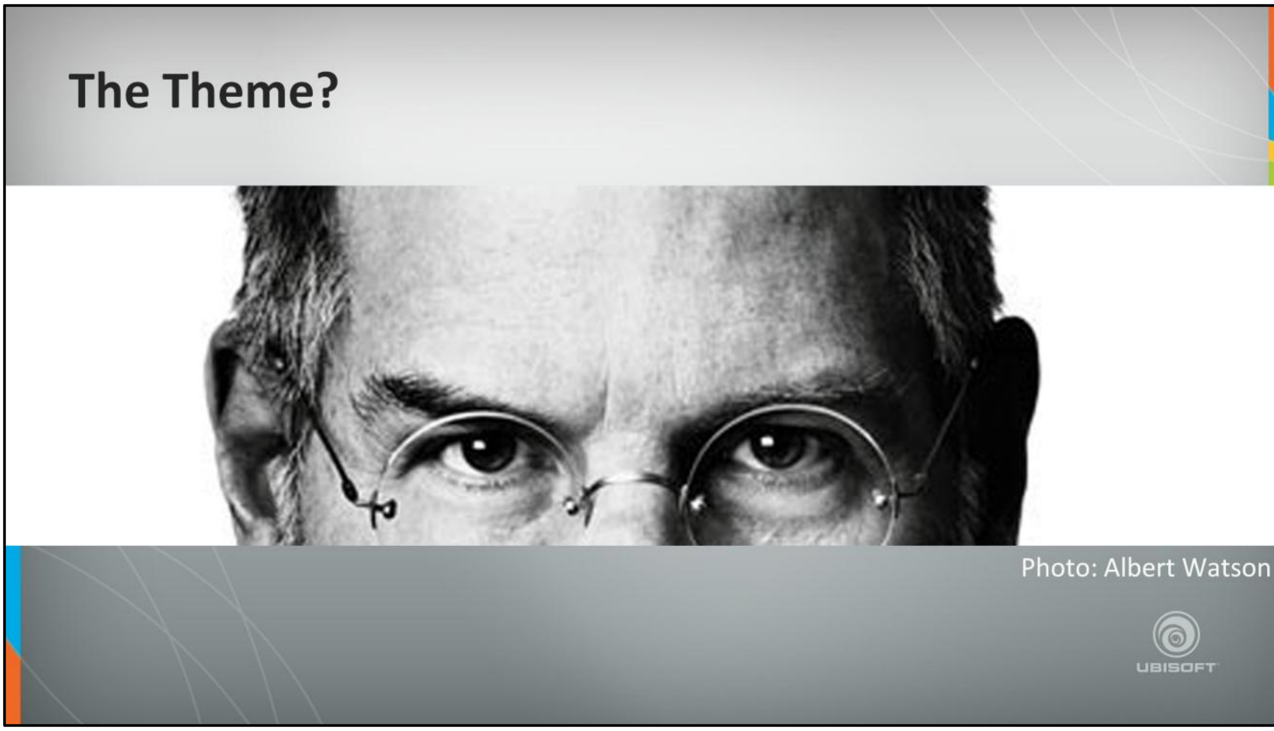
5 years is a long time

Particularly for one game

But finally I can talk about the renderer



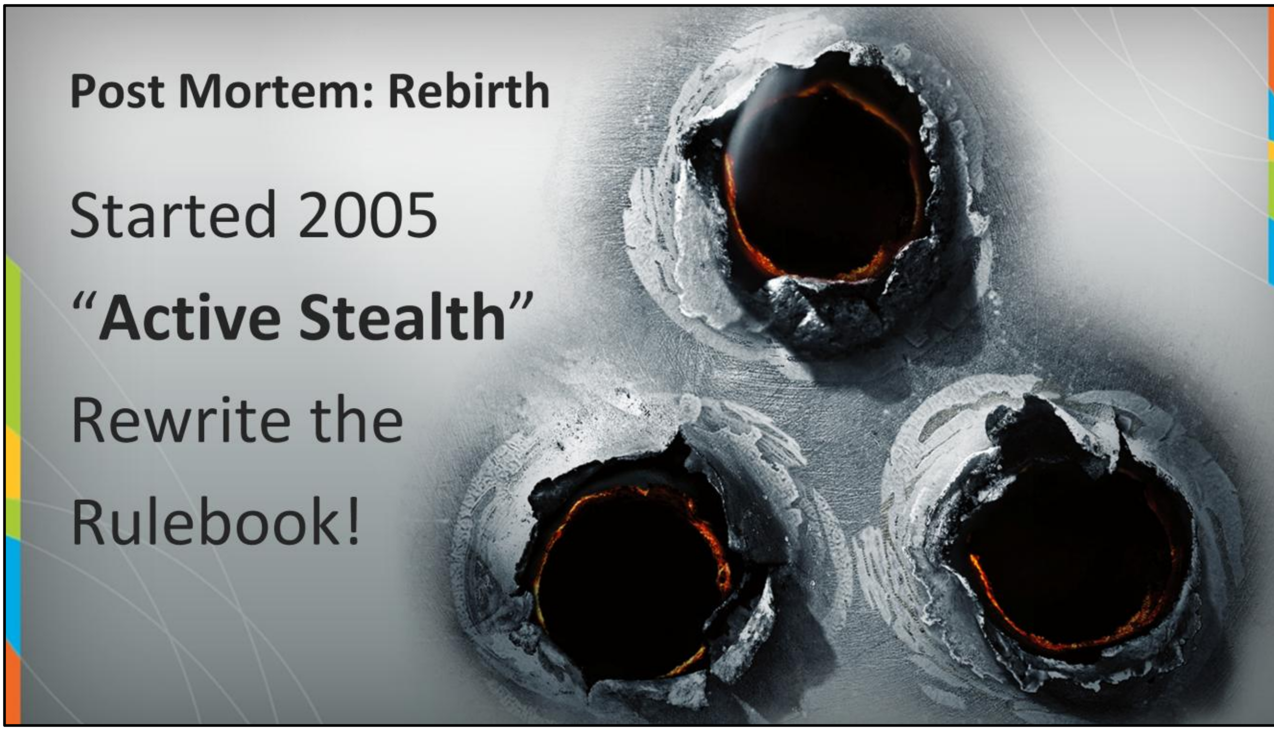
Think Different

How we tried to take Conviction in a **new direction**

How this motivated two new (different) approaches…

A completely dynamic visibility system

A unique, semi-dynamic Ambient Occlusion approach



Inspiration: Bourne series, 24

Initial design: "Nowhere to hide" (out in the open), improvisation, less reliance on gadgets. MacGyver-esque. Blending into the crowd. Destruction. Stuff blowing up. Hollywood action.

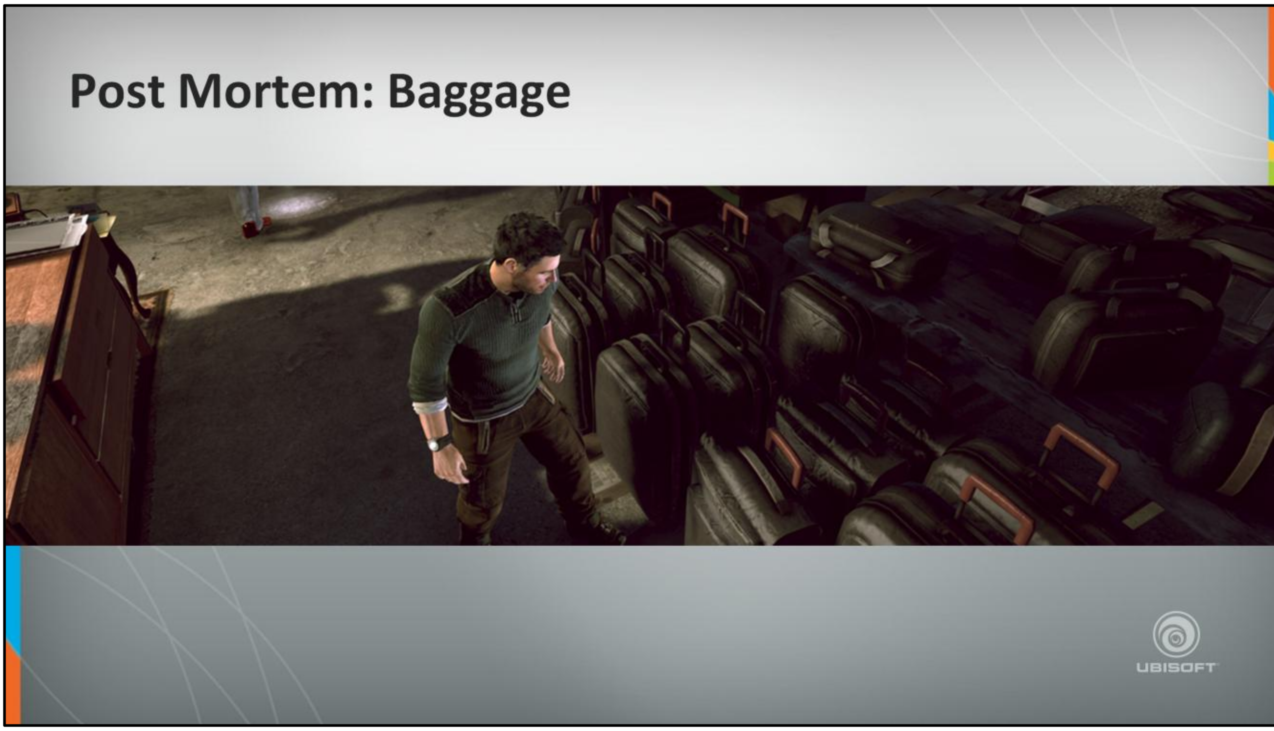
In terms of rendering:

Outdoor environments

HQ ambient lighting

Lots of dynamic objects

Radical departure…



No threading

Interiors

High-contrast lighting

High cost to rendering objects

Bolted down

Plus, also carrying a little ‘extra weight’ - code bloat

The great temptation? To start from scratch…

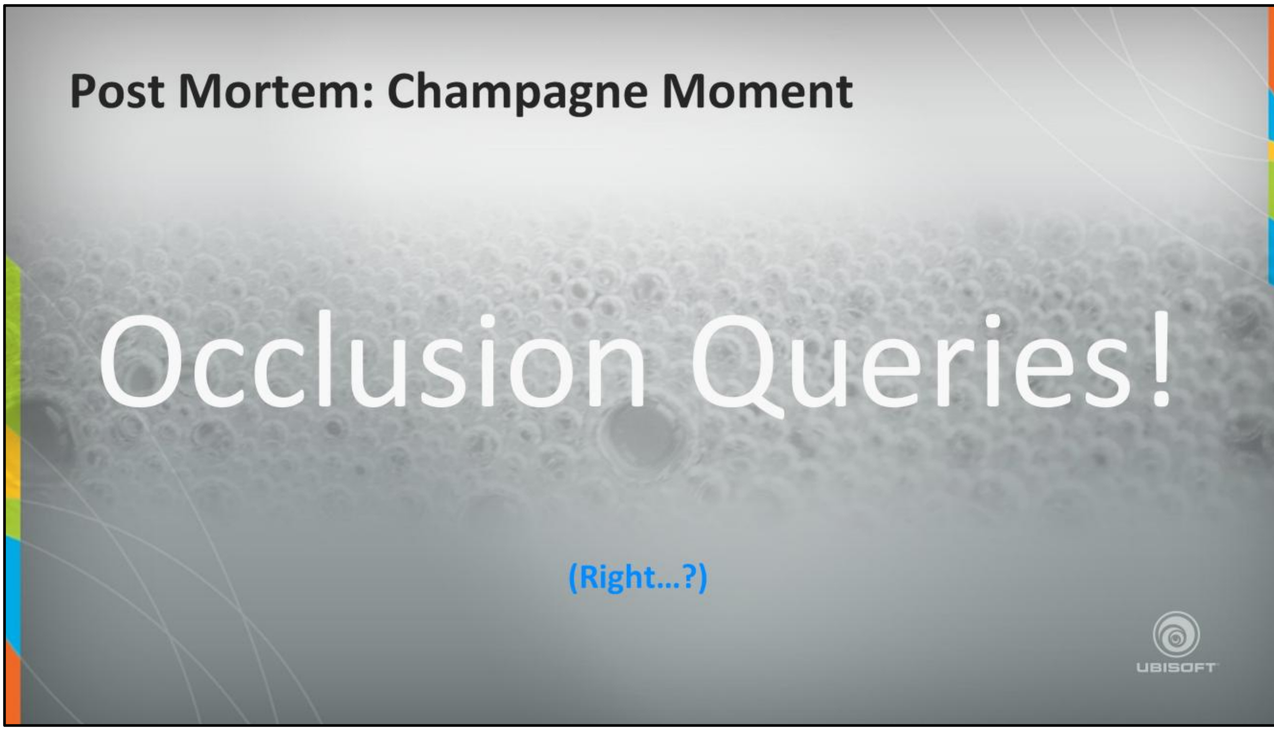
A prime example: BSP

An integral part of Unreal Engine

Showing its age
Messy implementation (we'd hacked on it)
Won't meet our goals – dynamic and/or localised occlusion (particularly outside)

But we had a solution…

[By the way, this is me back then getting messy with the code.
As I said, 5 years is a long time. ☺]



Fairly new to the scene

We had naïve expectations

Just render lots of queries – yay!

Whilst we were busy **rewriting** the renderer, back on the farm…

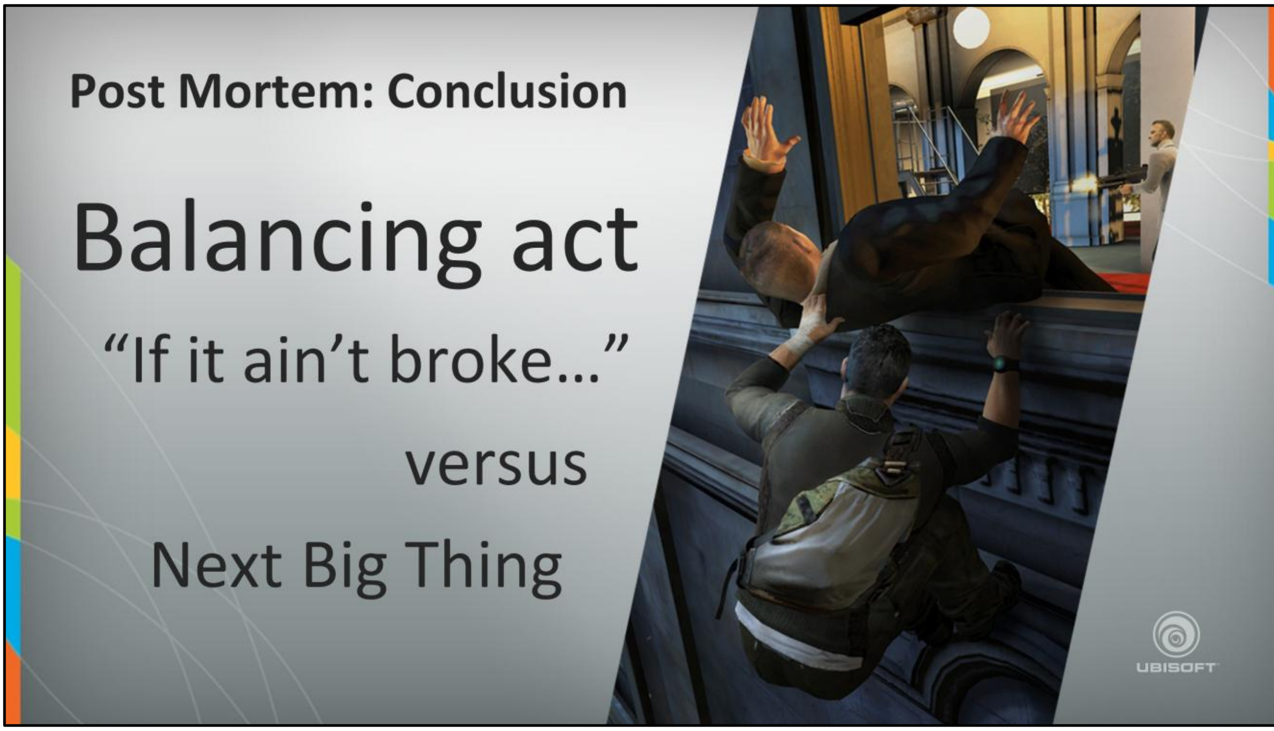
Removing the BSP:

Caused **major disruption for LDs**. They were used to blocking out maps with BSP brushes, not making meshes in 3ds Max!

Robbed engine of an acceleration structure

Should have **distilled** what we had!

The BSP geometry could have been converted to static mesh chunks and also used for collision, occlusion.

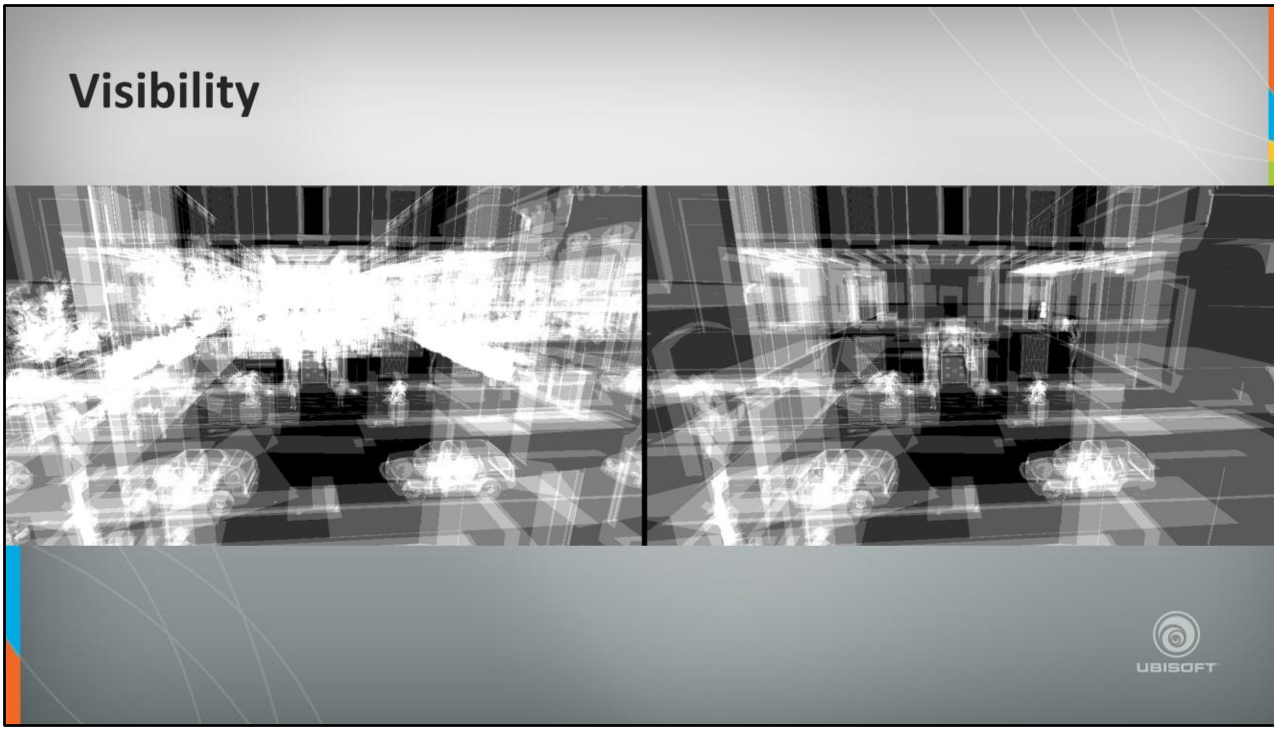


Avoid disruptive changes (rewrites) -> **Resistance**, **confusion**, **distrust**

But… you have to **push boundaries**

Fail Early, Fail Often. Get good at this and you **reduce risk.** Try 100 ways to find that one way…

An amazing personal experience



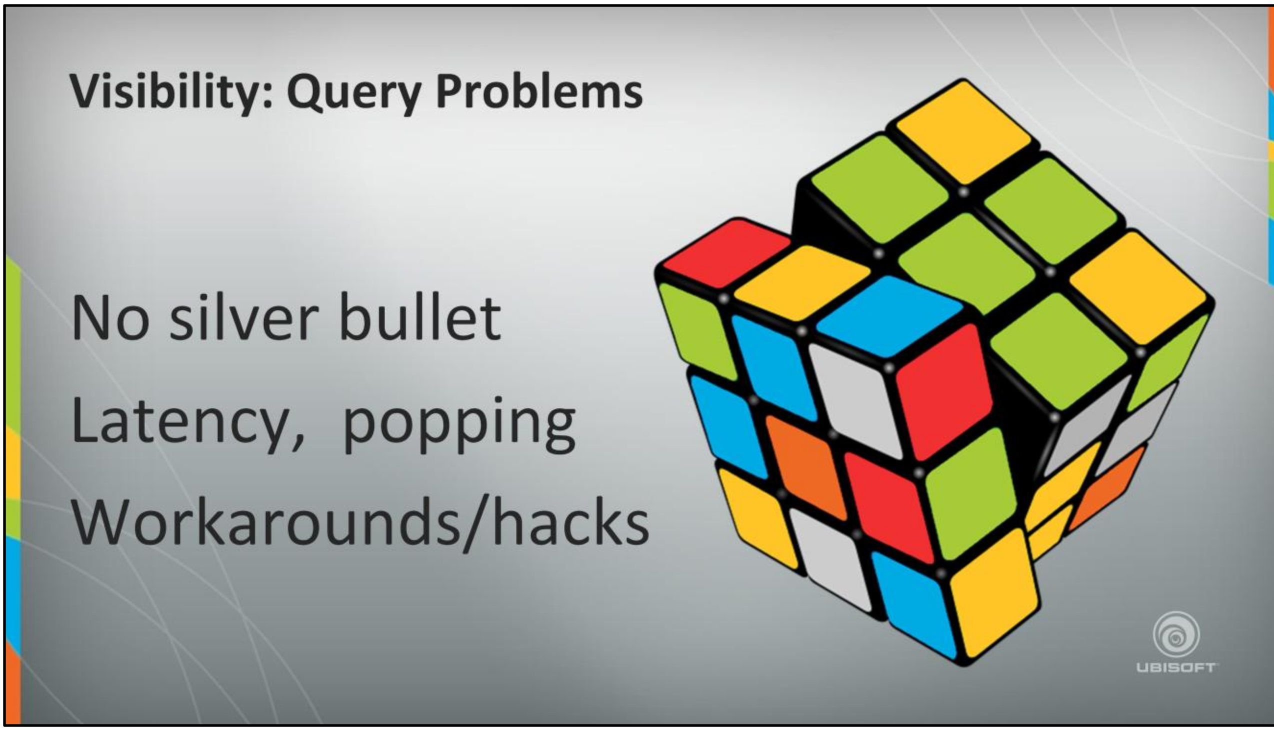
What is visibility?

Cull what you can't see

Ideally everything

Effectively **render more**

Before & **after**



Query problems:

Latency

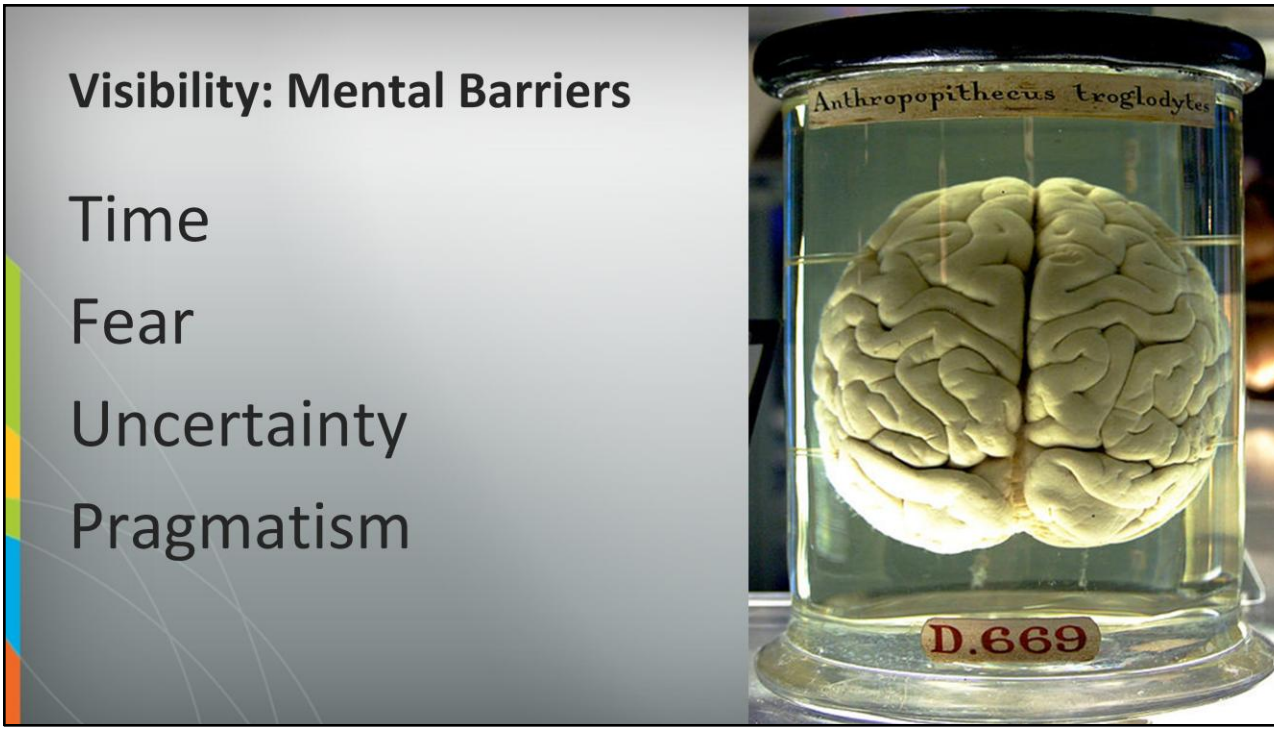
Popping

Can’t batch

Grouping? Complicated

Nothing worked fully

<rant>You’ll see these issues or their side effects even in commercial middleware. Either there’s popping (‘latent’ queries) or the tests must be interleaved with regular rendering, which can complicate things or restrict you.</rant>



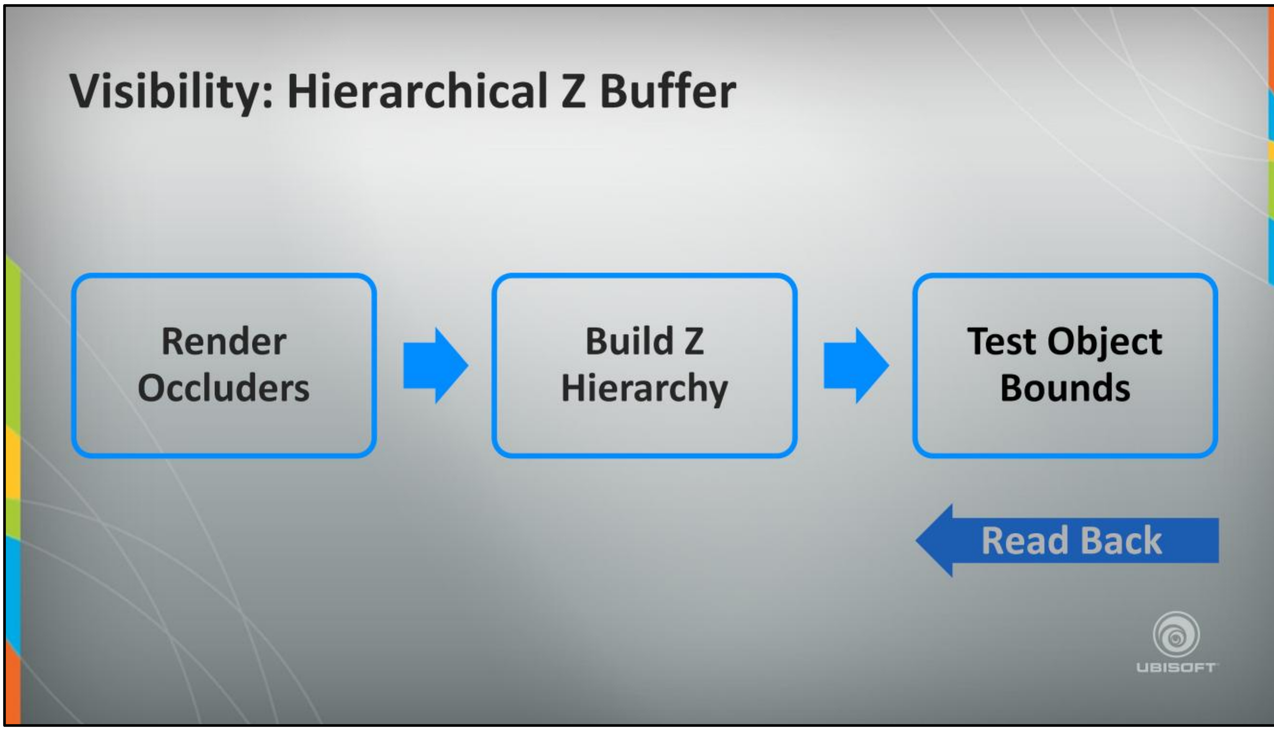
Had plenty of ideas

One was the "Hierarchical Z Buffer", Greene et al., Siggraph 93

But:

Ran out of time
Worried about performance
Unproved solutions (HZB in particular)
Thought we could **work around** every problem

Barriers lifted…
More time + inspiration (Josh & Jeremy at Siggraph '08 – Froblins talk)



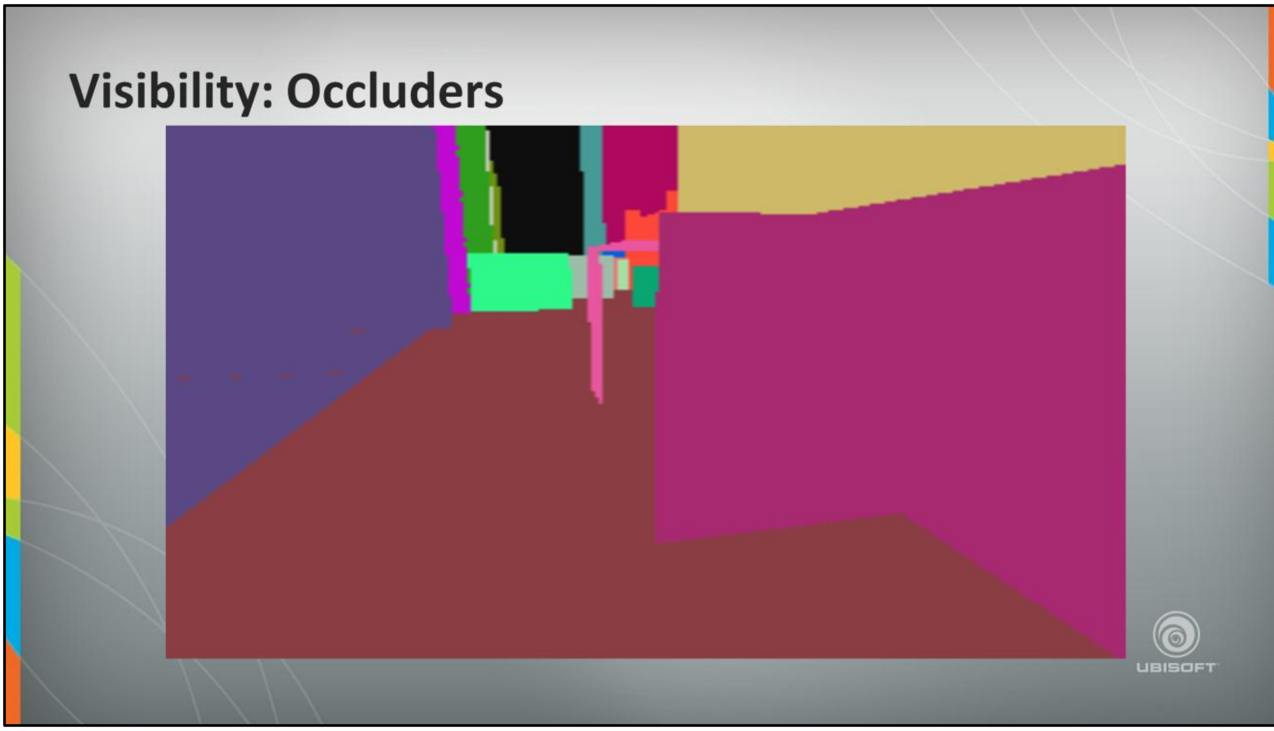
Simple, elegant

Render occluders - doing this anyway?

Build depth MIP chain

Test objects against this

[Besides read-back, all of this happens on the GPU]

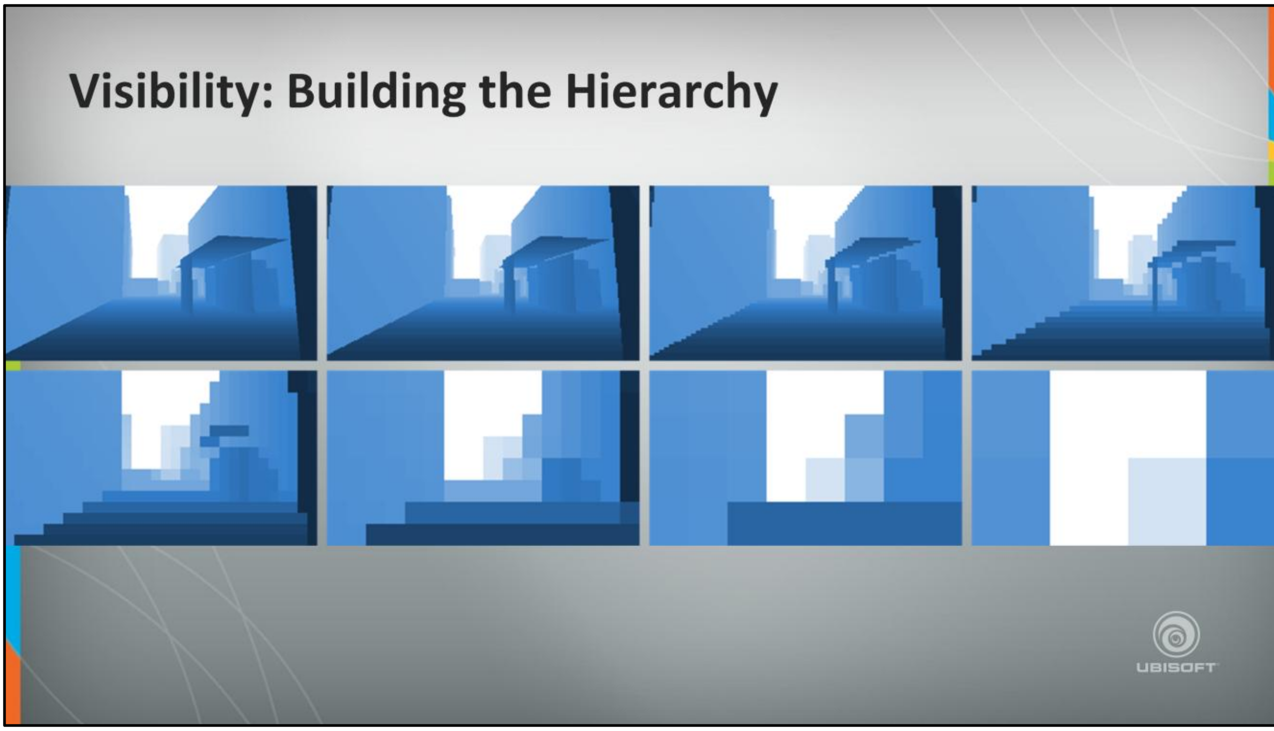


These are our occluders

Typically **decoupled** from the visual meshes

Pretty abstract

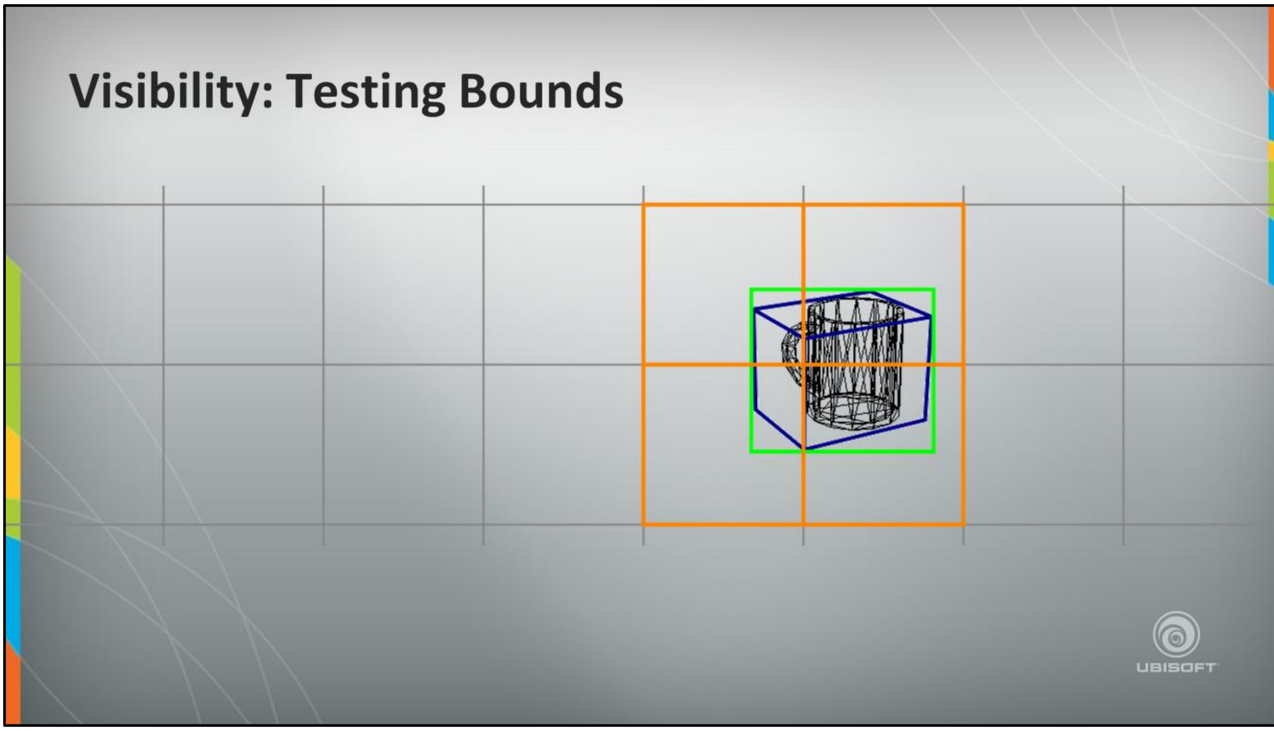
You'll see this market scene again shortly in context



This is your z-buffer on steroids

Take **max of 4 texels** when generating next level

Skybox (white) begins to dominate



Take the objects' bounds (blue)

Find the screen bounds (green)

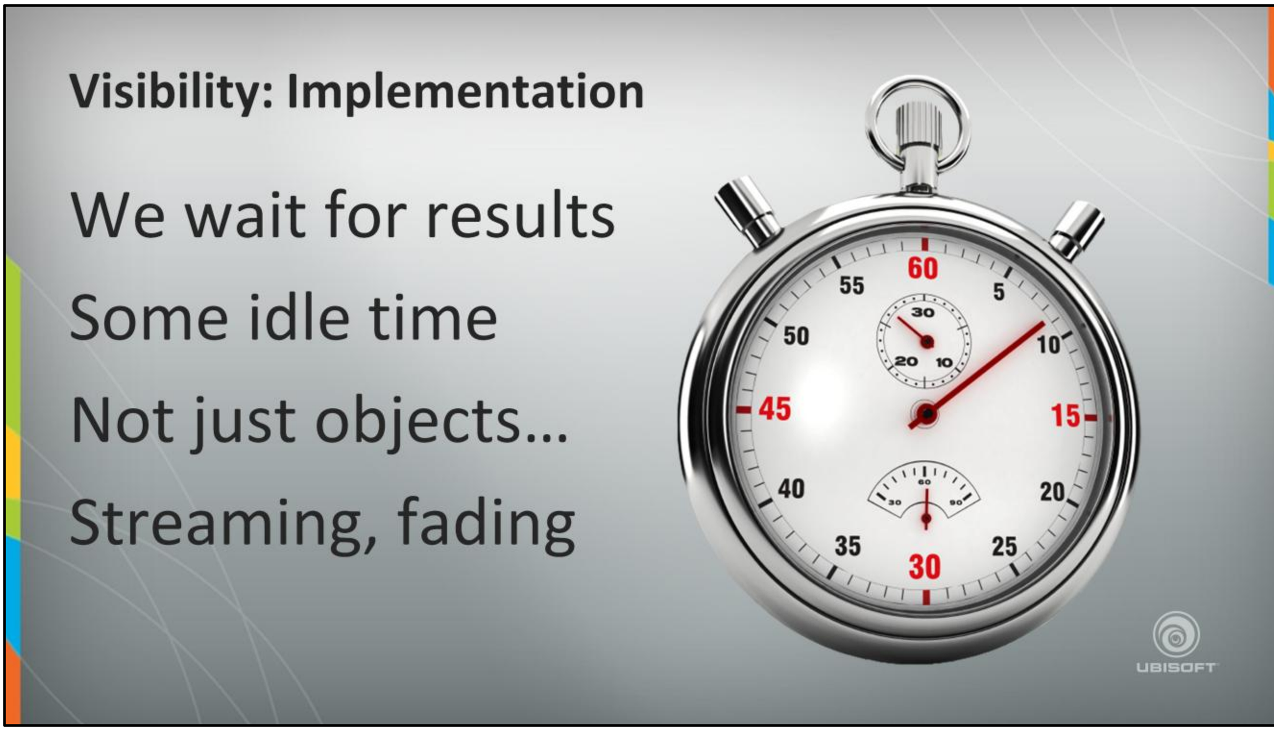
Find the right level of the HZB (orange) – the one that covers the screen bounds with <= N texels

Visibility test: Is object min_z < HZB (overlapping texels)

Advantages: Fixed cost, single batch (one big POINTLIST VB of bounds), **extremely fast**, in our case no frame delay

Trade off: Small objects are accurate, big objects are inaccurate. This is **probabilistic**.

Big objects (in screen terms) are more likely to be visible anyway



We wait for the results, you could defer

CPU typically has some work to do (light re-association)

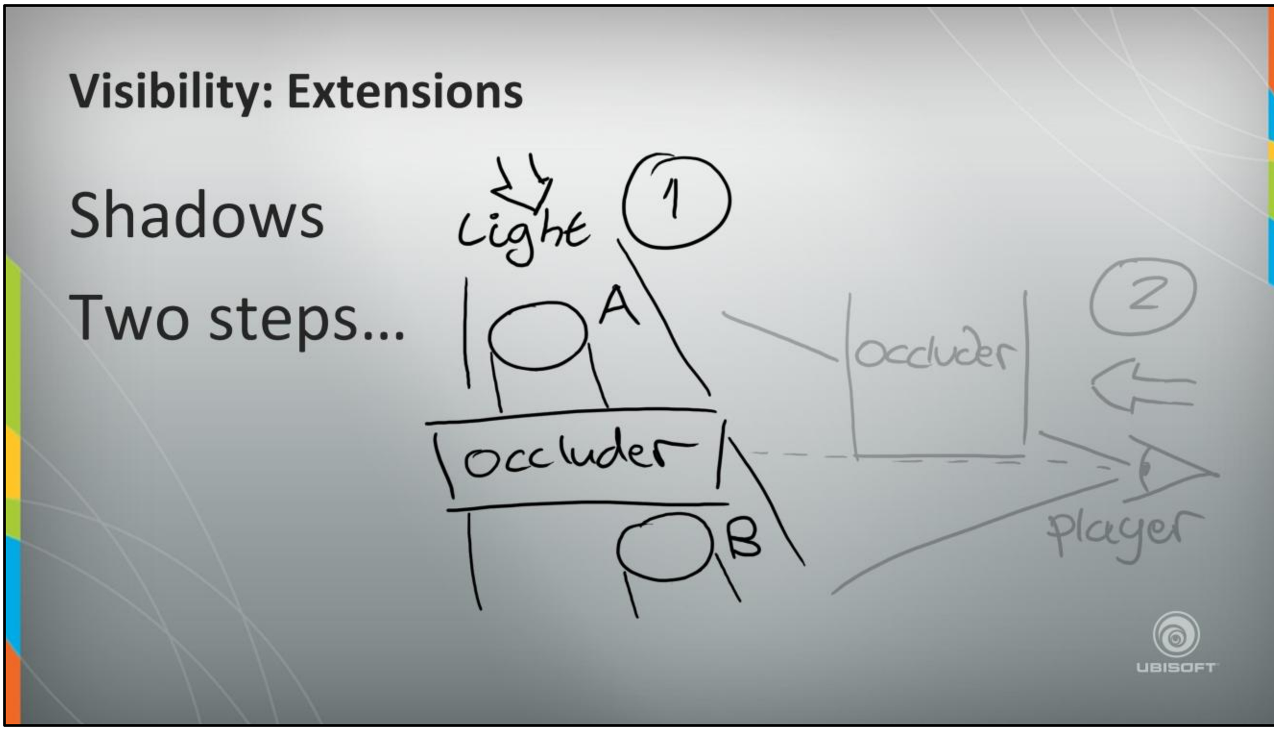
GPU can be idle as results are processed by the CPU (try to move most of this work until later in the frame)

We also test: Lights, AO fields, decals, deferred queries for main engine

We also check: Does object need to stream textures?, can it be screen-size faded/culled?, what tiles does it cover? (360)

360: No predicated tiling, no BUFFER_2_FRAMES!

Production proven!

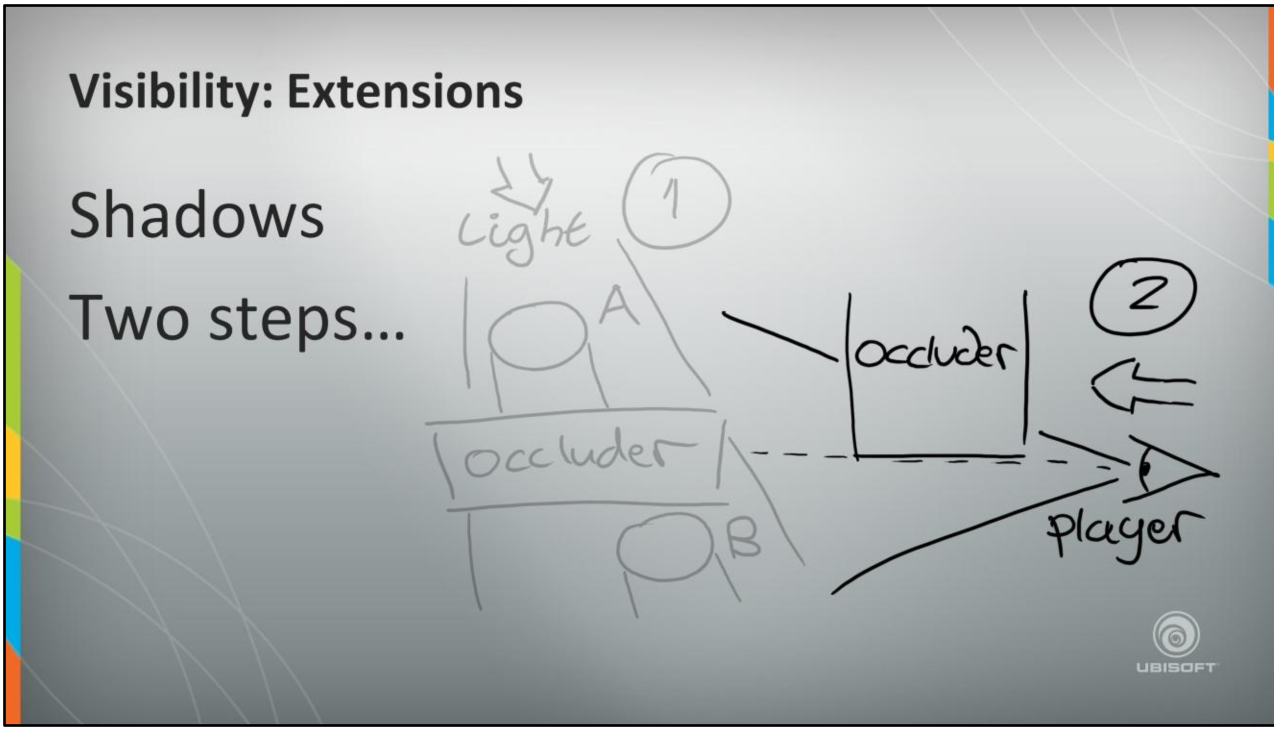


Inspired by CC Shadow Volumes

First pass: From light

Cull hidden

Clamp visible to occluders

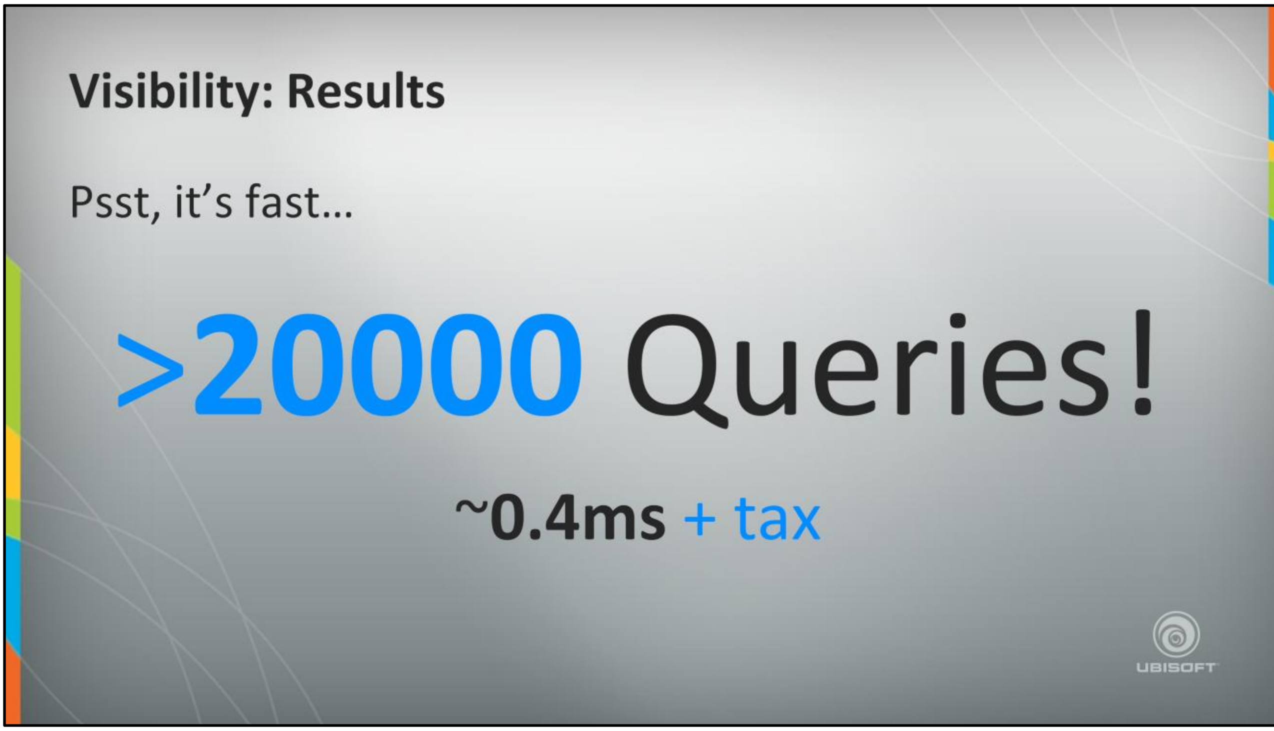


Second pass: From camera

Test clamped shafts

Can reuse the HZB from the main render

Used for cascaded shadows



Rough 360 stats:

~0.35ms for all the queries (worst case – not all levels have this many)

Plus

~0.1ms for downsample (512x256 - could possibly be lower**)**

Also not counting occluder rendering (maybe another ~0.1ms – can be CPU bound at the moment)

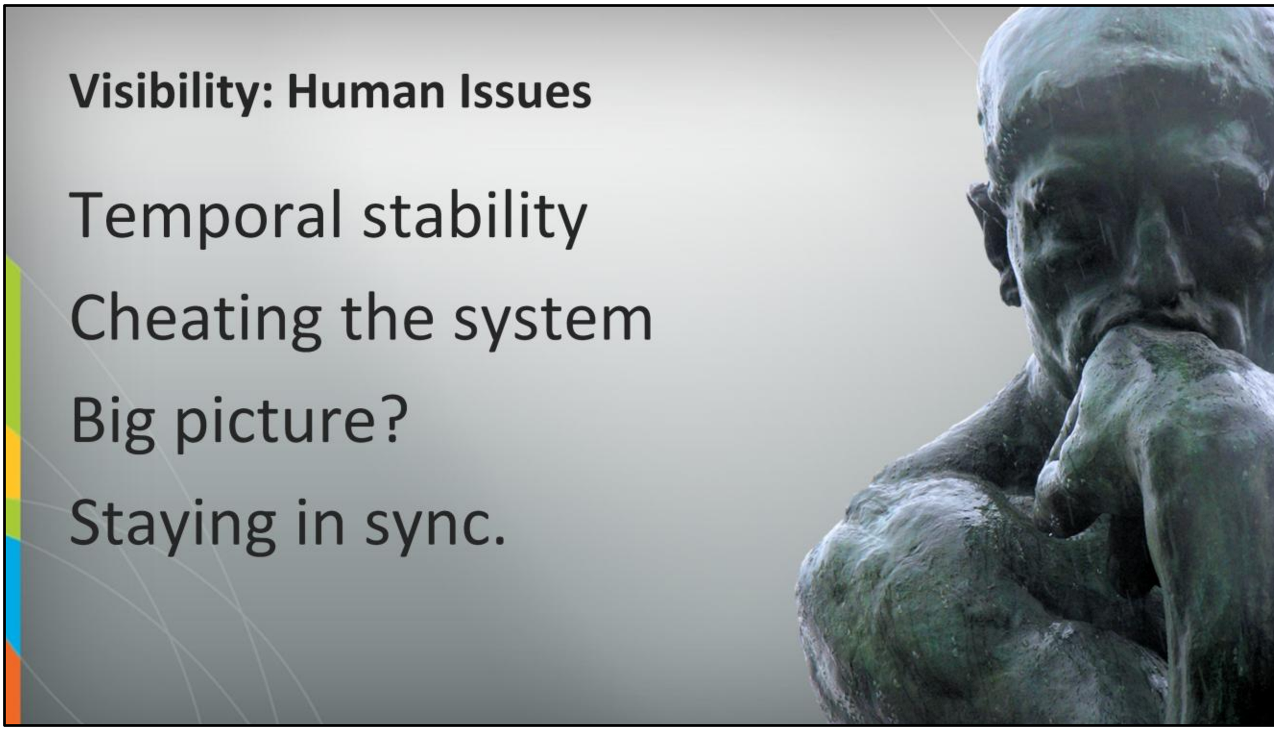
versus ~0.05ms per full-screen occlusion query. Think about that for a second!

It's *so* fast that we didn't even bother with a shallow hierarchy pre-pass

Could use this to drive pre-computed visibility too

<rant>I can't believe some developers suffer 6h+ static PVS pre-processing steps for their levels, even if they're aiming for 60FPS.</rant>

Visibility: Demo



Not perfect

Humans get in the way

Cull the vast majority of objects

Big object != expensive object

Occluder mesh != collision mesh

Testers will find these problems

But only right at the end!

Visual & occluder need to be in sync.

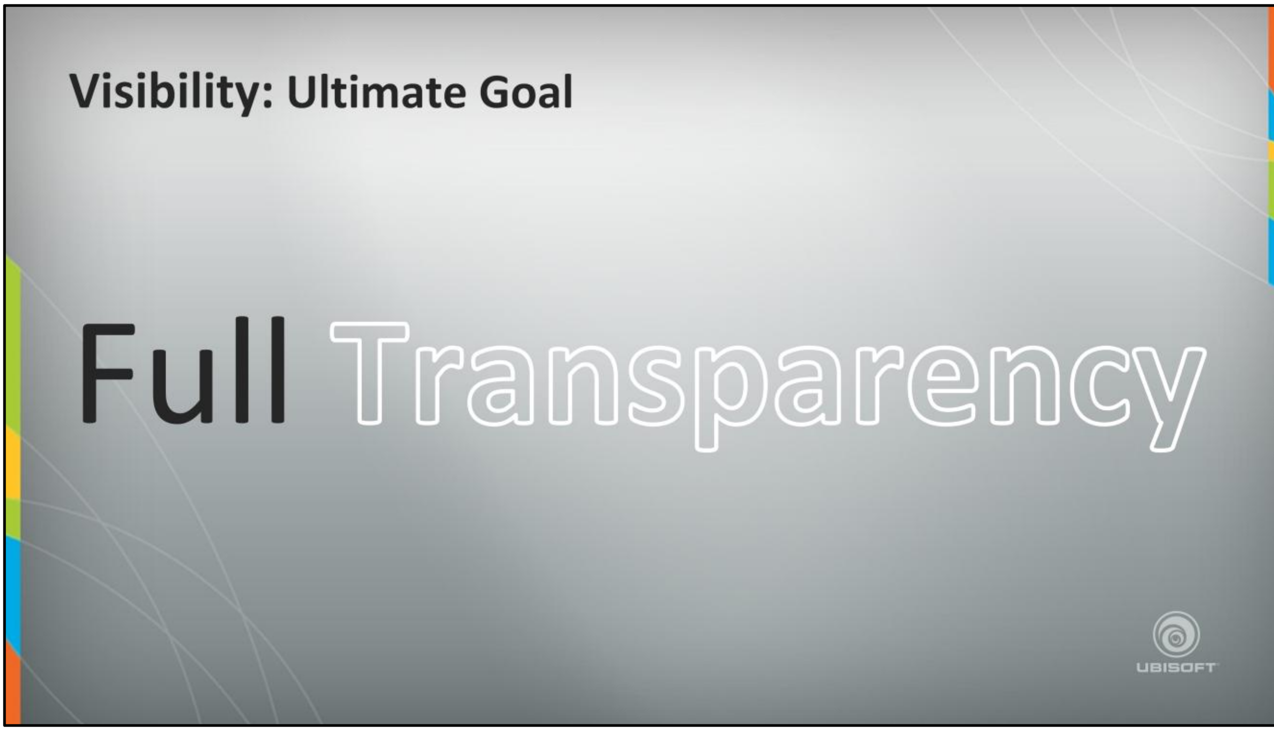
We’d like to use these more in the **main engine**…

Determinism was an issue – P2P COOP, particularly on PC

Several passes

Rasterisation?

But what’s my main goal?…

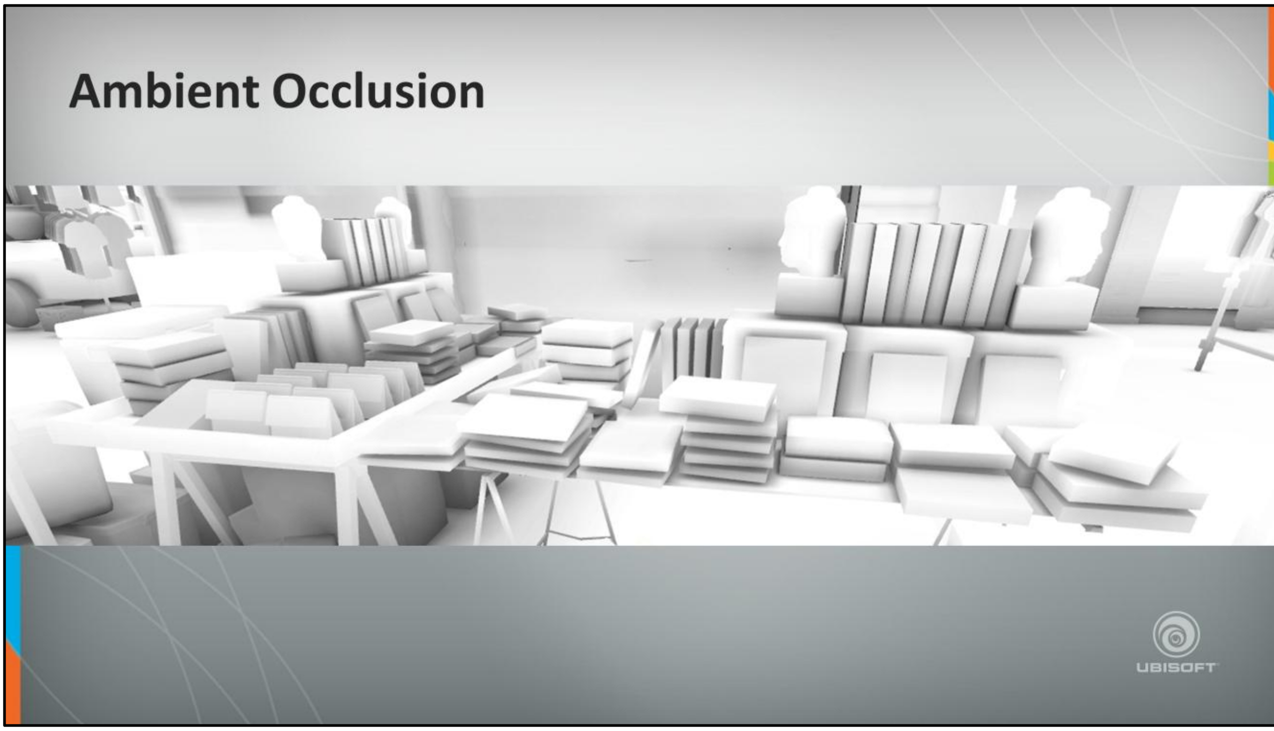


Take artists out of the loop as much as possible. There's no such thing as pretty visibility

Minimal production overhead. One less thing to worry about

No cheating. 100% correctness

Perhaps just have artists tag structural meshes, then we weld them all up, possibly simplify and convert to fixed-size chunks / minimise overdraw.



What is AO? This is AO

Average shadowing at a point. How much light can get there

Less flat ambient. Contact shadows

Constant/low-frequency ambient otherwise washes things out

Poor man’s GI. We **decouple** colour and luminance changes as an approximation

We **bake everything** but it’s still **dynamic**

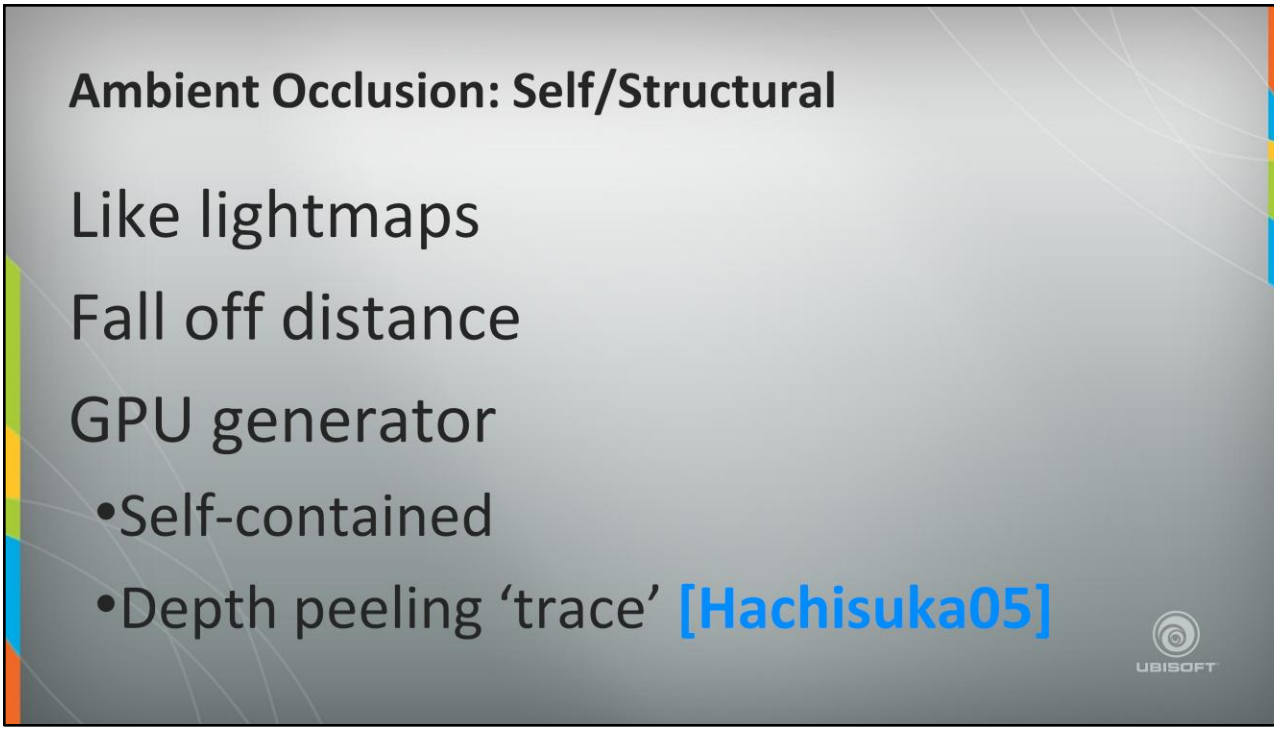
NOT SSAO… (although it *is* accumulated in screen space ☺)

No SSAO in 2005

But this gives us control, flexibility

Competitive

Not a crease shader



The first component is static baking for self occlusion (rigid bodies) and ‘structural’ meshes (big meshes that don’t move)

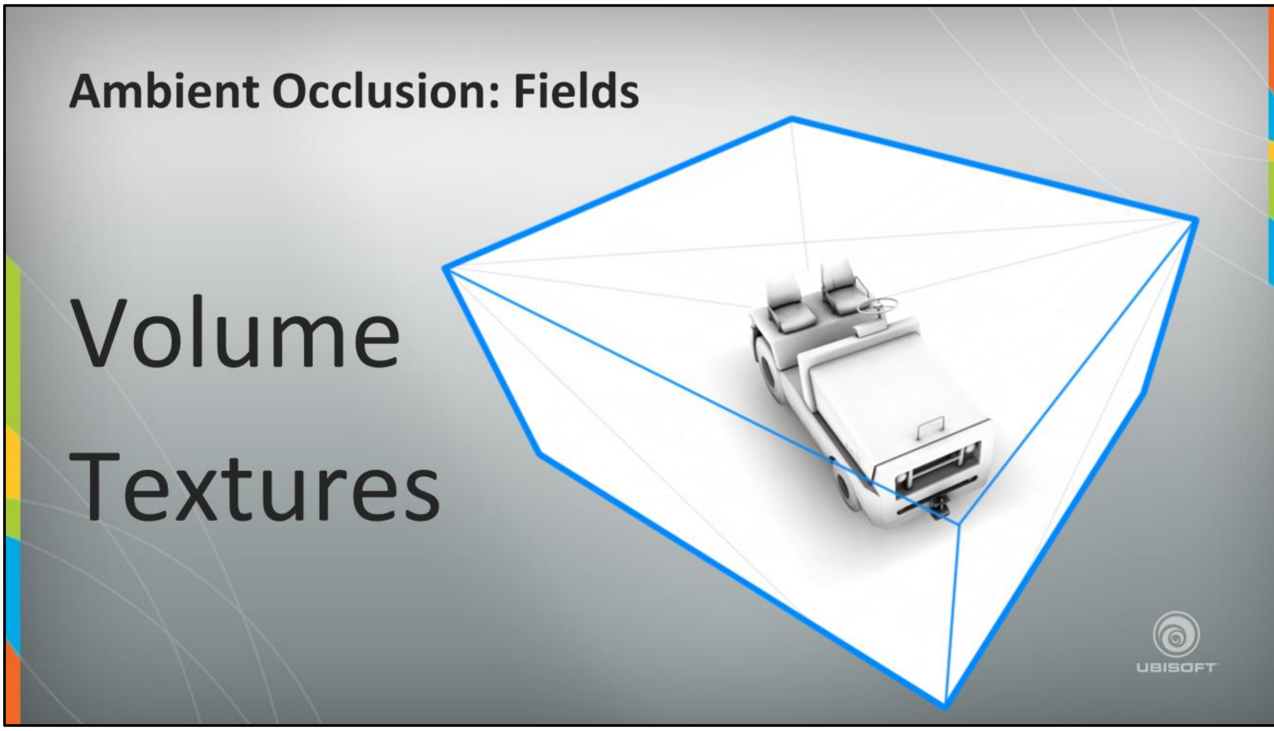
Artists can control the falloff/cutoff, which is important for interiors

This is generated with a mini-renderer

Essentially accumulating shadow maps, with depth peeling to support falloff/cutoff

<rant>Put the time in to ensure that artists have fast tools. So they can iterate quickly. So nothing gets out of sync.

It’s fun to boast about having awesome server farms, but you’re doing your artists a disservice if you think a round trip time of a few hours is a good idea. Same goes for PVS.</rant>

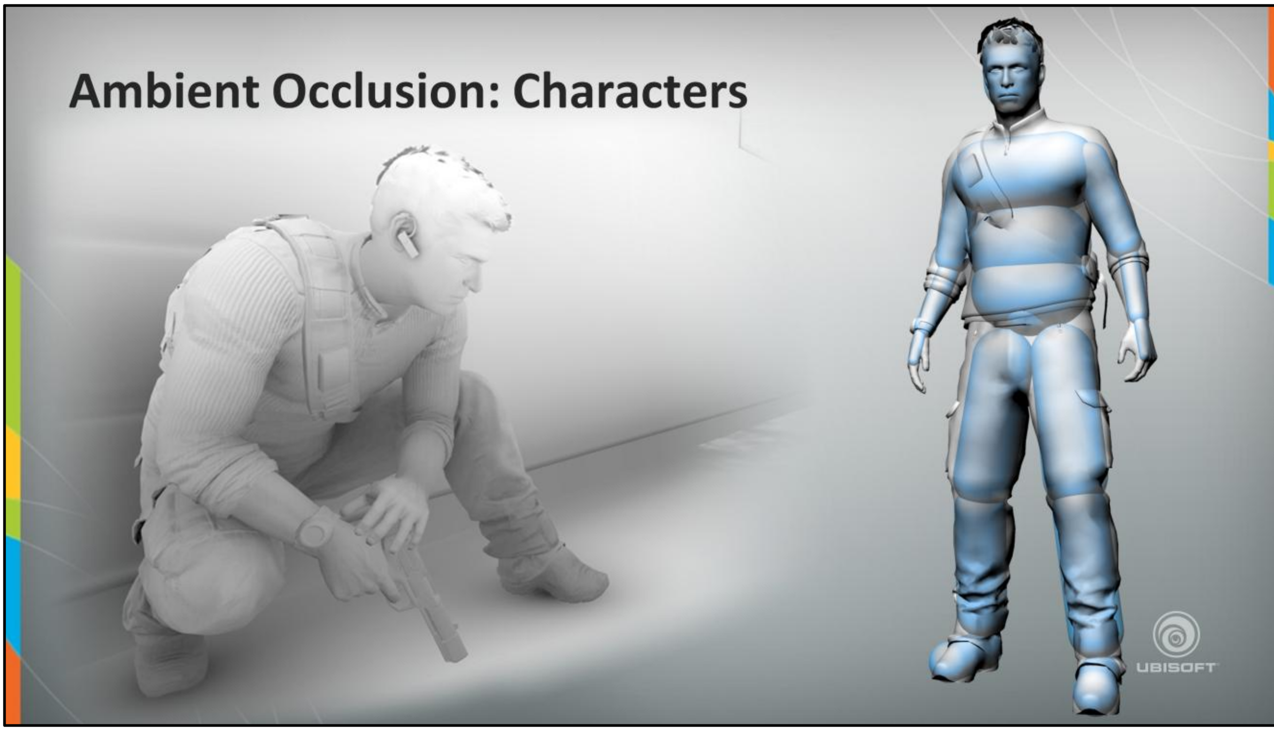


Inspired by AO Fields paper

We use **volumes** in order to capture **concave occlusion** (e.g. under a table)

Average + directional visibility (like second order SH, but the scale factors cancel)

Generated offline as with self AO



Analytical

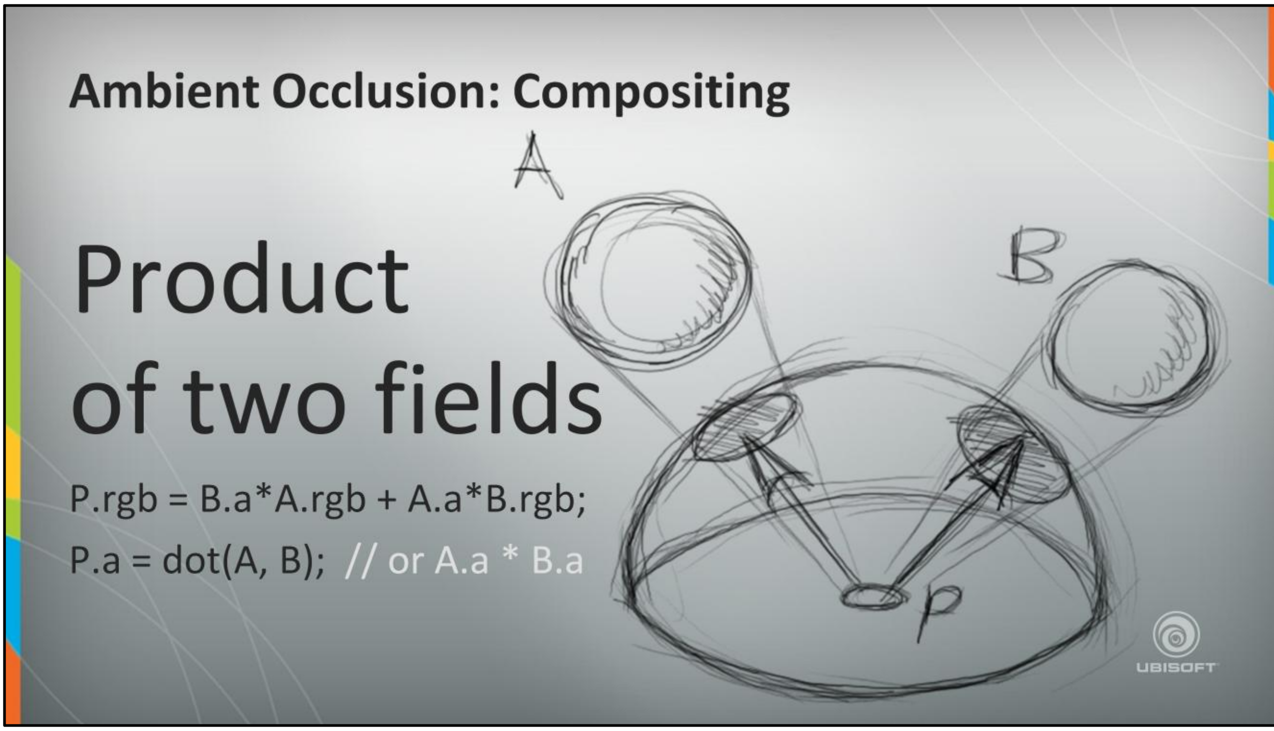
Second order zonal harmonics

1D Texture – unit sphere on Z

Attached to primary bones

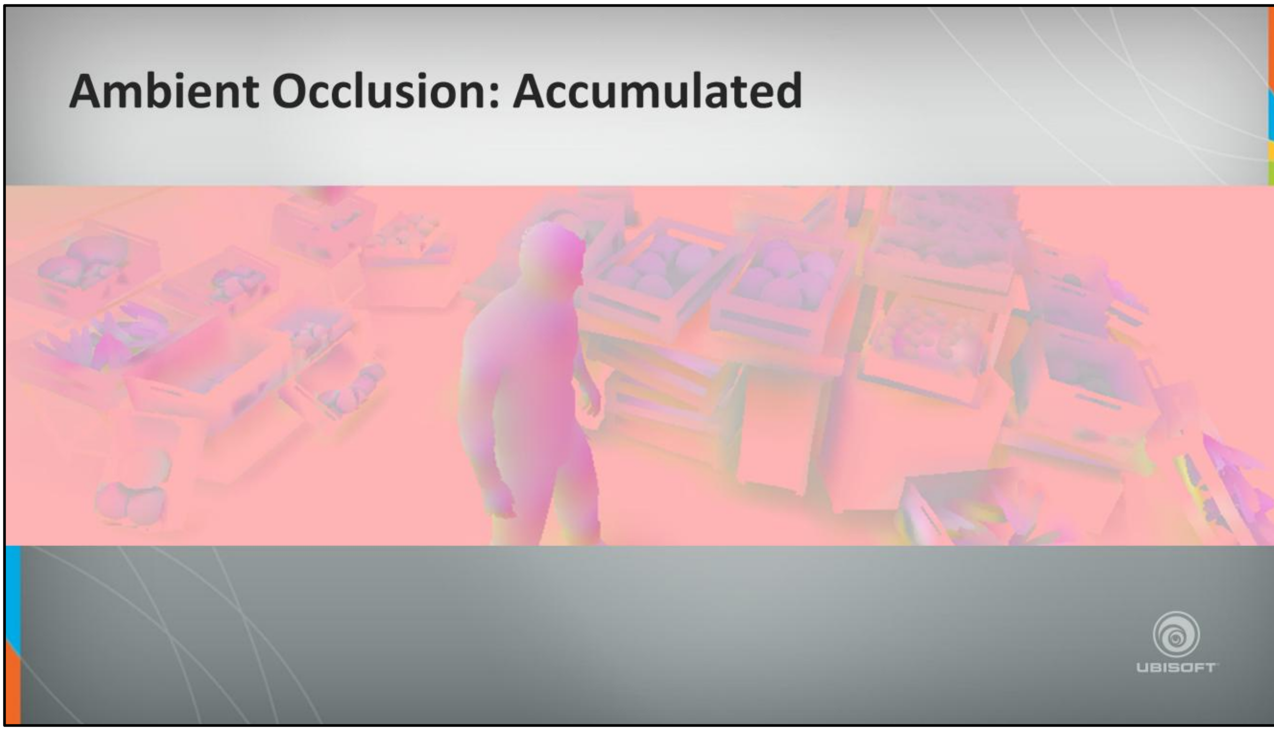
Used for self occlusion too

Those blue pills are just an artistic representation. They're really ellipsoids.



We combine (splat) fields in screen-space using **special blending**

Composited like deferred lighting



Smooth

Rendered at ¼ res.

Masking by ID for fields

Edge-aware up-sampling

Dot product in the lighting pass. Uses per-pixel normal

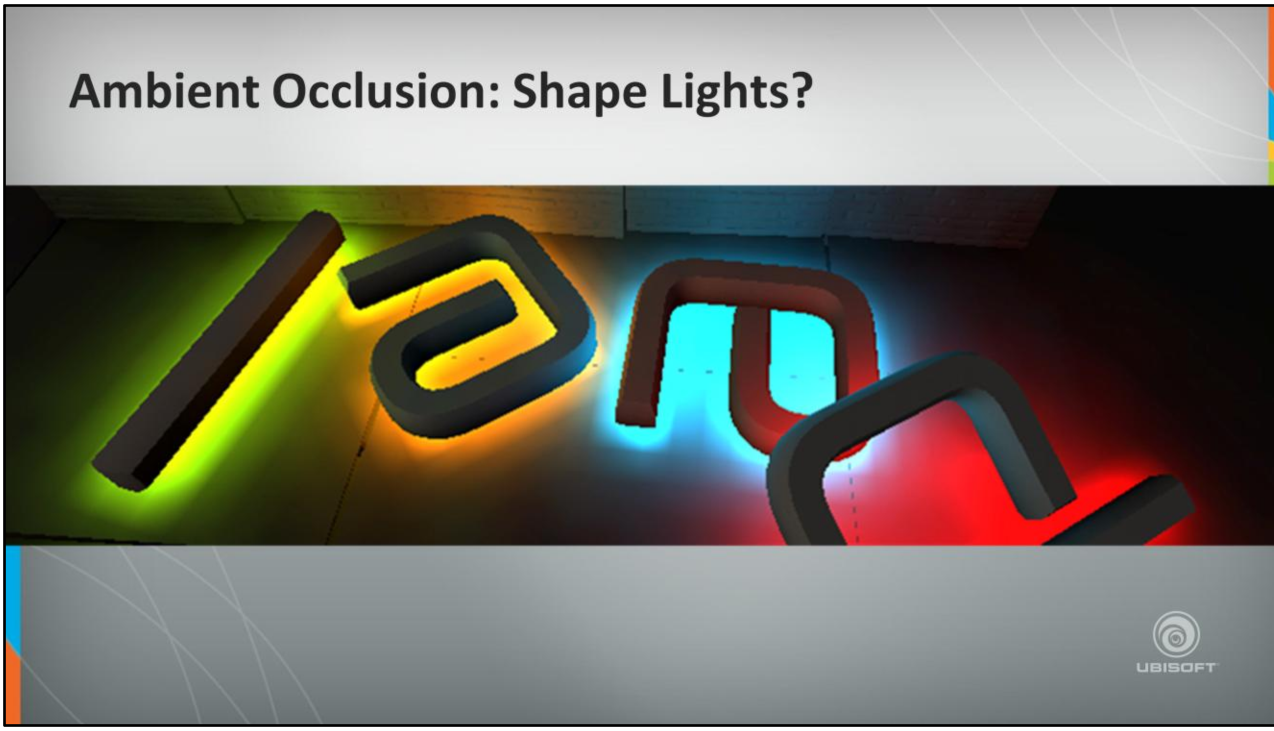
We've decoupled again: High-frequency surface normal vs. smoothly-varying AO

For our 'look', we scale regular diffuse/spec too and even apply contrast to the AO

Ambient Occlusion: Demo

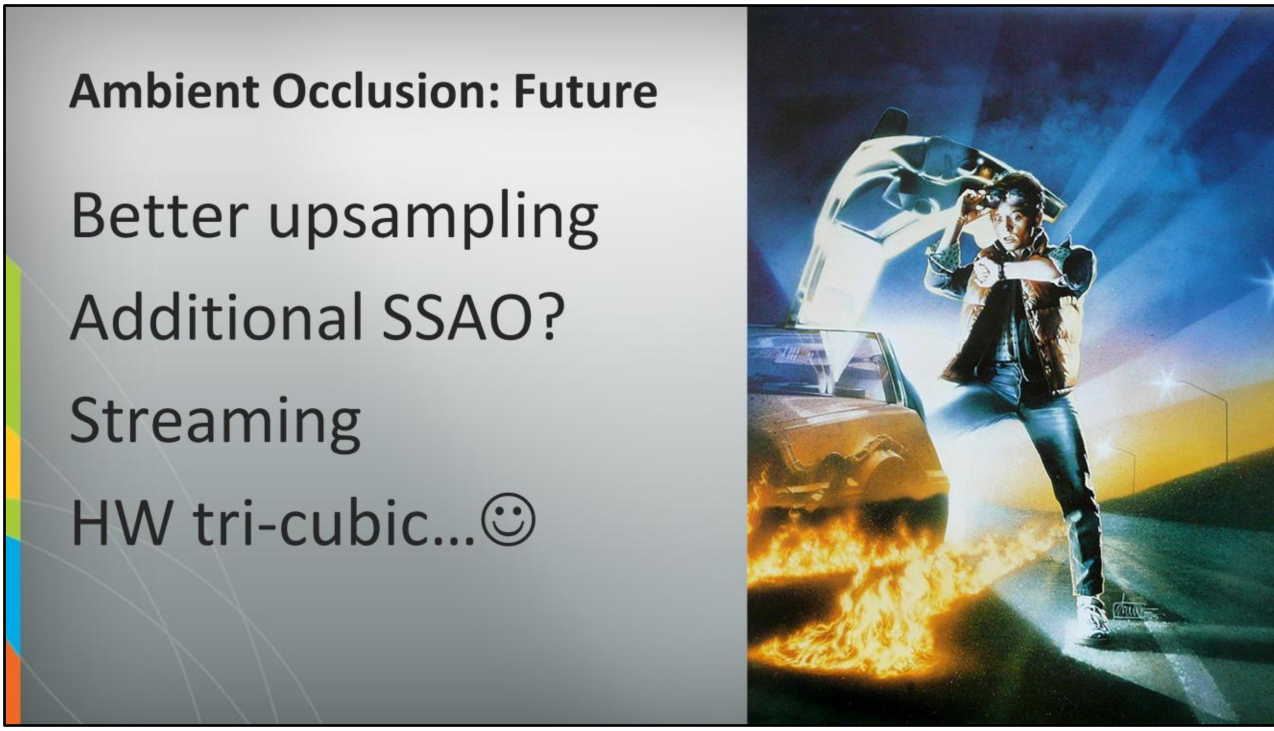
Ambient Occlusion: Demo

UBISOFT



This didn't make it in…

The reverse: lighting



This is a highly active field of research

RGB occlusion/bounce/light? (see earlier)

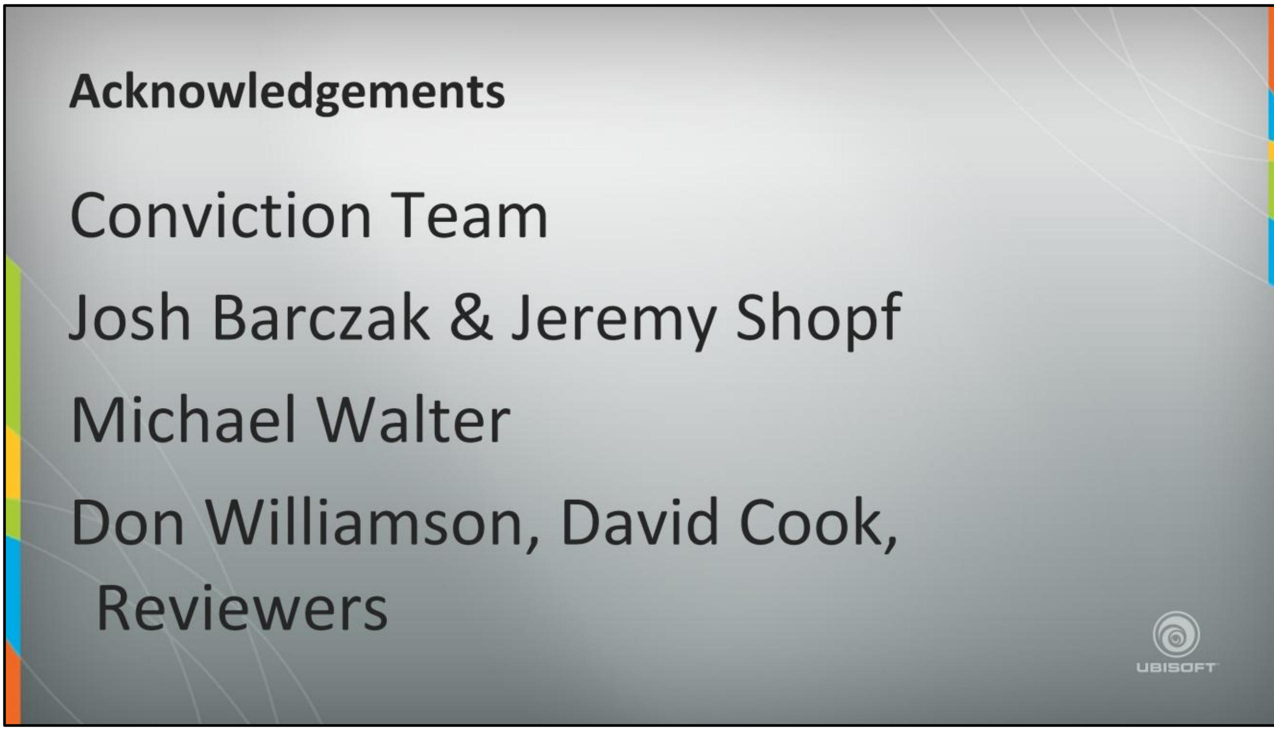
Combine with Crytek's GI?

We should have streamed in higher-res. volumes

I can't imagine hardware supporting cubic interpolation of volume textures anytime soon, but a developer can dream.

Conclusion

Think Different



I owe a debt of gratitude to all of these guys

All those artists

Josh and Jeremy for inspiration

Michael: Initial AO work

Everyone else for feedback on this talk

Questions and Answers

Rendering with Conviction

Ubisoft:

www.creatorsofemotions.com

Me: stephen.hill /at/ ubisoft.com

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