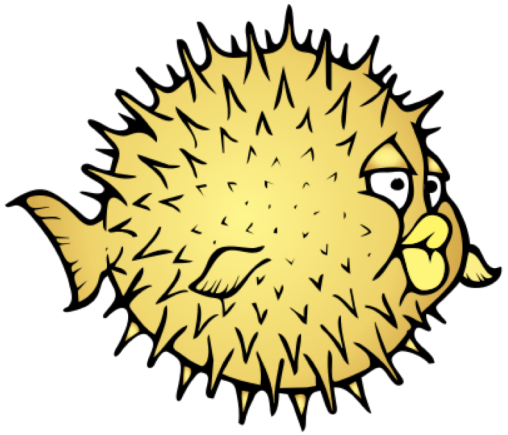

OpenBSD

The real security focused Operating System

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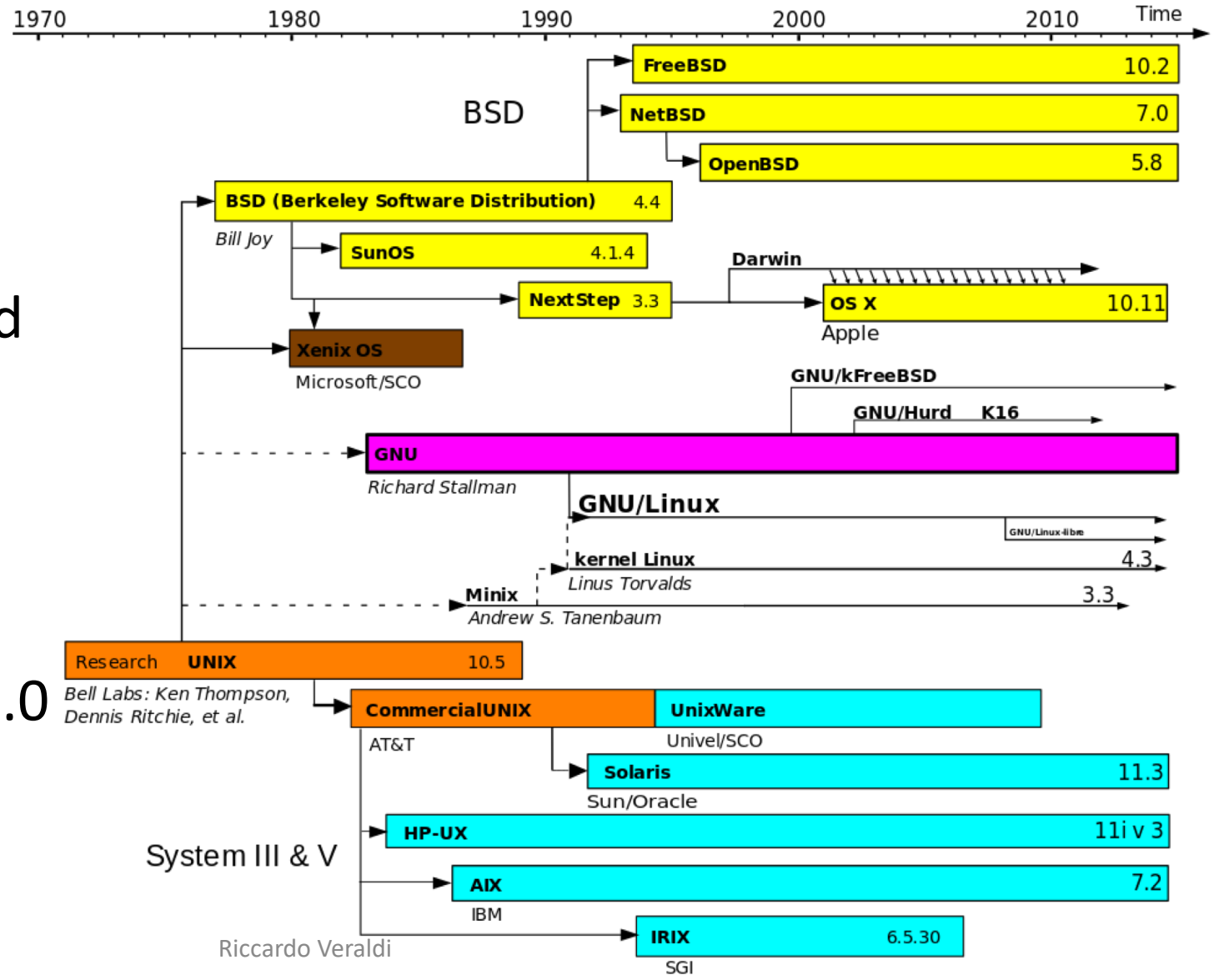
What is OpenBSD

- It IS NOT Linux
- It is a FREE, multi-platform 4.4BSD-based UNIX-like **complete operating system**
- Founded in 1995 by Theo de Raadt
- Forked from NetBSD 1.0



OpenBSD project goals

- Provide the best development platform possible. Provide full source access to developers and users, including the ability to look at CVS tree changes directly.
- Greater intergration of cryptographic software
- Provide code that can be freely used, copied, modified, and distributed by anyone and for any purpose.
- Be NUMBER ONE in the industry for security
- Track and implement standards (ANSI, POSIX, parts of X/Open, etc.)
- Work towards a very machine independent source tree
  - Support for different hw platforms

OpenBSD supported platforms

alpha	Digital Alpha-based systems
amd64	AMD64-based systems
arm64	64-bit ARM systems
armv7	ARM based devices, such as BeagleBone, PandaBoard, CuBox-i, SABRE Lite, Nitrogen6x and Wandboard
hppa	Hewlett-Packard Precision Architecture (PA-RISC) systems
i386	Standard PC and clones based on the Intel i386 architecture and compatible processors
landisk	IO-DATA Landisk systems (such as USL-5P) based on the SH4 cpu
loongson	Loongson 2E- and 2F-based systems, such as the Lemote Fuloong and Yeeloong, Gdium Liberty, etc.
luna88k	Omron LUNA-88K and LUNA-88K2 workstations
macppc	Apple *New World* PowerPC-based machines, from the iMac onwards
octeon	Cavium Octeon-based MIPS64 systems
powerpc64	IBM POWER-based PowerNV systems
sparc64	Sun UltraSPARC and Fujitsu SPARC64 systems

Proactive Security

- It is a cultural approach: «when we make a security technology, we apply it to the maximum extent possible, and don't wait for chance adoption and integration by others»
- OpenBSD audit process
  - Team of 6 to 12 members who constantly look for and fix security holes
  - Comprehensive file-by-file analysis of every critical software component
  - Looking for basic software bugs which years later is discovered to be a security issue
  - Code gets audited multiple times, and by multiple people with different auditing skills.
- Linux has hardening features but they are *optional*
  - First thing all people does after installing a Linux distribution is **disable selinux**
  - Linux is a kernel, all the rest comes from the specific Distribution flavor (with all possible security flaws)

OpenBSD Innovations

- First free operating system to implement a IPSec VPN stack (1997)
- Privilege separation: first released with OpenSSH (2002)
- Privilege revocation: ping, traceroute
- Stack protector: propolice (2002) implemented system wide
- W^X (2003)
- GOT and PLT protection: ro outside of ld.so
- ALSR (2003
- PIE (2013)
- SROP (2016): sigreturn()
- Static-PIE
- Library order randomization
- Trapsleds (2017)
- Kernel relinking at boot (2017)
- RETGUARD
- …

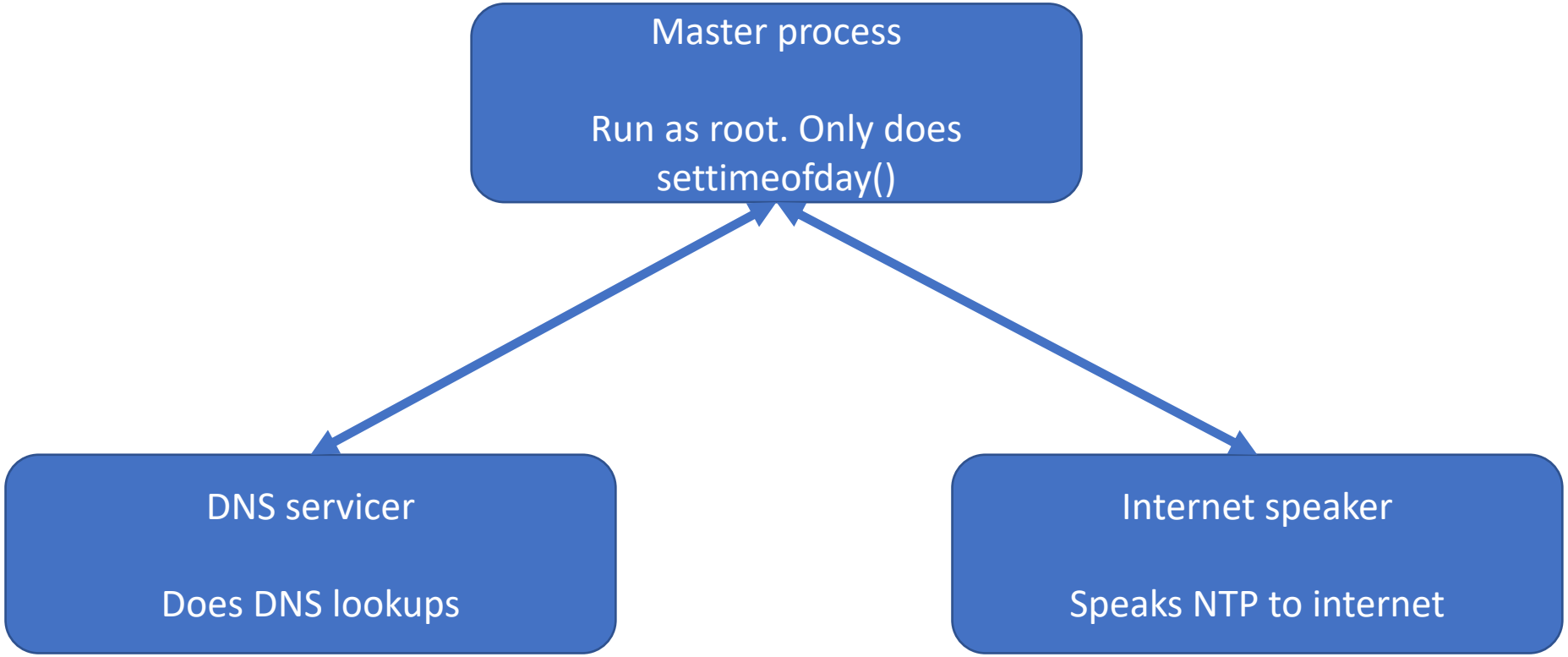
W^X

- Pioneered by the OpenBSD project in 3.3 in 2002, strictly enforced in 6.0
- Memory can either be write or execute, but not both (XOR)
- Similar to PaX Linux kernel extension (developed later)

Privilege Separation

- Split a program into processes performing different sub-functions
- Each process is designed to operate in a separate security domain
- Now used in almost all privileged programs in OpenBSD: bgpd(8), dhclient(8), dhcpd(8), dvmrpd(8), eigrpd(8), file(1), httpd(8), iked(8), ldapd(8), ldpd(8), mountd(8), npppd(8), ntpd(8), ospfd(8), ospf6d(8), pflogd(8), radiusd(8), relayd(8), ripd(8), script(1), smtpd(8), syslogd(8), tcpdump(8), tmux(1), xconsole(1), xdm(1), Xserver(1), ypldap(8), pkg_add(1), etc.

Privilege Separation example: OpenNTPD



Privilege Separation: pledge()

- Pledge syscall requests that only (a carefully selected) subset of POSIX functionality be permitted
- Subsets such as: stdio rpath wpath cpath fattr inet dns getpw proc exec sendfd recvfd ...
- Deep functional support in the kernel — more sophisticated than *seccomp*
  - pledge was designed so more applications can use it, by exposing all argument details
- I pledge this is the only subset of POSIX I will use, otherwise program will be killed

```
imsg_init(ibuf_dns, pipe_ntp[1]);
if (pledge("stdio dns", NULL) == -1)
        err(1, "pledge")
```

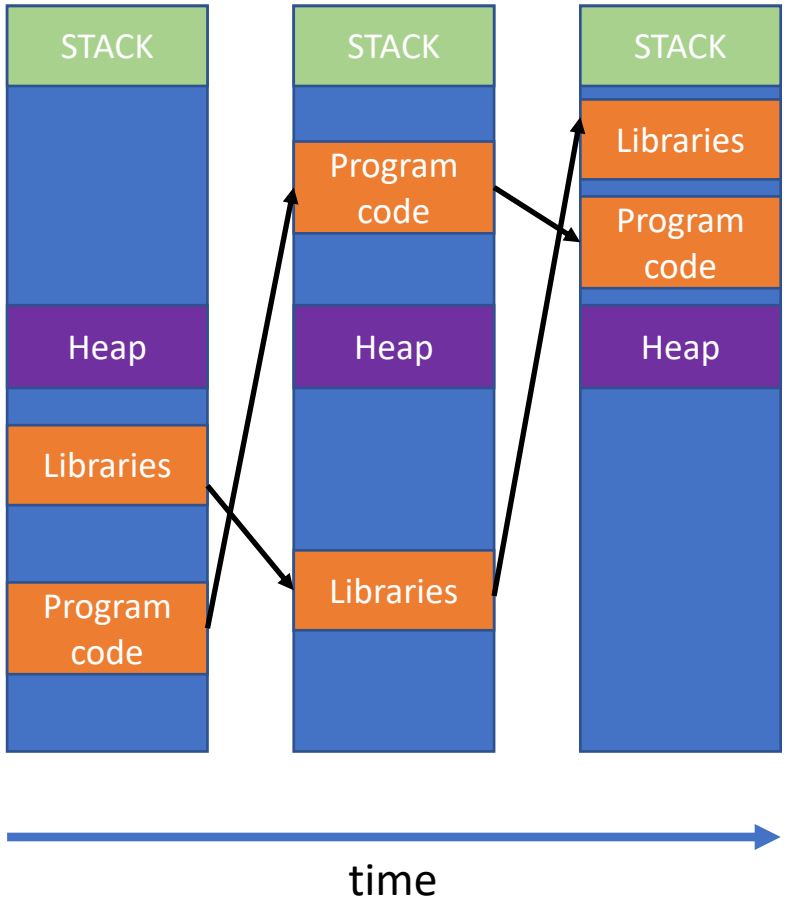
- Implementation errors found in 10% of privsep programs

Privilege Separation: unveil()

- Implemented in OpenBSD 6.4
- Hide the filesystem and only expose parts you need
- **unveil("/home/veraldi", "r")**
- Accessing anything other than **/home/veraldi** will throw **ENOENT**
- Trying to write to **/home/veraldi** will throw **EINVAL** or **EP**

Address Space Layout Randomisation (ASLR)

- Libraries, heap, program code are randomly distributed through virtual memory each time the program starts
- Random stack offset
- Every execution of a binary ends up in a different layout
- This makes it hard for an attacker to predict memory addresses and process behaviour



kernel address space randomized link

KARL

- Relinks kernel libraries in random orders
- Individually randomizes the object files that get linked into the binary
  - Unlike Linux's kernel address space layout randomization (KASLR), which randomizes the base address for all of the kernel code
- A single information leak of a function address from the kernel does not leak information about the location of all other functions.

arc4random()

- “A Replacement Call for Random”
  - rand() function conforms to ANSI X3.159-1989 (“ANSI C89”).
  - rand_r() function conforms to IEEE Std 1003.1-2008 (“POSIX.1”).
  - The srand() function does not conform to ANSI X3.159-1989 (“ANSI C89”)
- Very high quality random numbers
- Originally used RC4
- Now uses ChaCha20
- It may be replaced again in the future as cryptographic techniques advance

And more…

- Position-Independent Executables (PIE)
  - First OS to enable PIE by default
- RETGUARD
  - Mitigation against ROP exploits
  - Compiler-based exploit mitigation
  - Combine the function return address with a random cookie
  - Details at https://doi.asiabsdcon.org/10.25263/asiabsdcon2019/p01b
- Randomized PIDs
  - OpenBSD spawns each new process with a random, unused PID. This protects the user from attacks that predict new PIDs

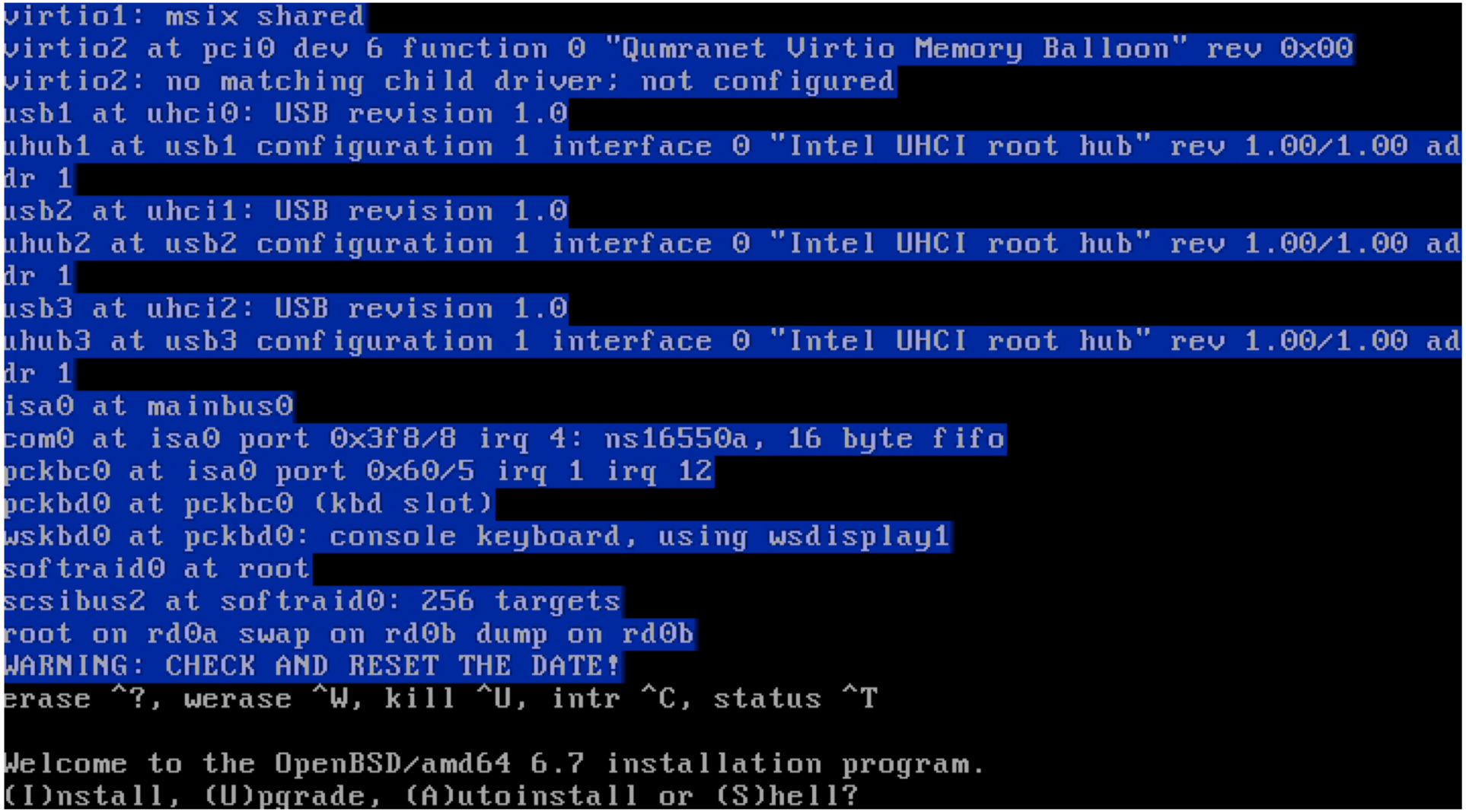
New functions

- strlcpy(), strlcat(): They are designed to be safer, more consistent, and less error prone replacements
- reallocarray(): Designed for safe allocation of arrays
- pledge()
- unveil()
- timingsafe_memcmp()
- …

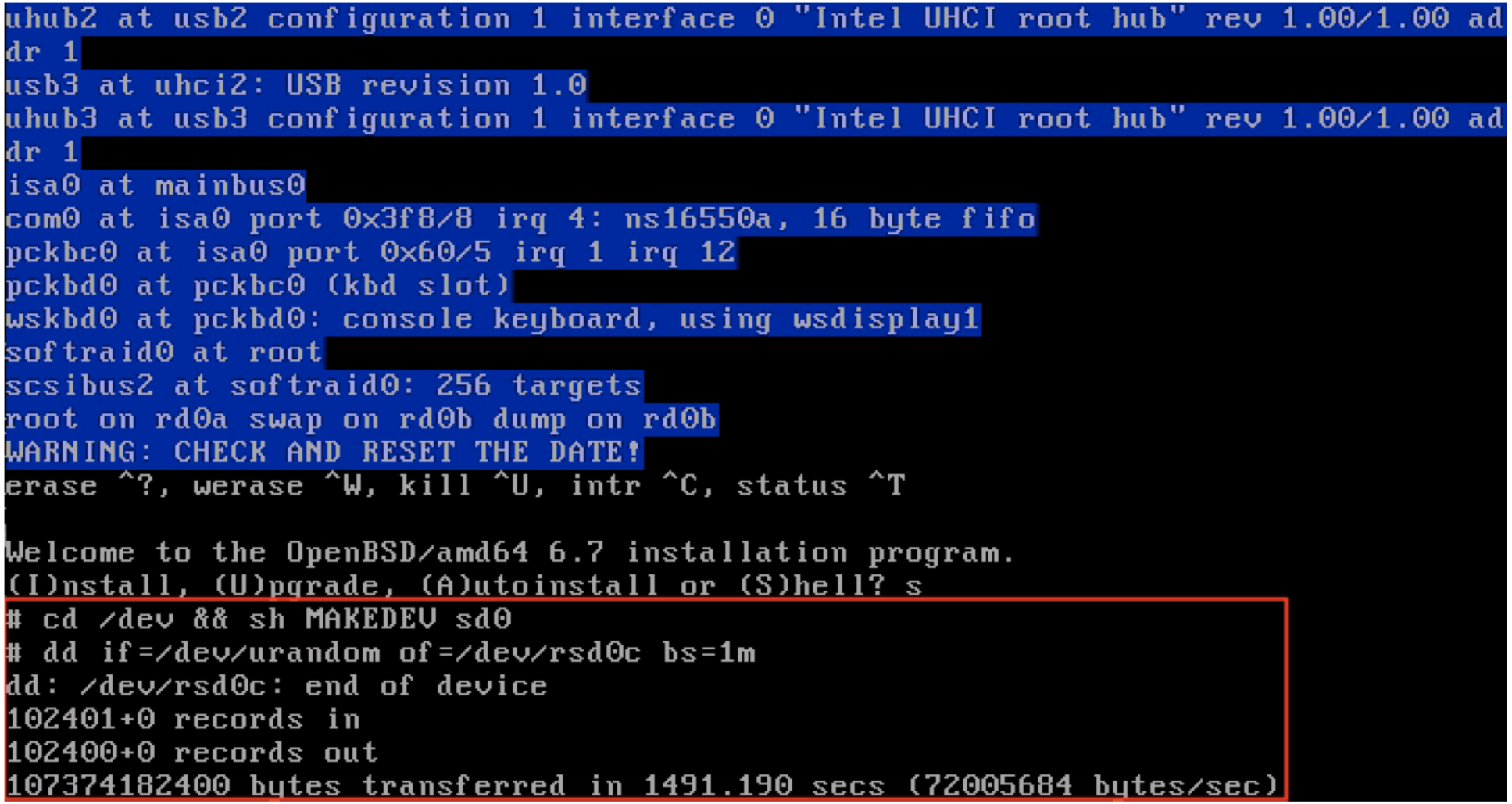
OpenBSD projects and more

- OpenSSH: we all know what is it
- LibreSSL: forked from OpenSSL dueing Heartbleed vuln+libtls
- OpenRSYNC: reimplamentation of rsync with priv separation
- pf: packet filter, ported to many other OSes
- vmm/vmd: hypervisor
- switchd: virtual switch (openflow specs)
- Unwind: DNS resolver
- Xenocara: X11 implementation (privilege separation)
- Doas: replacement for sudo
- httpd: replacement. For apache and nginx
- OpenSMTPD: new SMTP MTA
- CARP: secure, free alternative to the VRRP and the HSRP

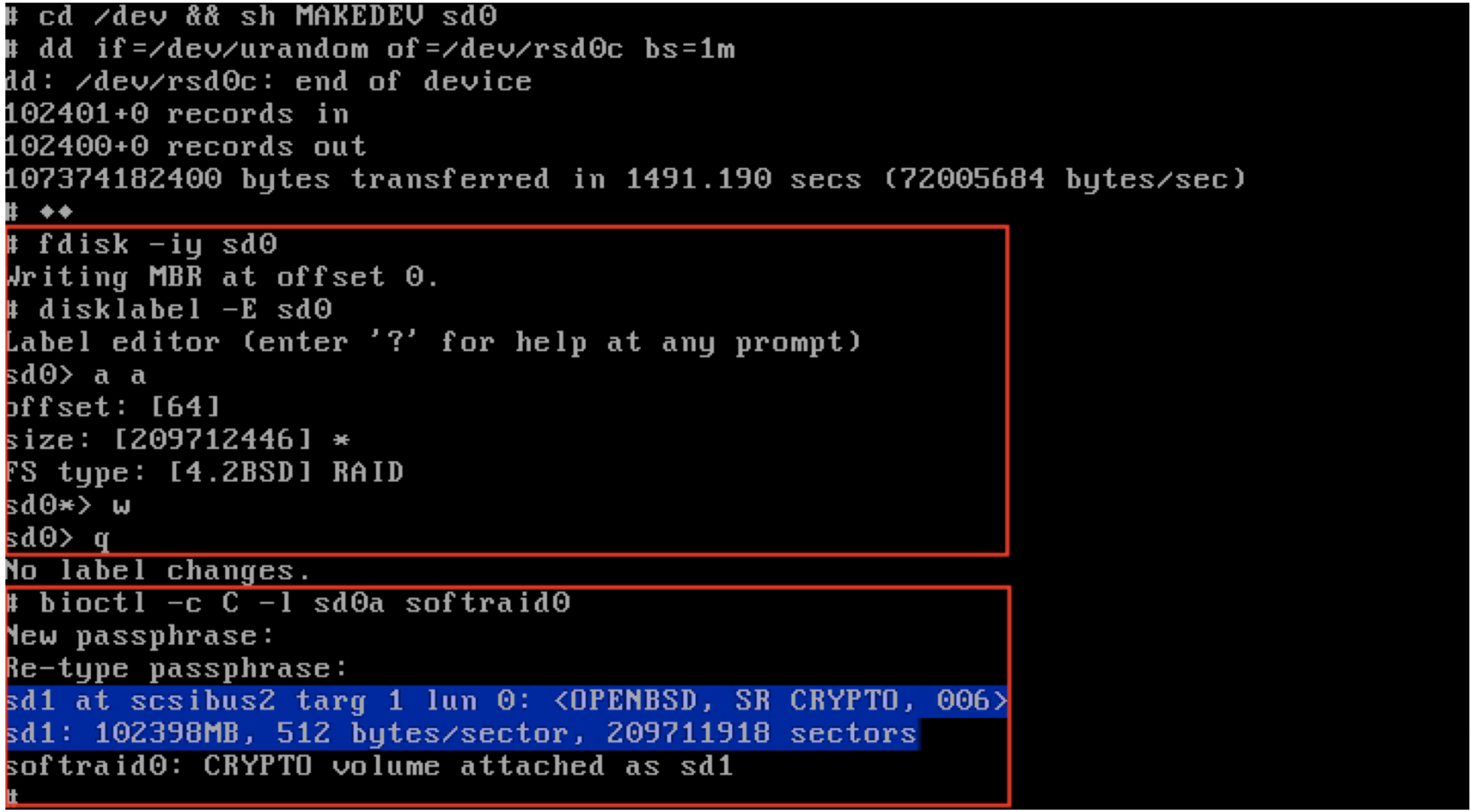
OpenBSD Installation (1)



OpenBSD Installation (2)
full disk encryption setup



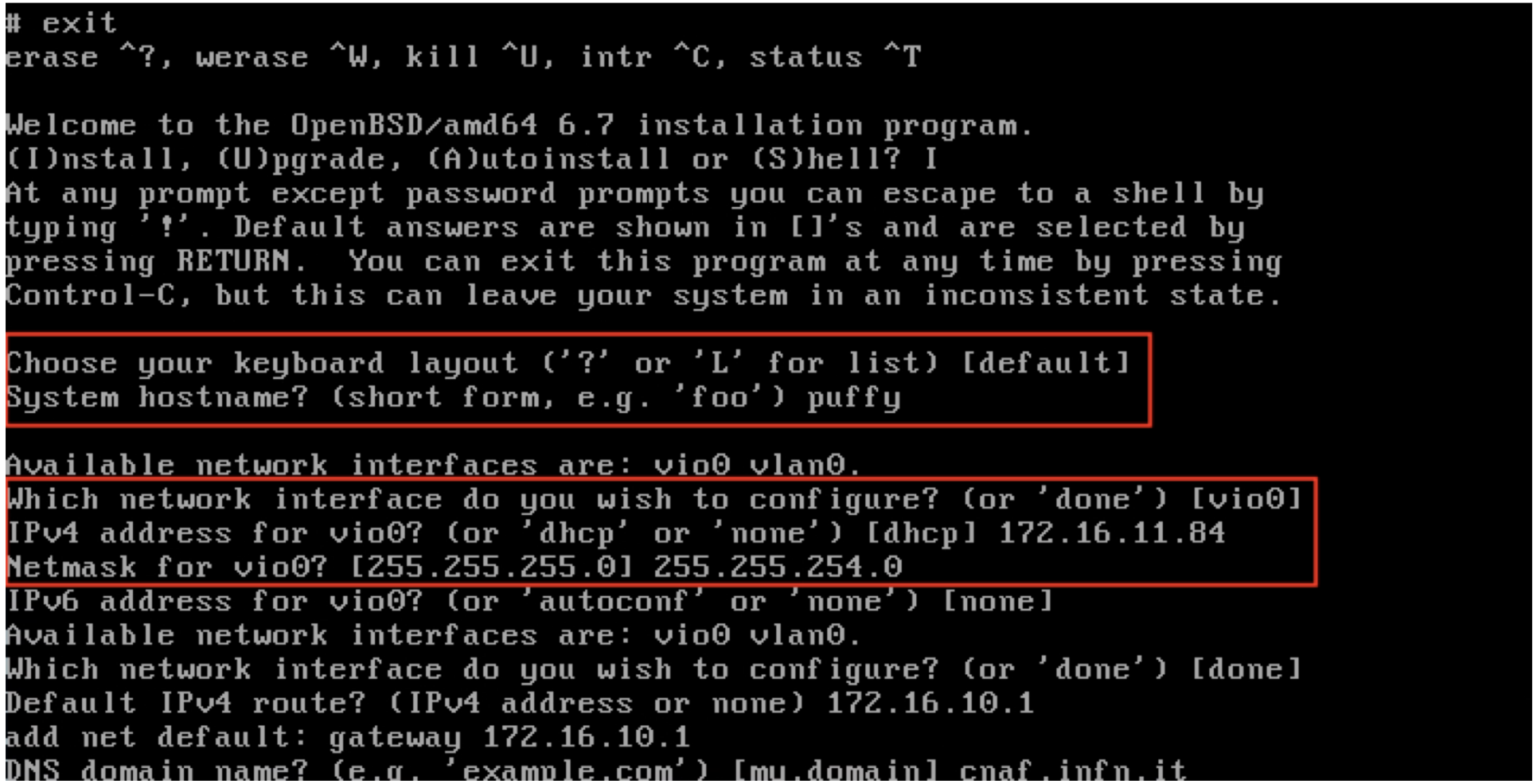
OpenBSD Installation (3)



OpenBSD installation (4)

```
#
# dd if=/dev/zero of=/dev/rsd1c bs=1m count=1
1+0 records in
1+0 records out
1048576 bytes transferred in 0.012 secs (81747271 bytes/sec)
#
```

OpenBSD Installation (5)



OpenBSD Installation (6)

```
Default IPv4 route? (IPv4 address or none) 172.16.10.1
add net default: gateway 172.16.10.1
DNS domain name? (e.g. 'example.com') [my.domain] cnaf.infn.it
DNS nameservers? (IP address list or 'none') [none] 131.154.3.1
```

```
Available disks are: sd0 sd1.
Which disk is the root disk? ('?' for details) [sd0] sd1
No valid MBR or GPT.
Use (W)hole disk MBR, whole disk (G)PT or (E)dit? [whole]
Setting OpenBSD MBR partition to whole sd1...done.
The auto-allocated layout for sd1 is:
#                size           offset  fstype [fsize bsize   cpg]
  a:              1.0G               64  4.2BSD   2048 16384     1 # /
  b:              2.2G          2097216    swap
  c:            100.0G                0  unused
  d:              4.0G          6782976  4.2BSD   2048 16384     1 # /tmp
  e:              8.0G         15171552  4.2BSD   2048 16384     1 # /var
  f:              6.0G         31883072  4.2BSD   2048 16384     1 # /usr
  g:              1.0G         44465984  4.2BSD   2048 16384     1 # /usr/X11R6
  h:             14.4G         46563136  4.2BSD   2048 16384     1 # /usr/local
  i:              2.0G         76802496  4.2BSD   2048 16384     1 # /usr/src
  j:              6.0G         80996800  4.2BSD   2048 16384     1 # /usr/obj
  k:             55.4G         93579712  4.2BSD   2048 16384     1 # /home
Use (A)uto layout, (E)dit auto layout, or create (C)ustom layout? [a]
```

OpenBSD Installation (7)

```
sd1> p
OpenBSD area: 64-209696445; size: 209696381; free: 209696381
#                size           offset  fstype [fsize bsize   cpg]
  c:        209711918                0  unused
sd1> _
```

```
partition: [a]
offset: [64]
size: [209696381] 50G
FS type: [4.2BSD]
mount point: [none] /
```

```
sd1*> a
partition: [b]
offset: [104872320]
size: [104824125] 8G
FS type: [swap]
sd1*>
```

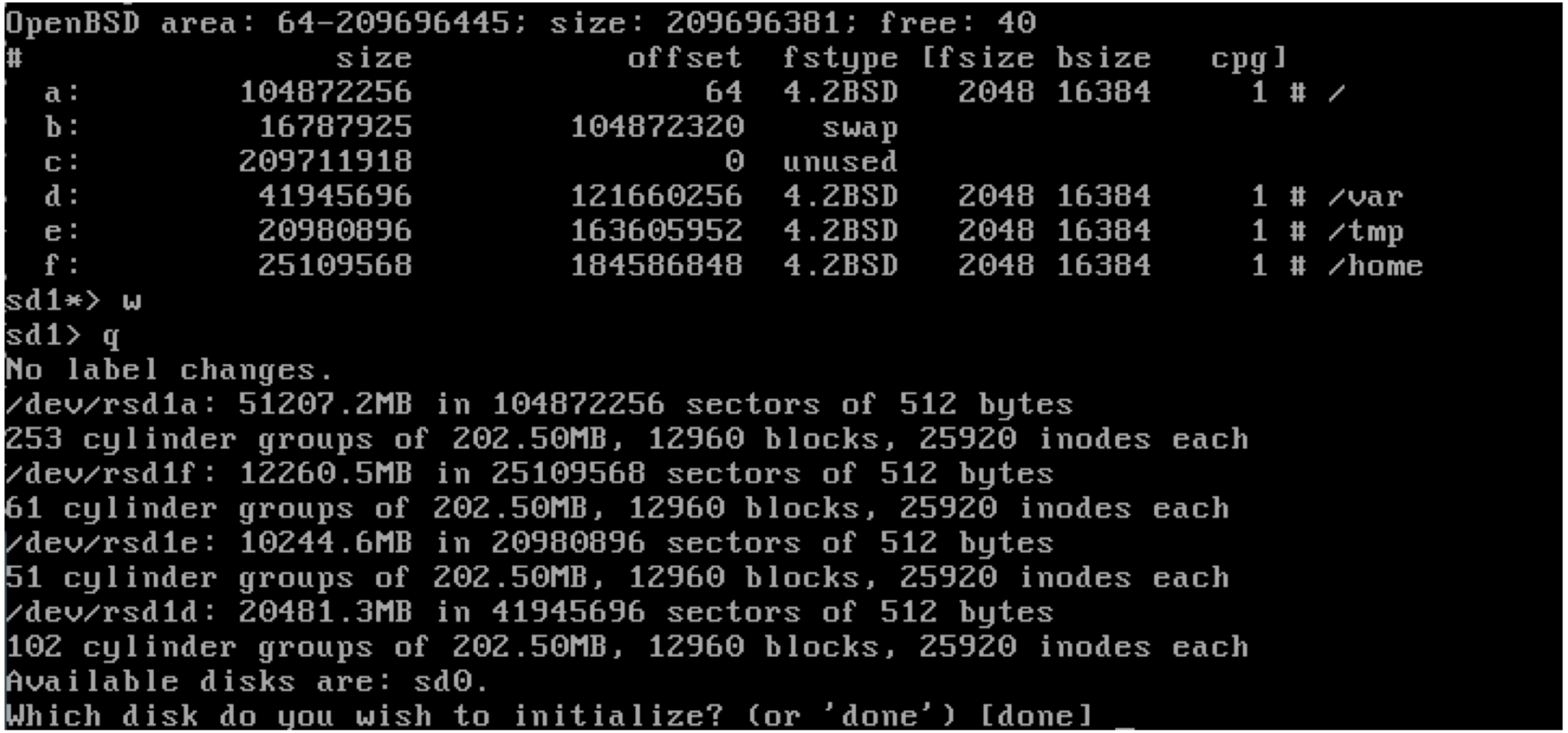
```
sd1*> a
partition: [d]
offset: [121660245]
size: [88036200] 20G
FS type: [4.2BSD]
mount point: [none] /var
sd1*> _
```

OpenBSD Installation (6)

```
sd1*> a
partition: [e]
offset: [163605952]
size: [46090493] 10G
FS type: [4.2BSD]
mount point: [none] /tmp
```

```
Password for root account? (will not echo)
Password for root account? (again)
Start sshd(8) by default? [yes]
Do you expect to run the X Window System? [yes] no
Change the default console to com0? [no]
Setup a user? (enter a lower-case loginname, or 'no') [no] veraldi
Full name for user veraldi? [veraldi]
Password for user veraldi? (will not echo)
Password for user veraldi? (again)
WARNING: root is targeted by password guessing attacks, pubkeys are safer.
Allow root ssh login? (yes, no, prohibit-password) [no]
What timezone are you in? ('?' for list) [Europe/Rome]
```

OpenBSD Installation (7)

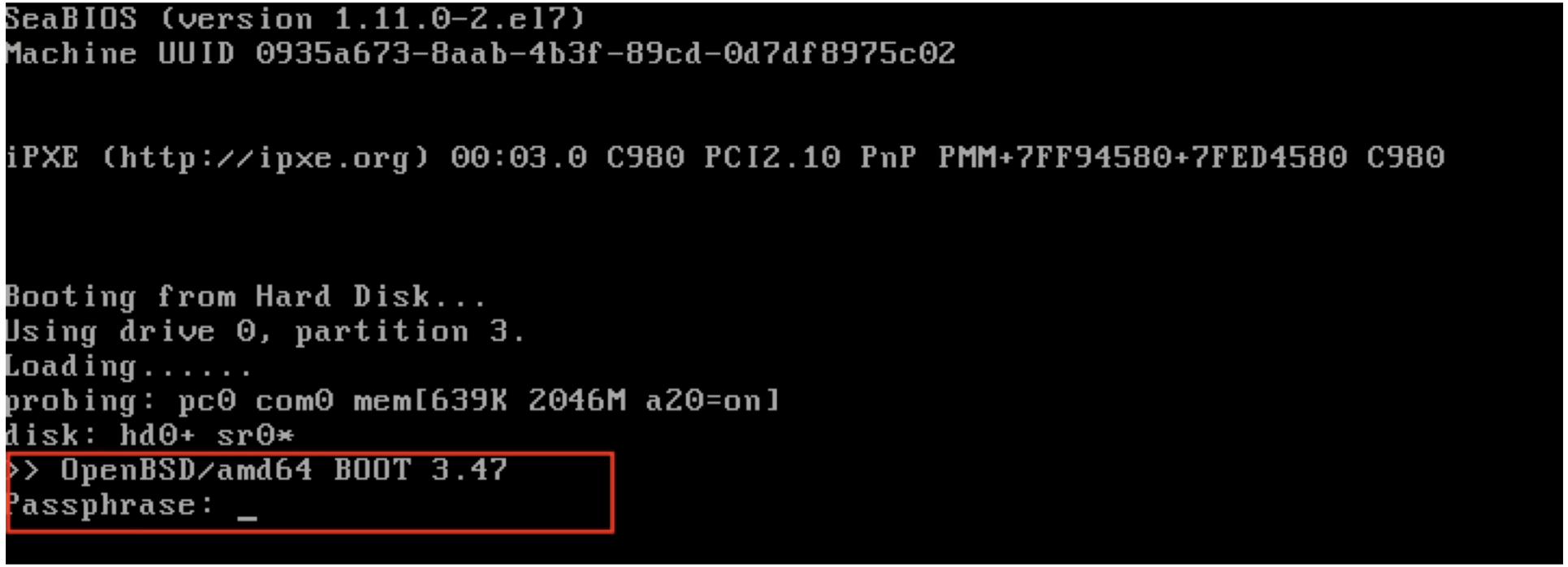


OpenBSD installation (8)

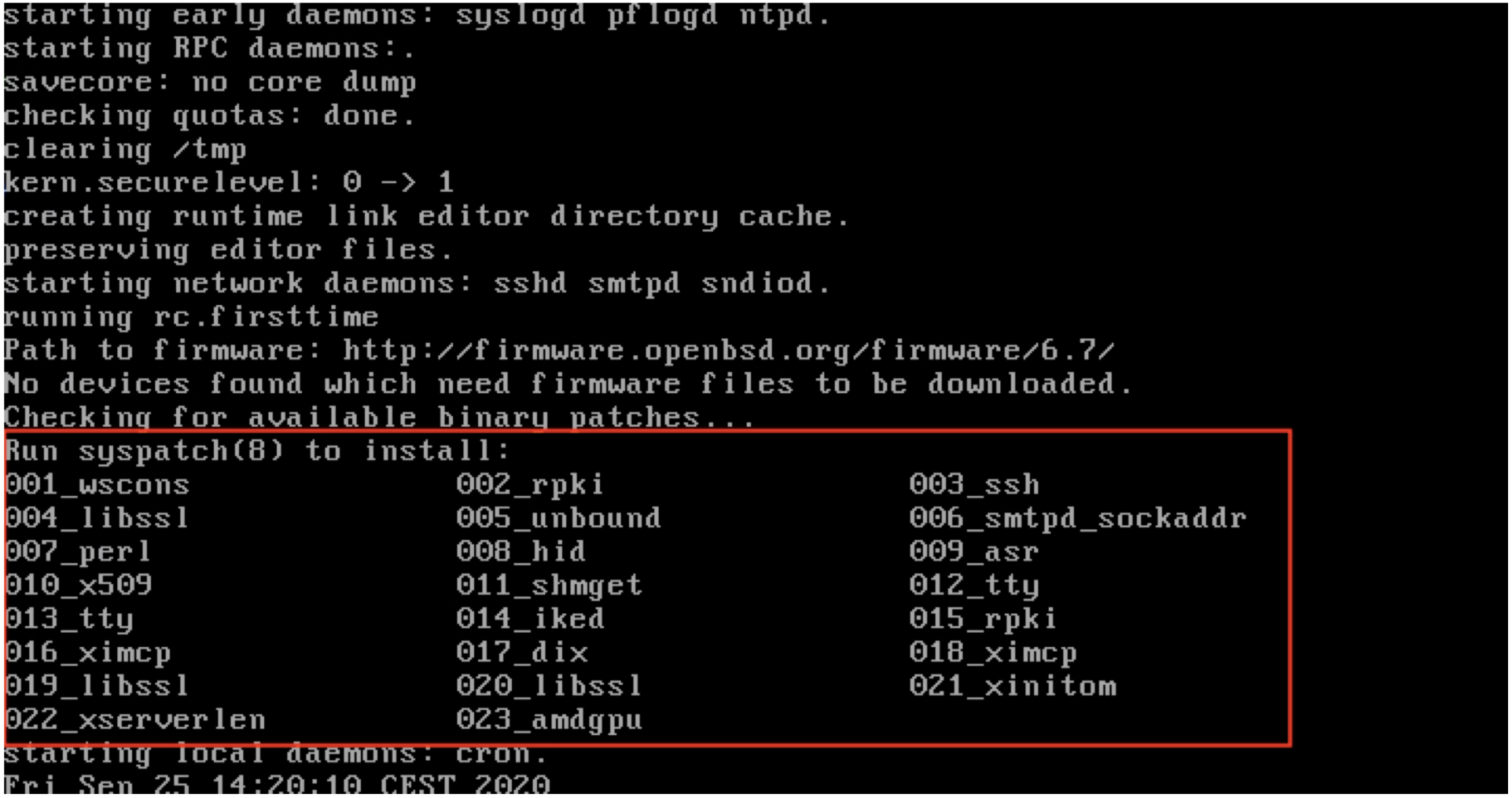
```
Let's install the sets!
Location of sets? (cd0 disk http nfs or 'done') [cd0]
Pathname to the sets? (or 'done') [6.7/amd64]

Select sets by entering a set name, a file name pattern or 'all'. De-select
sets by prepending a '-', e.g.: '-game*'. Selected sets are labelled '[X]'.
    [X] bsd           [X] base67.tgz    [X] game67.tgz    [X] xfont67.tgz
    [X] bsd.mp        [X] comp67.tgz    [X] xbase67.tgz   [X] xserv67.tgz
    [X] bsd.rd        [X] man67.tgz     [X] xshare67.tgz
Set name(s)? (or 'abort' or 'done') [done]
```

```
Saving configuration files... done.
Making all device nodes... done.
Multiprocessor machine; using bsd.mp instead of bsd.
Relinking to create unique kernel... done.

CONGRATULATIONS! Your OpenBSD install has been successfully completed!

When you login to your new system the first time, please read your mail
using the 'mail' command.

Exit to (S)hell, (H)alt or (R)eboot? [reboot]
```

OpenBSD installation (9)



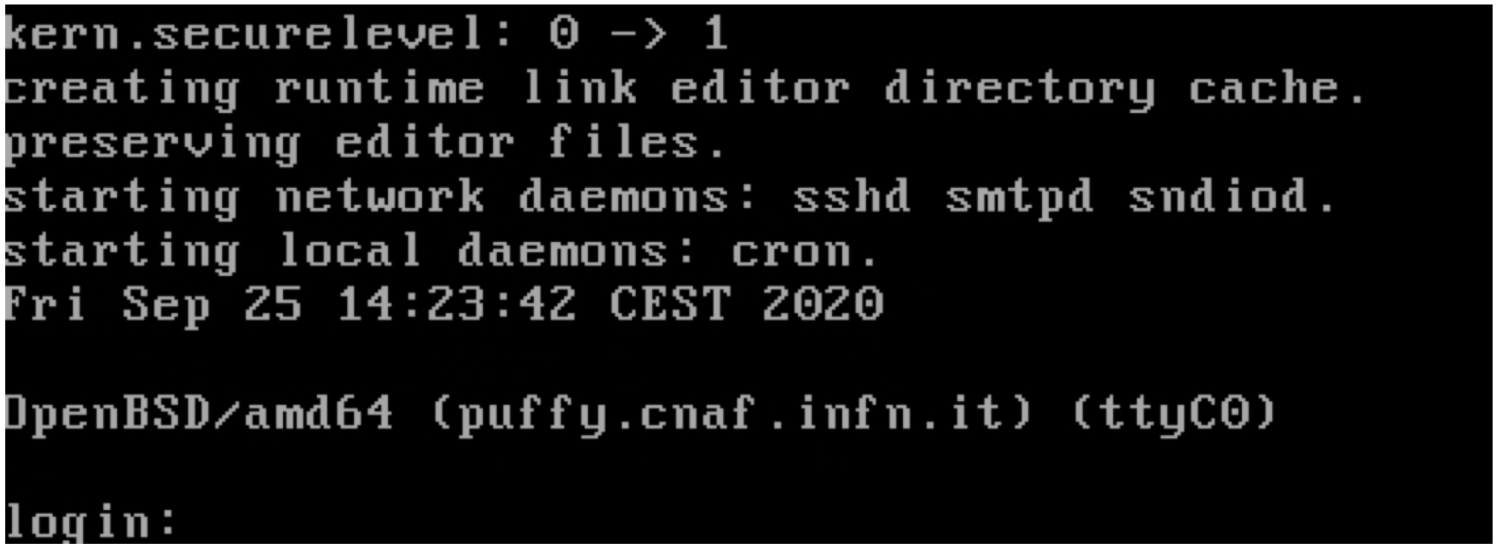
OpenBSD installation (10)



OpenBSD installation (11)

```
Get/Verify syspatch67-013_tty.tgz 100% |*****************|   192 KB    00:00
Installing patch 013_tty
Get/Verify syspatch67-014_iked.tgz 100% |*****************|   171 KB    00:00
Installing patch 014_iked
Get/Verify syspatch67-015_rpki.tgz 100% |*****************| 41289       00:00
Installing patch 015_rpki
Get/Verify syspatch67-016_ximcp.tgz 100% |****************|  1762 KB    00:01
Installing patch 016_ximcp
Get/Verify syspatch67-017_dix.tgz 100% |*****************|  4314 KB    00:00
Installing patch 017_dix
Get/Verify syspatch67-018_ximcp.tgz 100% |****************|  1760 KB    00:00
Installing patch 018_ximcp
Get/Verify syspatch67-019_libssl.tgz 100% |***************|  4460 KB    00:00
Installing patch 019_libssl
Get/Verify syspatch67-020_libssl.tgz 100% |***************|  4451 KB    00:00
Installing patch 020_libssl
Get/Verify syspatch67-021_xinitom... 100% |***************|  1760 KB    00:00
Installing patch 021_xinitom
Get/Verify syspatch67-022_xserver... 100% |***************|  4318 KB    00:01
Installing patch 022_xserverlen
Get/Verify syspatch67-023_amdgpu.tgz 100% |***************|   214 KB    00:00
Installing patch 023_amdgpu
Relinking to create unique kernel... done; reboot to load the new kernel
Errata can be reviewed under /var/syspatch
puffy#
```

OpenBSD installation (12)



OpenBSD kenel securelevel

- -1: Permanently insecure mode
  - init(8) will not attempt to raise the securelevel
  - may only be set with sysctl(8) while the system is insecure
- 0: Insecure mode
  - used during bootstrapping and while the system is single-user
  - all devices may be read or written subject to their permissions
  - system file flags may be cleared with chflags(2)
- 1: Secure mode
  - default mode when system is multi-user
  - securelevel may no longer be lowered except by init
  - /dev/mem and /dev/kmem cannot be opened
  - raw disk devices of mounted file systems are read-only
  - system immutable and append-only file flags may not be removed
  - Restrictions on a number of sysctl variables and GPIO settings
- 2: highly secure mode: all effects of level 1 plus
  - raw disk devices are always read-only whether mounted or not
  - settimeofday(2) and clock_settime(2) may not set the time backwards
  - pf(4) filter and NAT rules may not be altered

OpenBSD filesystem layout

- **/bsd** - The kernel
- **/bsd.mp** - The multiprocessing kernel, of you're on a platform that supports it
- **/bsd.rd** - The ramdisk kernel, used for installation
- **/bin/** - Statically-linked essential user tools
- **/sbin/** - Statically-linked essential superuser tools
- **/etc/** - Configuration files
- **/dev/** - Device files
- **/home/** - User home directories
- **/mnt/** - Empty mount point
- **/root/** - Root user home directory
- **/var/** - Persistent non-user data: logs, mail, databases, websites, etc.
- **/usr/bin/** - Most other user tools
- **/usr/sbin/** - Most other superuser tools
- **/usr/{lib,include,share}** - Program resources
- **/usr/local/{bin,lib,include}** - All package provided files, except for configuration files

OpenBSD user management

- **adduser** - Interactively add users
  chpass - Interactively change user info
- **useradd** - Non-interactively add users
  usermod - Non-interactively modify user info
- **userinfo** - Get information on a user
- **userdel** - Delete a user account

OpenBSD group management

- **groupadd** - Create a group
- **groupmod** - Modify a group
- **groupinfo** - Get information on a group
- **groupdel** - Delete a group

OpenBSD doas (sudo replacement)

```
[veraldi@puffy:$~$ doas /bin/ksh
[doas (veraldi@puffy.cnaf.infn.it) password:
[puffy# whoami
 root
[puffy# exit
[veraldi@puffy:$~$ doas -L
```

OpenBSD syspatch

- utility to fetch, verify, install and revert OpenBSD binary patches
- Very fast and very simple to use
  - **-c** List available patches; suitable for cron(8).
  - **-l** List installed patches.
  - **-R** Revert all patches.
  - **-r** Revert the most recently installed patch.

OpenBSD rc

- command script that is invoked by init(8) when the system starts up
- Very simple
- **rcctl**: configure and control daemons and services
- Split up into several parts
  - **/etc/rc** - Startup command script
  - **/etc/rc.conf** - System daemon configuration database (don’t touch)
  - **/etc/rc.conf.local** - System local configuration
  - **/etc/rc.d** - Location of rc.d(8) scripts

OpenBSD rc.conf.local

<daemon>_flags=<args>

- **apmd_flags=NO** - Daemon disabled
- **apmd_flags=** - Daemon enabled
- **apmd_flags=-A** - Daemons enabled with special flags

- Special services (**pf**, **ipsec**, etc.) only have a YES/NO option **pf_enable=YES**
- **pkg_scripts** - Services that have to startup and shutdown in order
  - Example: **pkg_scripts=messagebus cupsd**

OpenBSD rcctl (usage example)

```
# rcctl set apmd status on
# rcctl set apmd flags -A
# rcctl get apmd
    apmd_class=daemon
    apmd_flags=-A
    apmd_rtable=0
    apmd_timeout=30
    apmd_user=root
```

OpenBSD logs

- Most logs goes into /var/log
  - Auth, PF, mail, daemons, etc.
- httpd logs into /var/www/logs
- Syslog configuration in /etc/syslog.conf

OpenBSD network interfaces

- ifconfig used for all network configuration
- No *ip/iw_config/wpa_supplicant/brcrl/vconfig/nmcli* etc.
  - Join wifi**:** *ifconfig iw0 join MySSID wpakey ThePassword*
  - Create VLAN*: ifconfig vlan10 create*
    *ifconfig vlan10 parent **vio0** 10.10.1.3/24*

```
puffy$ cat /etc/hostname.vio0
inet 172.16.11.84 0xfffffe00
```

- /etc/hostname.<if> where <if> is the name of the interface
- /etc/netstart - Network startup script, configures: hostname, loopback ,bridges
- To re-apply a configuration to an interface: *sh /etc/netstart <if>*

```
puffy$ cat /etc/myname
puffy.cnaf.infn.it
puffy$ cat /etc/mygate
172.16.10.1
puffy$ cat /etc/resolv.conf
lookup file bind
nameserver 131.154.3.1
```

- Possibility to create bridges, trunks, equal cost multi path routing

```
puffy# ifconfig bridge0 create
puffy# ifconfig bridge0 add vio0
puffy# ifconfig bridge0
bridge0: flags=0<>
        index 6 llprio 3
        groups: bridge
        priority 32768 hellotime 2 fwddelay 15 maxage 20 holdcnt 6 proto rstp
        designated: id 00:00:00:00:00:00 priority 0
        vio0 flags=3<LEARNING,DISCOVER>
                port 1 ifpriority 0 ifcost 0
        Addresses (max cache: 100, timeout: 240):
```

OpenBSD systat

- displays various system statistics in a screen-oriented fashion
  - Memory usage
  - Memory allocations
  - CPU usage
  - Network usage
  - Interace usage
  - I/O usage
  - Sensors
  - Firewall rules
  - Firewall connections
  - …

OpenBSD package management

- pkg_add: for installing and upgrading packages
- pkg_check: for checking the consistency of installed packages
- pkg_delete: for removing installed packages
- pkg_info: for displaying information about packages

```
puffy$ doas pkg_add unzip
doas (veraldi@puffy.cnaf.infn.it) password:
quirks-3.326 signed on 2020-09-27T13:48:33Z
Ambiguous: choose package for unzip
a       0: <None>
        1: unzip-6.0p13
        2: unzip-6.0p13-iconv
Your choice: 1
unzip-6.0p13: ok
```

OpenBSD partitions

- Defined in /etc/fstab
- disklabel: utility can be used to install, examine, or modify the label on a disk
  - Partition **c** is the whole disk!!
  - *disklabel sd1*

```
#                size           offset  fstype [fsize bsize   cpg]
  a:        104872256               64  4.2BSD   2048 16384 12960 # /
  b:         16787925        104872320    swap                    # none
  c:        209711918                0  unused
  d:         41945696        121660256  4.2BSD   2048 16384 12960 # /var
  e:         20980896        163605952  4.2BSD   2048 16384 12960 # /tmp
  f:         25109568        184586848  4.2BSD   2048 16384 12960 # /home
```

- FFS2 (Enhanced Fast File System): derived from BSD UFS

OpenBSD commonly used commands

- **ksh(1)** default shell
- **sysctl(8)** manage kernel state
- **usbdevs(8)** to list usb devices
- **pcidump(8)** to list pci devices
- **disklabel(8)** to format OpenBSD disks
- **sysctl hw.disknames** to list disks
- **vmstat(8)** to check ram usage

OpenBSD PF

- OpenBSD packet filter for TCP/IP traffic and Network Address Translation, packet redirection, packet marking, authentication gateway
- capable of normalizing and conditioning TCP/IP traffic, as well as providing bandwidth control and packet prioritization
- Simple configuration and administration
- Ported to many other systems:
  - MacOS
  - iOS
  - FreeBSD (pfSense, OPNsense)
  - NetBSD
  - Solaris
  - QNX

OpenBSD PF controls

```
# pfctl -f  /etc/pf.conf        Load the pf.conf file
# pfctl -nf /etc/pf.conf        Parse the file, but don't load it
# pfctl -sr                     Show the current ruleset
# pfctl -ss                     Show the current state table
# pfctl -si                     Show filter stats and counters
# pfctl -sa                     Show EVERYTHING it can show
```

OpenBSD PF default rules

```
root@puffy:$/etc$ pfctl -sr
block return all
pass all flags S/SA
block return in on ! lo0 proto tcp from any to any port 6000:6010
block return out log proto tcp all user = 55
block return out log proto udp all user = 55
```

OpenBSD PF custom rules

```
root@puffy:$/home/veraldi$ pfctl -sr
match in all scrub (no-df)
block drop all
block drop in quick from urpf-failed to any
pass in quick on egress proto tcp from <goodssh> to any port = 22 flags S/SA
pass out on egress proto tcp all flags S/SA modulate state
pass out on egress proto udp all
pass out on egress proto icmp all
```

OpenBSD PF block specific user

```
root@puffy:$/var/log$ pfctl -sr
match in all scrub (no-df)
block drop all
block drop in quick from urpf-failed to any
pass in quick on egress proto tcp from <goodssh> to any port = 22 flags S/SA
pass out on egress proto tcp all flags S/SA modulate state
pass out on egress proto udp all
pass out on egress proto icmp all
block drop out log on egress proto tcp from any to any port = 22 user = 1001
```

```
root@puffy:$/var/log$ tcpdump -n -e -ttt -r /var/log/pflog outbound
tcpdump: WARNING: snaplen raised from 116 to 160
Sep 29 14:30:45.897580 rule 7/(match) block out on vio0: 172.16.11.84.47730 > 188.185.87.251.22: S
4088190421:4088190421(0) win 16384 <mss 1460,nop,nop,sackOK,nop,wscale 6,nop,nop,timestamp 12759504
36[|tcp]> (DF) [tos 0x10]
Sep 29 14:30:45.897856 rule 7/(match) block out on vio0: 172.16.11.84.24542 > 188.185.87.173.22: S
3525445062:3525445062(0) win 16384 <mss 1460,nop,nop,sackOK,nop,wscale 6,nop,nop,timestamp 38701291
57[|tcp]> (DF) [tos 0x10]
```

OpenBSD authpf gateway

- authpf: utility to implement an authentication gateway
- Access to the network is allowed only after succesful authentication
- Scenarios:
  - Requiring users to authenticate before allowing internet access.
  - Granting certain users -- such as administrators -- access to restricted parts of the network.
  - Allowing only known users to access the rest of the network or internet from a wireless network segment.
  - Allowing workers from home or on the road access to resources on the company network.
  - Restrict segments of the local network only to certain users and give default access to guests

OpenBSD httpd

- OpenBSD has its own web server called httpd
- FastCGI and TLS support
- /etc/httpd.conf is required in order to activate httpd service

```
root@puffy:~$ cat /etc/httpd.conf
# $OpenBSD: httpd.conf,v 1.20 2018/06/13 15:08:24 reyk Exp $

server "puffy.cnaf.infn.it" {
        listen on * port 80
        root "/htdocs/"
}
```

OpenBSD OpenSMTPD

CSIRT example

```
pki crash.infn.it key "/etc/ssl/private/crash_infn_it.key"
pki crash.infn.it cert "/etc/ssl/crash_infn_it.pem"
ca crash.infn.it cert "/etc/ssl/cert.pem"

listen on egress port 25 tls pki crash.infn.it

action "local" mbox alias <aliases>
action "relay" relay

match from any for domain "crash.infn.it" action "local"
match for local action "local"
match for any action "relay"
```

OpenBSD use cases @INFN

- Bastion hosts
- VPN servers
- CSIRT ticketing system and emails
- CSIRT systems with encrypted disks
- Firewalls
- CNAF DHCP

Questions ?

- Drop me an email if you end up installing OpenBSD

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