# Far Cry and DirectX

Carsten Wenzel

CRYTEK

# Far Cry uses the latest DX9 features

- Shader Models 2.x / 3.0 ✓
  - Except for vertex textures and dynamic flow control ✗
- Geometry Instancing ✓
- Floating-point render targets ✓

# Dynamic flow control in PS

- To consolidate multiple lights into one pass, we ideally would want to do something like this…

```
float3 finalCol = 0;
float3 diffuseCol = tex2D( diffuseMap, IN.diffuseUV.xy );
float3 normal = mul( IN.tangentToWorldSpace,
                     tex2D( normalMap, IN.bumpUV.xy ).xyz );
for( int i = 0; i < cNumLights; i++ )

   float3 lightCol = LightColor[ i ];
   float3 lightVec = normalize( cLightPos[ i ].xyz - IN.pos.xyz );
   // …
   // Attenuation, Specular, etc. calculated via if( const_boolean )
   // …
   float nDotL = saturate( dot( lightVec.xyz, normal ) );
   final += lightCol.xyz * diffuseCol.xyz * nDotL * atten;

return( float4( finalCol, 1 ) );
```

# Dynamic flow control in PS

- Welcome to the real world…
  - Dynamic indexing only allowed on input registers; prevents passing light data via constant registers and index them in a loop
  - Passing light info via input registers not feasible as there are not enough of them (only 10)
  - Dynamic branching is not free

# Loop unrolling

- We chose not to use dynamic branching and loops
- Used static branching and unrolled loops instead
- Works well with Far Cry's existing shader framework
- Shaders are precompiled for different light masks
  - 0-4 dynamic light sources per pass
  - 3 different light types (spot, omni, directional)
  - 2 modification types per light (specular only, occlusion map)
- Can result in over 160 instructions after loop unrolling when using 4 lights
  - Too long for ps_2_0
  - Just fine for ps_2_a, ps_2_b and ps_3_0!
- To avoid run time stalls, use a pre-warmed shader cache

# How the shader cache works

- Specific shader depends on:

  1) Material type
     (e.g. skin, phong, metal)
  2) Material usage flags
     (e.g. bump-mapped, specular)
  3) Specific environment
     (e.g. light mask, fog)

# How the shader cache works

- Cache access:
  - Object to render already has shader handles? Use those!
  - Otherwise try to find the shader in memory
  - If that fails load from harddisk
  - If that fails generate VS/PS, store backup on harddisk
  - Finally, save shader handles in object
- Not the ideal solution but
  - Works reasonably well on existing hardware
  - Was easy to integrate without changing assets
- For the cache to be efficient…
  - All used combinations of a shader should exist as pre-cached files on HD
    - On the fly update causes stalls due to time required for shader compilation!
  - However, maintaining the cache can become cumbersome

# Loop unrolling – Pros/Cons

- Pros:
  - Speed! Not branching dynamically saves quite a few cycles
  - At the time, we found switching shaders to be more efficient than dynamic branching
- Cons:
  - Needs sophisticated shader caching, due to number of shader combinations per light mask (244 after presorting of combinations)
  - Shader pre-compilation takes time
  - Shader cache for Far Cry 1.3 requires about 430 MB (compressed down to ~23 MB in patch exe)

# Geometry Instancing

- Potentially saves cost of *n-1* draw calls when rendering *n* instances of an object
- Far Cry uses it mainly to speed up vegetation rendering
- Per instance attributes:
  - Position
  - Size
  - Bending info
  - Rotation (only if needed)
- Reduce the number of instance attributes! Two methods:
  - Vertex shader constants
    - Use for objects having more than 100 polygons
  - Attribute streams
    - Use for smaller objects (sprites, impostors)

# Instance Attributes in VS Constants

- Best for objects with large numbers of polygons, prevents GPU from becoming attribute bound (see Cem's talk)
- Put instance data in VS constants and index into additional stream
  - WGF 2.0 will support an automatically generated instance index!
- Large batches need to be split up to fit attributes in VS constant (try to fit attributes for at least eight instances to amortize startup cost!)
- Use *SetStreamSourceFrequency* to setup geometry instancing as follows…

```
SetStreamSourceFrequency( geomStream,
   D3DSTREAMSOURCE_INDEXEDDATA | numInstances );
SetStreamSourceFrequency( instStream,
   D3DSTREAMSOURCE_INSTANCEDATA | 1 );
```

- Be sure to reset the vertex stream frequency once you're done, `SSSF( strNum, 1 )`!

# VS Snippet to unpack attributes (position & size) from VS constants to create matMVP and transform vertex

```
const float4x4 cMatViewProj;

const float4 cPackedInstanceData[ numInstances ];


float4x4 matWorld;

float4x4 matMVP;


int i = IN.InstanceIndex;


matWorld[ 0 ] = float4( cPackedInstanceData[ i ].w, 0, 0,
cPackedInstanceData[ i ].x );

matWorld[ 1 ] = float4( 0, cPackedInstanceData[ i ].w, 0,
cPackedInstanceData[ i ].y );

matWorld[ 2 ] = float4( 0, 0, cPackedInstanceData[ i ].w,
cPackedInstanceData[ i ].z );

matWorld[ 3 ] = float4( 0, 0, 0, 1 );


matMVP = mul( cMatViewProj, matWorld );

OUT.HPosition = mul( matMVP, IN.Position );
```

# Instance Attribute Streams

- Original geometry instancing approach… "Only pay the cost for 1 draw call when rendering *n* instances"
- Best for objects with few polygons, less likely to become attribute bound
- Put per instance data into additional stream
- Setup vertex stream frequency as before and reset when you're done

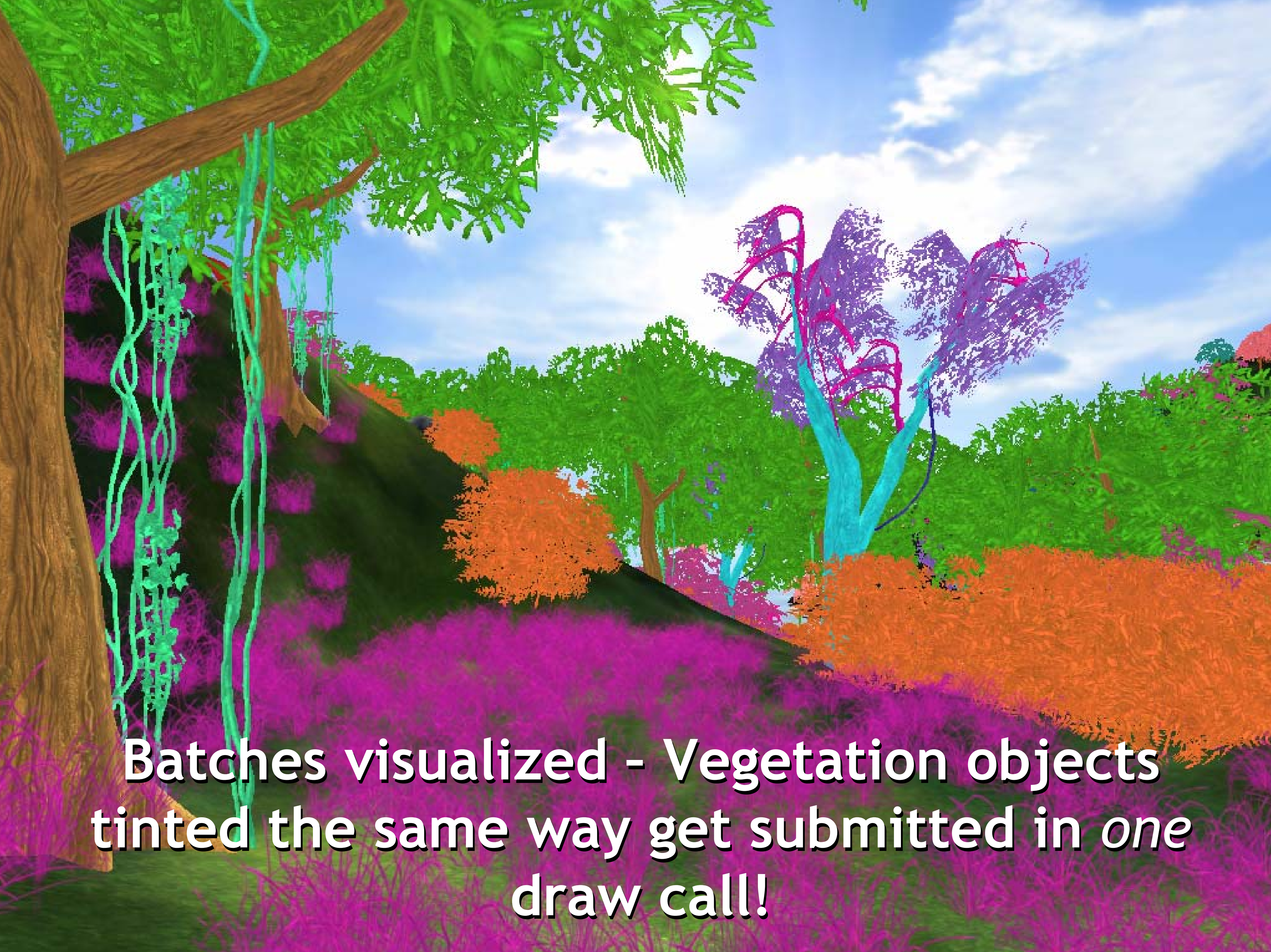
# VS Snippet to unpack attributes (position & size) from attribute stream to create matMVP and transform vertex

```
const float4x4 cMatViewProj;

float4x4 matWorld;

float4x4 matMVP;

matWorld[ 0 ] = float4( IN.PackedInstData.w, 0, 0,
IN.PackedInstData.x );

matWorld[ 1 ] = float4( 0, IN.PackedInstData.w, 0,
IN.PackedInstData.y );

matWorld[ 2 ] = float4( 0, 0, IN.PackedInstData.w,
IN.PackedInstData.z );

matWorld[ 3 ] = float4( 0, 0, 0, 1 );

matMVP = mul( cMatViewProj, matWorld );

OUT.HPosition = mul( matMVP, IN.Position );
```

# Geometry Instancing - Results

- Depending on the amount of vegetation, rendering speed increases up to 40% (when heavily draw call limited)
- Allows us to increase sprite distance ratio, a nice visual improvement with only a moderate rendering speed hit


Scene drawn normally


Batches visualized – Vegetation objects tinted the same way get submitted in *one* draw call!

# High Dynamic Range Rendering

# High Dynamic Range Rendering

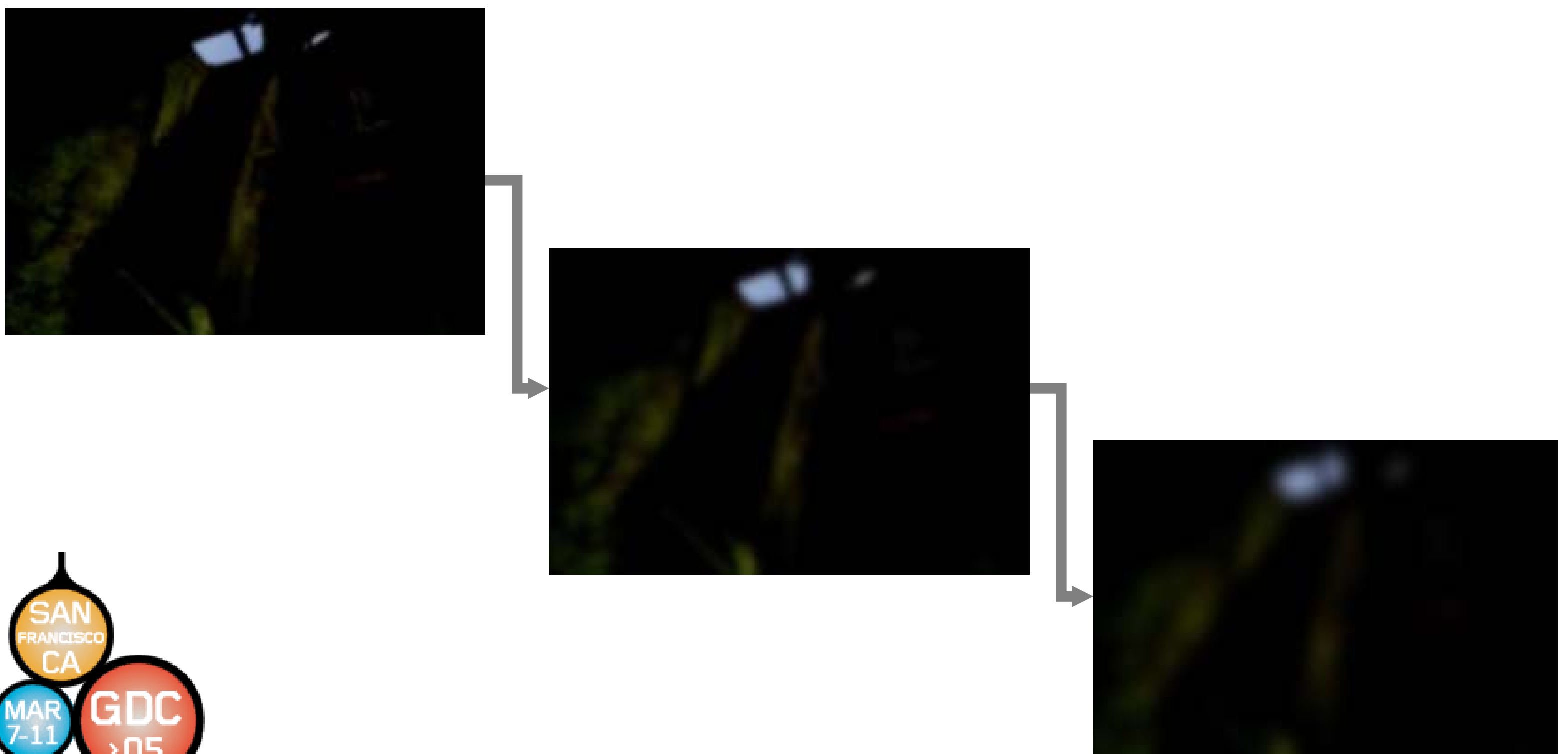
- Uses A16B16G16R16F render target format
- Alpha blending and filtering is essential
- Unified solution for post-processing
  - Glare, flares, etc. can be added more naturally

# HDR - Implementation

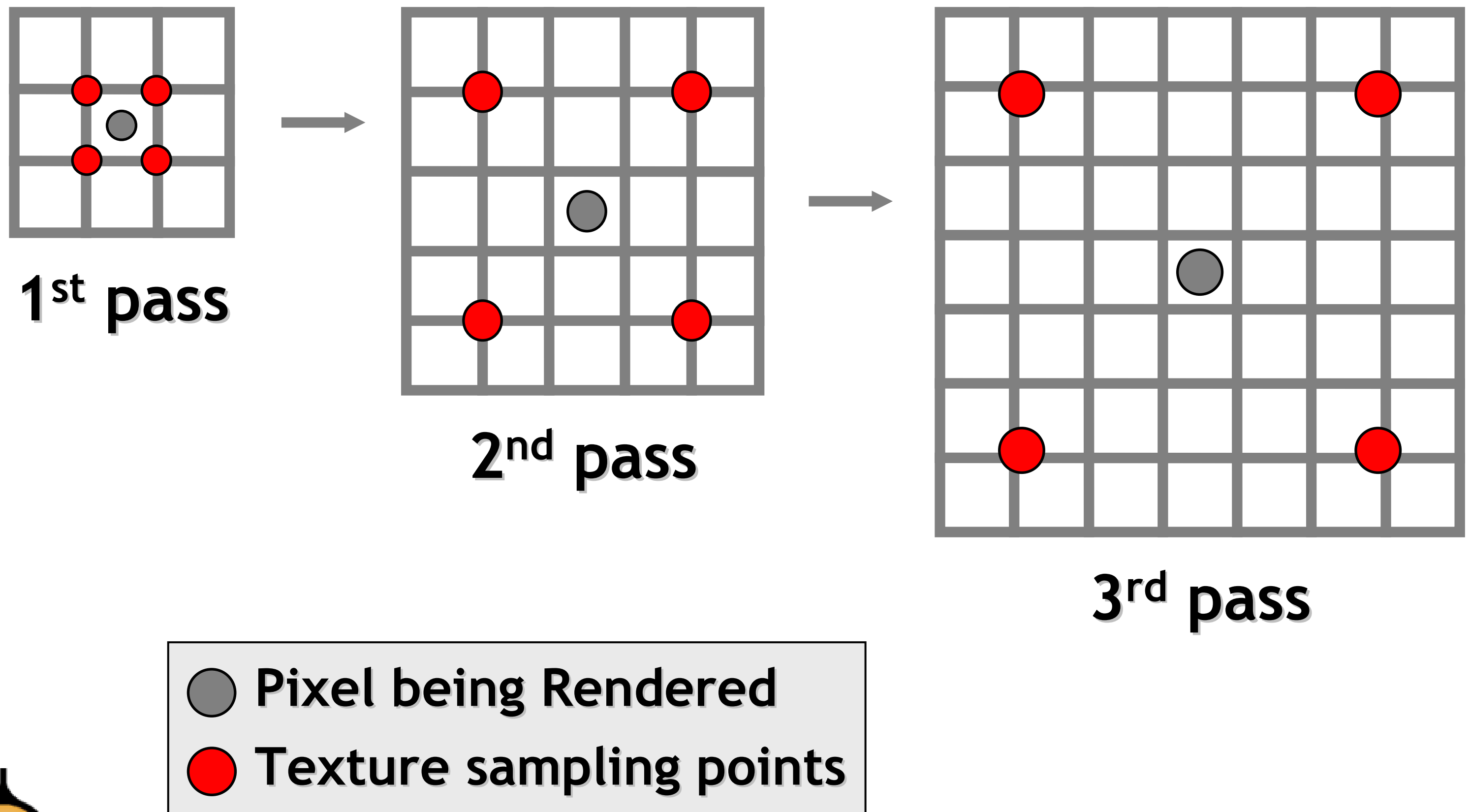
- HDR in Far Cry follows standard approaches
  - Kawase's bloom filters
  - Reinhard's tone mapping operator
  - See DXSDK sample
- Performance hint
  - For post processing try splitting your color into rg, ba and write them into two MRTs of format G16R16F. That's more cache efficient on some cards.

# Bloom from [Kawase03]

- Repeatedly apply small blur filters
- Composite bloom with original image
  - Ideally in HDR space, followed by tone mapping



# Increase Filter Size Each Pass




From [Kawase03]


GOD 0
NE
E
No HDR


HDR (tone mapped scene + bloom + stars)

# [Reinhard02] - Tone Mapping

1) **Calculate scene luminance**

   On GPU done by sampling the log() values, scaling them down to 1x1 and calculating the exp()

$$Lum_{avg} = \exp\left(\frac{1}{N}\sum_{x,y}\log(\delta + Lum(x,y))\right)$$

2) **Scale to target average luminance α**

$$Lum_{scaled}(x,y) = \frac{\alpha}{Lum_{avg}} Lum(x,y)$$

3) **Apply tone mapping operator**

$$Color(x,y) = \frac{Lum_{scaled}(x,y)}{1 + Lum_{scaled}(x,y)}$$

- To simulate light adaptation replace $Lum_{avg}$ in step 2 and 3 by an adapted luminance value which slowly converges towards $Lum_{avg}$
- For further information attend Reinhard’s session called “Tone Reproduction In Interactive Applications” this Friday, March 11 at 10:30am

# HDR – Watch out

- Currently no FSAA
- Extremely fill rate hungry
- Needs support for float buffer blending
- HDR-aware production[1] :
  - Light maps
  - Skybox

1) For prototyping, we actually modified our light map generator to generate HDR maps and tried HDR skyboxes. They look great. However we didn't include them in the patch because…
   - Compressing HDR light map textures is challenging
   - Bandwidth requirements would have been even bigger
   - Far Cry patch size would have been huge
   - No time to adjust and test all levels

# Conclusion

- Dynamic flow control in ps_3_0
- Geometry Instancing
- High Dynamic Range Rendering

# References


- [Kawase03] Masaki Kawase, "Frame Buffer Postprocessing Effects in DOUBLE-S.T.E.A.L (Wreckless)," Game Developer's Conference 2003
- [Reinhard02] Erik Reinhard, Michael Stark, Peter Shirley and James Ferwerda, "Photographic Tone Reproduction for Digital Images," SIGGRAPH 2002.

# Questions?

carsten@crytek.de

## Thanks to…

Martin Mittring & Andrey Khonich @ Crytek

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