Schedulability analysis of PWM tasks for the UPMSat-2 ADCS.

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Motivation

- Schedulabilty study of the ADCS subsytem implementing a PWM control algorithm
- Study of Ravenscar Profile restrictions

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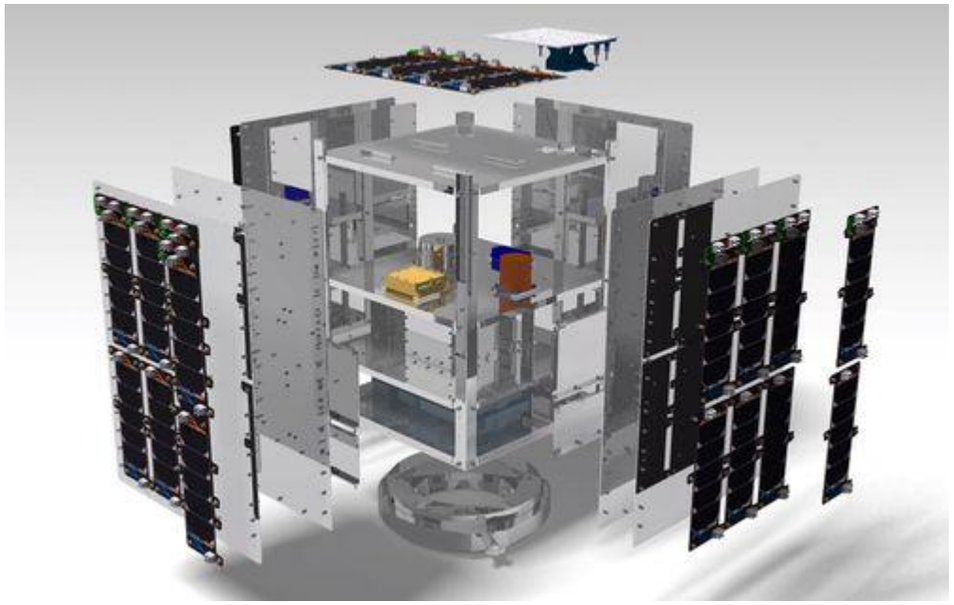
UPMSat-2

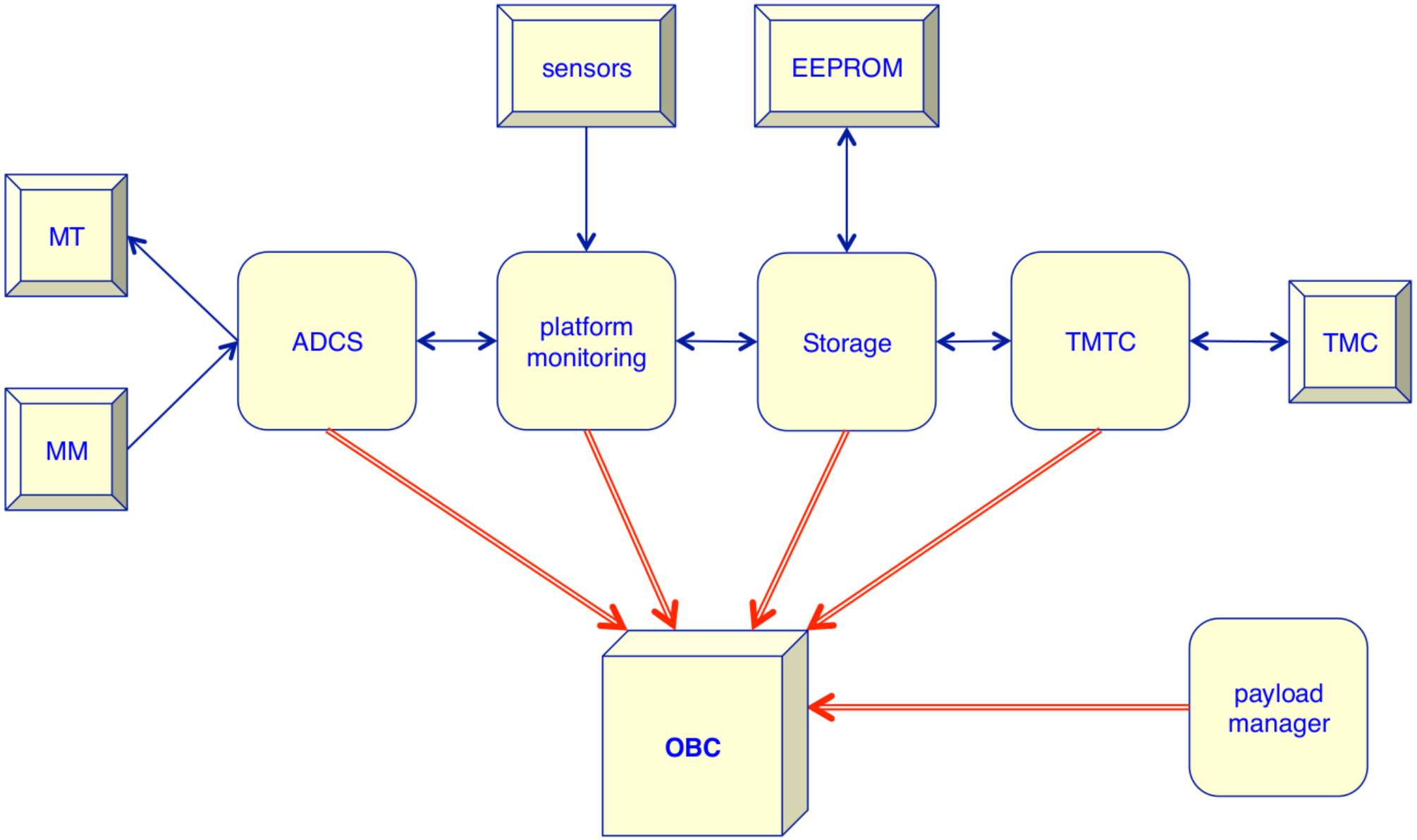
- UPM project
  - Previous experience UPMSat-1
- Developed from scratch
  - Industrial collaboration
- Academic research
  - ADCS, thermal control, …
  - Real-time software engineering

UPMSat-2

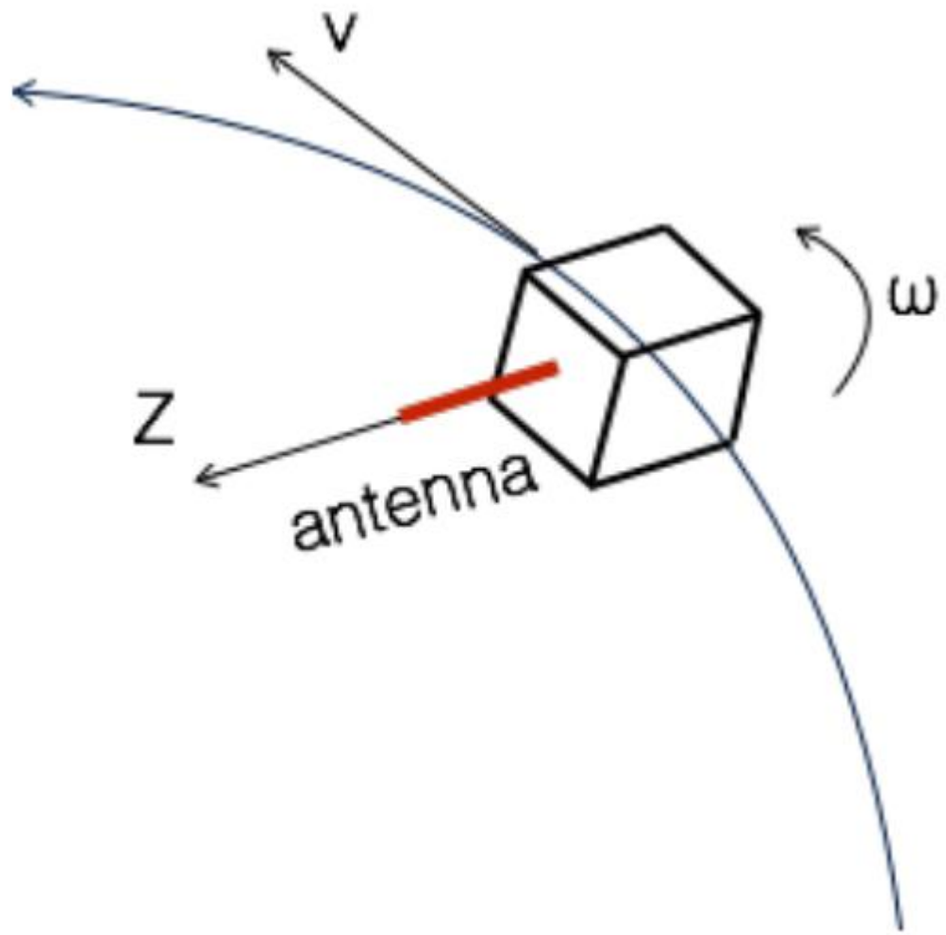
- Experimental micro-satellite to be launched in 2016
  - 50 x 50 x 60 cm envelope
  - Sun-synchronous orbit at 600 km altitude
  - Technology demonstrator
  - Experiment payload



SW overview

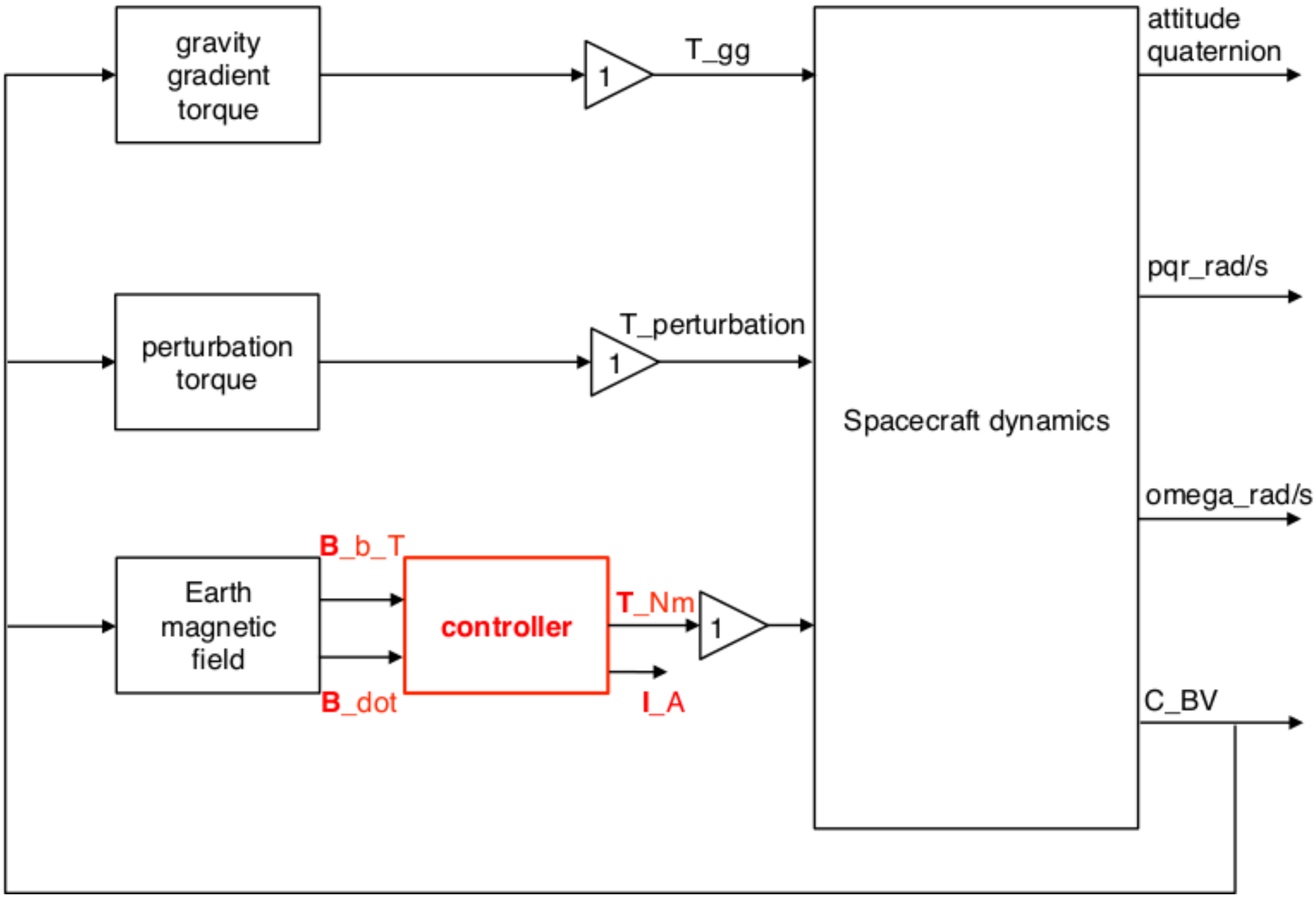


Attitude Determination and Control System



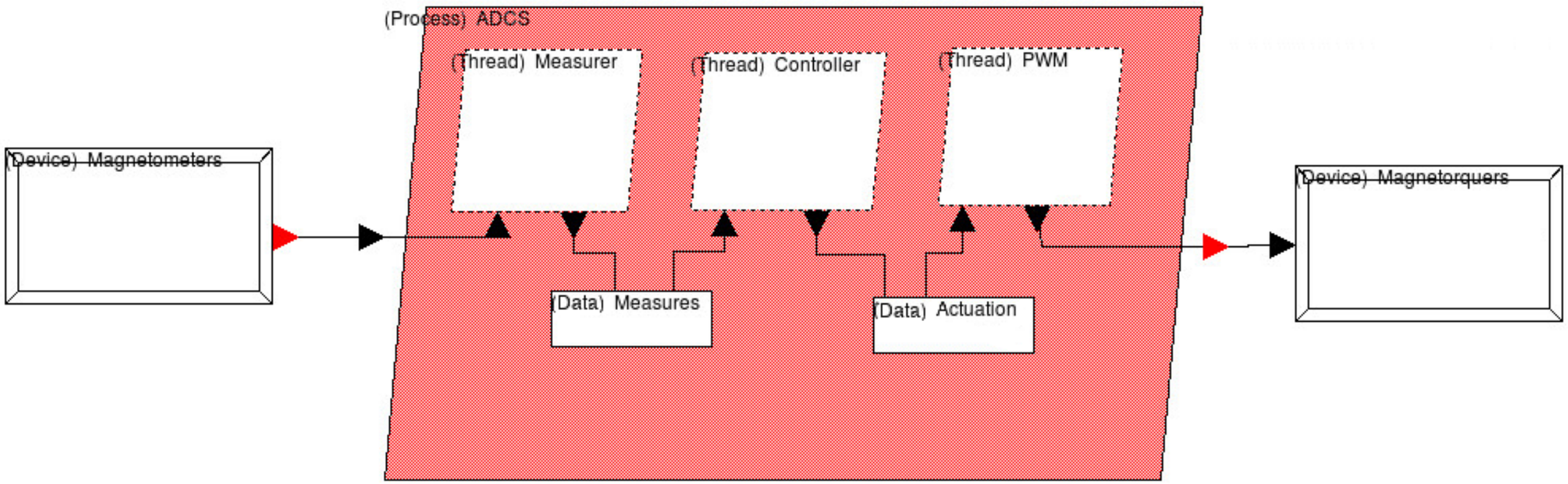
- Active control system
- Constant angular speed
- Based on Earth's magnetic field
- Model-based development

Simulink ADCS model

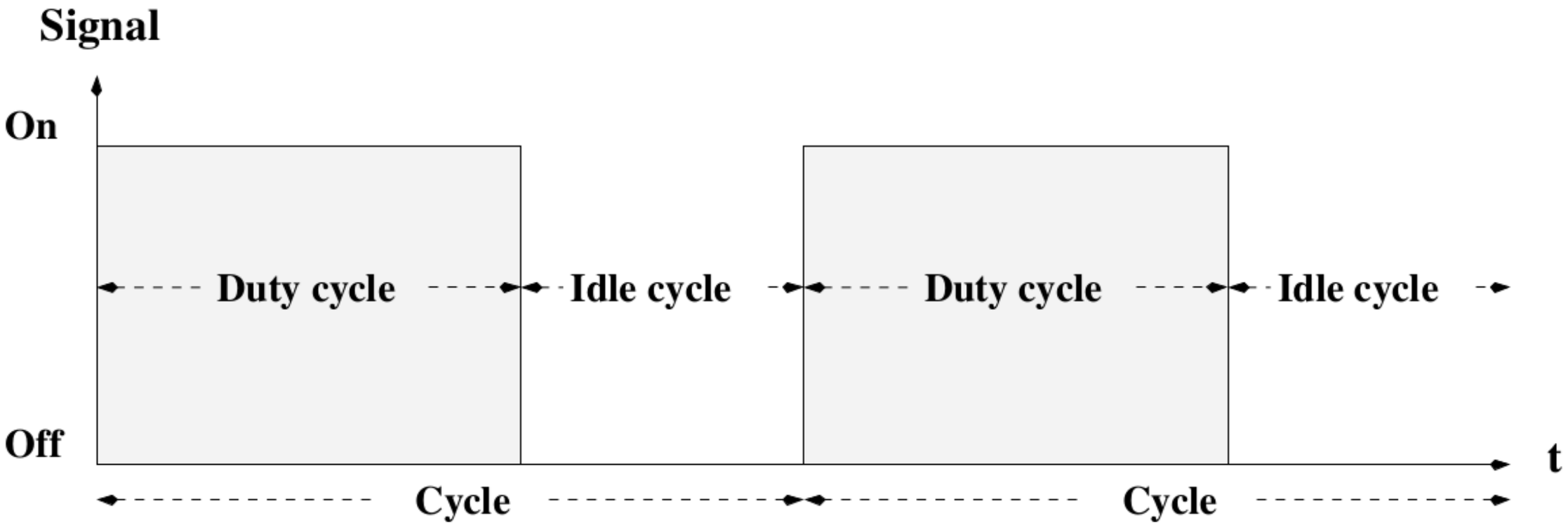


ADCS software architecture

- 2 seconds cycle: 1st measurements, 2nd actuation
  - Magnetometers can't be read while actuating on magnetorquers
- PWM actuation implemented by software

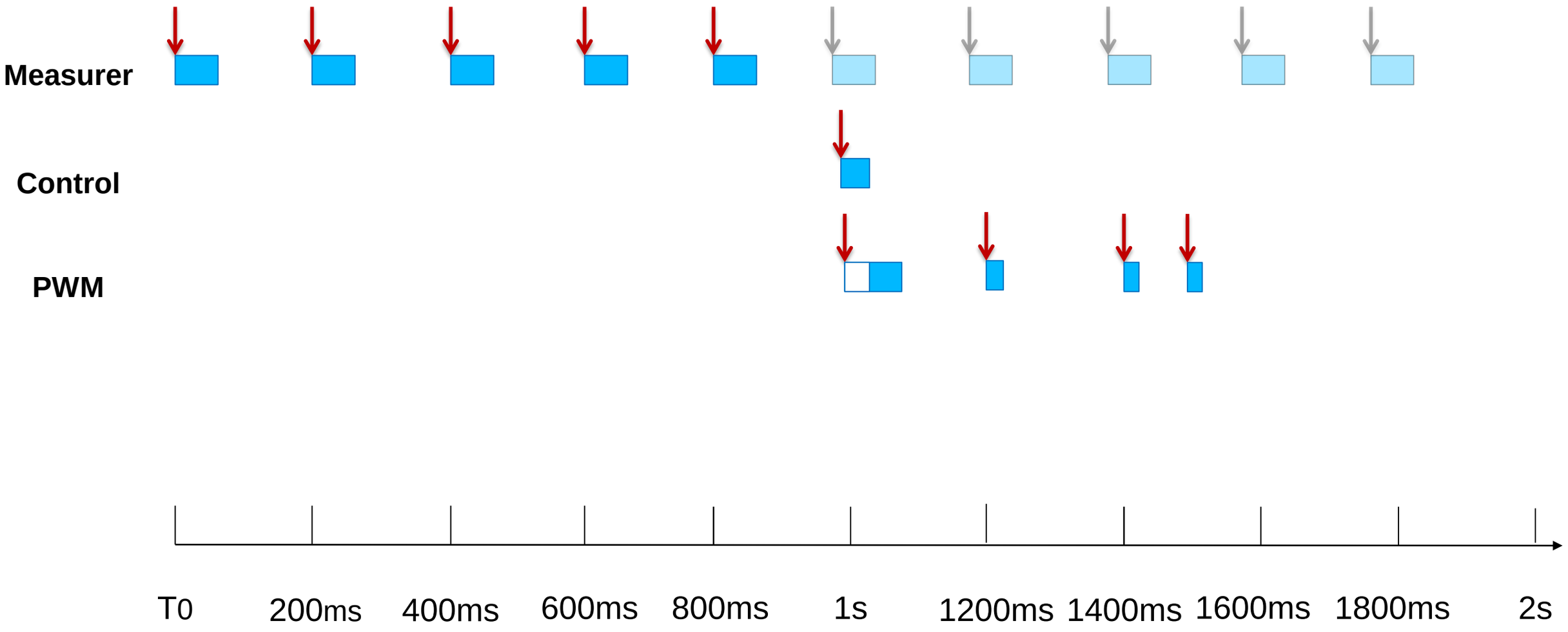


Pulse Width Modulation

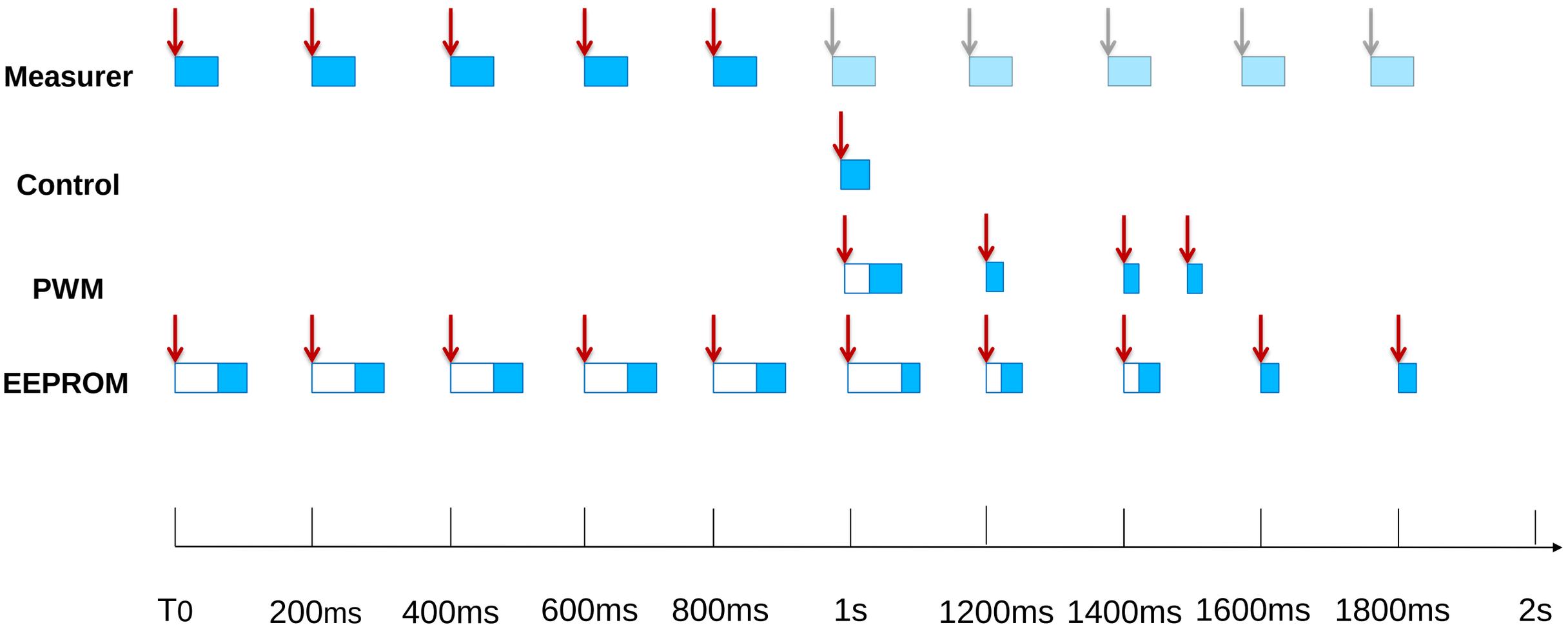


ADCS duty cycles: 0, 200, 300, 400, 500 ms

Chronogram of activities



Chronogram of activities



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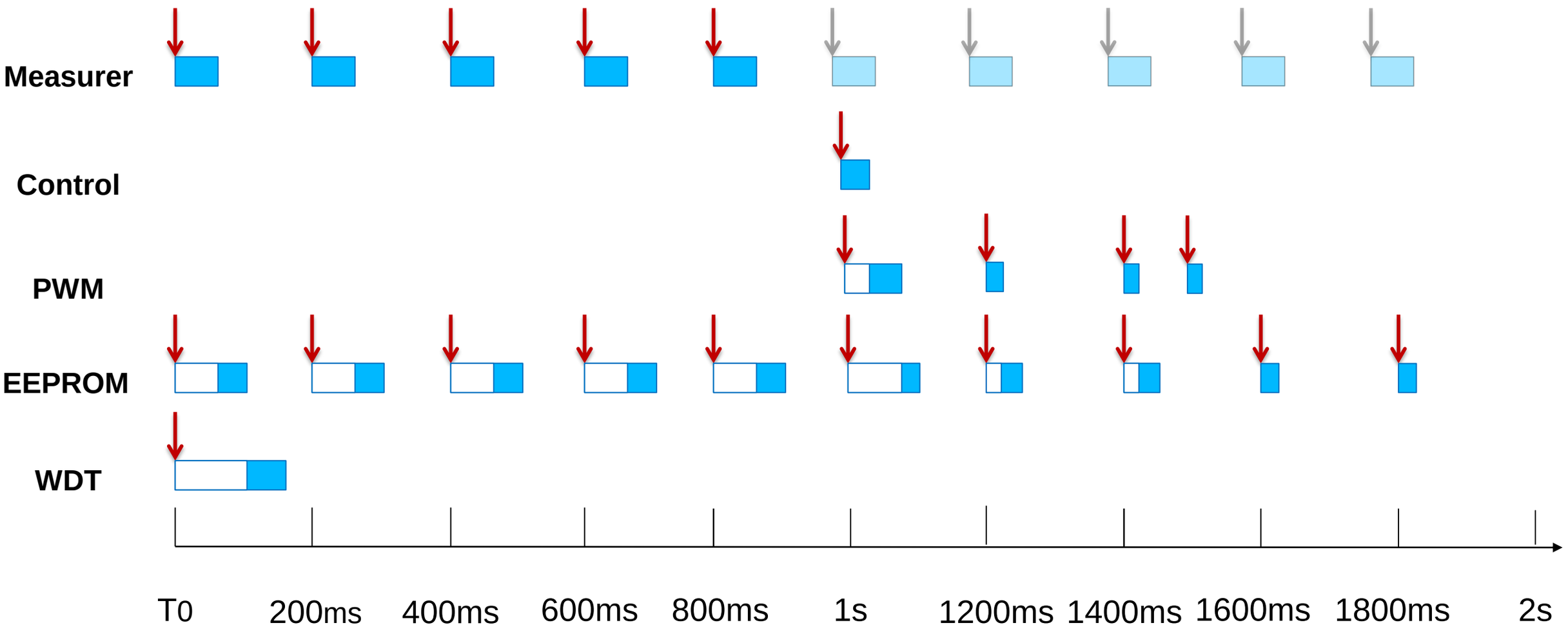
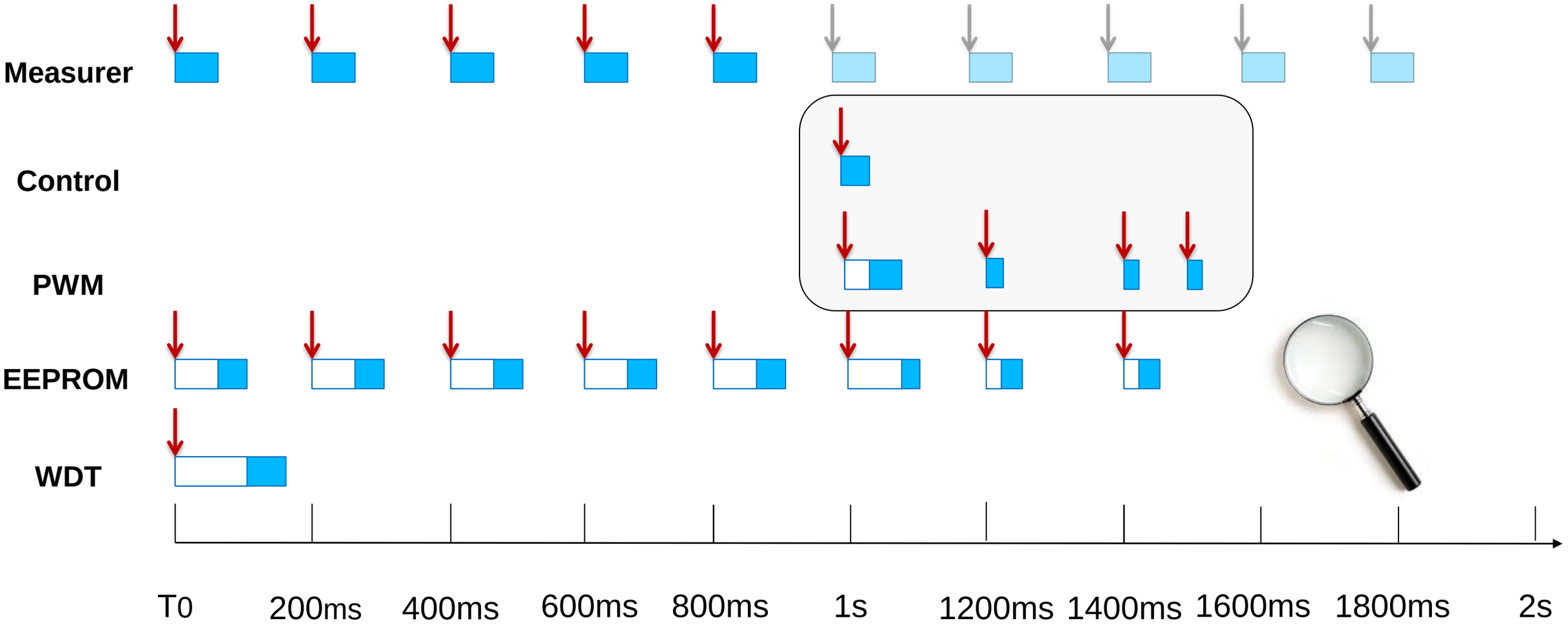
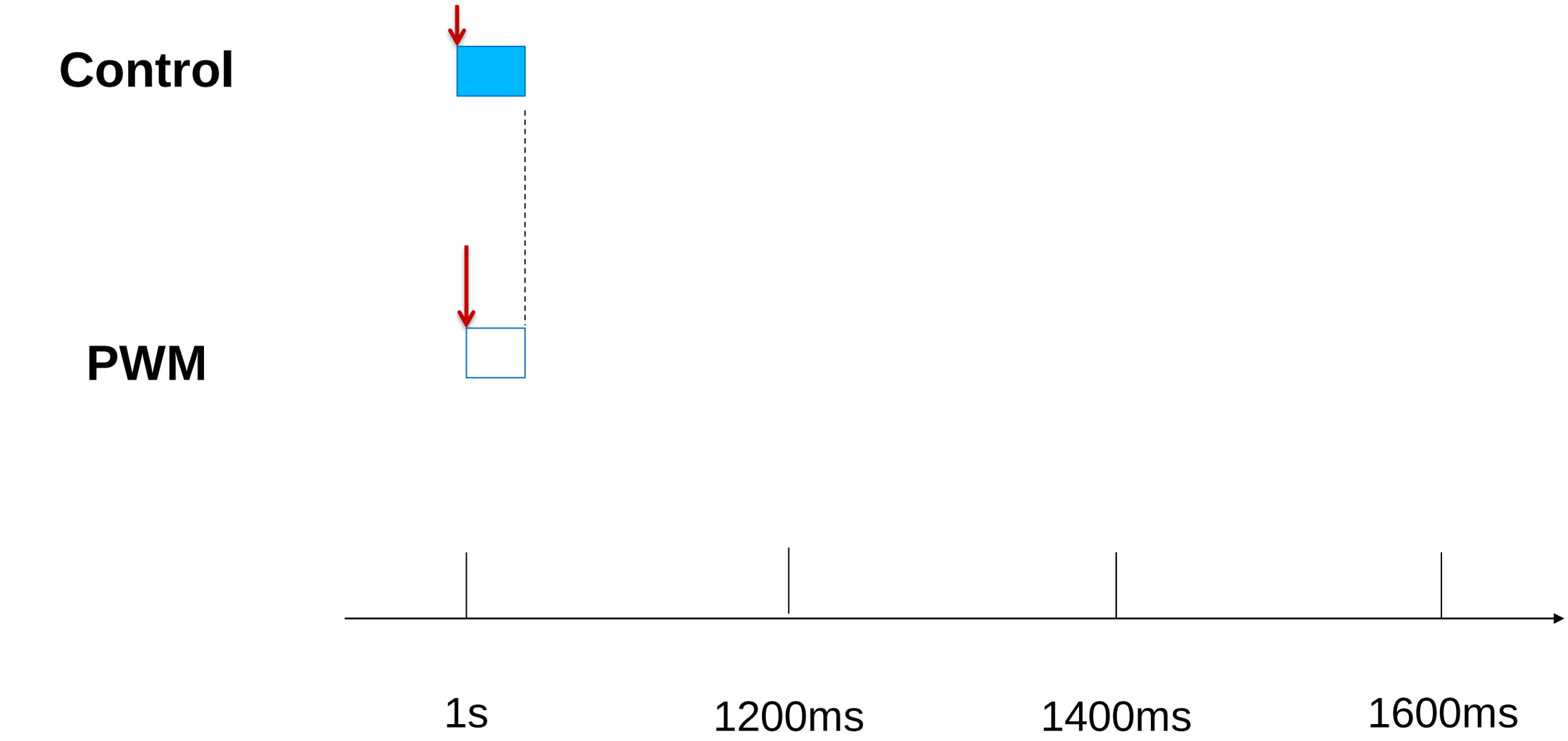


Chronogram of activities

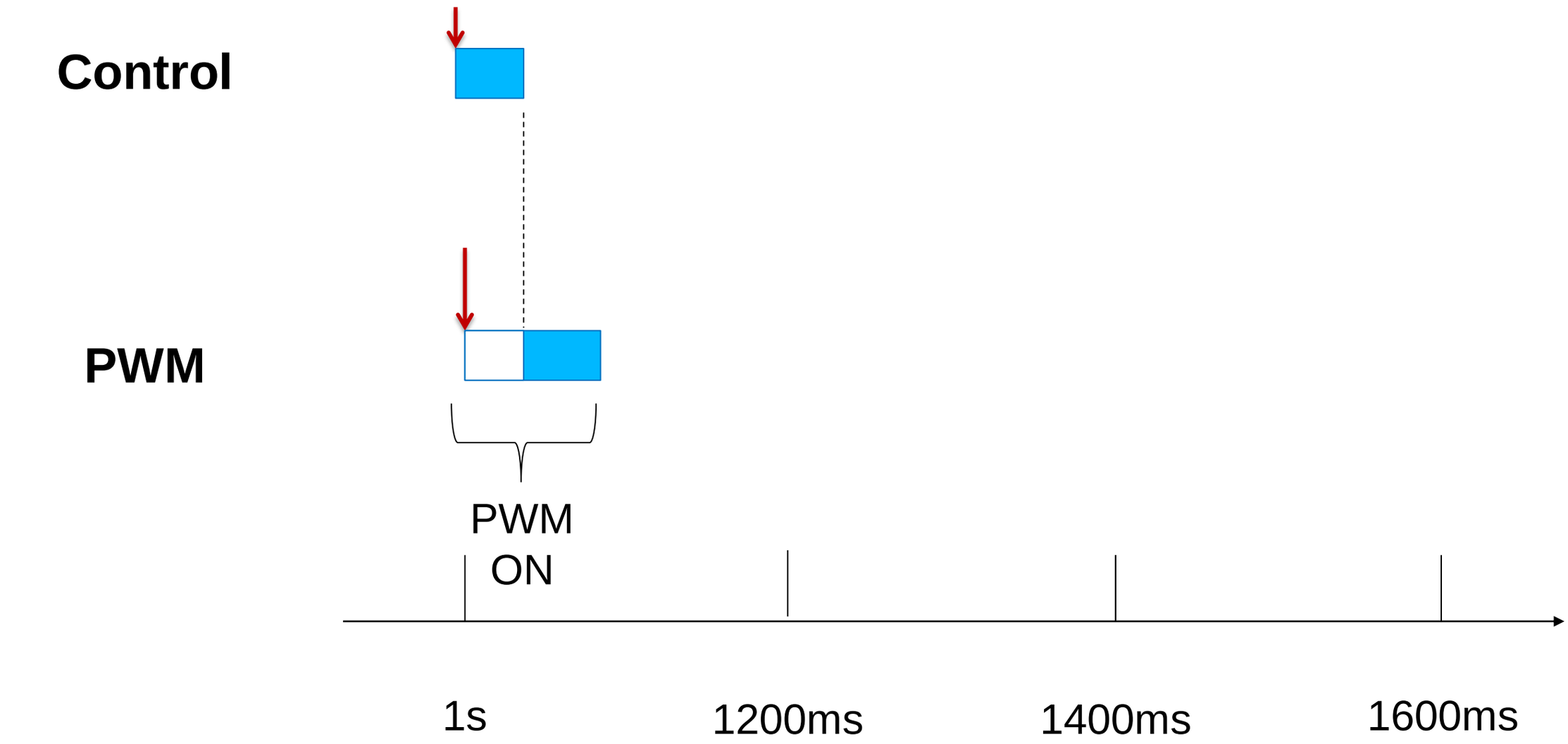


PWM detail



Task	Period	Offset	Release jitter	Deadline	WCET
Control	2 s	1 s	0		4.02 ms
PWM_{On}	2 s	1 s	$\text{R}_{Control}$		2.41 ms
PWM_{Off}	2 s	1200 ms	300 ms + $\text{R}_{PWM_{On}}$	800 ms	0.8 ms

PWM detail



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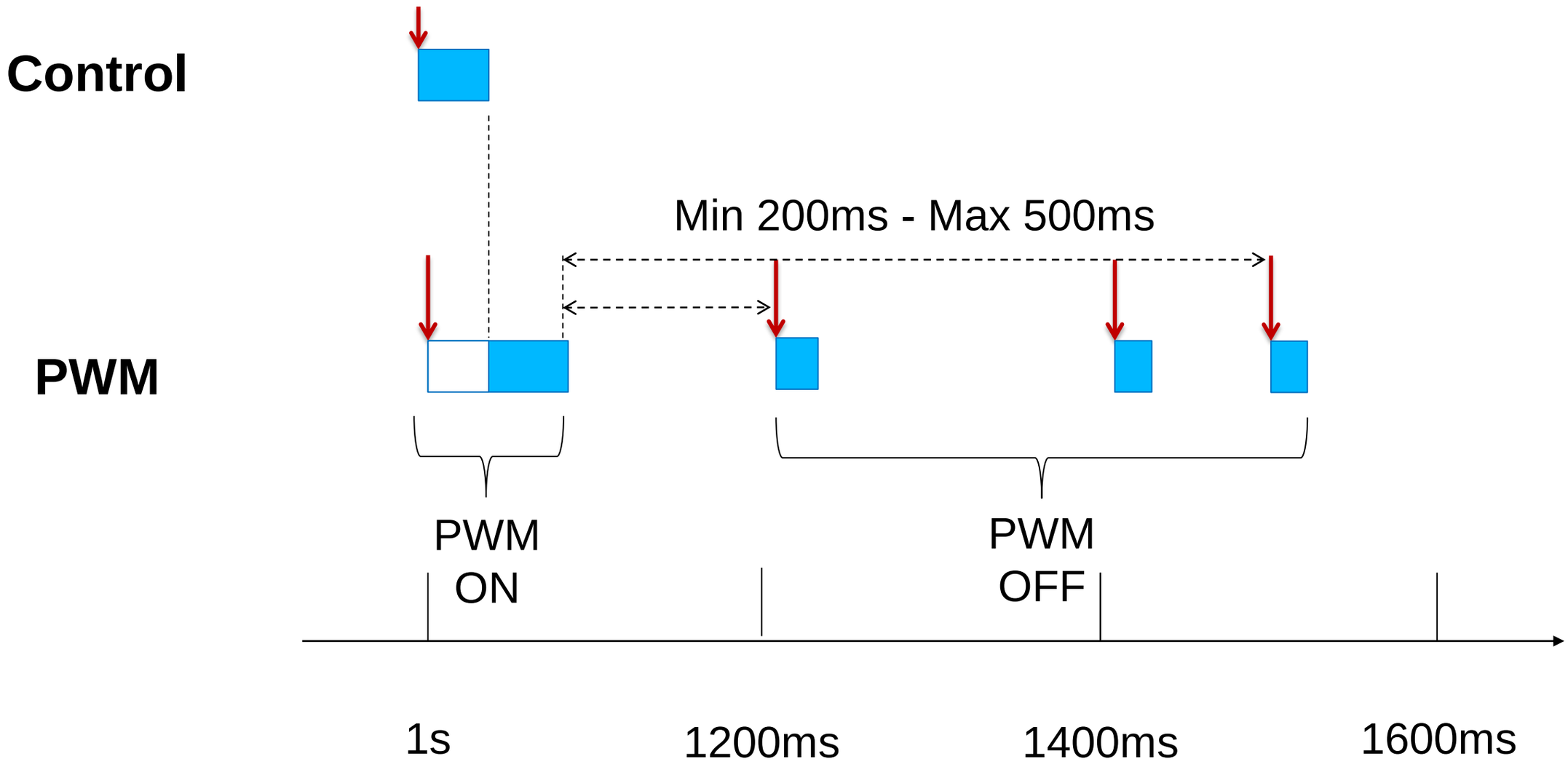

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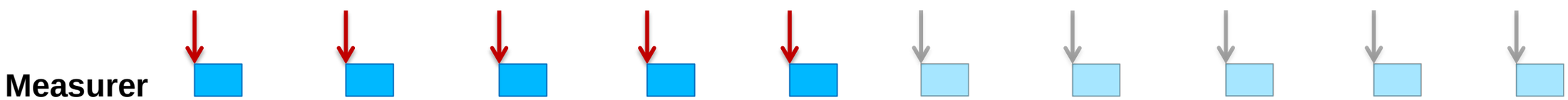
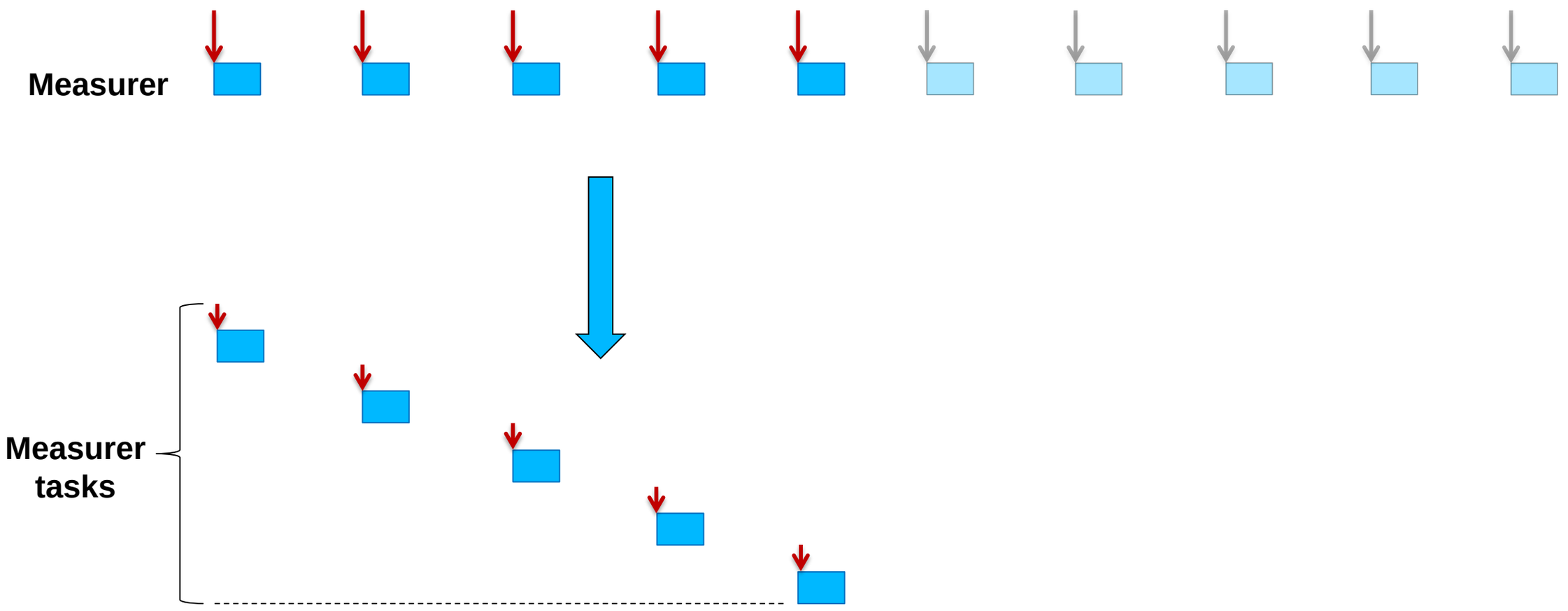
Preliminary analysis

- Measurer task is very pessimistic on the later second



Preliminary analysis

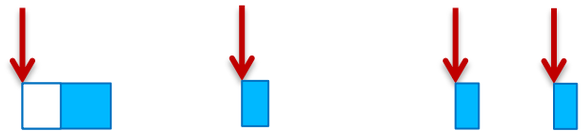
- Measurer task is very pessimistic on the later second
  - It can be modeled as 5 tasks



Preliminary analysis

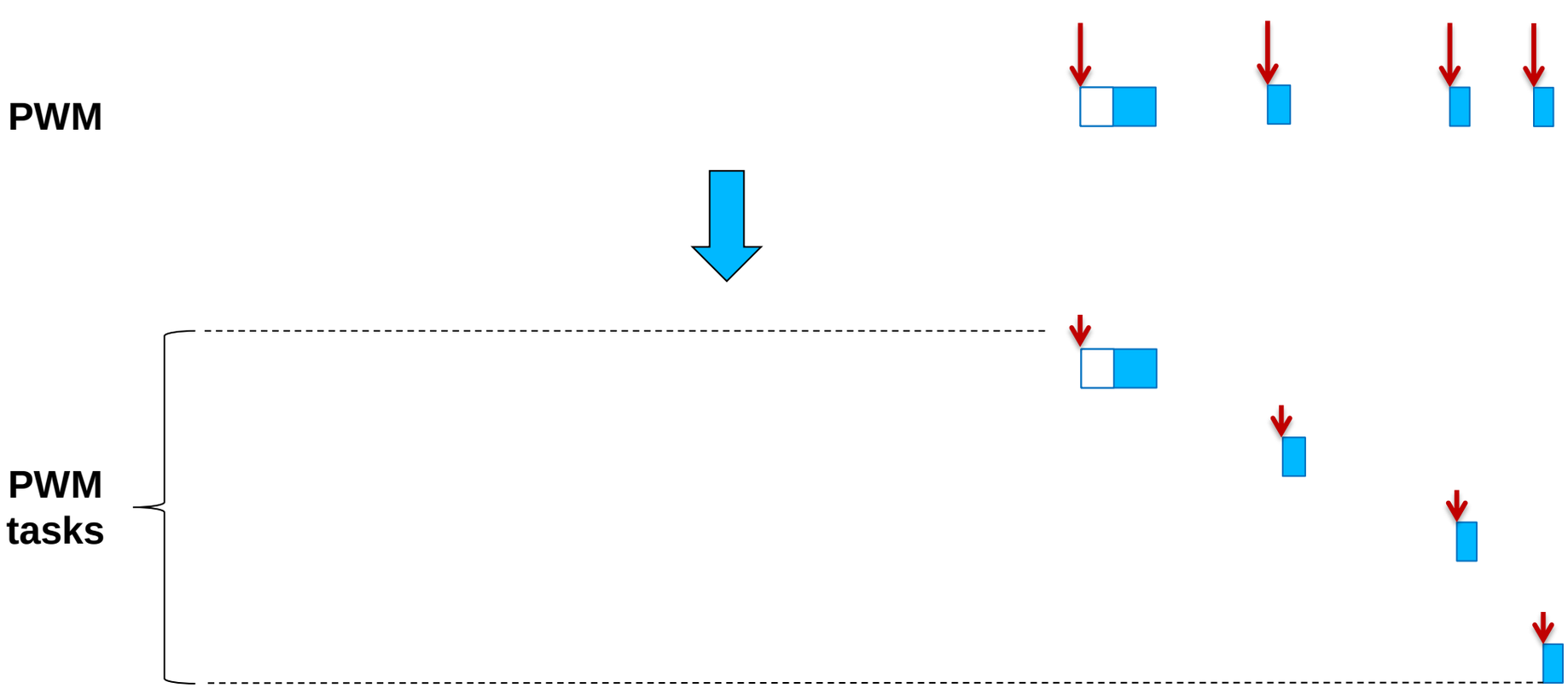
- PWM task violates the Ravenscar single activation point condition

PWM

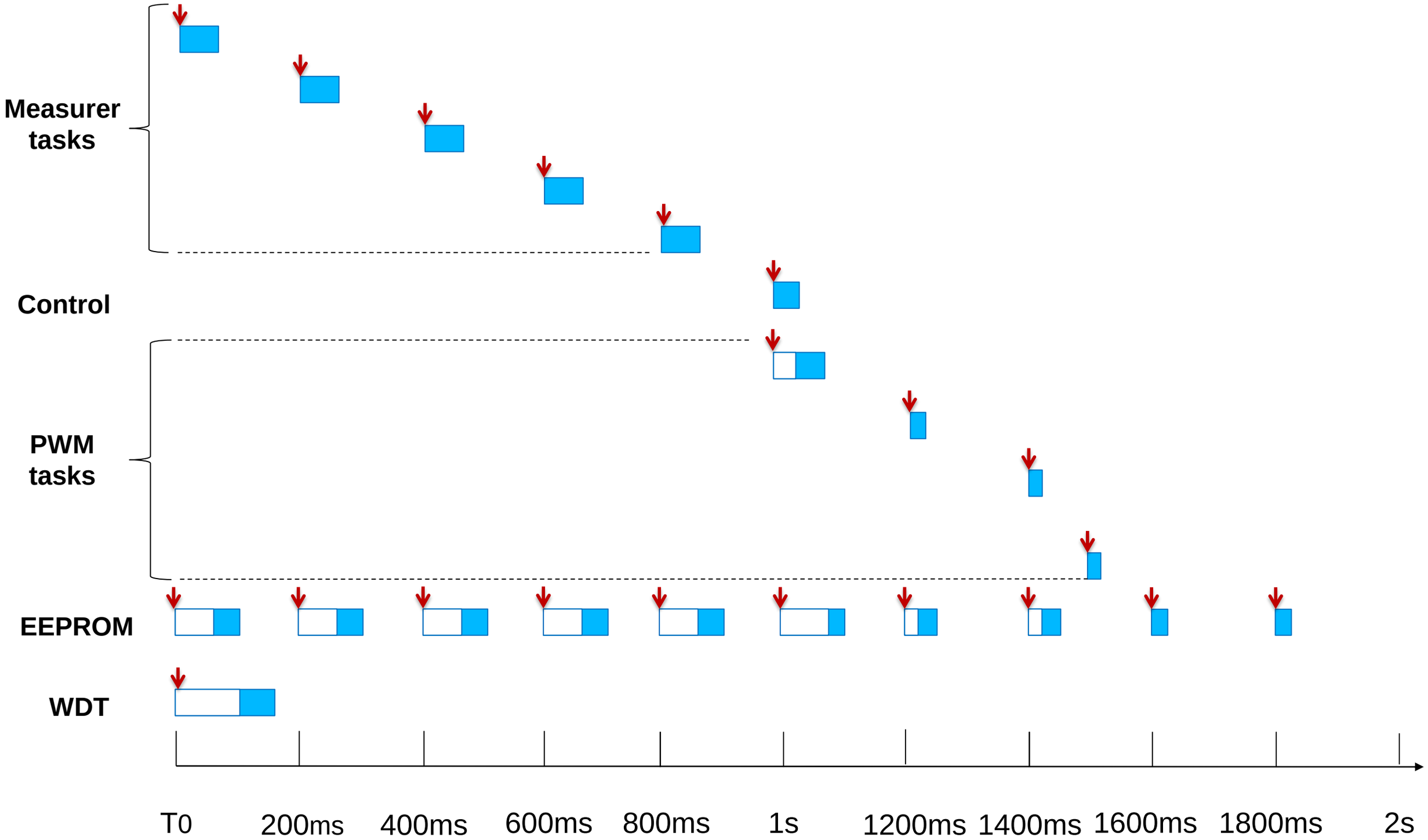


Preliminary analysis

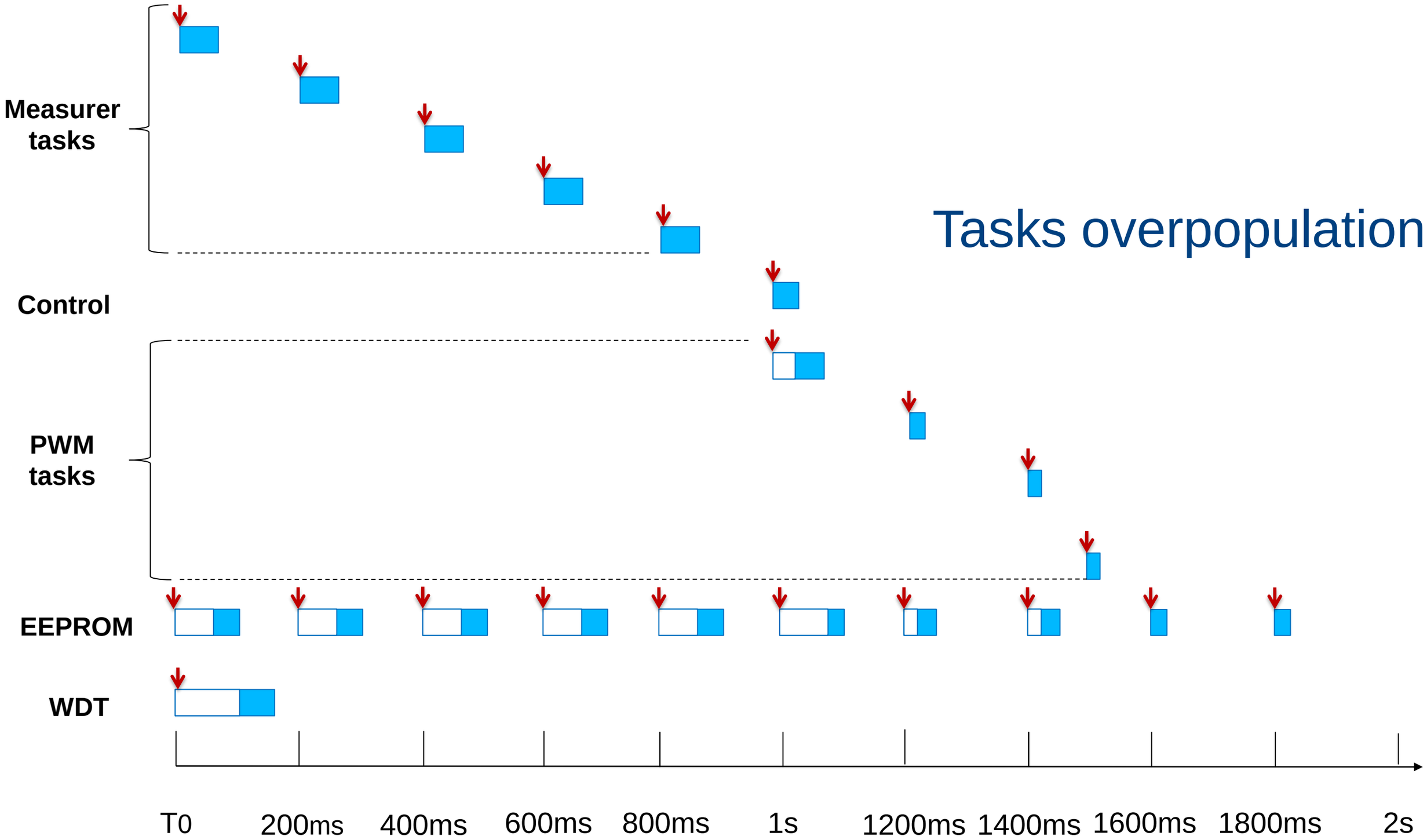
- PWM task violates the Ravenscar single activation point condition
  - It can be modeled as 4 tasks



Equivalent task set



Equivalent task set



Tasks overpopulation

Response time results

- Response time analysis using MAST
- Equivalent task set schedulable
- Processor utilization: 1.18%

Task	Period	Offset	Release jitter	Deadline	Blocking	WCET	Response
PWM_{Off}_1	2 s	1200 ms	313.916 ms	800 ms	0.048 ms	0.8 ms	314.584 ms
PWM_{Off}_2	2 s	1200 ms	313.916 ms	800 ms	0.048 ms	0.8 ms	315.384 ms
PWM_{Off}_3	2 s	1200 ms	313.916 ms	800 ms	0.048 ms	0.8 ms	316.184 ms
PWM_{On}	2 s	1 s	9.058 ms		0.048 ms	2.41 ms	13.736 ms
Control	2 s	1 s	0		0.048 ms	4.02 ms	8.878 ms
Measurer_1	2 s	0	0	200 ms	0.048 ms	2.73 ms	11.608 ms
Measurer_2	2 s	200 ms	0	200 ms	0.048 ms	2.73 ms	14.338 ms
Measurer_3	2 s	400 ms	0	200 ms	0.048 ms	2.73 ms	17.068 ms
Measurer_4	2 s	600 ms	0	200 ms	0.048 ms	2.73 ms	19.798 ms
Measurer_5	2 s	800 ms	0	200 ms	0.048 ms	2.73 ms	22.528 ms
EEPROM	200 ms	0	0	185 ms	0	0.87 ms	22.528 ms
WDT	10 s	0	0	5 s	0	1 ms	23.567 ms

Conclusions

- UPMSat-2 used as an experimental case study
- Validation of development approaches:
  - MultiPARTES, TASTE
  - GNAT Pro tools
  - Simulink automatic code generation
- Schedulability analysis feasible and successful using an equivalent task set

Future work

- Use QGen for ADCS
- Include SPARK
- Complete schedulabilty analysis
- Complete integration and testing

Acknowledgments

- IDR – UPM coordination of UPMSat-2 project
- AdaCore supplying development and analysis tools
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