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Zettalinux

It's not too late to start

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Problems We Want To Avoid

1. Large File Summit 2

```
#define _FILE_OFFSET_BITS=128
lloff_t pos;
lllseek()
```

2. `CONFIG_64BIT && CONFIG_HIGHMEM`

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Obvious Solution

- CPUs with 128-bit general-purpose registers

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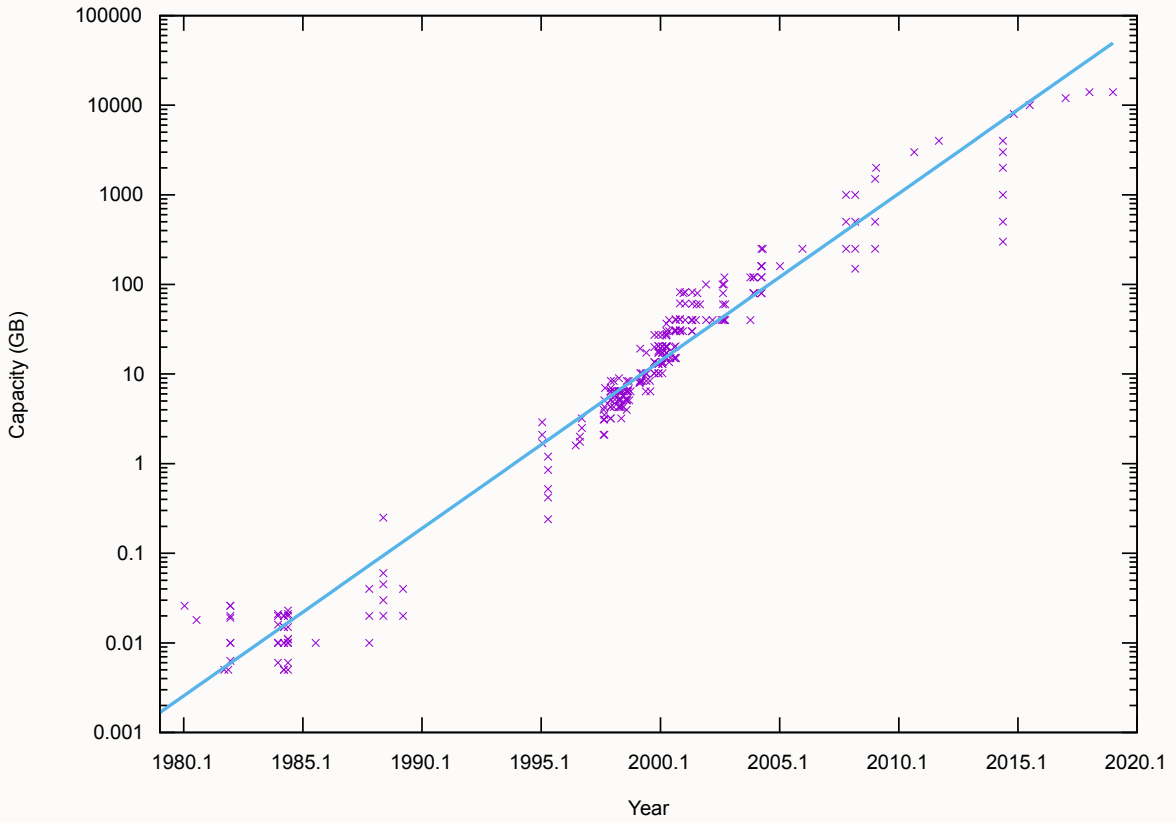
File sizes

- Customer demand for 8EiB file sizes projected around 2040
- Would like to get OS support in place by 2035
- Very limited arithmetic needed on `off_t`
  - Comparison
  - Addition / subtraction
  - Shift



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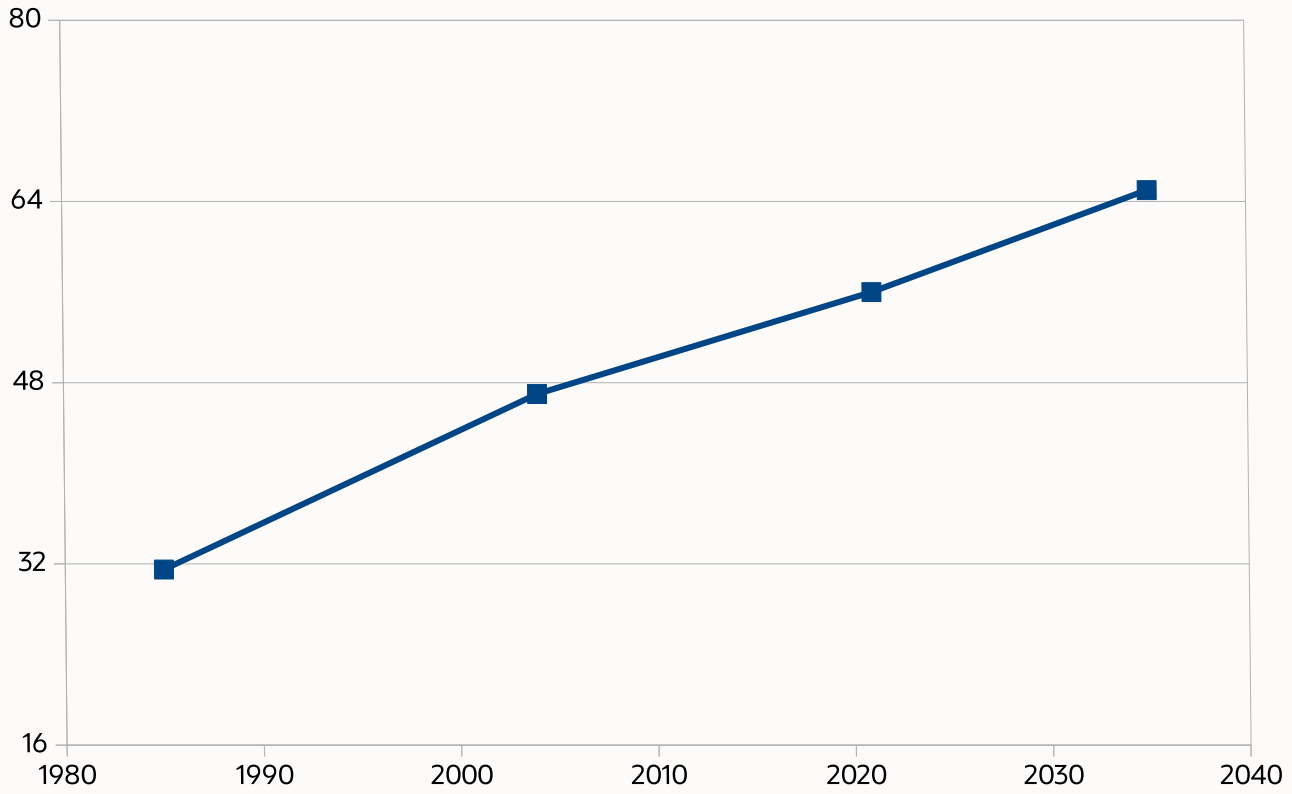
User Address Space

- 80386 (1985): 3GiB
- Nocona (2004): 128TiB
- Ice Lake (2021): 64PiB
- Future (2035?): 32EiB



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Pointers

- Address Space Layout Randomization uses address space bits for security
- Using 2MB / 1GB TLB entries reduces ASLR effectiveness – to just 17 bits in the worst case
- ADI/TBI/LAM/MTE/… only useful for debugging, not enough bits for security
- CHERI (Arm/MIPS/RISC-V) uses capability registers to provide better security
  - But does nothing for the impending address space crunch

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In-kernel types

- Decide type sizes
  - `32 bit: ILP32 (int:32, long:32, pointer:32, long long:64)`
  - `64 bit: I32LP64 (int:32, long:64, pointer:64, long long:64)`
  - ~~`128 bit: I32L64P128 (int:32, long:64, pointer:128, long long:128)`~~
  - `128 bit: I32LP128 (int:32, long:128, pointer:128, long long:128)`
- Ask compiler people for a `__int64_t` so we can leave a gap between `int` and `long`
- Encourage switching to Rust types
  - `int` → `i32`
  - `unsigned int` → `u32`
  - `long` → `isize`
  - `unsigned long` → `usize`
  - Use `i64`/`u64` where it makes sense (eg network protocols, hardware registers, storage formats)
- Add a `uaddr_t` for userspace virtual addresses to distinguish them from other `unsigned long`

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UAPI/UABI types

- Some interfaces specified with explicit 64-bit sizes to avoid compat syscalls

```
struct clone_args {
        __aligned_u64 flags;            /* OK */
        __aligned_u64 pidfd;            /* (int *) */
        __aligned_u64 child_tid;        /* (pid_t *) */
        __aligned_u64 parent_tid;       /* (pid_t *) */
        __aligned_u64 exit_signal;      /* OK */
        __aligned_u64 stack;            /* (void *) */
        __aligned_u64 stack_size;       /* OK */
        __aligned_u64 tls;              /* (void *) */
        __aligned_u64 set_tid;          /* (pid_t *) */
        __aligned_u64 set_tid_size;     /* OK */
        __aligned_u64 cgroup;           /* OK */
};
```

- Also DRM & io_uring, probably others
- Suggest a `__ptr_t` for these cases which is somewhat like a `uintptr_t` but is always 32 bytes

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Other Linux concerns

- Only one “compat” personality is supported (ie 32-bit on 64-bit)
- Data structures lovingly laid out by hand
- Alignment of 128-bit types
- `#if BITS_PER_LONG == 64`
- `if (sizeof(unsigned long) == 8)`

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Next Steps

- Leader for this effort
- Qemu RISC-V 128b implementation
- Compiler to match
- Influence CPU companies

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Conclusion

- Avoid Physical Address Extension and Large File Summit hacks by moving to 128-bit registers soon
- CPU companies must start work now, and we need to push them

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