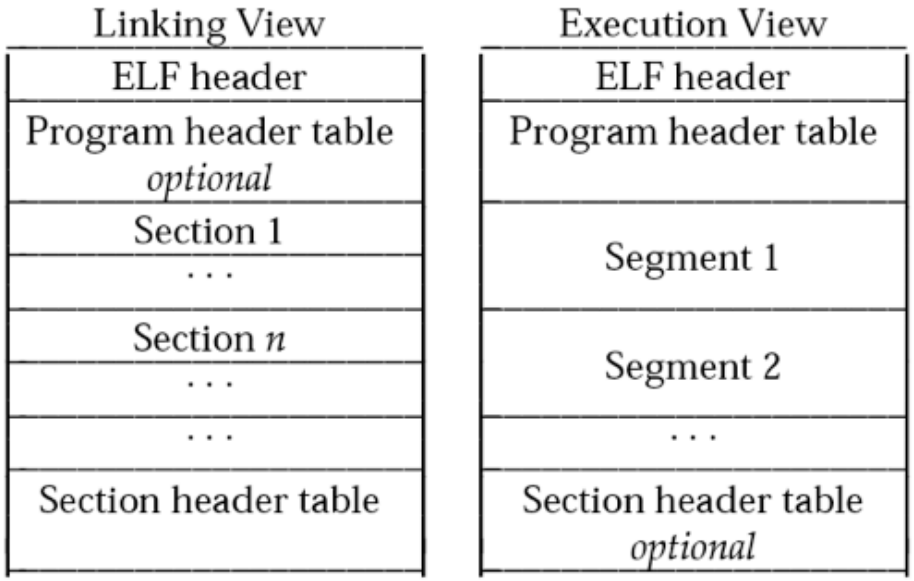
ELF

- Executable and Linkable Format
- Standard file format for
    - executables
    - object code
    - shared libraries
    - core dumps

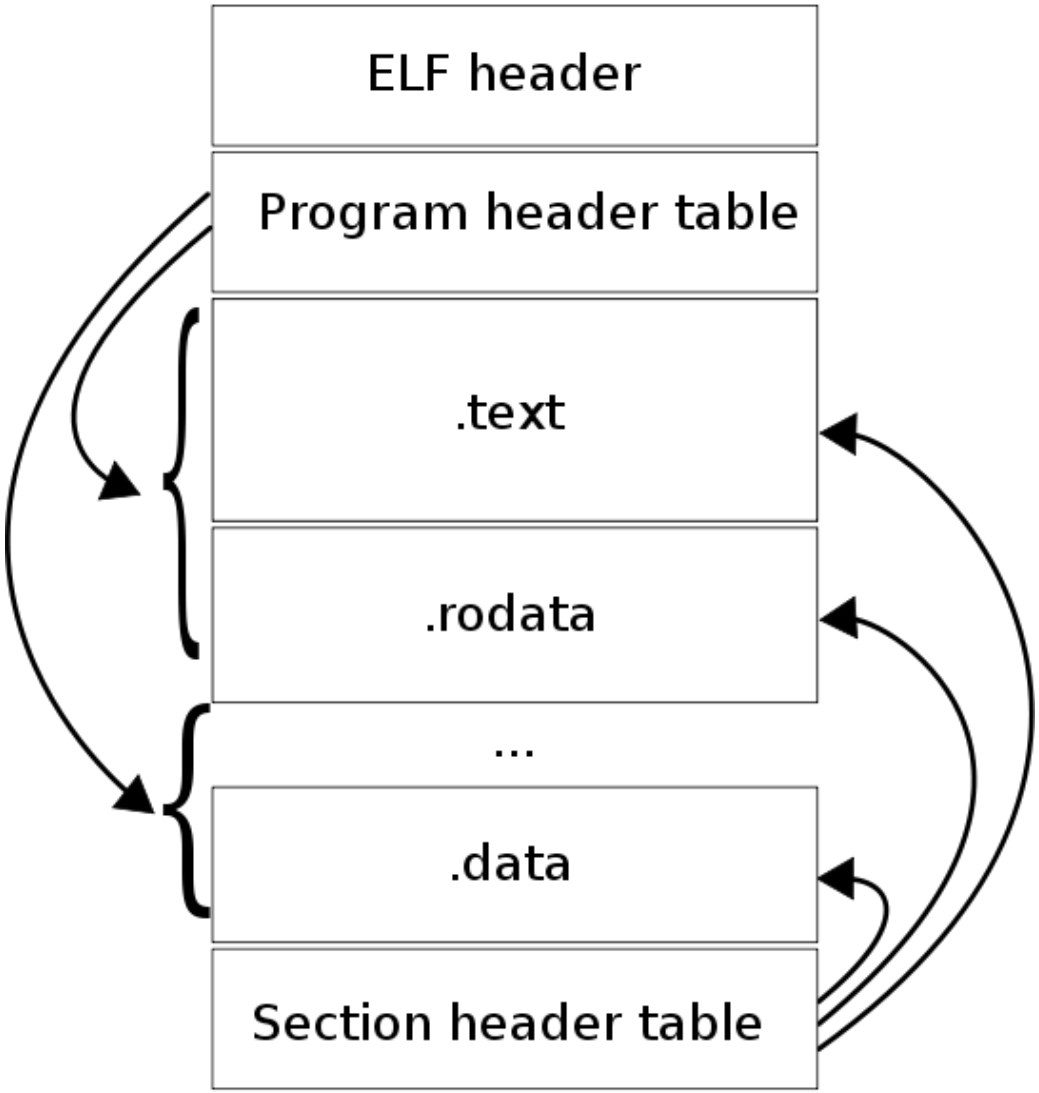
Figure 1-1: Object File Format



An *ELF header* resides at the beginning and holds a "road map" describing the file's organization. *Sections* hold the bulk of object file information for the linking view: instructions, data, symbol table, relocation information, and so on. Descriptions of special sections appear later in Part 1. Part 2 discusses *segments* and the program execution view of the file.

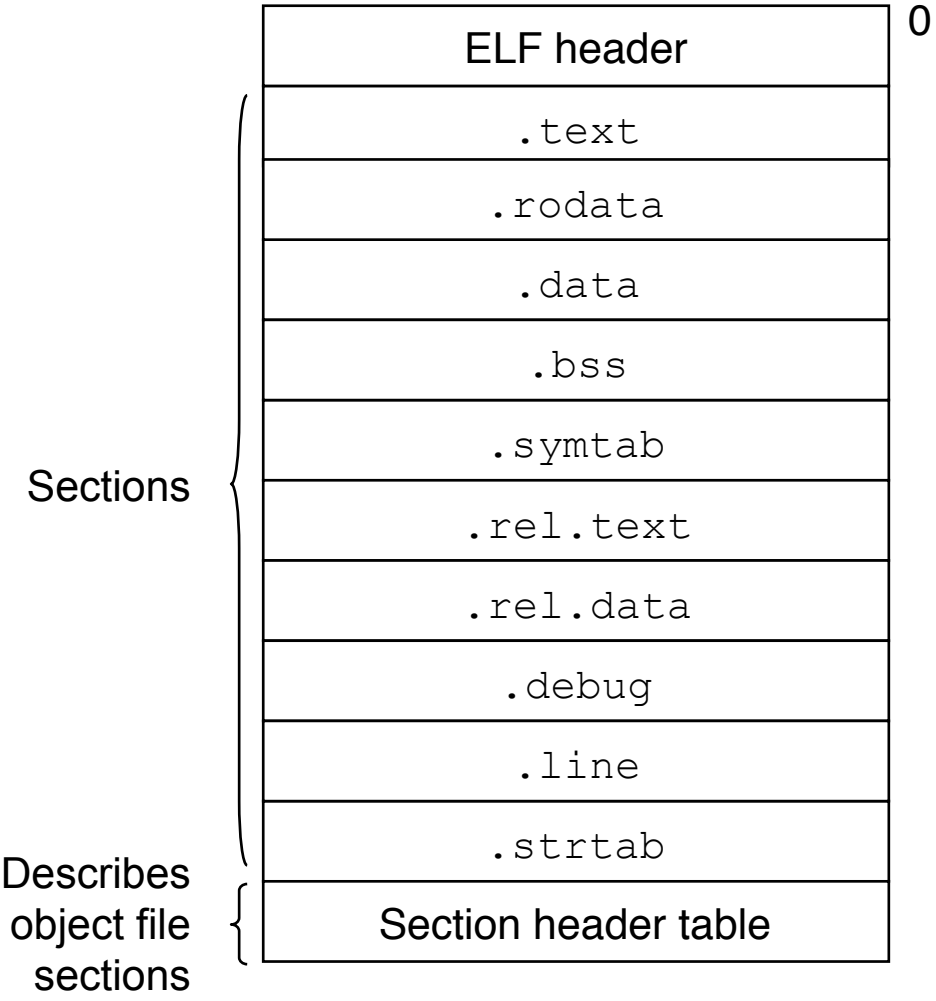
source: Tool Interface Standards (TIS) Portable Formats Specification, Version 1.1

Another view
source: Wikipedia



Relocatable Object Files

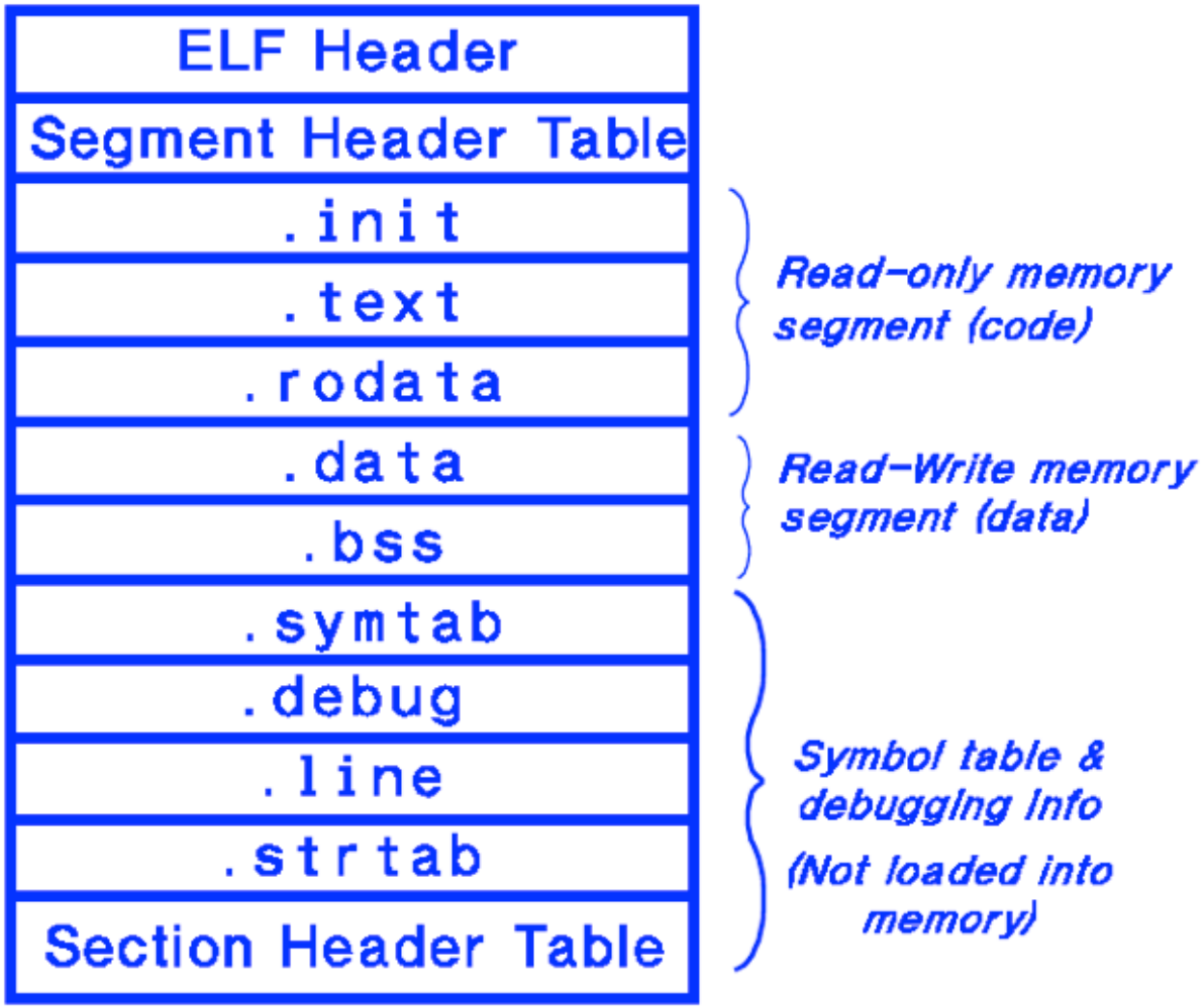
- Format of typical ELF relocatable object file



ELF Section examples

- .text: machine code of compiled program
- .data: initialized global C variables
- .bss: uninitialized data
- .symtab: a symbol table with info about functions and global variables
- .line: mapping between line numbers in the original C source program and machine code instructions in .text section. Only exists if -g compile option was used
- .debug: debugging symbol table

ELF – Executable File



ELF

- What is the motivation for having sections?
- What is a process image?
- Why don’t we just load everything jumbled together into the process image, e.g., as in DOS?

ELF

- Motivation is
  - how modern machine architectures allocate memory, e.g., 4kB pages (frames)
  - memory manager can set attributes on pages, e.g., read-only. What happens when you write to read-only memory?
  - allocating memory for initialized vs uninitialized variables

ELF

- What happens when kernel loads & runs an executable?
    - its starts looking at image header to see how it should load the image
    - locates .text section with executable, load it in read-only pages of memory
    - then it loads .data section of the executable into user space (read-write memory)
    - locates .bss section from image header and adds appropriate pages of memory, zeroing out the pages.

readelf with file header option -h

```
[krings@eternium /bin]$ readelf -h ./ls
ELF Header
  Magic:                             7f 45 4c 46 02 01 01 00 00 00 00 00 00 00 00 00
  Class:                             ELF64
  Data:                              2's complement, little endian
  Version:                           1 (current)
  OS/ABI:                            UNIX - System V
  ABI Version:                       0
  Type:                              EXEC (Executable file)
  Machine:                           Advanced Micro Devices X86-64
  Version:                           0x1
  Entry point address:               0x402460
  Start of program headers:          64 (bytes into file)
  Start of section headers:          89256 (bytes into file)
  Flags:                             0x0
  Size of this header:               64 (bytes)
  Size of program headers:           56 (bytes)
  Number of program headers:         8
  Size of section headers:           64 (bytes)
  Number of section headers:         31
  Section header string table index: 30
```

What does this tell us?

- executable was created for AMD X86-64 architecture
- when executed it will start running from virtual address 0x402460. That is not main() though, but a _start procedure, created by the linker
- program has 31 sections, 8 segments
- ...

```
readelf -S ./ls
There are 31 section headers, starting at offset 0x15ca8:

Section Headers:
  [Nr] Name              Type            Address          Offset
       Size              EntSize         Flags  Link  Info  Align
  [ 0]                   NULL            0000000000000000 00000000
       0000000000000000  0000000000000000           0     0     0
...
  [13] .text             PROGBITS        0000000000402460 00002460
       000000000000c228  0000000000000000  AX       0     0     16
  [14] .fini             PROGBITS        000000000040e688 0000e688
       000000000000000e  0000000000000000  AX       0     0     4
  [15] .rodata           PROGBITS        000000000040e6a0 0000e6a0
       000000000000382f  0000000000000000  A        0     0     32
 ...
  [26] .bss              PROGBITS        0000000000614820 00014820
       0000000000000538  0000000000000000  WA       0     0     32
...

Key to Flags:
  W (write), A (alloc), X (execute), M (merge), S (strings)
  I (info), L (link order), G (group), x (unknown)
  O (extra OS processing required) o (OS specific), p (processor specific)
```

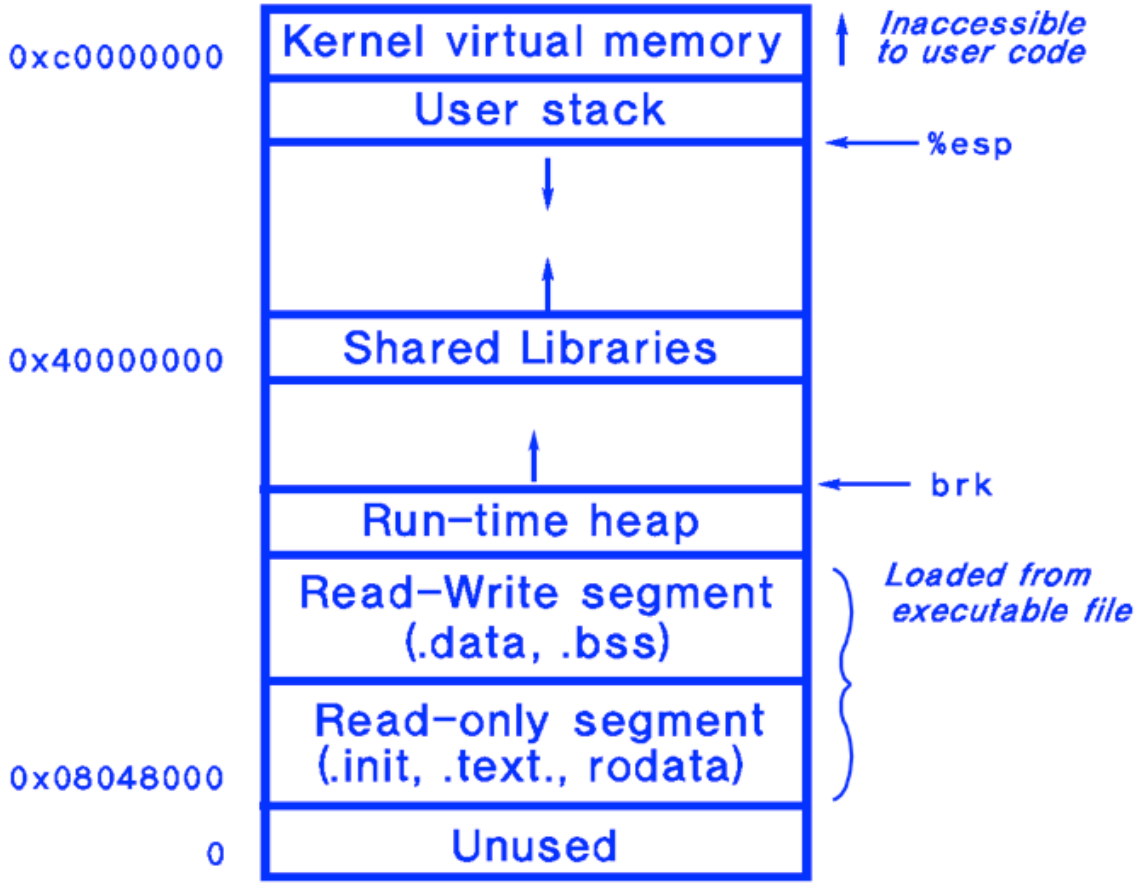
```
[krings@eternium /bin]$ objdump -d -j .text ls |more

ls:     file format elf64-x86-64

Disassembly of section .text:

0000000000402460 <close_stdout-0x6440>:
  402460:       31 ed                   xor    %ebp,%ebp
  402462:       49 89 d1                mov    %rdx,%r9
  402465:       5e                      pop    %rsi
  402466:       48 89 e2                mov    %rsp,%rdx
  402469:       48 83 e4 f0             and    $0xfffffffffffffff0,%rsp
  40246d:       50                      push   %rax
  40246e:       54                      push   %rsp
  40246f:       49 c7 c0 90 e5 40 00    mov    $0x40e590,%r8
  402476:       48 c7 c1 a0 e5 40 00    mov    $0x40e5a0,%rcx
  40247d:       48 c7 c7 60 69 40 00    mov    $0x406960,%rdi
  402484:       e8 1f fb ff ff          callq  401fa8 <__libc_start_main@plt>
  402489:       f4                      hlt
  40248a:       90                      nop
  40248b:       90                      nop
  40248c:       48 83 ec 08             sub    $0x8,%rsp
  402490:       48 8b 05 09 1e 21 00    mov    2170377(%rip),%rax        # 6142a0 <quoting_style_args+0x200>
  402497:       48 85 c0                test   %rax,%rax
  40249a:       74 02                   je     40249e <acl_from_text@plt+0x56>
  40249c:       ff d0                   callq  *%rax
  40249e:       48 83 c4 08             add    $0x8,%rsp
  4024a2:       c3                      retq
  4024a3:       90                      nop
  4024a4:       90                      nop
```

LINUX Runtime Memory Image



LINUX Startup Pseudo-Code

```
/* crt1.o  */

_start:                              /* entry point in .text  */
        call __libc_init_first       /* startup code in .text */
        call _init                   /* startup code in .init */
        call atexit                  /* startup code in .text */
        /* set up argument list for main here */
        call main                    /* application main code */
        call _exit                   /* returns control to shell */
```