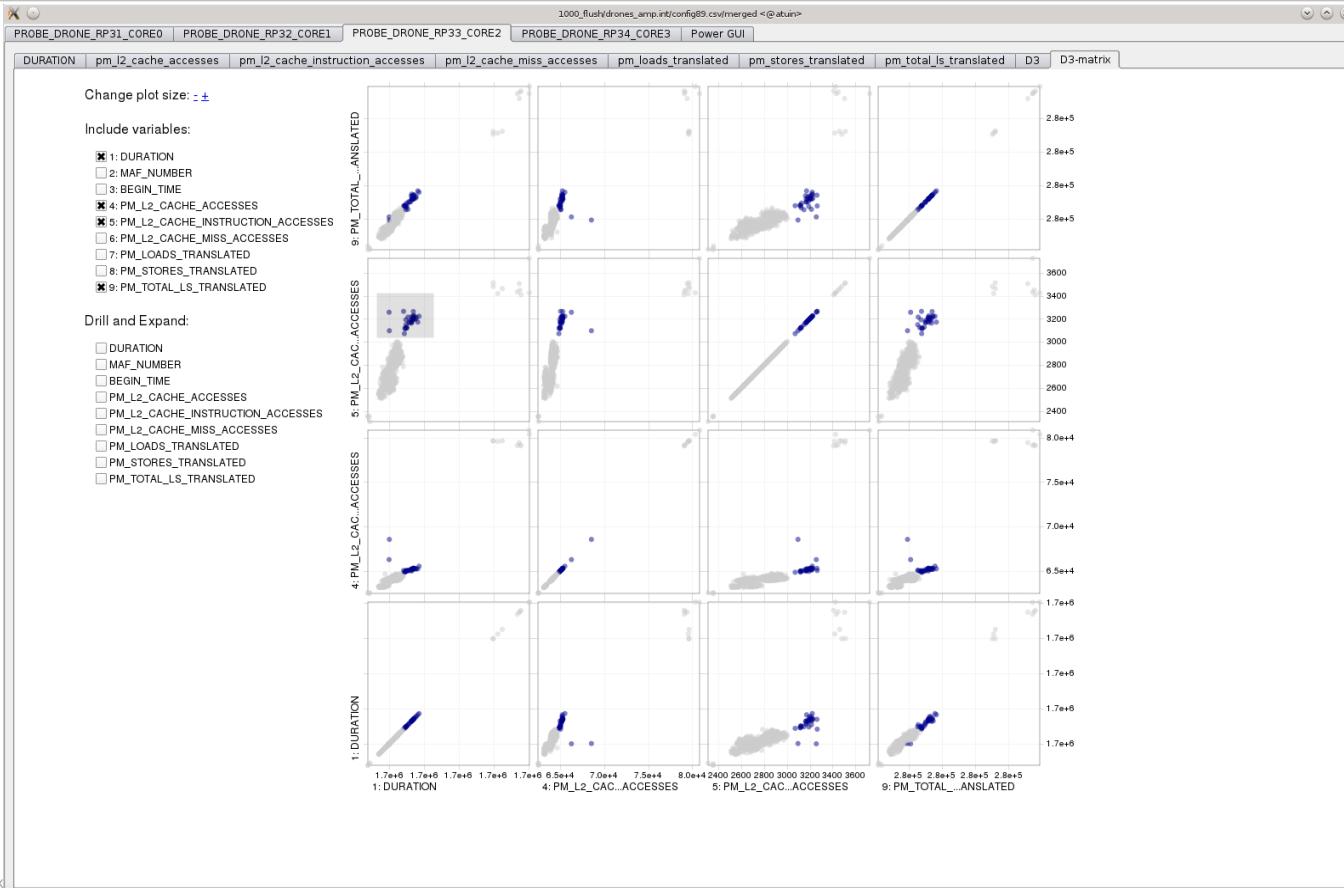
Resource access histograms & Timing VS access correlograms



Resource access histograms & Timing VS access correlograms



Access VS access correlograms



Réf. : xxxx-xxxxxx

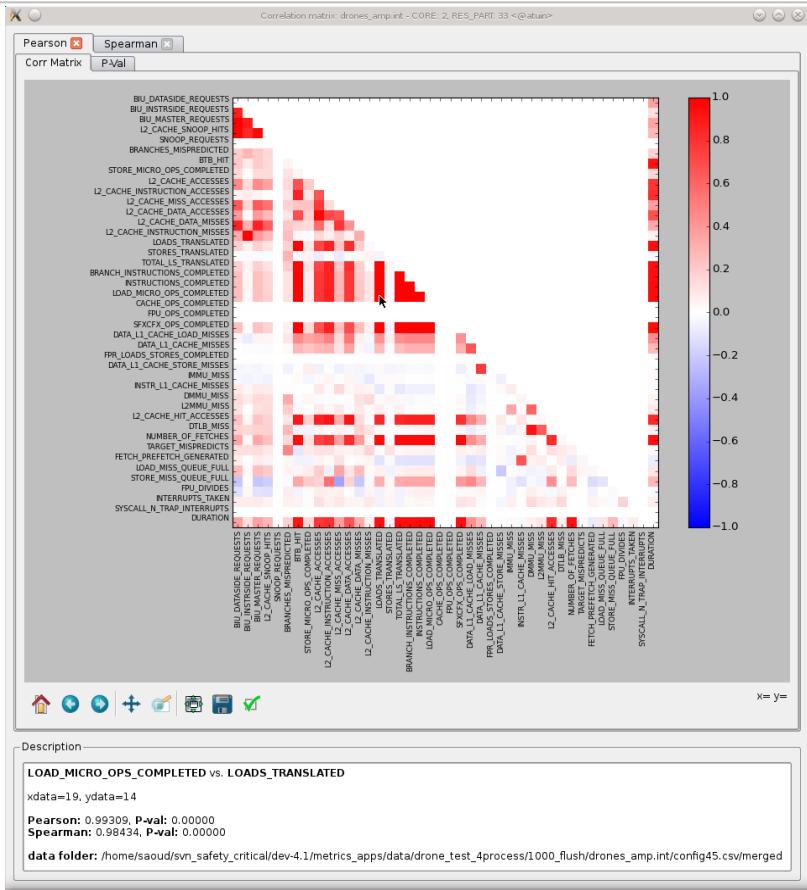
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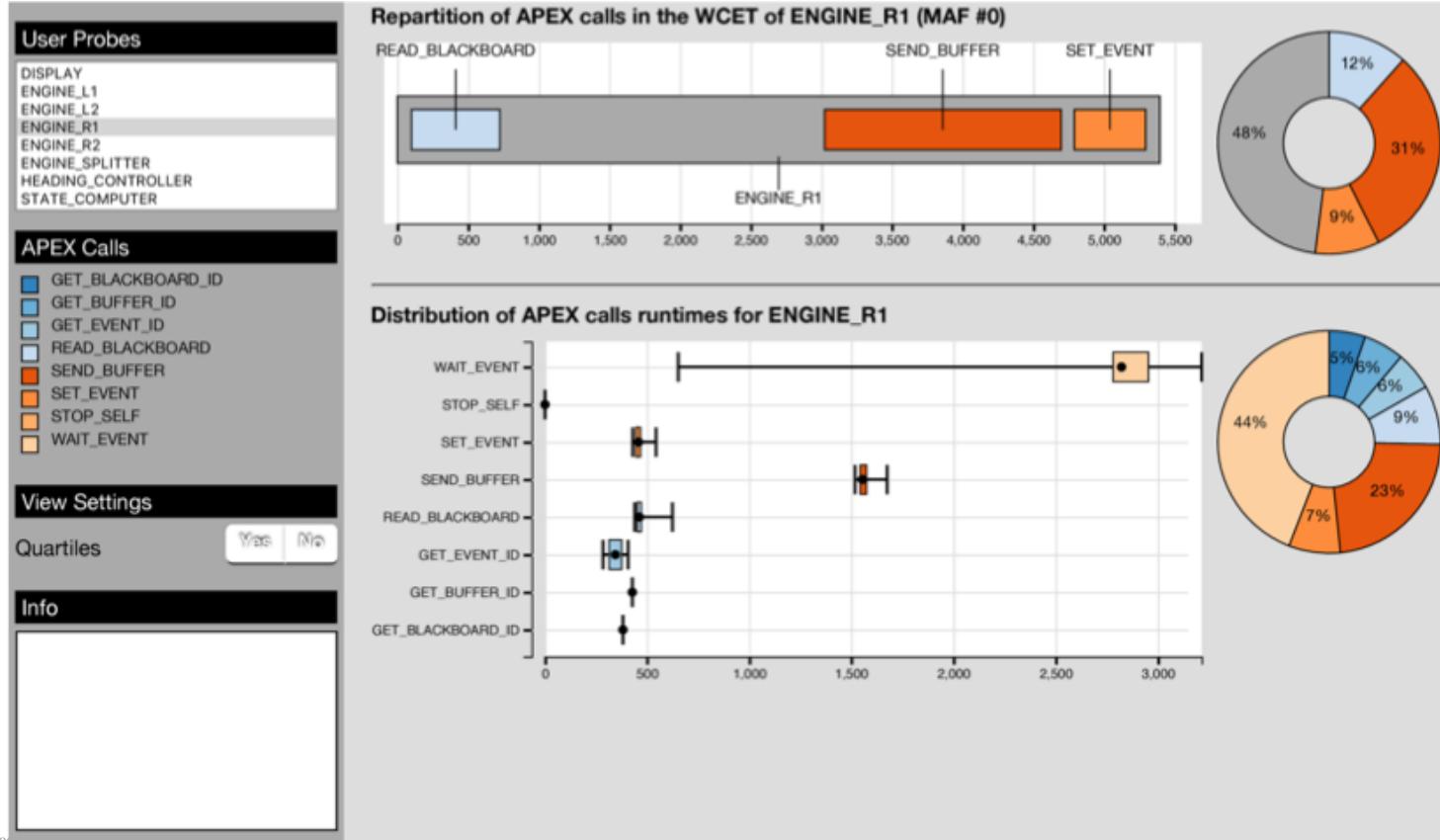
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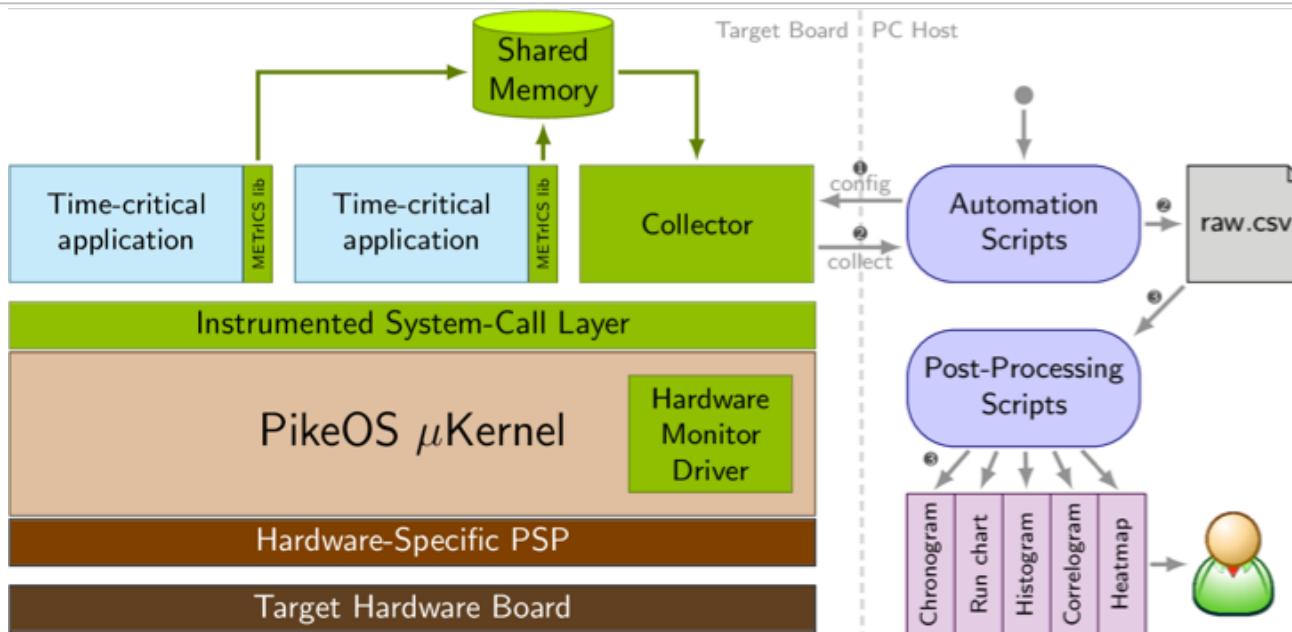
Access VS access correlograms



Rendering system call: repartition and distribution



METRICS: a Measurement Environment for Time Critical Systems



Measurement Environment

- Controlled accuracy and intrusiveness
- Can be turned into a RTE at the cost of more intrusiveness

Features

- Multiple hardware target
- Characterizing interference channels
- Visualization to guide expert's analysis

SAFURE Grant Agreement No. 644080

"This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 644080."

"This work was supported by the Swiss State Secretariat for Education, Research and Innovation (SERI) under contract number 15.0025. The opinions expressed and arguments employed herein do not necessarily reflect the official views of the Swiss Government."

If you need further information, please contact the coordinator:

TECHNIKON Forschungs- und Planungsgesellschaft mbH

Burgplatz 3a, 9500 Villach, AUSTRIA

Tel: +43 4242 233 55 Fax: +43 4242 233 55 77

E-Mail: coordination@safure.eu

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