Reconstructive Software Archaeology

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This is a case study in restoring the 1st Edition of UNIX from 1971.

The restoration is interesting in itself, but it also raises issues that are relevant to other software fields.

Happy 40th Birthday, UNIX!

Issues in Restoring A Computing Artifact

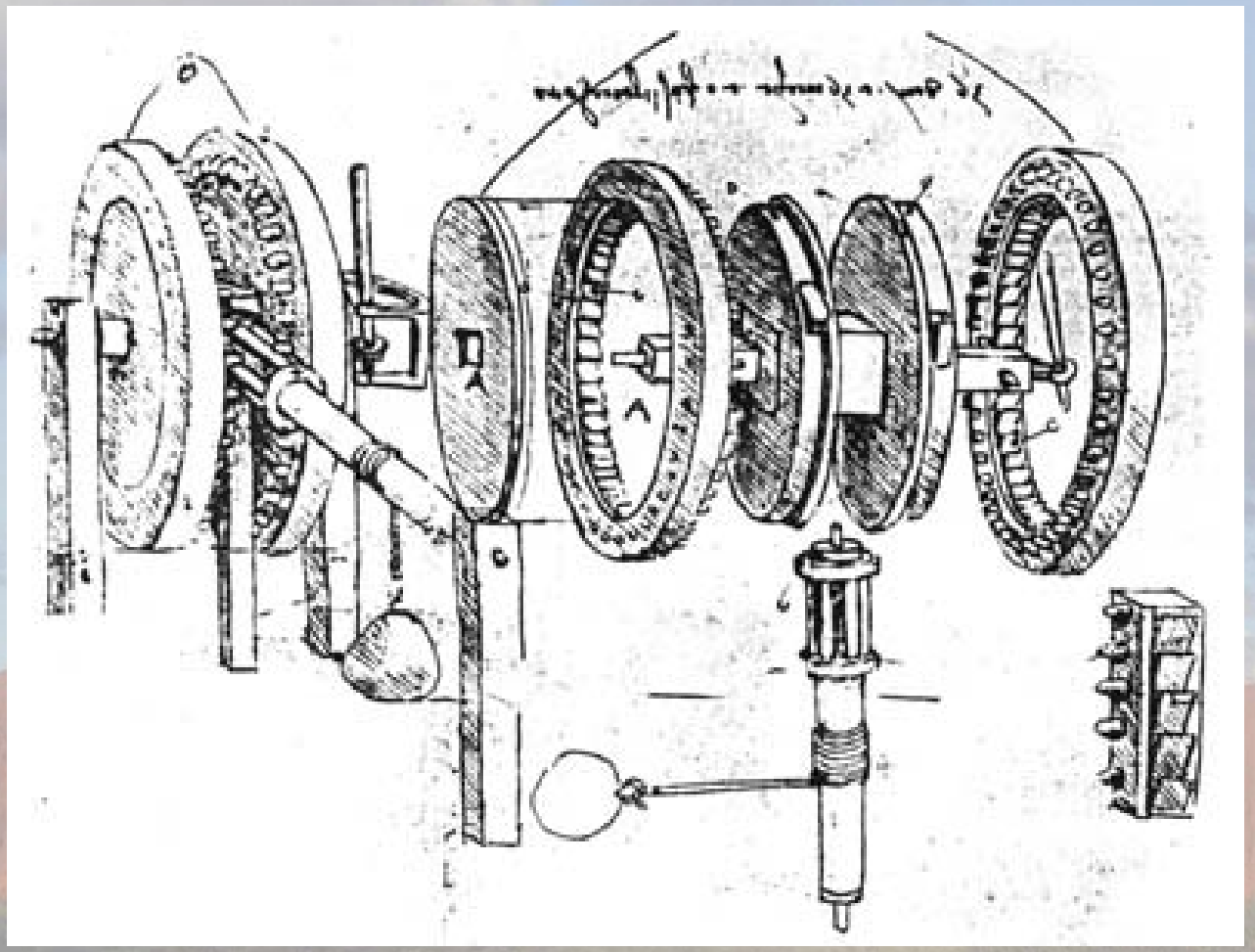
- Computing artifact: hardware, software
- Other resources: documentation, blueprints, schematics, configuration files, notes, written and oral anecdotes, contemporary publications
- What issues need to be considered when restoring a computing artifact to working order?

What if the artifact's purpose is unknown?

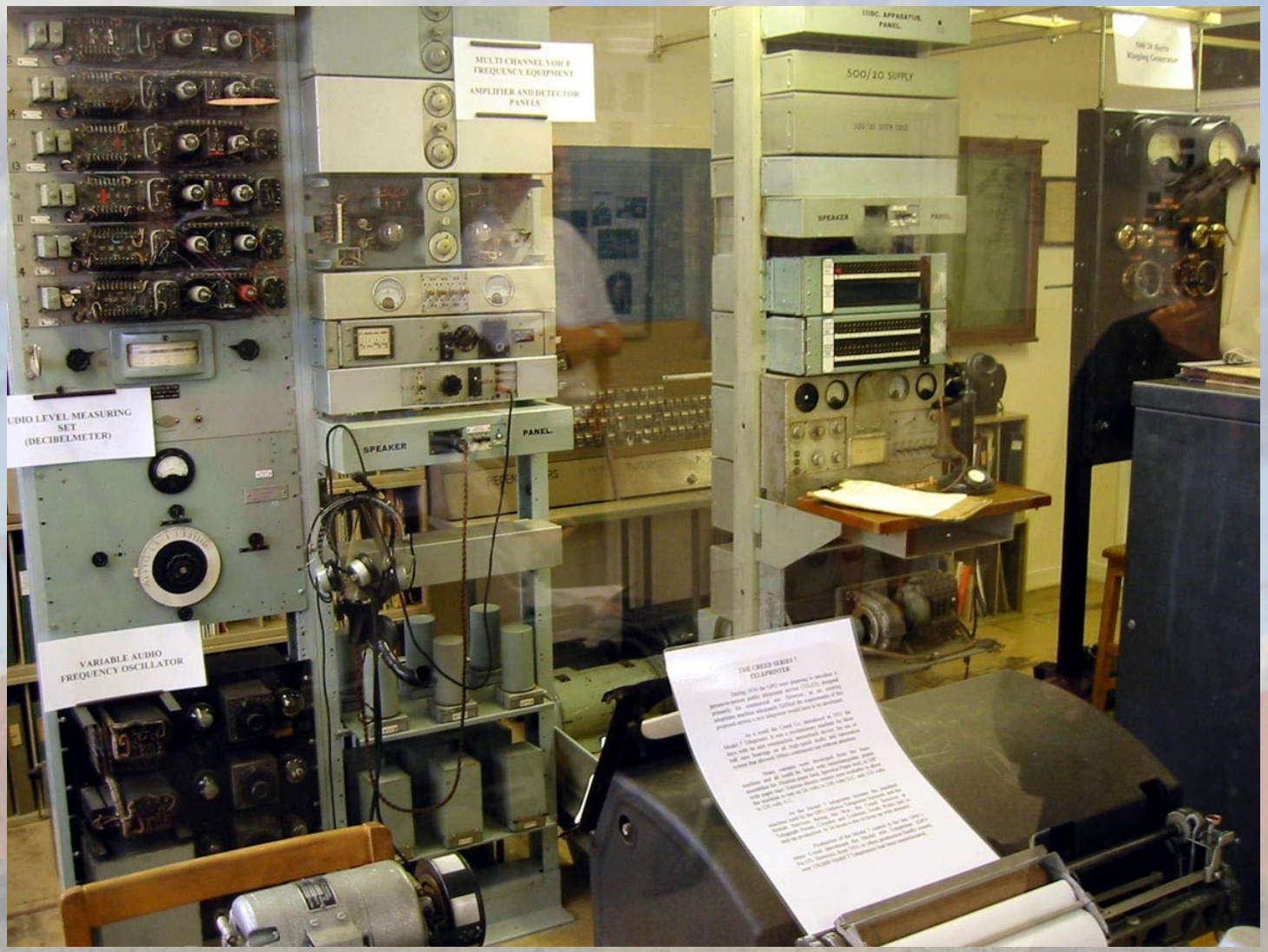
What if the documentation is missing?

What if the documentation is incomplete?

Is the artifact a blueprint? Can it be rebuilt?

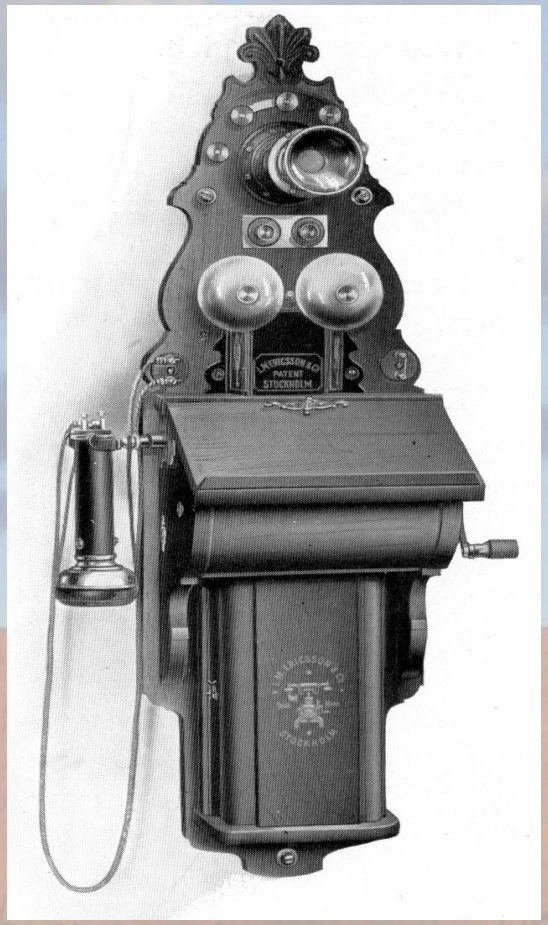


Do we have the tools to rebuild it?



Do we have to replace some of the parts of the artifact?

Do we have to make significant changes to make it work?



Software Restoration Issues

- Unlike physical hardware, software does not decay (at least, not while pristine copies exist)
- But in practice, software tends to exhibit what is commonly known as "*bit rot*"

- If software does not decay, then what causes the bit rot?
- Bit rot is a function of the software's *environment*, and not the software itself

The UNIX Heritage Society

- I'm a founding member of the Unix Heritage Society. Our aim is to preserve the knowledge and artifacts of early UNIX
- Where possible, we try to keep old systems working. Past successes:
  - Restoration of earliest C version of UNIX: 1973
  - Restoration of earliest C compiler: also 1973
  - Creation of executable environment for UNIX user-mode binaries, assembled in 1972
- The 1st Edition of UNIX, from 1971, was lost

1st Edition UNIX Features

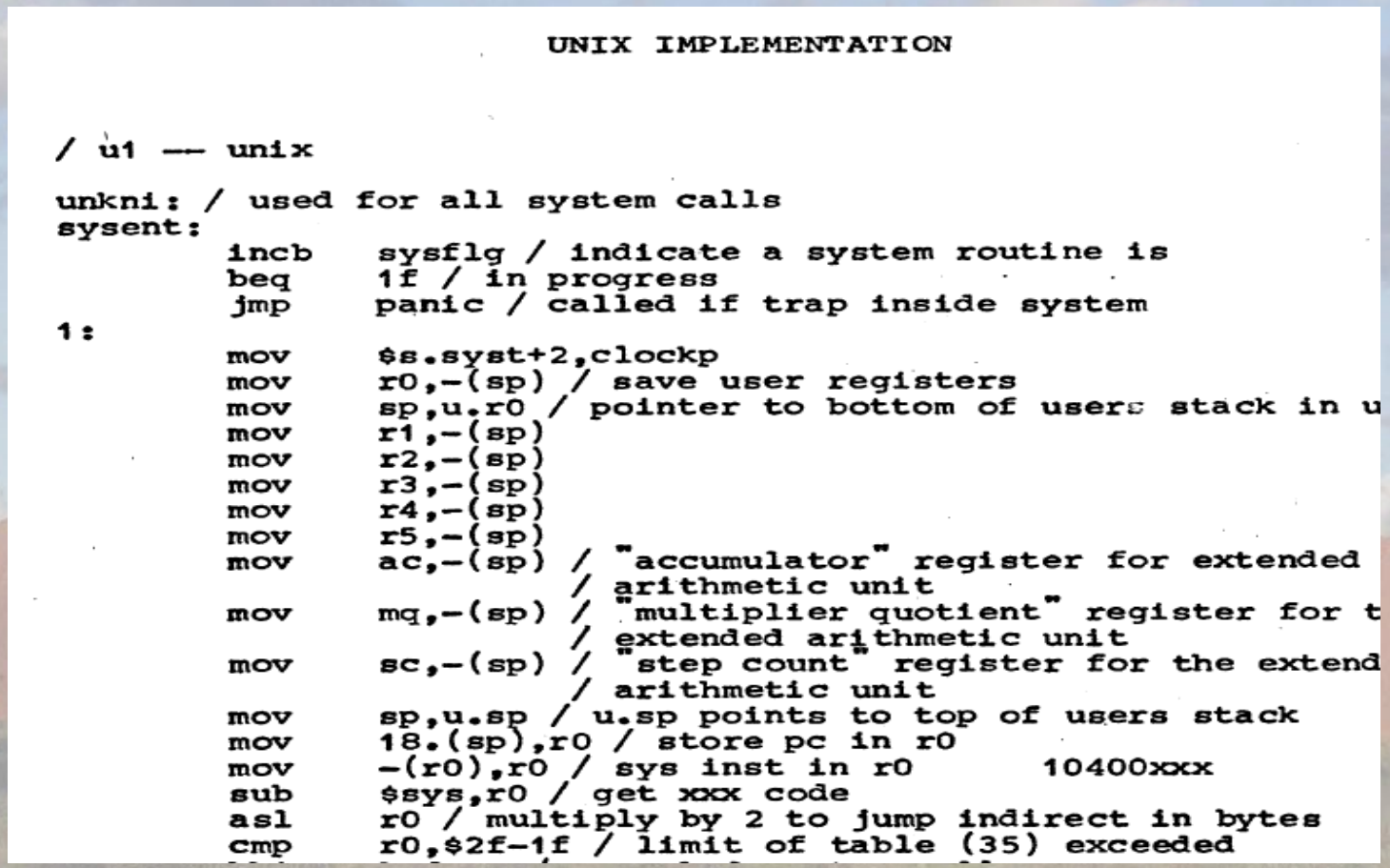
- Hierarchical filesystem: files, directories, subdirectories
- Pre-emptive multitasking & processes
- A flexible command-line interpreter
- Multiuser, including e-mail
- Mountable storage making a single filesystem tree
- Hard links: a file can have multiple names
- Multiple languages: assembly, FORTRAN, Basic, TMG, shell scripting

1st Edition UNIX

Dennis & Ken at the PDP-11/20 console

And then...

- A paper document containing a listing of the 1st Edition UNIX kernel was found



UNIX IMPLEMENTATION

```
/ u1 -- unix

unkni: / used for all system calls
sysent:
        incb    sysflg / indicate a system routine is
        beq     1f / in progress
        jmp     panic / called if trap inside system
1:
        mov     $s.syst+2,clockp
        mov     r0,-(sp) / save user registers
        mov     sp,u.r0 / pointer to bottom of users stack in u
        mov     r1,-(sp)
        mov     r2,-(sp)
        mov     r3,-(sp)
        mov     r4,-(sp)
        mov     r5,-(sp)
        mov     ac,-(sp) / "accumulator" register for extended
                         / arithmetic unit
        mov     mq,-(sp) / "multiplier quotient" register for t
                         / extended arithmetic unit
        mov     sc,-(sp) / "step count" register for the extend
                         / arithmetic unit
        mov     sp,u.sp / u.sp points to top of users stack
        mov     18.(sp),r0 / store pc in r0
        mov     -(r0),r0 / sys inst in r0       10400xxx
        sub     $sys,r0 / get xxx code
        asl     r0 / multiply by 2 to jump indirect in bytes
        cmp     r0,$2f-1f / limit of table (35) exceeded
```

Can It Be Restored?

- Needs to be OCR'd and eyeballed
- Contradictory typed & handwritten comments
- No 1st Edition assembler, only later ones
- No bootstrap code in any form
- No filesystem or creation tool, just the docs
- Need a PDP-11/20 simulator: one exists, but not all the required hardware
- Not sure if existing executables are from 1st Edition or 2nd Ed: will they be compatible?

What was Done, Part 1

- Document scanned, OCR'd, manually checked & cross-checked by ~10 people
- Tool written to modify output from 7th Edition assembler to be compatible with 1st Edition assembler
- Existing Apout tool allows 7th Ed assembler to run without a full PDP-11 simulator
- Several logic errors and missing lines found in the paper listing: fixed
- KE11A support added to PDP-11 simulator
- Result: kernel runs to a point, then hangs

What was Done, Part 2

- “Cold” kernel fixed, builds near-empty filesystem.
- “Warm” kernel boots, *init*, login & shell work!
- *mkfs* tool written to build and fully populate the root and /usr filesystems
- Result: Now we can run user-mode programs
- Simulator further modified to emulate DC-11
- Result: multiuser UNIX system
- Kernel modified to deal with “0407” executables
- Result: all old executables run; C compiler runs and can recompile itself

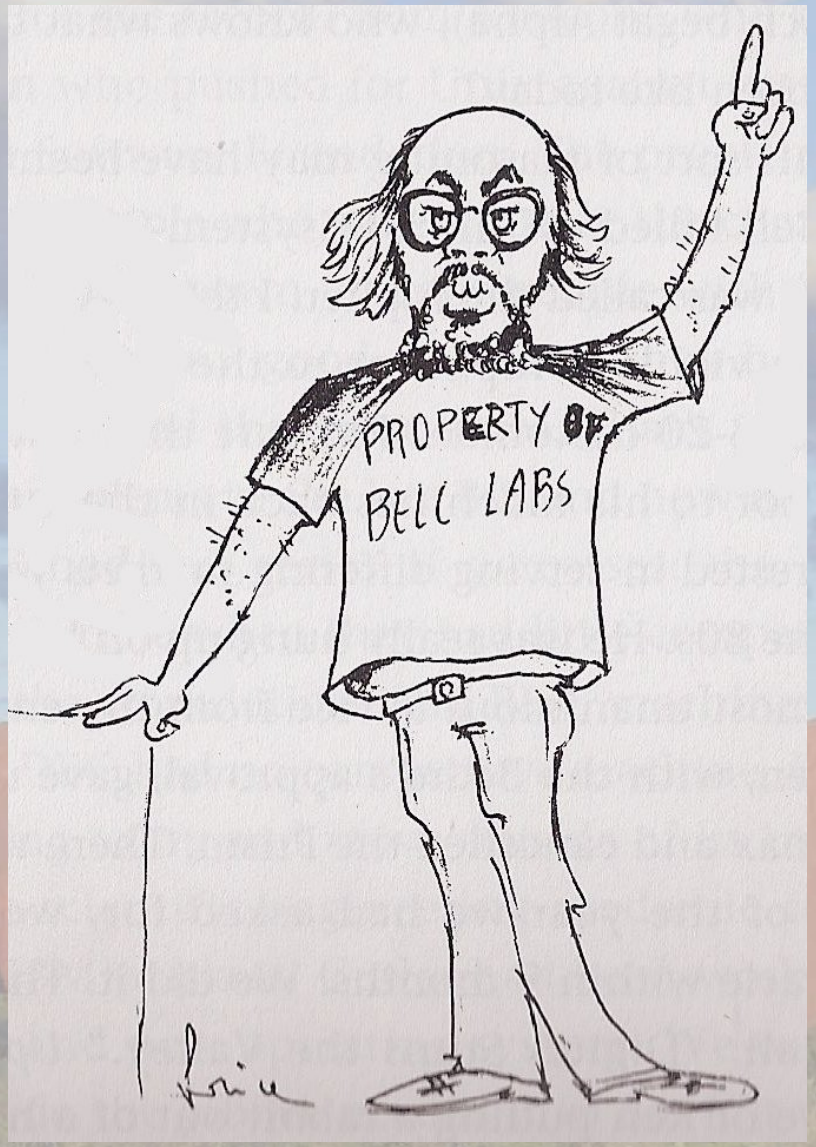
Software Reconstruction

- Software suffers from “bit rot”. We had to:
  - Fix typos, missing lines, logic mistakes in the source code
  - Build tools which could assemble the source code, and construct suitable filesystems
  - Modify an existing PDP-11 simulator to provide an executable environment for the system
  - Interpret old documentation: on the whole, it was excellent, but it was vague or omitted details in places
- Luck played a role: documentation, preserved executables, existing tools

Lessons Learned for Now

- Write good documentation
- Keep software current on new platforms
- If necessary, write simulators now while the hardware details still exist
  - Moore's Law helps here
- All software requires an environment. Take a crucial component away & it stops working:
  - Hardware, compilation tools, user manual, filesystem, even configuration files
- As system complexity increases, the work needed to resurrect/restore increases

Questions?



Old & New System Calls

1st Edition	Linux 2.6	1st Edition	Linux 2.6
1: exit	exit	15: chmod	chmod
2: fork	fork	16: chown	lchown
3: read	read	17: break	unused
4: write	write	18: stat	stat
5: open	open	19: seek	lseek
7: wait	waitpid	20: tell	getpid
8: creat	creat	21: mount	mount
9: link	link	22: umount	umount
10: unlink	unlink	23: setuid	setuid
11: exec	execve	24: getuid	getuid
12: chdir	chdir	25: stime	stime
13: time	time	26: quit	ptrace
14: mkdir	mknod	28: fstat	fstat