Lesson Outline

- Operating Systems
  - Purpose
  - Development
  - Types
  - Early OSes
  - CTSS
  - Multics
- Digital Equipment Corp. and Minicomputers
- Control Data Corp. and Supercomputers
- IBM System/360
- Other Noteworthy Events of the 1960s
Operating Systems

◆ Purpose:
  • Interface to system components
    • Resource Abstraction
  • Manage multiple tasks
    • Multiple jobs, users, etc.
    • Resource Sharing
  • Provide an Application Programming Interface (API) that makes the job of programming easier
    • “Canned” functions (I/O, files, timing, etc.)

◆ Attributes:
  • Run on “raw” hardware
    • Hide hardware details from programmer
  • Manage the hardware resources
  • May provide a “user interface” (much later)
Operating System Development

- **IOCS**
  - Input/Output Control System
  - Allowed programmer to “call” a subroutine to perform I/O operations
    - Didn’t have to rewrite I/O code for each program
    - Didn’t have to understand all aspects of I/O devices

- **Task (or “Job”) Management**
  - Control different steps of a process (e.g., compile and execute)

- **Resource Sharing (Multiprogramming)**
  - CPU speed grew faster than I/O speeds
  - Assume
    - 1 MIP CPU
    - 5,000 instructions to process a “record” or “transaction”
      - 200 transactions per second potential processing speed
    - Average disk or tape access time of 200 ms (probably low)
      - 5 reads (or 2.5 reads and writes) per second
  - Could process 40-80 records in same elapsed time
Operating System Development

- Interleaving Program (or User) Execution
Operating System Types

- **Batch (single job)**
  - Ran one “job” (one or more steps) at a time
  - Provided system services (e.g., IOCS) to that job
  - Queued and started next job at end of previous job
    - Might have job scheduler
    - Might allow overlapped printing
      - SPOOL – Simultaneous Peripheral Operation On-Line

- **Batch Multiprogramming**
  - Ran multiple jobs at a time (in Partitions)
  - Jobs submitted through cards
    - JCL – job control language
  - Output might consist of printout, punched cards, and/or tape
    - (or, of course, disk, if available)
Operating System Types

- Time-Sharing Systems
  - Runs user sessions instead of jobs
  - Interactive interface, rather than batch submission
  - Assumes:
    - Each user has a terminal that can communicate with system
      - Teletype/TTY (later VT100 or “glass teletype”)
    - System can handle I/O to multiple terminals “concurrently”
  - Earliest systems strictly command-line
    - Much like Unix terminal window or DOS screen
  - Various kinds of programs:
    - Editor (usually for programs, not text)
    - Compiler
    - Interpretive languages
      - BASIC, APL, scripting language, etc.
    - Ability to run user’s or other pre-compiled programs
      - Maybe a “debugger”
  - Programs tended to use predominantly terminal I/O
A Sampler of Early Operating Systems

◆ General Motors Research Center OS (unnamed), 1955
  • Basic supervisor for IBM 701
◆ FMS (FORTRAN Monitor System), late 1950s
  • IBM FORTRAN environment for 7090/7094
◆ UMES (University of Michigan Executive System) 1958
  • Descended from GM Executive System
  • MAD (Michigan Algorithmic Decoder) ran under UMES, IBM 704
◆ IBSYS, early 1960s
  • IBM programming environment for 7090/7094 (subsumed FMS)
◆ MCP (Master Control Program), 1961
  • Burroughs B5000 and successors
  • Written entirely in ESPOL (Executive Systems Programming Language, an extension of Burroughs ALGOL), a “first”
◆ SABRE (Semi-Automatic Business Environment Research, renamed for copyright reasons), 1960
  • Built by IBM for American Airlines reservations, 7090 (later 360)
  • Based on knowledge gained from SAGE (1955-1963-1983)
◆ CTSS and Multics (see following pages)
CTSS (Compatible Time-Sharing System)

- **First Time-Sharing System**
  - Each user had impression of a private machine
- **Developed at MIT’s Computation Center**
  - Eventually part of Project MAC (Man And Computer, also Multiple-Access Computer)
  - Ran on modified 7094s
    - Two banks of core, one for users and one for CTSS itself
  - Operational in 1961, used until 1973
- **Compatible with FMS**
  - FMS ran under CTSS
- **Early implementations of now-common applications**
  - Text formatting
  - Inter-user Electronic Mail
  - RUNCOM “shell script”
- **Demonstrated that time sharing was practical and useful**
  - Paved the way for future TS systems
  - Led to Multics project
Multics, 1963-1985

- “MULTIplexed Information and Computing Service”
- Also developed at MIT’s Computation Center
  - Joint project with AT&T Bell Labs, General Electric
- Goals:
  - Provide for Time-Sharing and Batch processing
  - Produce a Computing Utility (like electricity or telephone)
    - Scalable, Modular, Resilient
- Unique concepts/inventions:
  - Single-level store
  - Dynamic linking
  - One-line reconfiguration
    - Memory, disks, CPUs, etc., could be added or removed while system continued to operate
  - Secure OS design
- Ran on GE 645
  - Modified 635 to add virtual memory (and security)
    - IBM did not want to add this facility to the S/360 at the time
  - Later ran on Honeywell 6180 series
Multics

◆ Written in PL/I Language
  • Descendent of COBOL, FORTRAN, and ALGOL!
  • Designed by committee, never became dominant (more later…)

◆ Problems:
  • PL/I compiler was late, buggy
  • Project was very ambitious, took much longer than expected
  • Different expectations from partners
    • MIT: research and academic focus
    • GE: commercial operating system
    • ARPA (DoD): secure system for military and defense
  • By 1969, project was stalled under its own weight

◆ In 1969, Bell Labs left the project (too late & expensive)
  • Two Bell Labs employees, Ken Thompson and Dennis Ritchie
    returned to AT&T with many new ideas

◆ Went online at MIT in 1969

◆ In 1970, GE sold its computer business to Honeywell
  • Honeywell continued Multics development until 1985
  • Eventually installed at 80-100 sites

◆ Perhaps the most ambitious and influential OS ever
Digital Equipment Corp. (DEC)

- Produced PDP-1 in 1961, then 12-bit PDP-5 in 1963
- Followed by PDP-8 in 1964
  - 12-bit processor
  - All-transistor
  - Cost about $16,000
  - Used Teletype ASR-33 as user input/output device
  - Generally regarded as the first real “minicomputer”
  - Sold over 50,000 systems
- Small size allowed imbedding in other devices
- Often programmed by users or by “OEM”s
Digital Equipment Corp. (DEC)

- Other important DEC Systems
  - PDP-7 (1965)
    - 18-bit processor
    - First Unics (UNIX) implementation was done on an unused PDP-7 at Bells Labs
    - 16-bit processor
    - Memory-mapped I/O
    - One of the most successful computers ever
    - Second machine that UNIX ran on
      - Ritchie and Thompson at PDP-11
  - PDP-10 (1968-1983) (later known as DECSYSTEM-10 and -20)
    - 36-bit processor (descended from PDP-6)
    - Made timesharing common
    - TOPS-10 Operating System
    - Used at many universities, including at Project MAC, SAIL
    - Also used by Compuserve
Control Data Corp. (CDC)

- Old ERA team left Sperry to form CDC in 1959
- Produced 1604 (1959), then 160A (1960)
  - 12-bit processor, arguably the first “minicomputer”
- In 1960, Seymour Cray began plans for world’s fastest computer
  - Delivered in 1964 as CDC 6600
  - Popularized the term “Supercomputer”
  - Roughly 10 times faster than anything else available
    - 0.5-1 MFLOPs
- Advanced design:
  - Multiple asynchonynchronous functional units
  - 10 external I/O processors
- Purchased by “high-end” users:
  - National Labs, NSA, aerospace researchers, etc.
- Eventually displaced by CDC 7600
  - 4-5 times faster than 6600
In 1960, IBM had two successful but incompatible lines:
- Data Systems Division, Poughkeepsie, NY
  - 709x (also 707x for business)
- General Products Division, Endicott, NY
  - 1401 and compatible 1410 (also 1620 for scientific)

A new incompatible line was under development at DSD
- 8000 series

Also, SCAMP, a small, scientific system was being developed at Hursley, England

Thomas Watson, Jr, at the end of 1960:
- “Our computer product line had become wildly disorganized.”

Customer problems:
- Had to rewrite software for each incompatible larger system
- Peripherals also needed to be replaced with each change
IBM convened SPREAD committee
- Goal: Determine development and product direction for the next 10 years
- Included 11 members from both major divisions (GPD, DSD) and elsewhere (including Fred Brooks)
- Met daily for 2 months in late 1961
- Produced an 80 page report

The recommendation:
- Develop 5 processors, largest 200 times faster than the smallest
- Upward and downward compatibility between the systems
  - Use of microcode would hide differences such as speed, data path width, etc.
  - (Also allowed emulation, which turned out to be very important)
- Standard interfaces for peripherals (disk, tape, printers, etc.)
- “Since the processors must have capabilities not now present in any IBM processor product, the new family of products will not be compatible with our existing products.”

Called the result NPL (New Product Line)
IBM System/360

- The $5 billion gamble ($28 billion in 2002 dollars):
  - Original estimate was $675 million
  - $750 million on engineering, $4.5 billion on factories & equipment
  - “Bet the Company”
    - If NPL failed, the combination of expenditure and lack of any other product plan would effectively end IBM’s leadership in computing
  - “Biggest privately financed commercial project ever undertaken”
  - By mid-1960s, IBM was in danger of going broke
  - Meanwhile, IBM’s old products were not selling well and there was nothing new to replace them

- System/360 announced April 7, 1964
  - 360 for number of degrees in a circle
    - general-purpose, full line of computers
    - originally was to be System 500
  - Thomas Watson, Jr., led the press conference
    - Held in Poughkeepsie, NY
  - Parallel announcements in 165 U.S. cities and 14 other countries
IBM System/360

- **The Announcement:**
  - 6 new processors (up from recommended 5)
    - Speeds from about 1401 to twice the 7094
  - 44 new peripheral (I/O) devices
    - New disk, tape, printers, display, etc., devices
- **Within 4 weeks, more than 1,000 orders**
  - Next 4 weeks, another 1,000 orders
- **However, it took almost another 2 years to get systems built, installed, and running properly:**
  - New SLT (Solid Logic Technology) manufacturing
    - By 1966, one IBM plant was producing more semiconductor devices than the rest of the world combined
  - Logistics
    - Parts, manufacturing, etc.
  - Operating System
    - See next page
IBM System/360

- Operating System/360 (OS/360)
  - Led by Fred Brooks
    - See “Mythical Man Month” for lessons
  - Single largest expenditure in the entire project
    - Estimated at $40 Million, grew to more than $1/2 Billion
  - Initially 1,000,000 lines of code, grew to about 10,000,000
  - Was to be one operating system capable of spanning:
    - Entire line of systems
    - Batch to interactive (timesharing) usage
  - Eventually, was several iterations
    - BOS, TOS, DOS (Disk Operating System)
    - Finally, OS/360 released, but still several versions:
      - PCP (1 program or task)
      - MFT (fixed number of programs/tasks)
      - MVT (variable number of programs/tasks)
  - Evolved to MVS in 1970s, with additional of Virtual Storage
    - This OS is still running on tens of thousands of machines today
      - now called zOS
IBM System/360

- The System/360:
  - 32-bit processor architecture
  - 8-bit byte (EBCDIC)
  - 16 general-purpose registers
  - fixed point binary, decimal, floating point
  - 16MB memory addressing (later expanded to 2 GB per program)
  - Models 20 ('66), 30 ('65), 40 ('65), 50 ('65), 65 ('65), 75 ('66)
    - 12 models, up to Model 95, shipped through 1960s
  - In 1970’s enhanced (Virtual Storage) to S/370, many more models
    - Performance range of 200 to 1
IBM System/360

- By 1966:
  - 7,000-8,000 System/360s installed
  - More than $4 billion in new IBM revenue
    - $1 billion in profits
    - By 1970, revenues were up to $7.5 billion
  - By end of year, producing 1,000 units per month
- System/360 was a huge success
  - IBM has virtually owned the mainframe computer business since
    - In 1970, IBM had $24B worth of systems installed, 7 others $9B
- Spawned many imitators
  - RCA Spectra/70 (not quite compatible)
  - Russian Ryad or ES EVM (EC ЭВМ)
  - “Plug-compatible” Manufacturers (CPUs and peripherals)
    - Amdahl, Itel (Hitachi Data Systems), Magnusson, and others
- In 1985, Erich Bloch, Fred Brooks, and Bob Evans were presented with the National Medal of Technology by President Ronald Reagan
Other Noteworthy Events of the 1960s

- 1962: A Programming Language (APL language) published
  - Ken Iverson (first at Harvard, then at IBM)

\[ R \leftarrow x \div_1 N \]  
(R gets the value of N!)

- 1964: PL/I Language developed
  - Sponsored by IBM as part of S/360 project
    - Designed by committee of IBM programmers and users

```plaintext
DECLARE (N, RESULT) FIXED BINARY;

RESULT = 1;
DO WHILE (N >= 1)
  RESULT = RESULT * N;
  N = N - 1;
END;
```
Other Noteworthy Events of the 1960s

- **1964**: BASIC (Beginner’s All-purpose Symbolic Language)
  - Kemeny and Kurtz, Dartmouth

  ```
  10 R = 1
  20 FOR I=N TO 1 STEP -1
  30 R = R * I
  40 NEXT
  ```

- **1967**: Ex-Fairchild employees found Intel
  - “INTegrated ELectronics”

- **1968**: Data General Corporation founded
  - By Edson deCastro, of DEC
    - Project Manager of PDP-8
  - Nova 16-bit minicomputer introduced in 1969
    - $3995 base price, $7995 with additional core
  - SuperNova introduced in 1970
  - Important systems at low end of minicomputer market