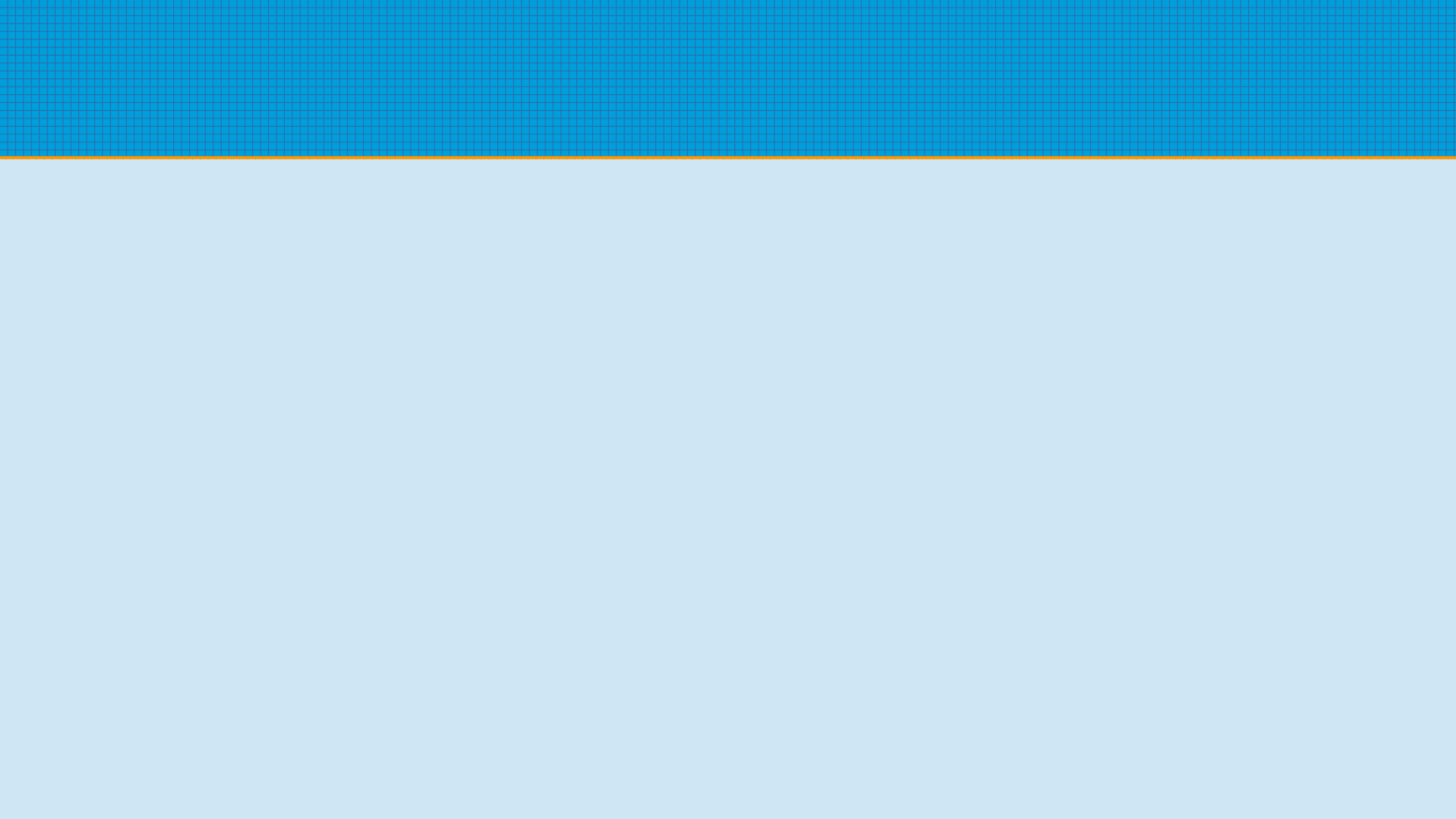


INF-2201

05 – Operating System structures

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2024

- How do we structure the operating system kernel?
- Monolithic
- Layered
- Microkernel
- Exokernels
- Virtual Machines



Monolithic systems

- Common structure for operating systems
- Everything in one "soup"
 - Everything has (in principle) access to everything else (runs in kernel context)
 - Can be efficient if you reduce the number of system calls / context switches
 - Subsystems often use other subsystems



Skype: "A monolithic operating system visualized as a pot of noodles with meat and vegetables."
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Monolithic systems

Will usually have some structure

- Subsystems
- Loadable modules (ex: Linux)
- Some division necessary to manage and understand the system



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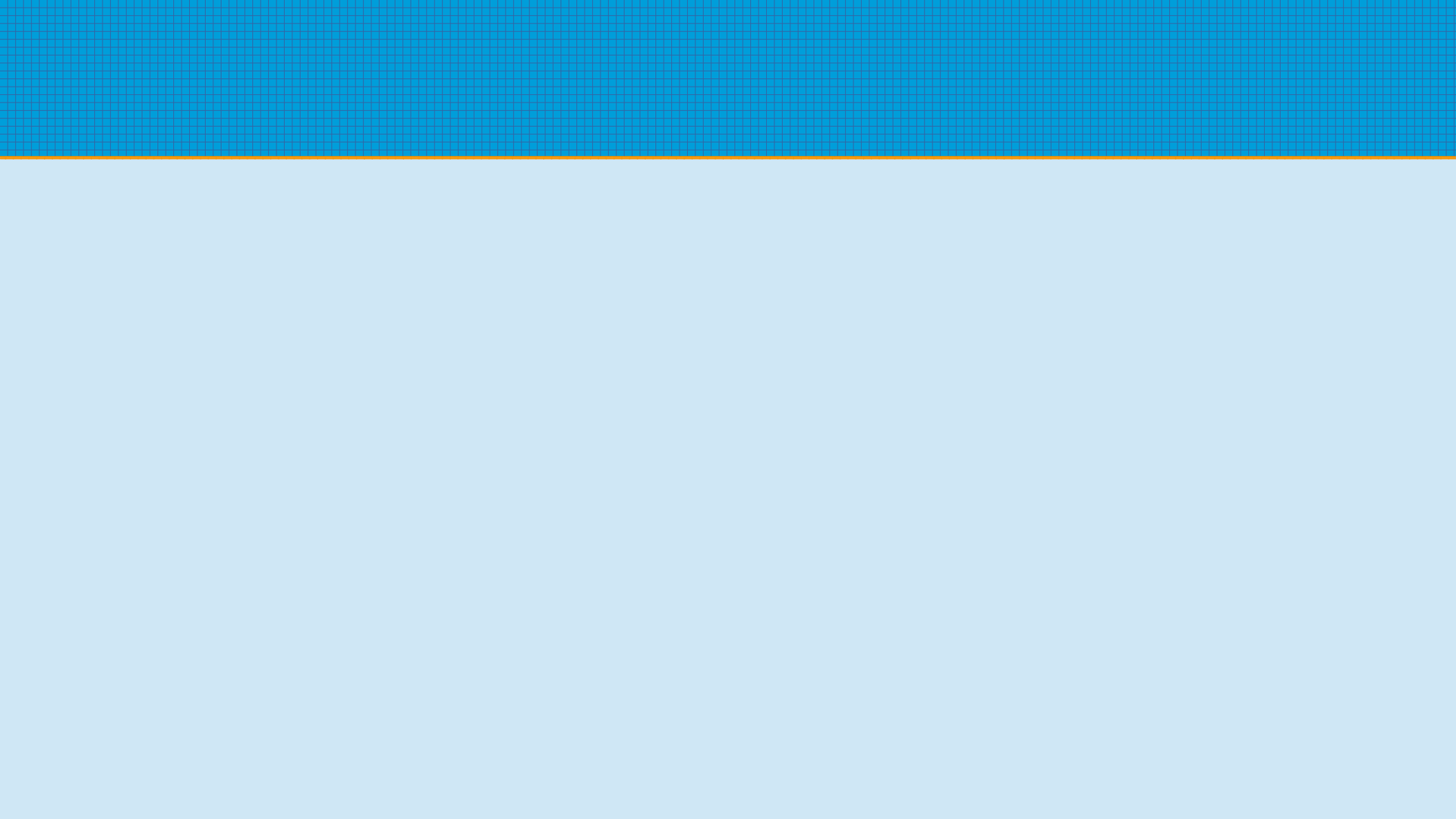
Monolithic systems

One main issue:

- Crashes in one subsystem may bring down the rest or make the system unstable
 - Overwriting memory
 - Leaving locks or other structures in an incorrect state



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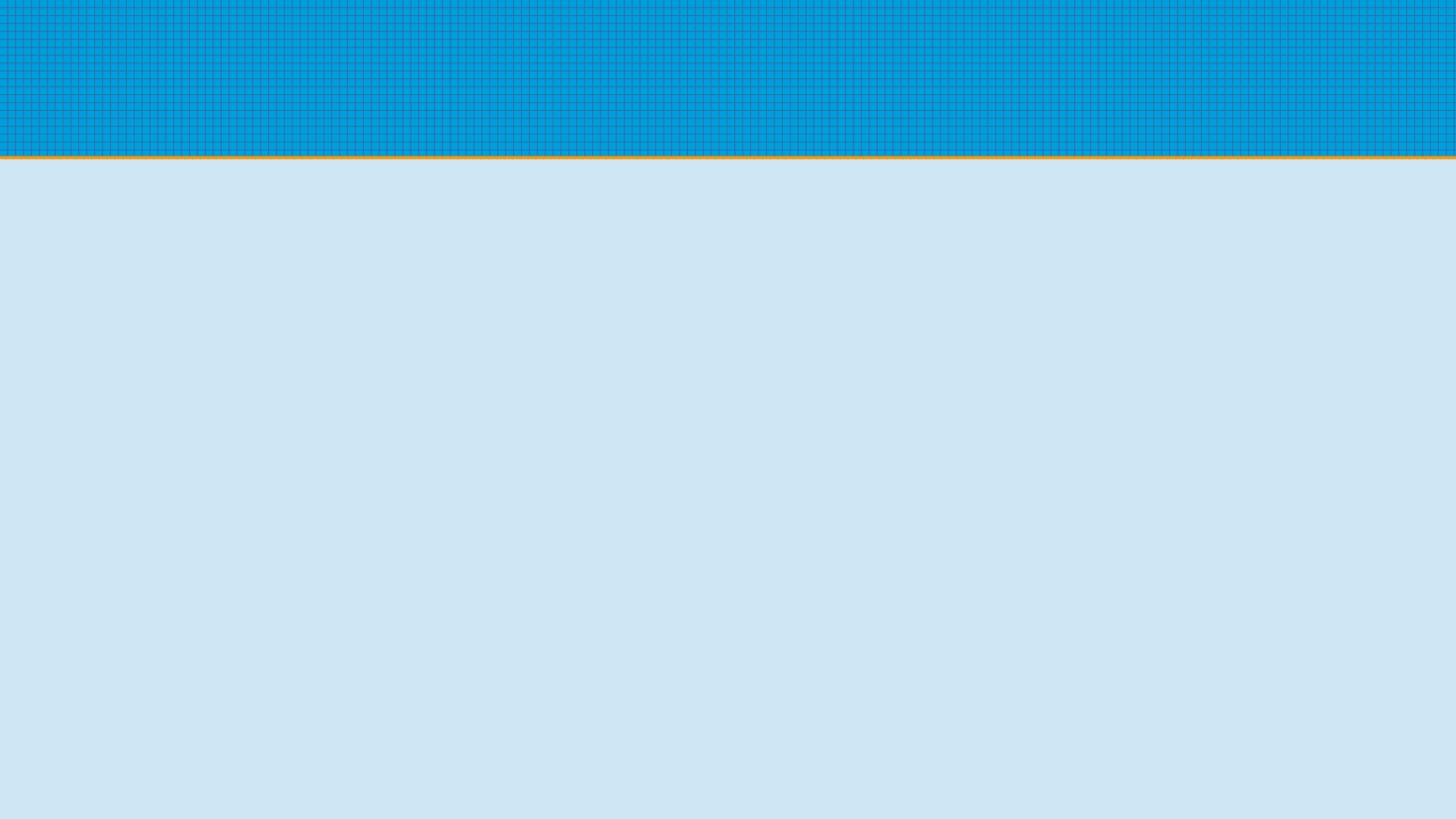


Layered systems

- Idea: clean layers with identified responsibilities
 - Layers above build on abstractions further down
- Examples:
 - THE (mostly a design principle)
 - Multics (uses rings instead of "flat" layers)
- Question: is it easy to define the right layers in practice to provide modern functionality? What builds on what?

Layer	Function
5	The operator
4	User programs
3	Input/output management
2	Operator-process communication
1	Memory and drum management
0	Processor allocation and multiprogramming

Figure 1-25. Structure of the THE operating system.
Modern Operating Systems, Tanenbaum & Bos



Microkernel

Idea:

- Minimalistic kernel
 - As little as possible inside the kernel – less complexity and hopefully fewer bugs
 - Only deals with permissions, protection and a way of communicating
 - Some systems put the mechanism in the kernel and policy in user level processes
- Services implemented in user level processes, like:
 - File systems
 - Device drivers

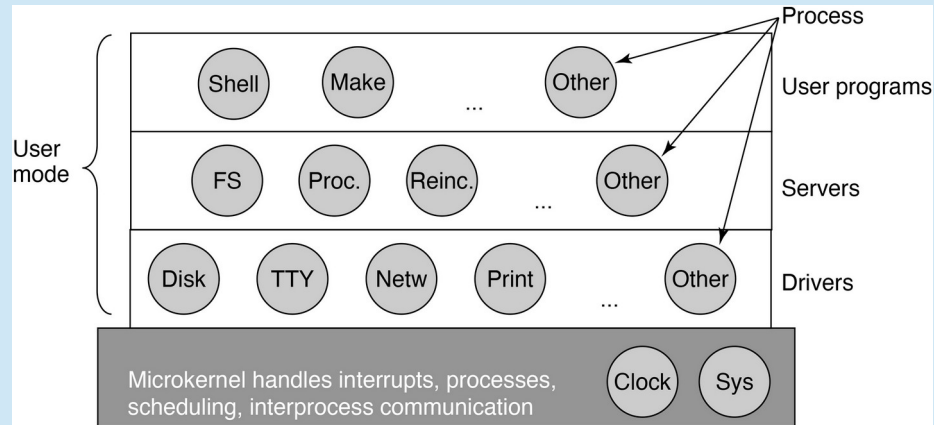


Figure 1-26. Simplified structure of the MINIX system.
Modern Operating Systems, Tanenbaum & Bos

Microkernel

- Communication between servers, drivers and user programs?
 - Message passing (Mach, Minix, ...)
- I/O?
 - Minix: send message to kernel

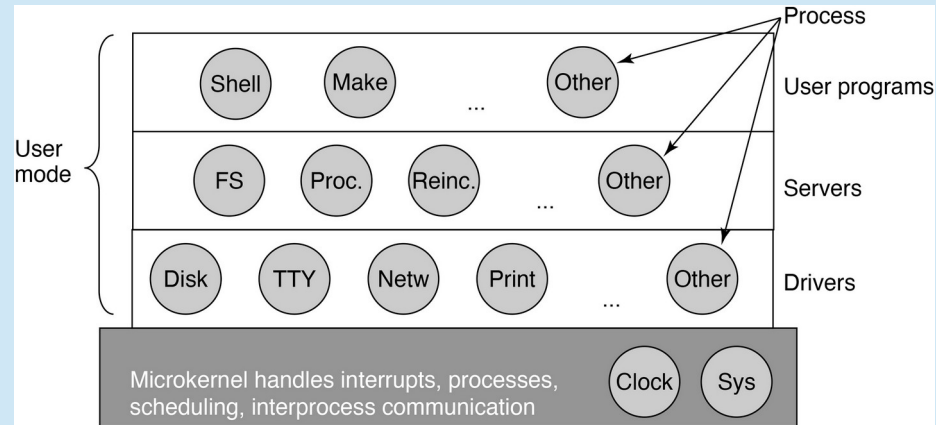


Figure 1-26. Simplified structure of the MINIX system.
Modern Operating Systems, Tanenbaum & Bos

Microkernel

- Examples:
 - L4
 - Formally verified version: seL4
 - QNX
 - Real time system
 - Also used in space
 - Mach
 - Also see XNU (for Apple users)
 - Fuchsia (Google) based on Zircon kernel
 - Minix

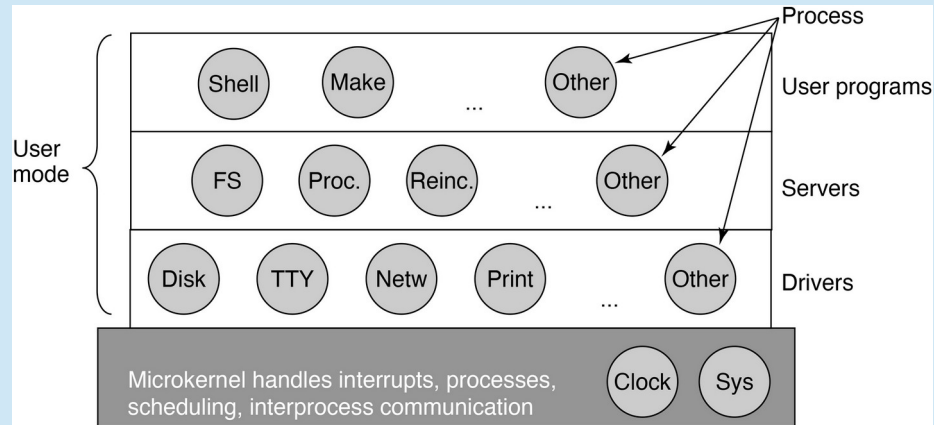
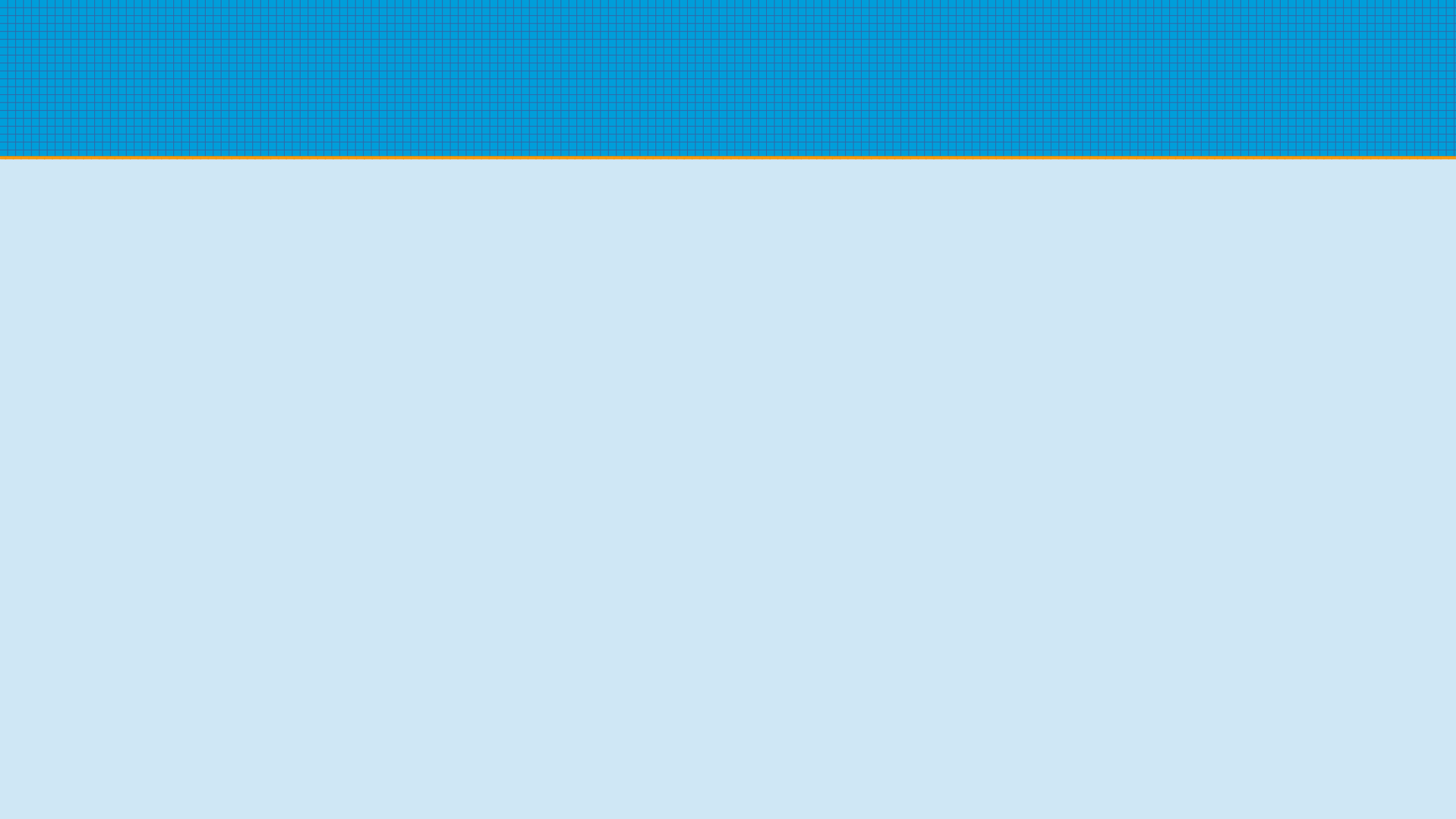
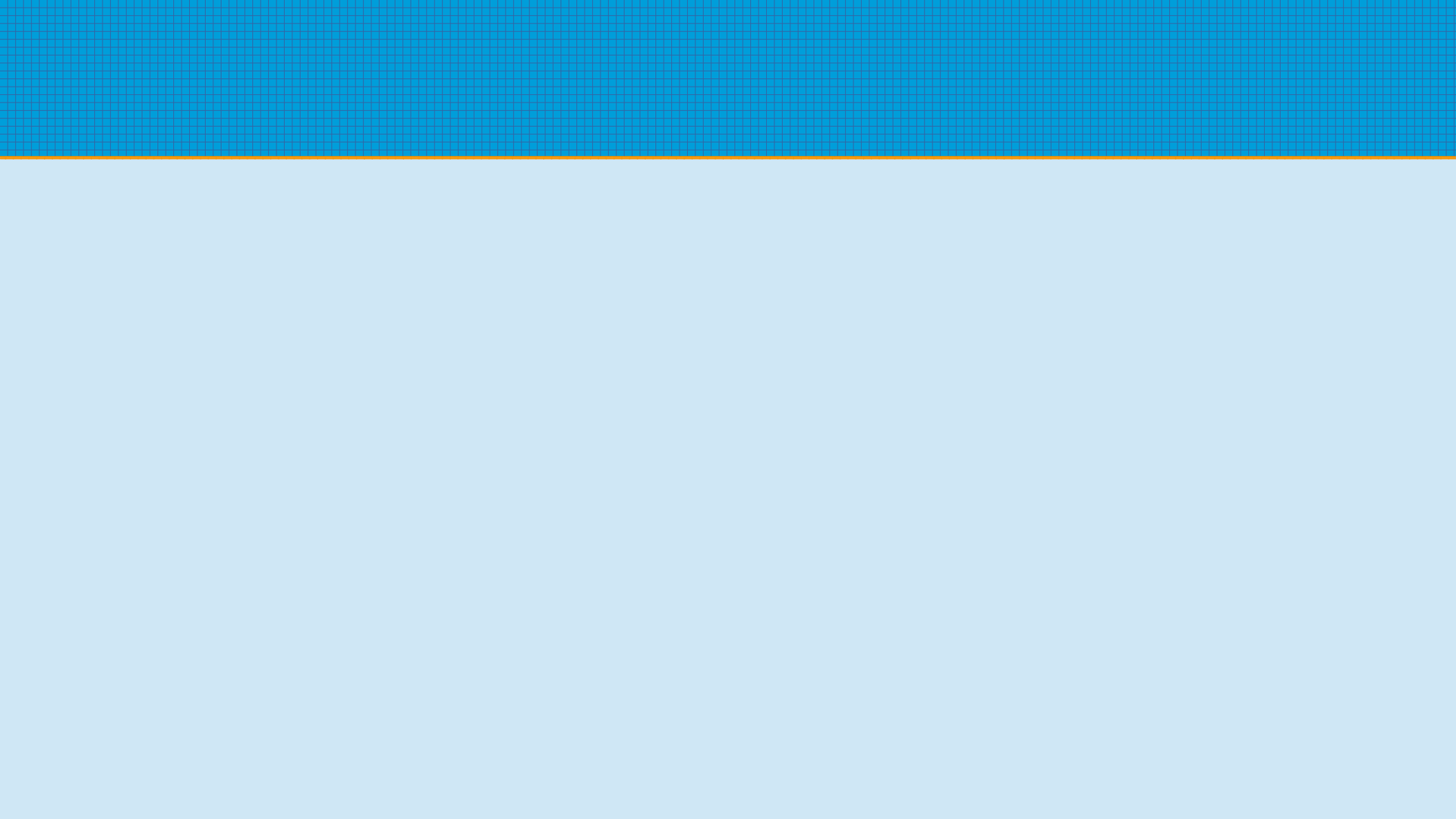


Figure 1-26. Simplified structure of the MINIX system.
Modern Operating Systems, Tanenbaum & Bos



Exokernel

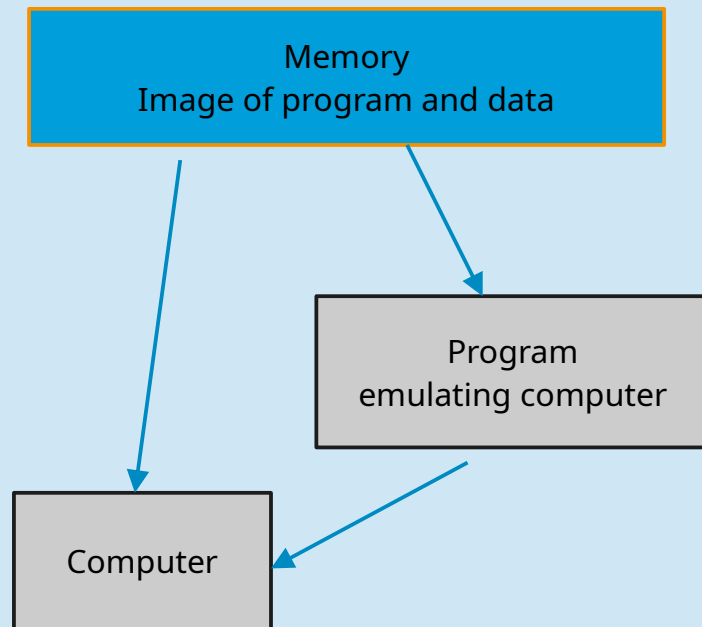
- Idea:
 - Tiny kernel
 - Don't provide abstractions that are not used by user
- Kernel partitions hardware
 - Higher level layers / library operating systems requests resources
 - Kernel assigns rights (if not used by others)



Virtual Machines

Idea

- Your computer is an implementation of an abstract idea (instruction set and architecture)
- We can implement the abstraction
 - As hardware
 - In software
 - As a combination of hardware and software



Virtual Machines

- The software idea 1: Java Virtual Machine (JVM)
 - Example of: interpret instructions and emulate instructions of an architecture.
 - Interpretation can be slow, but improved using binary translation (Just In Time (JIT) or pre-compiled)
 - Could also implement the instruction set in hardware.

Virtual Machines

- The hardware idea 1: IBM CP/CMS (1968) and IBM VM/370 (1970)
 - Make it an isolated copy of the real machine so that the software running inside thinks it's running on the real computer
 - Traps to OS treated as traps inside the VM!
 - Can run multiple versions of operating systems (or even different operating systems) at the same time
 - Applications or customers can get slices of the computer
 - Requires hardware support
- The idea took a long time before it was supported on commodity PCs

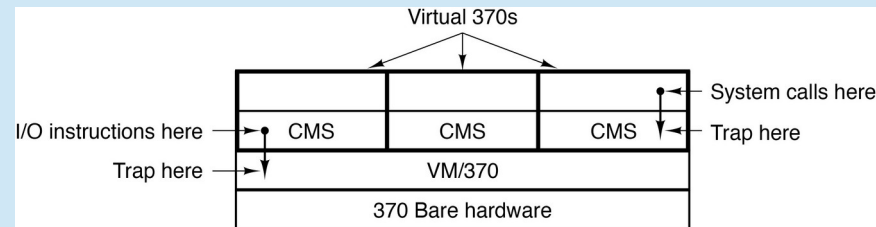


Figure 1-28. The structure of VM/370 with CMS
Modern Operating Systems, Tanenbaum & Bos

Virtual Machines

- The software idea 2: simulate real hardware
 - You have already started using one: bochs !
 - Interpret instructions and emulate instructions of an architecture.
 - More advanced uses binary translation (Just In Time (JIT) or pre-compiled)
- Still slower than running on the real hardware

Virtual Machines

- The software idea 2: simulate real hardware
 - You have already started using one: bochs !
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Virtual Machines

- The software idea 3: Type 2 hypervisors
 - PCs did not have VM hardware support, but OS kernels could give some support
 - Ex: Virtual Memory and shadowing of data to trap when modifying protected structures
 - Run a VM as a user level process, but use host CPU directly for user level instructions
 - Rewrite privileged instructions or trap to host OS kernel to support privileged instructions and modes
- Terms: Guest OS vs Host OS
- Getting closer, but still some performance gap

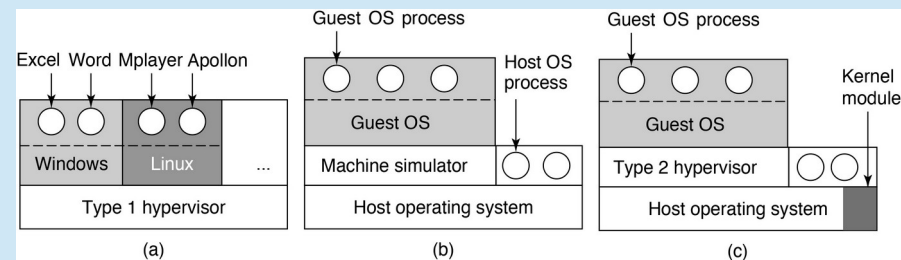


Figure 1-29. (a) A type 1 hypervisor. (b) A pure type 2 hypervisor. (c) A practical type 2 hypervisor.
Modern Operating Systems, Tanenbaum & Bos

Virtual Machines

- The software/hardware idea: Type 1 hypervisors
 - Add VM hardware support (ex: Intel VT-x, AMD-V)
 - Separate protection mode orthogonal to protection rings
 - Lets host computer expose a full computer inside a VM
 - Coordinate and manage VMs using a Virtual Machine Monitor or Type 1 Hypervisor
- Example: KVM

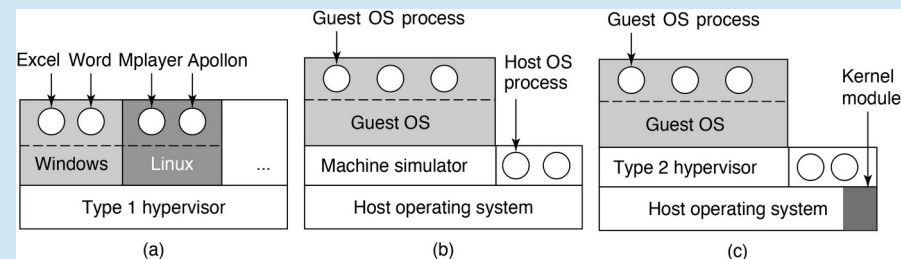
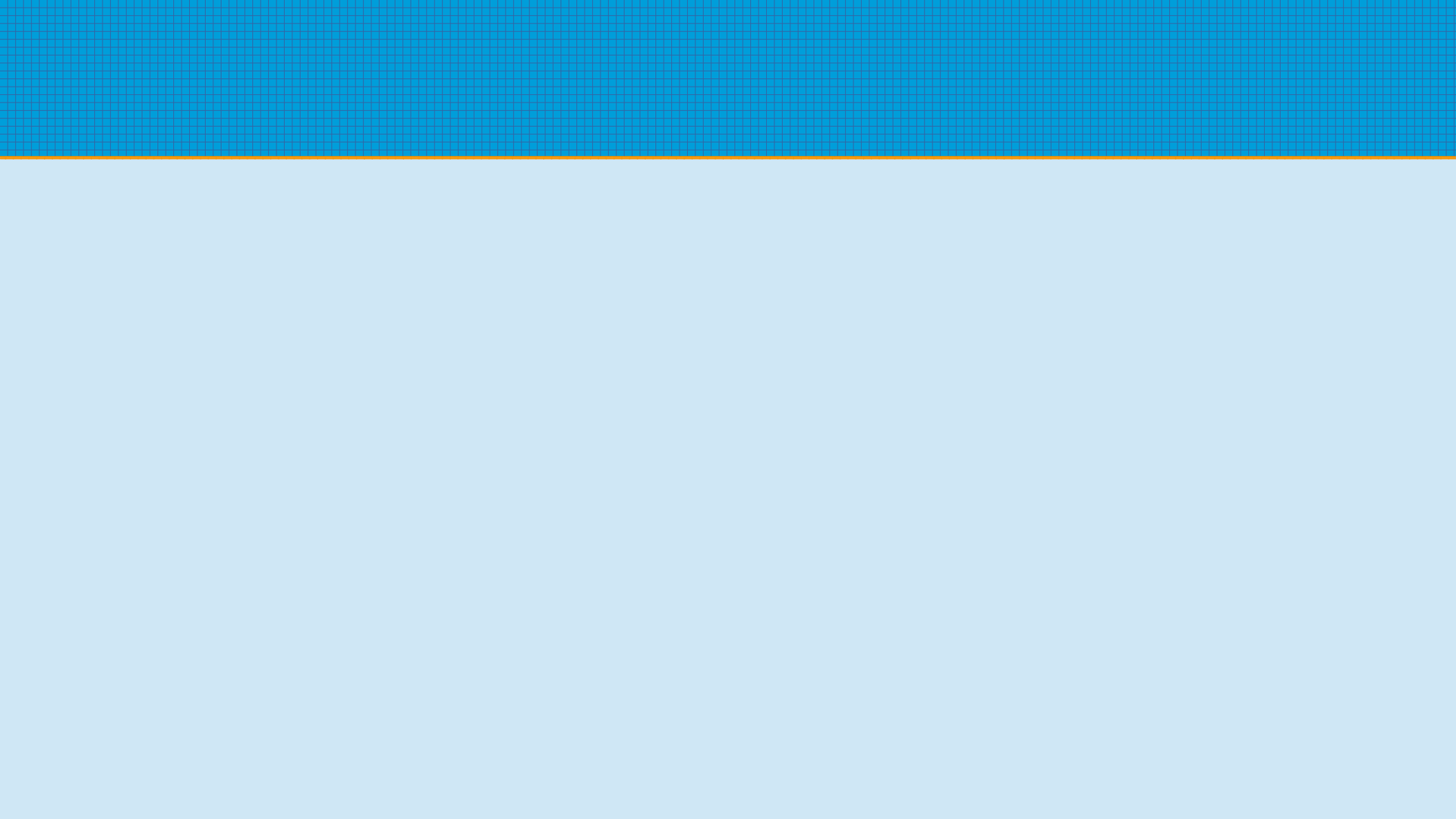
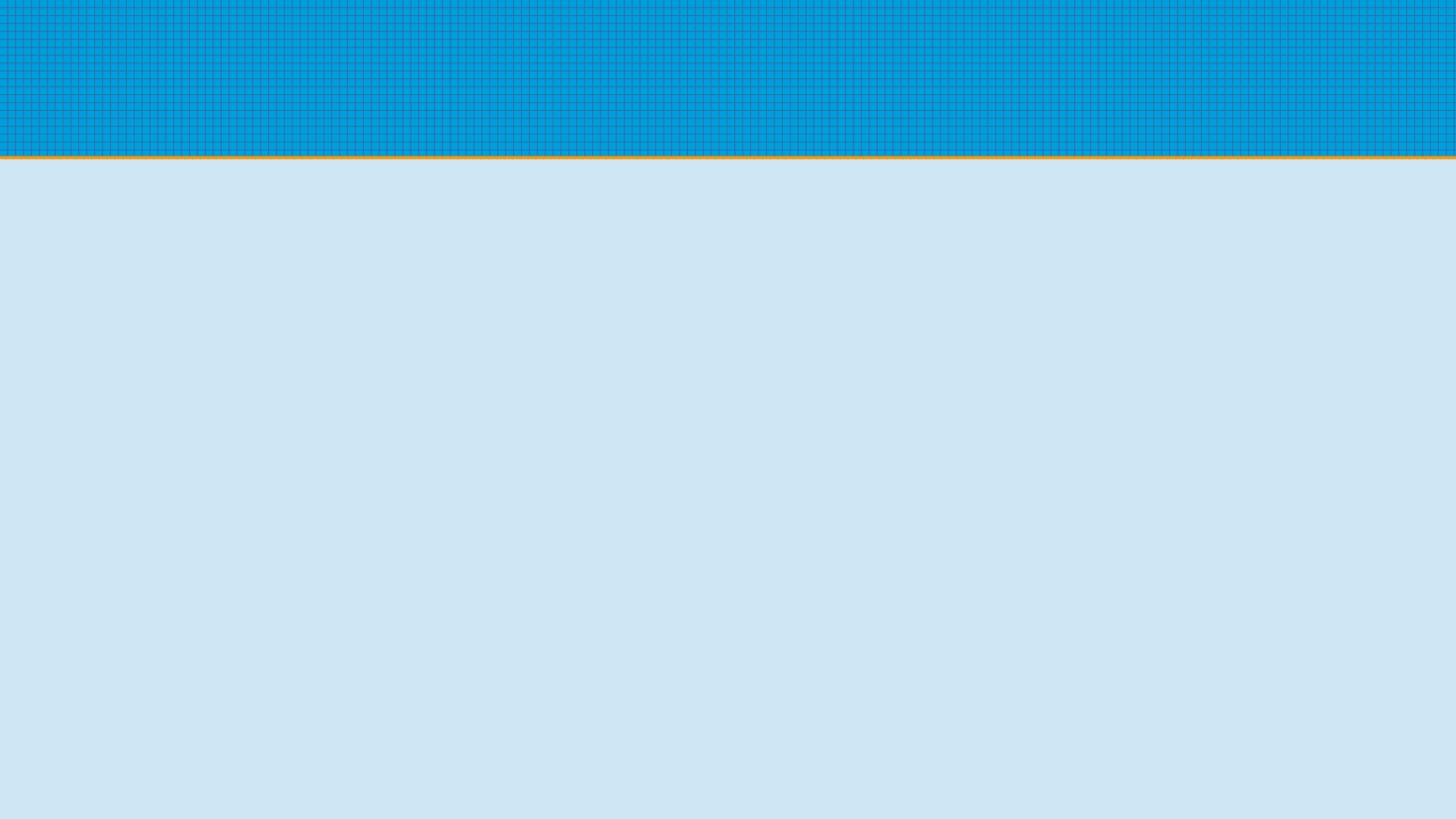


Figure 1-29. (a) A type 1 hypervisor. (b) A pure type 2 hypervisor. (c) A practical type 2 hypervisor.
Modern Operating Systems, Tanenbaum & Bos



Containers

- Idea:
 - Share kernel and resources with the host
 - Restrict the resources available and visible inside the containers
 - Low overhead (just runs as normal processes on the host)
- Simple example: chroot on Linux
 - Changes the "root" of the file system to a folder inside the host computer
 - The process that is contained inside the chroot environment shares the kernel with the host, but can only see the files inside the chroot environment.
 - Device files etc may not be visible (=> cannot access them)
 - Runs with the privileges of the user that the process was started with
 - Creates a "container" that limits access to the host system
- More advanced containers (LXC, Docker,):
 - Virtualize networks, devices and other resources in the operating system
 - More fine-grained restriction or exposing of resources
 - Tools for managing containers (move, copy, backup, configuration,)



Questions

- Why aren't we running everything that touches the internet in containers or VMs?
 - Browsers
 - ...