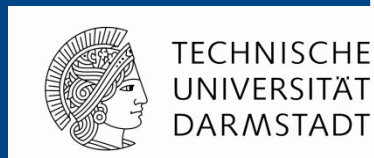
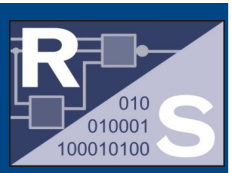
Combining Runtime Verification and Execution Time Estimation





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Agenda

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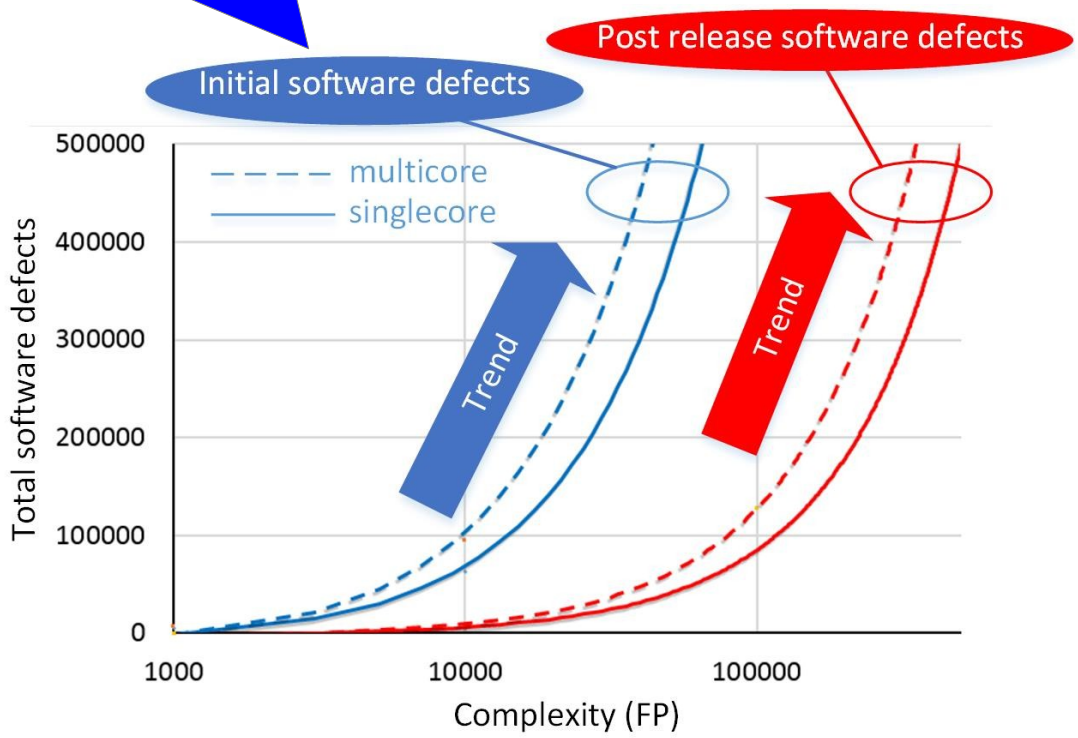
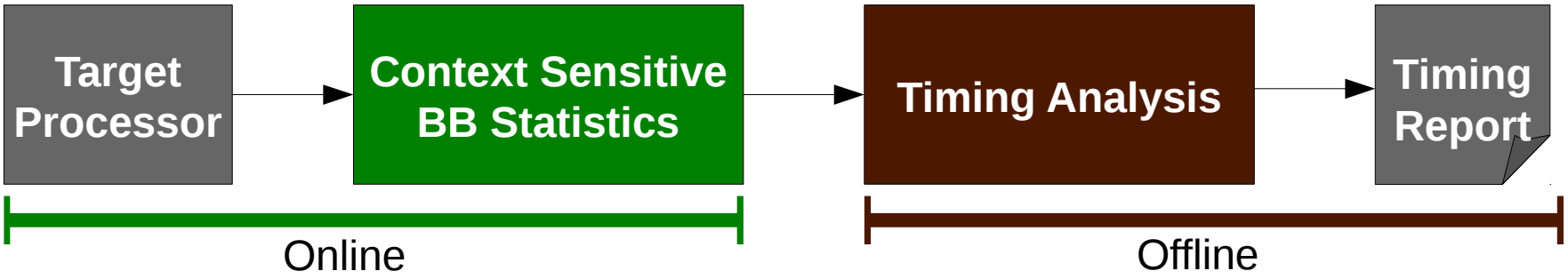
- **Motivation**
- **Measurement-based execution time analysis**
  - Context sensitive BB statistics
  - Architecture
- **Continuous timing validation**
  - Constraints monitors
  - Architecture
- **Conclusion**

Motivation – Timing Analysis

Solution: Measurement-based Execution Time Analysis



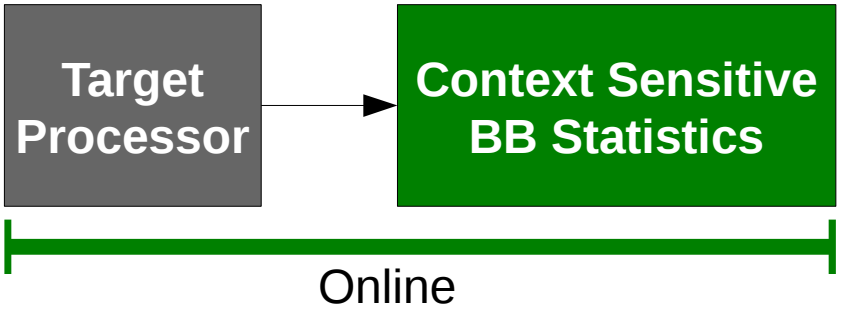
Measurement-based Execution Time Analysis



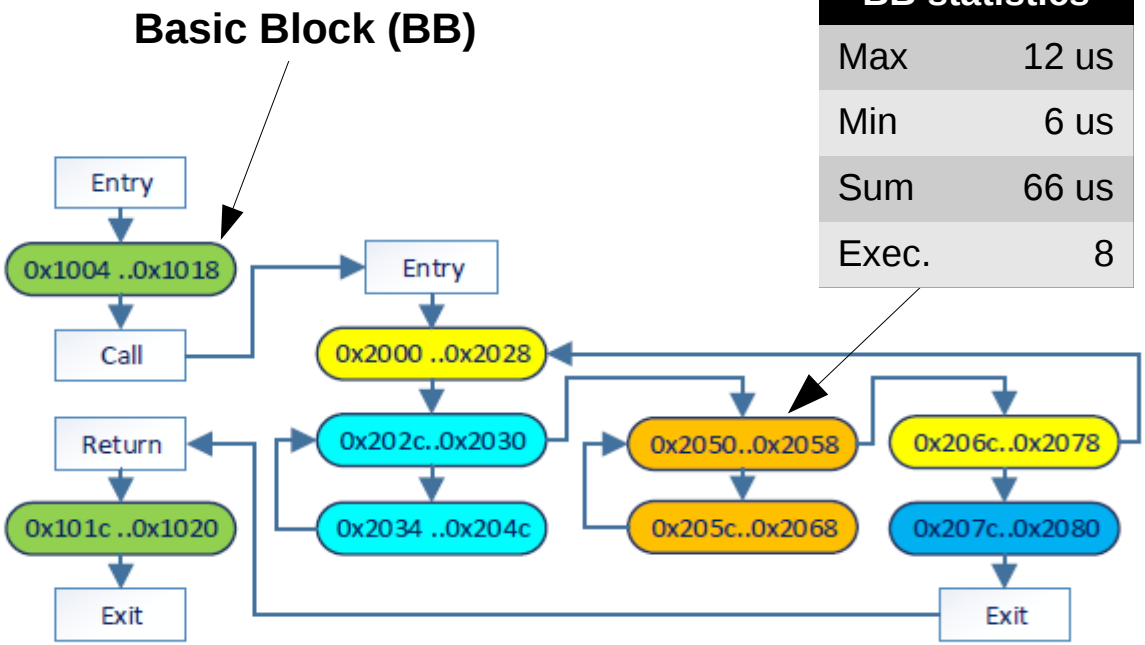
- **Online timing aggregation**
  - Storage depends on program size
  - Storage is independent of observation time
  - Arbitrary long observation time based on fine granular measurements

- **Offline timing analysis**
  - Precise timing analysis for developers
  - Timing constraints generation for *continuous timing validation*

BB Statistics

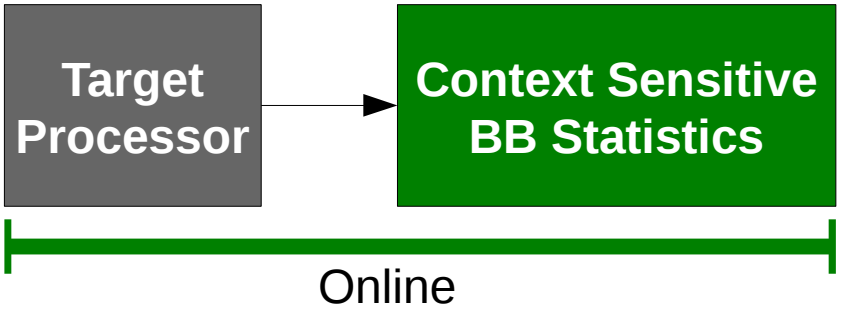



```
void f (…)
{
  g(…);
}
void g (…)
{
  do {                  // L1
    …;
    for (…;…;…)         // L2
      …;
    for (…;…;…)         // L3
      …;
  } while (…);
}
```



BB statistics	
Max	12 us
Min	6 us
Sum	66 us
Exec.	8

Context Sensitive BB Statistics

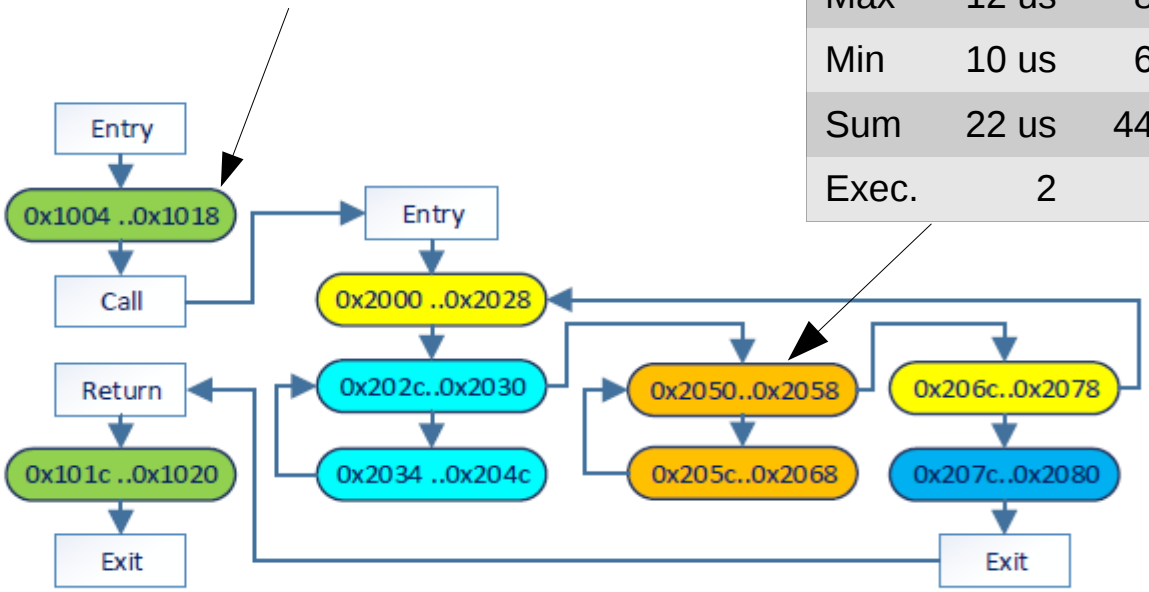


Context sensitive BB statistics

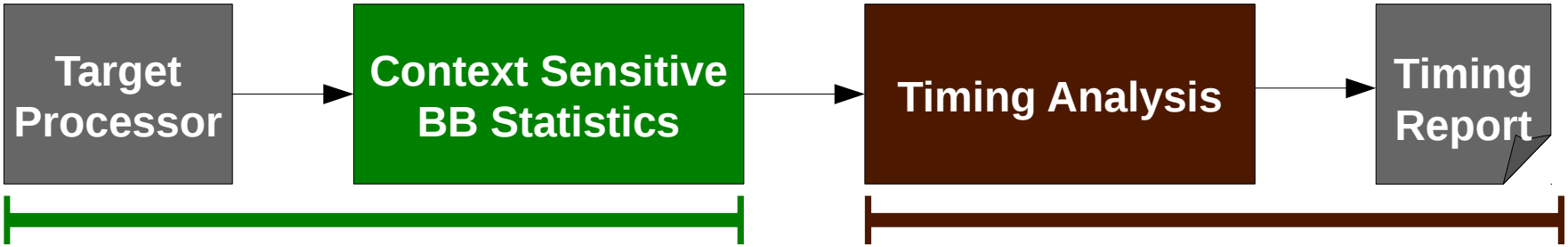
	Iterations First	Further
Max	12 us	8 us
Min	10 us	6 us
Sum	22 us	44 us
Exec.	2	6

Basic Block (BB)

```
void f (…)
{
  g(…);
}
void g (…)
{
  do {              // L1
    …;
    for (…;…;…)     // L2
      …;
    for (…;…;…)     // L3
      …;
  } while (…);
}
```

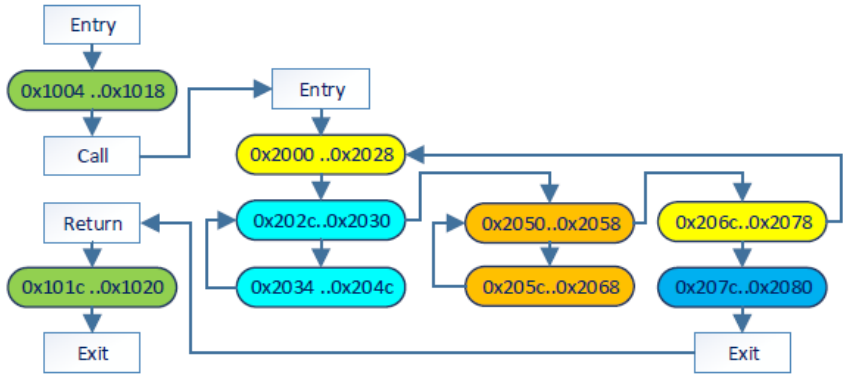


Timing Analysis



BB Address	Max First	Max Further
0x1004	8 us	0 us
0x2000	22 us	11 us
0x202c	16 us	8 us
0x2034	2 us	1 us
0x2050	12 us	8 us
0x205c	2 us	1 us
0x206c	8 us	4 us
0x207c	6 us	0 us
0x101c	6 us	0 us

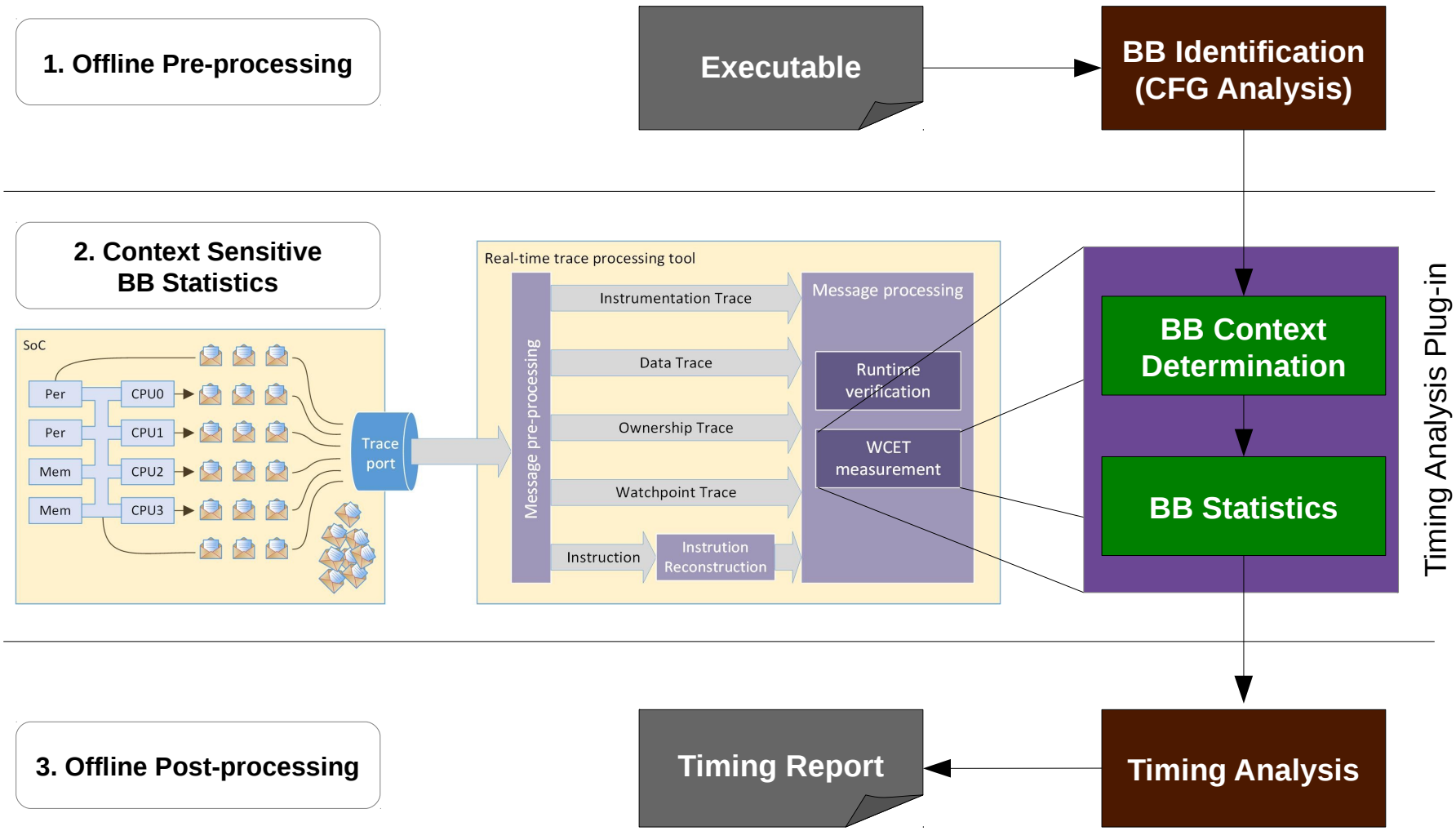
1. Annotate CFG



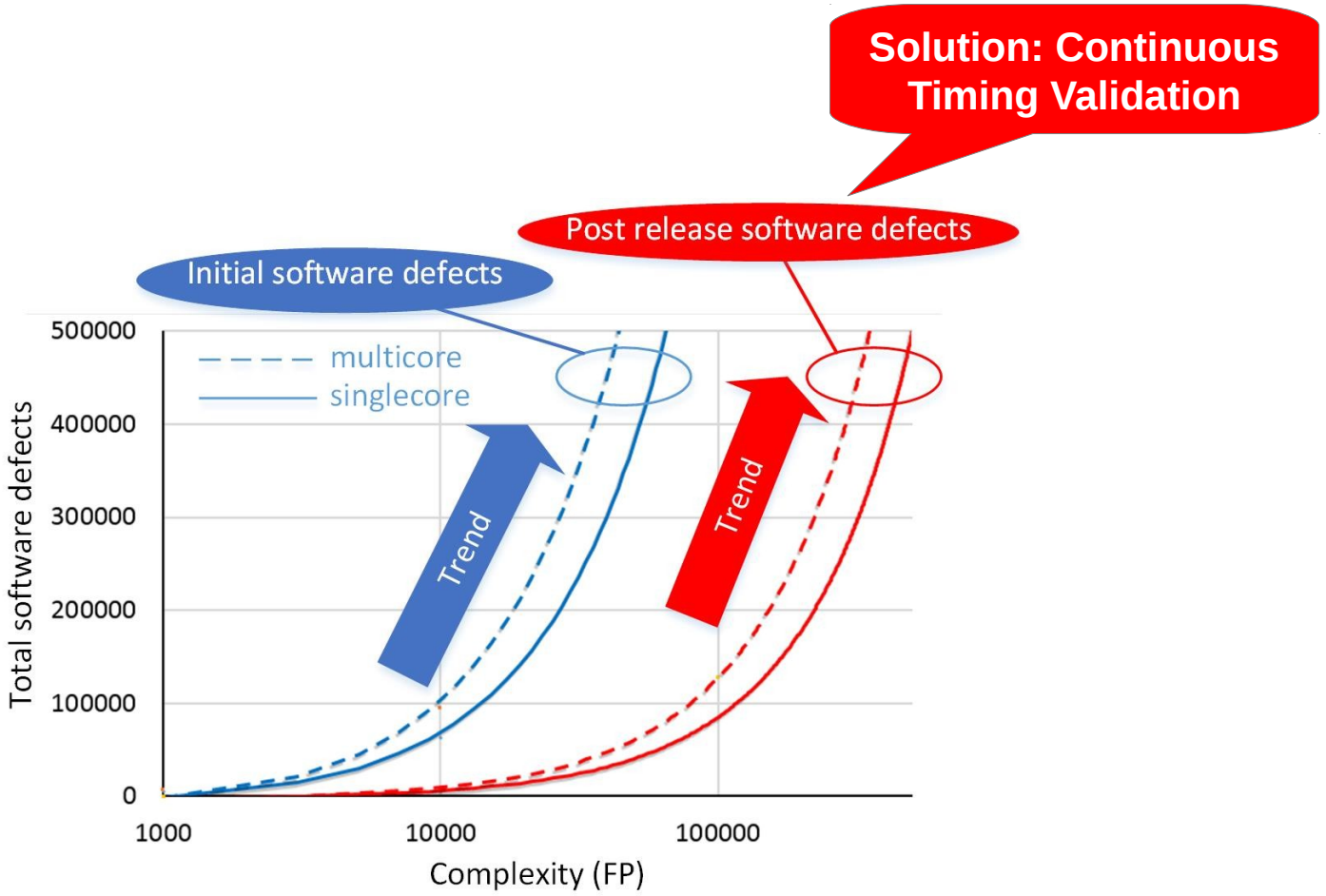
2. Find longest path (ILP based)

Overall execution time estimate
Our method: 191 us
Context insensitive: 208 us

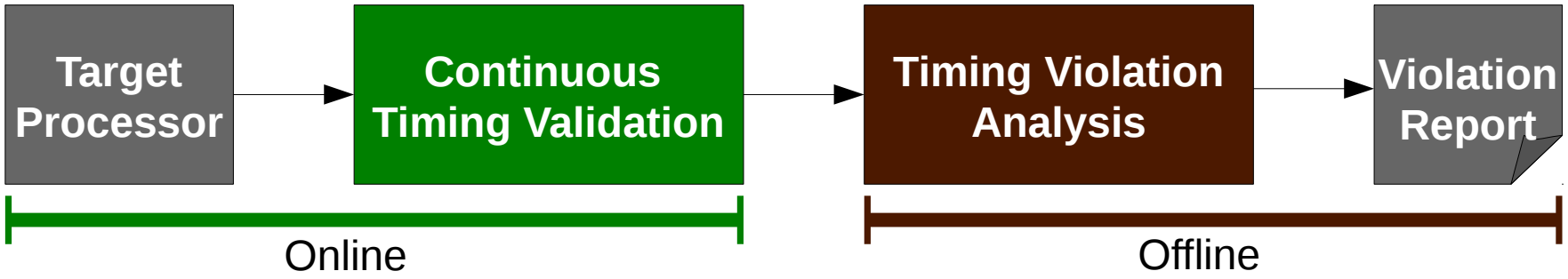
Timing Analysis Architecture



Motivation – Continuous Timing Validation

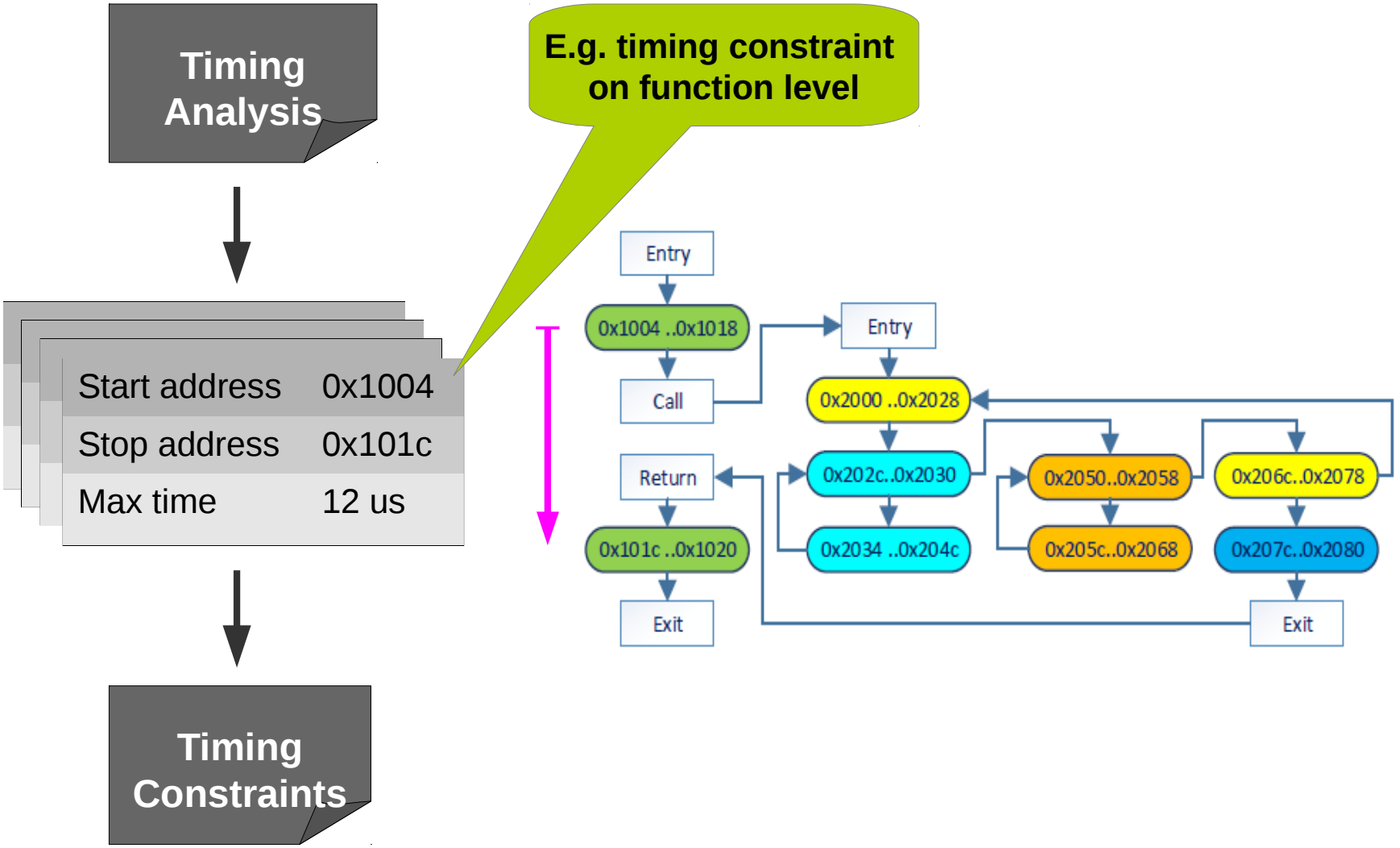


Continuous Timing Validation

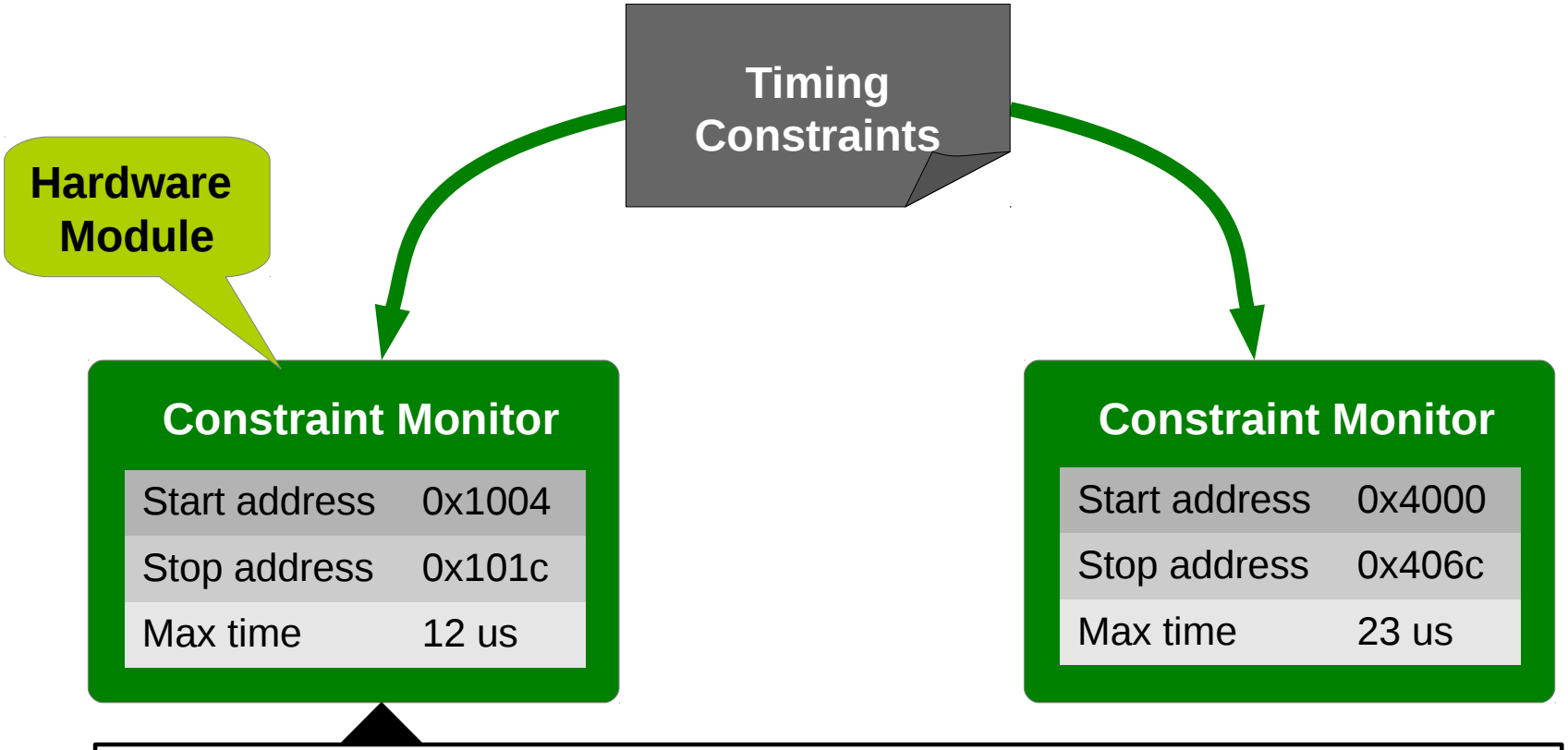


- **Online timing validation**
  - Storage depends on the timing violation error log size
  - Storage is independent of observation time
  - Arbitrary long timing validation
    - At arbitrary levels: BB level, function level, task level, ...
- **Offline violation analysis**
  - CFG annotation with recorded timing violations

Timing Constraints Extraction



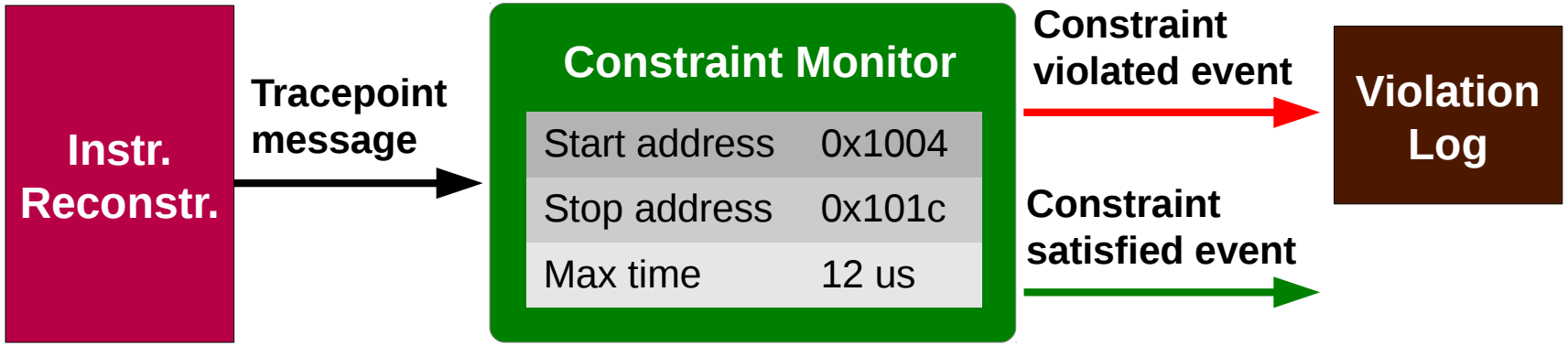
Timing Constraint Monitor



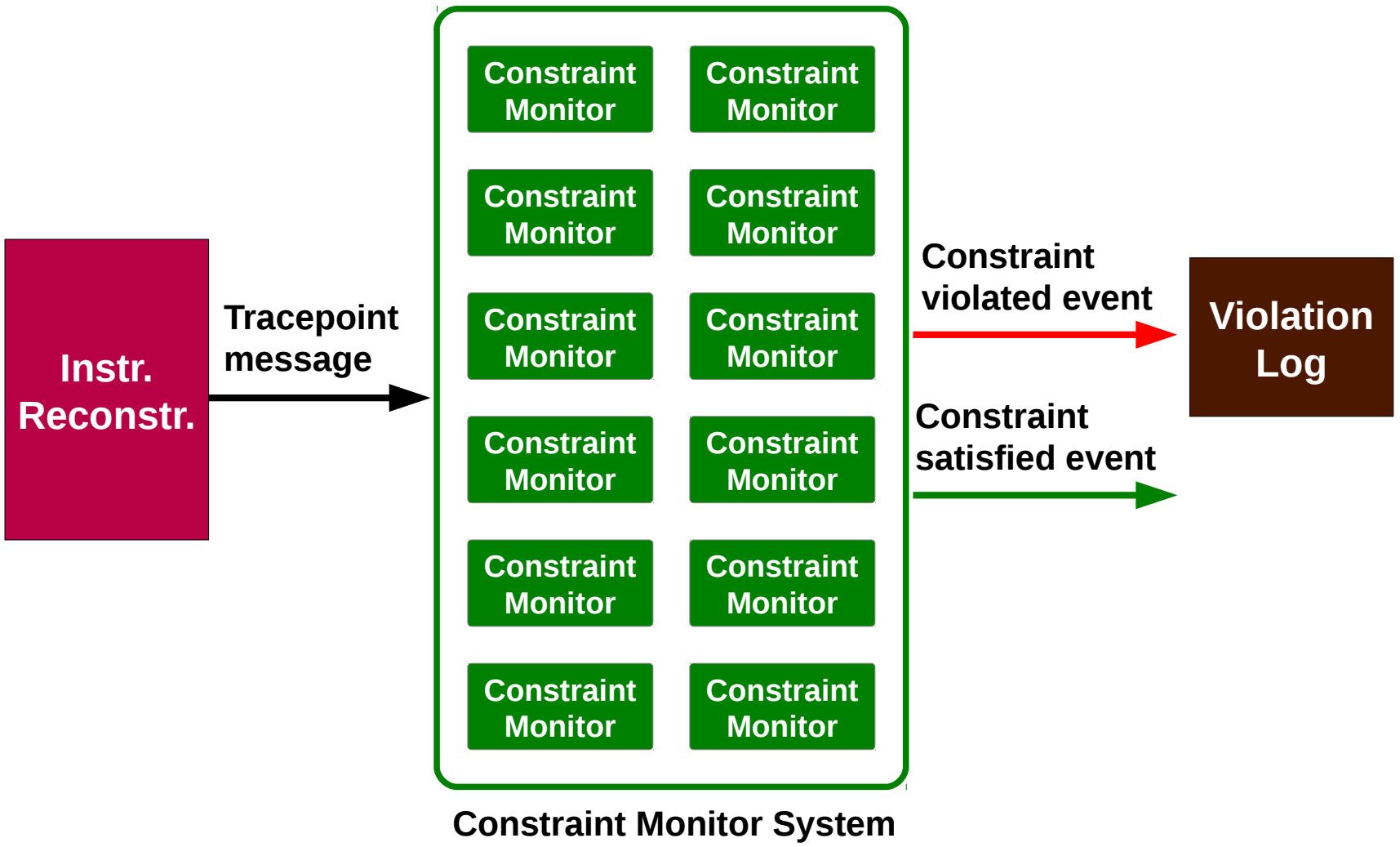
TeSSLa Specification

```
define block_start      := onExecuting 0x1004
define block_end        := onExecuting 0x101c
define timing_violation := on block_start if not (block_end within <=12μs)
```

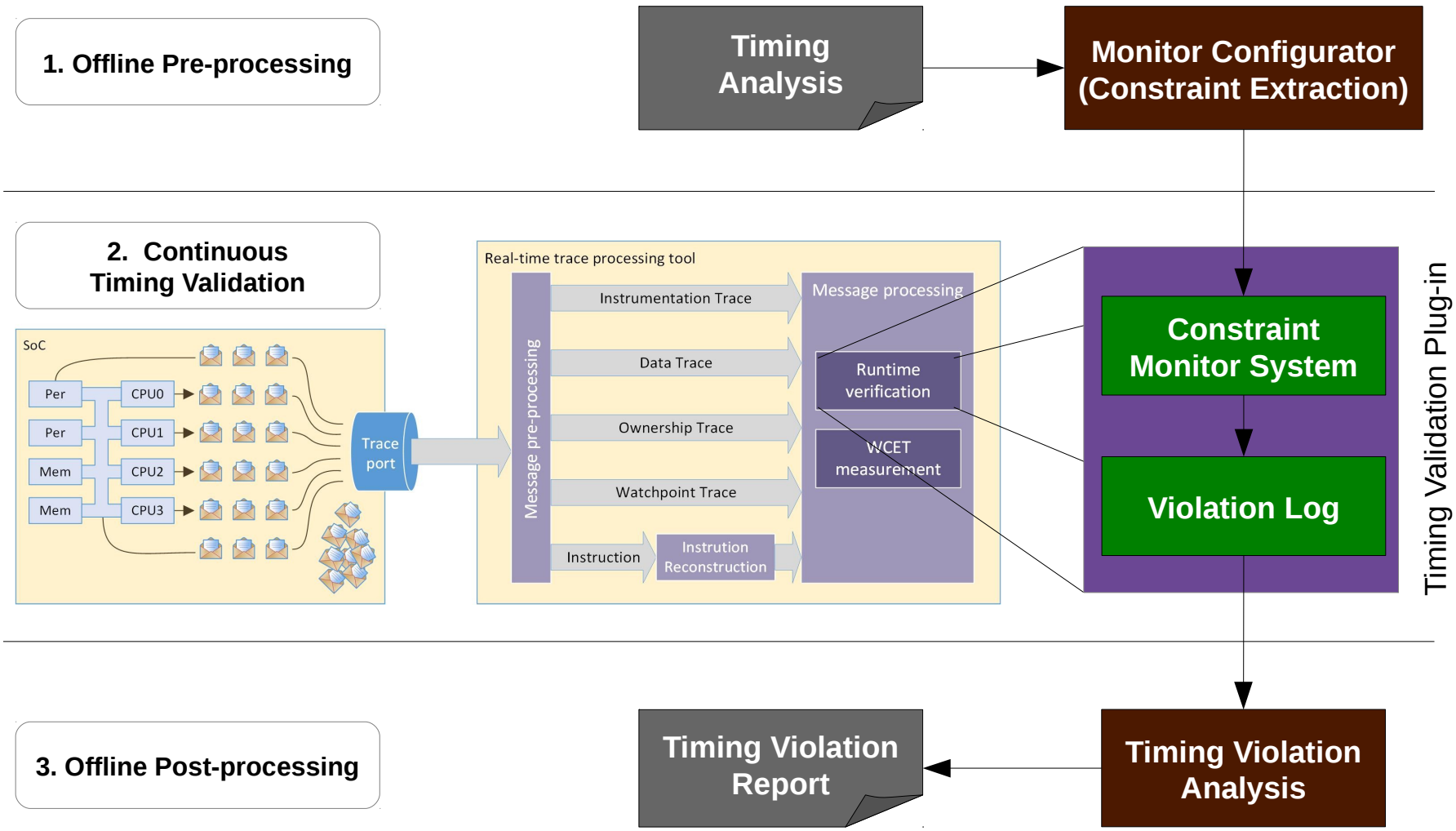
Timing Constraint Monitor



Timing Constraint Monitor System



Timing Validation Architecture



Conclusion

	Measurement-based Timing Analysis	Continuous Timing Validation
Task	Precise timing analysis	Timing constraints validation
Requirements	-	Initial timing analysis
Granularity	Basic Block level	Arbitrary
Application	Development	Field research Autonomous long-term observation

Thank you!

Acknowledgement

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