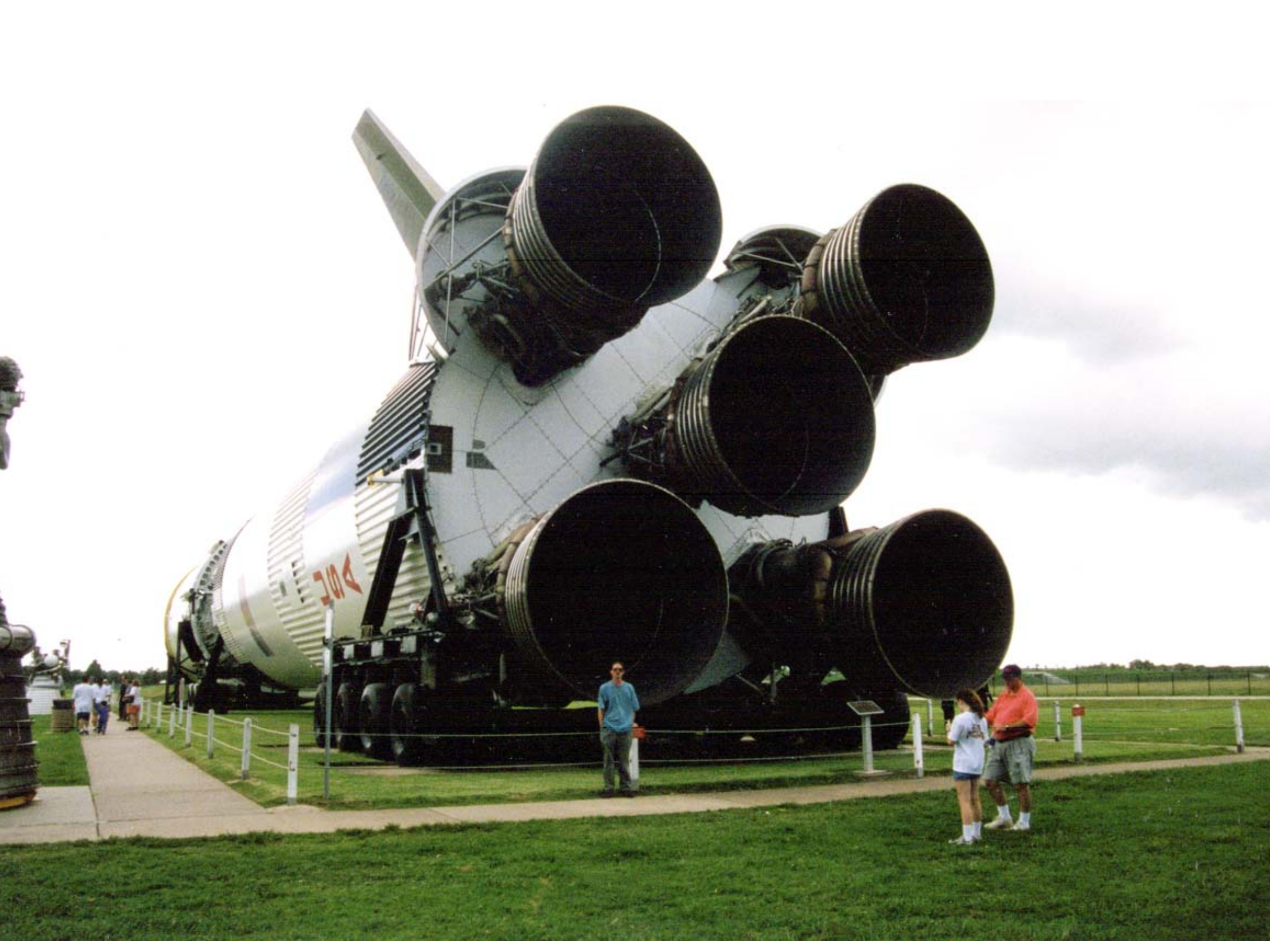
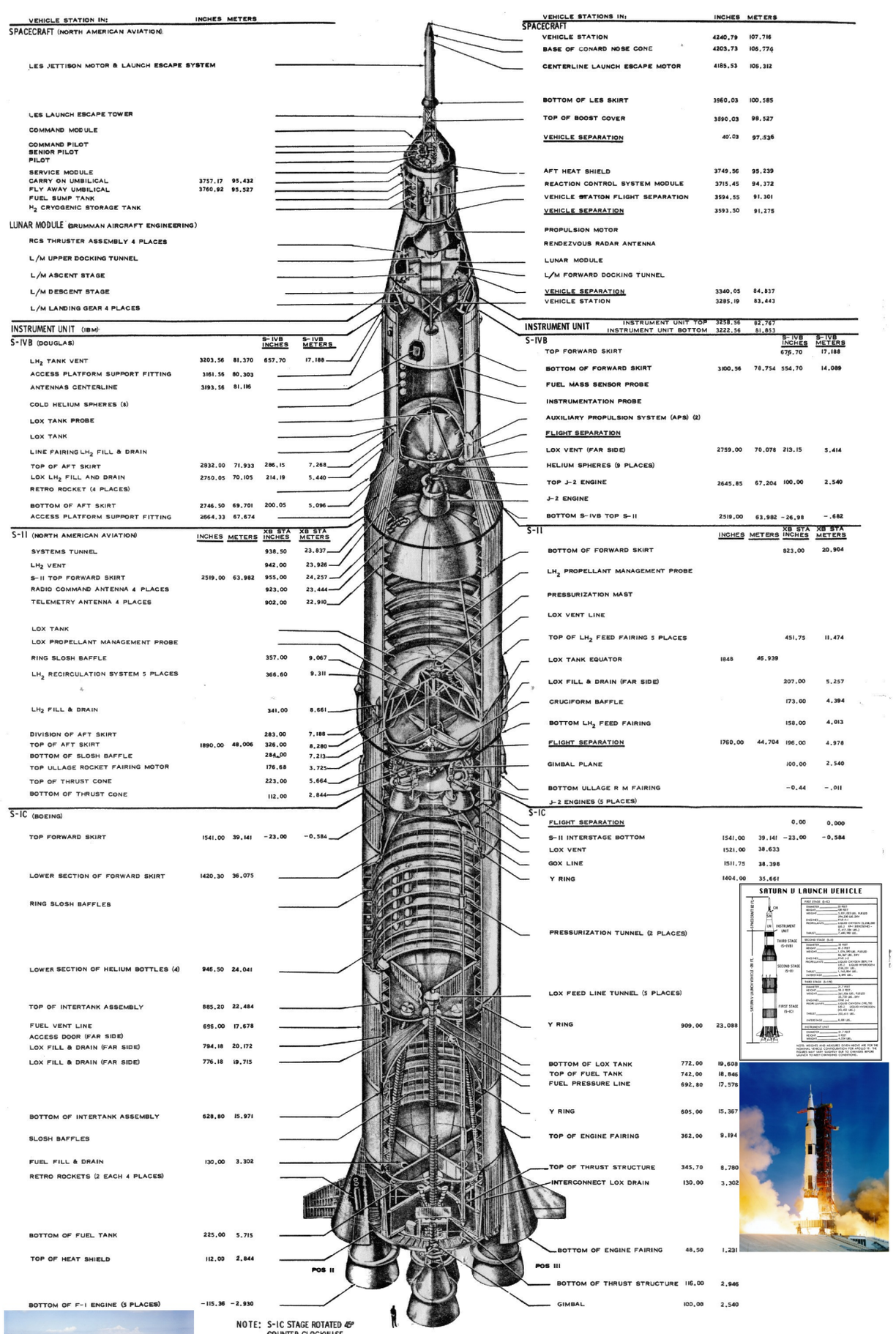
Performance





Command Module
64,000 lbs

Saturn V
6,200,000 lbs

Payload
1.5% of total weight


Falcon 9
Elon Musk

Demo: clear

Optimization Strategies

- **Compiler flags** - leverage automatic optimizations
- **Inlining** - Reduce function call overhead
- **Avoid volatile** - enable more compiler optimizations
- **Aggregate loads/stores** - less instructions per memory operation
- **Loop optimizations** - code hoisting, combination, unrolling
- **Manual assembly** - Be smarter than the compiler

Amdahl's Law

$$S_{latency}(s) = \frac{1}{(1-p) + \frac{p}{s}}$$

- $S_{latency}$ - the theoretical speedup of the execution of the entire program
- s - the speedup of the part of the program you're optimizing
- p - the proportion of execution time that the part the program you're optimizing originally occupied

Amdahl’s Law

Suppose your original program took **t** cycles to execute

Amdahl's Law

The program is divided into two distinct portions:

- Part **A** takes 75% of the time
- Part **B** takes 25% of the time

Amdahl’s Law

If we optimize part B to make it 5 times faster, this only reduces the overall computation time slightly

Amdahl’s Law

If we optimize part A to make it just twice as fast, we get a greater overall speedup

Amdahl's Law

Part B is 25% of the overall program ($p = .25$) and we speed it up by a factor of 5 ($s = 5$)

$$S_{latency} = \frac{1}{1 - .25 + \frac{.25}{5}} = 1.25$$

Overall program speedup is 1.25

Amdahl's Law

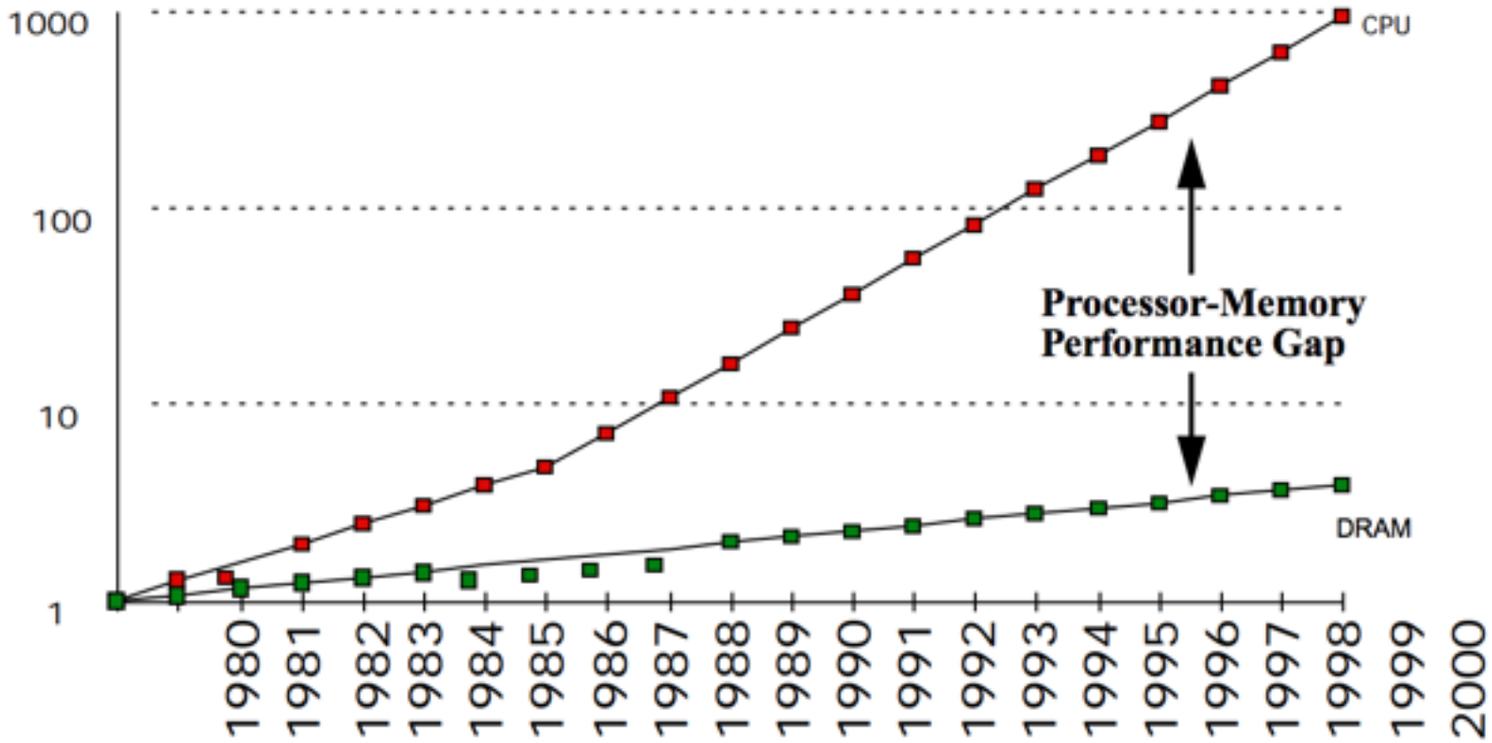
Part A is 75% of the overall program (*p = .75*) and we speed it up by a factor of 2 (*s = 2)*

$$S_{latency} = \frac{1}{1 - .75 + \frac{.75}{2}} = 1.60$$

Overall program speedup is 1.60

Beyond Software Optimization

Processor-Memory Performance Gap



[Hennessy, J.L.; Patterson, D.A. Computer Organization and Design, 2nd ed.]

Memory System Performance

Processor	Alpha 21164	
Machine	AlphaServer 8200	
Clock Rate	300 MHz	
Memory Performance	Latency	Bandwidth
I Cache (8KB on chip)	6.7 ns (2 clocks)	4800 MB/sec
D Cache (8KB on chip)	6.7 ns (2 clocks)	4800 MB/sec
L2 Cache (96KB on chip)	20 ns (6 clocks)	4800 MB/sec
L3 Cache (4MB off chip)	26 ns (8 clocks)	960 MB/sec
Main Memory Subsystem	253 ns (76 clocks)	1200 MB/sec
Single DRAM component	≈60ns (18 clocks)	≈30–100 MB/sec

[Patterson, David, et al. "A case for intelligent RAM.”]

Moving data between the cpu and memory is the bottleneck

strcpy

```
for (int i = 0; i <= strlen(src); i++) {
    dst[i] = src[i]
}
```

All we’re doing is loading data from memory into the CPU and storing it back into memory

Avoiding the Memory Bottleneck

- Raspberry Pi has a **DMA Controller** that allows us to read and write memory without having to go through the processor (avoiding the load/store latency)

- Section 4 of BCM2835-ARM-Peripherals.pdf

Demo: dma

Measuring Performance

Don’t optimize blind

Profiling

- Analyze your program at runtime to measure characteristics of interest
  - Space/time complexity
  - Frequency of certain instructions
  - Frequency and Duration of Function Calls
- Most often used for guiding optimization

Taking Measurements

- **Hardware interrupts** - gprof.c
- **Code Instrumentation** - timer
- Also: instruction set simulation, OS hooks, performance counters
- Many techniques rely on sampling (statistical profilers) to trade off accuracy for speed

Visualizing Measurements

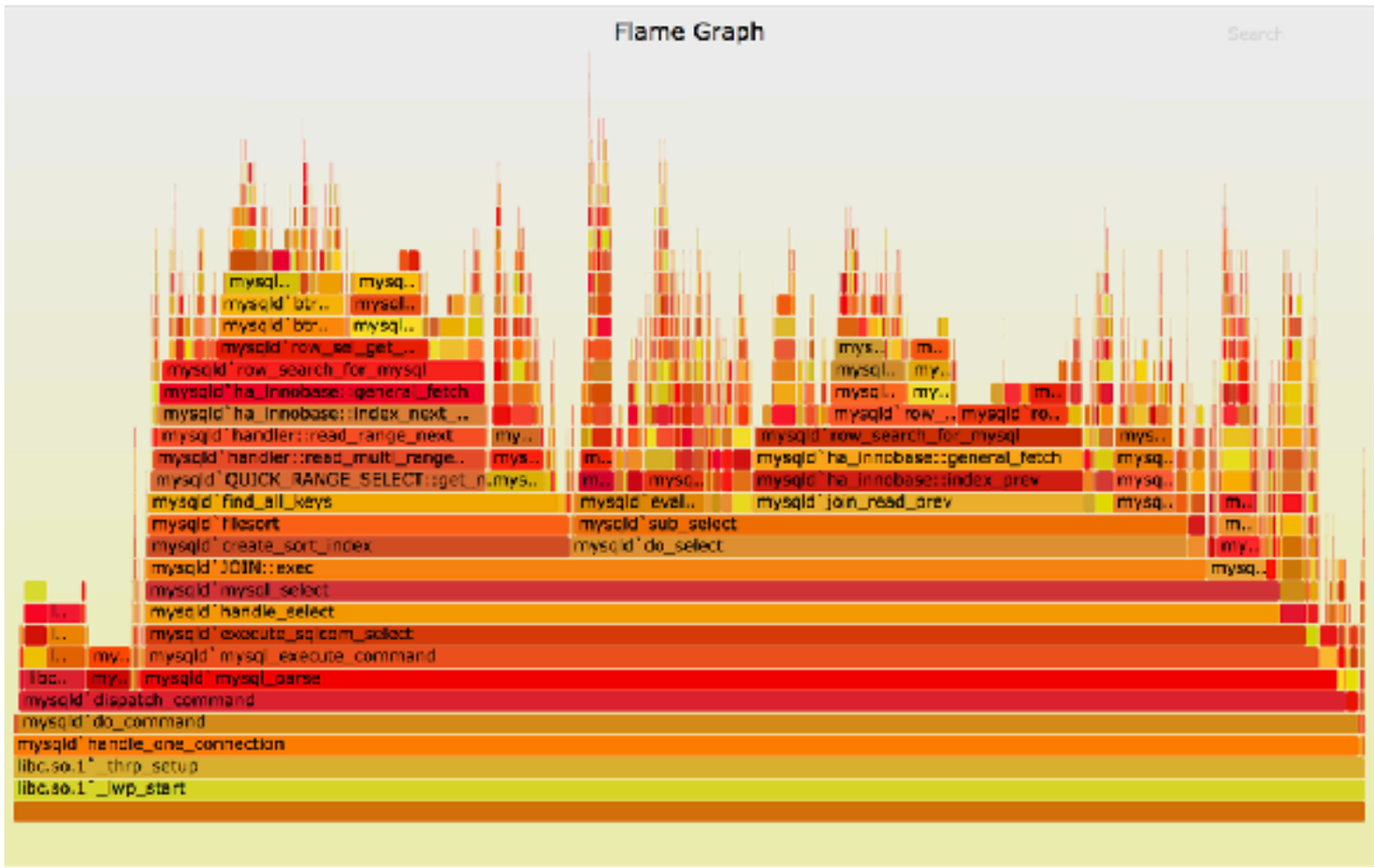
Chrome Developer Tools

- Output profiling information in standard format (linux *perf*)
- Use **thlorenz/cpuprofilify** to convert into *.cpuprofile* format

Demo: stackprof

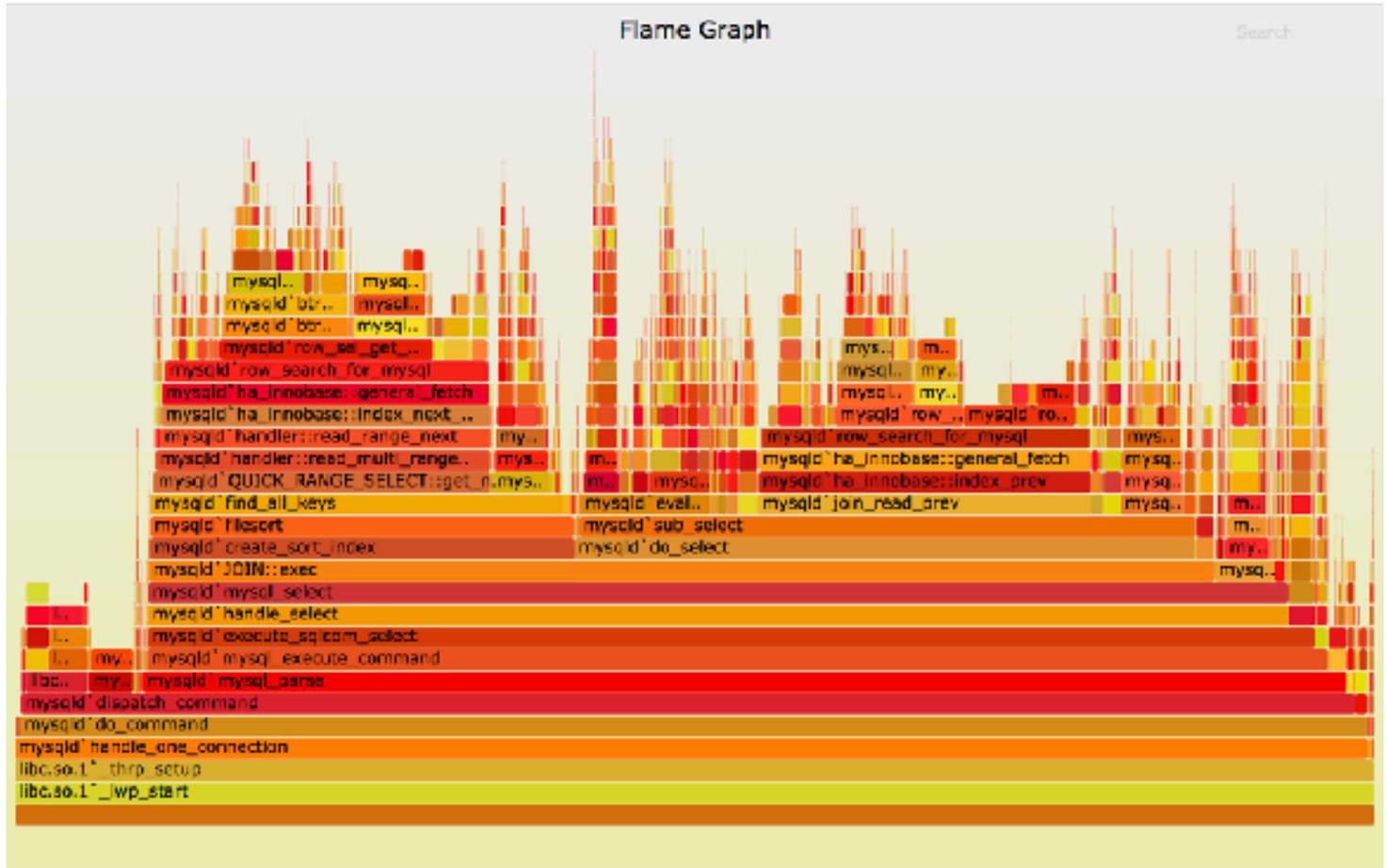
Visualizing Measurements

Flame Graph - designed to quickly and accurately find the most frequent code paths



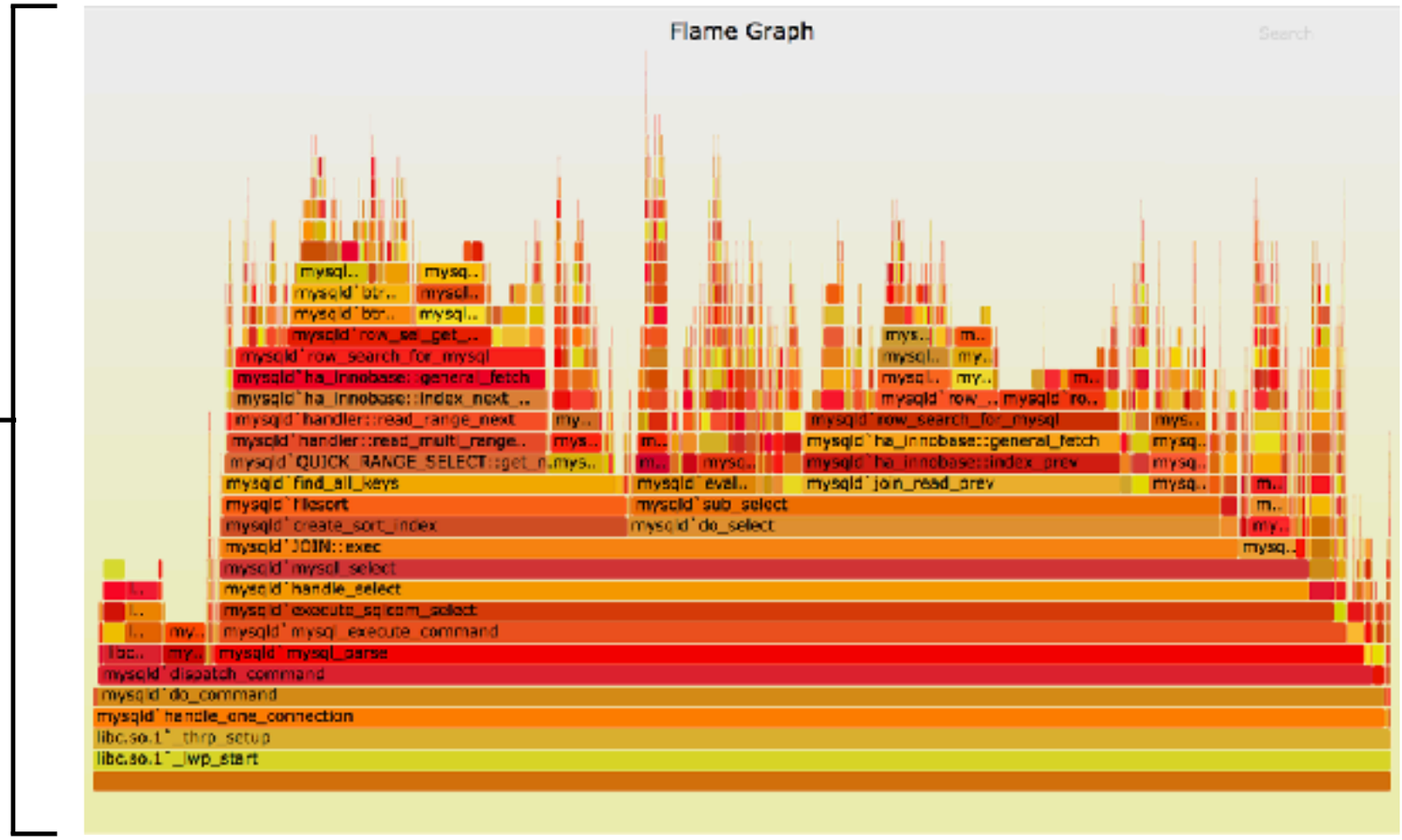
http://www.brendangregg.com/flamegraphs.html

Flame Graph



Stack Population Sorted Alphabetically (not time!)

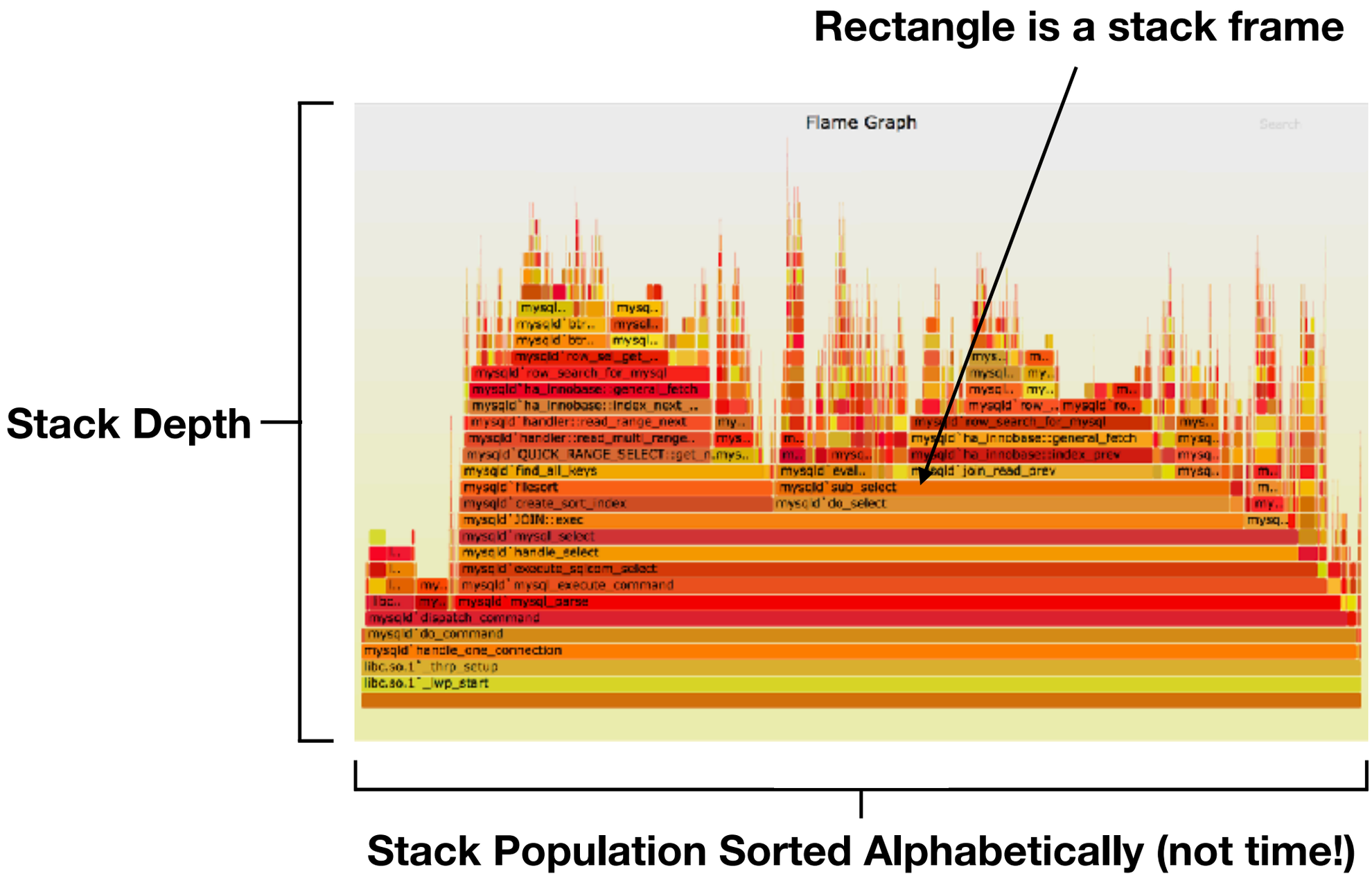
Flame Graph



Stack Depth

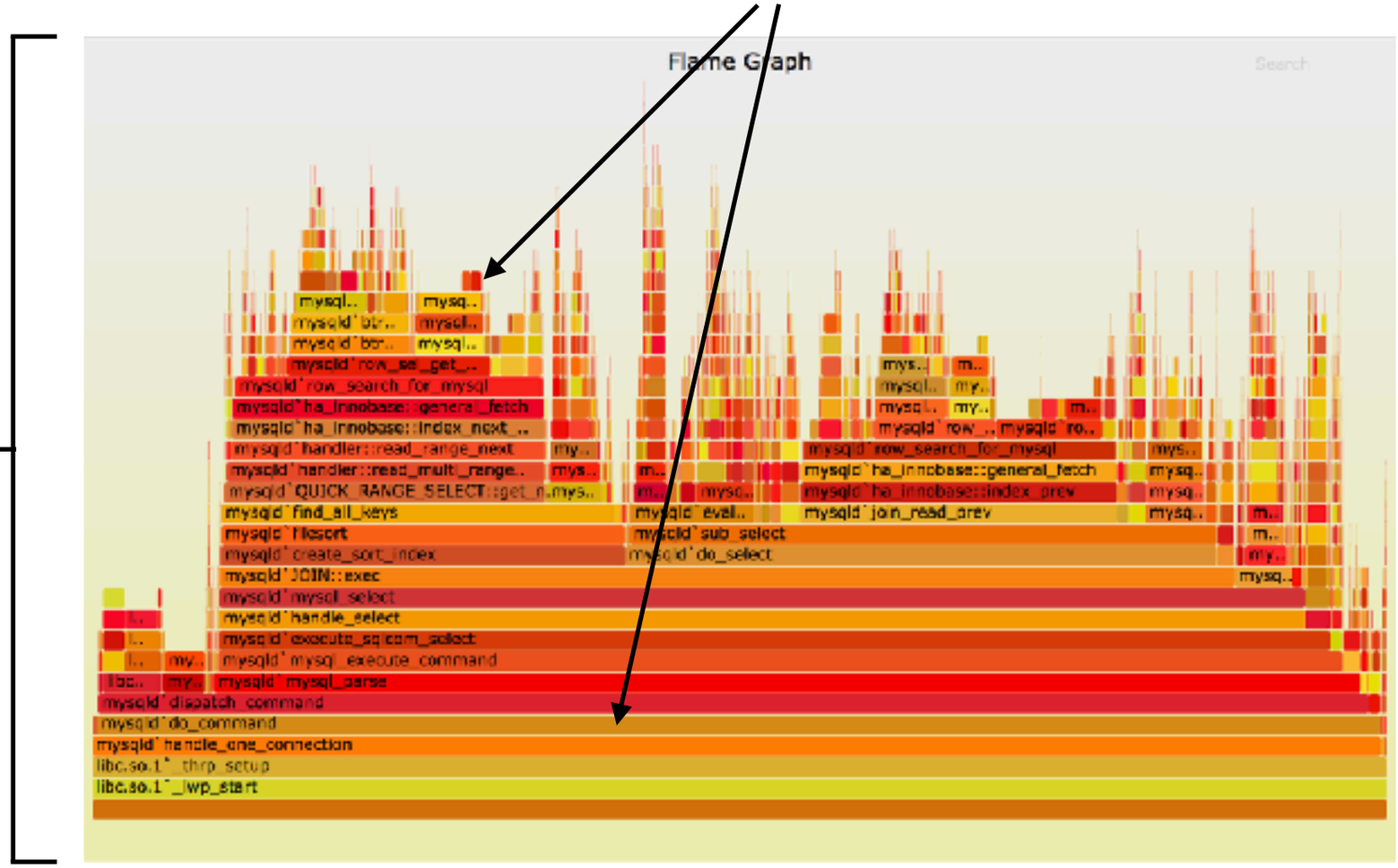
Stack Population Sorted Alphabetically (not time!)

Flame Graph


Rectangle is a stack frame
Stack Depth
Flame Graph
Search
mysqld`row_search_for_mysql
mysqld`ha_innobase::general_fetch
mysqld`ha_innobase::index_next_...
mysqld`handler::read_range_next
mysqld`handler::read_multi_range...
mysqld`QUICK_RANGE_SELECT::get_n...
mysqld`find_all_keys
mysqld`filesort
mysqld`create_sort_index
mysqld`JOIN::exec
mysqld`mysql_select
mysqld`handle_select
mysqld`execute_sqlcom_select
mysqld`mysql_execute_command
mysqld`mysql_parse
mysqld`dispatch_command
mysqld`do_command
mysqld`handle_one_connection
libc.so.1`_thrp_setup
libc.so.1`_lwp_start
mysqld`ha_innobase::general_fetch
mysqld`ha_innobase::index_prev
mysqld`join_read_prev
mysqld`sub_select
mysqld`do_select
Stack Population Sorted Alphabetically (not time!)

Flame Graph

Wider the frame, the more often is was on present in the stack



Stack Depth

Stack Population Sorted Alphabetically (not time!)