Threads

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Processes

- A process includes many things
  - An address space (defining all the code and data pages)
  - OS resources (e.g., open files) and accounting information
  - Execution state (PC, SP, regs, etc.)
- Creating a new process is costly because of all of the data structures that must be allocated and initialized
  - Recall `struct task_struct` in Linux
  - …which does not even include page tables, perhaps TLB flushing, etc.
- Communicating between processes is costly because most communication goes through the OS
  - Overhead of system calls and copying data

Multi-programming

- To execute parallel programs we need to
  - Create several processes that execute in parallel
  - Cause each to map to the same address space to share data
    - They are all part of the same computation
  - Have the OS schedule these processes in parallel
- This situation is very inefficient
  - Space: PCB, page tables, etc.
  - Time: create data structures, fork and copy addr space, etc.
- Solutions: possible to have more efficient, yet cooperative "processes"?

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Rethinking Processes

- What is similar in these cooperating processes?
  - They all share the same code and data (address space)
  - They all share the same privileges
  - They all share the same resources (files, sockets, etc.)
- What don't they share?
  - Each has its own execution state: PC, SP, and registers
- Key idea: Why don't we separate the concept of a process from its execution state?
  - Process: address space, privileges, resources, etc.
  - Execution state: PC, SP, registers
- Exec state also called thread of control, or thread

Threads

- Modern OSes (Mac, Windows, modern Unix) separate the concepts of processes and threads
  - The thread defines a sequential execution stream within a process (PC, SP, registers)
  - The process defines the address space and general process attributes (everything but threads of execution)
- A thread is bound to a single process
  - Processes, however, can have multiple threads
- Threads become the unit of scheduling
  - Processes are now the containers in which threads execute

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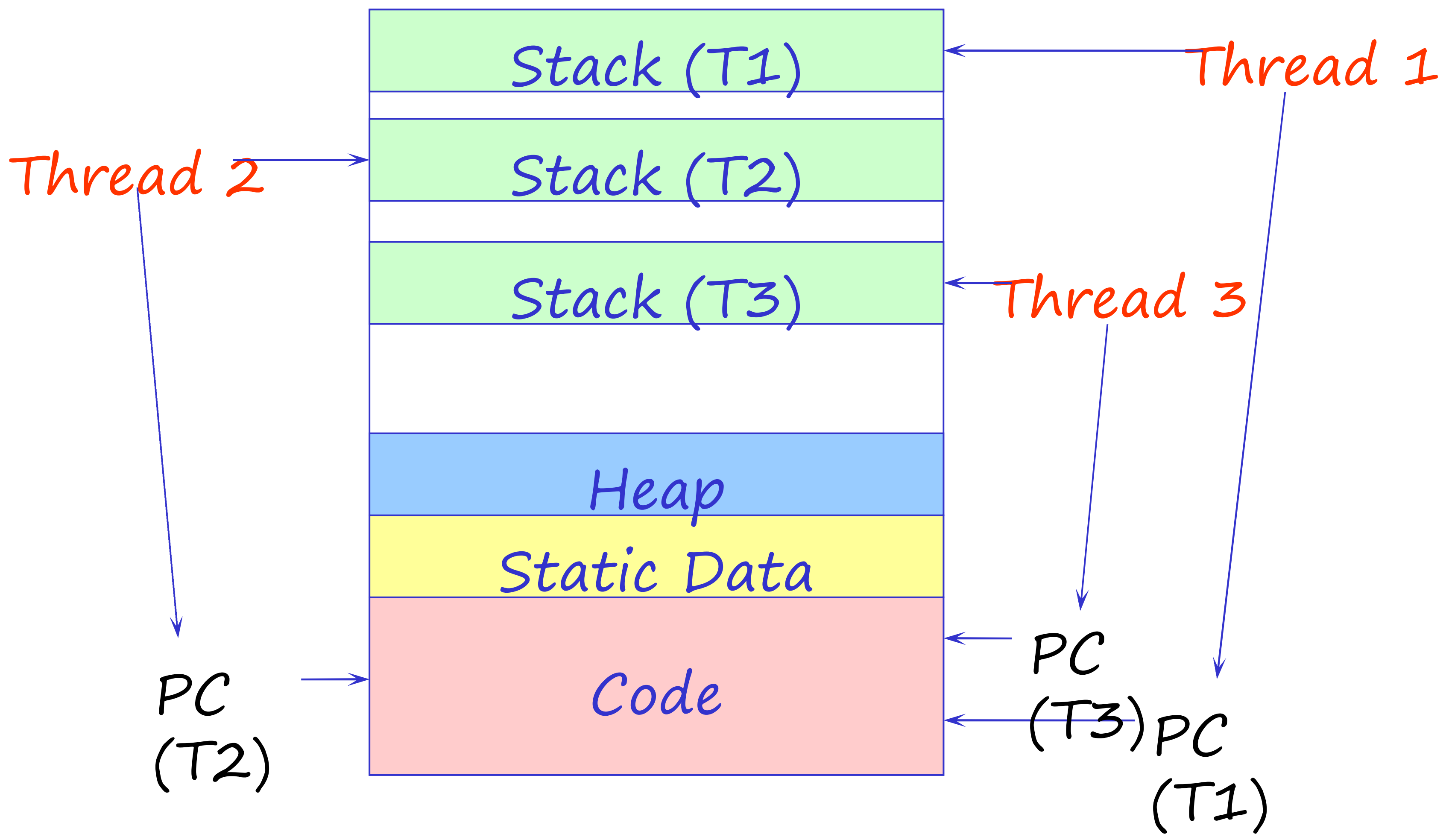
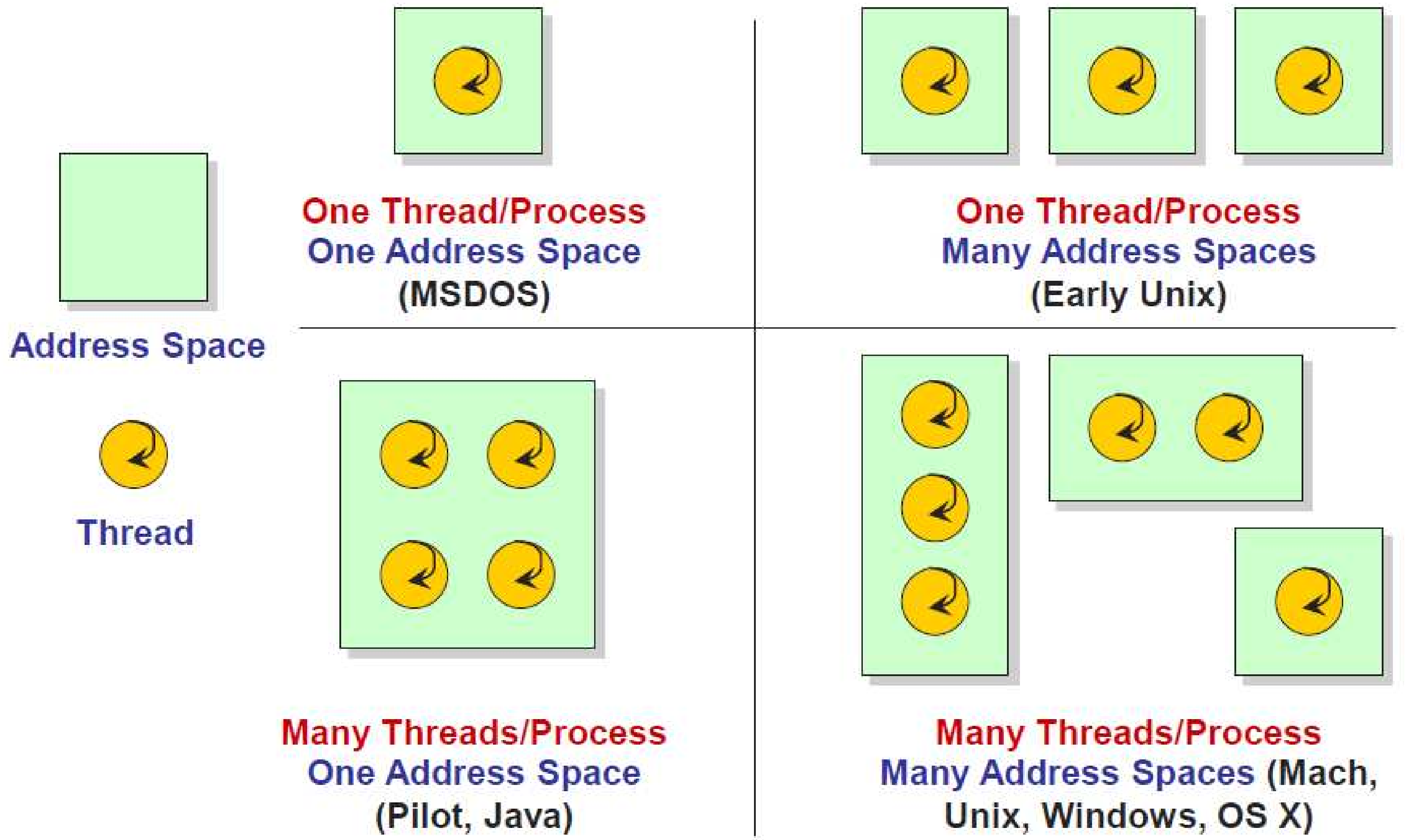
Threads in a Process



Thread Design Space



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