Steve Jobs, Bill Gates, and the PC
and
Course Review

Radical Innovation and the Transformation of Daily Life

CEE 102: Prof. Michael G. Littman
Course Administrator: Peter Wang pywang@princeton.edu

Please share your video – it helps to build a sense of community
Components of Innovation

Inventor and Entrepreneur

Noyce and Hoff – 4-bit Microcomputer

Intel 4004

Graph showing the performance of Supercomputers, Mainframes, Minicomputers, and Microprocessors with notable milestones including Intel 4004, Apple I 6502, Macintosh 68000, Altair 8800, Intel 8080, IBM PC, and Intel 8088.
Components of Innovation

Inventor and Entrepreneur

Noyce and Hoff – 4-bit Microcomputer

Intel 4004
Components of Innovation

Inventor and Entrepreneur

Noyce and Hoff – 4-bit Microcomputer

Intel 4004

Homebrew Computer Club

Silicon Valley 1975

Inspired by new 8-bit Intel 8080
Wozniak and Jobs
Apple Computer founded in 1976
(MOS Technology 6502 – 8-bit)

Wozniak in iWoz: “After my first meeting, I started designing … the Apple I”
Wozniak and Jobs
Apple Computer founded in 1976
(MOS Technology 6502 – 8-bit)

Wozniak in iWoz: “After my first meeting, I started designing … the Apple I”
Apple Introduces the First Low Cost Microcomputer System with a Video Terminal and 8K Bytes of RAM on a Single PC Card.

The Apple Computer. A truly complete microcomputer system on a single PC board. Based on the MOS Technology 6502 microprocessor, the Apple also has a built-in video terminal and sockets for 6K bytes of on-board RAM memory. With the addition of a keyboard and video monitor, you’ll have an extremely powerful computer system that can be used for anything from developing programs to playing games or running BASIC.

Combining the computer, video terminal and dynamic memory on a single board has resulted in a large reduction in chip counts, which means more reliability and lower cost. Since the Apple comes fully assembled, tested & burned-in and has a complete power supply on-board, initial set-up is essentially “plug-and-play” and you can be running within minutes. At $666.66 (including 8K bytes RAM) it opens many new possibilities for users and systems manufacturers.

You Don’t Need an Expensive Teletype.

Using the built-in video terminal and keyboard interface, you avoid all the expense, noise and maintenance associated with a teletype. And the Apple video terminal is six times faster than a teletype, which means more throughput and less waiting. The Apple connects directly to a video monitor (or home TV with an inexpensive RF modulator) and displays 960 easy-to-read characters in 24 rows of 40 characters per line with automatic scrolling. The video display section contains its own 8K bytes of memory, so all the RAM memory is available for user programs. And the keyboard interface lets you use almost any ASCII-encoded keyboard.

The Apple Computer makes it possible for many people with limited budgets to step up to a video terminal as an I/O device for their computer.

No More Switches,
No More Lights.

Compared to switches and LED’s, a video terminal can display vast amounts of information simultaneously. The Apple video terminal can display the contents of 192 memory locations at once on the screen. And the firmware in the Apple’s enables you to enter, display and delete programs (all in text) from the keyboard, rendering a front panel unnecessary. The firmware also allows your program to point characters on the display, and since you’ll be looking at letters and numbers instead of just LED’s, the door is open to all kinds of alphanumerical software (i.e., Games and BASIC).

8K Bytes RAM in 16 Chips!

The Apple Computer uses the new 16-pin 8K dynamic memory chips. They are faster and take up less space and power of even the low-power 2K2’s (16-bit memory chip that everyone else uses). That means 8K bytes in sixteen chips. It also means no more 8K amp-power supplies.

The system is fully expandable to 65K via an edge connector which carries both the address and data buses, power supplies and all timing signals. All dynamic memory refreshing for both on and off-board memory is done automatically. Also, the Apple Computer can be upgraded to use the 16K chips when they become available.

That’s 8K bytes on-board RAM in 16 IC’s—the equivalent of 5562512 bytes.

A Little Cassette Board
That Works!

Unlike many other cassette boards on the market, ours works every time. It plugs directly into the upright connector on the main board and stands only 2” tall. And since it is very fast (1500 bits per second), you can read or write 8K bytes in about 20 seconds. All timing is done in software, which results in crystal-controlled accuracy and uniformity from unit to unit.

Unlike some other cassette interfaces which require an expensive tape recorder, the Apple Cassette interface works reliably with almost any audio-grade cassette recorder.

Software:

A tape of APPLE BASIC is included free with the Cassette Interface. Apple BASIC features immediate error messages and fast execution, and lets you program in a higher level language immediately and without added cost. Also available now are a disk-assembler and many games, with many software packages, (including a macro assembler) in the works. Apple BASIC/BUSY is a complete software development environment for the Apple Computer.

Think different.
Apple Introduces the First Low Cost Microcomputer System with a Video Terminal and 8K Bytes of RAM on a Single PC Card.

The Apple Computer. A truly complete microcomputer system on a single PC board. Based on the MOS technology 6502 microprocessor, the Apple also has a built-in video terminal and sockets for 8K bytes of on-board RAM memory. With the addition of a keyboard and video monitor, you'll have an extremely powerful computer system that can be used for anything from developing programs to playing games or running BASIC.

Combining the computer, video terminal and dynamic memory on a single board has resulted in a large reduction in chip counts, which means reliability and lower cost. Since the Apple comes fully assembled, tested & burn-in and has a complete power supply on-board, initial set-up is essentially “hassle-free” and you can be running within minutes. At $666.66 (including 8K bytes RAM) it opens many new possibilities for users and systems manufacturers.

You Don't Need an Expensive Teletype.

Using the built-in video terminal and keyboard interface, you avoid all the expense, noise and maintenance associated with a teletype. And the Apple video terminal is six times faster than a teletype, which means more throughput and less waiting. The Apple connects directly to a video terminal (or home TV with an inexpensive RF modulator) and displays 960 easy to read characters in 24 rows of 40 characters per line with automatic scrolling. The video display section contains its own 8K bytes of memory, so all the RAM memory is available for user programs. And the keyboard interface lets you use almost any ASCII-encoded keyboard.

The Apple Computer makes it possible for many people with limited budgets to step up to a video terminal as an IO device for their computer.

No More Switches, No More Lights.

Compared to switches and LED's, a video terminal can display vast amounts of information simultaneously. The Apple's video terminal can display the contents of 192 memory locations at once on the screen. And the firmware in PASCAL enables you to enter, display and debug programs (all in hex) from the keyboard, rendering a front panel unnecessary. The firmware also allows you to program your programs to print characters on the display, and provide you're looking at letters and numbers instead of just LED's, the door is open to all kinds of alphanumeric software (i.e., Games and BASIC).

8K Bytes RAM in 16 Chips!

The Apple Computer uses the new 16-pin 8K dynamic memory chips. They are faster and take up less space and power of even the low power 2K's of the memory chip that everyone else uses. That means 8K bytes in sixteen chips. It also means no more 8K power supplies.

The system is fully expandable to 65K via an edge connector which carries both the address and data buses, power supplies and all timing signals. All dynamic memory refreshing is done automatically. Also, the Apple Computer can be upgraded to use the 16K chips when they become available. That's 32K bytes on-board RAM in 16 IC's—equivalent of 256 2132's.

A Little Cassette Board

That Works!

Unlike many other cassette boards on the marketplace, ours works every time. It plugs directly into the upright connector on the main board and stands only 2" tall. And since it is very fast (1500 bits per second), you can read or write 8K bytes in about 20 seconds. All timing is done in software, which results in crystal-controlled accuracy and uniformity from unit to unit.

Unlike some other cassette interfaces which require an expensive tape recorder, the Apple Cassette Interface works reliably with almost any audio-grade cassette recorders.

Software.

A tape of APPLE BASIC is included free with the Cassette Interface. Apple Basic features immediate error messages and fast execution, and lets you program in a higher level language immediately and without added cost. Also available now are 3 dis-assembler and many games, with many software packages, including a macro assembler in the works. And since our philosophy is to provide software for our machines free at minimal cost, you won't be continually paying for access to this growing software library.

The Apple Computer is in stock at almost all major computer stores. (If your local computer store doesn't carry our products, encourage them or write us direct). Dealer inquiries invited.

Byte into an Apple ............ $666.66

Includes 8K bytes RAM

COMPLETE VIDEO TERMINAL ELECTRONICS

INDEPENDENT POWER SUPPLY

CRIMSON CONTROLLED INTERFACES

FULLY REGULATED POWER SUPPLIES

EXPANSION CONNECTOR

CASSITE READER/WRITER CONNECTOR

220 Wach Rd., Palo Alto, CA 94304 (415) 326-4248

Demonstration

Think different.
MAE 412 Project – Load and Unload Marbles
TIME
STRIKING IT RICH
America’s Risk Takers
Steven Jobs
Of Apple Computer

1982

Think different.
Macintosh 128K – 1984
(Motorola 68000 – 16-bit)
Graphical User Interface
DEMONSTRATION

1982
PERQ - 1979
(Custom Bit Slice Processor)
Graphical User Interface
First GUI Computer

1982
1982

STRIKING IT RICH

America’s Risk Takers

Steve Jobs
Of Apple Computer

1997

EXCLUSIVE: Inside the Apple-Microsoft Deal

“Bill, thank you. The world’s a better place.”

—Steve Jobs talking to Bill Gates by cell phone last week about saving Apple
1999

Steve's Jobs
He saved Apple with his hot new iMac. He struck gold at Pixar with digital movies like Toy Story 2. You'd think he'd learn to chill. Think different.

2002

FLAT-OUT COOL!
Steve Jobs thinks he has seen the future—again. Apple's new iMac is an all-in-one hub for music, pictures and movies. It's elegant and affordable. But will millions of PC users get it?
2005

Iraq: Suicide Trainer
The Great Planet Hunt
Fat Fighters

The Man Who Always Seems to Know...

What's Next

Plus
Trendspotting
with Moby, Malcolm Gladwell, David Brooks and Esther Dyson

5 New Things that will blow your mind

Clint Eastwood's revolutionary movie for 2006

Apple CEO Steve Jobs with the new video iPod and iMac

2002

Afghanistan: Deadly Hunt
India & Pakistan: War Dance

Flat-Out Cool!

Steve Jobs thinks he has seen the future—again. Apple's new iMac is an all-in-one hub for music, pictures and movies. It's elegant and affordable. But will millions of PC users get it?
2005

Iraq: Suicide Trainers
The Great Planet Hunt
Fat Fighters

The Man Who Always Seems To Know...

What's Next

Plus.
Trendspotting
with Moby,
Malcolm Gladwell,
David Brooks and
Esther Dyson

5 New Things
that will blow
your mind

Clint Eastwood's
revolutionary
movie for 2006

Apple CEO
Steve Jobs
with the new
video iPod
and iMac

2007

Person of the Year

iPhone.
But seriously, we're running out of awards for this thing.
Environment Special: The Perils of Plastic

Inside Steve's Pad
How Jobs works by Stephen Fry
The tale of the tablet by Lev Grossman

PERSON OF THE YEAR

But seriously, we're running out of awards for this thing.
Homebrew Computer Club 30th Anniversary in 2005 - Silicon Valley
Bill Gates and Paul Allen – Micro-Soft Basic for Altair 8800 in 1975 (Intel 8080)
In fact, Microsoft would never have happened without Paul. In December 1974, he and I were both living in the Boston area – he was working and I was going to college. One day he came and got me, insisting that I rush over to a nearby newsstand with him. When we arrived, he showed me the cover of the January issue of *Popular Electronics*. It featured a new computer called the Altair 8800, which ran on a powerful new chip. Paul looked at me and said: “This is happening without us!” That moment marked the end of my college career and the beginning of our new company, Micro-soft. It happened because of Paul.
In fact, Microsoft would never have happened without Paul. In December 1974, he and I were both living in the Boston area – he was working and I was going to college. One day he came and got me, insisting that I rush over to a nearby newsstand with him. When we arrived, he showed me the cover of the January issue of *Popular Electronics*. It featured a new computer called the Altair 8800, which ran on a powerful new chip. Paul looked at me and said: “This is happening without us!” That moment marked the end of my college career and the beginning of our new company, Micro-soft. It happened because of Paul.
February 3, 1976

An Open Letter to Hobbyists

To me, the most critical thing in the hobby market right now is the lack of good software courses, books and software itself. Without good software and an owner who understands programming, a hobby computer is wasted. Will quality software be written for the hobby market?

Almost a year ago, Paul Allen and myself, expecting the hobby market to expand, hired Monte Davidoff and developed Altair BASIC. Though the initial work took only two months, the three of us have spent most of the last year documenting, improving and adding features to BASIC. Now we have 4K, 8K, EXTENDED, ROM and DISK BASIC. The value of the computer time we have used exceeds $40,000.

The feedback we have gotten from the hundreds of people who say they are using BASIC has all been positive. Two surprising things are apparent, however. 1) Most of the users either bought BASIC less than 10% of all Altair owners have bought BASIC, and 2) The amount of royalties we have received from sales to hobbyists makes the time spent of Altair BASIC worth less than $2 an hour.

Why is this? As the majority of hobbyists must be aware, most of you steal your software. Hardware must be paid for, but software is something to share. Who cares if the people who worked on it get paid?

Isn't this fair? One thing you don't do by stealing software is get back at MIT for some problem you may have had. MIT doesn't make money selling software. The royalty paid to us, the manual, the time and the overhead make it a break-even operation. One thing you do do is prevent good software from being written. Who can afford to do professional work for nothing? What hobbyist can put 3-man years into programming, finding all bugs, documenting his product and distribute for free? The fact is, no one besides us has invented a lot of money in hobby software. We have written 8000 BASIC, and are writing 8080 APL and 6800 APL, but there is very little incentive to make this software available to hobbyists. Most directly, the thing you do is theft.

What about the guys who re-sell Altair BASIC, aren't they making money on hobby software? Yes, but those who have been reported to us may have copies over 15 years old. They are the ones who give hobbyists a bad name, and should be kicked out of any club meeting they show up at.

I would appreciate letters from any one who wants to pay up, or has a suggestion or comment. Just write me at 1100 Alvarado SE, #14, Albuquerque, New Mexico, 87108. Nothing would please me more than being able to hire ten programmers and delve the hobby market with good software.

Bill Gates
General Partner, Micro-Soft

In fact, Microsoft would never have happened without Paul. In December 1974, he and I were both living in the Boston area – he was working and I was going to college. One day he came and got me, insisting that I rush over to a nearby newsstand with him. When we arrived, he showed me the cover of the January issue of Popular Electronics. It featured a new computer called the Altair 8800, which ran on a powerful new chip. Paul looked at me and said: “This is happening without us!” That moment marked the end of my college career and the beginning of our new company, Micro-soft. It happened because of Paul.

... As the majority of hobbyists must be aware, most of you steal your software. .... Is this fair?
February 3, 1976

An Open Letter to Hobbyists

To me, the most critical thing in the hobby market right now is the lack of good software, books and software itself. Without good software and an owner who understands programming, a hobby computer is wasted. Will quality software be written for the hobby market?

Almost a year ago, Paul Allen and myself, expecting the hobby market to expand, hired Monte Davidoff and developed Altair BASIC. Though the initial work took only two months, the three of us have spent most of the last year documenting, improving and adding features to BASIC. Now we have 4K, 8K EXTENDED, ROM and DISK BASIC. The value of the computer time we have used exceeds $40,000.

The feedback we have gotten from the hundreds of people who ask they are using BASIC has been all been positive. Two surprising things are apparent, however: 1) Most of these “users” never bought BASIC (less than 10% of all Altair owners have bought BASIC), and 2) The amount of royalties we have received from sales to hobbyists makes the time spent of Altair BASIC worth less than $2 an hour.

Why is this? As the majority of hobbyists must be aware, most of you steal your software. Hardware must be paid for, but software is something to share. Who cares if the people who worked on it get paid?

Is this fair? One thing you don’t do by stealing software is get back at MIT for some problem you may have had. MIT doesn’t make money selling software. The royalty paid to us, the manual, the tape and the overhead make it a break-even operation. One thing you do do is prevent good software from being written. Who can afford to to professional work for nothing? What hobbyist can put 3-man years into programming, finding all bugs, documenting his product and distribute for free? The fact is, no one besides us has invented a lot of money in hobby software. We have written 6800 BASIC, and are writing 8080 APL and 6800 APL, but there is very little incentive to make this software available to hobbyists. Most directly, the thing you do is theft.

What about the guys who re-sell Altair BASIC, aren’t they making money on hobby software? Yes, but those who have been reported to us may lose in the end. They are the ones who give hobbyists a bad name, and should be kicked out of any club meeting they show up at.

I would appreciate letters from any one who wants to pay up, or has a suggestion or comment. Just write me at 1180 Alvarado SE, #114, Albuquerque, New Mexico, 87108. Nothing would please me more than being able to hire ten programmers and delve the hobby market with good software.

Bill Gates
General Partner, Micro-Soft

… As the majority of hobbyists must be aware, most of you steal your software. … Is this fair?
IBM Personal Computer (Intel 8088 – 16-bit internal) Command Line Interface

Bill Gates and Paul Allen – MiCROSOFT MS- DOS for IBM PC in 1981
Bill Gates and Paul Allen – MiCROSOFT MS- DOS for IBM PC in 1981

8086, 80186, 80286  16-bit
80386, 80486, Pentium 1-4  32-bit
Pentium 4 and beyond  64-bit
Key Ideas

Scientific :
Whole Computer on a Chip
Graphical User Interface

Social and Personal :
Computation
Communication
Commerce

Symbolic :
Individual Genius
Immigrants
Alexander Graham Bell
Andrew Carnegie
Othmar Ammann
John Von Neumann

Key Ideas

Scientific :
Whole Computer on a Chip
Graphical User Interface

Social and Personal :
Computation
Communication
Commerce

Symbolic :
Individual Genius

Telephone for Communication
Immigrants

Alexander Graham Bell
Andrew Carnegie
Othmar Ammann
John Von Neumann

Telephone for Communication

Steel for Railroads, Bridges, and Buildings
Iconic Structures

Steel for Railroads, Bridges, and Buildings
Iconic Structures

Digital Computer for calculations
Inventors

Thomas Telford  Efficient Bridge
Wright Brothers  Flying Machine
Thomas Edison  Power Network
Henry Bessemer  Strong Material

Digital Computer for calculations

\[ H = \frac{1}{8} qL \frac{L}{d} \]
Inventors

Thomas Telford  Efficient Bridge
Wright Brothers  Flying Machine
Thomas Edison  Power Network
Henry Bessemer  Strong Material

\[ H = \frac{1}{8} q L \frac{L}{d} \]

\[ L = 0.00257 \ V^2 \ C_L \ A \]
\[ P_L = I^2 R \]

Safety Factor \( = \frac{f_B}{f} \)
Partners

James Watt – Mathew Boulton
Robert Fulton – Robert Livingston
G.W. Goethals – Teddy Roosevelt

Safety Factor = $\frac{f_B}{f}$
Partners

James Watt – Mathew Boulton
Robert Fulton – Robert Livingston
G.W. Goethals – Teddy Roosevelt
Patents

Telephone
Electric Light
Airplane
Radio
Rocket
Transistor
Integrated Circuit

What are positive and negative effects of patents?
Patents

Telephone
Electric Light
Airplane
Radio
Rocket
Transistor
Integrated Circuit

What are positive and negative effects of patents?

delays competition

Bell captures Edison patents from Western Union
“War of the Currents”
Westinghouse (AC) wins

Bell captures Edison patents from Western Union

delays competition

delays competition
delays competition

WWI – patent suspended in national interest

“War of the Currents” Westinghouse (AC) wins
Sarnoff sues – delays FM

Armstrong suicide
Armstrong’s widow wins

WWI – patent suspended in national interest

delays competition
1964 – 50th Anniversary

Goddard not taken seriously until after WWII

Sarnoff sues – delays FM

Armstrong suicide
Armstrong’s widow wins
1964 – 50th Anniversary

Goddard not taken seriously until after WWII

Bell Telephone Research

Transistor revolutionizes electronics industry
Kilby and Noyce share credit and revenue

Individually invented by Jack Kilby and Robert Noyce, the integrated circuit was first available commercially in 1961. It led to smaller, inexpensive, mass-produced electronic circuits, revolutionizing the computer industry.

CELEBRATE THE CENTURY – 1960s

Bell Telephone Research

Transistor revolutionizes electronics industry
Artists and Engineers

Telford
Morse
Ammann

Independently invented by Jack Kilby and Robert Noyce, the integrated circuit was first available commercially in 1961. It led to smaller, inexpensive, mass-produced electronic circuits, revolutionizing the computer industry.

Kilby and Noyce share credit and revenue

Elegant bridge replaces the ferry
Intelligence at a distance

Elegant bridge replaces the ferry
Intelligence at a distance

Structural Artist and Entrepreneur
Public Works Entrepreneurs

Ammann Norris Hoover

Structural Artist and Entrepreneur
Public Works Entrepreneurs

Ammann Norris Hoover

TVA – REA architect
Advocate for Public Power
Commerce Secretary
Colorado River Compact

TVA – REA architect
Advocate for Public Power
Focus on Whole System
(and Inflexible Pioneers)

Edison
Ford
Marconi

Commerce Secretary
Colorado River Compact

Competition with Gas Lighting
Focus on Whole System (and Inflexible Pioneers)

Edison
Ford
Marconi

Assembly Line
Integrated Factory

Competition with Gas Lighting
Assembly Line
Integrated Factory

World Wide Wireless Network
Energy Conversion

Steam Engine
IC Engine
Jet Engine
Rocket Motor

Machine replaces Horse
External Combustion

World Wide Wireless Network
Energy Conversion

Steam Engine
IC Engine
Jet Engine
Rocket Motor

Machine replaces Horse
External Combustion

Compact and Efficient Engine
Internal Combustion
Air-breathing Turbojet Engine
Batch to Continuous

Compact and Efficient Engine
Internal Combustion
Rocket Motor carries own $O_2$ Thrust in the Vacuum of Space

Air-breathing Turbojet Engine Batch to Continuous
Regional Restructuring

Port Authority
Valley Authority
River Compact

Congested
Depressed
Undeveloped

Rocket Motor carries own $O_2$
Thrust in the Vacuum of Space

Port Authority Bridge
Automobiles
Regional Restructuring

Port Authority
Valley Authority
River Compact
Congested
Depressed
Undeveloped

Valley Authority Dam
Electric Power

Port Authority Bridge
Automobiles
River Compact Dam
Flood Control and Electric Power

Valley Authority Dam
Electric Power
Daring ‘Firsts’

Water
Air
Space

River Compact Dam
Flood Control and Electric Power

First Trip - Colorado River
Daring ‘Firsts’

Water
Air
Space

First Flight - Heavier than Air

First Trip - Colorado River
First Flight - Heavier than Air

Faster than Sound
bullet-shaped rocket plane
First Earth Orbit

Faster than Sound bullet-shaped rocket plane
First Earth Orbit

First Moon Landing
Transformation of Daily Life

Railroad
Telephone
Electricity
Canal
Automobile
Airplane
Computer

First Moon Landing

Continent Crossed - 1869
Iron and Steel Rails
Transformation of Daily Life

Railroad
Telephone
Electricity
Canal
Automobile
Airplane
Computer

City Illuminated – 1882
Continent Crossed – 1915
Copper Wires

Continent Crossed - 1869
Iron and Steel Rails
Oceans United - 1914
Concrete Dams and Steel Lock Gates

City Illuminated – 1882
Continent Crossed – 1915
Copper Wires
Atlantic Ocean Crossed - 1927
Wood and Aluminum Airplanes powered by Gasoline

Oceans United - 1914
Concrete Dams and Steel Lock Gates

Federal Highway Act - 1956
Steel Automobiles using Gasoline on Asphalt and Concrete Roads
Atlantic Ocean Crossed - 1927
Wood and Aluminum Airplanes powered by Gasoline

Information Age begins - 1946
Glass Tubes with Tungsten Wires
Silicon Transistors

Federal Highway Act - 1956
Steel Automobiles using Gasoline on Asphalt and Concrete Roads
Innovations

How do they happen?
Why are they significant?

Scientific:
- science – engineering inspired
- engineering – science enabled

Social Process:
- context and transformations:
  - economics
  - politics
  - culture

Symbolic:
- works of individual geniuses:
  - iconic elegant structures
  - fast efficient vehicles
  - high speed networks
  - strong useful materials

Information Age begins - 1946
Glass Tubes with Tungsten Wires
Silicon Transistors
Innovations

How do they happen?
Why are they significant?

Scientific:
- science – engineering inspired
- engineering – science enabled

Social Process:
- context and transformations:
  - economics
  - politics
  - culture

Symbolic:
- works of individual geniuses:
  - iconic elegant structures
  - fast efficient vehicles
  - high speed networks
  - strong useful materials