# Multicore Resource Management for Embedded Real-Time Systems

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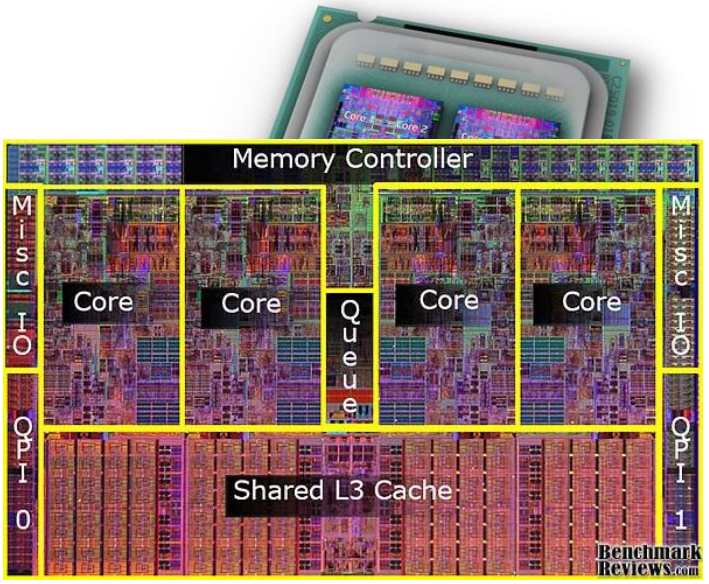
# High-Performance **Multicores** for Embedded **Real-Time** Systems

- Why?
  - Intelligence → more performance
  - Space, weight, power (SWaP), cost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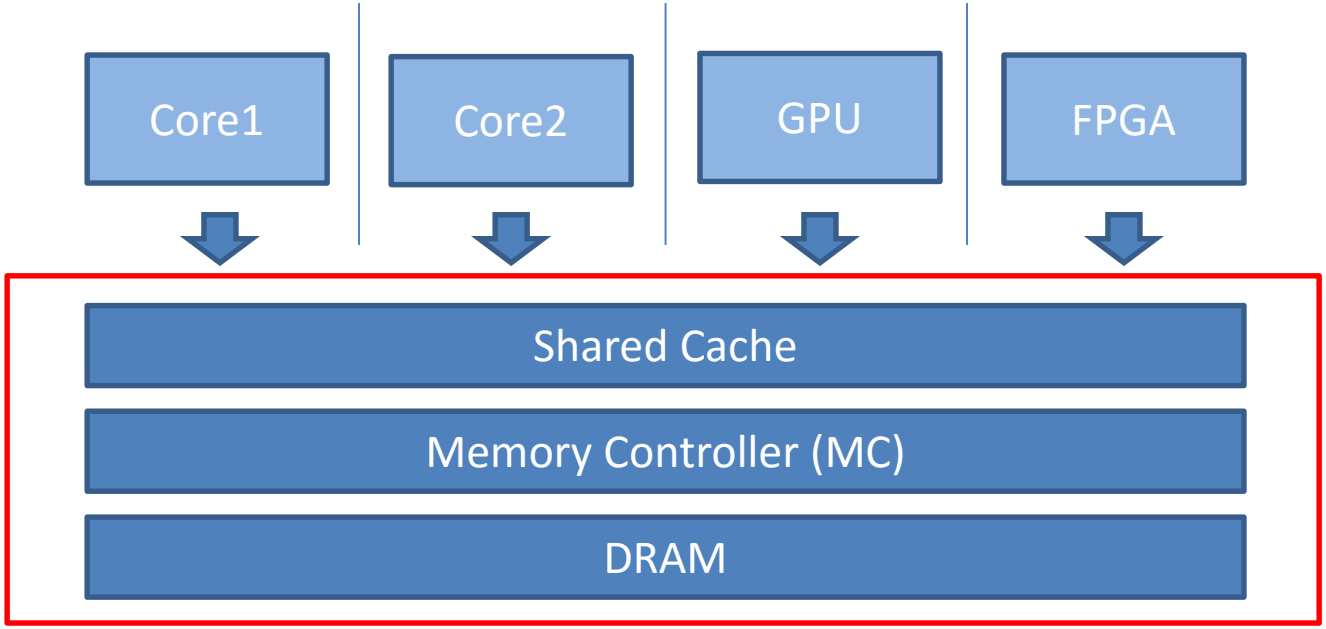
# Time Predictability Challenge




- Hardware resources are shared among the cores
- Tasks can suffer significant **interference delays**
  - unpredictable, non-deterministic ➔ non-certifiable, unsafe

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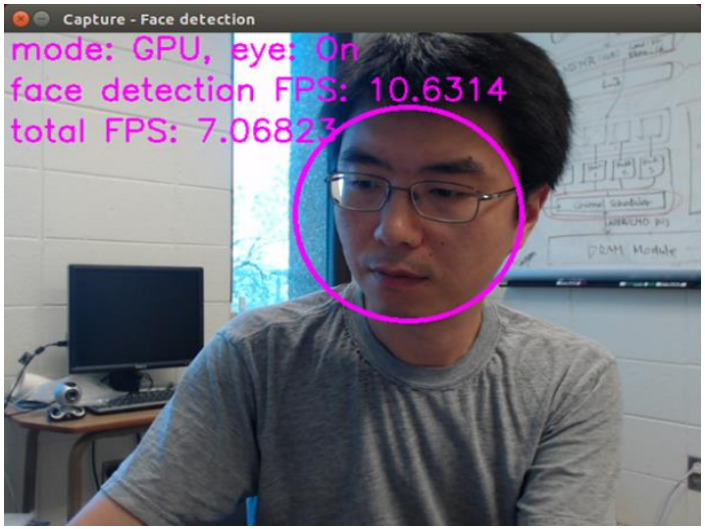
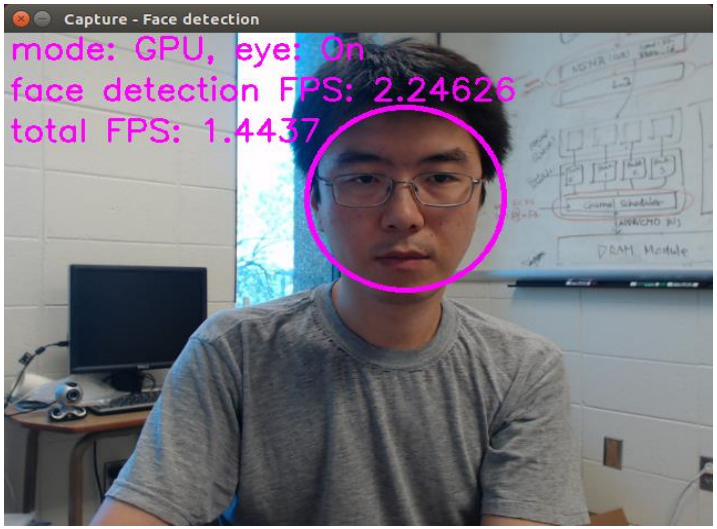
# Example: Real-Time Obstacle Detection and Avoidance




*Run-alone*




*w/ Co-runners*

- Co-runners were launched on idle CPU cores
- 5X slowdown in detection speed (~10fps → 2fps)
  - can fail to avoid obstacle
    - e.g., ) 10m/s aircraft (MAV) can move 1m in 100ms

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# Research Mission

- Our research goal is to build **predictable**, **efficient**, and **safe** computing infrastructure for the next generation of intelligent embedded real-time systems, a.k.a., Cyber Physical Systems (CPS).

- Approach
  - Develop software/hardware mechanisms
  - Develop analysis framework

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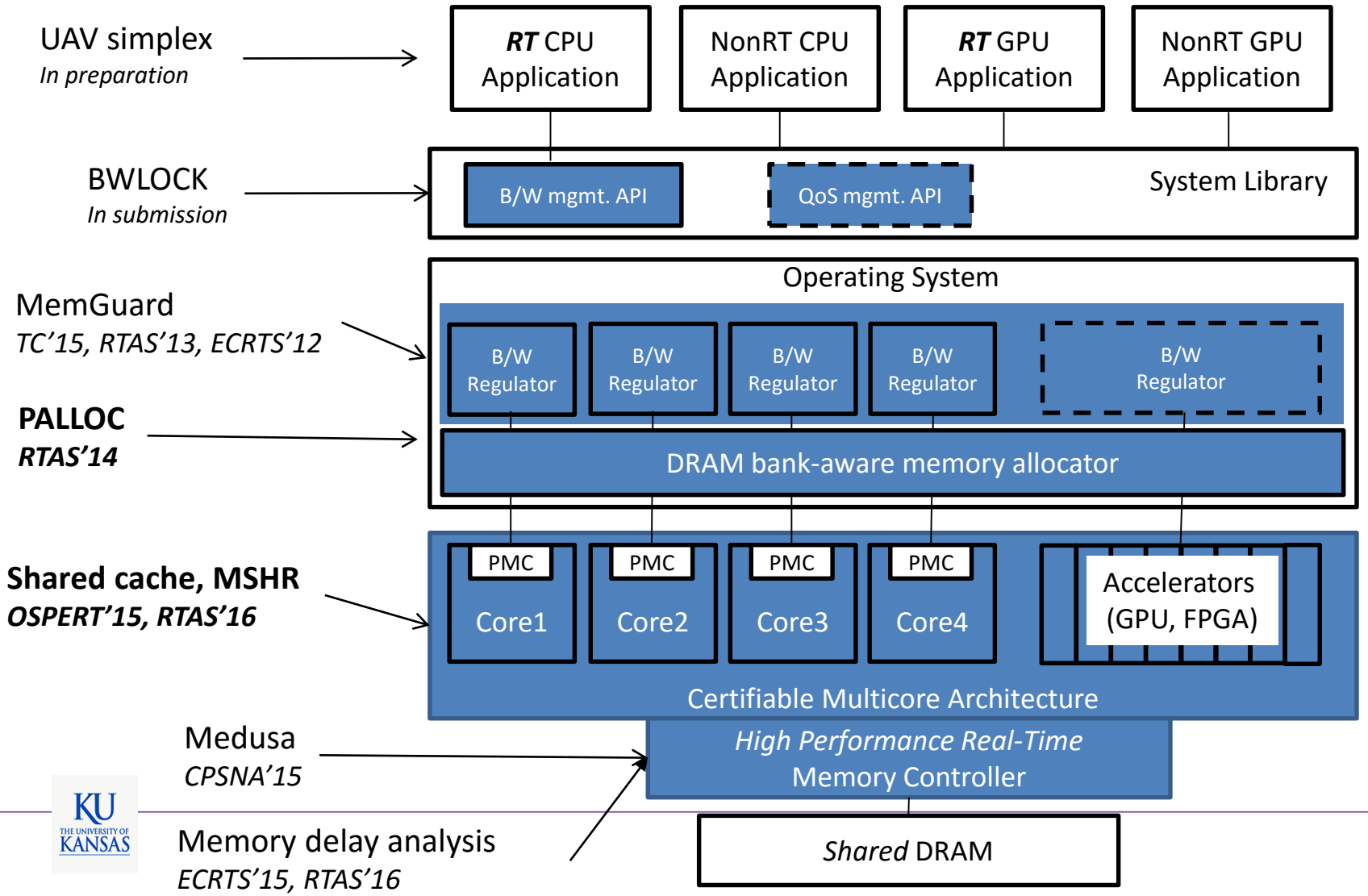
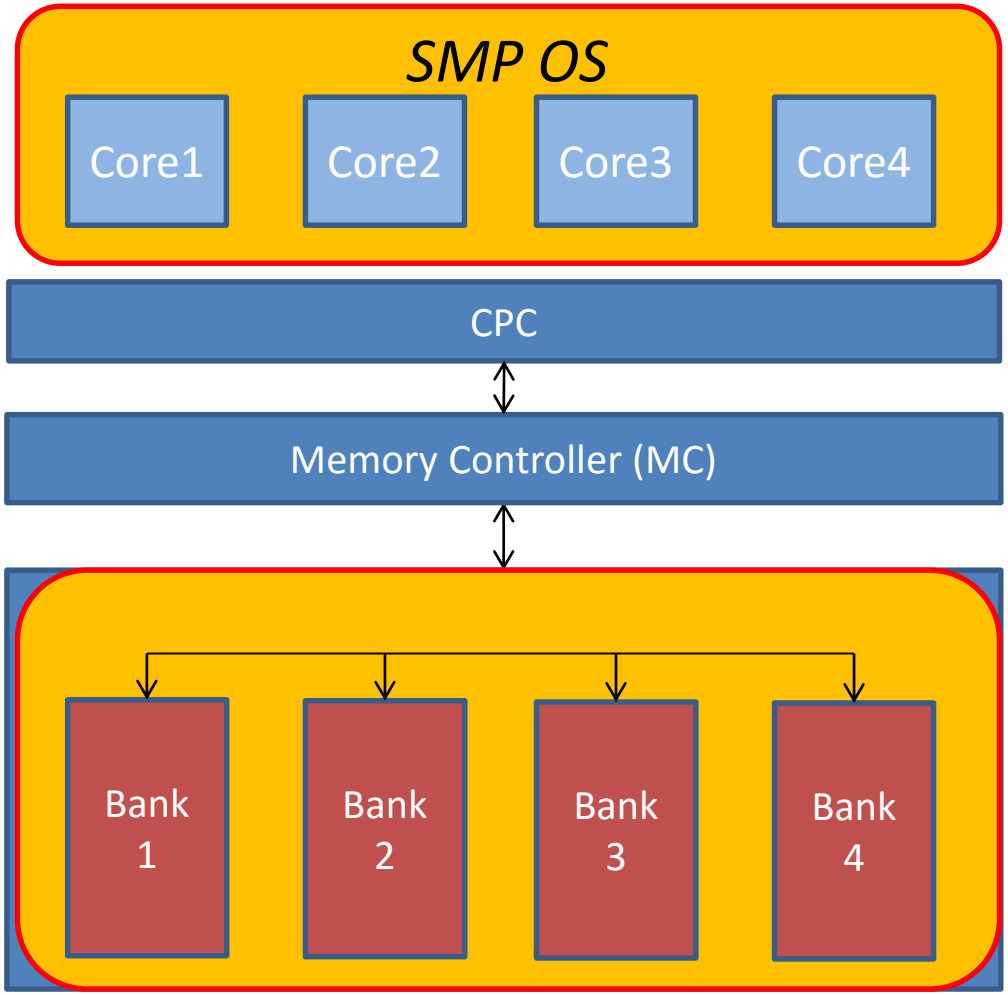
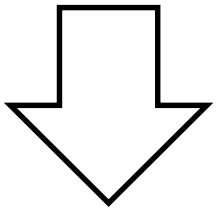
# Research Results



# PALLOC




- DRAM bank-aware kernel memory allocator
- Can void bank conflict

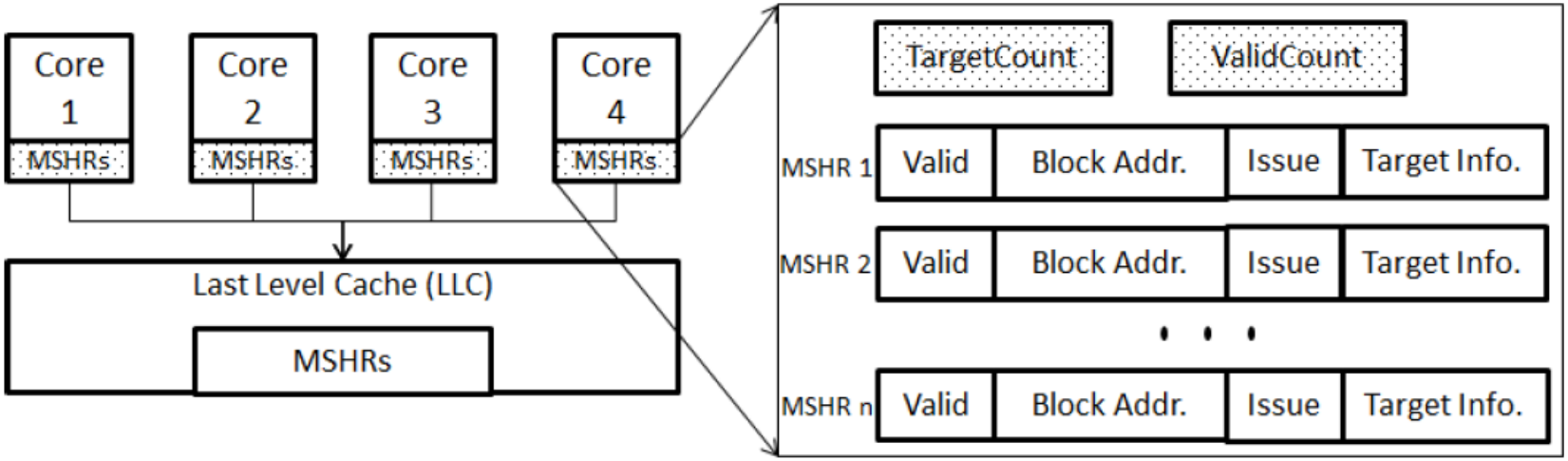


*Improved Isolation*



[RTAS14] **Heechul Yun**, Renato Mancuso, Zheng Wu, Rodolfo Pellizzoni. PALLOC: DRAM Bank-Aware Memory Allocator for Performance Isolation on Multicore Real-Time Systems, *IEEE Intl. Conference on Real-Time and Embedded Technology and Applications Symposium (RTAS)*. 2014, pp. 155-166.

# OS Controlled MSHR Partitioning




- Experimentally showed cache partitioning doesn't provide cache performance isolation in non-blocking caches
- Proposed a OS/hardware collaborative solution that guarantees cache perf. isolation

# References


- [RTAS16-1] Prathap Kumar Valsan (*), **Heechul Yun**, Farzad Farshchi (*). Taming Non-blocking Caches to Improve Isolation in Multicore Real-Time Systems. In *IEEE Intl. Conference on Real-Time and Embedded Technology and Applications Symposium (RTAS)*, 2016 (**Best paper award.** *: KU students**)**
- [RTAS16-2] Rodolfo Pellizzoni, **Heechul Yun**. Memory Servers for Multicore Systems. *IEEE Intl. Conference on Real-Time and Embedded Technology and Applications Symposium (RTAS)*, IEEE, 2016
- [TC15] **Heechul Yun**, Gang Yao, Rodolfo Pellizzoni, Marco Caccamo, and Lui Sha. Memory Bandwidth Management for Efficient Performance Isolation in Multi-core Platforms, *IEEE Transactions on Computers,* Vol 65, Issue 2, 2015, pp. 562 – 576 (Selected as **the Feature paper** by the editors)
- [CPSNA15] Prathap Kumar Valsan (*), **Heechul Yun**. MEDUSA: A Predictable and High-Performance DRAM Controller for Multicore based Embedded Systems *IEEE Intl. Conference on Cyber-Physical Systems, Networks, and Applications (CPSNA)* , 2015, pp. 86 – 93
- [ECRTS15-1] **Heechul Yun**, Rodolfo Pellizzoni, Prathap Kumar Valsan (*). Parallelism-Aware Memory Interference Delay Analysis for COTS Multicore Systems. *IEEE Euromicro Conference on Real-Time Systems (ECRTS)*, 2015.
- [ECRTS15-2] Renato Mancuso, Rodolfo Pellizzoni, Marco Caccamo, Lui Sha and Heechul Yun. WCET(m) Estimation in Multi-Core Systems using Single Core Equivalence. *Euromicro Conference on Real-Time Systems (ECRTS)*, 2015.
- [RTAS14] **Heechul Yun**, Renato Mancuso, Zheng Wu, Rodolfo Pellizzoni. PALLOC: DRAM Bank-Aware Memory Allocator for Performance Isolation on Multicore Real-Time Systems, *IEEE Intl. Conference on Real-Time and Embedded Technology and Applications Symposium (RTAS)*. 2014, pp. 155-166.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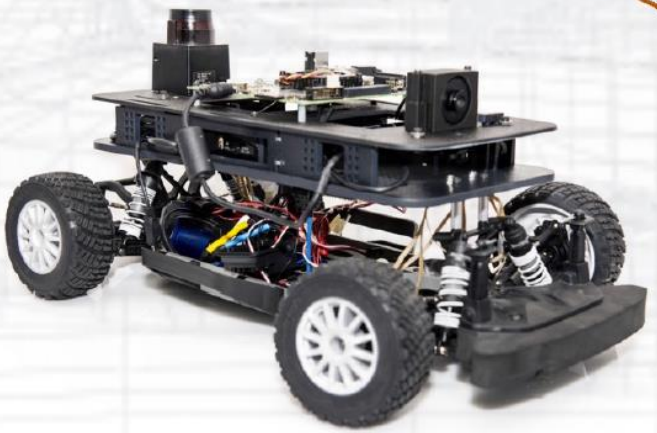
# On-going Projects

- Multicore Resource Management
  - OS, architecture research for time predictability
  - Funding Agencies: NSF, ETRI
- UAV Software Platform
  - ROS (Robot Operating System) based autopilot and real-time sensor (radar and vision) processing
  - Funding Agencies: NASA

# Autonomous Racing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# Prospective Students

- Solid background in operating systems and computer architecture
- Good system programming skills
- **Interests and experiences in building Intelligent cyber-physical systems**
  - ROS, python, Linux, OpenCV, CUDA
  - PID control, real-time sensor fusion

- Send me your CV and schedule a meeting

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