Computer Science 1000: Part #6

System Software

System Software: An Overview

Operating Systems

Assemblers and Assembly Language

Implementing System Software

System Software: An Overview

- "Naked" computer hard to deal with, e.g.,
  1. Write machine language program.
  2. Load program into memory starting at address 0.
  3. Load 0 into PC and start execution.
- Need virtual machine interface, which does the following:
  - Hides details of machine operation.
  - Does not require in-depth knowledge of machine internals.
  - Provides easy access to system resources.
  - Prevents accidental or intentional damage to hardware, programs, and data.
- Create virtual machine and associated interface with **system software**.

System Software: An Overview (Cont'd)

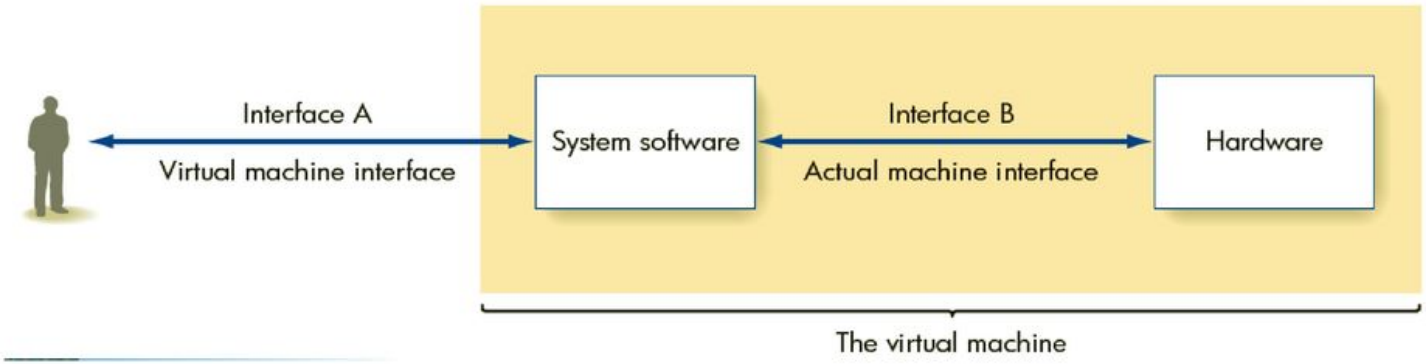


Figure 6.1 The Role of System Software

Operating Systems

- System software provided by **Operating System (OS)**.
- Many types of system software in an OS, e.g.,
  - **Graphical User Interface (GUI)**: Access system services.
  - **Language services**: Allow programming in high-level languages, e.g., text editor, assembler, loader, compiler, debugger.
  - **Memory manager**: Allocate memory for programs and data and retrieve memory after use.
  - **Information manager**: Organize program and data files for easy access, e.g., folders, directories.
  - **I/O system manager**: Access I/O devices.
  - **Scheduler**: Manage multiple active programs.

Operating Systems (Cont'd)

Major duties of an operating system:

- **User Interface**: Accept **system commands** from user and, if these commands are valid, schedule appropriate system software to execute command.
- **System Security and Protection**: Determine valid users and valid activities and accesses for users using usernames, passwords, and **access control lists**.
- **Efficient Management of Resources**: Optimize processor use by maintaining Running (active program), Ready (programs ready to execute), and Waiting (programs waiting on I/O requests) queues.
- **Safe Use of Resources**: Prevent **deadlock** (two or more users have partial required resources) using resolution algorithms and protocols.

Operating Systems (Cont'd)

OS dramatically simplifies creation of software, e.g.,

1. Write **source program** P in high-level programming language using a text editor.
2. Use an information manager to store P as a file in a directory.
3. Use a compiler and an assembler to translate P into an equivalent machine language program M.
4. Use scheduler to load, schedule, and run M (with scheduler calling memory manager and loader).
5. Use I/O system manager to display output on screen.
6. If necessary, use debugger to isolate and text editor to correct program errors.

Assemblers and Assembly Language

- An assembly language is the human-friendly version of a machine language, courtesy of several features:
  - Symbolic op-codes, e.g., `ADD, COMPARE`;
  - Symbolic memory addresses and labels, e.g., `IND, ONE, AFTERLOOP`; and
  - **Pseudo-ops** which specify extra assembler directives, e.g., `.DATA, .BEGIN, .END`.
- An assembler converts an assembly language source program into a machine language **object program**; a loader then places the instructions in that object program in the specified memory addresses.

Assemblers and Assembly Language (Cont'd)

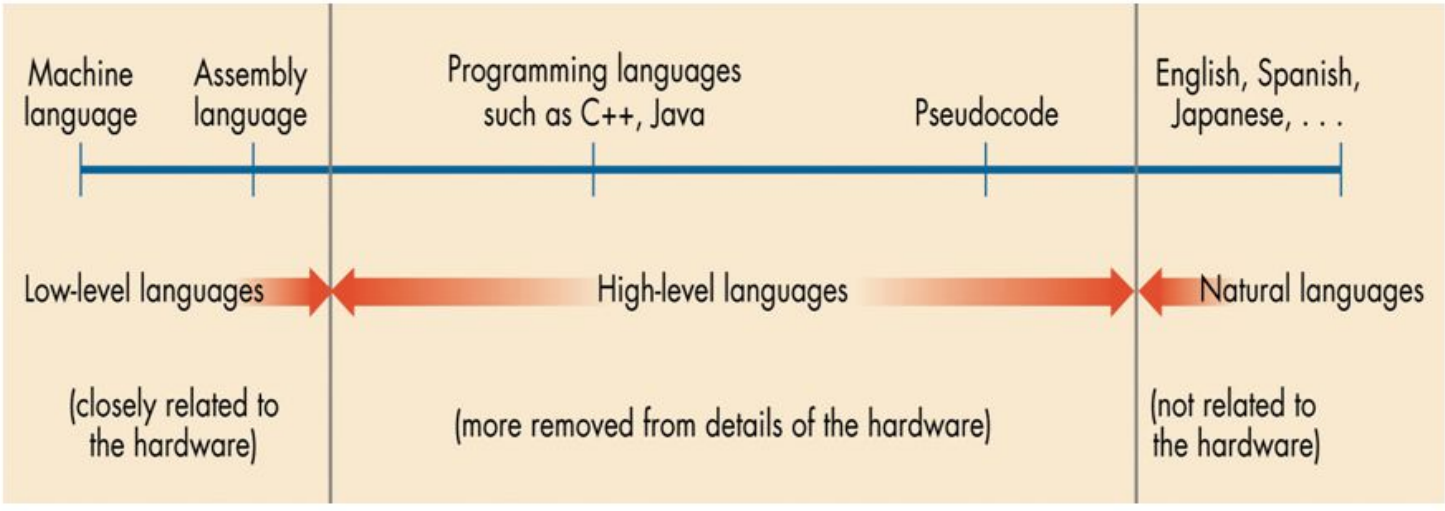


Figure 6.3
The Continuum of Programming Languages

Assemblers and Assembly Language: An Example Assembly Language

OC	Instruction	Meaning
0	`LOAD Lbl`	$CON(Lbl) \longrightarrow R$
1	`STORE Lbl`	$R \longrightarrow CON(Lbl)$
2	`CLEAR Lbl`	$0 \longrightarrow CON(Lbl)$
3	`ADD Lbl`	$R + CON(Lbl) \longrightarrow R$
4	`INCREMENT Lbl`	$CON(Lbl) + 1 \longrightarrow CON(Lbl)$
5	`SUBTRACT Lbl`	$R - CON(Lbl) \longrightarrow R$
6	`DECREMENT Lbl`	$CON(Lbl) - 1 \longrightarrow CON(Lbl)$
7	`COMPARE Lbl`	if $CON(Lbl) > R$ then $GT = 1$ else 0
		if $CON(Lbl) = R$ then $EQ = 1$ else 0
		if $CON(Lbl) < R$ then $LT = 1$ else 0
8	`JUMP Lbl`	$ADDR(Lbl) \longrightarrow PC$
9	`JUMPGT Lbl`	if $GT = 1$ then $ADDR(Lbl) \longrightarrow PC$

Assemblers and Assembly Language: An Example Assembly Language (Cont'd)

OC	Instruction	Meaning
10	`JUMPEQ Lbl`	if $EQ = 1$ then $ADDR(Lbl) \longrightarrow PC$
11	`JUMPLT Lbl`	if $LT = 1$ then $ADDR(Lbl) \longrightarrow PC$
12	`JUMPNEQ Lbl`	if $EQ = 0$ then $ADDR(Lbl) \longrightarrow PC$
13	`IN Lbl`	Store input value at $ADDR(Lbl)$
14	`OUT Lbl`	Output $CON(Lbl)$
15	`HALT`	Stop program execution

	Pseudo-op	Meaning
	`.DATA Val`	Create memory cell with value Val
	`.BEGIN`	Begin program translation process
	`.END`	End program translation process

Assemblers and Assembly Language: An Example Assembly Language (Cont'd)

- Access `.DATA`-created values with symbolic labels, e.g.,

```
NEGSEVEN:   .DATA -7
```

$$\Downarrow$$

54: | 10000111 |

$$\texttt{NEGSEVEN} = 54$$

- To prevent `.DATA`-created values from being interpreted as instructions, place all `.DATA` pseudo-ops after `HALT` at the end of the program.

Assemblers and Assembly Language: Example Assembly Language Code

set A to the value of $B + C$

```
     LOAD B
     ADD C
     STORE A
     ...
A:   .DATA 1
B:   .DATA 2
C:   .DATA 3
```

Assemblers and Assembly Language: Example Assembly Language Code (Cont'd)

if $A > B$ then
    set C to the value of A
else
    set C to the value of B

```
        LOAD B
        COMPARE A
        JUMPGT IFPART
        LOAD B
        STORE C
        JUMP ENDIF
IFPART: LOAD A
        STORE C
ENDIF:  ...
        ...
A:      .DATA 1
B:      .DATA 2
C:      .DATA 3
```

Assemblers and Assembly Language: Example Assembly Language Code (Cont'd)

set IND to 0
while $IND \leq MAXIND$ do
    $\langle LOOPBODY \rangle$
    set IND to $IND + 1$

```
                    CLEAR IND
LOOPSTART:          LOAD MAXIND
                    COMPARE IND
                    JUMPGT LOOPEND
                    ⟨LOOPBODY⟩
                    INCREMENT IND
                    JUMP LOOPSTART
LOOPEND:            ...
                    ...
IND:                .DATA 0
MAXIND:             .DATA 25
```

Assemblers and Assembly Language: An Assembly Language Program

Consider the following algorithm for computing and printing the sum of all values in a -1-terminated list:

Step	Operation
1.	Set SUM to 0
2.	Read the first list value into $CURVAL$
3.	while ($CURVAL \neq -1$) do
4.	Set SUM to $SUM + CURVAL$
5.	Read the next list value into $CURVAL$
6.	Print the value of SUM
7.	Stop

Let's implement this algorithm in assembly language.

Assemblers and Assembly Language: An Assembly Language Program (Cont'd)

```
                          .BEGIN
Step 2                    IN CURVAL
Step 3   LOOPSTART:       LOAD ENDVAL
                          COMPARE CURVAL
                          JUMPEQ LOOPEND
Step 4                    LOAD SUM
                          ADD CURVAL
                          STORE SUM
Step 5                    IN CURVAL
                          JUMP LOOPSTART
Step 6     LOOPEND:       OUT SUM
Step 7                    HALT
Step 1          SUM:      .DATA 0
              CURVAL:     .DATA 0
              ENDVAL:     .DATA -1
                          .END
```

Assemblers and Assembly Language: The Big Picture

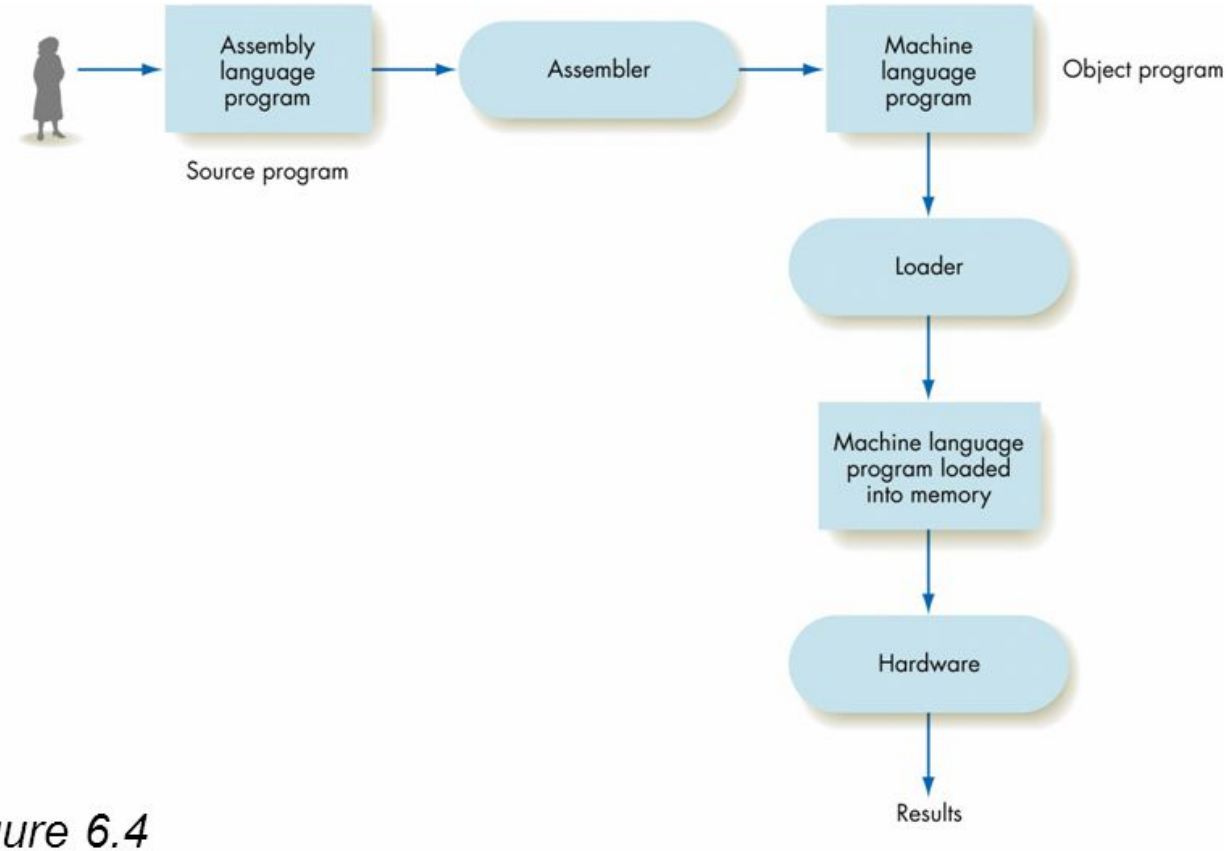


Figure 6.4

The Translation/Loading/Execution Process (Assembly --> M.C.)

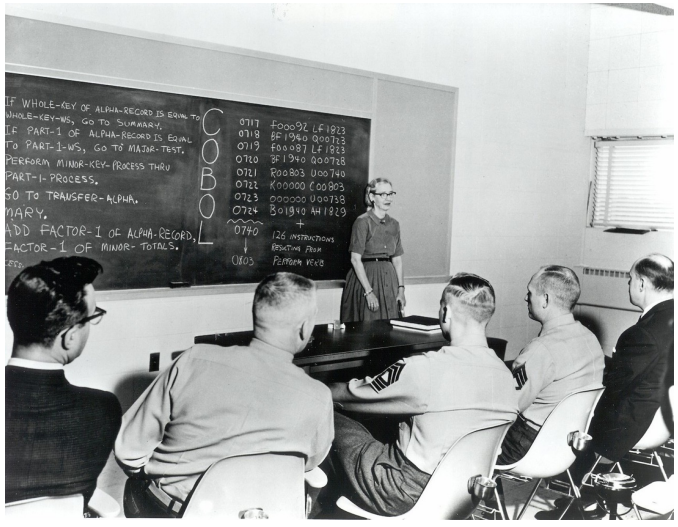
Implementing System Software: Compilers

Grace Hopper
(1906–1992)

- A compiler translates a program in a high-level programming language into a behaviorally equivalent program in a lower-level programming language.
- First compilers developed by Grace Hopper in early 1950s.
- Compilers can be cascaded, *e.g.*, high-level language $\Rightarrow$ medium-level language $\Rightarrow$ assembly language $\Rightarrow$ machine language.

Implementing System Software: Programming Languages

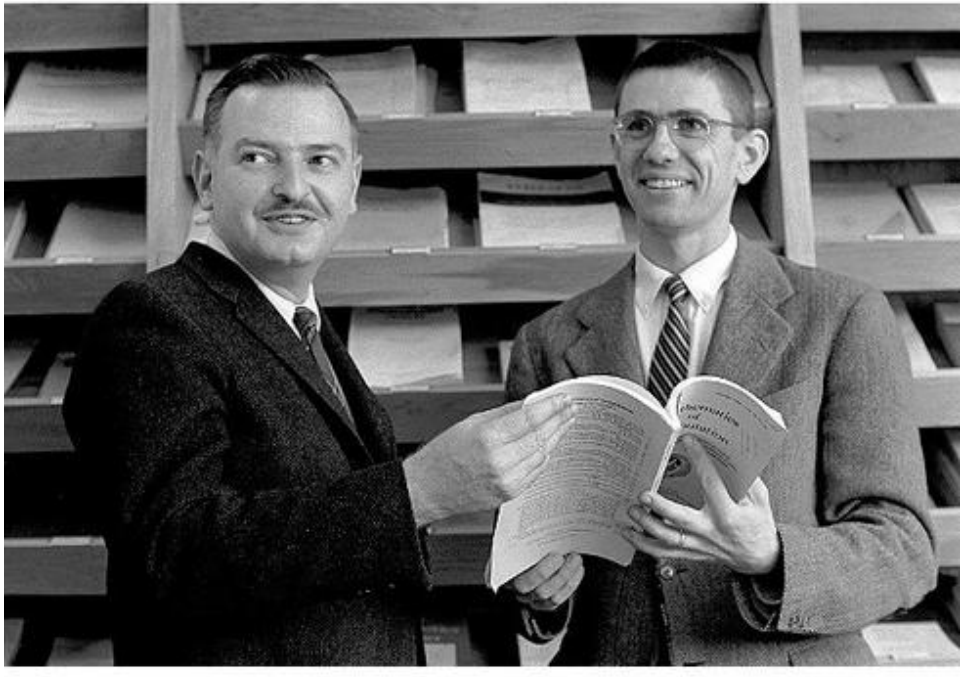
John Backus
(1924–2007)



Grace Hopper teaching
COBOL (early 1960's)

- FORTRAN (FORmula TRANslation) created by Backus team at IBM in 1957; designed for scientific computation.
- COBOL (COmmon Business-Oriented Language) created by industry / government committee in 1959.

Implementing System Software: Programming Languages (Cont'd)

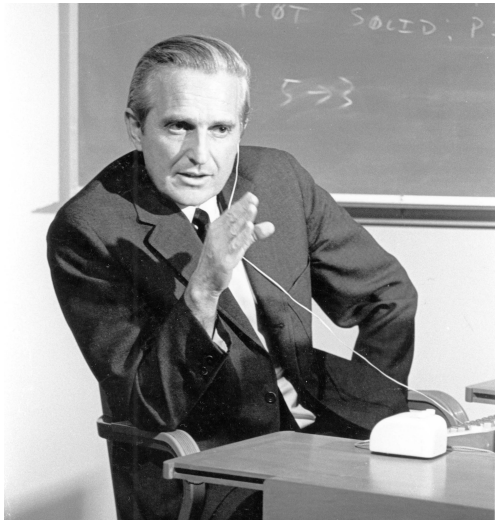


- BASIC (Beginner's All-purpose Symbolic Instruction Code) created by Thomas Kurtz (1928–) and John Kemeney (1926-1992) at Dartmouth College in 1964.
- Designed as a programming language for *everyone*.

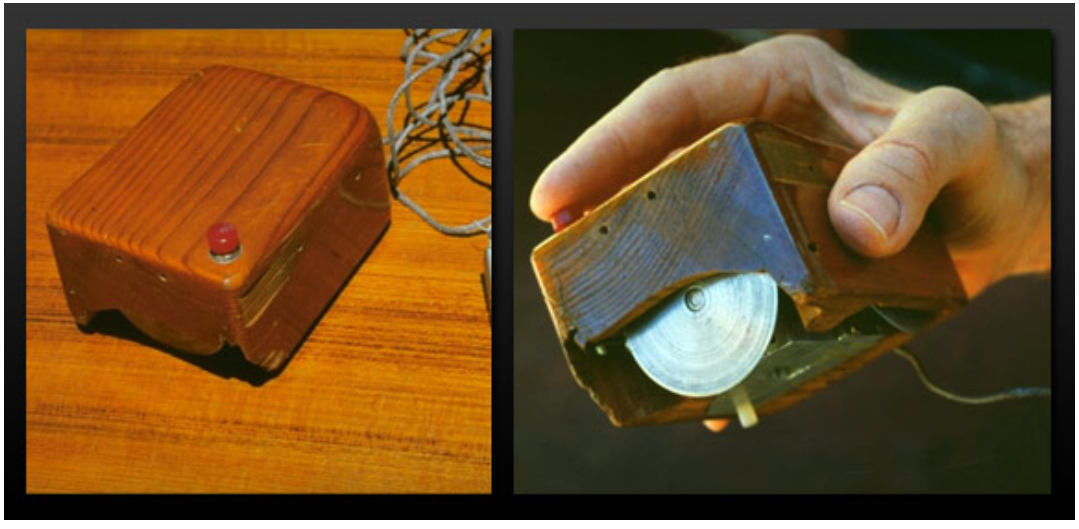
Implementing System Software: Operating Systems

- OS only possible after sufficient computer memory available starting around 1955.
- Three OS generations to date:
  1. Single-user batch-style OS (1955–1965)
     Run multiple programs in sequence with aid of Job Control Language (JCL).
  2. Multi-user time-sharing OS (1965–1985)
     Run multiple programs in apparent parallel by swapping programs in and out of the control unit.
  3. Multi-user network OS (1985–present)
- Future OS will incorporate multimedia user interfaces (e.g., voice / gesture-based) and fully distributed execution.

Implementing System Software: User Interfaces



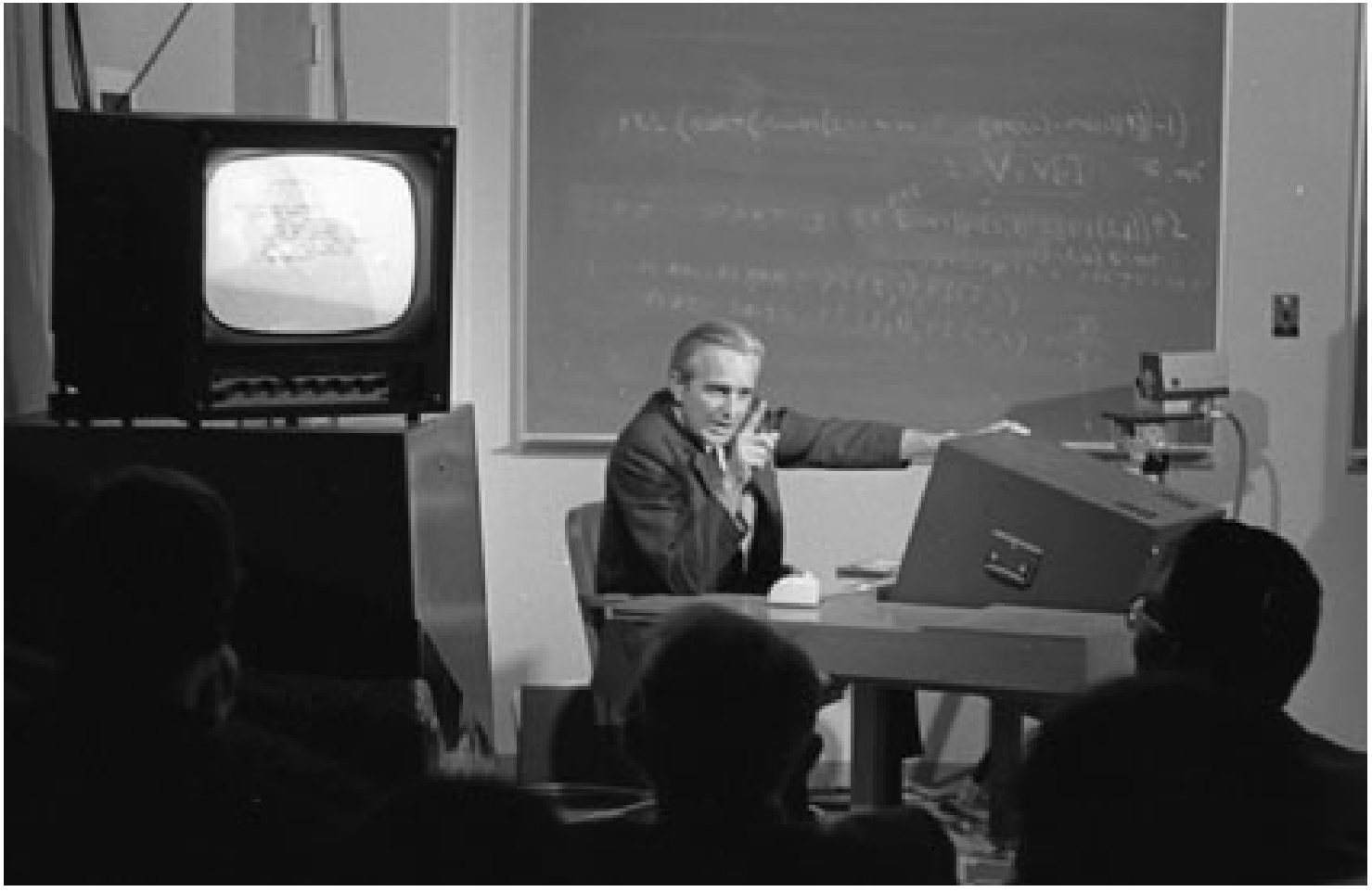
Doug Engelbart
(1925-2013)



Computer Mouse
(1965)

- Engelbart and colleagues develop graphical user interface (GUI) and computer mouse at Stanford starting in 1963.

Implementing System Software: User Interfaces (Cont'd)



"The Mother of All Demos" (1968)

Implementing System Software: User Interfaces (Cont'd)

- Xerox creates Palo Alto Research Center (PARC) in 1970 with aim of establishing competitive advantage.
- Half of $100M budget in 1970s spent on hiring top computing personnel and developing advanced personal computing technologies ("office of the future").

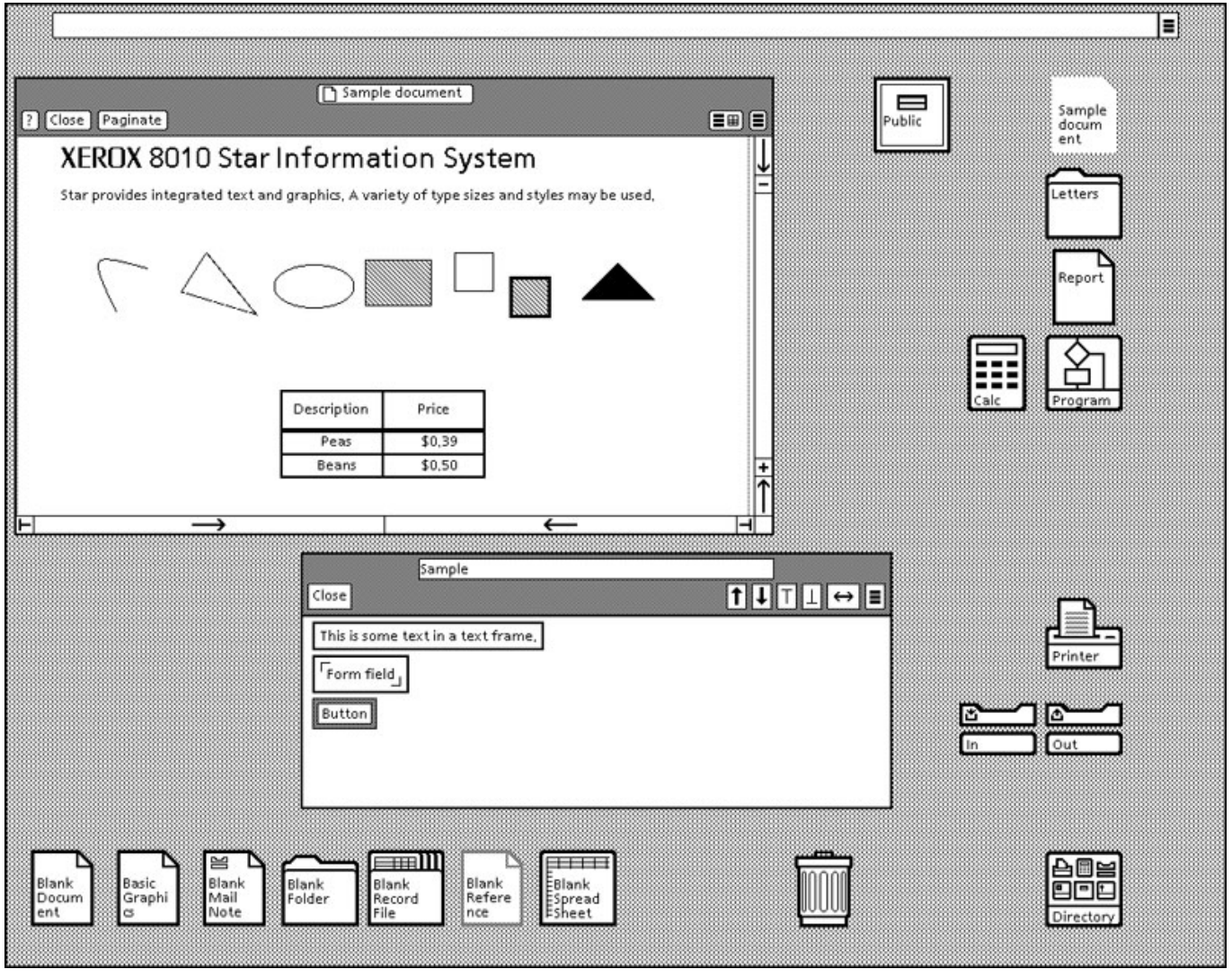
Implementing System Software: User Interfaces (Cont'd)

Xerox Alto (1973) [$25K (est)]

Xerox Star (1981) [$75K]

- Alto was first modern GUI-driven PC; also incorporated local-area networking and laserjet printers (WYSIWYG).
- Star intended for use in large corporations.

Implementing System Software: User Interfaces (Cont'd)

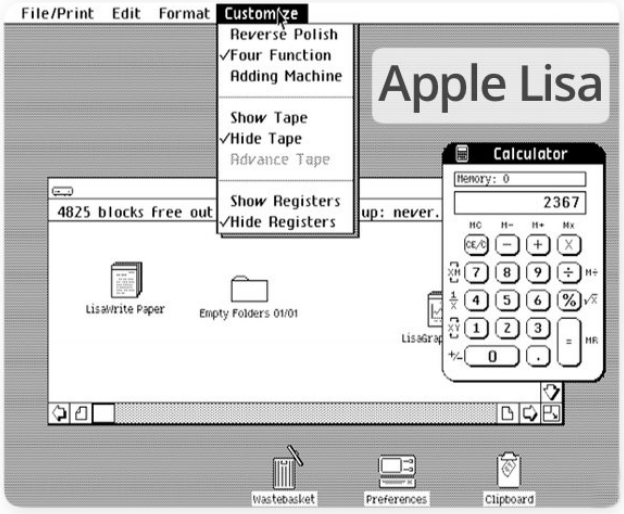


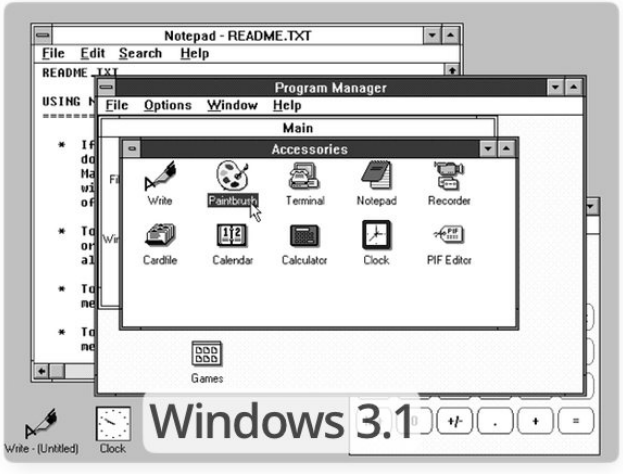
Implementing System Software: User Interfaces (Cont'd)

Apple Macintosh (1984) [$2,500]

- Starting in 1979, Steve Jobs re-creates GUI-based functionality at Apple in the Lisa and Macintosh PCs.
- Part of Macintosh application and OS development sub-contracted to Microsoft starting in 1981.

Implementing System Software: User Interfaces (Cont'd)





- Microsoft releases Windows v1.0 in 1985; legally emulated portions of Lisa and Mac look.
- Microsoft releases Windows v2.0 in late 1987; is not only much faster but (now illegally) *identical* to Mac look.
- Apple sues Microsoft over Windows 2.0 "look and feel" in 1988; case dismissed in 1991.
- By late 1980s, Windows has 90% market-share in GUI-based PC computing.

. . . And If You Liked This . . .

- MUN Computer Science courses on this area:
  - COMP 2001: Object-oriented Programming and HCI
  - COMP 2003: Operating Systems
  - COMP 3300: Interactive Technologies
  - COMP 4712: Compiler Construction
- MUN Computer Science professors teaching courses / doing research in in this area:
  - Ed Brown
  - Rod Byrne
  - Oscar Meruvia-Pastor