It's not an embedded Linux distribution –
It creates a custom one for you.

Tuning Embedded Linux
When Less is More

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Agenda

- Objectives, Motivation, and Target
- Current image type summary reports
- Require concepts and tools
- Iterate over configurations
  - Analyze the kernel and root fs for bloat
  - Identify configuration changes
  - Rebuild and compare reports
- Summary
- Next steps

Objectives

- Reduce raw image size
- Reduce static memory use
- Reduce dynamic memory use
- Minimize boot time

Motivation

- System-on-chip
  - On-die memory is expensive in terms of real-estate and power usage
- Mass market
  - Saving pennies on a smaller flash chip translates to real money
- Performance
  - Smaller images translate to more efficient cache use
- Power usage
  - Less memory means less power
- Smaller images reduce processing due to IO overhead
  - Fewer background services means longer idle states
- Boot time
  - Smaller images translate to less IO and decompression time
- Reduced development overhead
  - Smaller images contain less unnecessary code to build and validate

Real-World Examples

- Digital camera
  - 10 MB memory
  - Critical boot time
- Medical devices
  - 8 MB flash
  - 4 MB memory
- Network boot RAM FS
  - No flash on device
  - Entire FS in RAM
- Small headless systems
  - 8 MB SPI flash
  - MMC/SD for additional storage
- Partitioned flash
  - Smaller parallel NAND
  - Larger MMC/SD

Thank you to the individuals who shared their experiences on the Yocto mailing list to generate these examples.

Target

- Generate a Kernel + RootFS in under 4MB
- Boot in under 8MB
  - (4MB would be better)
- Boot to shell in under 2 seconds
- Maintain ipv4 functionality
- Avoid an initial RAM disk
  - (No cheating by building everything as modules)
- We'll use qemux86 for the purposes of this exercise

Sato: Size Report

- Contents
  - Linux kernel
  - Eglibc
  - Udev
  - Login
  - X Server
  - Sato Desktop and Applications

- Size Report

BzImage:	4.0 MB
RootFS:	118.0 MB
~~Modules:~~	~~35.0 MB~~
Total:	**122.0 MB**

- Memory Report

RAM:	128 MB
Early boot:	9.8 MB
Login:	82.3 MB
Kernel Freed:	444 KB

- Boot Time

Kernel*:	4.26s
Sato Desktop:	21.9s

* At "`Freeing unused kernel memory`"

Minimal: Size Report

- Contents
  - Linux kernel
  - Eglibc
  - Udev
  - Login

- Size Report

BzImage:	4.0 MB
RootFS:	11.0 MB (-107.0 MB)
~~Modules:~~	~~35.0 MB~~
Total:	**15.0 MB**

- Memory Report

RAM:	32 MB
Early boot:	8.6 MB
Login:	15.8 MB
Kernel Freed:	444 KB

- Boot Time

Kernel:	3.84s
Login:	9.5s

Components

- Root filesystem
  - Packages
    - Boot
    - Libraries
    - Applications
  - Package configuration
  - Filesystem

- Linux kernel
  - Policy
  - Subsystems
  - Architecture
  - Drivers

Guiding Principles

- Prepare a budget
  - Linux Kernel: 1 MB
  - Root FS: 3 MB
- Don't sweat the small stuff (90% rule)
- Avoid difficult to maintain hacks
  - At first anyway...
- Leverage device specific options
- Develop in a separate layer

Concepts: Storage

- ELF Sections
  - text: the code itself
  - data: initialized data
  - bss: uninitialized data
- Image Size
  - Includes text and data sections only, not bss.
- Measure size in blocks with df (not in bytes with du)

```
$ df mnt-stage1/
Filesystem  1K-blocks  Used  Available Use% Mounted on
/dev/loop1  8059       5407       2243  71% mnt-stage1
```

Concepts: Memory

- Static Memory
  - The text, data, and bss sections.
- Dynamic Memory
  - Memory allocated at runtime
  - Stacks
  - Hashtables
  - Allocators
  - Page Cache
  - Reservations
- Temporary Memory
  - Decompression
  - __init__

Tools

- Identify, quantify, and record your changes
  - ksize.py
  - dirsize.py
  - merge_config.sh

```
$ bitbake -u depexp -g core-image-*
```

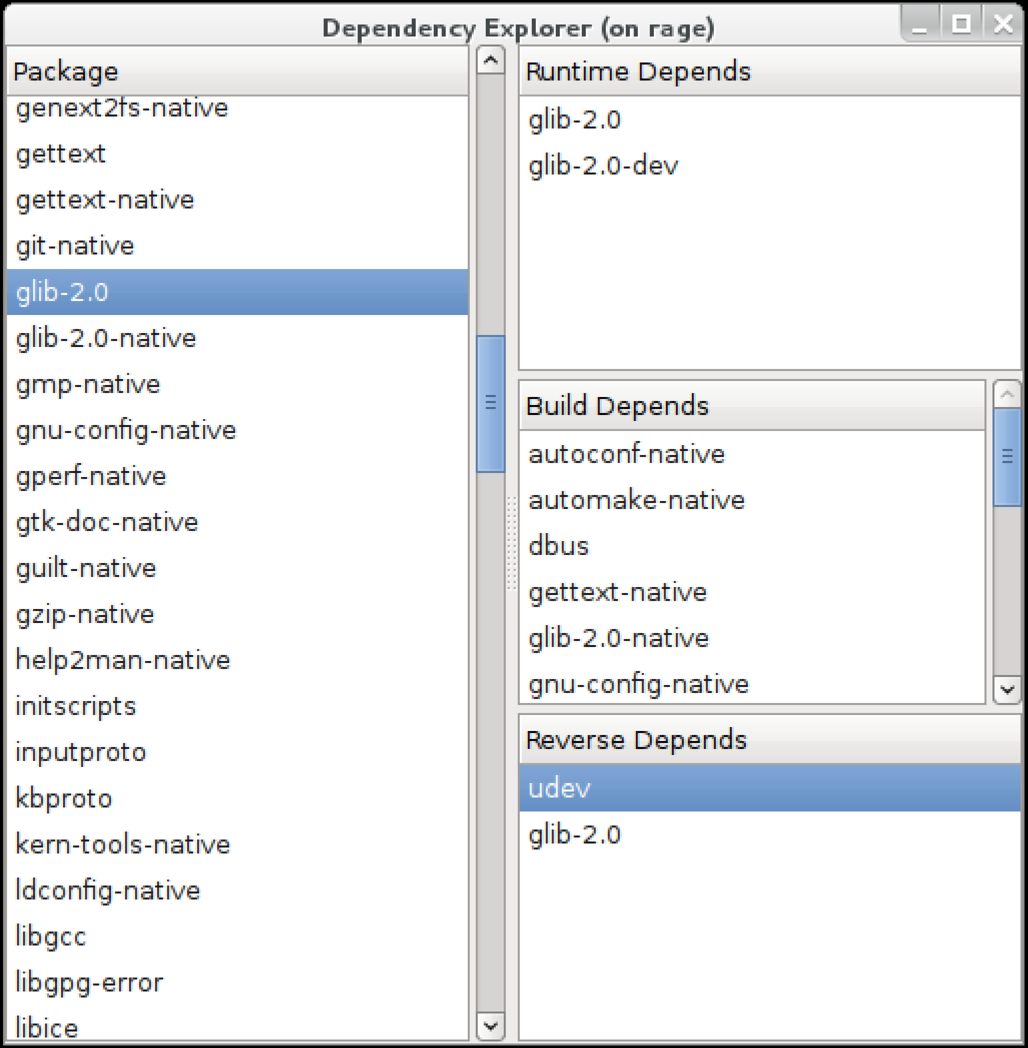
- Scripts available here until merged upstream
  - http://dvhart.com/darren/yocto/tiny/

Minimal: Root FS

```
$ cat dirsize-100k.log
   9850251 .
   3878968 ./lib
   1457504 ./lib/libc-2.13.so
    173908 ./lib/libm-2.13.so
    158617 ./lib/libacl.so.1.1.0
    127228 ./lib/ld-2.13.so
       ...
    696977 ./lib/modules/3.0.4-yocto-standard+/kernel/drivers/video
    645004 ./lib/udev
   2907574 ./usr
   2516900 ./usr/lib
   1047940 ./usr/lib/libgio-2.0.so.0.2800.8
   1036944 ./usr/lib/libglib-2.0.so.0.2800.8
    249756 ./usr/lib/libgobject-2.0.so.0.2800.8
    299502 ./usr/share
    170680 ./usr/share/pci.ids.gz
    124206 ./usr/share/usb.ids.gz
   1263456 ./sbin
    691588 ./sbin/ldconfig
    137012 ./sbin/udevadm
    133132 ./sbin/udevd
    115932 ./sbin/v86d
   1138391 ./etc
   1044480 ./etc/dev.tar
    659740 ./bin
    602752 ./bin/busybox
Displayed 7968656/9850251 bytes (80.90%)
```

Glib?

```
$ bitbake -u depexp -g core-image-minimal
```


Dependency Explorer (on rage)

Package
genext2fs-native
gettext
gettext-native
git-native
glib-2.0
glib-2.0-native
gmp-native
gnu-config-native
gperf-native
gtk-doc-native
guilt-native
gzip-native
help2man-native
initscripts
inputproto
kbproto
kern-tools-native
ldconfig-native
libgcc
libgpg-error
libice

Runtime Depends
glib-2.0
glib-2.0-dev

Build Depends
autoconf-native
automake-native
dbus
gettext-native
glib-2.0-native
gnu-config-native

Reverse Depends
udev
glib-2.0

Minimal → Stage 1

- Reduce size with minimal impact on features
- We can get by with devtmpfs and mdev
- We don't **need** a VGA display, we have serial
- Drop udev and v86d

```
$ cat conf/local.conf | head -n 7
################# MINIMAL STAGE 1 Mods #################
# Drop udev (and glib) and use mdev
# Save 4MB from minimal image rootfs!
VIRTUAL-RUNTIME_dev_manager = ""
# Drop v86d from qemux86 required packages
MACHINE_ESSENTIAL_EXTRA_RDEPENDS_qemux86 = ""
```

Filesystem Options

- Minimal builds ext3 by default
- ext3 requires a 1k block journal
  - 1 MB with 1024 byte blocks (instead of 4096)
- If we don't **need** the journal, we can save 1 MB by using ext2
  - 5.3 MB ext3
  - 4.0 MB ext2
- For a small image, you are most likely going to use JFFS2 or UBIFS anyway

Stage 1: Size Report

- Contents
  - Linux kernel
  - Eglibc
  - Login
- Size Report

bzImage:	4.0 MB (minimal)
rootfs:	4.0 MB (-7.0 MB)
~~modules:~~	~~35.0 MB~~
Total:	**8.0 MB (-7.0 MB)**

- Memory Report

RAM:	32 MB
Early boot:	8.6 MB
Login:	15.7 MB
Kernel Freed:	444 KB

- Boot Time

Kernel:	3.54s
Login:	7.19s

Stage 1: Root FS

```
$ cat dirsize-30k.log
   3878774 .
   2242550 ./lib
   1457504 ./lib/libc-2.13.so
    173908 ./lib/libm-2.13.so
    127228 ./lib/ld-2.13.so
     96624 ./lib/libpthread-2.13.so
     91956 ./lib/libnsl-2.13.so
     79620 ./lib/libresolv-2.13.so
     46672 ./lib/libnss_files-2.13.so
     35956 ./lib/libcrypt-2.13.so
     34588 ./lib/libnss_compat-2.13.so
     30624 ./lib/librt-2.13.so
    807168 ./sbin
    691588 ./sbin/ldconfig
     34300 ./sbin/init.sysvinit
    659740 ./bin
    602752 ./bin/busybox
     50308 ./bin/tinylogin
     87565 ./usr
     50168 ./usr/bin
     80786 ./etc
     34406 ./etc/init.d
Displayed 3553628/3878774 bytes (91.62%)
```

Stage 1: Kernel

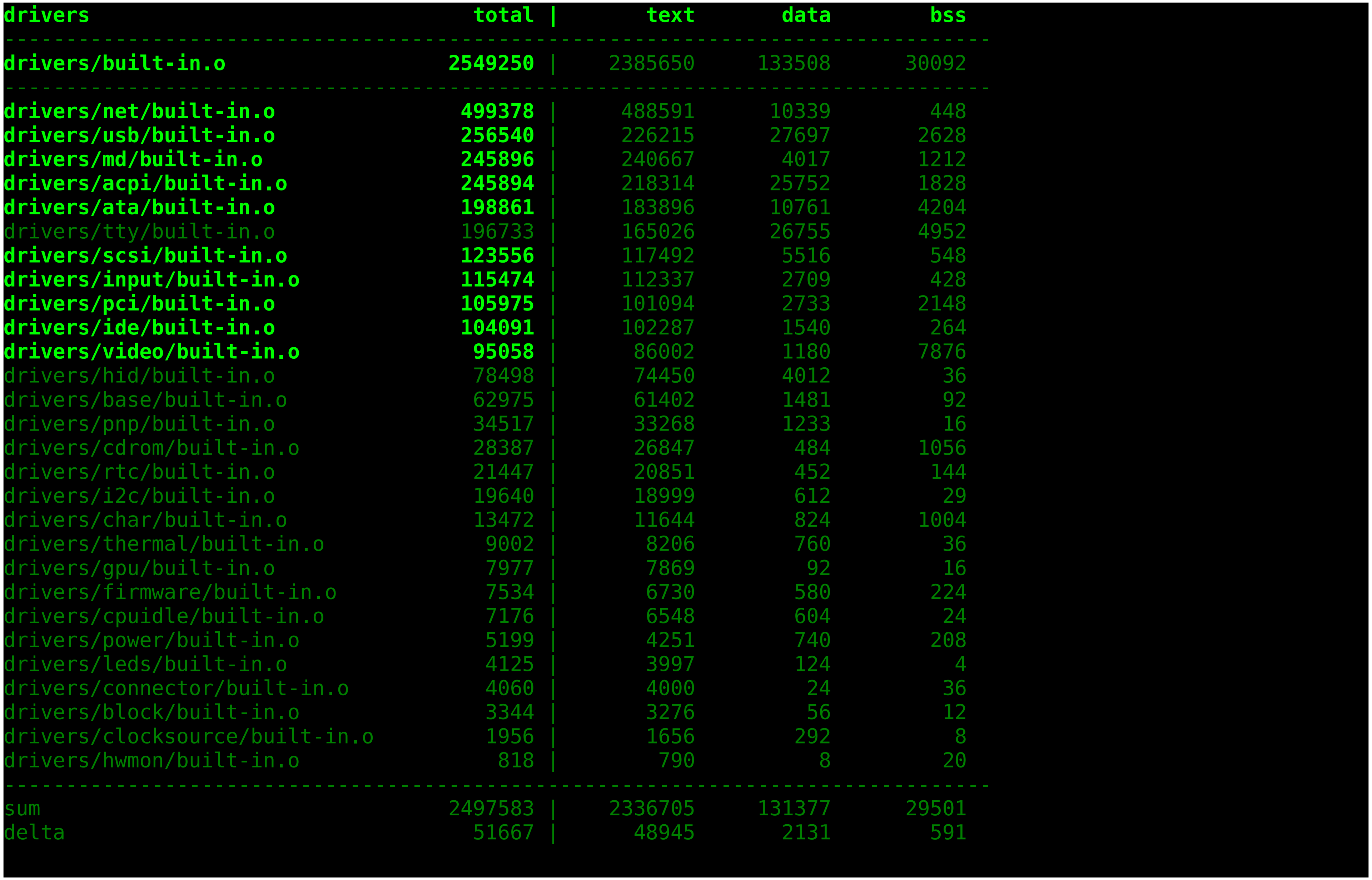
```
$ ls -s bzImage
4064 bzImage-qemux86.bin

$ cat ksize.log
Linux Kernel                          total |       text       data        bss
--------------------------------------------------------------------------------
vmlinux                             9657412 |    7538548     529616    1589248
--------------------------------------------------------------------------------
drivers/built-in.o                  2549250 |    2385650     133508      30092
net/built-in.o                      1194464 |    1137786      29358      27320
kernel/built-in.o                   1033129 |     723329      45832     263968
fs/built-in.o                        948917 |     926681      18564       3672
sound/built-in.o                     699821 |     684877       9624       5320
arch/x86/built-in.o                  459019 |     277038      87265      94716
mm/built-in.o                        345158 |     294330      23816      27012
block/built-in.o                     126489 |     119272       5741       1476
crypto/built-in.o                     84412 |      82364       2028         20
lib/built-in.o                        52607 |      52561         38          8
security/built-in.o                   46993 |      44778       1879        336
ipc/built-in.o                        36996 |      35880       1100         16
init/built-in.o                       31256 |      20186      10921        149
firmware/built-in.o                   15375 |      15375          0          0
usr/built-in.o                          516 |        516          0          0
--------------------------------------------------------------------------------
sum                                 7624402 |    6800623     369674     454105
delta                               2033010 |     737925     159942    1135143
```

Stage 1 → Stage 2

- 91.62% of the Root FS is composed of:
  - Eglibc
  - Busybox
- 66.53% of the Kernel image is composed of:
  - Drivers
  - Networking
  - Core kernel
  - Filesystems
  - Sound
- Bound to be more fluff in the kernel image

Drivers



```
drivers                                   total |      text      data        bss
--------------------------------------------------------------------------------
drivers/built-in.o                      2549250 |   2385650    133508      30092
--------------------------------------------------------------------------------
drivers/net/built-in.o                   499378 |    488591     10339        448
drivers/usb/built-in.o                   256540 |    226215     27697       2628
drivers/md/built-in.o                    245896 |    240667      4017       1212
drivers/acpi/built-in.o                  245894 |    218314     25752       1828
drivers/ata/built-in.o                   198861 |    183896     10761       4204
drivers/tty/built-in.o                   196733 |    165026     26755       4952
drivers/scsi/built-in.o                  123556 |    117492      5516        548
drivers/input/built-in.o                 115474 |    112337      2709        428
drivers/pci/built-in.o                   105975 |    101094      2733       2148
drivers/ide/built-in.o                   104091 |    102287      1540        264
drivers/video/built-in.o                  95058 |     86002      1180       7876
drivers/hid/built-in.o                    78498 |     74450      4012         36
drivers/base/built-in.o                   62975 |     61402      1481         92
drivers/pnp/built-in.o                    34517 |     33268      1233         16
drivers/cdrom/built-in.o                  28387 |     26847       484       1056
drivers/rtc/built-in.o                    21447 |     20851       452        144
drivers/i2c/built-in.o                    19640 |     18999       612         29
drivers/char/built-in.o                   13472 |     11644       824       1004
drivers/thermal/built-in.o                 9002 |      8206       760         36
drivers/gpu/built-in.o                     7977 |      7869        92         16
drivers/firmware/built-in.o                7534 |      6730       580        224
drivers/cpuidle/built-in.o                 7176 |      6548       604         24
drivers/power/built-in.o                   5199 |      4251       740        208
drivers/leds/built-in.o                    4125 |      3997       124          4
drivers/connector/built-in.o               4060 |      4000        24         36
drivers/block/built-in.o                   3344 |      3276        56         12
drivers/clocksource/built-in.o             1956 |      1656       292          8
drivers/hwmon/built-in.o                    818 |       790         8         20
--------------------------------------------------------------------------------
sum                                     2497583 |   2336705    131377      29501
delta                                     51667 |     48945      2131        591
```

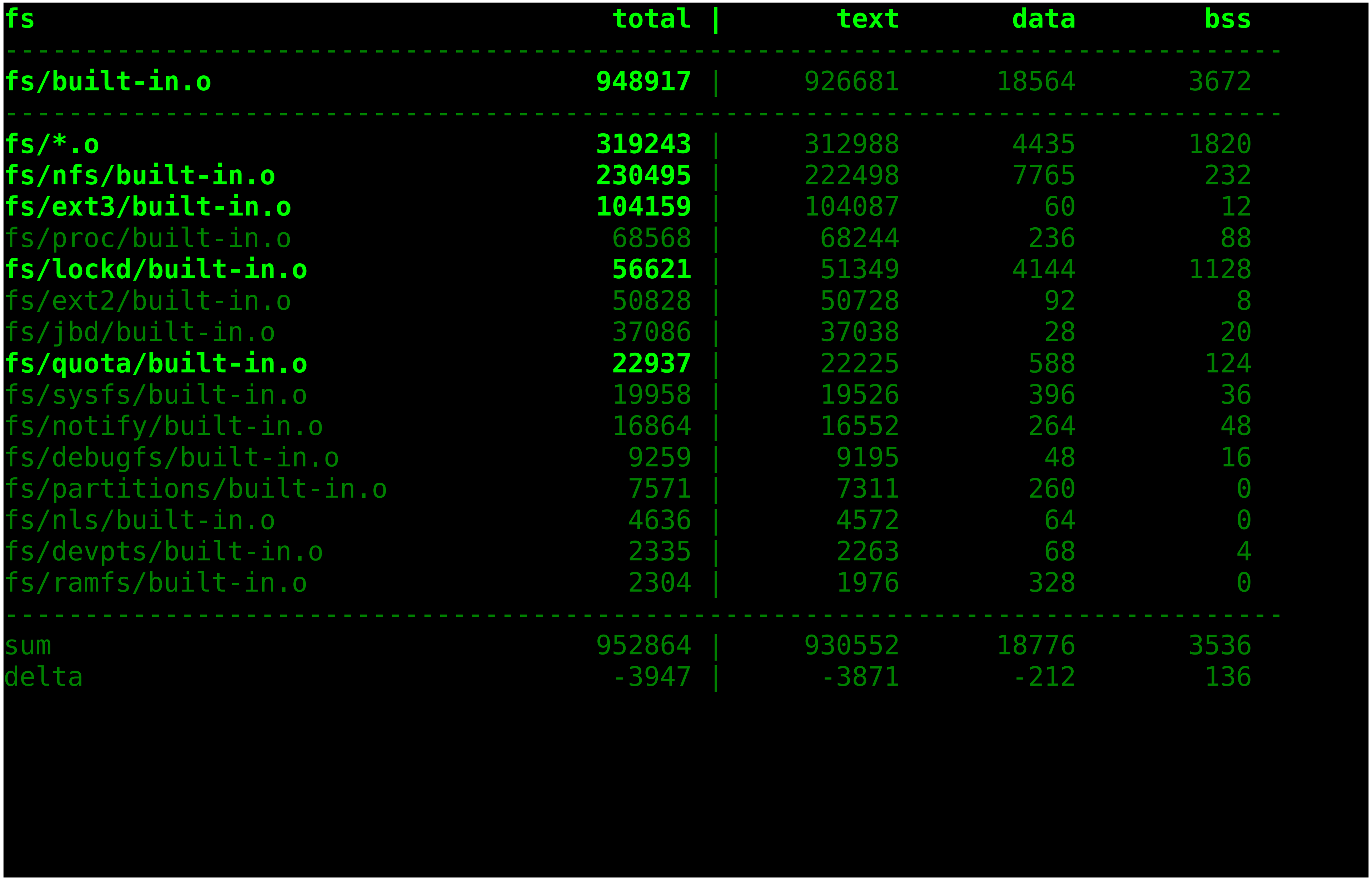
Networking

```
net                                       total |      text      data       bss
--------------------------------------------------------------------------------
net/built-in.o                          1194464 |   1137786     29358     27320
--------------------------------------------------------------------------------
net/ipv4/built-in.o                      364644 |    346523     13037      5084
net/core/built-in.o                      196473 |    188607      4781      3085
net/sunrpc/built-in.o                    178398 |    158816      3102     16480
net/mac80211/built-in.o                  152576 |    152020       444       112
net/wireless/built-in.o                  131551 |    128631      2664       256
net/xfrm/built-in.o                       52381 |     50921      1076       384
net/sched/built-in.o                      22183 |     21023      1148        12
net/netlink/built-in.o                    21614 |     20934       520       160
net/unix/built-in.o                       19811 |     18423       348      1040
net/*.o                                   16690 |     16282       392        16
net/packet/built-in.o                     16356 |     16092       264         0
net/netfilter/built-in.o                   9509 |      7637      1268       604
net/ipv6/built-in.o                        4865 |      4865         0         0
net/dns_resolver/built-in.o                3525 |      3457        60         8
net/ethernet/built-in.o                    1887 |      1875        12         0
net/8021q/built-in.o                       1386 |      1386         0         0
--------------------------------------------------------------------------------
sum                                     1193849 |   1137492     29116     27241
delta                                       615 |       294       242        79
```

Core Kernel

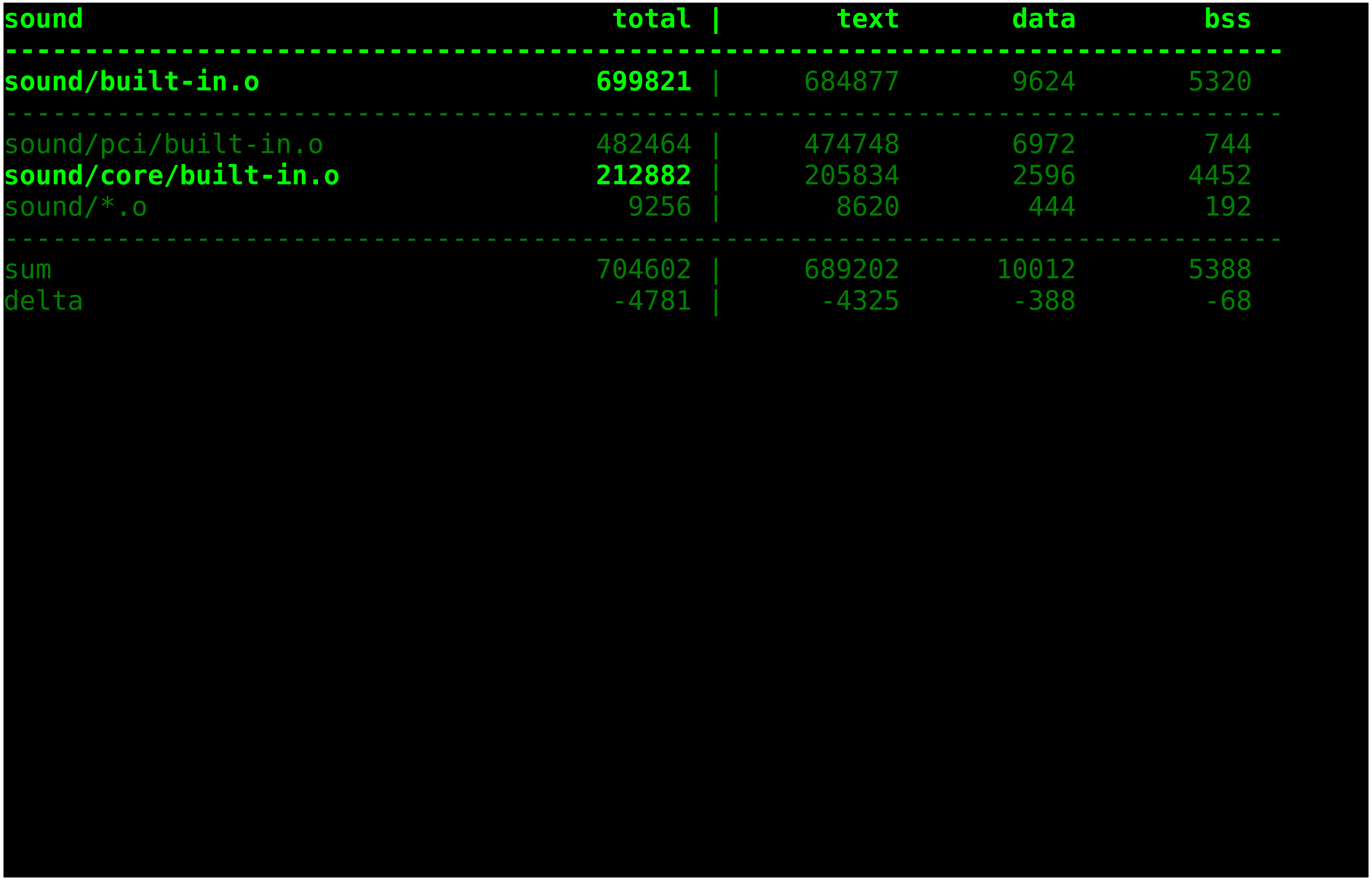
```
kernel                                 total |        text       data        bss
----------------------------------------------------------------------------------
kernel/built-in.o                    1033129 |      723329      45832     263968
----------------------------------------------------------------------------------
kernel/*.o                            535934 |      466134      24338      45462
kernel/trace/built-in.o               305798 |      142282      14860     148656
kernel/time/built-in.o                 94008 |       40975       3065      49968
kernel/events/built-in.o               40549 |       39613        808        128
kernel/debug/built-in.o                29591 |       10074        190      19327
kernel/irq/built-in.o                  20706 |       18754       1924         28
kernel/power/built-in.o                 4442 |        4278        148         16
----------------------------------------------------------------------------------
sum                                  1031028 |      722110      45333     263585
delta                                   2101 |        1219        499        383
```

Filesystems



```
fs                                      total |     text       data       bss
-------------------------------------------------------------------------------
fs/built-in.o                          948917 |   926681      18564      3672
-------------------------------------------------------------------------------
fs/*.o                                 319243 |   312988       4435      1820
fs/nfs/built-in.o                      230495 |   222498       7765       232
fs/ext3/built-in.o                     104159 |   104087         60        12
fs/proc/built-in.o                      68568 |    68244        236        88
fs/lockd/built-in.o                     56621 |    51349       4144      1128
fs/ext2/built-in.o                      50828 |    50728         92         8
fs/jbd/built-in.o                       37086 |    37038         28        20
fs/quota/built-in.o                     22937 |    22225        588       124
fs/sysfs/built-in.o                     19958 |    19526        396        36
fs/notify/built-in.o                    16864 |    16552        264        48
fs/debugfs/built-in.o                    9259 |     9195         48        16
fs/partitions/built-in.o                 7571 |     7311        260         0
fs/nls/built-in.o                        4636 |     4572         64         0
fs/devpts/built-in.o                     2335 |     2263         68         4
fs/ramfs/built-in.o                      2304 |     1976        328         0
-------------------------------------------------------------------------------
sum                                    952864 |   930552      18776      3536
delta                                   -3947 |    -3871       -212       136
```

Sound



```
sound                                   total |       text       data        bss
--------------------------------------------------------------------------------
sound/built-in.o                       699821 |     684877       9624       5320
--------------------------------------------------------------------------------
sound/pci/built-in.o                   482464 |     474748       6972        744
sound/core/built-in.o                  212882 |     205834       2596       4452
sound/*.o                                9256 |       8620        444        192
--------------------------------------------------------------------------------
sum                                    704602 |     689202      10012       5388
delta                                   -4781 |      -4325       -388        -68
```

Linux Kernel Config Fragments

- Entire defconfigs make it difficult to quantify cost of individual options
- Better to assemble config fragments
- Avoid modules and the initial RAM disk
- Start with allnoconfig
- Merge fragments with merge_config.pl
  - Generates a .config
  - Warns on overrides
  - Warns on missing CONFIG_ options
    (possibly due to missing dependencies)

Minimal Linux Kernel Config

- Start with the bare minimal for an x86-32 machine:
  - defconfig (x86_32_allnoconfig)
  - core.cfg
  - smp.cfg
  - rtc-pc.cfg
- Some basic policy:
  - serial.cfg
  - devtmpfs.cfg
  - sysfs.cfg
  - ext2.cfg
  - ext3.cfg
  - net.cfg
  - vt.cfg
  - fb.cfg
  - debug.cfg
- QEMU “hardware” support
  - ata.cfg
  - e1000.cfg
  - floppy.cfg
  - usb.cfg
  - vga.cfg
  - intel-hda.cfg

Stage 2: Size Report

- Contents
  - Linux kernel
  - Eglibc
  - Login

- Size Report

BzImage:	1.8 MB (-2.2 MB)
RootFS:	4.0 MB (stage 1)
Total:	**5.8 MB (-2.2 MB)**

- Memory Report

RAM:	32 MB
Early boot:	4.49 MB
Login:	9.37 MB
Kernel Freed:	240 KB

- Boot Time

Kernel:	0.90s
Login:	3.38s

Stage 2: Kernel

```
$ ls -s bzImage
4064 bzImage-qemux86.bin

$ cat ksize.log
Linux Kernel                          total |       text       data        bss
--------------------------------------------------------------------------------
vmlinux                             5214442 |    3569634     276744    1368064
--------------------------------------------------------------------------------
drivers/built-in.o                  1285171 |    1175622      78161      31388
sound/built-in.o                     559278 |     548606       8456       2216
kernel/built-in.o                    538539 |     322032      77555     138952
net/built-in.o                       475916 |     451509      17507       6900
fs/built-in.o                        456887 |     451541       3370       1976
arch/x86/built-in.o                  289285 |     219562      44515      25208
mm/built-in.o                        231360 |     189117      16543      25700
block/built-in.o                      77877 |      74707       1722       1448
lib/built-in.o                        33087 |      32999         80          8
ipc/built-in.o                        22097 |      21365        724          8
init/built-in.o                       13549 |       8215       5221        113
security/built-in.o                    3738 |       3722          8          8
--------------------------------------------------------------------------------
sum                                 3986784 |    3498997     253862     233925
delta                               1227658 |      70637      22882    1134139
```

Stage 2 → Stage 3

- 91.62% of the Root FS is composed of:
  - eglibc
  - busybox
- 44.13% of the Kernel image is composed of:
  - drivers
  - sound
  - Filesystems
- Let's see what we can shave off from each

Kernel: Only the Essentials

- Drop everything but the essentials for boot, serial console, and networking

- Drop from policy
  - vt.cfg
  - ext3.cfg
  - fb.cfg

- Drop from Qemux86 “Hardware” support
  - floppy.cfg
  - usb.cfg
  - vga.cfg
  - intel-hda.cfg

Root FS: Busybox

- Drop all the vt services from busybox, this needs a simple patch to avoid opening tty devices
- Drop ipv6 and all the Linux module utilities
- Use a busybox bbappend recipe and a new defconfig

Root FS: eglibc

```
# Reconfigure eglibc for a smaller installation
# Comment out any of the lines below to disable them in the eglibc build
DISTRO_FEATURES_LIBC_TINY = "libc-libm libc-crypt"
DISTRO_FEATURES_LIBC_REGEX = "libc-posix-regexp"
DISTRO_FEATURES_LIBC_NET = "libc-inet libc-nis"
DISTRO_FEATURES_LIBC_MINIMAL = "libc-utmp libc-getlogin"

DISTRO_FEATURES_LIBC = "${DISTRO_FEATURES_LIBC_TINY} \
                        ${DISTRO_FEATURES_LIBC_MINIMAL} \
                        ${DISTRO_FEATURES_LIBC_REGEX} \
                        ${DISTRO_FEATURES_LIBC_NET}"

# Comment out any of the lines below to disable them in the build
DISTRO_FEATURES_TINY = "ext2 pci"
DISTRO_FEATURES_NET = "ipv4 nfs"

DISTRO_FEATURES = "${DISTRO_FEATURES_TINY} \
                   ${DISTRO_FEATURES_NET} \
                   ${DISTRO_FEATURES_LIBC}"
```

- Dropping 'who' and tools like 'grep' and 'sed' allow the removal of libc-posix-regexp, libc-utmp, and libc-getlogin, but start to limit functionality

Root FS: System Services

- Drop tinylogin, modutils-initscripts, and netbase
- Define a new image type, core-image-tiny which is built using a new task-core-tiny task

```
RDEPENDS_task-core-tiny = "base-files base-passwd \
                           busybox initscripts"

# task-core-tiny RDEPENDS on a subset of what task-core-boot does:
#RDEPENDS_task-core-boot = "base-files base-passwd \
#                            busybox initscripts    \
# ${@base_contains("MACHINE_FEATURES", "keyboard", "keymaps", "", d)} \
#                            modutils-initscripts netbase \
#                            ${VIRTUAL-RUNTIME_login_manager} \
#                            ${VIRTUAL-RUNTIME_init_manager} \
#                            ${VIRTUAL-RUNTIME_dev_manager} \
#                            ${VIRTUAL-RUNTIME_update-alternatives} \
#                            ${MACHINE_ESSENTIAL_EXTRA_RDEPENDS}"
```

Stage 3: Size Report

- Contents
  - Linux kernel
  - Eglibc
  - Busybox shell

- Size Report

BzImage:	1.2 MB (-0.6 MB)
RootFS:	3.2 MB (-0.8 MB)
Total:	**4.4 MB (-1.4 MB)**

- Memory Report

RAM:	32 MB
Early boot:	3.42 MB
Login:	6.66 MB
Kernel Freed:	220 KB

- Boot Time

Kernel:	0.60s
Shell:	2.13s

Now What?

- Kernel
  - networking
  - SMP
  - ACPI
  - SysV IPC, Futexes
  - Printk

- Eglibc
  - networking
  - regular expressions

- To get below 4.0 MB, we should look at uclibc

Stage 3 → Stage 4

- Switch to uclibc

```
DISTRO_FEATURES_NET = "ipv4 nfs"

DISTRO_FEATURES = "${DISTRO_FEATURES_TINY} \
                   ${DISTRO_FEATURES_NET} \
                   ${DISTRO_FEATURES_LIBC}"

TCLIBC = "uclibc"
```

Stage 4: Size Report

- Contents
  - Linux kernel
  - Uclibc
  - Busybox shell

- Size Report

BzImage:	1.2 MB (stage 3)
RootFS:	1.5 MB (-1.7 MB)
Total:	**2.7 MB (-1.7 MB)**

- Memory Report

RAM:	32 MB
Early boot:	3.42 MB
Login:	5.84 MB
Kernel Freed:	220 KB

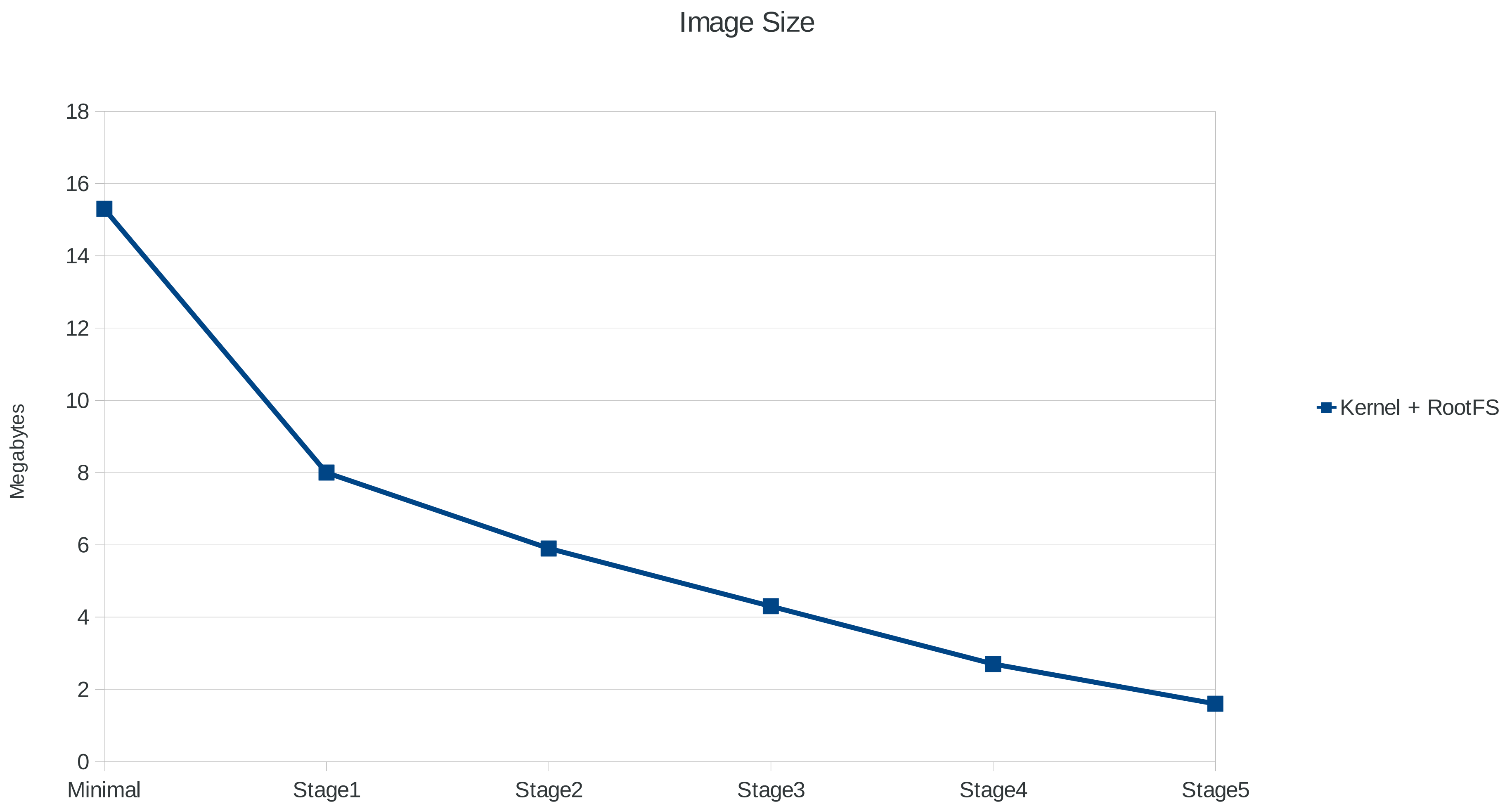
- Boot Time

Kernel:	0.61s
Shell:	2.07s

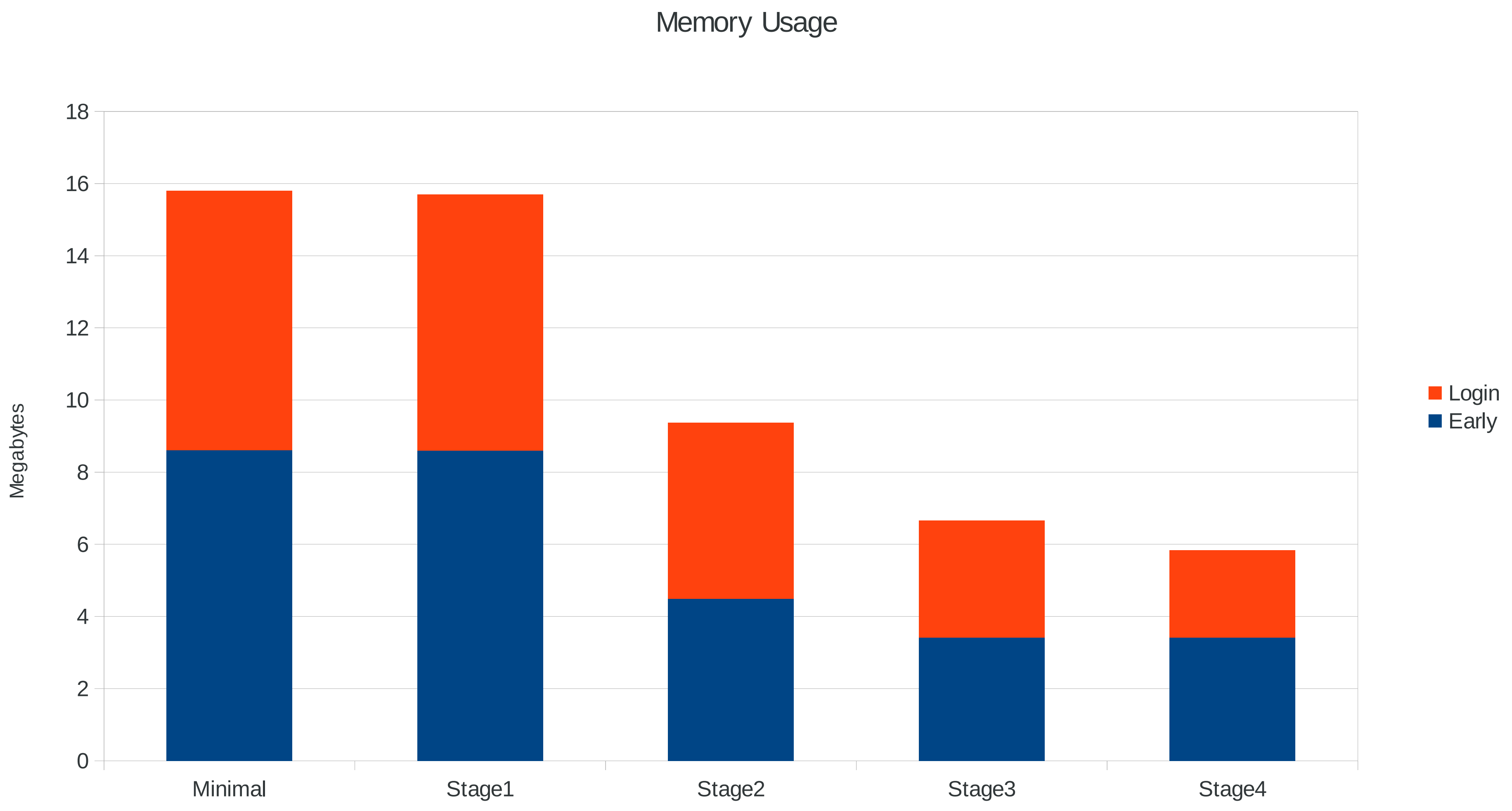
Stupid Small

- You can go further still if you want
  - Drop networking support (uclibc and kernel)
  - Cripple Busybox (grep, network tools, etc)
  - Cripple Linux kernel (acpi, smp, ipc, futex, printk)
- Size Report
  - bzImage: 585K (-0.7 MB)
  - rootfs: 1.1MB (-0.4 MB)
  - **Total: 1.6 MB (-1.1 MB)**
- Memory Report
  - We removed printk and proc!
- Boot Time
  - Shell: 1.28s
- You have lost a lot of functionality to get here

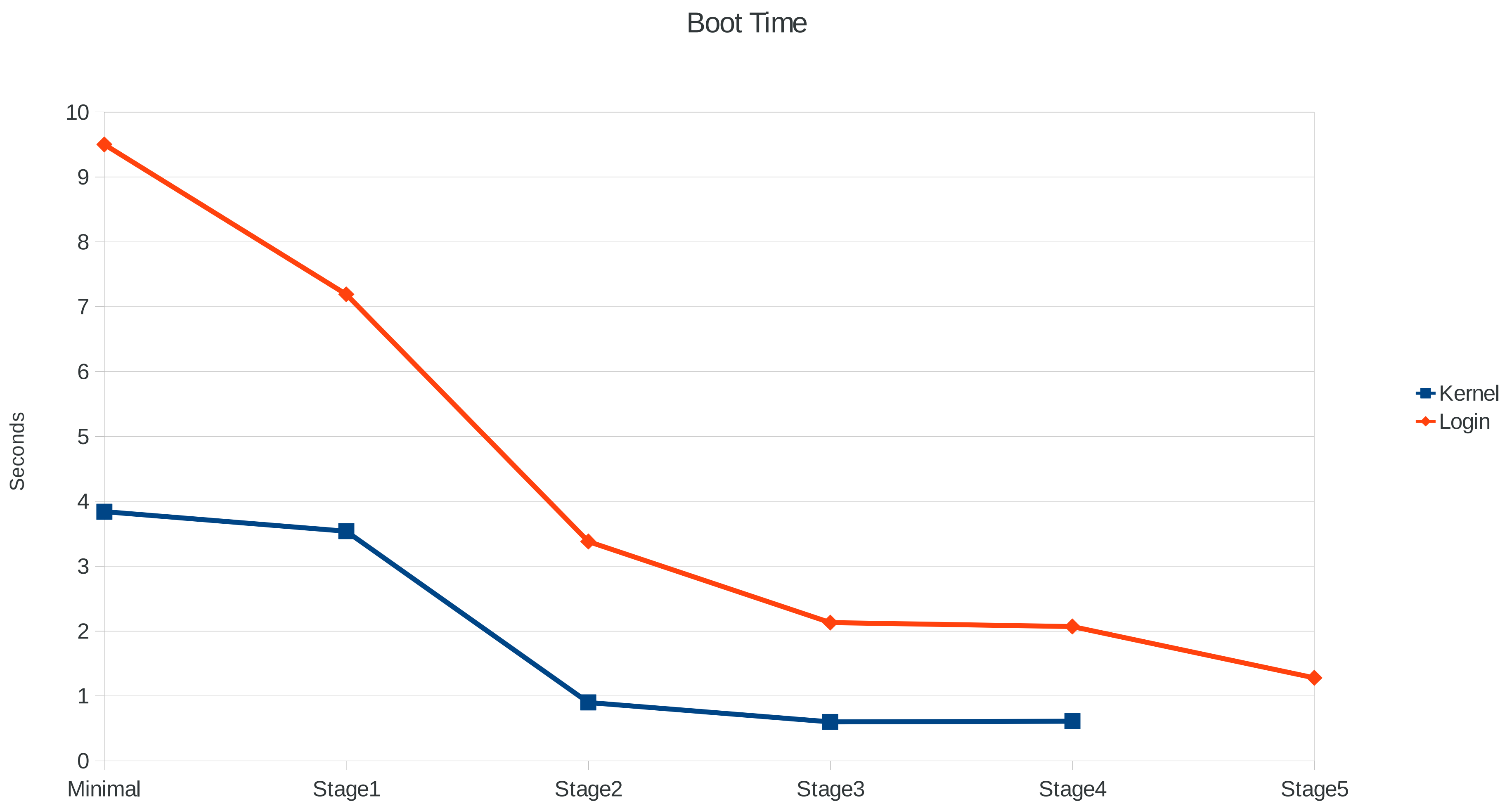
Image Size by Stage



Memory Usage Summary



Boot Time Summary



Next Steps

- Bitbake config fragments
  - Incorporate config fragment management from the Yocto Project kernel tools into the Bitbake recipe
- Distribution package feature mechanism
  - Prepare a distro package feature configuration mechanism for fine tuning recipe configs, such as bitbake and linux-yocto.
  - Eglibc and uclibc have similar mechanisms, but may need to be modified for a consistent implementation across recipes.
- Define one or more poky-tiny distributions and images
  - Your input is needed here
  - Do we define a no-network image?
  - Do we define a smaller graphical image?
    - Perhaps something with directfb instead of X

Resources

- Yocto Project and Meta-Tiny
  - http://www.yoctoproject.org
  - http://git.yoctoproject.org/cgit.cgi/user-contrib/dvhart/meta-tiny
- ELCE 2010 Videos
  - The Right Approach to Minimal Boot Time by Andrew Murray
  - http://free-electrons.com/blog/elce-2010-videos/
- Andi Kleen's Memory Usage Papers
  - http://halobates.de/memorywaste.pdf
  - http://halobates.de/memory.pdf
- Phil Blundell's meta-micro layer
  - http://cgit.openembedded.org/meta-micro/

yocto

PROJECT

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