If the automobile had followed the same development cycle as the computer, a Rolls-Royce would today cost $100, get a million miles per gallon, and explode once a year, killing everyone inside.

-- Robert X. Cringely
1.1 Functions and Coarse Structure

Operating system (Definition according DIN 44300)

“The programs of a digital computing system which lay - together with the basic properties of the computing system - the foundation for the possible modes of operation and especially control and monitor the execution of programs.”

Main Tasks

- Provision of virtual machine
  - as an abstraction of the computer system
- Resource Management
Tasks

- Adaption of machine structure to user requirements
- Laying the foundation for a controlled concurrency of activities
- Management of data and programs
- Efficient usage of resources
- Support in case of faults and failures
Operating system architecture

- Quotation:
  "The job of a system architect is similar to the one of a witty octopus juggling daily new balls of different size on the back of a jumping dolphin at the shore of Waikiki."

New applications

Operating system

New Hardware

Market
Quality features:
- Security
- Real-time
- Mobility
- Energy consumption
- Dependability
- ....

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Operating systems for general purpose computers

- Operating system: Control
  - Application
  - Application
  - Application

- Operating system: Management and operation

Hardware

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System architecture

- Complex systems (in all areas) are composed of single components of different types.
- Successful design of a complex system requires the knowledge of different variants of the components and their interplay.

Example: Buildings (20 000 years of experience)

- Walls
- Columns
- Ceilings
- Roofs
- Stairs
- Doors
- Windows

Material
Form
Strength
System architecture

- **Example Electrical Engineering (ca. 120 years of experience)**
  - Resistor
  - Coil
  - Capacitor
  - Diode
  - Tube
  - Transistor

- **Example Operating systems (ca. 60 years of experience)**
  - Process
  - Signal
  - Address space
  - Channel
  - Interrupt
  - Driver
  - File
  - Capacity
  - Synchronization
  - Type of message transfer
1.2 Historical Sketch

The Fifties (Early stages)

- *One* program is being executed by *one* processor.
  - Batch operation
- The Operating system functionality is limited to
  - support of input/output,
  - transformation of number and character representation.
The Sixties (Virtualization)

- The ratio between CPU- and I/O-speed becomes large.
- OS support the interleaving execution of several independent programs (Multiprogramming).
- Real parallelism due to the advent of I/O-processors.
- The notion of a process as a virtual processor is born.
- Also the memory is „virtualized“ (virtual memory).
- The process also becomes an internal mean of structurization for OS.
- Interactive operation by more than one user (Timesharing).
- Prototypes or predecessors of today’s mainframe OS are developed (OS/360, CTSS/Multics, CP67, VMOS/BS2000).
The Seventies (Software Engineering)

- The beginning of the software crisis: OS become large, complex and error prone.
- Unix is built according to the principle „simple is beautiful“ based on simple hardware (PDP-11).
- The quest for structured system design, maintainability, reliability, protection and security comes up.
- Employment of high level programming languages to implement OS.
- Process becomes a protection domain (context) with a private protected address space and access control (rights, capabilities).
- Quest for support of modular programming abstract data types and object orientation.
- Application of these principles to the operating system itself.
The Eighties (Distributed Systems)

- Workstation computers and personal computers come up.
- Increased communication bandwidth: Ethernet, connected systems.
- For efficient implementation of communication software processes are needed.
- Processes are meanwhile complex entities: A process switch costs several thousand machine instructions. Therefore, address space and process are separated allowing for several processes sharing an address space (*lightweight process, thread*).
- Concepts for parallelism are integrated into program languages.
- Distributed (parallel) computing on networks of workstation computers.
- Workstations provide an ideal means for dissemination of UNIX and UNIX becomes sort of a “standard”.
- Necessity for integration generates pressure for standardization (OSI, TCP/IP, NFS, POSIX, OSF, X/OPEN, OMG, ODP).
- OS overcome node boundaries: From communicating computers to distributed systems.
Due to high production numbers, microprocessors become cheap.

Connecting thousands of microprocessors achieves (theoretically) higher performance at a lower price compared to supercomputer (e.g. Cray).

New OS-Functionality needed to support parallel processing.

PCs and GUIs for OSs become mainstream (Windows 3, Linux).

Multimedia-applications require support for audio- and video data (real-time capabilities).

Software in embedded systems needs OS-support (e.g. Consumer Electronics).

Birth and rise of the Web leading to distributed systems in heterogeneous environments (e.g. Corba, Web services).
The 2000s and Today

- Computing technology moves into the everyday while becoming increasingly small and invisible.
- OS support for ubiquitous and pervasive computing and intelligent devices (cf. Internet of things)
- OS platforms for mobile phones with multi-touch user interfaces (e.g. iOS and Android OS)
- Thin clients running web-applications within a browser (e.g. Chrome OS)
- Emulation of other OS-interfaces (i.e. several “OS worlds” on the same computer).
- Converged infrastructures, shared services and the renaissance of virtualization are enabling factors for Cloud computing.
Current topics

- Safety and security
- Robustness and dependability
- Virtualization
- Optimization for multi- and many-core processors (scheduling, locking)
- Energy consumption (mobile devices, data centers)
- User interface
- Database support for file systems
- Cluster-, Grid-, and Cloud-Computing
- Small OS (e.g. for sensor networks)
Further Reading

• Hansen, P.B.: Classic Operating Systems
  Springer, New York, 2001

• The Virtual Museum of Computing
  http://vlmp.museophile.com/computing.html

• ACM Special Interest Group on Operating systems:
  http://www.sigops.org
Example: UNIX

- USG/USDL/ATTIS/DSG/USO/USL
- Bell Laboratories Research (AT&T)
- Berkeley Software Distribution
- Multics
  (Ken Thompson, Dennis Ritchie, Brian Kernighan)
- UNIX First Edition
- Fifth Edition
- Sixth Edition
- 1965
- 1969
- 1973
- 1976
- 1977
- 1978
- 1979
- 1980
- 1BSD
- 1BSD
- 2BSD
- 3BSD
- 4.0BSD
- 3BSD
- 32V
- 2BSD
- UNIX RT
- Seventh Edition
- CB UNIX
- PWB MERT CB UNIX
- UNIX RT
- XENIX (Microsoft, SCO)
- 1977
- 1978
- 1979
- 1980
- 3.0
- 3.0.1
- 1979
- 1980
- 32V
Example: UNIX

- 3.0.1 (1981)
- 4.0.1 (1981)
- 5.0 (1982)
- System III (1982)
- 5.2 (1983)
- System V (1983)
- SunOS (1987)
- 2.8BSD (1984)
- 2.9BSD (1985)
- 4.0BSD (1984)
- 2BSD (1984)
- 4.1BSD (1985)
- 2.8BSD (1985)
- 4.1aBSD (1985)
- 4.1cBSD (1985)
- 2.9BSD (1985)
- 4.2BSD (1986)
- 4.3BSD (1986)
- 4.3BSD-Tahoe (1986)
- 2.10BSD (1986)
- 2.11BSD (1986)
- MACH (1986)
- XENIX 3 (1986)
- XENIX 5 (1987)
- SunOS3 (1987)
- SunOS4 (1988)
- SunOS5 (1988)
- NeXT Step (1988)
- System V (1988)
- Chorus V3 (1989)
- System V (1989)
- System Release 3 (1989)
- Chorus Release 3 (1989)
- Chorus Release 2 (1989)
Example: UNIX
More information ;-) 

- **Halt and Catch Fire**