Shaders in Eve Online

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EVE Online


EVERYONE
Y U NO PLAY EVE!?

Eve Online

- Trinity
  - First released 2003
  - Proprietary graphics engine
  - DirectX 9 (DX11 on its way)
  - Shader Model 3 (4 & 5 in development)
  - HLSL

Turning this

0	granny_real32 Position	-26.500799	85.897544	-21.859985	
	granny_uint8 BoneWeights	255	0	0	0
	granny_uint8 BoneIndices	0	0	0	0
	granny_real16 Normal	-0.322265	0.751953	-0.574707	0
	granny_real16 Tangent	-0.056732	0.590820	0.804687	0
	granny_real16 Binormal	0.944824	0.291992	-0.147705	0
	granny_real16 TextureCoordinates0	0.246093	0.079345		
1	granny_real32 Position	-26.500797	87.188888	-15.219329	
	granny_uint8 BoneWeights	255	0	0	0
	granny_uint8 BoneIndices	0	0	0	0
	granny_real16 Normal	-0.390869	0.619140	-0.681152	0
	granny_real16 Tangent	-0.225463	0.652832	0.723144	0
	granny_real16 Binormal	0.892578	0.436279	-0.115722	0
	granny_real16 TextureCoordinates0	0.258544	0.079711		

...

9692	granny_real32 Position	-49.182678	70.347160	-62.935657	
	granny_uint8 BoneWeights	255	0	0	0
	granny_uint8 BoneIndices	1	1	1	1
	granny_real16 Normal	-0.805664	0.496337	0.323242	0
	granny_real16 Tangent	0.211914	0.751464	-0.625000	0
	granny_real16 Binormal	-0.553222	-0.435058	-0.710449	0
	granny_real16 TextureCoordinates0	0.422119	0.091247		
9693	granny_real32 Position	-41.317810	77.452629	-66.020416	
	granny_uint8 BoneWeights	255	0	0	0
	granny_uint8 BoneIndices	1	1	1	1
	granny_real16 Normal	-0.293212	0.897949	0.328369	0
	granny_real16 Tangent	0.101501	0.370849	-0.923339	0
	granny_real16 Binormal	-0.950683	-0.237426	-0.199951	0
	granny_real16 TextureCoordinates0	0.435058	0.104003		

Into this

HLSL code structure

- **Matrices, Variables and Structures**
- **Vertex Shaders**
- **Pixel shaders**
- **Techniques**
- **Functions**

HLSL code structure

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Matrices, Variables and Structures

```
//<variable name> : SEMANTIC FROM APP

//world space
float4x4 wMatrix : World;

//World View Projection
float4x4 wvpMatrix : WorldViewProjection;

//contains camera position
float4x4 vitMatrix : ViewInverseTranspose;
```

Matrices, Variables and Structures

```
// -----------------------------------------------------------
// Vertex shader input
// -----------------------------------------------------------

struct SimpleAppVtx
{
    float3 pos : POSITION;
    float3 normal : NORMAL;
    float3 tangent : TANGENT;
    float3 bitangent : BINORMAL;
    float2 texcoord : TEXCOORD;
};
```

Matrices, Variables and Structures

```
// -----------------------------------------------------
// Vertex shader output / Pixel shader input
// -----------------------------------------------------

struct SimpleShaderVtx
{
    float4 posClip : POSITION;
    float2 texcoord0 : TEXCOORD0;
};
```

Matrices, Variables and Structures

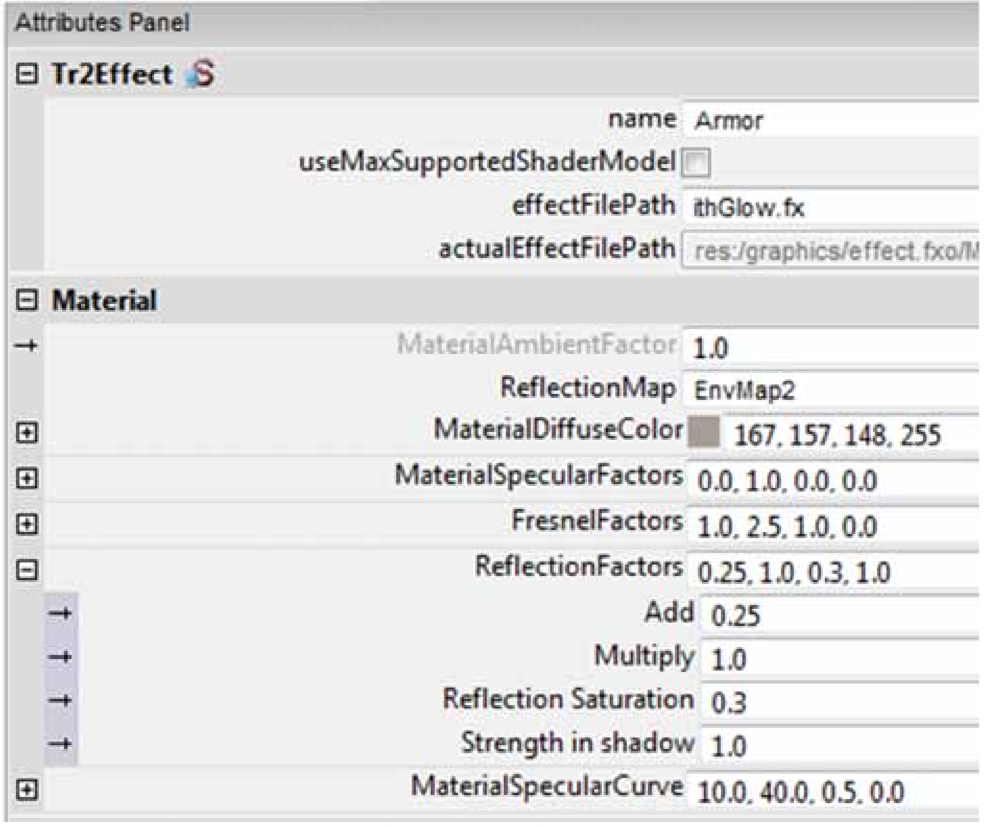
```
struct StandardShaderVtx
{
    float4 posClip : POSITION;
    float4 texcoord01 : TEXCOORD0;
    float3 normalWorld : TEXCOORD1;
    float3 tangentWorld : TEXCOORD2;
    float3 bitangentWorld : TEXCOORD3;
    float4 eyeDirWorld : TEXCOORD4; // 4th component is the
fogcoefficient (0 = full fog, 1 = no fog)
    float3 posWorld : TEXCOORD5;
#if SHADOW_ENABLED
    float4 posShadowView : TEXCOORD7;
    float4 posShadowViewProjection : TEXCOORD8;
#endif
};
```

Matrices, Variables and Structures

```
struct BaseLightingParams
{
    float3 normalWorld;
    float diffuse;
    float specularMaskedBrightness;
    float specularDot;
    float3 pointLights;
    float3 reflectDir;
};
```

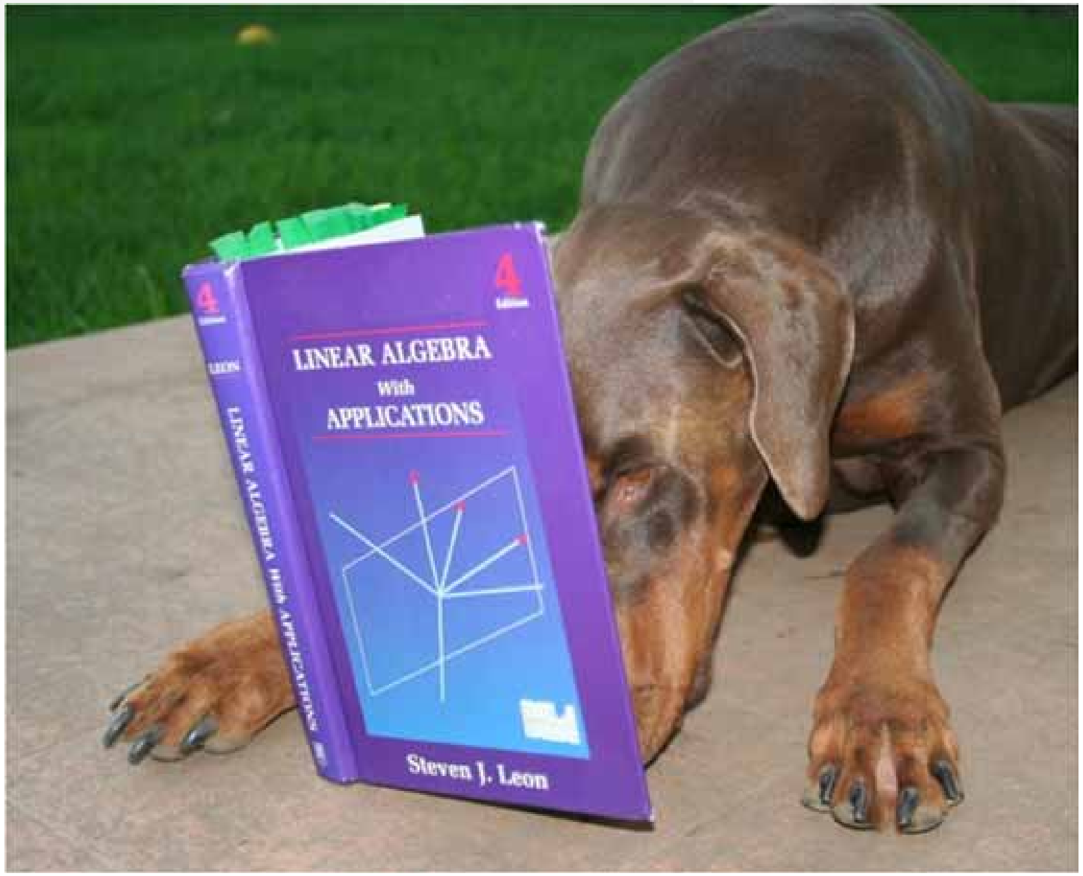
Matrices, Variables and Structures

```
float4 ReflectionFactors
<
    string Group = "Material";
    bool SasUiVisible = true;
    string UIWidget = "VectorMixed";
    string Component1 = "Add";
    string Component2 = "Multiply";
    string Component3 = "Reflection Saturation";
    string Component4 = "Strength in shadow";
> = { 1.0, 1.0, 0.0, 1.0 };
```



HLSL code structure

- Matrices, Variables and Structures
- **Vertex Shaders**
- Pixel shaders
- Functions
- Techniques



Vertex Shaders

```
StandardShaderVtx StandardVS( StandardAppVtx inVtx, float4x4 world )
{
    StandardShaderVtx outVtx = (StandardShaderVtx)0;

    // position
    float4 posWorld = mul( float4( inVtx.pos, 1.0f ), world );
    outVtx.posClip = mul( posWorld, PerFrameVS.ViewProjectionMat );
    // texcoord
    outVtx.texcoord01 = inVtx.tex.xyyy;
    float4x4 worldInverseTranspose = PerObjectVS.WorldInverseTransposeMat;
    outVtx.normalWorld = mul( inVtx.normal, worldInverseTranspose );
    outVtx.tangentWorld = mul( inVtx.tangent, worldInverseTranspose );
    outVtx.bitangentWorld = mul( inVtx.bitangent, worldInverseTranspose );
    float3 eyePosWorld = ExtractEyePosFromViewMatrix( PerFrameVS.ViewInverseTransposeMat );
    float3 pos2eye = eyePosWorld - posWorld.xyz;
    float4 eyeDirWorld;
    outVtx.eyeDirWorld = float4( normalize( pos2eye ), 0.0f );
    outVtx.posWorld = posWorld;
    ProjectPositionToShadow( posWorld, outVtx.posShadowView, outVtx.posShadowViewProjection );
    return outVtx;
}
```

HLSL code structure

- Matrices, Variables and Structures
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- Functions
- Techniques

Pixel Shaders

```
float4 SinglePS( StandardShaderVtx inVtx ) : COLOR
{
    BaseLightingParams params = CalcBaseLightingParams( inVtx );
    float4 diffuseMap = tex2D( DiffuseMapSampler, inVtx.texcoord01.xy );
    return ColorWithFog( inVtx, CalcBaseLighting( params, diffuseMap,
MaterialDiffuseColor, MaterialAmbientFactor, MaterialSpecularFactors,
MaterialSpecularCurve ) );
}
```

HLSL code structure

- Matrices, Variables and Structures
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- Pixel shaders
- **Functions**
- Techniques

Functions

```
struct BaseLightingParams
{
    float3 normalWorld;
    float diffuse;
    float specularMaskedBrightness;
    float specularDot;
    float3 pointLights;
    float3 reflectDir;
};
```

```
BaseLightingParams CalcBaseLightingParams( StandardShaderVtx inVtx )
{
    BaseLightingParams ret;
    ret.normalWorld = CalcNormalFromMap( inVtx );
    ret.pointLights = CalcPointLightsColor( inVtx.posWorld, inVtx.normalWorld );
    float2 brightness = CalcBrightnessFromShadowMap( inVtx );
    // diffuse
    ret.diffuse = saturate( 2.0f * dot( ret.normalWorld, PerFramePS.Sun.DirWorld ) - 0.2f );
    ret.diffuse *= brightness.x;
    // specular
    float3 halfDirWorld = normalize( PerFramePS.Sun.DirWorld + inVtx.eyeDirWorld.xyz );
    ret.specularDot = saturate( dot( ret.normalWorld, halfDirWorld ) );
    float specularMask = GetSpecularStrengthFromMap( inVtx.texcoord01.xy );
    ret.specularMaskedBrightness = specularMask * brightness.x;
    // reflection (Need to negate the reflect function since it is implemented all backwards!)
    float3 reflectDirWorld = -reflect( inVtx.eyeDirWorld, ret.normalWorld );
    ret.reflectDir = mul( float4( reflectDirWorld, 1.0 ), ReflectionMapTransform );
    return ret;
}
```

HLSL code structure

- **Matrices, Variables and Structures**
- **Vertex Shaders**
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- **Functions**
- **Techniques**

Techniques

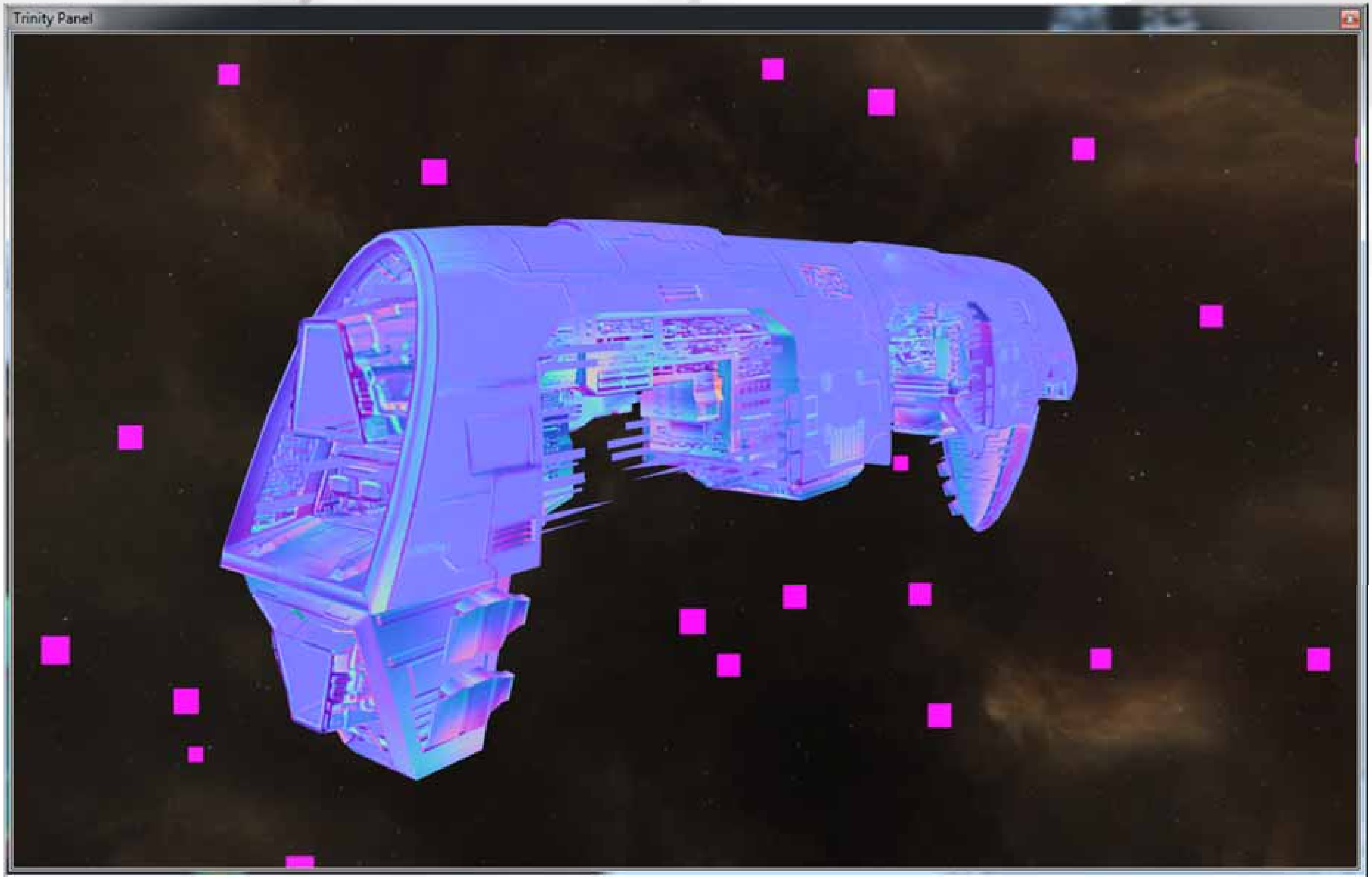
```
technique Main
{
    pass P0
    {
        // We can put device state changes here,
        // But we try not to do them per-shader
        // Explained later in the talk.

        VertexShader = COMPILE_VS( StandardStaticVS );
        PixelShader  = COMPILE_PS( SinglePS );
    }
    pass P1
        ...
}
```

Textures

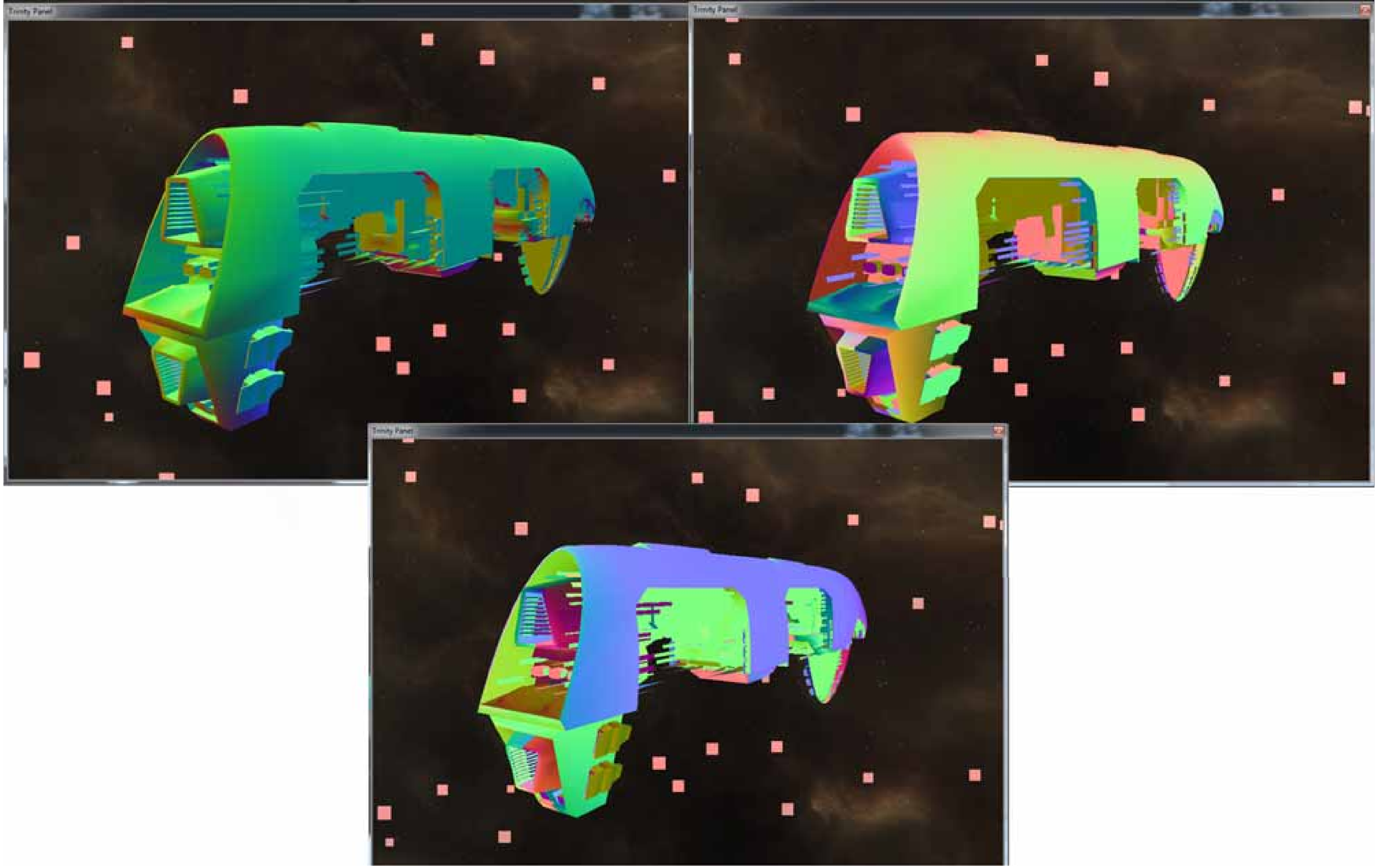
Diffuse

Specular map

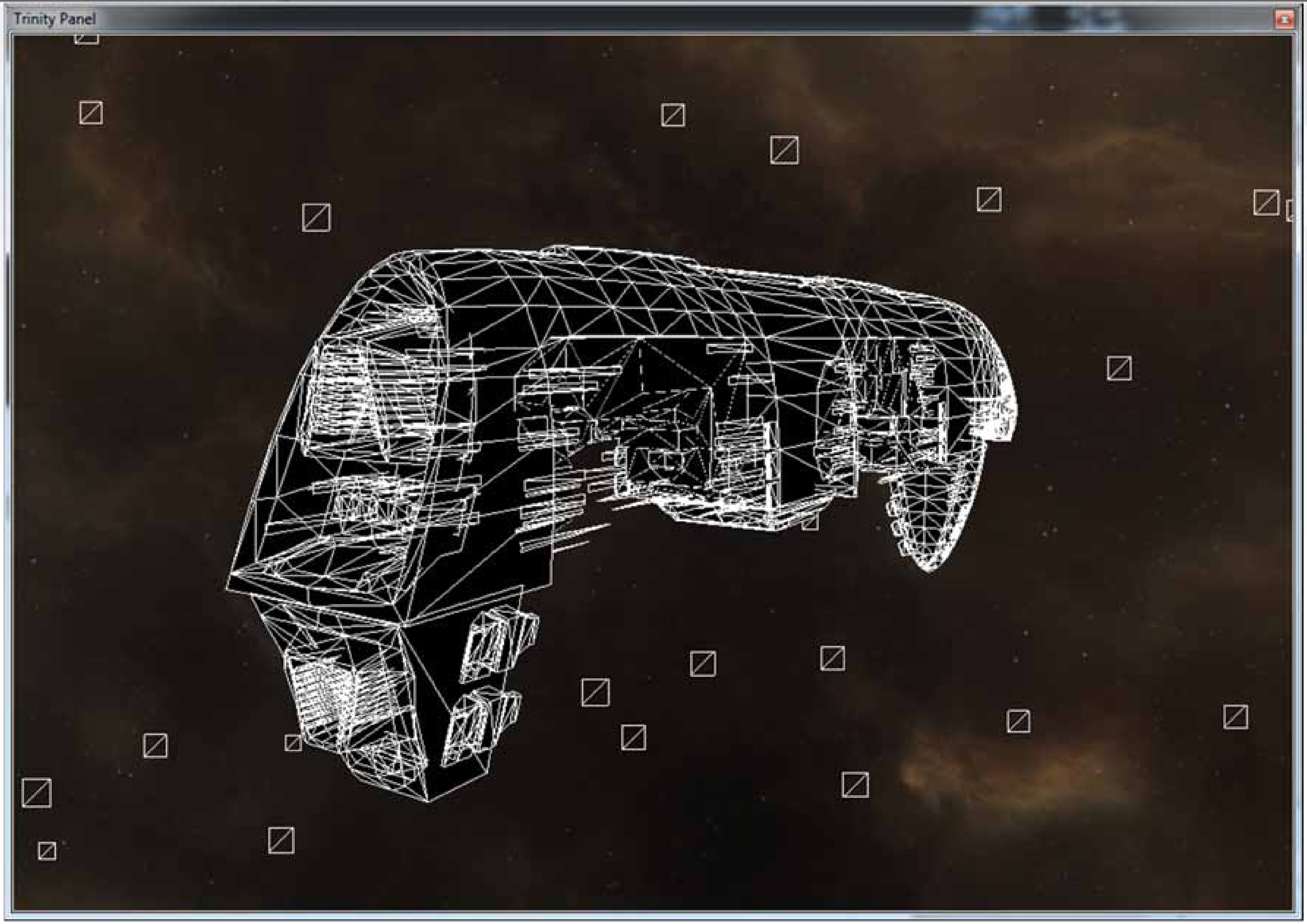
Normal map



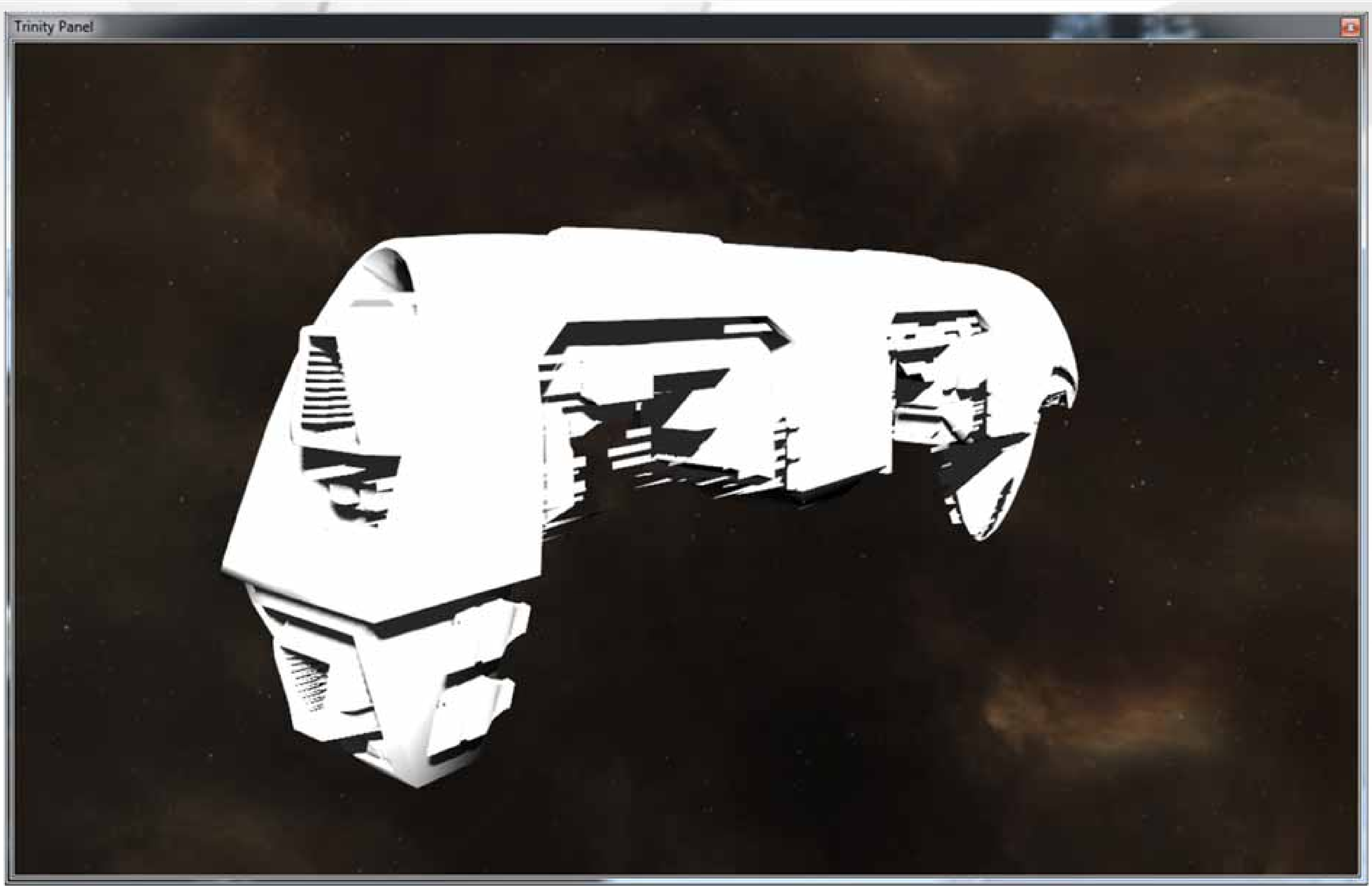
Object normals, tangents and bitangents



Wire frame



Shadow map



Shadows – shadow maps

- For each object receiving shadows
  - Create a frustum from the bounding info of the object
  - Use this frustum to gather list of objects casting shadows on this object
  - Render the shadow casters using the frustum
    - In Eve the sun is always assumed to be far away so we use orthogonal projection matrix
    - We override the pixel shader, but keep the vertex shader intact
  - Only store the depth, discard the color info
  - End up with one shadow map per receiver

Shadows continued

- During rendering
  - We project the pixel position into the light's coordinate space using the light's view and projection transforms
  - The depth in the camera's frustum is the z value of the projected position
  - The x and y values are used to calculate the UVs needed to look up into the shadow map rendered earlier.
  - If the projected value is closer to the light than the value read from the texture the pixel in question is not behind a shadow caster, and is fully lit.

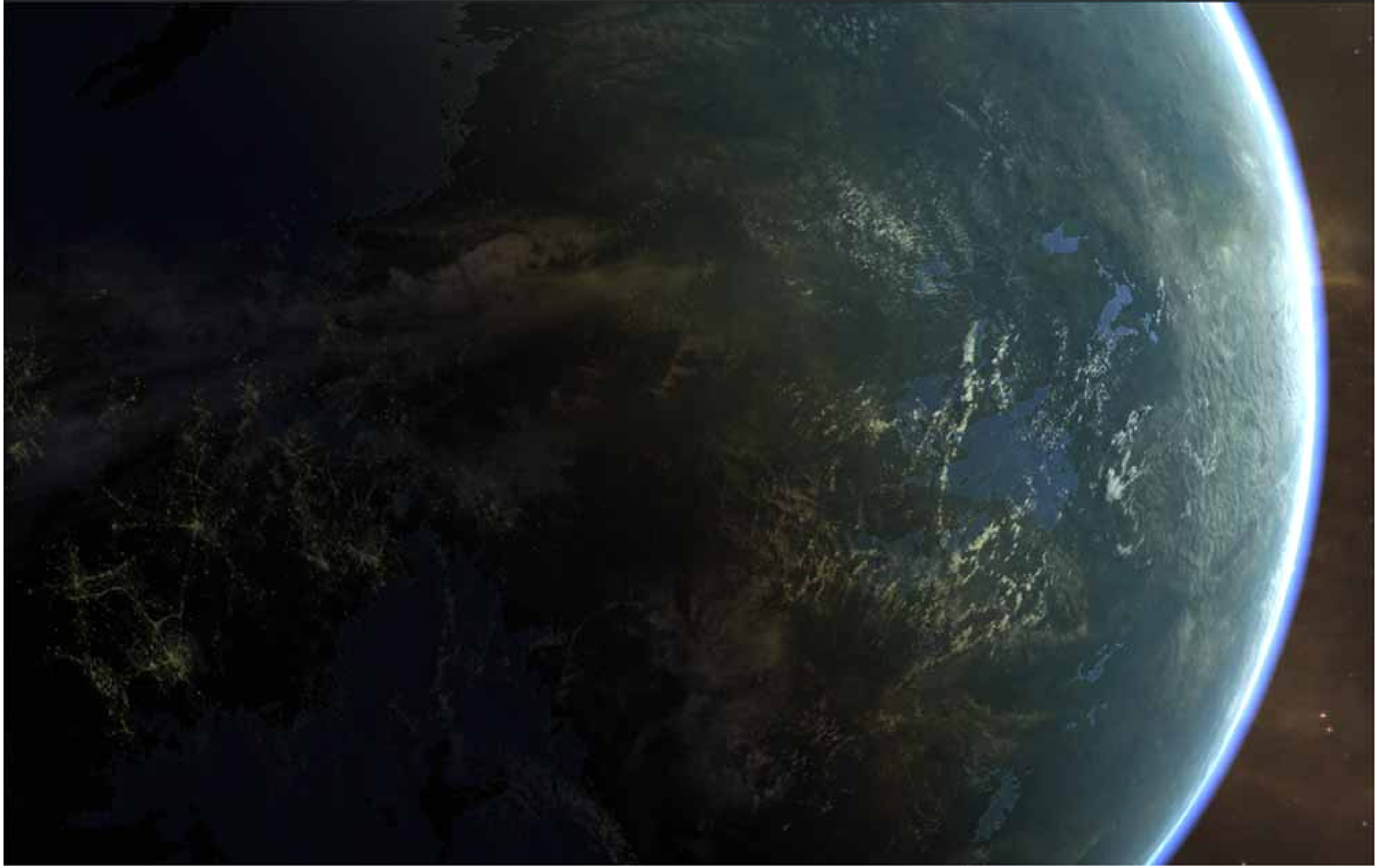
Trinity graphics engine

- Batches
  - Sending triangles to the GPU is fairly slow
  - A batch is a group of triangles that you can render with one draw call
  - We want to have few draw calls
  - We want to have few device state changes
- Trinity uses “areas” for this purpose
  - Each object in the scene has a list of different area lists
  - The most commonly used are opaque, decal, transparent and additive

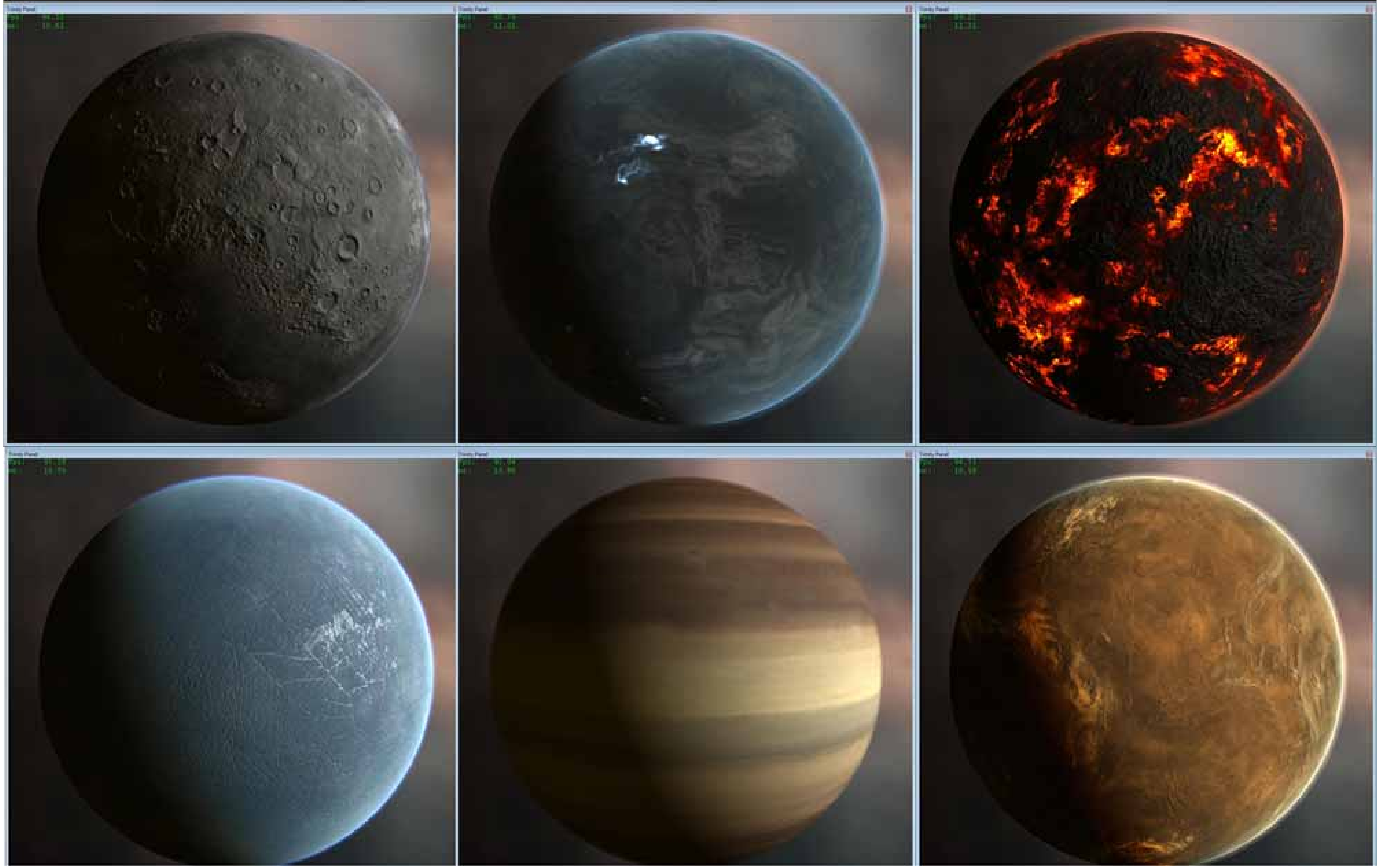
Trinity graphics engine

- Areas
  - During rendering we gather the batches from each area type and render together
  - We only change render states between batches
  - Opaque batches are not sorted
    - Should they be?
  - Transparent batches are sorted and rendered back to front
  - Additive areas are not sorted

Not just ships



Not Just ships

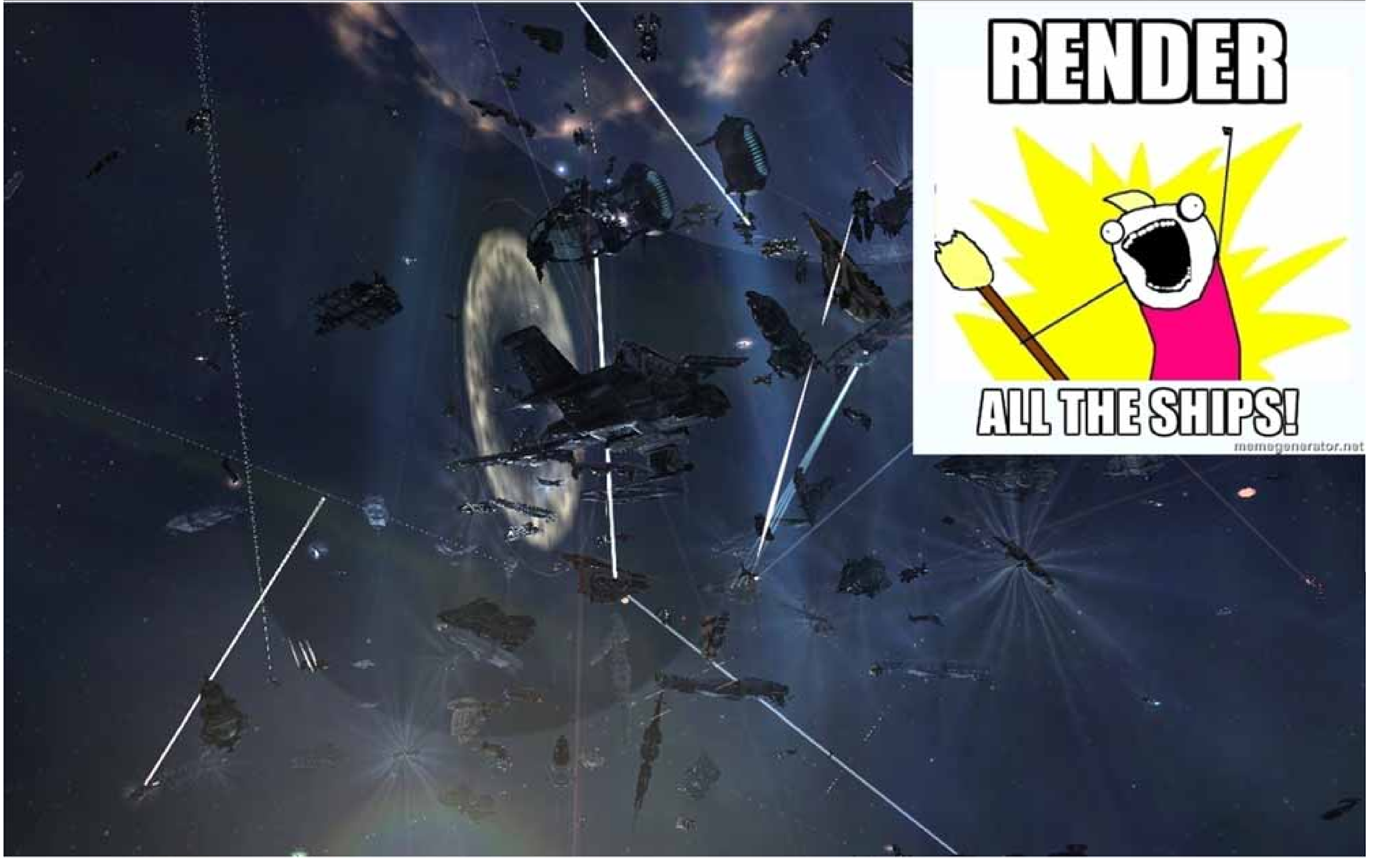


Not just ships

Not just ships

But sometimes A LOT OF SHIPS

But sometimes A LOT OF SHIPS



Depth effects – God rays

God rays

- Render depth to a texture
- Render a quad centered on the sun
- In the pixel shader:
  - Use VPOS to get screen UV
  - Walk form this screen position to the center of the quad
  - For each step, sample the depth map, with random jitter and compare the value to a threshold
  - Accumulate all “Hits” and find the occlusion ratio
  - Subtract the occlusion from the texture of the quad (a faint glow)

God rays

```
for (int i = 0; i < numSamples; ++i)
{
    float ratio = (float)i / (float)numSamples;
    float2 uv = lerp( screenTextureUV, spriteCenterScreen, ratio + noise);
    depth = GetDepthFromMirroredTexture( uv );
    occlusion += step(thresholdDepth, depth);
}
texColor = saturate( texColor - float4(occlusion.xxx, 0.0 ) );
```

Physical not always best

- We make games, not simulations
- Art director has the final say
- Artists want control
- If a cheap hack delivers almost the same results, then by all means hack away.

Best practices

- **General Performance Tips**
  - Clear only when you must.
  - Minimize state changes and group the remaining state changes.
  - Use smaller textures, if you can do so.
  - Draw objects in your scene from front to back.
  - Use triangle strips instead of lists and fans. For optimal vertex cache performance, arrange strips to reuse triangle vertices sooner, rather than later.
  - Gracefully degrade special effects that require a disproportionate share of system resources.

Best practices

- **General Performance Tips**
  - Constantly test your application's performance.
  - Minimize vertex buffer switches.
  - Use static vertex buffers where possible.
  - Choose texture formats wisely.
  - Draw using indexed primitives. This can allow for more efficient vertex caching within hardware.
  - If the depth buffer format contains a stencil channel, always clear the depth and stencil channels at the same time.

Questions

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