



To see speaker notes, hover over dialog bubble.

Game Developers
Conference

08

How To Go From PC to Cross Platform Development Without Killing Your Studio

Elan Ruskin

Valve



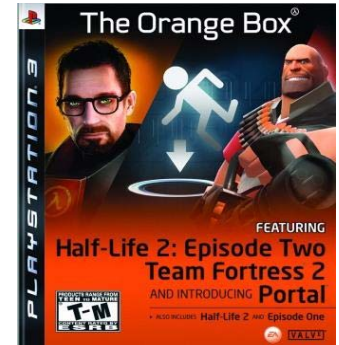
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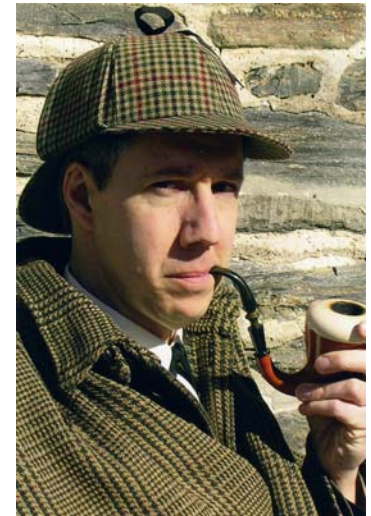


WWW.GDCONF.COM

We Are a PC Shop That Recently Added Console.



- Some of this talk may seem *elementary* to console-exclusive developers ...
- ... but each one of these issues has burned an actual project.
- Experienced console devs will still find useful info here.



This Is a High-Level Talk



This Talk is Based On:

- Our work at Valve
- My work elsewhere
- Interviews with others throughout industry



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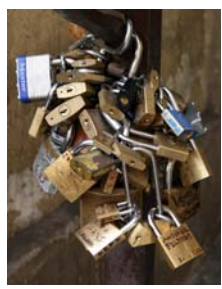
What Landmines Await A PC Developer Going To Console?

Consoles are like PCs...



A PC

+



Closed Platform

+



Manufacturer QA

+



Limited Memory

=



Common Problems of Crossplatform Development

- Developer Efficiency
- Certification Failure
- User Experience
- Programming Issues

Targeting Console is Similar to Targeting a Minspec PC

- Valve always tiers our PC experience

High-end (Shader Model 3)



Midrange (Shader Model 2)

Low-end (DirectX 8)

Now We Know Where The Mines Are...



Common Problems of Crossplatform Development

- Developer Efficiency
 - Staff allocation
 - Trouble Iterating
- Certification Failure
- User Experience
- Programming Issues

The Core Team

- **The Console Person**
- Your most experienced programmer.
- Understands the entire codebase.
- Senior enough to affect schedule.
- Gets the game running for the first time.
- Becomes an oracle by project end.

The Core Team

- **The TCR** (Technical Certification Requirements)
Expert
- Producer, Programmer, or QA.
- Learns every item on Microsoft/Sony's certification checklist.
- Builds test cases.
- TCR is not a job for one programmer.
 - Does need one person in charge.

The Core Team

- **The Devkit Guy**
- Gets people up and running.
- Sets up artists to look at their levels,
- Gets programmers set up with their debugger.
- Isn't a full time job, but can be a major distraction.
- Doesn't need to be a lead.

Common problems of cross platform development

- Developer Efficiency
 - Staff allocation
 - Trouble Iterating
- Certification Failure
- User Experience
- Programming Issues

Problem: Iteration is slow.

- Iterating on PC:
- Iterating on Devkit:



Keep your PC version working.

- Debug and load times always faster on PC than console.
- Runtime iteration much easier on PC
 - Edit & continue
 - Reloading assets
- Compiling slower for console target

Simulate console content features on PC

- PC workflow is more comfortable for artists
- PCs are cheaper than devkits
- Encourages experimentation



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Cross platform assets

- Consoles have their own formats.
 - Do you byte swap on load?
- Consoles prefer assets compiled into big files.
 - PCs have disk caches.



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The Catch-22:

Load asset files
individually:

- ⊕ launch times longer
- ⊕ Changing data faster

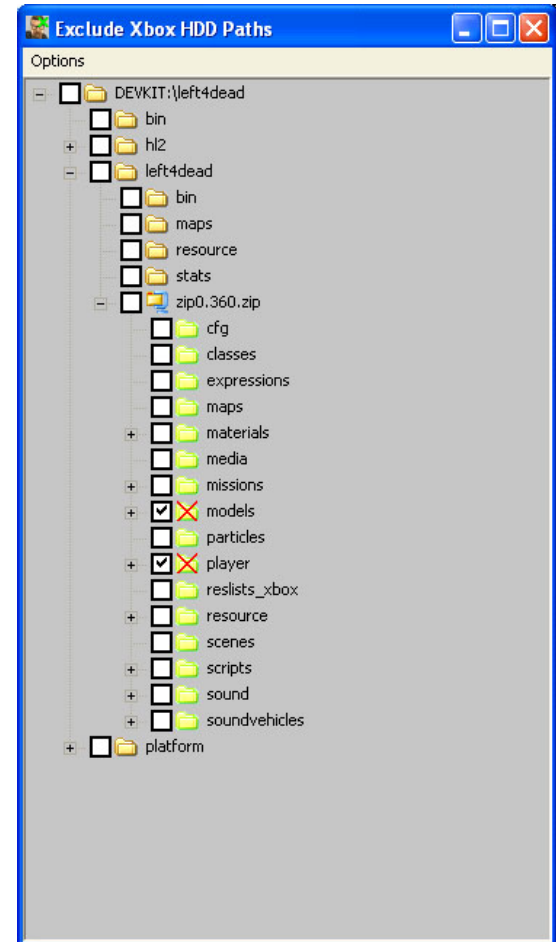
Compile paks:

- ⊕ code changes faster
- ⊕ data changes slower



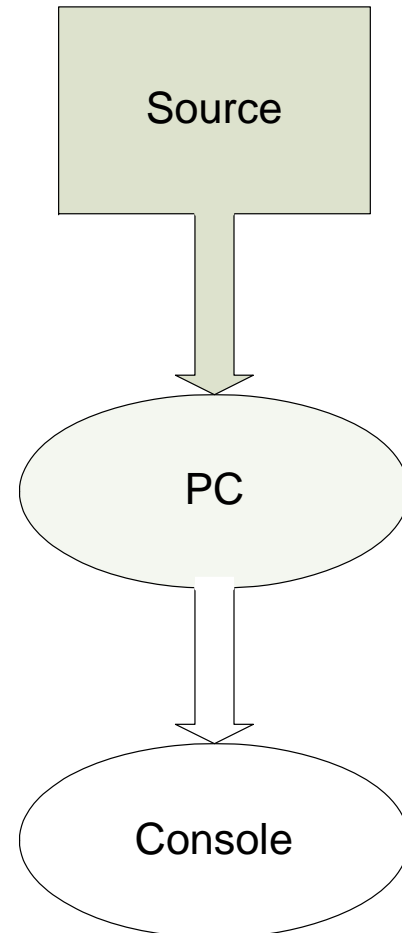
Our hybrid solution:

- Compile asset tree into paks nightly.
- Artists specify individual assets to override locally
- Best of both worlds



Branch In Pipeline, Not In Source

- You will need to recompile every asset
- Try not to diverge assets
- Make tools deal with platform differences, instead of artists.
- Keep the source art for everything.



Common problems of cross platform development

- Developer Efficiency
- Certification Failure
 - Out Of Memory
 - Starting Too Late
 - Multiplayer
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Technical Certification Requirements / Technical Requirement Checklist / CERT

- The process by which console manufacturer ensures quality.
- A specific list of requirements that your game must meet.
- Pass, or don't ship.



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Most Common Problems:

- Stability
- UI – very specific requirements
- Savegames
 - Need to be completable with no save media
- Online / LIVE

Problem: Game Runs Out Of Memory.

PC:



Console:



Memory

- Memory is critically strict.
- The #1 reason levels get changed.
 - The later you wait, the more drastic the cuts.
- You will always wish you had worried about memory sooner.
- Account for *everything*.



Dynamic Allocation Is Bad.

- If you don't know how much memory you're going to need, you don't know if you're going to run out.
- PC games tend to allocate memory ad-hoc.
- Keep track of where it goes.



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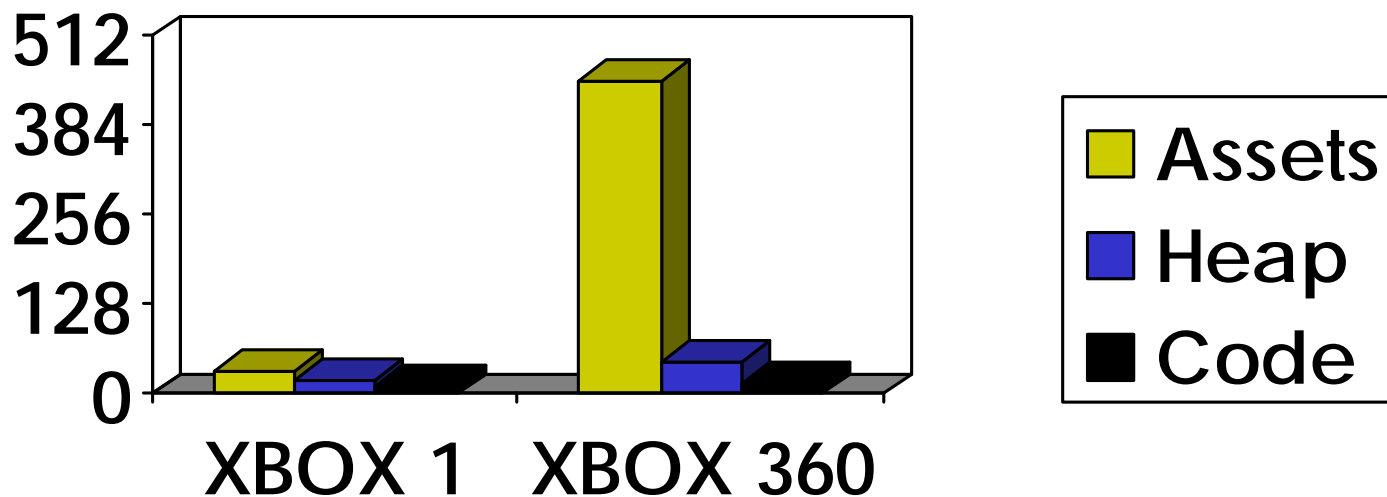
Where Does Memory Go?

- Executable code
 - Does not change at runtime.
- Assets
 - Textures, level geometry, models, animations, sound, sprites, ...
 - Loaded into memory from disk.
- Heap
 - Data generated at runtime by code.
 - Anything that is not assets.



Assets Have Grown Faster Than Heap.

Half-Life 2 Memory Use



Squeezing assets, Step 1: Account.

- Track every asset allocated.
- Emit spreadsheets for each level.
- Automate this process.
- Do it every night.
- Will highlight all serious problems...
- ... and make new ones obvious.



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Squeezing assets, step 2: Compress.

- Use platform-specific formats.
 - XMA, AAC have good ratios
- Leverage your shaders' and SPU's power
 - Compress normal maps, grayscale textures, animations...
- May need to split up textures



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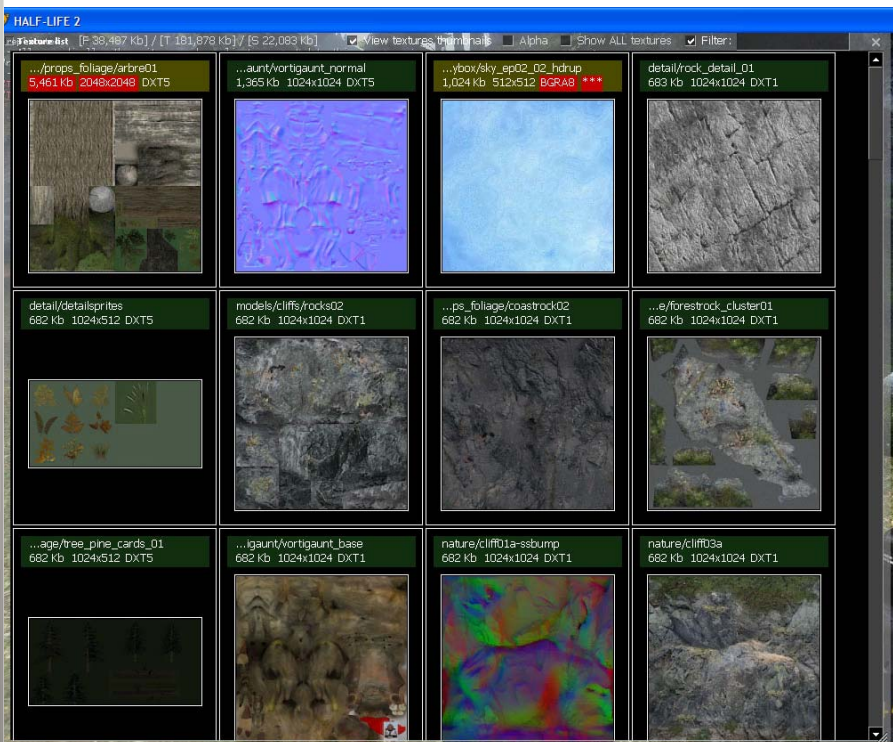
Squeezing assets, step 3: Reduce.

- Budget your textures / models / meshes carefully.
- It's easy to just downsample all your textures...
- But you can get much better results with careful targeting.



Squeezing textures

- 20% of the textures are 80% of the problem.
- Source has tools to show us *which* 20%:



Squeezing textures

- Halving one 1024x1024 texture saves as much memory as eliminating 32 128x128's.
- Focus on what's actually visible, so you can reduce where no one will notice.



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Squeezing assets, step 4: Maintain.

- Staying in memory is everyone's job.
- Know exactly when and where regressions occur.
- Find exactly which change to blame.



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Squeezing assets, step 5: Panic.

- If all else fails... split levels.
- Remove characters.
- Decimate textures.
- Downsample animation.
- Dealing with memory *sooner* will spare you all these painful measures.



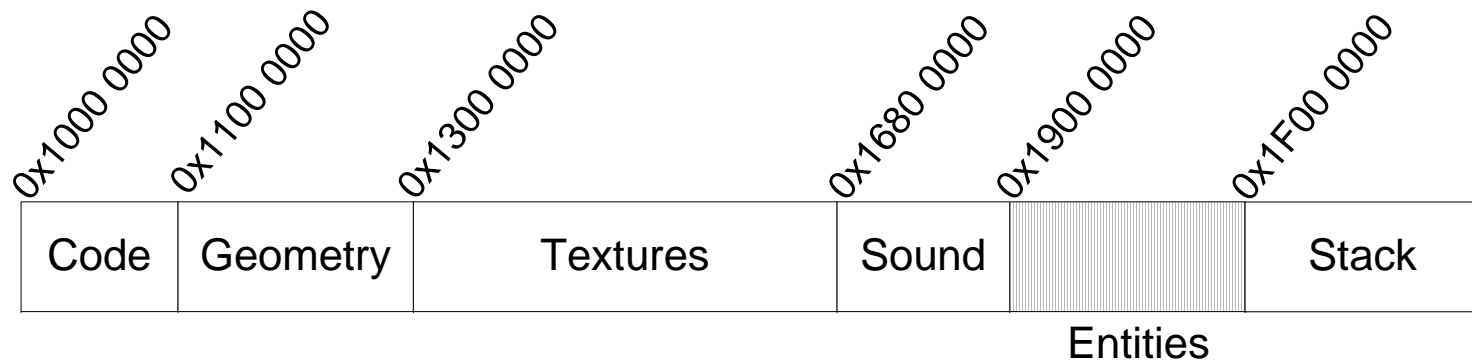
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In An Ideal World

- Memory would be allocated at load time...



Managing Heap Growth

- Many games load assets ad hoc
 - Textures, models, animations, sound
- Code generates data too
 - Spawning entities, particle systems, AI state...
- Crashes most likely in level loads



malloc() Considered Harmful

(new/delete too)

- Gameplay systems most likely source of leaks.
- Good container classes provide easier management, less leakage.
- Only if you write your own allocator!



WHYTO: Make A Custom Memory Allocator

- Replace `malloc()`, `calloc()`, **new**, etc. with your own code.
- Better than `STUDIONEW`, `STUDIODELETE` macros:
- No big search and replace.
- You can't fix all the `new/deletes` in 3d party libraries...
- ... so link them to your own allocator.

HOWTO: Make A Custom Memory Allocator

- Override *every* function in the CRT .obj that contains malloc:
 - malloc, free, calloc, realloc...
- Put your implementation in its own .cpp
- Link this .cpp to every project in your game.
- Only works if you override the *whole* module...
- ... so you need to re-do this if you change compilers or CRTs.



pwn your memory

- If you own every allocation, you can track every allocation.
 - Even those coming from the STL.
- Write global fixed-size pool allocators.
- Limit fragmentation.
- Look up the **Translation Lookaside Buffer**.



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Track Memory Based On Exactly Who Allocates It

- Budget asset allocation by type
 - Texture, geometry, sound...
- Budget code allocation by purpose
 - AI::Navmesh, Particles, Rendertarget...
 - *Not* std::vector<int>



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Track Memory Based On Exactly Who Allocates It

```
Thingy *WasteMemory( Thingy* input,  
    std::vector<Thingy> &list )  
{  
    MEM_ALLOC_CREDIT( IMPORTANT_SYSTEM );  
    globalSystemList.AddToTail( input );  
    list.append( *input );  
    Thingy *output = new Thingy;  
    output = DeepCopy( input );  
    return output;  
}
```

Be Careful With Containers

- Container classes mean more:
 - Dynamic allocation
 - Range checking
 - Copying things around
- Use `std::vector::reserve`



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We Do This Work For PC Too

- Disk swapping bad!
- Budget tracking means reliable information everywhere.
- Retrofitting later means touching a thousand different places.



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Common problems of cross platform development

- Developer Efficiency
- Certification Failure
 - Out Of Memory
 - Starting Too Late
 - Multiplayer
- User Experience
- Programming Issues

Other Interesting TCRs

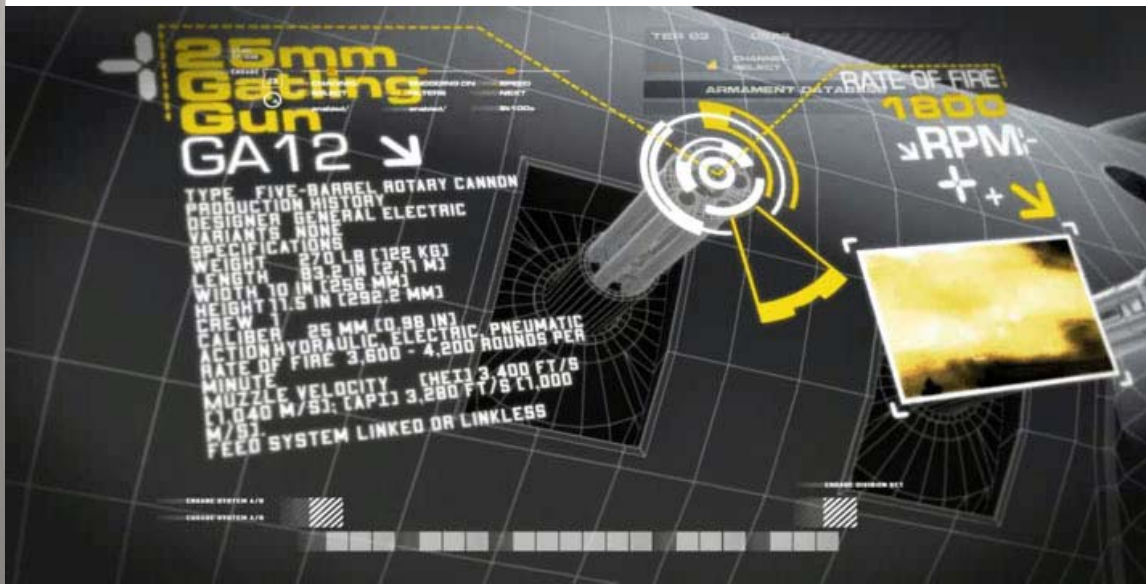
- Load times no more than x seconds.
- Letting people play their MP3 collection in your game.
- Minimum refresh interval... even while loading.
- Compiled with recent SDK.



Solve It In Design

- Make cert requirements part of your architecture.
- Think about Achievements / Skill Points in your design.
 - (you can get them on PC with SteamWorks)

engaging player during load in *Call of Duty 4*



Savegames

- Use small individual files, not one large package
 - Fits on memory cards.
- Deal with losing memory card during save.
- Do you really need save-anywhere?
 - If you rely on quicksave,
 - preallocate a RAM disk big enough.



UI

- Consider title-safe and widescreen
 - Be readable in 4:3 SD and 16:9 720p.
 - Be readable in 4:3 SD... *in German.*
- TCR has specific requirements for UI layout & flow:
 - Need a way to pop dialogs on top
 - Manufacturer-approved graphics, names
- This usability work makes your PC game better.

Common problems of crossplatform development

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Multiplayer / LIVE

- Was the majority of our cert issues.
- Start working on this from day #1.
 - Do your preliminary work in sample apps.
 - Do not let it be blocked by engine development.
- Rich presence may require architecture changes.
- Enlist Microsoft/Sony's help.
 - They have lots of good tools for you.

Cort is playing TF: Badlands!
Ahead 3-2 in CTF

Multiplayer Testing

- Your office LAN is not the Internet.
- Debugging without encryption, voice hides problems.
- Some problems arise only with high load.
 - Do a beta if you can.
- Latency, bandwidth, ping, problems as always...

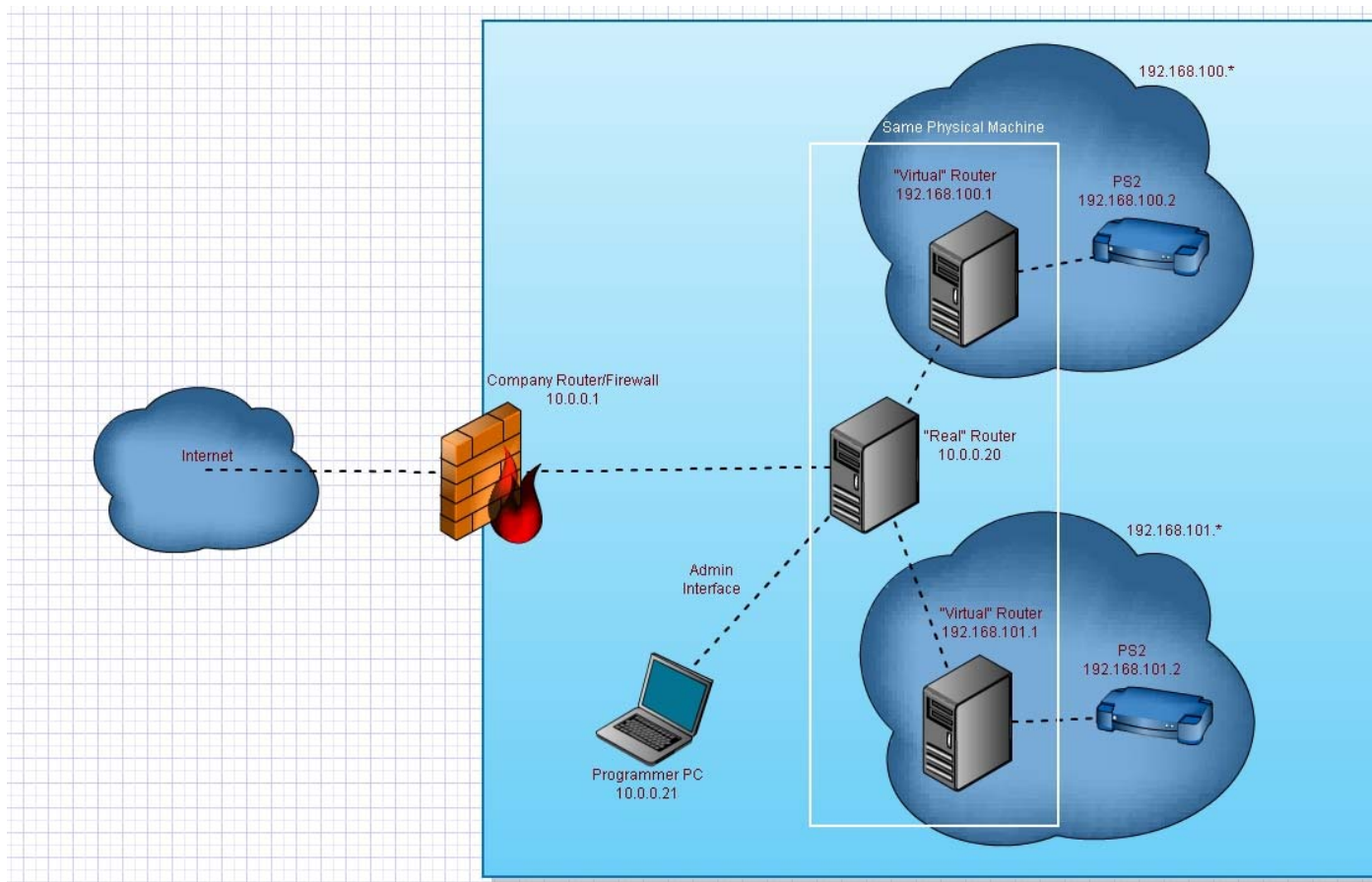


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Multiplayer Testing: Simulate Your Own Network Backbone.



Courtesy Ben Stragnell

Common problems of crossplatform development

- Developer Efficiency
- Certification Failure
- User Experience
 - Load Times
 - Use of multicore
 - Controls
- Programming Issues

Problem: Game Takes Too Long To Load.





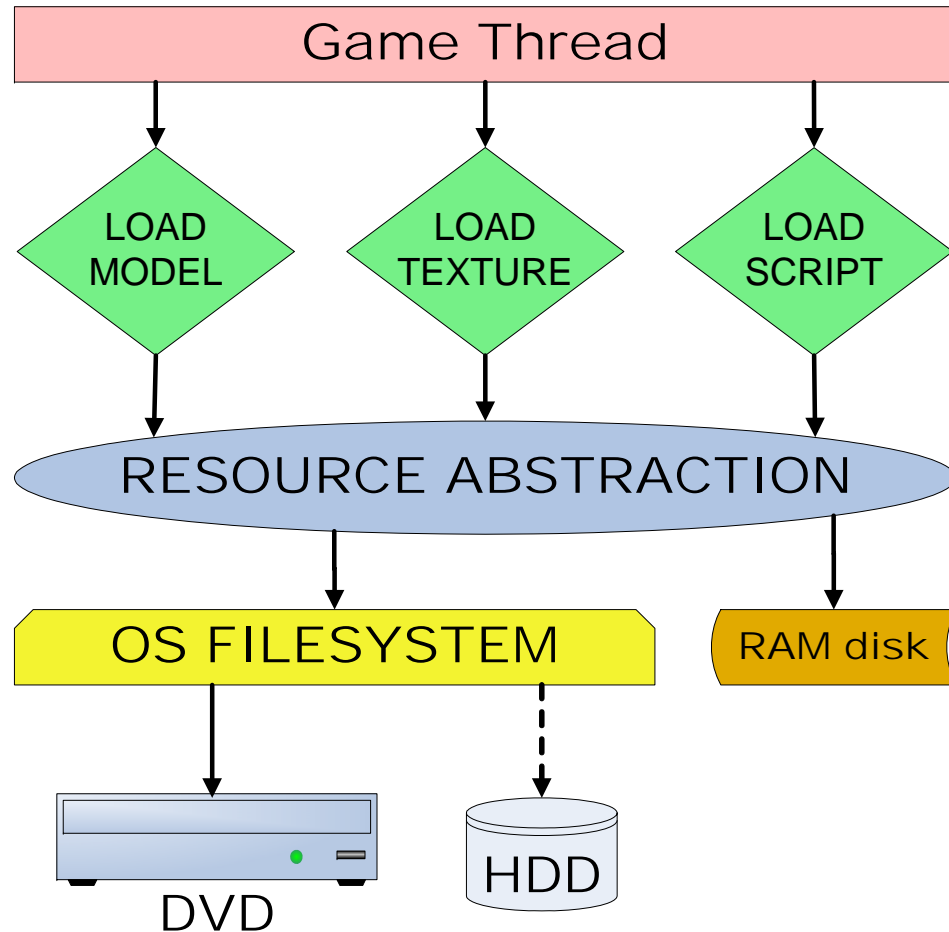
Optical Load Times

<u>PROBLEM</u>	<u>SOLUTION</u>
Seeks	Contiguous files, careful layout
Misaligned reads	Sector alignment
Buffered access	Unbuffered DMA I/O
Synchronous stalls	Asynchronous loading
Small files loaded on demand	Large, single files

Things That Make A DVD Load Faster

- .ZIP files
- Compression
 - (trade CPU for I/O bandwidth)
- Asynchronous loads in a separate thread

How We Refit Our Game Without Rewriting Everything

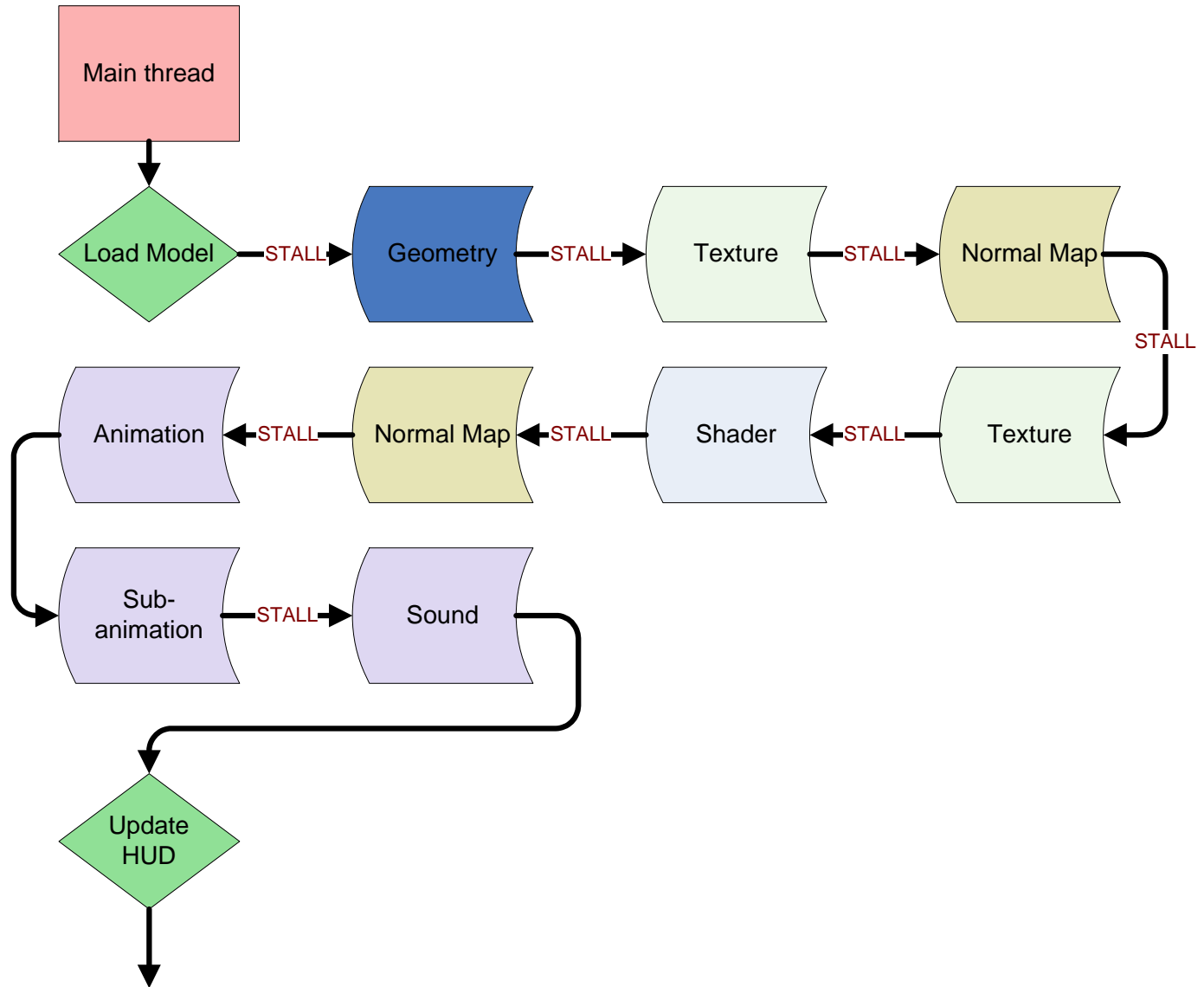


Three Categories Of Data

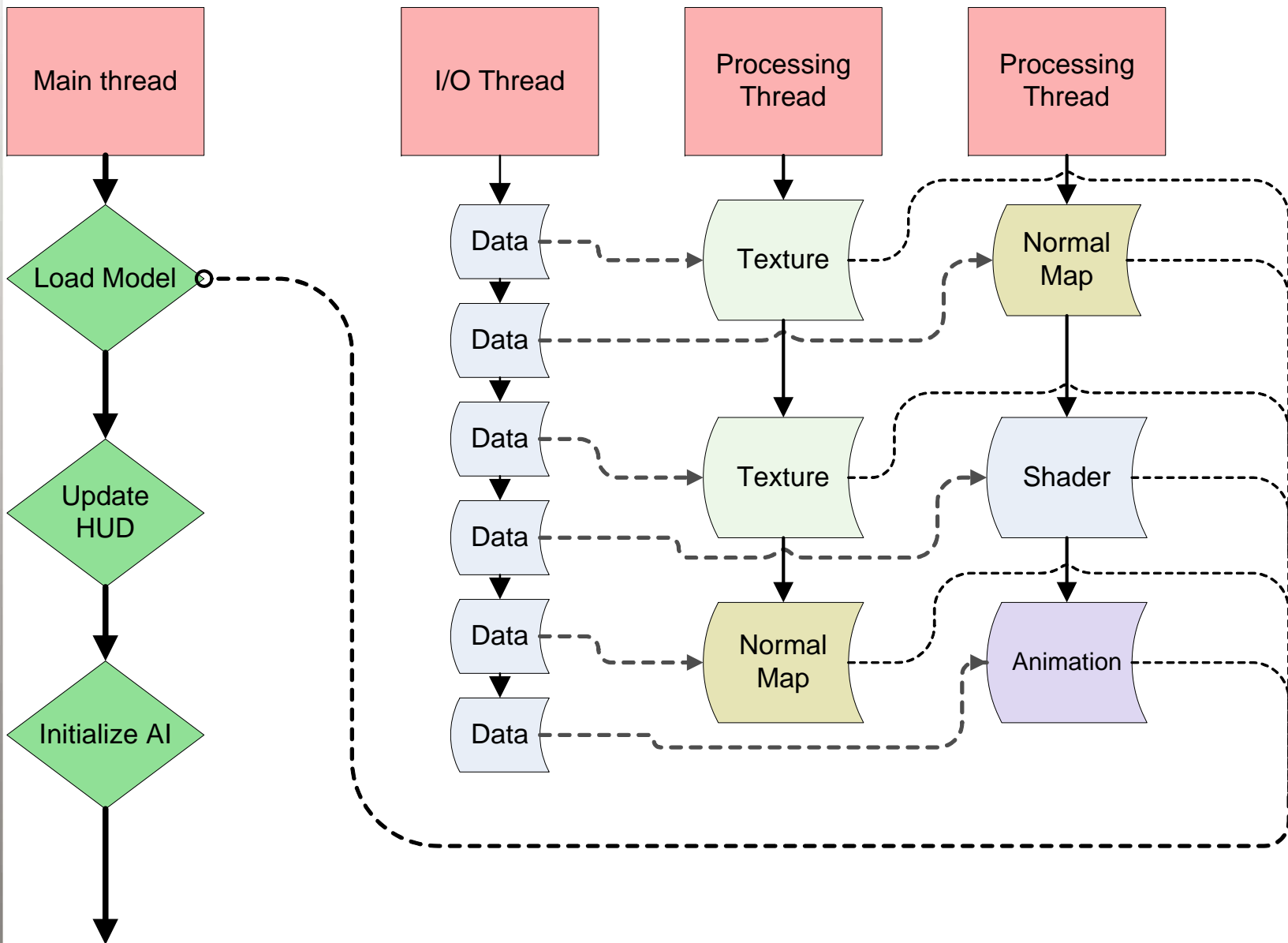
- Big
 - Textures, models, BSP, sprites, SFX
- Small
 - Config files, scripts, <4k odds and ends
- Really Big
 - Dialog, long animations
 - Stuff you don't need right away



Synchronous (naïve) loading



Asynchronous loading



Key features

- I/O thread does unbuffered DMA transfers.
 - Keeps the disk *spinning continuously*.
- Lockless implementation
- Trade CPU/SPU for I/O bandwidth
- Return dummy values to sync loads.

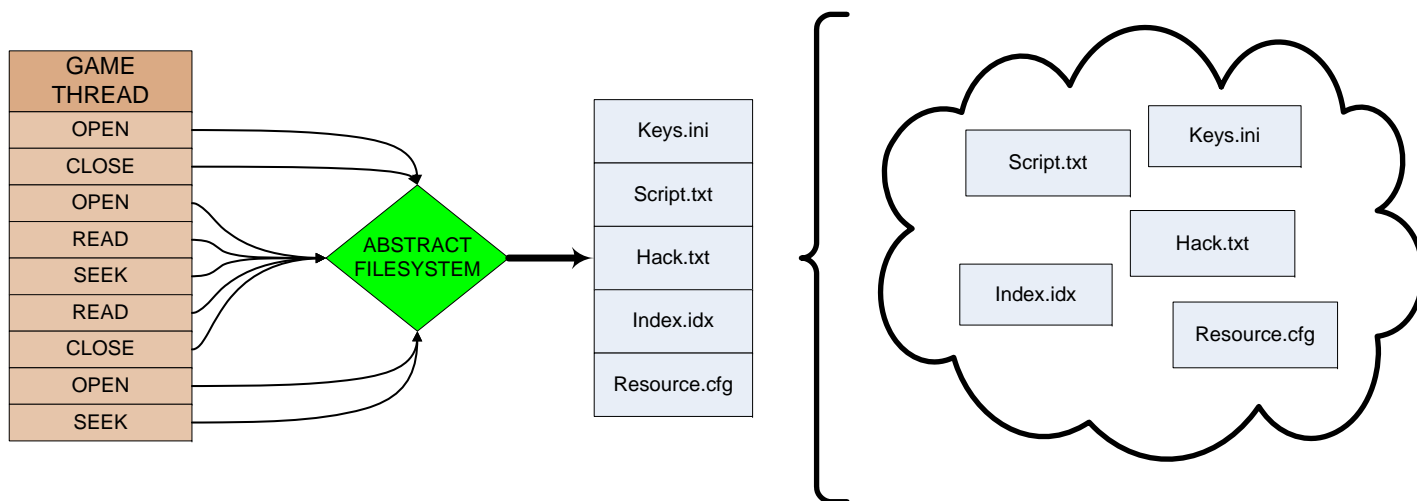


Really big files: streaming

- Store the first ½ sec of each animation and audio always
- Asynchronously load the rest in the background
- Need a resource abstraction layer that can say:
 - We have the data
 - We're getting the data
 - We will never get the data

Small files

- Precompile all small ad-hoc files into one large blob
- Read it in one operation with level
- Create a fake file system
- Don't have to change game code!



Know In Advance Each Level's Resource Needs

- If you're going to build a pak, you need to know what goes in it.
- Every single asset.
- Analyze loading dependencies.
- Crash when loading out-of-pak.



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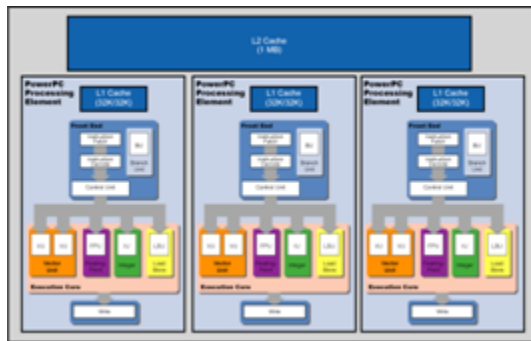
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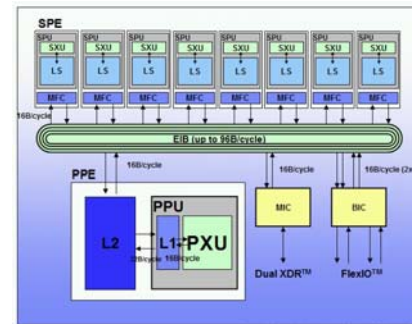
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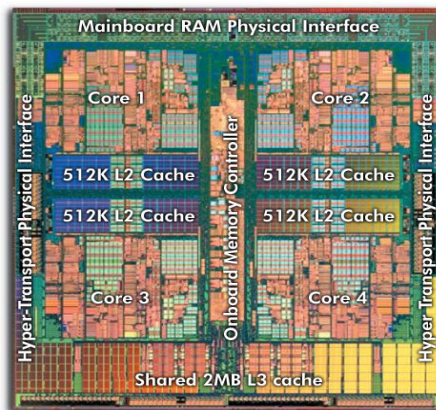
Going Multithreaded: It's not *next-gen* any more.



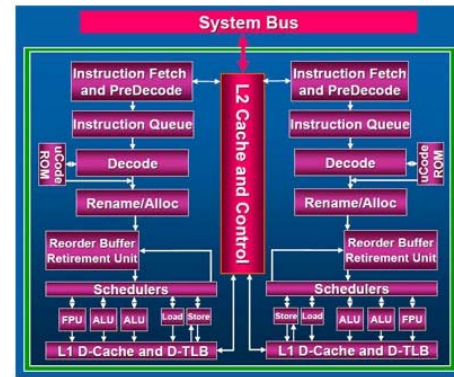
Xenon



Cell



AMD Barcelona



Intel Core 2

All Major Platforms Are Multicore.

- **360**: 3 symmetric PowerPC cores, 6 threads
- **PS3**: 1 PowerPC, 2 threads; 7 vector processors
- **Intel/AMD**: Quadcore now, 8-core tomorrow
- This is not "next gen", it is "today."

Our technique: Discussed here before

*"Dragged Kicking and Screaming:
Source Multicore"*

Tom Leonard (Valve), GDC 2007

<http://www.valvesoftware.com/publications.html>

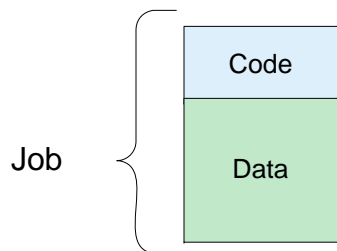


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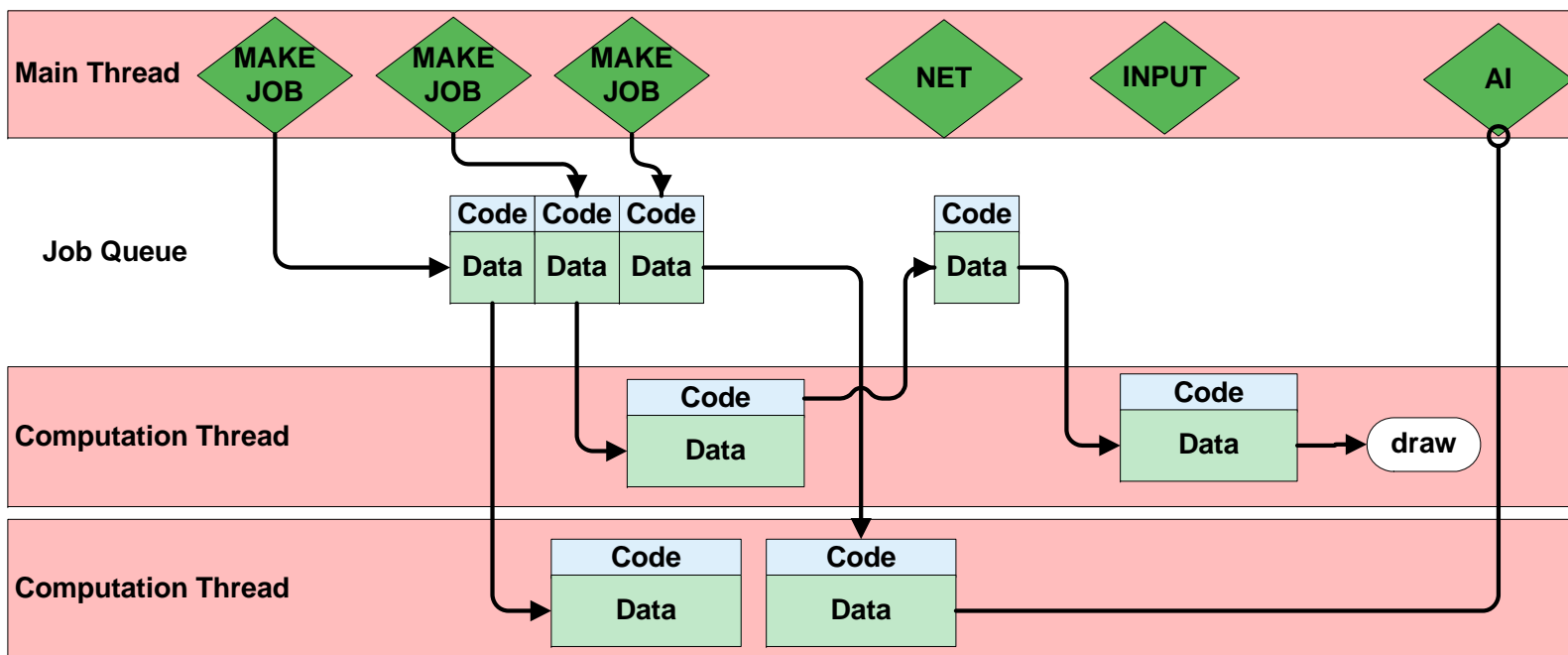
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Job queues: a summary



- ⊕ A job is code and local data
- ⊕ Put into a queue; other threads consume from queue



Worked Better Than We Expected!

- On the 360:
 - 50% performance improvement just from queuing graphics functions.
 - 4x increase in framerate with full implementation.
- On the PS3:
 - Game wouldn't run otherwise!
- Our game already had a client/server split.



De-Globalize Your Data

- Pack jobs' data up so they work locally.
 - Put global data into a closure.
- Avoid chasing pointers all over memory.
- Especially critical on PS3.
 - SPUs have only 256kb of memory.
 - Random memory access is huge stall.



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PS3 Requires More Aggressive Threading

- All the power of the PS3 is in its Cells.
- The PPU will be always saturated.
- General C++ code does not run well on SPUs.
- Code memory is tight.



Some Things To Worry About

- Callbacks
- Synchronizing simulation clocks
- Mutexes (can make you slower than singlethreaded)
- Hardware threads useful only in certain cases – measure it.

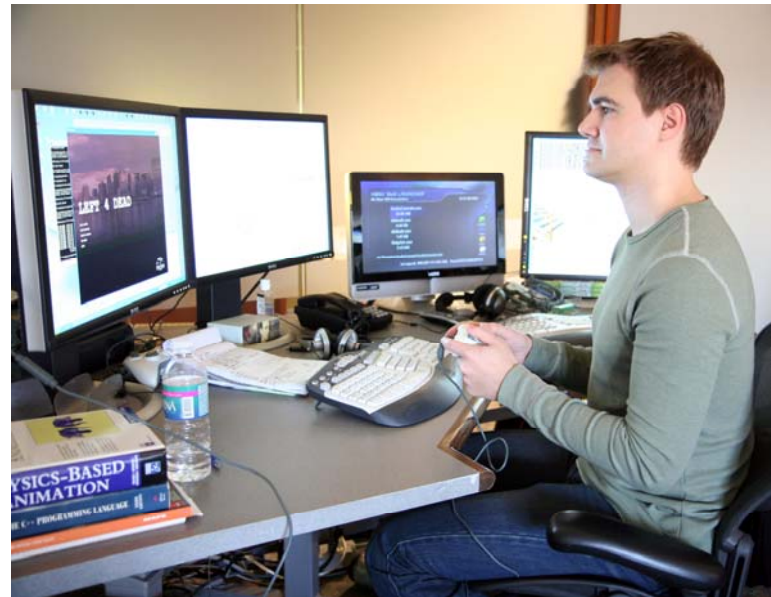


Common problems of cross platform development

- Developer Efficiency
- Certification Failure
- User Experience
 - Load Times
 - Use of multicore
 - Controls
- Programming Issues

Problem: controls don't feel right.

- Have PC devs test with 360/PS3 controllers.
 - Yes, you can connect them to a PC.
- Makes everyone a usability tester all the time.
- PS3, 360 have different thumbstick calibrations.



Common problems of cross platform development

- Developer Efficiency
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- Programming Issues
 - Graphics
 - Framerate / CPU

Time For *Good* Graphics!

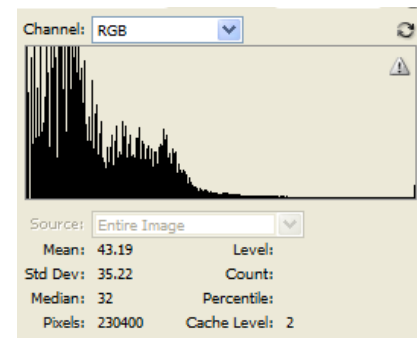
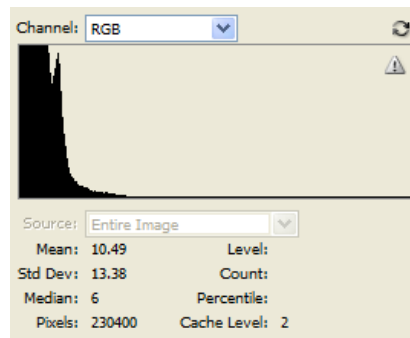


Homestar Runner

TV pixel and color spaces differ from monitors



TVs rebalance histograms



TVs vary in quality

- A common office fight:
 - Look good on a default-settings TV?
 - Or one that's been calibrated?
- TV default settings vary very widely.
- The solution:



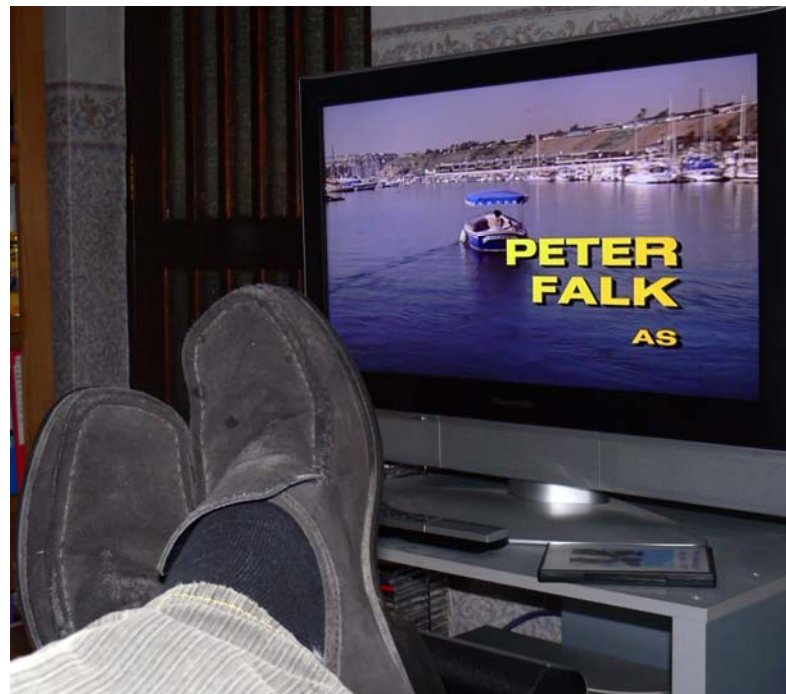
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Watch TV At The Office.

- Watch television on the displays you're developing with.
- Calibrate your TV so TV looks good.
- **Don't buy the same TV for everyone!**



Shaders

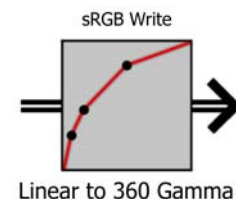
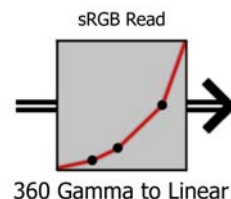
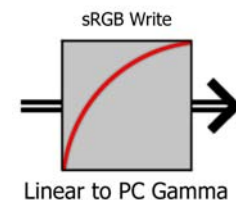
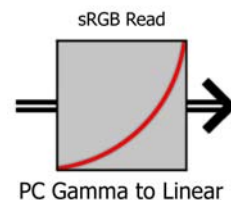
- PC uses HLSL. Consoles use HLSL. Done.
- Shader compilers may be a bit different.
 - The few problems will be with the most complicated shader.
- GPU/CPU power balance a little different.
 - Shader conditionals perform well!
- We distribute our shader compiles.
 - Compile each shader for both platforms before checkin.
 - Compile everything offline nightly for regression testing.



sRGB

- sRGB read/write curve different on 360.
- Keep your source art
 - Compiling from another space loses precision.
- See Alex Vlachos' talk: "Post Processing In *The Orange Box*", Feb 18, 2008.

<http://www.valvesoftware.com/publications.html>



Other notes:

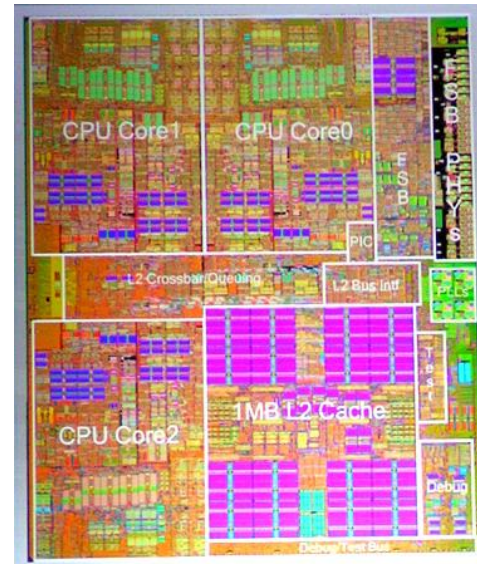
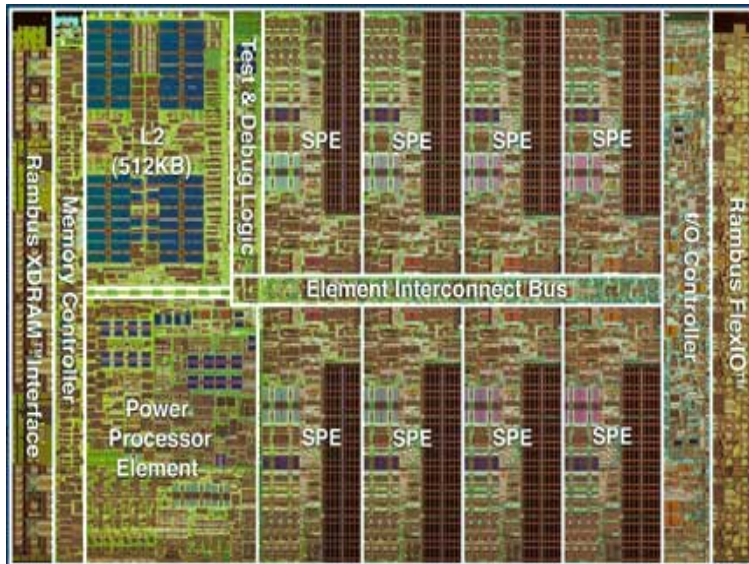
- PIX / GCM Hud excellent for very specific, actionable info.
- Look into tiled rendering on 360
 - Makes antialiasing easier, but isn't critical.
- If you're hung up on getting PC and console to match perfectly... let go.
 - No one is playing your game twice simultaneously side-by-side.
 - It just has to look good.

Common problems of crossplatform development

- Developer Efficiency
- Certification Failure
- User Experience
- Programming Issues
 - Graphics
 - Framerate / CPU

360, PS3 have in-order PowerPC CPUs.

- They do not rearrange instructions to eliminate dependencies.
- Sloppy code runs more slowly.
- Why? Reorder circuitry is costly, takes up space...
- ...space now used for *additional entire cores!*



In-order PPCs run sloppy code more slowly than x86

- 25%-50% speed for straight cross-compiled code.
- Careful optimization gets close to parity.
- SIMD a bigger win on PPC than x86.
- Remember: on 360 you have *three of them*.



LEARN THE ASSEMBLY

- Sometimes you still have to do this.
- Use intrinsics, understand what they are doing.
- Helps debug release-build crashes.
 - Learn the calling convention, how to augur crash dumps.
- Double-check what compiler emits.



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LEARN THE PIPELINE

- PPCs are high-latency, high-throughput
- Learn about all the hazards
 - Register dependency, load-hit-store, cache miss, microcode, ERAT, TLB...
 - Understand what the profiler is telling you.
 - 80% of perf from touching 20% of code.



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Actually Use SIMD

- Abstract interface for all platforms.
- Push native vector class everywhere.
- Replace doubles with floats.

```
FORCEINLINE Vector Add ( const Vector & a,  
                          const Vector & b )  
{  
#ifdef _X360  
    return __vaddfp( a, b );  
#elif defined(_SSE)  
    return _mm_add_ps( a, b );  
#else  
    return Vector( a.x + b.x, a.y + b.y,  
                  a.z + b.z, a.w + b.w );  
#endif  
}
```



#ifdef Is Not The Way To Go

- Compilers will elide code in an if() block that is always false.

```
#define IsX360() true
#define IsPC() false

void DoStuff()
{
    if ( IsX360() )
    {
        PlatformSpecificFunction();
    }
    else if ( IsPC() )
    {
        WindowsSpecificFunction();
    }
    else
    {
        // you might be on the Wii one day!
        GeneralCaseFunction(); // or throw an assert
    }
}
```



Use `if()` Instead of `#ifdef`.

- Stops "the PC guys broke the PS3 build again!"
- You may need stub functions
- Don't assume "if" PC "else" 360. You might be on PS3 or Wii one day.



Not All Optimization Is Premature

- Don't "do a big perf pass at the end".
- Getting from 5fps to 15fps isn't optimization, it's a key feature.
- Have budgets from the start,
 - Have tools to stay inside them.



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Things you need to buy: Devkits

- Development kits
 - Live debugging
 - Engine, system programmers – anyone whose bugs block someone else
- Test kits
 - Printf debugging.
 - Artists, QA, maybe gameplay programmers.
- Prepare for failure rate.

Cost:



Cost:



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Other Suggestions

- For your first title: keep it simple!
- Keep people on kits.
- Work to the most constrained platform.



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Measure Everything

- Measure everything yourself, as often as you can.
- Take nothing for granted.
- Verify your compiler output.



Recap

- Make cert part of your design.
- Memory will always be a struggle.
- Automate offline testing.
 - Regression is a bigger problem in cross-platform development.
- Keep the PC version working!
- Most importantly...

DO IT NOW

- The sooner you start, the better off you will be.
- Manufacturing lead times are longer on console, and you have TRC.



The Terrible Secret Of Cross-Platform Development:



All This Will Make Your PC Title Better!

- TRC is just a group of good usability rules.
- Memory efficiency helped us on every platform.
- PC games deserve shorter load times.
- Making money on the PC means hitting the low end.
- If it runs well on console, it's easy to make it run well on PC.
 - Steamworks even lets you have achievements and updates!

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answers, please go to:
<http://assemblyrequired.wordpress.com>

See other Valve
presentations at:
<http://www.valvesoftware.com/publications.html>