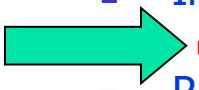
Course Outline (lectures)

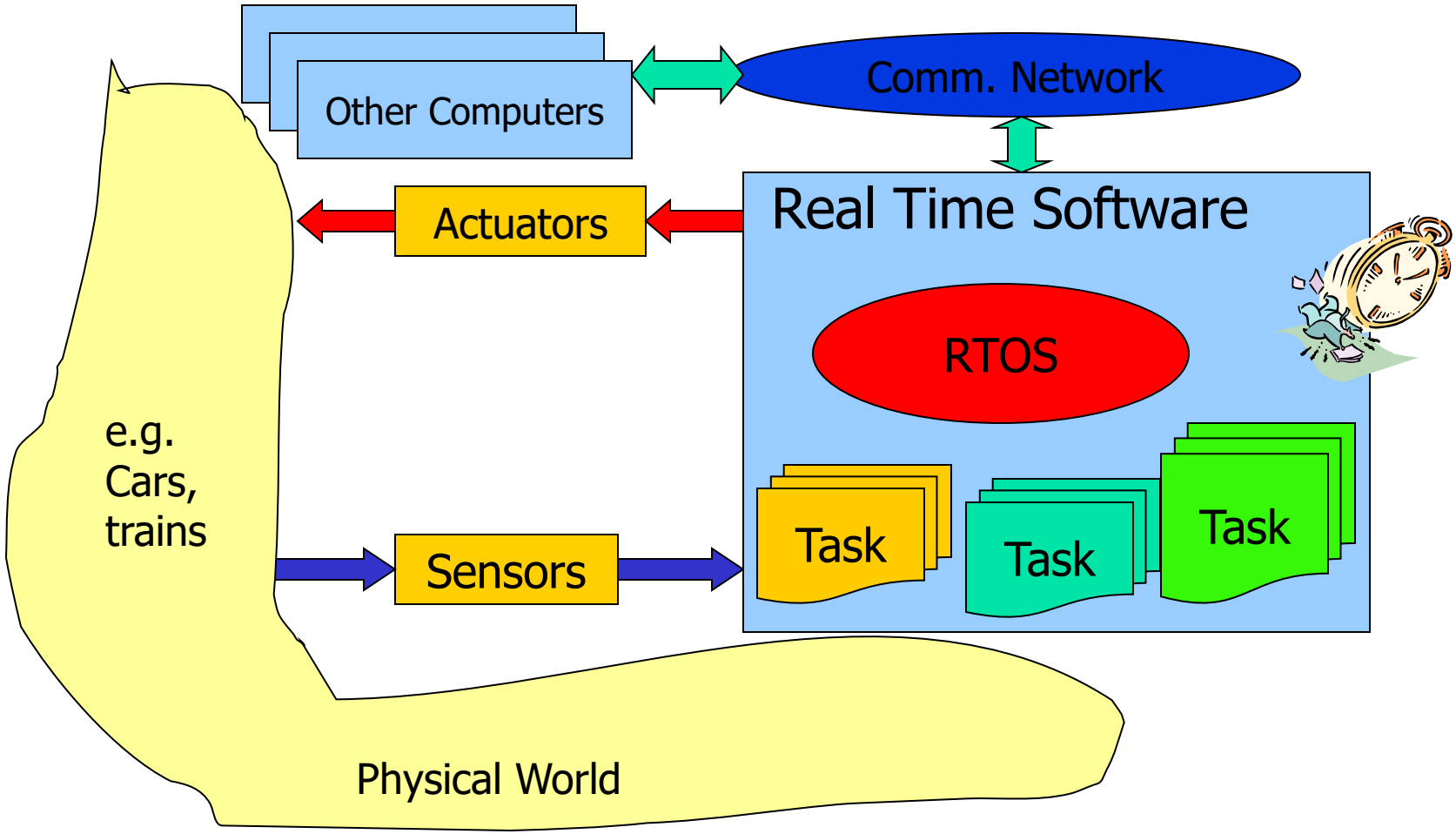


- Introduction
  - Characteristics of RTS
- Real Time Operating Systems (RTOS)
  - OS support: tasking, scheduling, resource handling, OSEK
- Real Time Programming Languages
  - Language support, e.g. Ada tasking
- Scheduling and Timing Analysis
  - Worst-case execitiom and response time analysis
- Distributed real time systems
  - Real Time Communication: CAN Bus
- Workload Models (advanced topic)
  - Graph-based task models
- Multiprocessor real-time systems (advanced topics)
  - Architectures and real-time scheduling
- Design and Validation (advanced topics)
  - Modeling and Verification

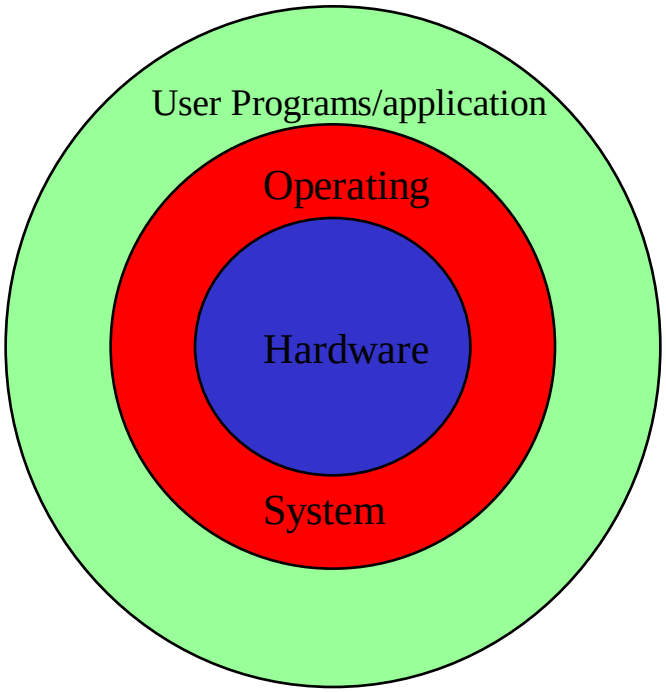
Overall Structure of RT Systems

- Hardware (CPU, I/O device etc)
  - a clock!
- A real time OS (function as standard OS, with predictable behavior and well-defined functionality)
- A collection of RT tasks/processes (share resourses, communicate/synchronize with each other and the environment)

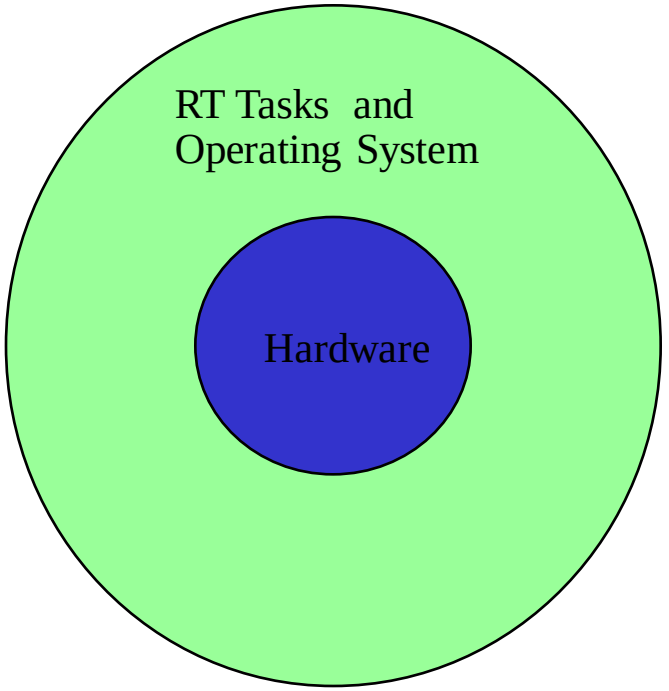
Components of RT Systems



General-Purpose vs. Embedded RT Computer Systems



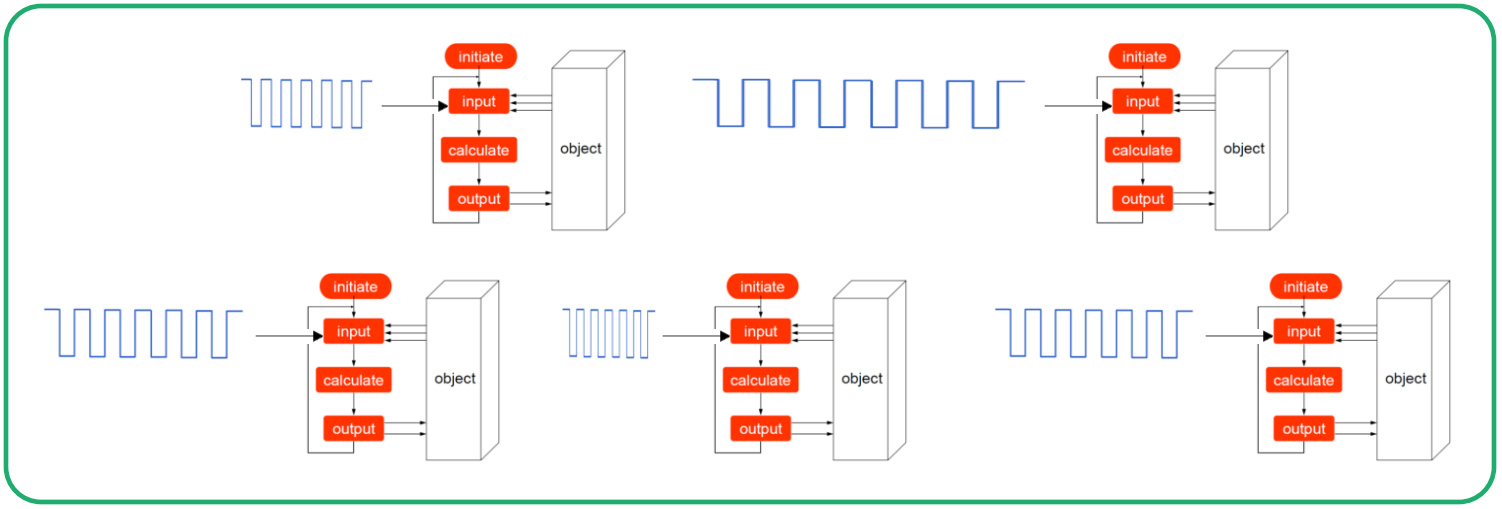
General-purpose computer systems



Typical Embedded Configuration
-- Real-Time Systems

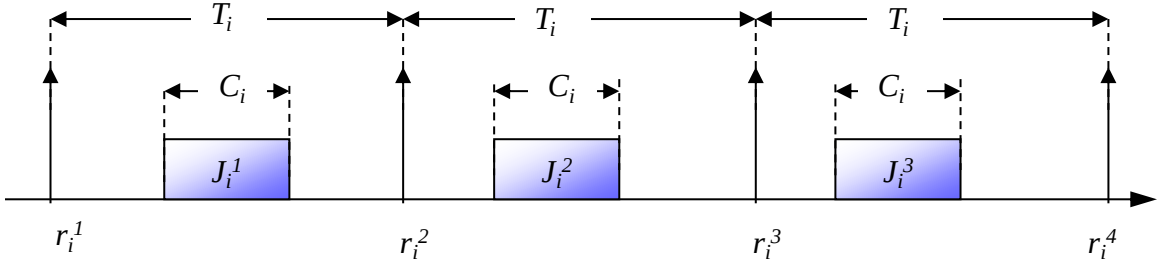
Embedded/Real-Time Software

- Multi-rate real-time tasks



- Each task

Utilization: C_i/T_i



Example: a Car Controller

Activities of a car control system. Let

1. C= resource budget (worst case execution time)
2. T= period (rate, 1/period)
3. D= deadline

- Speed control: C=4ms, T=20ms (50Hz), D=5ms
- Brake control: C=10ms,T=40ms (25Hz), D=40ms
- Engine control: C=40ms, T=80ms (12.5Hz),D=80ms
- Other software with soft deadlines e.g audio, air condition etc

Construct a controller meeting all the deadlines!

Programming the car controller (1)

Process Speed: Loop read sensor,compute,display... sleep (0.02) /*period*/ End loop	Process Brake Loop Read sensor, compute, react sleep(0.04) End loop
Process Engine Loop read data, compute, inject ... sleep(0.08) End loop	Soft RT Processes Loop read temperature el hiss, stereo .... End loop

Any problem?

- We forgot the execution times …

e.g. Process speed:

20ms = execution time + sleep(X)

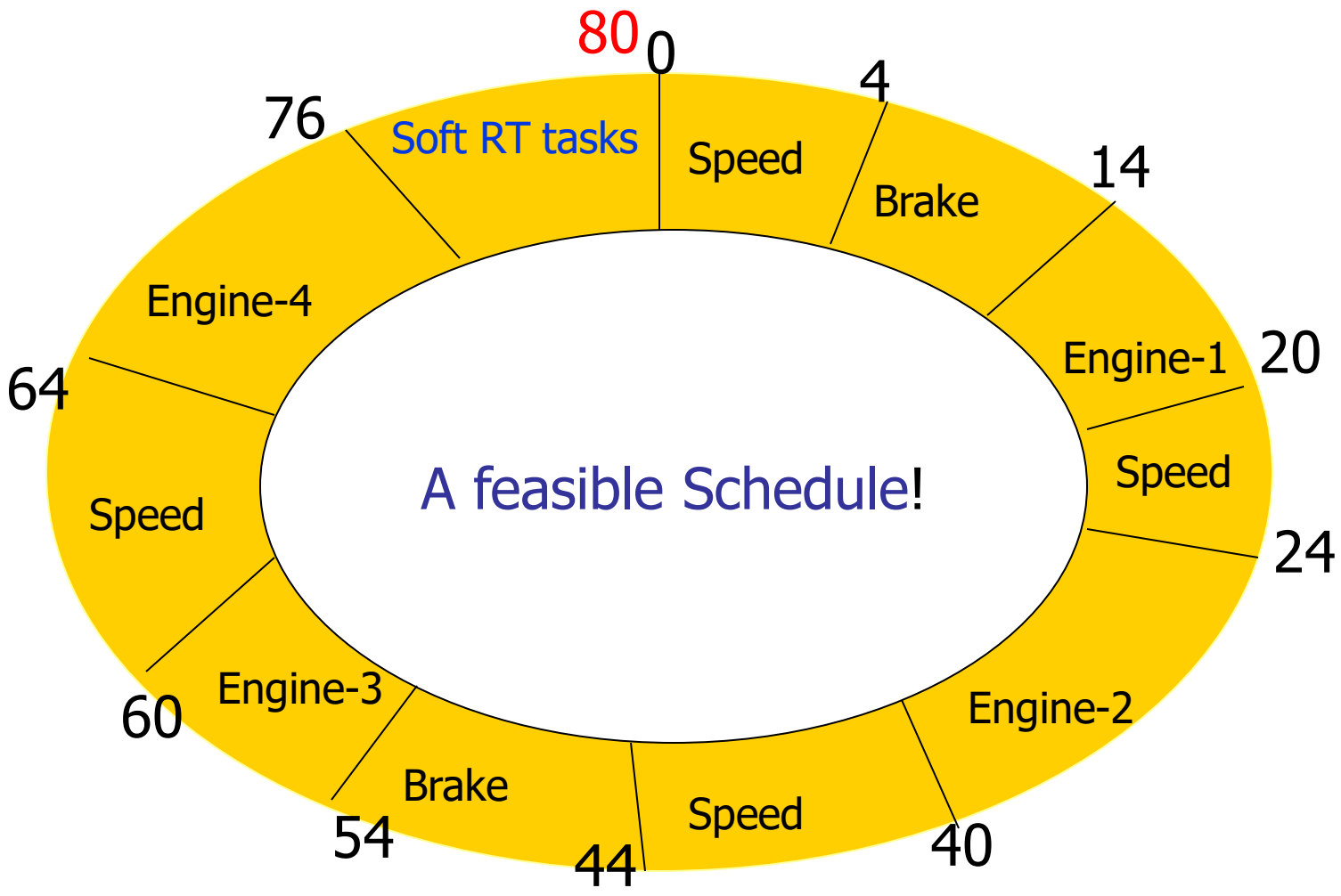
Programming the car controller (2)

Process Speed: Loop next := get-time + 0.02 read sensor,compute,display... sleep until next End loop	Process Brake Loop next:=get-time + 0.04 Read sensor, compute, react sleep until next End loop
Process Engine Loop next:=get-time + 0.08 read data, compute, inject ... sleep until next End loop	Soft RT Processes Loop read temperature elevator, stereo .... End loop

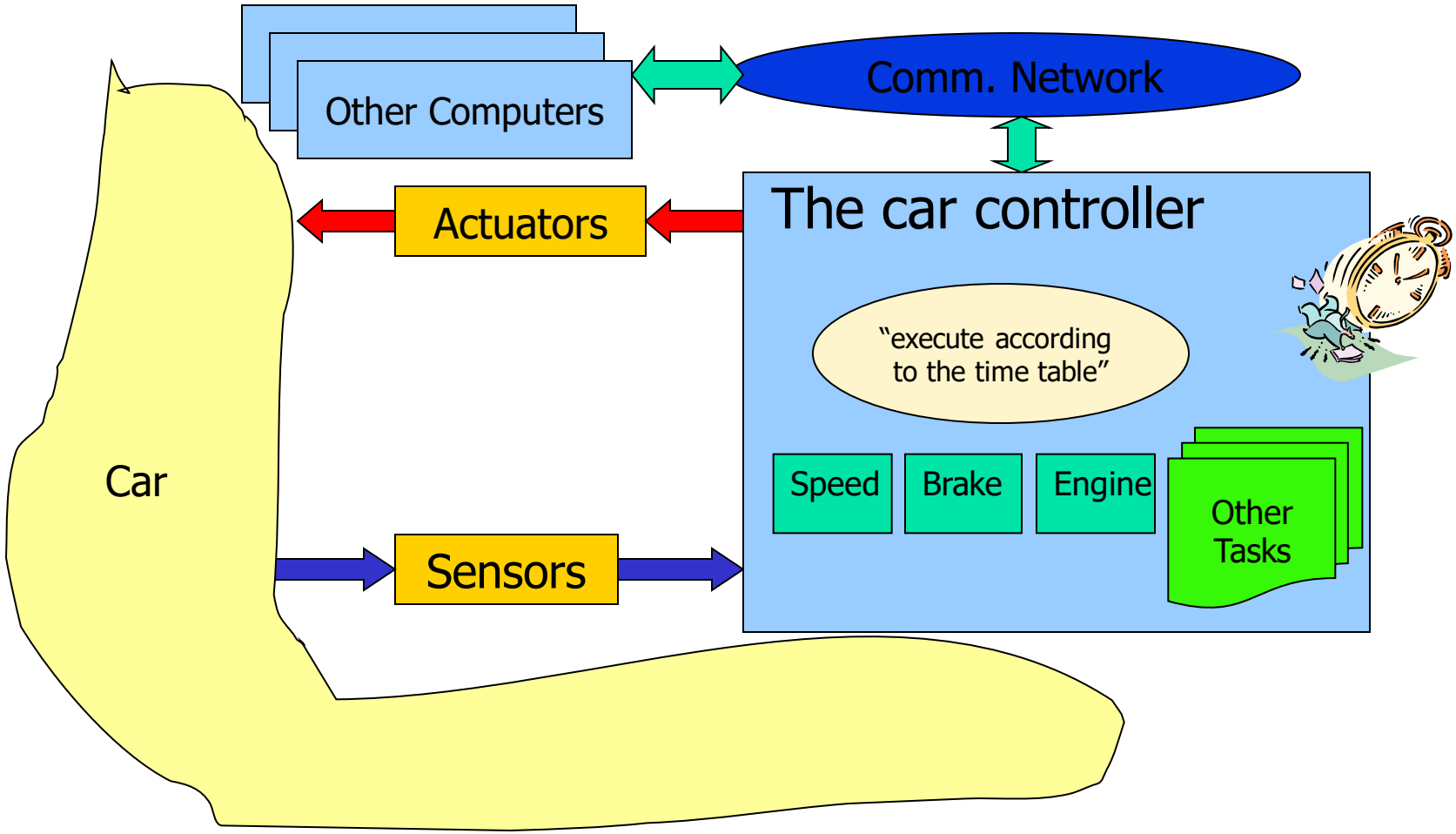
To ensure that the deadlines are not violated:

- We need to know the execution times
- We need to do schedulability analysis
- We need to construct a schedule

Programming the car controller (3)

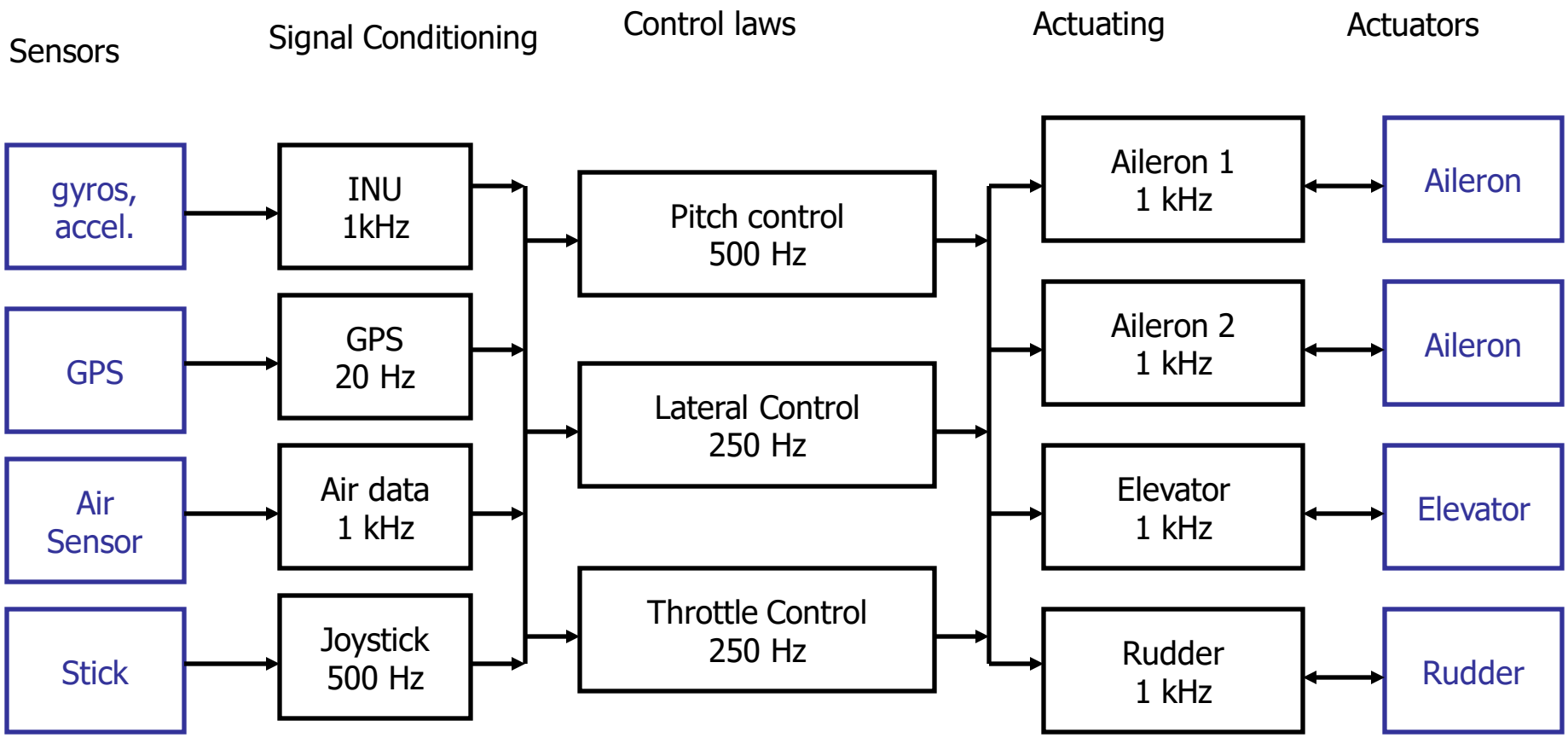


Components of RT Systems



Example: Fly-by-wire Avionics:

Hard real-time system with multi-rate tasks (Hz = #cycles per sec)



Challenges in RT Systems Design

- Predictability: the system behaviour is known before it is put into operation!

  e.g. Response times, deadlock freedom etc

- Certisfiability: provide clear evidance to show your system works reliably and safe according to ISO standards

  --- predictability is the key challenge

Challenges in RT Systems Design

- Cost optimality: e.g. Energy consumption, memory blocks etc
- Testability: easy to test e.g. any deadline miss?
- Robustness: must not collapse when subject to peak load, exception, manage all possible scenarios
- Fault tolerance: hardware and software failures should not cause the system to crash - down-grading
- Maintainability: modular structure for local changes

Difficult to achieve predictability: Hardware and OS

- Cache sharing, processor pipelines, multicores, DMA ...
- Interrupt handling may introduce unbounded delays
- Priority inversion (low-prority tasks blocking high-prior taskts)
- Memory management (static allocation may not be enough, dynamic data structures e.g. Queue), no virtual memory
- Communication delays in a distributed environment
- New hardware platforms ... Multicores

Difficult to achieve predictability: Software

- Difficult to calculate the worst case execution time for tasks (theoretically impossible, halting problem)
  - Avoid dynamic data structures
  - Avoid recursion
  - Bounded loops e.g. For-loops only
- Complex synchronization patterns between tasks: potential deadlocks (formal verification)
- Multi-tasking, tasks that share resources
- Software components provided by a third party