Lessons Learned from 30 Years of MINIX?

Andrew S. Tanenbaum

Vrije Universiteit

PREHISTORY

- MINIX wasn't created in a vacuum
- There was a lot of history before it
- Let's review some of it
- In 1960, M.I.T. had an IBM 7094
- It filled a big room and ran batch jobs from cards

IBM 7094

COMPARISON OF IBM 7094 AND iPAD

Item	IBM 7094	iPad Air	Ratio
Speed	0.4 MIPS	2 x 1400 MIPS	7,000x
Memory	0.288 MB	1024 MB	3,500x
Ext storage	3MB	128 GB	800x
Volume	800 m^3	.0004m^3	2,000,000x
Price (2016 $)	$12 million	$900	13,000x

Multiplied out: 5 x 10^{20} x better

IF BOEING 707 HAD THIS IMPROVEMENT

iPad Item	Aircraft item	Aircraft could
Speed	Flight time	AMS to SFO in 12 sec
Memory	Passengers	700,000 passengers
Disk space	Range	160x around earth nonstop
Volume	Size	Size of iPhone
Price (2016 $)	Price	Round-trip ticket for 9 cents

- But your baggage would still end up in Siberia
- One in 50 flights would crash
- The engineers would be proud of this safety record

CTSS

- Jobs were turned in as a deck of punched cards
- It took hours to get a job back
- If you entered one comma wrong, job failed
- Very hard to get work done
- In 1961 to improve matters, M.I.T created CTSS
- This was an online system, response of seconds
- Huge success

MULTICS

- Successor to CTSS was MULTICS
- MULTIplexed Information & Computing Service
- Designed in 1964
- M.I.T. partnered with General Electric & Bell Labs
- MULTICS had a troubled youth
- When first compiled, the kernel didn't fit in RAM
- In 1969 Bell Labs dropped out
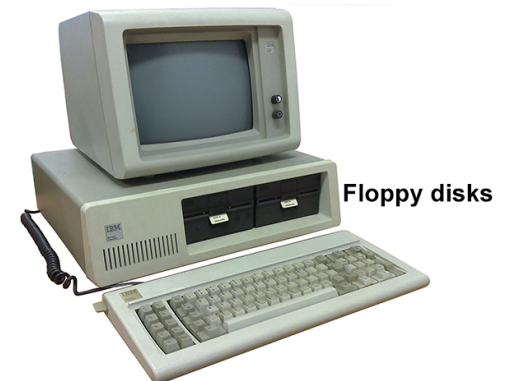- A programmer, Ken Thompson went back to NJ

UNICS

- Ken found an old PDP-7 at Bell Labs and rewrote it
- It could support only one user
- Brian: UNIplexed Information & Computing Service
- For short: UNICS
- Puns about EUNUCHS being castrated MULTICS
- Spelling later changed to UNIX

UNIX AT BELL LABS

- When the PDP-11 came out Bell Labs bought one
- Dennis Ritchie invented C and wrote the compiler
- Ken & Dennis rewrote Ken's system for the PDP-11
- Went through 6 editions of the manual internally
- Universities wanted it, Bell Labs agreed
- V6 was licensed in 1976
- John Lions wrote a book describing it line by line
- Bell Labs lawyers didn't like this at all
- V7 (1979) came with a license that said: no books

MINIX

- In 1984 I decided to rewrite V7 for the IBM PC
- They cost about $1500
- Possible for a student to own one
- It took me 2 years, evenings and weekends
- It sort of worked and I could use it for development
- I was very conscious of flaws in the system
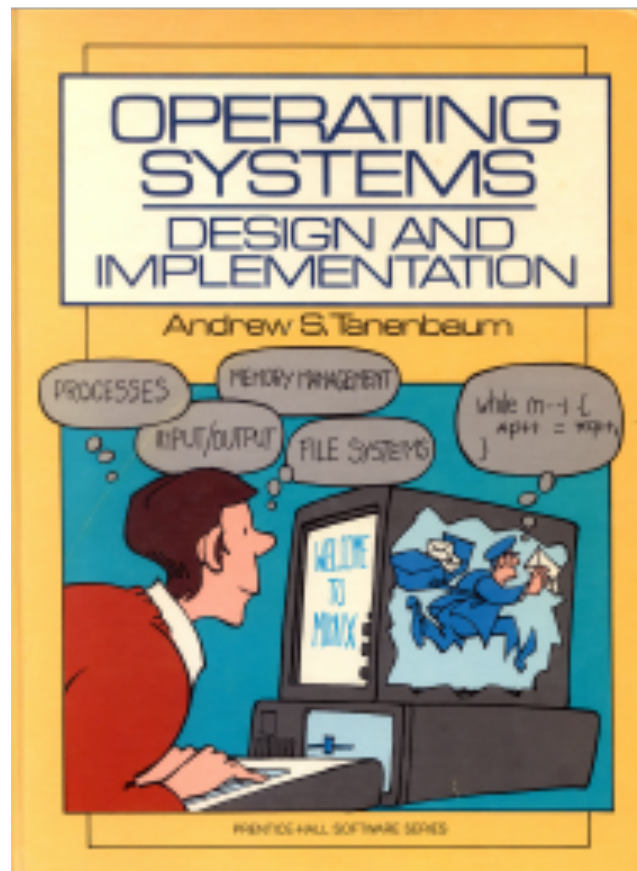- **Lesson: Eat your own dog food**

Floppy disks

IT CRASHED AFTER AN HOUR

- I didn't understand why it crashed after an hour
- In desperation, I wrote a PC simulator
- It worked perfectly on the simulator!
- I told my student, Robbert van Renesse
- He said: I heard 8088 gives interrupt 15 when hot
- I said: Nothing about that in the documentation
- I changed it to catch interrupt 15 and it worked
- **Lesson: Don't trust the documentation**
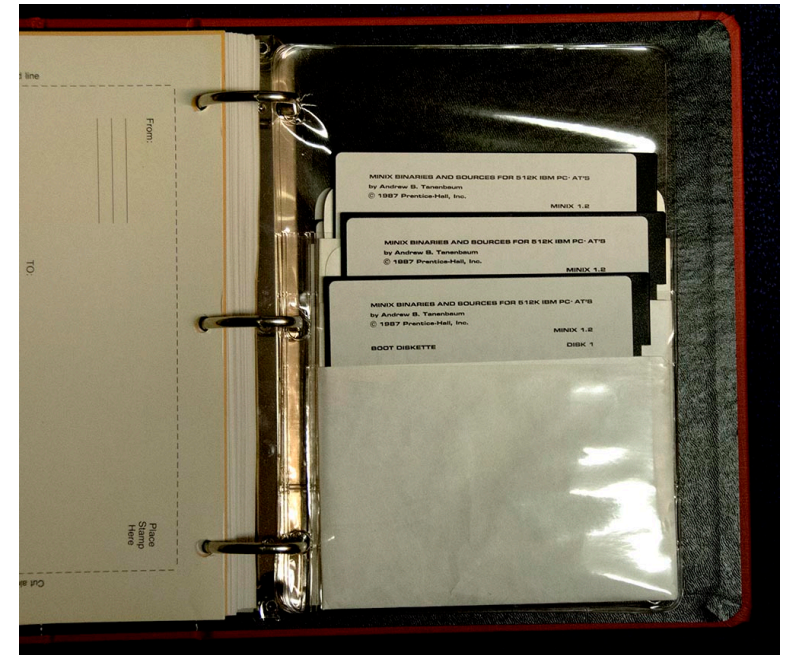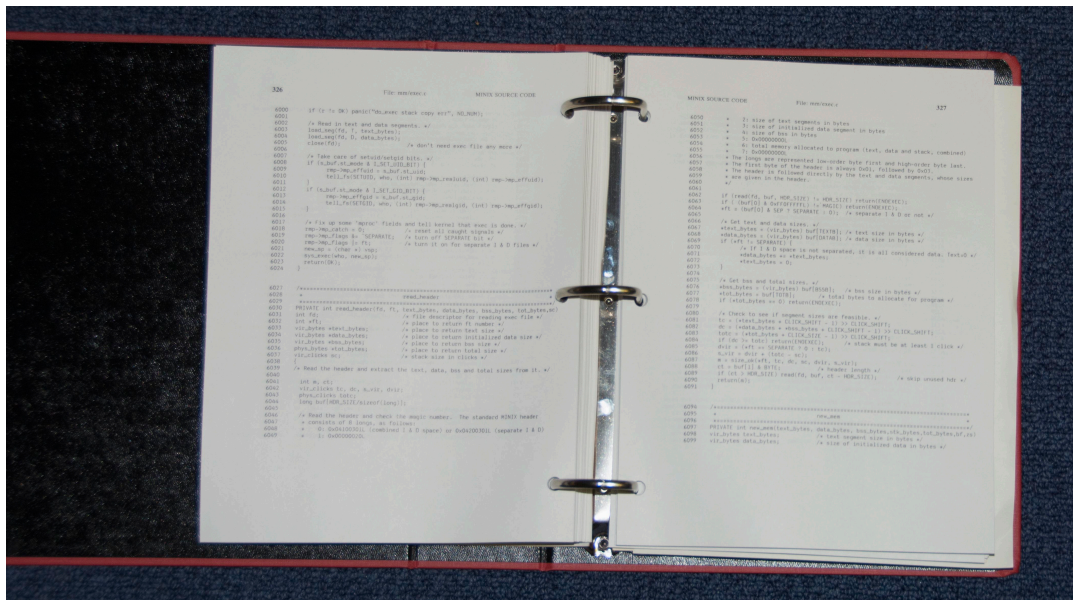- **Lesson: Your students might know more than you**

I WROTE A BOOK ABOUT MINIX

- In 1987 I published a book describing MINIX
- Like Lions book, but no hassle with Bell Labs

HOW TO DISTRIBUTE THE SOFTWARE?

- Almost no one had an Internet connection then
- Publisher sold box of 8 floppies + 500 pg book for $69
- **Lesson: You need a way to distribute your product**

POST-RELEASE REACTION

- Bookstore owner in California asks me to visit
- I figured he would set up a table & I'd sign books
- He rented the Santa Clara Convention Center
- And filled it up
- USENET Newsgroup had 40,000 readers in 1 mo.
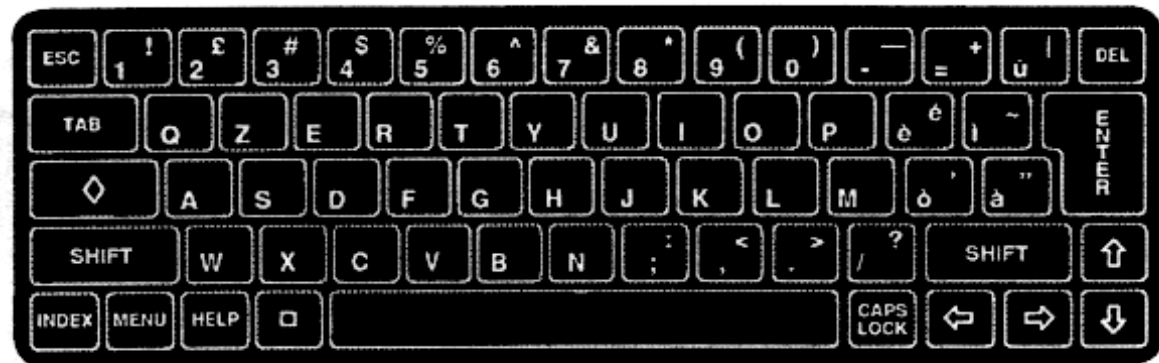- People started contributing software

TEACHING VS. FULL-BLOWN OS

- Many people wanted full-blown OS
- I was afraid it would get to complicated to study
- Also, I thought BSD or GNU would happen
- I resisted trying to make it into full-blown OS
- Nevertheless a lot of good software came in
- Jan-Mark Wams wrote a very good test suite and a compression program that saved 2 floppy disks
- Later important for people with 2400 bps modems
- **Lesson: Size matters**

32-BIT PROCESSOR ARRIVES

- In 1985, Intel released the 32-bit 386

- Bruce Evans ported MINIX to 386

- Code distinguished kernel mode from user mode

- Code distinguished physical & virtual addresses

- Neither were actually necessary on 8088

- Doing so made the port to the 386 much easier

- **Lesson: Think about future hardware**

OLIVETTI PC

- MINIX on Olivetti PC acted strangely
- As if the keyboard were broken
- All Olivettis had the same problem
- Discovery: Italian computers have different keybd
- Input code was changed to accept national keybds
- **Lesson: If someone gives you a lemon, make lemonade**

Italian Keyboard

LINUS TORVALDS BOUGHT A PC

- In 1991 Linus Torvalds bought a PC to run MINIX
- On 29 March 1991 he posted to comp.os.minix
- 10 Days later he mocked a another newbie
- Clearly as an educational tool, MINIX succeeded
- In Aug. 1991, Linus said: I'm writing a new OS
- He developed it using MINIX
- This eventually became the Linux kernel

FLAMEWAR

- In 1992, I said microkernels were better than monolithic designs

- Big flamewar with Linus Torvalds ensues

- 24 years later I still get lots of mail about this

- **Lesson: The Internet is like an elephant; it never forgets**

MORE ON MICROKERNELS

- Windows NT was originally a microkernel design
- Performance forced everything back into kernel
- OS X is FreeBSD on top on Mach microkernel
- L4 microkernel is inside a billion cell phones
- QNX: widely used microkernel in embedded systems

IS TODAY'S SOFTWARE FOREVER?

- Linux is written in gcc
- MINIX is written in ANSI Standard C
- What happens when a better compiler comes out?
- MINIX switched easily to Clang/LLVM
- Linux is still stuck with gcc
- **Lesson: Stick with international standards**

AT&T VS. BSDI

- BSD developers formed a company to sell BSD
- AT&T sued them
- This handcuffed BSD from 1992 to 1994
- This gave Linux a window with no BSD to fight
- Eventually settled out of court
- AT&T still didn't know what to do with UNIX
- **Lesson: When a tiny startup appears that knows more than your company, buy them**

MINIX V2

- In 1997 MINIX 2 came out
- Was POSIX compatible instead of V7
- In 2000 I convinced my publisher to release it under BSD license and put it on the Internet
- I should have done this much earlier
- **Lesson: Reexamine your plan periodically**

ACADEMY PROFESSOR

- In 2004, I got a grant to do research on reliability
- In 2004, I became an Academy Professor
- This gave me €2 million to use MINIX for research
- **Lesson: Doing something outside the mainstream can get you research funding if it is important**

MOVING DRIVERS OUT OF THE KERNEL

- Initially device drivers were in kernel address space
- But they were scheduled as processes
- Because context switch was expensive on 8088
- Jorrit Herder moved them all to user space
- Failed drivers could be replace on the fly
- Now we had something no one else had
- **Lesson: Each driver should run as a user process**
- **Lesson: Try for an early success; it builds morale**

MINIX 3

- In 2005, we released MINIX 3
- This was a much more serious system
- MINIX 1 was unfortunately very well known
- No one believed MINIX 3 was really different
- Windows 95/98 were just MS-DOS with a GUI
- But Microsoft renamed it "Windows" – smart!
- **Lesson: If V3 != V1, give it a new name**

EUROPEAN RESEARCH COUNCIL GRANT

- EU has been thinking about product liability for SW
- Suppose 1 in 10 million tires explodes
- Manufacturer can't say: Tire explosions happen"
- For software that works
- In 2008 I got a €2.5 grant for OS research
- Goal was to make MINIX into reliable system
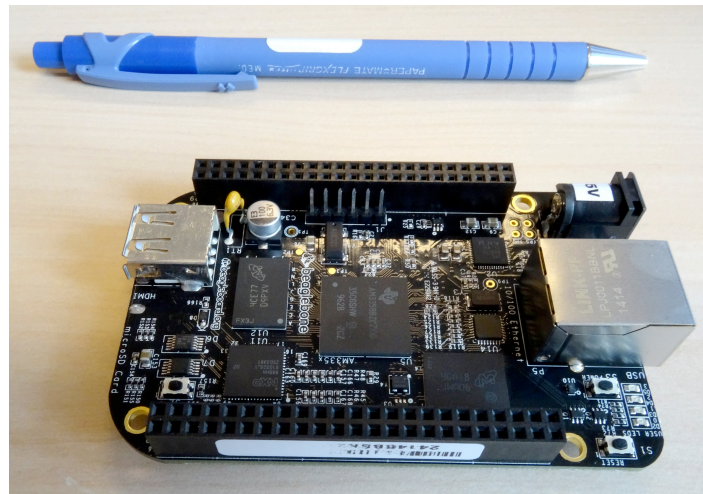
NEW RESEARCH GROUP

- I could hire
  - 4 expert programmers
  - 6 Ph.D. students & a postdoc
- Programmers built a very solid product
- Students did research
- Everybody had their own copy of the code
- We used source code control systems, git, etc.
- Still we had huge problems merging code later
- **Lesson: Combining research & a product is hard**

HOW TO GET USERS

- We discovered that MINIX couldn't do anything
- So we made it NetBSD compatible
- This gave us 6,000 packages for free
- **Lesson: To be used, a system must do something**

EMBEDDED SYSTEMS

- We also decided to focus on embedded systems
- We ported MINIX to the ARM
- The port was straightforward
- There was no inline x86 code ever in MINIX
- **Lesson: Today's hardware may not be tomorrow's**

MINIX 3.4 RELEASE CANDIDATE 2

- Main new feature: live update

- Goal: no more reboots

- Can be used for security fixes or new versions

- Replace drivers and servers without rebooting

- Summary:
  - Start a new driver or server as a new process
  - Transfer the old state to the new process
  - Cut over to the new one

FINAL LESSON

- **Lesson: It is hard to change existing ways of doing things**
- In this case, microkernels
- Other examples
  - FORTRAN
  - Windows XP (still 250 million XP machines running)
  - QWERTY keyboard
  - Interlaced NTSC television sets
  - Magnetic stripe credit cards

CACM PAPER

- I wrote a paper covering much of this material
- It will be in the March 2016
  Communications of the ACM

MASTERS PROGRAM AT THE VU

- PDCS: Parallel and Distributed Computer Systems
- Focus is on experimental computer science
- Design, implementation, and testing of software
- Many lab courses, little theory
- Emphasis on research
- Opportunity to be a serf
- Good preparation for a Ph.D. later
- See **pdcs.vu.nl**

MINIX 3

What Is MINIX 3?

MINIX 3 is a free, open-source, operating system designed to be highly reliable, flexible, and secure. It is based on a tiny microkernel running in kernel mode with the rest of the operating system running as a number of isolated, protected, processes in user mode. It runs on x86 and ARM CPUs, is compatible with NetBSD, and runs thousands of NetBSD packages. Get MINIX 3 now and join our community!

Read More   **Download**

LEARN MORE ABOUT MINIX 3

FEATURES. See a list of the MINIX 3 features

FAQ. Get quick answers to common questions

RESOURCES FOR NEWBIES. Info for beginners

DOCUMENTATION. Various articles

NEWS. Read our new posts

RESEARCH. MINIX 3 as a base for research

GET INVOLVED WITH MINIX 3

GETTING STARTED. If you are new to MINIX 3

DOWNLOAD. Get the current version as a CD-ROM image

NEWSGROUP. Ask question and get answers

HELP US. How can I help the project?

HIRE A CONSULTANT. Tailor MINIX 3 to your company's needs

DONATE. All financial contributions are welcome

Google Search   ☑ search only www.minix3.org

Get a masters degree in Computer Systems at the university where MINIX 3 was written, VU University, in Amsterdam.

DISCUSSION – THE FUTURE OF MINIX

- How to build a community?
- Steering committee: rules for selecting members? tasks?
- What niche is there for MINIX3?
- What roadmap is needed to fill that niche?
  - Other platforms? Raspberry Pi?
  - Key software missing that people need?
- How to improve collaboration?
  - Conference in 2017? For €100?
- What kind of PR do we need?
- Better documentation on the wiki?
- As an open-source project, we need serious volunteers
- Note: Continue discussion later on the newsgroup