Notcurses

blingful TUIs and character graphics

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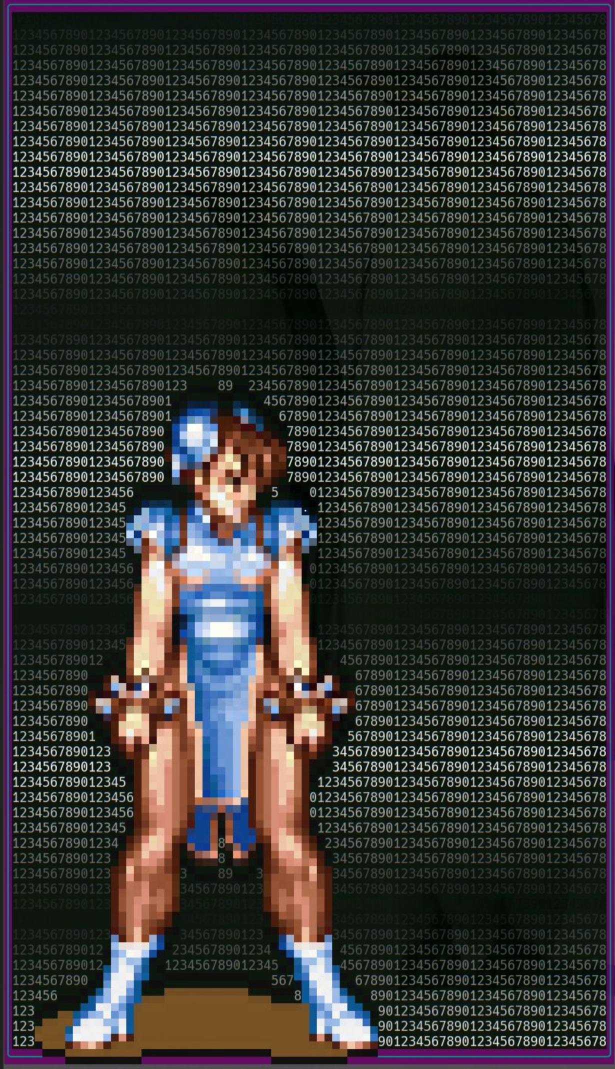
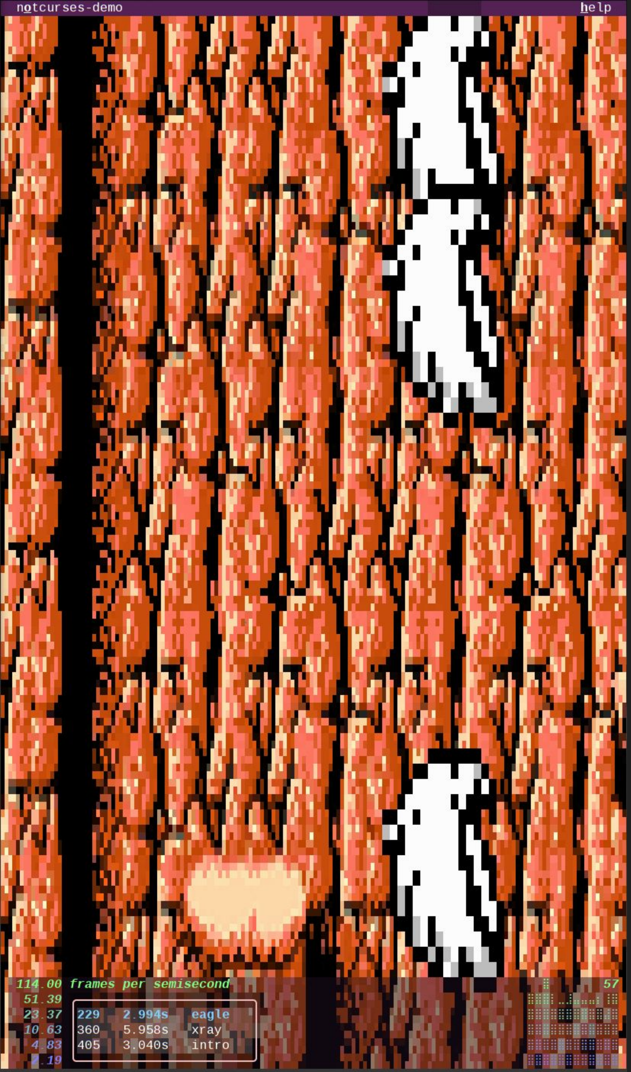
for FOSDEM 2021 (2021-02-06)





```
notcurses-demo                                                   help
```

```
114.00 frames per semisecond                                    57
 51.39
 23.37   229    2.994s   eagle
 10.63   360    5.958s   xray
  4.83   405    3.040s   intro
  2.19
```

who are you, what's all [gestures] this?

- hacker from the southeastern us (atlanta)
- normally an hpc/compilers guy
- wrote two large NCURSES programs
  - didn't care to write another

- Notcurses: an intellectual descendant of Curses...
  - ...but neither attempts nor claims compatibility

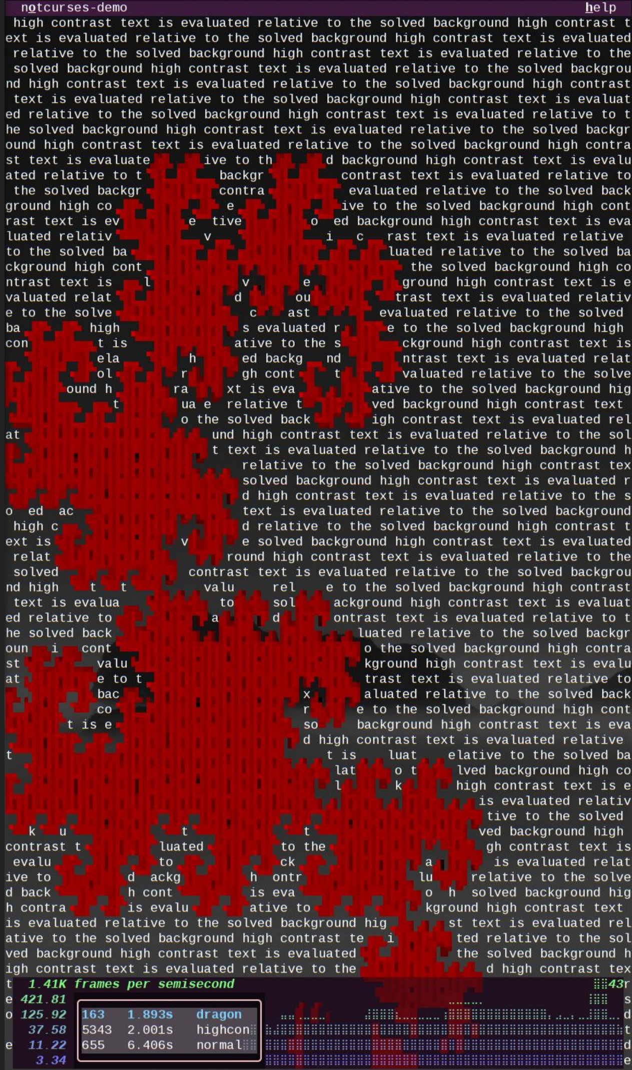
Goal: become the de facto TUI/character graphics library for new applications

text user interfaces / character graphics

Defined by two properties:

- *Text mode:* drawable unit is a glyph, not a pixel
- *Stream I/O:* we read and write to streams
  - (rather than a framebuffer)

- Linux/FreeBSD virtual console
- terminal emulator under X/Wayland
- pseudottys (e.g. ssh or a terminal multiplexor)
- and even hardware terminals.



```
 notcurses-demo                                                            help
 high contrast text is evaluated relative to the solved background high contrast t
ext is evaluated relative to the solved background high contrast text is evaluated
 relative to the solved background high contrast text is evaluated relative to the
 solved background high contrast text is evaluated relative to the solved backgrou
nd high contrast text is evaluated relative to the solved background high contrast
 text is evaluated relative to the solved background high contrast text is evaluat
ed relative to the solved background high contrast text is evaluated relative to t
he solved background high contrast text is evaluated relative to the solved backgr
ound high contrast text is evaluated relative to the solved background high contra
st text is evaluate       ive to th      d background high contrast text is evalu
ated relative to t        backgr           contrast text is evaluated relative to
 the solved backgr        contra             evaluated relative to the solved back
ground high co             e                ive to the solved background high cont
rast text is ev          e  tive         o  ed background high contrast text is eva
luated relativ             v            i   c    rast text is evaluated relative
to the solved ba                                 luated relative to the solved ba
ckground high cont                                  the solved background high co
ntrast text is     l            v       e          ground high contrast text is e
valuated relat                 d        ou        trast text is evaluated relativ
e to the solve                   c      ast     evaluated relative to the solved
ba          high              s evaluated r     e to the solved background high
con          t is             ative to the s      ckground high contrast text is
             ela          h   ed backg   nd       ntrast text is evaluated relat
             ol          r    gh cont     t       valuated relative to the solve
        ound h          ra    xt is eva         ative to the solved background hig
              t          ua e relative t        ved background high contrast text
                         o the solved back      igh contrast text is evaluated rel
at                         und high contrast text is evaluated relative to the sol
                           t text is evaluated relative to the solved background h
                               relative to the solved background high contrast tex
                               solved background high contrast text is evaluated r
                               d high contrast text is evaluated relative to the s
o  ed  ac                      text is evaluated relative to the solved background
 high c                        d relative to the solved background high contrast t
ext is                 v       e solved background high contrast text is evaluated
 relat                       round high contrast text is evaluated relative to the
 solved                 contrast text is evaluated relative to the solved backgrou
nd high    t   t          valu     rel     e to the solved background high contrast
 text is evalua            to      sol      ackground high contrast text is evaluat
ed relative to            a       d         ontrast text is evaluated relative to t
he solved back                                 luated relative to the solved backgr
oun    i   cont                                 o the solved background high contra
st          valu                                kground high contrast text is evalu
at          e to t                              trast text is evaluated relative to
            bac                        x        aluated relative to the solved back
            co                         r       e to the solved background high cont
        t is e                         so      background high contrast text is eva
                                      d high contrast text is evaluated relative
t                                         t is    luat    elative to the solved ba
                                          lat       o t     lved background high co
                                          l         k       high contrast text is e
                                                               is evaluated relativ
                                                                tive to the solved
  k   u                  t                t                     ved background high
contrast t            luated          to the                    gh contrast text is
 evalu                to              ck              a           is evaluated relat
ive to           d  ackg          h  ontr             lu       relative to the solve
d back           h cont           is eva              o  h  solved background hig
h contra         is evalu         ative to             kground high contrast text
is evaluated relative to the solved background hig    st text is evaluated rel
ative to the solved background high contrast te   i    ted relative to the sol
ved background high contrast text is evaluated          the solved background h
igh contrast text is evaluated relative to the            d high contrast tex
t  1.41K frames per semisecond                                                43r
e  421.81
o  125.92   163    1.893s   dragon
    37.58   5343   2.001s   highcon
e   11.22   655    6.406s   normal
     3.34
```

character sets and control sequences

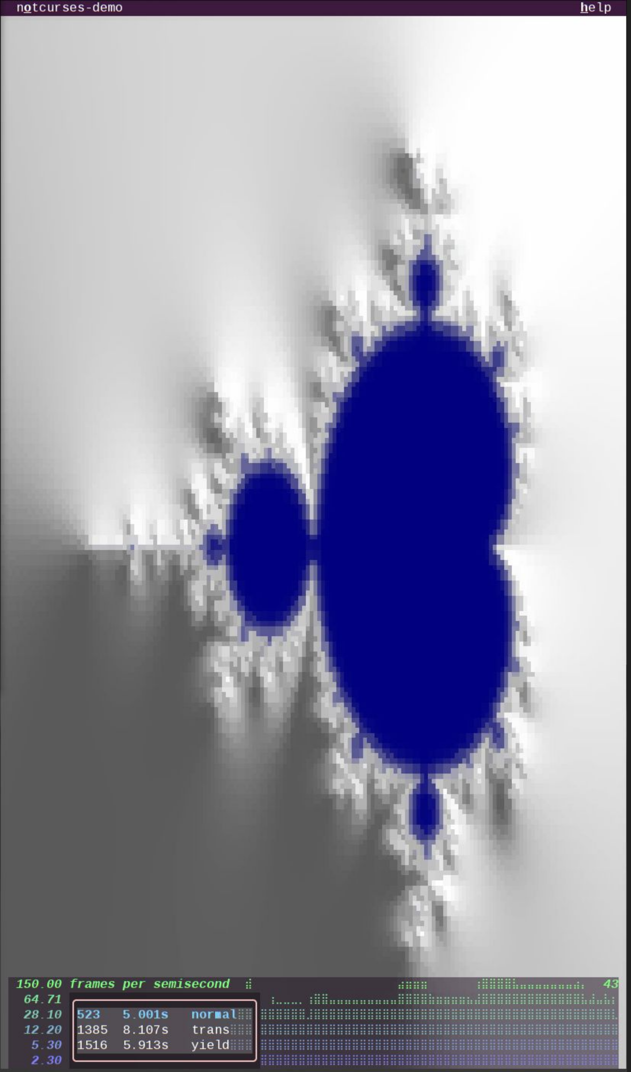
We draw with *glyphs*, styling them (and moving around the terminal) with control sequences. Glyphs correspond to EGCs—*Extended Grapheme Clusters*.

The glyphs available are a function of our (process-scope) encoding, our font (outside of our control, and often unknowable), and our terminal.

- Notcurses supports only the UTF-8 encoding of Unicode (UCS), or `ANSI_X3.4-1968` (ASCII). Unicode is *strongly* preferred.

Control sequences are a function of our terminal, abstracted via terminfo.

- Make sure your `TERM` environment variable is accurate!



```
150.00 frames per semisecond                     43
 64.71
 28.10  523   5.001s   normal
 12.20  1385  8.107s   trans
  5.30  1516  5.913s   yield
  2.30
```

why not X/Open (now SUS4) Curses?

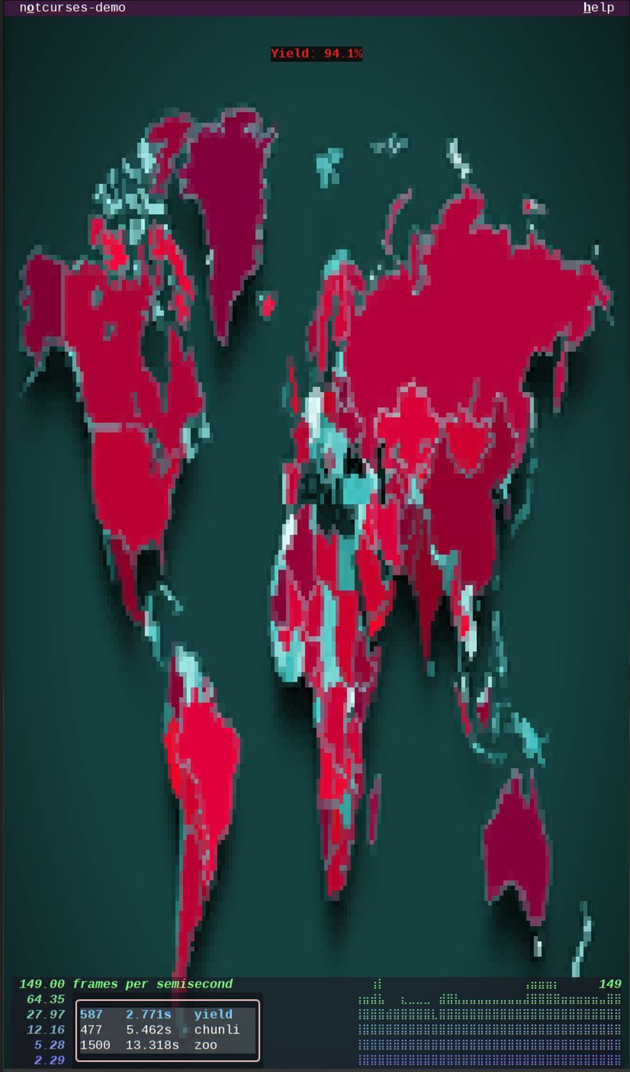
- Limited Unicode support
- Limited threading support
- PseudoColor and crufty colorpair system
- Control via global variables
- Identifier naming all over the place
- Basic functionality available only as extensions

NCURSES is a superb implementation (and extension) of Curses. The limitations of Curses are **fundamental to, and embedded in, the Curses API**.

what of other existing TUI libraries?

There is no shortage of alternative TUI/CG libraries (several dozen at least), at various levels of completeness / activity, in many different languages.

None of them met all my goals for a Curses successor.



```
Yield: 94.1%
```

```
149.00 frames per semisecond                                149
 64.35
 27.97   587    2.771s   yield
 12.16   477    5.462s   chunli
  5.28   1500   13.318s  zoo
  2.29
```

design goals for a 21st century Curses—Notcurses (1/4)

- Written and usable in C, but intended for use in safer languages
  - C is the base language / *lingua franca* of UNIX and its system calls
  - We can wrap it in just about any other language
  - Notcurses was designed in conjunction with c++/rust wrappers
  - Very real performance results, as we'll see later

- Two modes to address two major application styles
  - *Direct mode:* works with standard I/O, for batch/line-driven CLIs
  - *Rendered mode:* renders and blits frames for fullscreen TUIs
  - Code extensively shared between the two, single shared library

design goals for a 21st century Curses—Notcurses (2/4)

- Designed for use with multiple threads, meaning:
  - Areas of safe concurrent use are clearly delineated
  - Designed to maximize the area of safe parallel intersections

- Generalize drawing surface support
  - Surfaces can be any size, and are free to be partially/totally offscreen
  - Z-axis (total ordering for presentation) within each pile
  - Binding (directed acyclic forest) within each pile, with resize cascades
  - Three independent channels per cell: glyph, fg color, bg color

design goals for a 21st century Curses—Notcurses (3/4)

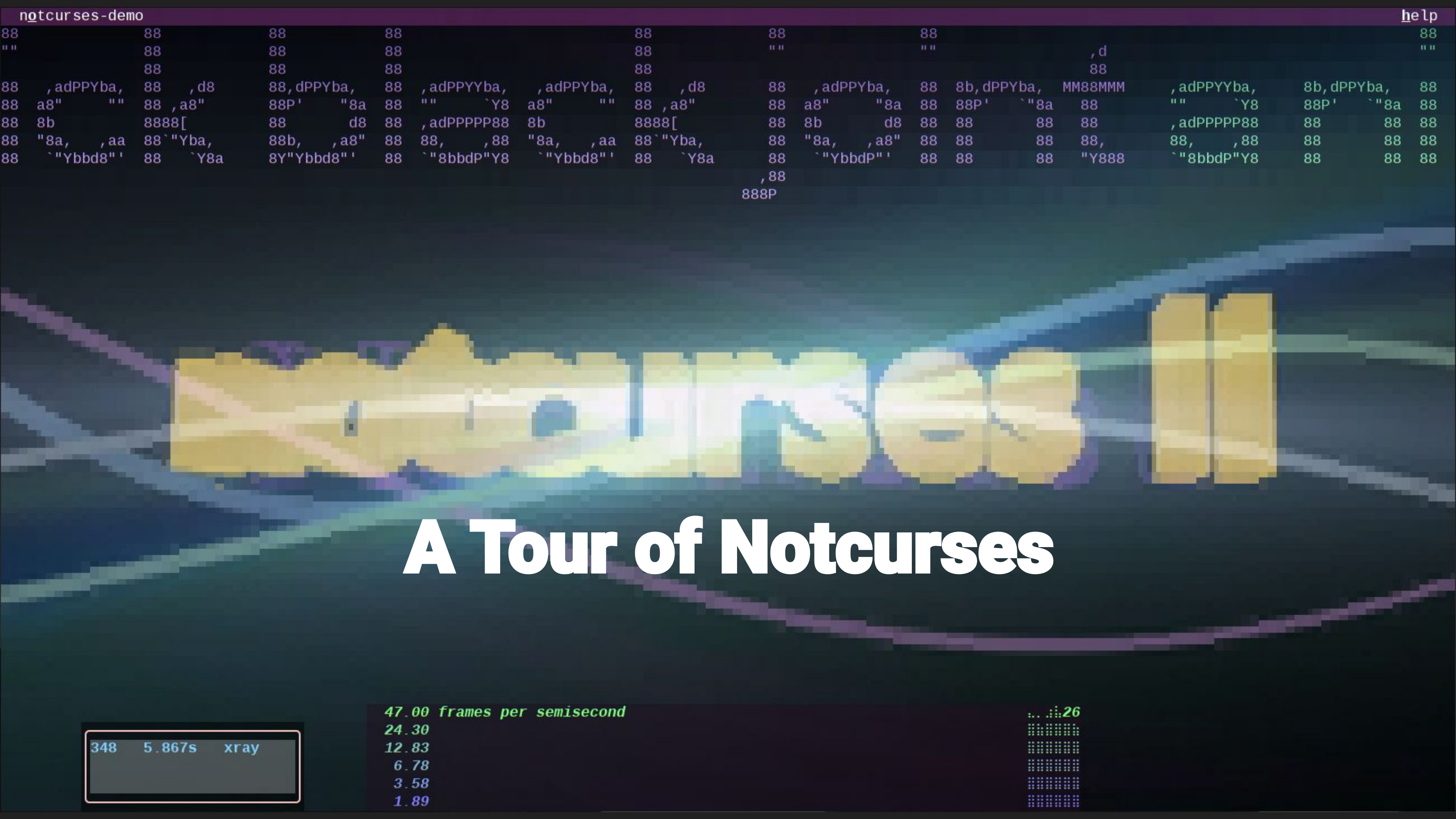
- TrueColor, color blending, and default colors
  - Default colors are taken from the terminal configuration
  - Allows transparency to the desktop, if so configured
  - Use default colors when reasonable; they allow a degree of user configuration
  - Palette-indexed PseudoColor to minimize bandwidth when possible

- Multimedia support
  - Sits atop FFmpeg or OpenImageIO (GStreamer coming soon), or null implementation
  - State-of-the-art quad- and sexblitters

design goals for a 21st century Curses—Notcurses (4/4)

- Widgets (in both rendered and direct mode)
  - High-res progress bar (8 steps per cell)
  - Selector, multiselector, tree selector
  - Menus, plots
  - Freeform input boxes (libreadline in direct mode)
  - Several types of boxes, polyfills, rotations

- Perf domination!
  - O(1) translation, z-axis move, reparenting, destruction
  - Optimal rendering and rasterization
  - Extensive profiling, performance tracking as part of CI, 25 benchmarks in `notcurses-demo`



A Tour of Notcurses

```
 notcurses-demo                                                                                                                                                  help
88              88            88           88                           88             88               88                                                      88
""              88            88           88                           88             ""               ""                ,d                                    ""
                88            88           88                           88                                                88
88   ,adPPYba,  88   ,d8      88,dPPYba,   88  ,adPPYYba,   ,adPPYba,   88   ,d8       88   ,adPPYba,   88  8b,dPPYba,  MM88MMM     ,adPPYYba,     8b,dPPYba,   88
88  a8"     ""  88 ,a8"       88P'    "8a  88  ""     `Y8  a8"      ""  88 ,a8"        88  a8"     "8a  88  88P'   `"8a   88        ""     `Y8     88P'   `"8a  88
88  8b          8888[         88       d8  88  ,adPPPPP88  8b           8888[          88  8b       d8  88  88       88   88        ,adPPPPP88     88       88  88
88  "8a,   ,aa  88`"Yba,      88b,   ,a8"  88  88,    ,88  "8a,    ,aa  88`"Yba,       88  "8a,   ,a8"  88  88       88   88,       88,    ,88     88       88  88
88   `"Ybbd8"'  88   `Y8a     8Y"Ybbd8"'   88  `"8bbdP"Y8   `"Ybbd8"'   88   `Y8a      88   `"YbbdP"'   88  88       88   "Y888     `"8bbdP"Y8     88       88  88
                                                                                      ,88
                                                                                    888P
```

```
348   5.867s   xray
```

```
47.00 frames per semisecond                                                    26
24.30
12.83
 6.78
 3.58
 1.89
```

direct mode: style your `printf()`s

- Best for scrolling, line-based UIs.
- Use regular stdio, plus `ncdirect_*()` functions to emit control sequences.
- The cursor can be moved/located, and screen coordinates determined
  - Useful for e.g. spinners and multiline widgets
- Images can be rendered, boxes and progress bars drawn, etc.

For more complex graphics, including forms, plots, and just about anything that needs rapidly update the full screen, we instead use...

rendered mode

- Rendered mode operates like more of an OpenGL model
- Create surfaces (ncplanes), draw on them, order them
- Render a collection of surfaces (ncpile) to a frame
- Rasterize a frame to the terminal as a unit
- Only upon rasterization is the output area changed
    - Operations between rasterizations are wholly virtual
- Only updated cells are emitted
- Pile/plane state persists across rendering operations
- Can achieve thousands of FPS
- Can use the *alternate screen* where available
- Mixing with standard I/O will result in madness

rendered mode operation model

- A frame is rendered from a single pile
- Piles are entirely independent
  - Multiple threads can freely mutate multiple piles
- A pile is rendered using the Painter's Algorithm
  - Only cells overlapping the visual area are rendered
  - Painting proceeds from higher planes to lower ones
  - An output cell is *solved* when we have a defined glyph, fg, and bg
- No need to use multiple piles except for parallel performance
  - Can also be convenient for multimodal UIs
- Rasterizing a frame syncs the visual display to the frame
  - A frame, once rendered, can be held an arbitrary amount of time
  - Rasterization is optimized via damage maps

rendered mode data model—`ncpile`s (1/4)

- One or more piles in a rendered mode context, defined by:
  - Visual area (geometry can change at any time)
  - User doesn't work with piles explicitly
  - One or more planes
    - If all planes within a pile are destroyed/reparented, the pile is destroyed
  - Each pile has a z-axis (total order) and binding forest (DAF)
    - Subtree-wide moves, reparentings, destruction
    - Resize events cascade down to all children
- Piles (and all their planes) cannot be mutated while being rendered
- Only one thread may reorder/create/destroy planes within a pile at a time
- Multiple threads may mutate distinct piles concurrently

rendered mode data model—`ncplane`s (2/4)

- One or more planes per pile, defined by:
  - A geometry, and an origin relative to the pile's visual area
  - An active background color, foreground color, and style (used for output)
  - A framebuffer of nccells and a backing EGCPool
  - A user-managed opaque pointer, and a name (used for debugging)
  - A resize callback function
  - A virtual cursor location
  - A base cell, used where cells are undefined
  - Scrolling/z-axis/binding forest state
- Planes are the fundamental drawing surface of Notcurses
- Multiple threads may mutate multiple planes concurrently

rendered mode data model—`nccell`s (3a/4)

- A cell is a 16-byte structure, with possible spillover into an EGCPool

```
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|       gcluster (up to 4 UTF-8 bytes, OR a 24-bit index)      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    backstop   |     width     |           stylemask           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    foreground                                                 |
+                            channels                           +
|                                                 background    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

rendered mode data model—`nccell`s (3b/4)

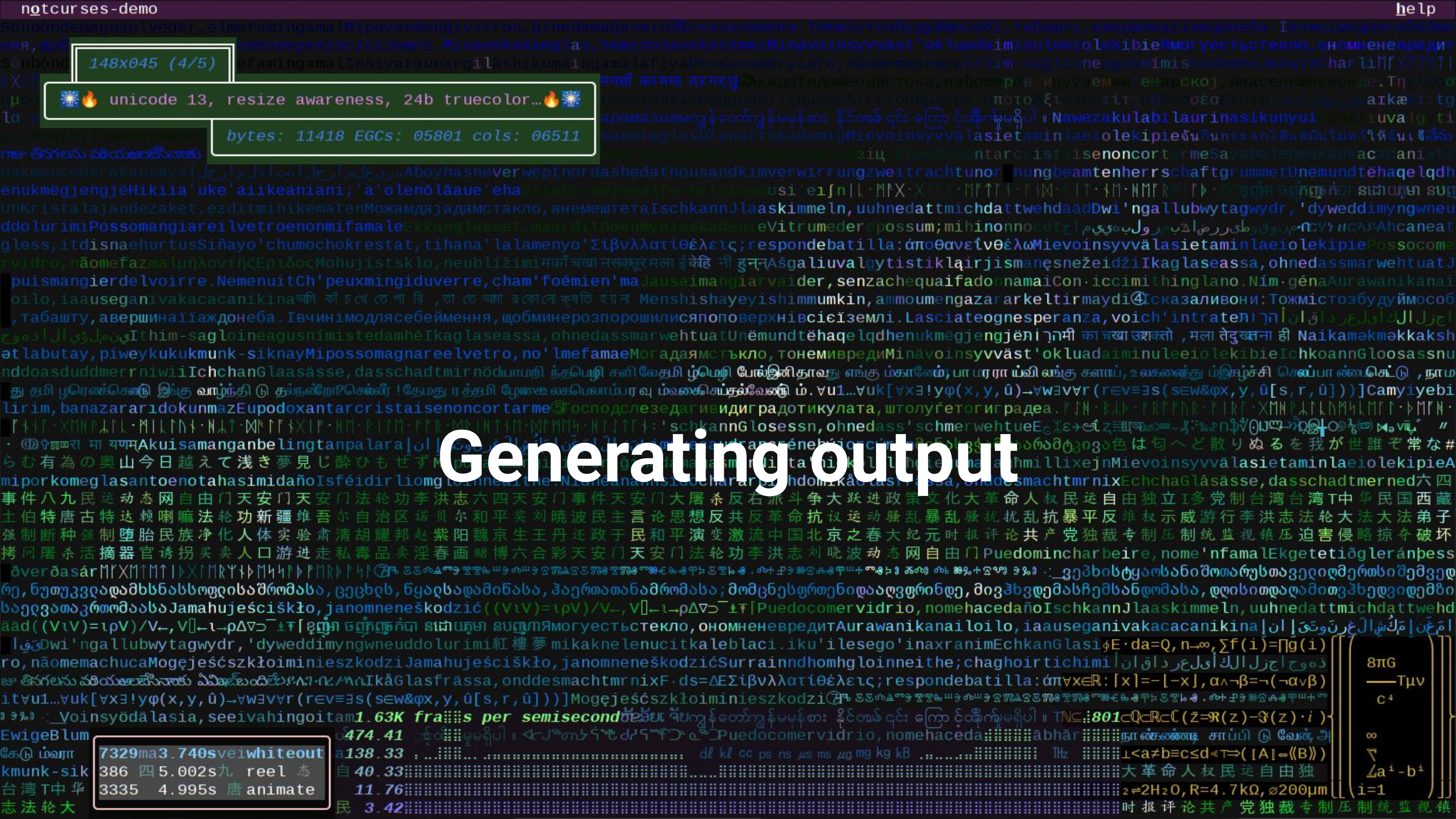
- EGCs of 4 or fewer UTF-8 bytes are inlined directly into `gcluster`
  - All currently-defined UCS characters are encoded in 4 or fewer UTF-8 bytes
- Larger EGCs are stored in the EGCPool
  - Indicated via initial byte of 0x01, followed by 24-bit offset
  - UTF-8 guarantees bytes < 128 are single ASCII characters
  - We don't allow control characters into a cell, thus 0x01 is unambiguous
- `backstop` is always 0, so that `gcluster` can be used as a C string
- `width` is the number of columns occupied by the EGC
  - Secondary cells of a multicolumn EGC have `width` != 0, `gcluster` == 0
- `stylemask` is a bitfield corresponding to italics, reverse video, blink etc.

rendered mode data model—`channel`s (4/4)

- 64-bit structure composed of two 32-bit channels
- Each channel encodes either 24-bit RGB, 8-bit palette index, or default color
- 2 bits of "alpha" (`OPAQUE`, `BLEND`, `TRANSPARENT`, `HIGHCONTRAST`)

```
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|0|n| α |p|  0  |               rgb/palette index               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Generating output



```
148x045 (4/5)
🎇🔥 unicode 13, resize awareness, 24b truecolor…🔥🎇
bytes: 11418 EGCs: 05801 cols: 06511
```

```
1.63K frames per semisecond
474.41
138.33
40.33
11.76
3.42
```

```
7329 3.740s whiteout
386  5.002s reel
3335 4.995s animate
```

formatted output, parameterized by type

`ncplane_putc`	Cell (including style/channels)	`nccell`
`ncplane_putchar`	7-bit ASCII as EGC	`char`
`ncplane_putwc`	Wide char as EGC	`wchar_t`
`ncplane_putegc`	UTF-8 EGC	`const char*`
`ncplane_putwegc`	Wide char EGC	`const wchar_t*`
`ncplane_putstr`	UTF-8 string	`const char*`
`ncplane_putwstr`	Wide string	`const wchar_t*`
`ncplane_printf`	Formatted output	`const char*, ...`
`ncplane_vprintf`	Formatted output	`const char*, va_list`

boxes and fills

- At their most generic, boxes are drawn:
  - At some starting location, with some geometry
  - With six specified `nccell`s (including style and channels)
  - With the ability to leave out arbitrary edges/corners
  - With the ability to interpolate between corner channels
  - Simple, double, and rounded prepared variants
  - `ncplane_perimeter()` prepared geometry
- `ncplane_gradient()` fills a rectangular area with a gradient and EGC
  - interpolation from four sets of corner channels
- `ncplane_polyfill()` replaces a region of the same EGC with an `nccell`

multimedia

- currently supports FFmpeg and OpenImageIO backends
- the multimedia backend (chosen at compile time) is in libnotcurses
- linking against only libnotcurses-core requires no multimedia backend
- `ncvisual` objects created with
  - `ncvisual_from_file()`: open and decode arbitrary files
  - `ncvisual_from_rgba()`: loaded from decoded RGBA in memory
  - `ncvisual_from_plane()`: loaded from `ncplane` contents
- even when linking against libnotcurses, check for runtime support
  - `notcurses_canopen_images()` / `notcurses_canopen_videos()`

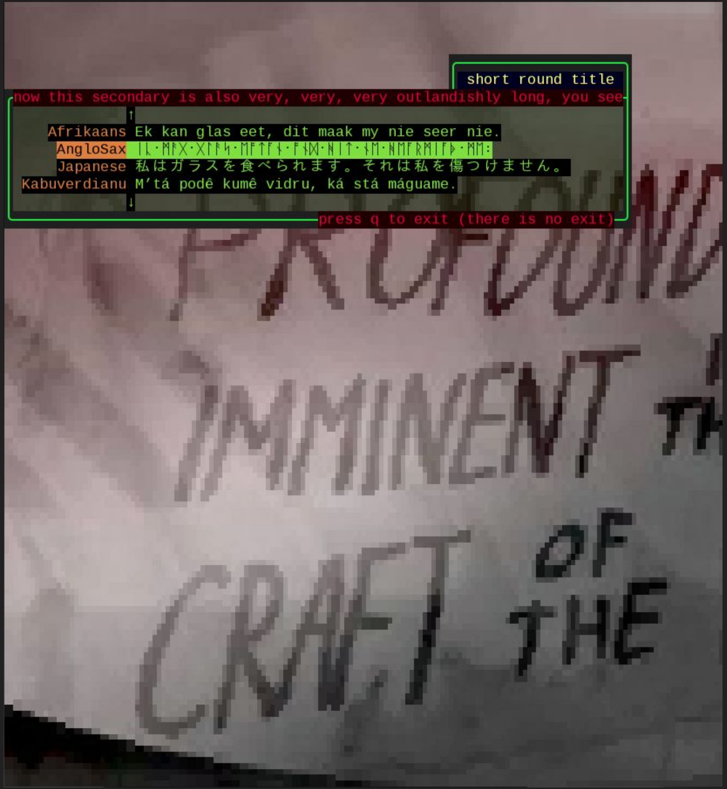
image blitters

NAME	GEOMETRY	ASPECT	FIDELITY	GLYPHS
Space	1x1	2:1	100%	1
Half	2x1	1:1	100%	3
Quad	2x2	2:1	50%	15
Sex	3x2	1.5:1	33%	63
Braille	4x2	1:1	12.5%	255

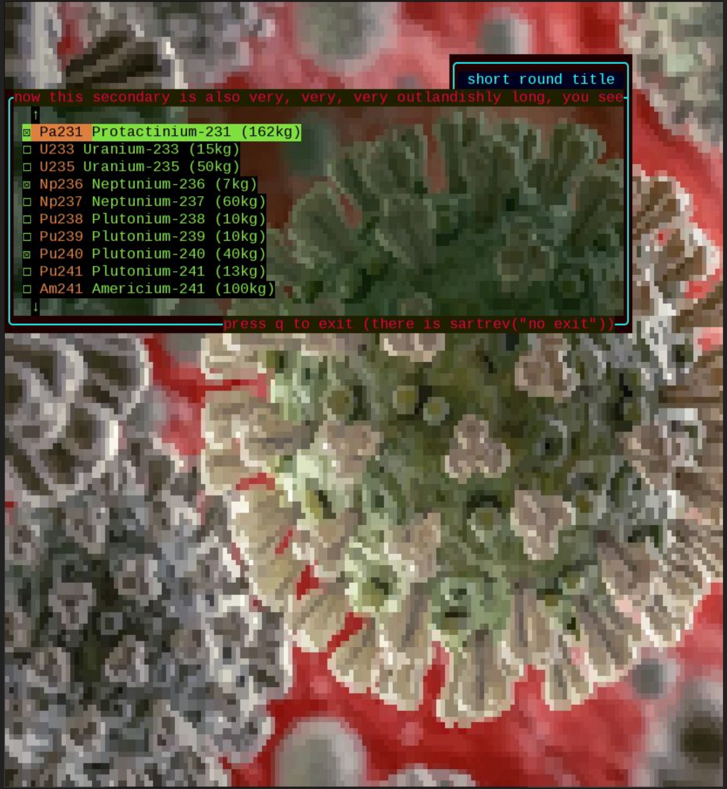
plot blitters

NAME	GEOMETRY	GLYPHS
Space	1x1	1
Half	2x1	2
Fourths	4x1	4
Quad	2x2	8
Eighths	8x1	8
Sex	3x2	11
Braille	4x2	14

selector and multiselector

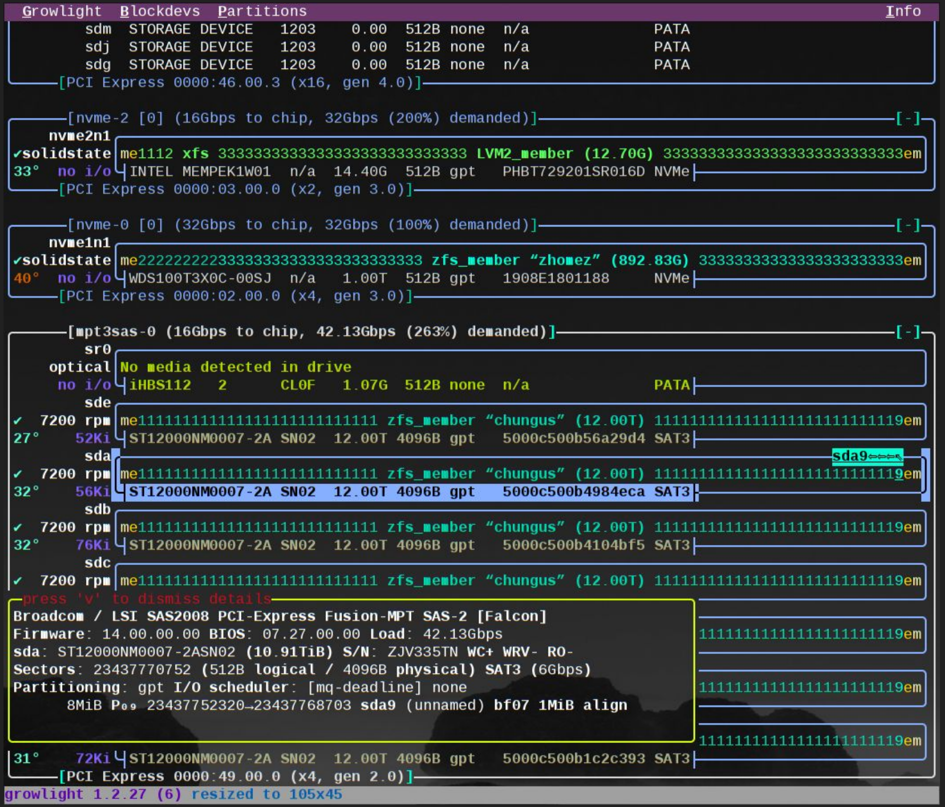


```
                                                          short round title
now this secondary is also very, very, very outlandishly long, you see
                     ↑
   Afrikaans Ek kan glas eet, dit maak my nie seer nie.
    AngloSax ᛁᚳ᛫ᛗᚨᚷ᛫ᚷᛚᚨᛋ᛫ᛖᚩᛏᚪᚾ᛫ᚩᚾᛞ᛫ᚻᛁᛏ᛫ᚾᛖ᛫ᚻᛖᚪᚱᛗᛁᚪᚧ᛫ᛗᛖ᛬
    Japanese 私はガラスを食べられます。それは私を傷つけません。
 Kabuverdianu M’tá podê kumê vidru, ká stá máguame.
                     ↓
                                        press q to exit (there is no exit)
```



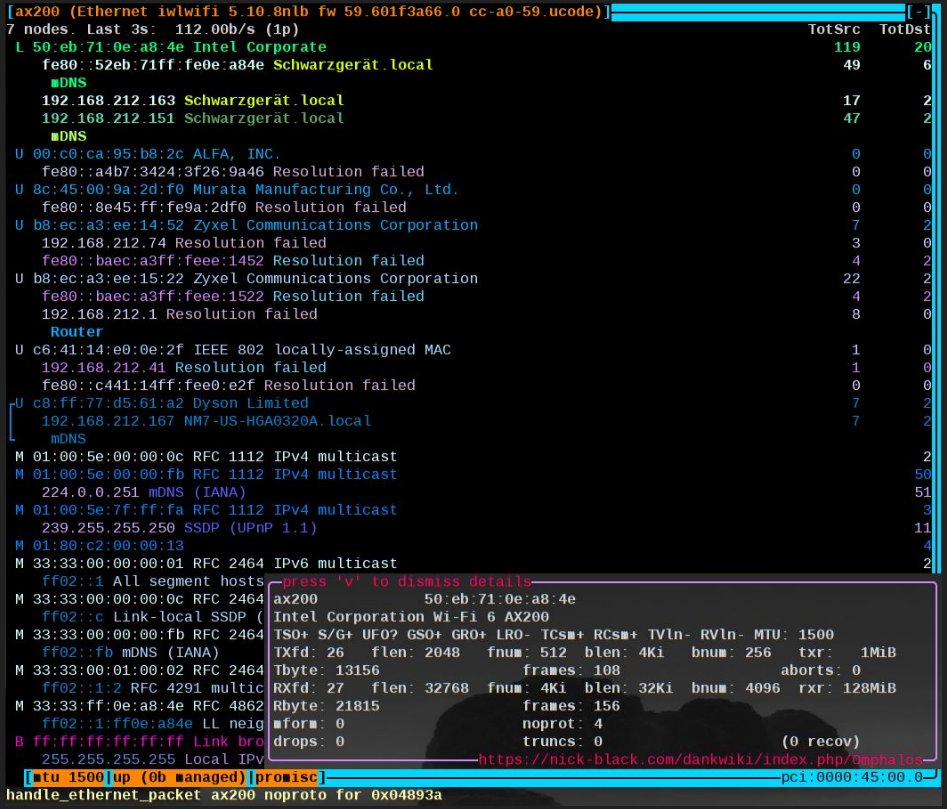
```
                                                          short round title
now this secondary is also very, very, very outlandishly long, you see
  ↑
 ☒ Pa231 Protactinium-231 (162kg)
 □ U233 Uranium-233 (15kg)
 □ U235 Uranium-235 (50kg)
 ☒ Np236 Neptunium-236 (7kg)
 □ Np237 Neptunium-237 (60kg)
 □ Pu238 Plutonium-238 (10kg)
 □ Pu239 Plutonium-239 (10kg)
 ☒ Pu240 Plutonium-240 (40kg)
 □ Pu241 Plutonium-241 (13kg)
 □ Am241 Americium-241 (100kg)
  ↓
                     press q to exit (there is sartrev("no exit"))
```

results (`growlight` disk manager)



```
 Growlight  Blockdevs  Partitions                                                          Info
         sdm  STORAGE DEVICE   1203    0.00  512B none  n/a              PATA
         sdj  STORAGE DEVICE   1203    0.00  512B none  n/a              PATA
         sdg  STORAGE DEVICE   1203    0.00  512B none  n/a              PATA
      [PCI Express 0000:46.00.3 (x16, gen 4.0)]

       [nvme-2 [0] (16Gbps to chip, 32Gbps (200%) demanded)]                                  [-]
     nvme2n1
✓solidstate me1112 xfs 33333333333333333333333333333 LVM2_member (12.70G) 33333333333333333333333333333em
33°   no i/o  INTEL MEMPEK1W01  n/a  14.40G  512B gpt   PHBT729201SR016D NVMe
      [PCI Express 0000:03.00.0 (x2, gen 3.0)]

       [nvme-0 [0] (32Gbps to chip, 32Gbps (100%) demanded)]                                  [-]
     nvme1n1
✓solidstate me222222223333333333333333333333333 zfs_member “zhomez” (892.83G) 333333333333333333333333em
40°   no i/o  WDS100T3X0C-00SJ  n/a   1.00T  512B gpt   1908E1801188     NVMe
      [PCI Express 0000:02.00.0 (x4, gen 3.0)]

       [mpt3sas-0 (16Gbps to chip, 42.13Gbps (263%) demanded)]                                [-]
         sr0
     optical No media detected in drive
      no i/o  iHBS112   2      CL0F   1.07G  512B none  n/a              PATA
         sde
✓  7200 rpm me1111111111111111111111111111 zfs_member “chungus” (12.00T) 11111111111111111111111111119em
27°    52Ki  ST12000NM0007-2A SN02  12.00T 4096B gpt   5000c500b56a29d4 SAT3
         sda                                                                                sda9⇐⇐⇐↖
✓  7200 rpm me1111111111111111111111111111 zfs_member “chungus” (12.00T) 11111111111111111111111111119em
32°    56Ki  ST12000NM0007-2A SN02  12.00T 4096B gpt   5000c500b4984eca SAT3
         sdb
✓  7200 rpm me1111111111111111111111111111 zfs_member “chungus” (12.00T) 11111111111111111111111111119em
32°    76Ki  ST12000NM0007-2A SN02  12.00T 4096B gpt   5000c500b4104bf5 SAT3
         sdc
✓  7200 rpm me1111111111111111111111111111 zfs_member “chungus” (12.00T) 11111111111111111111111111119em
 press 'v' to dismiss details
Broadcom / LSI SAS2008 PCI-Express Fusion-MPT SAS-2 [Falcon]
Firmware: 14.00.00.00 BIOS: 07.27.00.00 Load: 42.13Gbps                 1111111111111111111111119em
sda: ST12000NM0007-2ASN02 (10.91TiB) S/N: ZJV335TN WC+ WRV- RO-
Sectors: 23437770752 (512B logical / 4096B physical) SAT3 (6Gbps)
Partitioning: gpt I/O scheduler: [mq-deadline] none                     1111111111111111111111119em
      8MiB P₀₉ 23437752320→23437768703 sda9 (unnamed) bf07 1MiB align

                                                                        1111111111111111111111119em
31°    72Ki  ST12000NM0007-2A SN02  12.00T 4096B gpt   5000c500b1c2c393 SAT3
      [PCI Express 0000:49.00.0 (x4, gen 2.0)]
growlight 1.2.27 (6) resized to 105x45
```

results (omphalos network explorer)



```
[ax200 (Ethernet iwlwifi 5.10.8nlb fw 59.601f3a66.0 cc-a0-59.ucode)]                     [-]
7 nodes. Last 3s:  112.00b/s (1p)                                                 TotSrc  TotDst
 L 50:eb:71:0e:a8:4e Intel Corporate                                                 119      20
    fe80::52eb:71ff:fe0e:a84e Schwarzgerät.local                                      49       6
     ■DNS
    192.168.212.163 Schwarzgerät.local                                                17       2
    192.168.212.151 Schwarzgerät.local                                                47       2
     ■DNS
 U 00:c0:ca:95:b8:2c ALFA, INC.                                                        0       0
    fe80::a4b7:3424:3f26:9a46 Resolution failed                                        0       0
 U 8c:45:00:9a:2d:f0 Murata Manufacturing Co., Ltd.                                    0       0
    fe80::8e45:ff:fe9a:2df0 Resolution failed                                          0       0
 U b8:ec:a3:ee:14:52 Zyxel Communications Corporation                                  7       2
    192.168.212.74 Resolution failed                                                   3       0
    fe80::baec:a3ff:feee:1452 Resolution failed                                        4       2
 U b8:ec:a3:ee:15:22 Zyxel Communications Corporation                                 22       2
    fe80::baec:a3ff:feee:1522 Resolution failed                                        4       2
    192.168.212.1 Resolution failed                                                    8       0
     Router
 U c6:41:14:e0:0e:2f IEEE 802 locally-assigned MAC                                     1       0
    192.168.212.41 Resolution failed                                                   1       0
    fe80::c441:14ff:fee0:e2f Resolution failed                                         0       0
┌U c8:ff:77:d5:61:a2 Dyson Limited                                                     7       2
│   192.168.212.167 NM7-US-HGA0320A.local                                              7       2
└    mDNS
 M 01:00:5e:00:00:0c RFC 1112 IPv4 multicast                                                   2
 M 01:00:5e:00:00:fb RFC 1112 IPv4 multicast                                                  50
    224.0.0.251 mDNS (IANA)                                                                   51
 M 01:00:5e:7f:ff:fa RFC 1112 IPv4 multicast                                                   3
    239.255.255.250 SSDP (UPnP 1.1)                                                           11
 M 01:80:c2:00:00:13                                                                           4
 M 33:33:00:00:00:01 RFC 2464 IPv6 multicast                                                   2
    ff02::1 All segment hosts ┌press 'v' to dismiss details────────────────────────────────────┐
 M 33:33:00:00:00:0c RFC 2464 │ax200           50:eb:71:0e:a8:4e                               │
    ff02::c Link-local SSDP ( │Intel Corporation Wi-Fi 6 AX200                                 │
 M 33:33:00:00:00:fb RFC 2464 │TSO+ S/G+ UFO? GSO+ GRO+ LRO- TCs■+ RCs■+ TVln- RVln- MTU: 1500 │
    ff02::fb mDNS (IANA)      │TXfd: 26   flen: 2048   fnu■: 512  blen: 4Ki   bnu■: 256   txr:   1MiB │
 M 33:33:00:01:00:02 RFC 2464 │Tbyte: 13156               fra■es: 108               aborts: 0  │
    ff02::1:2 RFC 4291 multic │RXfd: 27   flen: 32768  fnu■: 4Ki  blen: 32Ki  bnu■: 4096  rxr: 128MiB │
 M 33:33:ff:0e:a8:4e RFC 4862 │Rbyte: 21815               fra■es: 156                          │
    ff02::1:ff0e:a84e LL neig │■for■: 0                   noprot: 4                            │
 B ff:ff:ff:ff:ff:ff Link bro │drops: 0                   truncs: 0             (0 recov)      │
    255.255.255.255 Local IPv └──────────────https://nick-black.com/dankwiki/index.php/Omphalos┘
  [■tu 1500|up (0b ■anaged)|pro■isc]──────────────────────────────────────────pci:0000:45:00.0┘
handle_ethernet_packet ax200 noproto for 0x04893a
```

thanks, FOSDEM 2021!

go watch the demo