Exploration of New Approaches to Depth-Based Render Techniques Utilizing Pixel Synchronization

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April 10, 2015

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1 Introduction and Background

Since the advent of computer graphics, engineers have been trying to find new ways to create graphics hardware solutions intended to yield higher performance and image quality. However, image quality can mean many things to many people. Individuals may use grapchics hardware to create vibrant and abstract experiences, where others may create an experience where the images being created are as photorealistic as possible. The question that graphics hardware engineers must ask, is, "What can we make that will help developers create a higher quality experience?" For some GPU distributors, the solution comes with a concept called Pixel Synchronization.

Before we get into the gory details of what my project is all about, there are some key concepts that must be covered. This project utilized a lot of different concepts within Computer Science outside of the realm of graphics. We first need to cover what the hardware is and why it is different, then take a general look at the graphics pipeline, and finally discuss two key topics in parallel programming. My goal is to make sure my rationale for this project is completely clear.

1.1 Project Environment Details

At the beginning of this project, we did not have any choices, as far as what chip/chipset on which to run and test our code. The hardware we used has the Intel® Core i7, since this CPU/GPU includes the Iris™ Graphics Pro 5200. This project was developed as a desktop application on Windows 8.1, using the DirectX 11 SDK. Any and all references to Pixel Synchronization calls are done according to how they are implemented in the Intel DirectX extensions. Within the application, all HLSL code was compiled using the HLSL version 5.0, as any lower version does not support the extensions needed to access Pixel Synchronization.

1.2 The Graphics Pipeline

In modern computer graphics, we describe our objects mathematically as a group of vertices, then pass them to the graphics card where the vertices are connected and then drawn to the screen, given constraints we have originally passed. In the beginning, all we, as graphics programmers could do was tell the GPU to draw, but then our influence on the graphics was over. Later on, though, the ability to program stages of the pipeline became possible. With this programmability of the pipeline, graphics programmers now have the ability to create and define custom effects for the graphics card to carry out and process.

1.2.1 The Vertex Shader

The Vertex shader is the area of entry for every 3D point. Within the vertex shader, the GPU generally stores the key information and properties of each vertex, prior to passing it through to the later stages of the pipeline for these values to be interpolated. The purpose of this, is that it greatly reduces the amount of space needed to express the looks and properties of an object. If we can describe the key pieces of information at a few points on the object, the idea is that the GPU will be able to make informed assumptions about the other parts of the model where we have provided no information, thus filling in/connecting the dots.

1.2.2 The Pixel/Fragment Shader

Depending on Direct3D or OpenGL, this stage of the pipeline is either called the Pixel Shader or the Fragment Shader, respectively. Prior to the Pixel Shader stage, the 3D object has been transformed, and the object's properties have been interpolated across its entire surface. After this interpolation takes place, the GPU then decides where, in screen space, the object is, then runs the pixel shader to color those specific pixels. Most rendering techniques do most of their lighting effects and color computations at this stage of the pipeline to help create a smoother coloring of the model. In a traditional pipeline, the pixels are evluated in parallel, making rendering a potentially fast process. The tradeoff, however, is that with increased rendering speed comes a lack of knowledge of other parts of the object being evaluated. The more naive the pixel is about its neighbors or its surroundings, the quicker the computation will finish, and the final image displayed.

1.3 Parallel Programming

Pixel Synchronization and my implementation of these different render techniques borrow concepts from parallel computing. As vertices are passed through the pipeline and on to the pixel shader, these parts of the pipeline are actually happening in parallel for all of the different instances of vertices and pixels. The problem with doing anything depth-based in realtime graphics, is that each fragment or potential pixel doesn't really have any knowledge of any of the neighboring pixels, they do not execute in any specific order, either. In order to know if one potential pixel is deeper than another potential pixel, we need a predictable way of determining this. If we were to naively try to gather this information within the pixel shader, we would run in to a race condition. We also need a way to share this information across different instances of the pixel shader.

1.3.1 Shared Resources

To determine the depth of a certain spot of a 3D model within the pipeline, we need some sort of a way for the related potential pixels to communicate with each other. To do this, we use a feature of Direct3D 11 called Unordered Access Views. Unordered Access Views (UAVs) are basically a read/write texture that can only be accessed within the GPU, during the Pixel Shader stage. UAVs can be used in either a 1 or 2 dimensional array. The size of the UAV is specified to the graphics device before rendering begins. Within the shader, the programmer must take care to list the UAVs in the same order as they are initialized within the CPU side of the application. Once properly initialized, the UAVs are identified within the shader as RWTexture2D data structures.

1.3.2 Synchronization and Barriers

Oftentimes, in parallel programs, we must make sure our threads (or in the case of this project, pixels) are synchronized and executed in some sort of order. If we know that our programs are executed in some predictable order, it is easier for us to write more advanced algorithms or have guaranteed knowledge of what data lies at each checkpoint. If barriers did not exist, we come across **race conditions**. When an algorithm is written where race conditions exist, it is difficult, or impossible to predict the output of the algorithm, itself.

1.4 Pixel Synchronization

1.4.1 What is Pixel Synchronization?

With Pixel Synchronization, the pipeline is now capable of creating a barrier during the pixel shader stage per pixel, where multiple instances of the pixel being rendered will happen in-order, based on the primitive number. Parallel programming concepts such as barriers and synchronization have not before been possible within the real-time pipeline. To have this emerging hardware capability gives programmers the opportunity to approach existing render techniques from a new angle, potentially yielding higher performance and more spectacular images.

1.4.2 How Pixel Synchronization Works in Code

On the programmer side, there is not much coding overhead as far as initializing, then calling Pixel Synchronization. On the application side, the programmer must first check the hardware to make sure that the hardware is capable of Pixel Synchronization. This is the only thing to be done on the application side. Within the pixel shader, we have to first enable Pixel Synchronization with a call to **IntelExt_Init()**. Then, once we reach the part of our code that must be syncrhonized, we must call the pixel ordering function by calling **IntelExt_BeginPixelShaderOrdering()** (**NOTE:** These function calls are hardware specific. Please see section 1.1 on page 1 for details about the hardware used for this project). An important point to keep in mind is that this specific implementation of Pixel Synchronization lasts until the end of the Pixel Shader code. What this means, is that it is recommended that all code over which syncronization must occur should come as close to the end as possible. Listing 1.1 (below) shows how a bare bones Pixel Shader using Pixel Synchronization might look. For more information on how Pixel Synchronization works, please rever to section 5.3.

```
1  float4 PSExample(/*parameters...*/) : SV_TARGET
2  {
3
4          //Variable Definitions
5
6          IntelExt_Init();
7
8          //all non synchronization-specific code;
9
10         IntelExt_BeginPixelShaderOrdering();
11
12         //all synchronization-specific code goes here
13         //critical section must happen at the end.
14
15         return finalColor;
16 }
```

Figure 1.1: How Pixel Synchronization Pixel Shader Code Might Look

2 Simple Subsurface Scattering

2.1 What is Subsurface Scattering?

Subsurface Scattering is a phenomenon which occurs when photons hit some sort of translucent material, such as skin, fat, milk, plant leaves, etc. The photons enter that material, scatter, then exit out of a different point. This phenomenon is constantly and naturally occuring in the real world, but it is a rather tough lighting effect or phenomenon to calculate in realtime graphics, since knowledge of the object, and sometimes its surrounding environment, is required to produce an image with accurate subsurface scattering effects. Even so, many approximate implementations have been developed to mimic this natural phenomenon as convincingly as possible, all while retaining performance/framerate.

All of the techniques out there attempt to find a fast way to build knowledge of the 3D object (what is its depth at a certain point, and where is it with respect to the light). The techniques that exist are either quite general, or are very complex, coding wise (further detail to come below). Pixel Synchronization offers a new approach to the subsurface scattering problem that is both straightforward and does not sacrifice performance.

2.2 Previous Implementations

As stated above, there exist approaches to approximating the subsurface scattering effect in realtime graphics. The two approaches detailed below have trade-offs, when it comes to generality or coding complexity. However, both methods are quite effective within the correct scope. With the Pixel Synchronization approach detailed in section 2.3 (pg.5), we hope to improve upon these two methods by creating a more detailed and accurate approach, while keeping the code intuitive.

2.2.1 Wrapping Approximation

This simple approach to a subsurface scattering approximation takes the calculation of the diffuse component of your standard Phong lighting equation, and basically "wraps" the diffuse around the object further than the standart diffuse calculation. For instance, is illustrated in the equation in Figure 2.1 (where L is the light vector and N is the normal vector).

$$diffuse = max(0, L \bullet N)$$

Figure 2.1: Standard diffuse calculation in smooth shading

However, when we apply the wrapping approximation, the equation for the diffuse component is slightly changed. In Figure 2.2, the programmer specifies a wrap value, or makes the value interactive to show the difference in realtime, then the value is applied to the existing equation as follows:

$$diffuse = max(0, ((L \bullet N) + wrap) \div (1 + wrap))$$

Figure 2.2: Diffuse Calculation in smooth shading with wrap value added

As can be seen by observing the above equations, the addition of the wrapping value in equation complicates it only slightly, but the effect of adding the is very apparent. The advantage to this approach is that it requires only a slight modification of Phong illumination. Within shader code, a graphics programmer could insert a hook in their shader code to show the difference between Phong Illumination with and without diffuse wrapping. For an idea on how this is implemented, refer to the code listing in figure 2.3.

```
1 float calc = dot(Normal, Light) + wrap) / 1 + wrap);
2 if(mode & DIFFUSE_WRAP) d = max(calc, 0);
3 else d = max(dot(Normal, Light), 0);
```

Figure 2.3: HLSL hook to determine whether or not to wrap the normal

In line 2, a bitwise 'and' operator is used to check if wrapping has been selected because all display mode settings are passed into the graphics program as a single unsigned integer (in OpenGL, this would be the same as passing in a single uniform variable to evaluate all user true-false settings. This saves time and space when passing these types of variables to the GPU). A more detailed discussion about this and why this approach for uniform variables is used can be found in section **??** on page **??**.

2.2.2 Depth Mapping

Given the nature of what Subsurface Scattering is, it is imperative to know the thickness of the object in question, such that the programmer can make a decision on how much light escapes the obejct at a different point. For this reason, a technique was developed called depth mapping. In the first pass, the scene is rendered from the light's position, toward the object, where we store the distance from the light to that location on the object. Another pass is made to measure where the ray has entered and exited, by mapping the depths to the object's texture space. Finally, in the render pass, we render the object from the camera's point of view, and for each point on the object being rendered, we find the point of entry and the point of exit for the specific ray pertaining to the current fragment of the object, then calculated the distance between the two. After this distance has been calculated, the new calculation of the diffuse light can be applied. For a visual representation of the render pass of the approach, see figure 2.5 on page 6.

The effect from this approach causes more of a subsurface scattering type of "lifelike glow" than the method detailed in Section 2.2.1. However, when this method is implemented, it requires three passes to render the image with correct depth information. Further, there is no intuitive way to project the the depth information with respect to the light to the object. To recap, here are the three render passes that take place.

2.3 Pixel Synchronization Accelerated Depth Mapping

The approach described in section 2.2.2 is the groundwork for the new Pixel Synchronization accelerated approach. The concept remains relatively the same, however, we are able to use a psuedo raytrace to guage the distance between two points in the same ray with increased ease. This more straighforward approach to depth mapping takes less time to code and yields no loss of performance.

First Pass

Render the object from the perspective of the light and record the distances from the light.

Second Pass

Calculate the distances between the entry and exit points of the light rays. These will be mapped, in texture space, to the object.

Third Pass

Use the depth calculations to scale the backfacing (with respect to the light) diffuse component of the object.

Figure 2.4: Description of the depth mapping approach to subsurface scattering

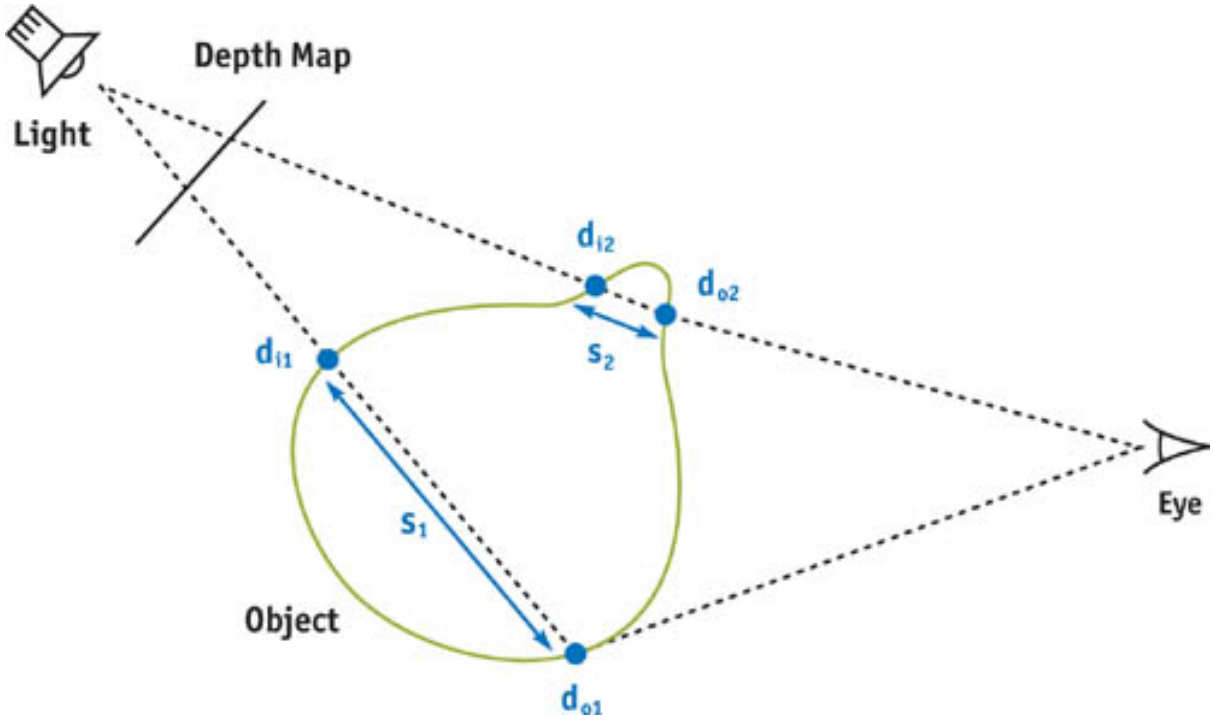

Figure 2.5: Diagram to visualize how the depth map is used to calculate the distance a light ray has traveled within a 3D object

2.3.1 In-Depth Description of Implementation

As stated above, the approach to this technique remains generally the same, but with a few differences. For clarity's sake, refer to the description in 2.4 as a reference to what the changes in the pixel shader based approach would be, in comparison to the description below.

First Pass

This pass remains relatively the same. We take this pass to map which pixel from the perspective of the light. However, we map the object to the screen with respect to its texture coordinates. This way, we guarantee that all of the object is being seen and processed by the GPU. For a better idea of what this means, see the listing 2.6 on page 8. More specifically, see lines 6 through 8. Here, we take the text coordinates, then convert them into a space spanning from -1 to 1 in the x and y axes. Then, when these positions are passed from the vertex to the pixel shader, they are converted to screen space.

After this screen space conversion, we calculate and store the distance of each part of the model from the light source. Following this, we then map which rays intersect which parts of the model in 3D space. This is why we also store and keep track of the 3D position of the model, as seen on line 11 in listing 2.6. We map these ray values (which coincide with the pixels) to another texture, which we will use in the next pass as a "mask." For an idea of these mappings, refer to 2.7 on page 9. We use Unordered Access Views to accomplish these mappings (5.1, page 18).

Second Pass

This pass is from the perspective of the light, but this time, we project the correct object into space, rather than its texture coordinates. The only difference here, is that $output.svposition$ gets $mul(final, position)$ rather than the calculated screen space coordinates as it does in line 9 of figure 2.6. However, within the Pixel Shader this time, we create our shallow mask. This is basically a UAV-created depth buffer to keep the shallowest positions with respect to the light. To see how this is implemented within the shader, please see listing 2.8 on page 9. With the aid of Pixel Synchronization, we can determine which parts of the object are closest to (facing) the light.

Third Pass

The final render pass remains the same as what we had in the approach on page 5. We take the current depth, with respect to the light, then compare it to the corresponding member of the shallow mask. For a coding example, turn to page 10 and see figure 2.9. The code block from lines 6 to 25 show how to both get the ray and the current light-based depth of the object, compare them, and then re evaluate the diffuse component, originally calculated above this section Other parts of the shader were edited out for the sake of readability and clarity. There will be a complete discussion on the code within $PSHader2()$ later on in this paper. We can get away with using array notation, since UAVs support access via array notation, and not with a call to $sample()$.

3 Refraction

Refraction is a visual phenomenon that occurs when a translucent object, such as a glass figurine, bends light in such a way that it distorts the image beyond it. This is how real-life

```
VOut VShader(...)
{
        VOut output;

        float2 movedCoords = texCoord * 2;
                movedCoords.x -= 1;
                movedCoords.y -= 1;
        float4 svPos = float4(movedCoords, 0.0, 1.0);
        output.svposition = svPos;
        output.position = mul(final, position);

        // set the ambient light
        output.color = ambientcol;


        float4 norm1 = normalize(mul(rotation, normal));
        float diffusebrightness = saturate(dot(norm1,lightvec));
        float4 norm = normalize(mul(final, normal));

        //output.color += lightcol * diffusebrightness;

        output.UVs.x = texCoord.x * SCREEN_WIDTH;
        output.UVs.y = texCoord.y * SCREEN_HEIGHT;

        output.normal = norm;

        output.camera = mul(final, lightPos);

        output.mode = mode;


        return output;
}
```

Figure 2.6: Vertex Shader for first Pass of Depth Map accelerated by Pixel Synchronization

lenses accomplish vision correction, or the image of an object gets distorted when it is submerged in water. As humans, we rely on refraction a great deal, so we are very, very used to seeing this effect on a day-to-day basis. There are many ways to accomplish the approximate effect of refraction on the GPU. The first approach, detailed in section 3.1, is a simple refraction algorithm, that takes into account only the front face of the object to compute the color of the object at that point.

```
float4 PShader(...) : SV_TARGET
{
        float2 svPos = position.xy;
        float mdepth = distance(position, camera);
        uint2 uv = UVs;

        svPos.y = 0 - svPos.y;
        svPos += 1;
        svPos = svPos / 2;

        float2 newPos;

        newPos.x = svPos.x * SCREEN_WIDTH;
        newPos.y = svPos.y * SCREEN_HEIGHT;

        fromLightX[uv] = newPos.x;
        fromLightY[uv] = newPos.y;
        uvDepth[uv] = mdepth;

        return color;
}
```

Figure 2.7: Pixel Shader from first pass of Pixel Synchronization-Accelerated depth mapping.

```
float4 POShader(...) : SV_TARGET
{
        uint2 pixelAddr = svposition.xy;

        float pos = distance(position, camera);

        IntelExt_Init();
        IntelExt_BeginPixelShaderOrdering();

        if (pos < Shallow[pixelAddr])
        {
                Shallow[pixelAddr] = pos;
        }

        return color;

}
```

Figure 2.8: Pixel Ordering step of the alternate approach to depth mapping

3.1 "Fake" Convex Object Refraction

The most used approach to refraction is to just bounce the viewing "ray" once on the front surface of the object, then samples the cubemap to return a color. In code, this effect requires

```
1  float4 PShader2(...)
2  {
3
4          /*...*/
5
6          if (!(mode & PHONG_RENDER))
7          {
8            uint2 lightCoords;
9
10           lightCoords.x = fromLightX[uv];
11           lightCoords.y = fromLightY[uv];
12
13           float mdepth = uvDepth[uv];
14
15           float shallow = Shallow[lightCoords];
16           if ((mode & PIXSYNC_OFF) &&
17               (uvDepth[uv] > Shallow[lightCoords])){
18
19                   float4 lColor = lightcol;
20                   lColor -=
21                     (uvDepth[uv] - Shallow[lightCoords]) * 3;
22
23                   diffuse += lColor;
24           }
25         }
26
27         /*...*/
28 }
```

Figure 2.9: Render Pass from perspective of camera

just a Vertex and Pixel Shader.

3.1.1 Vertex Shader

All of the heavy-lifting for refraction is done within the Vertex Shader (3.1). Given the proper transform and rotation matrices, the refract vector is computed within the Vertex shader. Essentially, the distance between

3.2 Better Convex Refraction With Pixel Synchronization

The idea behind this approach is to create a volumetric representation of the scene which stores the object's surface normals, with respect to the eye. For the render step, we could step through this voxelization at the entrypoint, then trace the first refracted ray to the exit point, refract again, then return this double-refracted color to give a more accurate coloring of the pixel.

```
1  VOUT VShader(...)
2  {
3
4          VOUT output;
5
6          output.svPos = mul(WVP, pos);
7          output.Pos = mul(WVP, pos);
8          float4 norm = mul(Rotation, normal);
9
10
11         float diffusebrightness =
12                         saturate(dot(norm, LightVector));
13
14         float3 ECPosition = mul(World, pos).xyz;
15         float3 eyeDir = float3(0.0f, 0.0f, 0.0f) - ECPosition;
16
17         output.Color = AmbientColor;
18
19         output.Color += LightColor * diffusebrightness;
20         output.Normal = norm;
21         output.texCoord = texCoord;
22
23         float3 reflectVector = refract(norm, eyeDir, -.90);
24
25                 output.vRef = reflectVector;
26
27
28         return output;
29 }
```

Figure 3.1: Vertex shader for simple refraction

3.2.1 Shader-Based Description of Implementation

To get our volumetric representation, I attempted (see section **??** for more details) to utilize the shader to take care of that for me. Using Pixel Ordering, I tried to create a voxel- based representation of the entire scene. I tried to use two 3D textures to accomplish this. One 3D texture would have $unsignedint$ representations of every voxel element saying whether it was inside, outside, or on the face of the object within the scene:

0: outside of the object

1: on the object's face

2: inside of the object

The suface normals are stored in another 3-D texture. We would first mark all of the spaces according to the above description. The surface normal texture is populated at the beginning of populating this unsigned integer texture. How this texture is populated can be better

```
1 float4 PShader( VOUT input ) : SV_TARGET
2 {
3         float3 bounceVec = input.vRef.xyz;
4
5         float4 newColor =
6          SkyMap.Sample(ObjSamplerState, normalize(bounceVec));
7
8         return newColor;
9 }
```

Figure 3.2: Pixel shader for simple refraction

described by the code within figure 3.3. On line 8, we begin our loop to populate the 3D texture. As can be seen, pixel ordering has been invoked within this shader. So, what we do is step through our $unsignedint$ Texture3D at every pixel address, in order. this way, we are able to indicate which parts of the scene are inside or outside of the model. We keep another 3D texture to keep track of the surface normals. The idea behind this, was once we hit an index in the $unsignedint$ Texture3D of value 1, we could then use that index where the 1 value is to refract the ray further, since that is where the surface normal at that point is stored in the other Texture3D. Using these textures in tandem serves as a good way to trace through a solid object to find the accurate refraction. However, I didn't get as far as a tracing stage to my algorithm, as there are fundamental aspects of this algorithm that GPU compilers do not allow to happen, due to memory access restrictions. This will be covered in more detail in section **??**, where the implementations will be discussed. However, the source code for this attempted demo will still be included in my final source code.

4 Findings

There are a lot of quirks and behaviors that have been logged throughout the entirety of this project. Firstly, I'd like to touch on the performance metrics of my project, and compare how it stacks up with existing algorithms, performance-wise, and also give a side-by-side comparison of the output images to show whether or not utilizing pixel synchronization to simulate a depth- based technique, such as a Subsurface Scattering approximation is worth it.

Following performance metrics, I will write about my observations of how the hardware, itself works, UAVs, and how they work, and then small coding oddities I found along my way toward my finishing my project. Included will be photos demonstrating behavior, along with explanations and recommendations on how to deal with these issues. The following sections are key to knowing how this hardware works, to extend to projects that use explore this same type of hardware (nVidia's Pixel Interlock technology, for example). Reading through this section should save time on the setup and boilerplate side of things.

```
1  float4 PShader(...)
2  {
3
4          IntelExt_Init();
5          IntelExt_BeginPixelShaderOrdering();
6
7          /*...*/
8
9          uint3 tempi = voxPos;
10
11         [loop]
12         for (i = voxPos.z + 1; i < 512; i++)
13         {
14                 tempi.z = i;
15                 unsigned int cond = VoxMask[tempi];
16                 if (cond == 0)
17                 {
18                         VoxMask[tempi] = 2;
19                         continue;
20                 }
21                 else if(cond == 2)
22                 {
23                         VoxMask[tempi] = 0;
24                         continute;
25                 }
26                 break;
27         }
28         /*...*/
29 }
```

Figure 3.3: Populating the *unsigned int* 3D texture.

4.1 Performance Metrics

4.1.1 Raw Performance Check of Pixel Synchronization

When just using pixel synchronization, the performance takes a 10% hit, regardless of model's resolution. This makes sense, since the pixel synchronization happens after the the primitive assembly and interpolation stage. To get as accurate of a measurment as possible, I disabled culling, such that every vertex of the model that is within the view volume is rendered.

This metric is consistent with the documentation that intel provides, discussing pixel synchronization. This test was also run with the critical section containing the entirety of the pixel shader, which was the pixel shader stage of the Phong illumination technique. Phong illumination was chosen for this test, due to ease of programming, and knowing that the illumination was as correct as possible. See the figure below for comparisons. The graph is organized by model, complete with listing the resolution of the model (how many vertices), the frames per second performance of each model.

4.1.2 Subsurface Scattering

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Cras dapibus, augue quis scelerisque ultricies, felis dolor placerat sem, id porta velit odio eu elit. Aenean interdum nibh sed wisi. Praesent sollicitudin vulputate dui. Praesent iaculis viverra augue. Quisque in libero. Aenean gravida lorem vitae sem ullamcorper cursus. Nunc adipiscing rutrum ante. Nunc ipsum massa, faucibus sit amet, viverra vel, elementum semper, orci. Cras eros sem, vulputate et, tincidunt id, ultrices eget, magna. Nulla varius ornare odio. Donec accumsan mauris sit amet augue. Sed ligula lacus, laoreet non, aliquam sit amet, iaculis tempor, lorem. Suspendisse eros. Nam porta, leo sed congue tempor, felis est ultrices eros, id mattis velit felis non metus. Curabitur vitae elit non mauris varius pretium. Aenean lacus sem, tincidunt ut, consequat quis, porta vitae, turpis. Nullam laoreet fermentum urna. Proin iaculis lectus.

Sed mattis, erat sit amet gravida malesuada, elit augue egestas diam, tempus scelerisque nunc nisl vitae libero. Sed consequat feugiat massa. Nunc porta, eros in eleifend varius,

erat leo rutrum dui, non convallis lectus orci ut nibh. Sed lorem massa, nonummy quis, egestas id, condimentum at, nisl. Maecenas at nibh. Aliquam et augue at nunc pellentesque ullamcorper. Duis nisl nibh, laoreet suscipit, convallis ut, rutrum id, enim. Phasellus odio. Nulla nulla elit, molestie non, scelerisque at, vestibulum eu, nulla. Ut odio nisl, facilisis id, mollis et, scelerisque nec, enim. Aenean sem leo, pellentesque sit amet, scelerisque sit amet, vehicula pellentesque, sapien.

Sed consequat tellus et tortor. Ut tempor laoreet quam. Nullam id wisi a libero tristique semper. Nullam nisl massa, rutrum ut, egestas semper, mollis id, leo. Nulla ac massa eu risus blandit mattis. Mauris ut nunc. In hac habitasse platea dictumst. Aliquam eget tortor. Quisque dapibus pede in erat. Nunc enim. In dui nulla, commodo at, consectetuer nec, malesuada nec, elit. Aliquam ornare tellus eu urna. Sed nec metus. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas.

Phasellus id magna. Duis malesuada interdum arcu. Integer metus. Morbi pulvinar pellentesque mi. Suspendisse sed est eu magna molestie egestas. Quisque mi lorem, pulvinar eget, egestas quis, luctus at, ante. Proin auctor vehicula purus. Fusce ac nisl aliquam ante hendrerit pellentesque. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Morbi wisi. Etiam arcu mauris, facilisis sed, eleifend non, nonummy ut, pede. Cras ut lacus tempor metus mollis placerat. Vivamus eu tortor vel metus interdum malesuada.

Sed eleifend, eros sit amet faucibus elementum, urna sapien consectetuer mauris, quis egestas leo justo non risus. Morbi non felis ac libero vulputate fringilla. Mauris libero eros, lacinia non, sodales quis, dapibus porttitor, pede. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Morbi dapibus mauris condimentum nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Etiam sit amet erat. Nulla varius. Etiam tincidunt dui vitae turpis. Donec leo. Morbi vulputate convallis est. Integer aliquet. Pellentesque aliquet sodales urna.

Nullam eleifend justo in nisl. In hac habitasse platea dictumst. Morbi nonummy. Aliquam ut felis. In velit leo, dictum vitae, posuere id, vulputate nec, ante. Maecenas vitae pede nec dui dignissim suscipit. Morbi magna. Vestibulum id purus eget velit laoreet laoreet. Praesent sed leo vel nibh convallis blandit. Ut rutrum. Donec nibh. Donec interdum. Fusce sed pede sit amet elit rhoncus ultrices. Nullam at enim vitae pede vehicula iaculis.

Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Aenean nonummy turpis id odio. Integer euismod imperdiet turpis. Ut nec leo nec diam imperdiet lacinia. Etiam eget lacus eget mi ultricies posuere. In placerat tristique tortor. Sed porta vestibulum metus. Nulla iaculis sollicitudin pede. Fusce luctus tellus in dolor. Curabitur auctor velit a sem. Morbi sapien. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Donec adipiscing urna vehicula nunc. Sed ornare leo in leo. In rhoncus leo ut dui. Aenean dolor quam, volutpat nec, fringilla id, consectetuer vel, pede.

Nulla malesuada risus ut urna. Aenean pretium velit sit amet metus. Duis iaculis. In hac habitasse platea dictumst. Nullam molestie turpis eget nisl. Duis a massa id pede dapibus ultricies. Sed eu leo. In at mauris sit amet tortor bibendum varius. Phasellus justo risus, posuere in, sagittis ac, varius vel, tortor. Quisque id enim. Phasellus consequat, libero pretium nonummy fringilla, tortor lacus vestibulum nunc, ut rhoncus ligula neque id justo. Nullam accumsan euismod nunc. Proin vitae ipsum ac metus dictum tempus. Nam ut wisi. Quisque tortor felis, interdum ac, sodales a, semper a, sem. Curabitur in velit sit amet dui tristique sodales. Vivamus mauris pede, lacinia eget, pellentesque quis, scelerisque eu, est. Aliquam risus. Quisque bibendum pede eu dolor.

Donec tempus neque vitae est. Aenean egestas odio sed risus ullamcorper ullamcorper. Sed in nulla a tortor tincidunt egestas. Nam sapien tortor, elementum sit amet, aliquam in, porttitor faucibus, enim. Nullam congue suscipit nibh. Quisque convallis. Praesent arcu nibh, vehicula eget, accumsan eu, tincidunt a, nibh. Suspendisse vulputate, tortor quis adipiscing viverra, lacus nibh dignissim tellus, eu suscipit risus ante fringilla diam. Quisque a libero vel pede imperdiet aliquet. Pellentesque nunc nibh, eleifend a, consequat consequat, hendrerit nec, diam. Sed urna. Maecenas laoreet eleifend neque. Vivamus purus odio, eleifend non, iaculis a, ultrices sit amet, urna. Mauris faucibus odio vitae risus. In nisl. Praesent purus. Integer iaculis, sem eu egestas lacinia, lacus pede scelerisque augue, in ullamcorper dolor eros ac lacus. Nunc in libero.

Fusce suscipit cursus sem. Vivamus risus mi, egestas ac, imperdiet varius, faucibus quis, leo. Aenean tincidunt. Donec suscipit. Cras id justo quis nibh scelerisque dignissim. Aliquam sagittis elementum dolor. Aenean consectetuer justo in pede. Curabitur ullamcorper ligula nec orci. Aliquam purus turpis, aliquam id, ornare vitae, porttitor non, wisi. Maecenas luctus porta lorem. Donec vitae ligula eu ante pretium varius. Proin tortor metus, convallis et, hendrerit non, scelerisque in, urna. Cras quis libero eu ligula bibendum tempor. Vivamus tellus quam, malesuada eu, tempus sed, tempor sed, velit. Donec lacinia auctor libero.

4.1.3 Refraction

Praesent sed neque id pede mollis rutrum. Vestibulum iaculis risus. Pellentesque lacus. Ut quis nunc sed odio malesuada egestas. Duis a magna sit amet ligula tristique pretium. Ut pharetra. Vestibulum imperdiet magna nec wisi. Mauris convallis. Sed accumsan sollicitudin massa. Sed id enim. Nunc pede enim, lacinia ut, pulvinar quis, suscipit semper, elit. Cras accumsan erat vitae enim. Cras sollicitudin. Vestibulum rutrum blandit massa.

Sed gravida lectus ut purus. Morbi laoreet magna. Pellentesque eu wisi. Proin turpis. Integer sollicitudin augue nec dui. Fusce lectus. Vivamus faucibus nulla nec lacus. Integer diam. Pellentesque sodales, enim feugiat cursus volutpat, sem mauris dignissim mauris, quis consequat sem est fermentum ligula. Nullam justo lectus, condimentum sit amet, posuere a, fringilla mollis, felis. Morbi nulla nibh, pellentesque at, nonummy eu, sollicitudin nec, ipsum. Cras neque. Nunc augue. Nullam vitae quam id quam pulvinar blandit. Nunc sit amet orci. Aliquam erat elit, pharetra nec, aliquet a, gravida in, mi. Quisque urna enim, viverra quis, suscipit quis, tincidunt ut, sapien. Cras placerat consequat sem. Curabitur ac diam. Curabitur diam tortor, mollis et, viverra ac, tempus vel, metus.

Curabitur ac lorem. Vivamus non justo in dui mattis posuere. Etiam accumsan ligula id pede. Maecenas tincidunt diam nec velit. Praesent convallis sapien ac est. Aliquam ullamcorper euismod nulla. Integer mollis enim vel tortor. Nulla sodales placerat nunc. Sed tempus rutrum wisi. Duis accumsan gravida purus. Nunc nunc. Etiam facilisis dui eu sem. Vestibulum semper. Praesent eu eros. Vestibulum tellus nisl, dapibus id, vestibulum sit amet, placerat ac, mauris. Maecenas et elit ut erat placerat dictum. Nam feugiat, turpis et sodales volutpat, wisi quam rhoncus neque, vitae aliquam ipsum sapien vel enim. Maecenas suscipit cursus mi.

Quisque consectetuer. In suscipit mauris a dolor pellentesque consectetuer. Mauris convallis neque non erat. In lacinia. Pellentesque leo eros, sagittis quis, fermentum quis, tincidunt ut, sapien. Maecenas sem. Curabitur eros odio, interdum eu, feugiat eu, porta ac, nisl. Curabitur nunc. Etiam fermentum convallis velit. Pellentesque laoreet lacus. Quisque sed elit. Nam quis tellus. Aliquam tellus arcu, adipiscing non, tincidunt eleifend, adipiscing quis, augue. Vivamus elementum placerat enim. Suspendisse ut tortor. Integer faucibus

adipiscing felis. Aenean consectetuer mattis lectus. Morbi malesuada faucibus dolor. Nam lacus. Etiam arcu libero, malesuada vitae, aliquam vitae, blandit tristique, nisl.

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In hac habitasse platea dictumst. Proin at est. Curabitur tempus vulputate elit. Pellentesque sem. Praesent eu sapien. Duis elit magna, aliquet at, tempus sed, vehicula non, enim. Morbi viverra arcu nec purus. Vivamus fringilla, enim et commodo malesuada, tortor metus elementum ligula, nec aliquet est sapien ut lectus. Aliquam mi. Ut nec elit. Fusce euismod luctus tellus. Curabitur scelerisque. Nullam purus. Nam ultricies accumsan magna. Morbi pulvinar lorem sit amet ipsum. Donec ut justo vitae nibh mollis congue. Fusce quis diam. Praesent tempus eros ut quam.

Donec in nisl. Fusce vitae est. Vivamus ante ante, mattis laoreet, posuere eget, congue vel, nunc. Fusce sem. Nam vel orci eu eros viverra luctus. Pellentesque sit amet augue. Nunc sit amet ipsum et lacus varius nonummy. Integer rutrum sem eget wisi. Aenean eu sapien. Quisque ornare dignissim mi. Duis a urna vel risus pharetra imperdiet. Suspendisse potenti.

Morbi justo. Aenean nec dolor. In hac habitasse platea dictumst. Proin nonummy porttitor velit. Sed sit amet leo nec metus rhoncus varius. Cras ante. Vestibulum commodo sem tincidunt massa. Nam justo. Aenean luctus, felis et condimentum lacinia, lectus enim pulvinar purus, non porta velit nisl sed eros. Suspendisse consequat. Mauris a dui et tortor mattis pretium. Sed nulla metus, volutpat id, aliquam eget, ullamcorper ut, ipsum. Morbi eu nunc. Praesent pretium. Duis aliquam pulvinar ligula. Ut blandit egestas justo. Quisque posuere metus viverra pede.

Vivamus sodales elementum neque. Vivamus dignissim accumsan neque. Sed at enim.

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Maecenas dui. Aliquam volutpat auctor lorem. Cras placerat est vitae lectus. Curabitur massa lectus, rutrum euismod, dignissim ut, dapibus a, odio. Ut eros erat, vulputate ut, interdum non, porta eu, erat. Cras fermentum, felis in porta congue, velit leo facilisis odio, vitae consectetuer lorem quam vitae orci. Sed ultrices, pede eu placerat auctor, ante ligula rutrum tellus, vel posuere nibh lacus nec nibh. Maecenas laoreet dolor at enim. Donec molestie dolor nec metus. Vestibulum libero. Sed quis erat. Sed tristique. Duis pede leo, fermentum quis, consectetuer eget, vulputate sit amet, erat.

Donec vitae velit. Suspendisse porta fermentum mauris. Ut vel nunc non mauris pharetra varius. Duis consequat libero quis urna. Maecenas at ante. Vivamus varius, wisi sed egestas tristique, odio wisi luctus nulla, lobortis dictum dolor ligula in lacus. Vivamus aliquam, urna sed interdum porttitor, metus orci interdum odio, sit amet euismod lectus felis et leo. Praesent ac wisi. Nam suscipit vestibulum sem. Praesent eu ipsum vitae pede cursus venenatis. Duis sed odio. Vestibulum eleifend. Nulla ut massa. Proin rutrum mattis sapien. Curabitur dictum gravida ante.

Phasellus placerat vulputate quam. Maecenas at tellus. Pellentesque neque diam, dignissim ac, venenatis vitae, consequat ut, lacus. Nam nibh. Vestibulum fringilla arcu mollis arcu. Sed et turpis. Donec sem tellus, volutpat et, varius eu, commodo sed, lectus. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Quisque enim arcu, suscipit nec, tempus at, imperdiet vel, metus. Morbi volutpat purus at erat. Donec dignissim, sem id semper tempus, nibh massa eleifend turpis, sed pellentesque wisi purus sed libero. Nullam lobortis tortor vel risus. Pellentesque consequat nulla eu tellus. Donec velit. Aliquam fermentum, wisi ac rhoncus iaculis, tellus nunc malesuada orci, quis volutpat dui magna id mi. Nunc vel ante. Duis vitae lacus. Cras nec ipsum.

5 Observations

5.1 Creating and Using Unordered Access Views

When using pixel synchronization, Unordered Access Views (UAVs) are key to allowing a programmer to get all he or she can out of the pixel synch capability. UAVs are set up to use on the application side, and can be used on the GPU side after certain specifications are made. Firstly, we must create and define the UAV on the application side of our program.

We first create a texture for our UAV on the application side. To create our texture, we have to create a description to send to the system, then create a texture by that description (fig. 5.1). Notice in the code on line 10, we populate a member of **texDesc** called **BindFlags**, and specify that this texture will be used for unordered access. The population of this flag

does not mean the UAV will be set up and ready for use.

We must map a UAV instance to that texture (fig. 5.2). We must first describe the instance of the UAV to the program. We do this in a very similar way to how we described our texture. However the description structure is now of type **D3D11_UNORDERED_ACCESS_VIEW_DESC** instead of **D3D11_TEXTURE2D_DESC**. As a quick note, the texture description can be interchangeable among **D3D11_TEXTURE1D_DESC**, **D3D11_TEXTURE2D_DESC** or **D3D11_TEXTURE3D_DESC** you must make sure that the dimension of the UAV description matches what you have described and created for your texture. If no error occurs after executing the code in figure 5.2, then we are only a couple of small, yet key, steps to utilizing UAVs within our code.

```
1  D3D11_TEXTURE2D_DESC texDesc;
2  ZeroMemory(&texDesc, sizeof(texDesc));
3  texDesc.Width = SCREEN_WIDTH;
4  texDesc.Height = SCREEN_HEIGHT;
5  texDesc.MipLevels = 1;
6  texDesc.ArraySize = 1;
7  texDesc.SampleDesc.Count = 1;
8  texDesc.SampleDesc.Quality = 0;
9  texDesc.Usage = D3D11_USAGE_DEFAULT;
10 texDesc.BindFlags = D3D11_BIND_UNORDERED_ACCESS;
11 texDesc.Format = DXGI_FORMAT_R32_FLOAT;
12
13 //We then use our description to create our texture.
14
15 HRESULT texRes = dev->CreateTexture2D(&texDesc, NULL, &pUAVTex);
16
17 //We always have a hook to check if our
18 //device-side calls were successful.
19 if (texRes != S_OK)
20 {
21         MessageBox(HWND_DESKTOP,
22                 L"Texture Creation Unsuccessful!",
23                 L"Texture Error!", MB_OK);
24         exit(EXIT_FAILURE);
25 }
```

Figure 5.1: Describing and creating the 2D texture that we will use for our UAV.

Now that we have a texture created, and a UAV instance bound to that texture, we must now tell the GPU when we want to utilize the UAV and where exactly we want that UAV to be mapped, register wise, on the GPU side. We do this by making a call to the GPU to not only set the render target, but also the UAVs tied to this render pass. So, we change the set render target call, as shown in figure 5.3.

After we change this call, we know exactly in which registers our UAVs will live. So, following

```
1  D3D11_UNORDERED_ACCESS_VIEW_DESC UAVdesc;
2  ZeroMemory(&UAVdesc, sizeof(UAVdesc));
3
4  UAVdesc.Format = DXGI_FORMAT_R32_FLOAT;
5  UAVdesc.ViewDimension = D3D11_UAV_DIMENSION_TEXTURE2D;
6  UAVdesc.Texture2D.MipSlice = 0;
7
8  HRESULT UAVRes =
9          dev->CreateUnorderedAccessView(pUAVTex,
10                 &UAVdesc, &pUAV[1]);
11
12 if (UAVRes != S_OK){
13         MessageBox(HWND_DESKTOP,
14                 L"Our UAV view was not successful...",
15                 L"UAV Error!", MB_OK);
16         exit(EXIT_FAILURE);
17 }
```

Figure 5.2: Mapping our UAV to the texture we created in figure 5.1

that, we make sure to specify where these UAVs live on the shader side as a global variable, as shown in figure 5.4. A few things to note: In the code, The token "DataType" should be replaced with whatever datatype was specified (**unsigned int**, **float***). Something to consider, though, is that each element within a UAV texture is limited to 32 bits. I recommend **float3** only be used in very specific cases, where precision is not paramount, as you are only able to specify a format of DXGI_FORMAT_R11G11B10_FLOAT, which means that a programmer is only given 11 bits for the first and second channels, and 10 bits for the third channel. There are special registers in HLSL shaders in which we must utilize for the use of UAVs. There are 8 of these registers, and they are preceded with a 'u'. By specifying our register, we know exactly what the datatype and makeup of that UAV is, by what we have defined on the application side.

To reiterate, a UAV is a texture that has been mapped to a read/write register on the GPU. Since it is a texture, we can also sample from it. This behavior exists for the following reason: say we populate this UAV texture in one shader pass, then want to read from it within a different one. This can be accomplished in two ways, but some programmers prefer to sample from the texture using the sample intrinsic, rather than indexing it like a UAV. To do so, we would have to specify that we want our texture to be used as both a UAV and a read-in texture, by changing the bind flags from **D3D11_BIND_UNORDERED_ACCESS** to **D3D11_BIND_UNORDERED_ACCESS** | **D3D11_BIND_SHADER_RESOURCE**. This allows us to also tie a texture sampler to the same texture that a UAV is bound to. However, to smaple from the texture, we must firt unplug it from the program as a UAV and plug it back in as a sampled texture. This means that writing to a texture, then sampling from it in the same pass would not be allowed (nor would it be very practical). A good use for setting a texture as both a UAV and a Sampled Texture would be in a case such as the Subsurface Scattering demo, where we store the depth of each fragment, with respect to the light in one pass, as well as which ray passes through that fragment.

```
1  //we change from this call...
2  devcon->OMSetRenderTargets(
3                    numTargets,
4                    &RenderTargetViews,
5                    DepthBuffer);
6
7  //...to this call...
8  devcon->OMSetRenderTargetsAndUnorderedAccessViews(
9                    numTargets,
10                   &RenderTargetViews,
11                   DepthBuffer,
12                   UAVStartSlot,
13                   NumUAVS,
14                   &UAVs,
15                   UAVInitialCounts);
```

Figure 5.3: Comparison of the two OMSetRenderTargets*() calls.

```
1  RWTextureXD<[DataType]> UAVName : register(uY);
```

Figure 5.4: General layout of UAV declaration on the shader side Where **X** is a dimension from 1 to 3, and **Y** is a register number from 0 to 7.

5.2 Unordered Access View Limitations and Recommendations

UAVs are quite useful in the grand scheme of things, but how useful they can be, really depends on the amount of memory the GPU has at its disposal, and whether or not the data the programmer would like to store must be iterated over. The memory bandwidth issue is not necessarily a pressing one for the demo presented within this paper, but it could present itself as an issue for larger projects, if not monitered.

UAVs cannot be looped over within a shader. What this means, is that if a programmer would like to search for a value within a UAV, this is not possible and the HLSL compiler will not even compile the programmer's shader. This means that any sort of iteration over dynamic data within a pixel shader is not possible at this time. I speculate that this is done as a precaution to keep programmers from shooting themselves in the foot, or creating an infinite loop within the GPU, which could cause trouble in the form of Denial of Service. However, if the programmer sets up their UAV diligently within the shader, this should never be the case.

Another issue is that application side UAVs and their Shader-side counterparts are seemingly very disparate entities within code. A programmer must be very diligent in keeping track which UAVs are tied to which textures, what datatype is associated with said UAV, whether or not the UAV is bound, and if bound, to which register. However, following all of the bookkeeping steps, UAVs make shaders more powerful.

As mentioned above, there are 8 UAV registers available on the hardware on which I ran my code. However, we may only bind 7 UAVs at a time, since one of these UAV registers is actually reserved for the render target (if we are utilizing UAVs within a pass that renders

to screen). When designing a graphics program, remember to keep track of how many Read/Write datastructures needed within the GPU, and which can be sampled as textures at any point. It is also recommended that a programmer become very familiar with data packing algorithms, such that the 32 bits per each UAV element is used to as much of its capacity as possible. Packing data efficiently will lead to a far more efficient HLSL program, as long as the pack/unpack functions are quick.

There remain other issues while using UAVs, including the following:

Clearing UAVs

Clearing a UAV on the application side can be quite expensive, and seems to scale quite a bit with the size of the UAV. For instance, within my refract code, I have a UAV that points to a Texture3D that greatly slows down the performance of the application. Please see figure (make figure) for a visual explanation. It is up to the programmer's discression to discern a 'sweet spot' size for their UAVs to get equal parts quality and performance. As can be seen in the graph, having a large UAV can really slow down a render pass.

Uninitialized UAVs

Within HLSL code, the compiler allows the programmer to define a RWTextureXD, as demonstrated in figure 5.4, at any time. There is no check from the compiler to see if there is a UAV register that has been initialized to a texture. The reason why is because shader programs are compiled and linked prior to setting any UAVs. In other words, the HLSL compiler allows this because it is trusting the programmer to populate that register with a texture when it comes time to run the shader program. However, if a UAV is never initialized or populated, the programmer may still reference that RWTexture, but any writes to or reads from will not work. In most cases, any read or write will cause the program to crash. Any methods specific to RWTexture can still be executed, such as RWTexture2D.GetDimensions(). However, the X and Y dimensions returned will just be zero. This is an easily avoidable pitfall, so long as the programmer keeps track of his or her UAVs accordingly.

UAV Order is important

Programmers using UAVs in their shader code must keep track of the order in which their they are given to the GPU when Binding their UAVs and Render Target(s). Seeing as this is only possible if the UAVs are kept in an array, it is good to keep a note of which UAVs are meant for certain purposes. If multiple sets of UAVs are needed, it is recommended these UAV sets are named accordingly. While rendering, shader code is allowed to access UAVs as a datatype that conflicts with what a programmer might have defined at that UAV slot, because every element in a UAV texture is 32 bits. This makes it quite difficult to catch potential errors, unless diligent precautionary measures are taken.

5.3 Pixel Synchronization Behavior

The Behavior of Pixel Synchronization can be confusing, unless if we take time to understand what it actually does. However, let us first take the time to figure out how prepare it for use on the application side. In order to see if the Iris extensions are available, the programmer must include the following files into his or her C++ code: *ID3D10Extensions.h*, *IGFXExtensionsHelper.h* and *IGFXExtensionHelper.cpp*. These three files can be found within the github repository in the IGFXExtensions folder. After including these files in your C++ application, the programmer may now use the IGFX namespace. To initialize these extensions, simply execute the following commands during the DirectX setup function (in this project, this part of code is called **InitD3D()**). As is shown in figure 5.5, to initialize Iris Extensions on the application is quite simple. This is because Iris Extensions are meant to happen without having to be too visible to the DirectX side of code. After we initialize our graphics extensions, we can see which extensions we have available to us, if any. Now that we have this information, our program can make informed decisions on what kind of hardware it has at its disposal to accomplish render techniques. As this demo is meant only for Iris extensions, a decision was made to not utilize this available extension check to enhance robustness of the program.

```
1 //global variable...
2 IGFX::Extensions myExtensions;
3
4 //Within setup code...
5 HRESULT res = IGFX::Init(dev);
6 if(res == S_OK) myExtensions =
7         IGFX::getAvailableExtensions(dev);
```

Figure 5.5: Intel Iris extension setup on the application side.

After we ensure our program/Direct3D device can use Pixel Synchronization, there isn't anything more that the GPU device requires from the application, itself. Now, all we must do is specify when, inside of our pixel shader, we want to synchronize our pixels, and that's it! For an actual shader code snippet of this, please refer to the snippet in section 1.4.2, figure 1.1. Recall that the Pixel Shader must include *IntelExtensions.hlsl*.

So at this point, we should be able to initialize Iris Extensions and invoke Pixel Synchronization. However, as programmers, we can't very well utilize Pixel Synchronization without first knowing how it behaves.

When invoked, it is known that Pixel Synchronization first creates a barrier for all shaders in flight at the same pixel position. Following this barrier, we know that all shaders that hit this barrier are ordered by Primitive ID. The question is, "How does this ordering occur?" The answer is actually quite straightforward. They appear to be ordered by primitive number because they are ordered by order of submission from the vertex stage. Knowing that this happens, whether the pixels actually accomplish a front-back or back-front sorting depends on how the model was defined within its object file.

Knowing that the ordering takes place as such, it is not safe to assume that the ordering will take place the way the programmer wants to. As a result, this begs the question: What

is the benefit of Pixel Synchronization, exactly? The benefit of this extension comes from the fact that we can guarantee a portion of memory will be read/written without data races. This allows for programmers to accomplish much more within the pixel shader than has been done before. To be able to accomplish sorting based upon depth within the shader is a remarkable thing. However, there are some workarounds that must take place. As it was mentioned in section 5.2, we cannot loop over our UAVs, but one thing we are able to do is make create a 'mask' that keeps track of what depth of a Texture3D or Texture2D array has not been written to, then write to that. After this step, we can sort through the UAV as a sampled texture in a later pass, such that we can do something meaningful with the information.

5.4 Coding and Behavior Quirks

As this project deals with raw DirectX, there are a lot of places in code which could serve as confusing pitfalls. These pieces of code range from application or CPU-side issues, or even within the pipeline itself. This section is meant to detail some of those more common pitfalls and also point out some behavior inherent to the pipeline or hardware that are not the programmer's fault.

5.4.1 Working With the GPU Device on the Application Side

Just the same as in OpenGL applications, DirectX applications allow the program to continue even if there is an error or failure within the graphics device. For this reason, self-error checking is a very important practice when building a graphics program from scratch. Within a DirectX application, this can be easily done, as the appropriate device and device context related functions return a datatype called HRESULT. By checking this HRESULT, a programmer can get a good idea of what type of error is happening within his or her code. However, this doesn't encompass all errors. There are some instances in which a call to the GPU can cause an internal error, and force the device to unplug itself from the program. The instance in which this "Device Removed Error" occurred most commonly for this project was when attempting to create a UAV texture that was too large for the program. If the program is allowed to let itself run without having this error caught, other errors will occur down the line, and in the best case, the program will yield a viewport full of garbage.

5.4.2 Pipeline Behavior

The most fascinating behavior of the pipeline during this project was finding that the pipeline may make rounding errors during the interpolation phase of the pipeline. These rounding errors were made apparent when attempting to work with a UAV that was a larger resolution than 512x512 pixels in the Subsurface Scattering Demo. If the texture was too high of a resolution, the resulting depth-based shadow would cause an immense amount of artifacts. This was mitigated when using a lower resolution texture. The only conclusion I could draw from this was that there were rounding errors taking place within the interpolation stage, forcing certain indices of the texture to be missed. Screenshots and a graph demonstrating this behavior can be found on page(put pictures into this document now, ok thanks).

5.4.3 Placement of Pixel Synchronization call

As state previously, making a call to pixel synchronization creates a critical section within a pixel shader. The catch to this, however, is that, beginning with the pixel synchronization

call, the rest of the pixel shader is a critical section until the end of the shader. Since this is the case, it is highly recommended that all operations that are not dependant upon synchronization happen prior to the barrier to mitigate the number of operations that must be ordered. However, if the pixel shader does not have many operations taking place, it may not be a noticeable difference to have the non-dependant code within the critical section. Code with pixel syncronization saw a 10% drop in frames per second, compared to the same code with the barrier removed.

5.4.4 Vertices are Still the Bottleneck

As the vertices have been processed and all values have been interpolated across the pipeline at the point of the Pixel Shader, a bigger influence on runtime will still be the number of vertices used to define the 3D object. For instance, this project contains two pawn models. One is very low resolution with a smal number of faces, and the other has been smoothed and vertices have been added. The runtime still scales with the number of vertices, regardless of any influence of pixel synchronization.

5.5 Suggestions and Advice When Using Pixel Synchronization

Pixel Synchronization melds the world of graphics and parallelism even further, by adding the capabilites of barriers to the end of the graphics pipeline. However, to take advantage of this capability to the fullest, some practices in parallel programming must be taken up within graphics programming.

Design the Critical Section

Since our critical section will be ordered and will execute one-at-a-time, the programmer must do what he or she can to keep that section of code lean. To make sure our critical section is as lean as possible, it is recommended that the programmer evaluate and design the pixel shader to make smart, informed decisions on what operations can happen outside or inside of the ordered section of code. One very simple rule is that any write to or read from shared memory must take place within a critical section. As a translation, any access to memory that would require a mutex in a parallel program should be accessed inside of the Pixel Sync critical section.

Know the Necessary Relationships

Having multiple render passes per object in a scene is quite costly. However, a good way to mitigate erroneous passes is to think about the relationship between the object and, in the case of Subsurface Scattering, the light source. In the case of Subsurface scattering, we know that the depth information stored at that object does not change until either the object or the light changes their orientation within the scene. A flag can be inserted into the program such that if either of the two involved entities change their orientation or position, the Pixel Ordering passes are activated to gather the new depth information. Executing Pixel Ordering passes based upon a condition has the potential to vastly speed up the runtime of a graphics progrom that uses this functionality to implement effects such as subsurface scattering, and help to make a case for its viability in practical use.

Keep the UAVs a reasonable size

One of the biggest hits to performance was using a UAV texture that was quite large. UAVs that were large ended up incurring a rather larger performance hit. To mitigate this, it is recommended to find a "sweet spot" between quality and performance. Along with the performance of the shaders with the UAV, it takes quite a bit of time to clear these UAVs with each rendering of the scene. This was made very apparent when creating a Texture3D UAV of size 800^3.

Take Advantage of Having a Texture Be Both a UAV and a Sampled Texture

Sampling a texture takes less time than indexing a UAV. As this is the case, it is recommended that the programmer access the texture with a Sampler if the shader is only reading from the texture, and not Read/Writing. This will help ensure that the final render pass is as fast as possible.

5.6 General Suggestions and Advice

When writing raw DirectX, there are some pitfalls and coding tricks that are necessary to point out. However, paying attention to these pitfalls and tricks won't necessarily make a programmer's DirectX application bug-free, but knowledge and consideration of these suggestions and advice could save debugging and head-scratching time.

Constant Buffers

Constant Buffers are how DirectX approaches application-specific variables within the GPU. For instance, if the programmer would like to include an interactive coefficient for brightness of a light source, he or she would do so by creating a constant buffer that held that coeffiecient, then updating it on the application side prior to rendering. OpenGL approaches this by using Uniform Variables, all of which have their own ID number on the GPU and are updated one-by-one.

If a programmer has multiple values to pass into his or her DirectX program, it can be done by adding multiple members to the constant buffer data structure. This reduces the communication to/from the GPU to just one instance, while updating the entire buffer. However, it is important that the definition of the struct on the GPU side mirrors the application side's definition. Further, take note that the Constant Buffer's size must be a multiple of 16. This is so the call to copy the information from the application to GPU will always be a predicatable size for the GPU. To mitigate problems, the creation of the constant buffer in the Subsurface Scattering Demo added the size of the constant buffer, mod 16. For a better idea, please consider the code snippet below. On line 5 in the below code snippet, the multiple of 16 size constraint is accounted for by adding the size of the buffer, mod 16. This means that the constant buffer could have anywhere from 0 to 15 bytes of extra space. Another way to account for the multiple of 16 size constraint is to add pad variables to the constant buffer, itself. Some programmers prefer this method, as it gives the padding a representation in the form of a defined datatype.

```
1  D3D11_BUFFER_DESC bd;
2  ZeroMemory(&bd, sizeof(bd));
3
4  bd.Usage = D3D11_USAGE_DEFAULT;
5  bd.ByteWidth = sizeof(CBUFFER) + (sizeof(CBUFFER) % 16);
6  bd.BindFlags = D3D11_BIND_CONSTANT_BUFFER;
7
8  HRESULT bres = dev->CreateBuffer(&bd, NULL, &pCBuffer);
9
10 if (bres != S_OK)
11 {
12         MessageBox(HWND_DESKTOP,
13                 L"FAILED CONSTANT BUFFER CREATION",
14                 L"CBUFFER ERROR", MB_OK);
15         exit(EXIT_FAILURE);
16 }
17 devcon->VSSetConstantBuffers(0, 1, &pCBuffer);
```

Learn the HLSL Semantics

In HLSL a Semantic is an optional string that identifies the intended usage of return data. These semantics are quite useful in telling the GPU how to interpolate values across the pipeline. For instance, consider the following Data Structure defined in HLSL:

```
struct VOut
{
        float4 svposition : SV_POSITION;
        float4 color : COLOR;
        float4 position : POSITION;
        float2 UVs : TEXCOORD;
        float4 normal : NORMAL;
        float4 camera : CAMERA;
        float3 lightVec : NORMAL1;
        float4 lightCol : COLOR1;
        uint mode : MODE;
        float4 rotNorm : NORMAL2;
        float3 eyeVec : NORMAL3;
};
```

This is a data structure defined within the shader file, such that the vertex shader can pass many values to the pipeline. Some sematics are built in, but some others are programmer-defined. In this case, the only programmer-defined semantic would be MODE. The use for mode will be covered in the implementation discussion. Notice the differences between the SV_POSITION and POSITION semantics. These two Semantics tell the pipeline how to interpolate these values. As can be seen in the listed Shaders, both the SV_POSITON and POSITION members get the same value in the vertex shader. However, SV_POSITION gets interpolated into X/Y screen positons, and POSITION gets interpolated in the same -1 to 1 space for the X/Y/Z position

given to it. Once a fragment or pixel shader has completed its running, the computed color is assigned to the pixel at the X/Y SV_POSITION. These semantics are a great way to keep track of values passed across the pipeline, and helps shed a little bit more light on what they are, and what they are used for.

Invest Time into Learning a Good Menuing Library

Creating a menu window for this project could have been made a lot simpler with a proper menuing library, instead of building it from scratch. The advantage of using a premade menuing library is that many of the functionalities of buttons can be linked in a simple call, rather than using the vanilla window class. For instance, within the Subsurface Scattering code, the menu was built entirely from scratch, and had to have its own window process, where it must check the state of global variables with which the buttons on the menu are tied to, and checked/unchecked, or presed without a convenient construct for relationship. The problem with this approach is that the relationship between the menu's buttons and what they are supposed to indicate, where they are located on the menu window, and which checkboxes are related to each other all must be managed explicitly by the programmer. In short, to save time, it is highly recommended that a menuing library be used, so as to avoid any extra debugging that does not have anything directly to do with the project.

Further, using the raw windows framework to create a menu doesn't abstract away anything for the programmer; every bit of the subclasses that the menu window holds are at the most raw level. For a better idea, please see the code below:

```
hGBButton = CreateWindowEx(
        NULL,
        L"BUTTON",
        L"GOOD/BAD",
        WS_TABSTOP | WS_VISIBLE | WS_CHILD | BS_AUTOCHECKBOX,
        50,
        20,
        100,
        24,
        hWnd,
        (HMENU)GOODBAD_BUTTON,
        GetModuleHandle(NULL),
        NULL);

SendMessage(hGBButton,
        WM_SETFONT,
        (WPARAM)hfDefault,
        MAKELPARAM(FALSE, 0));

Button_SetCheck(hGBButton, true);
```

To make a button without any menuing library, we must define a new window instance which lives inside of the current window, $hWnd$, define its size and position within the window, whether it is a checkbox button, and pass messages to and from the button,

itself. The last line of the listing is meant to show that the programmer must set whether the checkbox is checked or unchecked, which implies that the programmer must track the value associated with that button and change that value accordingly. In short, without a proper Menuing library, building a menu can become quite convoluted and confusing.

Use Separate Render Functions

To demonstrate different effects, there could be potentially many differences in setup and dispatching of the GPU. For instance, the difference between the regular Phong Illumination technique and the Subsurface Scattering algorithm utilizing pixel synchronization are quite different, as far as how many UAVs must be set and bound to the render target and the number of passes. To keep the code readable and to mitigate too many conditionals within the render function, it is recommended that each render technique get its own render function.

If render techniques are not separated into different render functions, there could be mistakes made that could skew timing measurements. For instance, within the Subsurface Scattering Project, the Phong Illumination technique had been measured to perform at about the same framerate as the Pixel Synch Subsurface Scatter. As it turns out, what was happening was that the two setup render passes were still being executed, then the information was basically just being ignored. However, problems such as this are specific to the programmer, and not necesarily a general problem. For readability and clearcut management of code, splitting render techniques into their own separate functions is recommended.

6 Conclusion and Recommended Future Work

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7 Implementation Discussion

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Donec libero. Quisque vitae est quis dui bibendum suscipit. Fusce leo felis, sagittis non, vehicula ac, ultricies vitae, diam. Aenean congue libero et metus. Nulla convallis libero a lacus. Donec hendrerit lorem sit amet leo. Mauris libero. Pellentesque pulvinar molestie dolor. Proin nibh mauris, ornare at, pretium sit amet, porttitor vel, mi. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas.

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Aenean sem dolor, fermentum nec, gravida hendrerit, mattis eget, felis. Nullam non diam vitae mi lacinia consectetuer. Fusce non massa eget quam luctus posuere. Aenean vulputate velit. Quisque et dolor. Donec ipsum tortor, rutrum quis, mollis eu, mollis a, pede. Donec nulla. Duis molestie. Duis lobortis commodo purus. Pellentesque vel quam. Ut congue congue risus. Sed ligula. Aenean dictum pede vitae felis. Donec sit amet nibh. Maecenas eu orci. Quisque gravida quam sed massa.

Nunc euismod, mauris luctus adipiscing pellentesque, augue ligula pellentesque lectus, vitae posuere purus velit a pede. Phasellus leo mi, egestas imperdiet, blandit non, sollicitudin pharetra, enim. Nullam faucibus tellus non enim. Sed egestas nunc eu eros. Nunc euismod venenatis urna. Phasellus ullamcorper. Vivamus varius est ac lorem. In id pede eleifend nibh consectetuer faucibus. Phasellus accumsan euismod elit. Etiam vitae elit. Integer imperdiet nibh. Morbi imperdiet orci euismod mi.

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In sit amet dui eget lacus rutrum accumsan. Phasellus ac metus sed massa varius auctor. Curabitur velit elit, pellentesque eget, molestie nec, congue at, pede. Maecenas quis tellus non lorem vulputate ornare. Vestibulum ante ipsum primis in faucibus orci luctus et ultrices posuere cubilia Curae; Etiam magna arcu, vulputate egestas, aliquet ut, facilisis ut, nisl. Donec vulputate wisi ac dolor. Aliquam feugiat nibh id tellus. Morbi eget massa sit amet purus accumsan dictum. Aenean a lorem. Fusce semper porta sapien.

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sed, eleifend in, elit. Phasellus non purus sed elit viverra rhoncus. Vestibulum id tellus vel sem imperdiet congue. Aenean in arcu. Nullam urna justo, imperdiet eget, volutpat vitae, semper eu, quam. Sed turpis dui, porttitor ut, egestas ac, condimentum non, wisi. Fusce iaculis turpis eget dui. Quisque pulvinar est pellentesque leo. Ut nulla elit, mattis vel, scelerisque vel, blandit ut, justo. Nulla feugiat risus in erat.

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Aenean eget justo id lorem congue tristique. Maecenas sit amet nunc. Aenean bibendum risus. Nam convallis, mi sed ultrices sodales, metus nibh placerat dui, eu hendrerit erat enim vel libero. Duis placerat sem vitae wisi imperdiet condimentum. Aliquam pellentesque dui ac diam eleifend venenatis. Nulla facilisis posuere sapien. Cras euismod. Praesent ut enim. Aliquam ut ipsum quis urna interdum vehicula. Fusce eget sem. Nullam accumsan ullamcorper turpis.

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In accumsan convallis metus. Aenean est. Donec pharetra porta odio. Duis nunc nisl, imperdiet ac, tincidunt vitae, varius sit amet, felis. Curabitur wisi. Ut iaculis, nunc in lacinia egestas, elit enim tincidunt turpis, at luctus ipsum augue condimentum metus. Aenean lorem wisi, cursus sit amet, mollis nec, porta ac, augue. Vivamus massa. Praesent rhoncus imperdiet orci. Aenean pharetra dolor ut sapien. Maecenas egestas augue semper dolor.

Vestibulum at lectus. Vestibulum dapibus placerat magna. Suspendisse dolor urna, condimentum sit amet, euismod a, adipiscing a, enim. Aliquam erat volutpat. Donec imperdiet dolor non mi. Phasellus magna metus, dictum sit amet, laoreet non, dictum vel, dui. Suspendisse potenti. Nunc turpis risus, porta vel, pharetra id, eleifend vitae, justo. Duis pulvinar dolor sit amet urna. Integer eu eros. Nulla facilisi. Duis dui. Nullam vitae quam. Morbi a nunc in elit sodales euismod. Nunc sed orci. Etiam malesuada metus vitae felis. Suspendisse imperdiet velit in tellus.

Nullam elit orci, condimentum vitae, accumsan quis, gravida non, velit. Morbi pellentesque accumsan elit. Aenean est purus, eleifend ac, dictum at, dignissim sed, dolor. Vestibulum volutpat sapien quis augue. Maecenas vulputate accumsan sapien. Nam mattis, lacus non iaculis aliquet, mi elit varius lectus, eu malesuada dolor nunc at wisi. Aliquam ligula. Mauris nisl elit, molestie vitae, gravida sit amet, facilisis convallis, enim. Sed urna. Praesent et augue. Fusce pellentesque. Maecenas varius orci eget nisl. Donec tempor rhoncus turpis.

Integer nibh. Cras metus erat, tincidunt et, scelerisque quis, bibendum sed, dui. Suspendisse potenti.

Integer ac diam. Nullam porttitor dolor eget metus. Nulla sed metus quis tortor lacinia tempor. Mauris mauris dui, faucibus vitae, aliquet sit amet, placerat a, ante. Nunc placerat tincidunt neque. Mauris egestas dolor ut ipsum cursus malesuada. Curabitur odio. Nunc lobortis. Sed mattis tempor felis. Mauris dolor quam, facilisis at, bibendum sit amet, rutrum ornare, pede. Suspendisse accumsan sagittis velit. Pellentesque varius laoreet lorem. Vivamus egestas sapien id diam.

Integer viverra, felis ac tempus cursus, neque risus interdum turpis, eget venenatis tellus velit in neque. Nulla feugiat luctus tellus. Nam pulvinar lacus id leo. Vestibulum at ligula. Duis laoreet tincidunt enim. Suspendisse at nisl molestie est laoreet laoreet. Suspendisse euismod metus vel nisl. Aenean ullamcorper imperdiet massa. Aliquam nibh. Donec quis erat. Nunc sodales auctor ante.

Nam quis ante. Nullam interdum quam in eros. Sed eleifend libero eu tellus consequat fermentum. Nullam pellentesque risus ut augue. Vestibulum eu tellus. Integer eleifend suscipit urna. Fusce porttitor leo et odio. Vivamus vehicula justo a nisl. In rutrum, purus ut dictum auctor, dolor velit accumsan dolor, eu convallis augue dui ac lectus. Nullam eleifend pellentesque ligula. Nam quis magna. Donec elementum dapibus erat. Pellentesque vel ipsum nec orci fermentum accumsan. Nunc porta magna eu neque. Nam id erat eu mi aliquet cursus. Morbi ut felis. Vestibulum in ipsum.

Donec vel augue. Morbi a turpis sed libero consequat porta. Quisque lacinia consequat odio. Sed vehicula sollicitudin purus. Vestibulum eget est. In hac habitasse platea dictumst. Sed blandit, tortor a auctor imperdiet, wisi nibh ornare leo, ac dictum nibh enim eu orci. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Aliquam tincidunt ullamcorper justo. Etiam accumsan lacus nec ante. Ut dictum luctus mauris. Ut metus. Maecenas gravida. Proin iaculis. Integer convallis, justo iaculis ullamcorper sollicitudin, lectus neque tincidunt mi, at condimentum sem quam vel diam. Aenean sit amet purus.

Sed justo. Maecenas lacinia, turpis sed commodo congue, odio urna elementum nunc, vitae molestie velit nunc eu sem. Maecenas enim. Proin quis neque nec tortor sollicitudin volutpat. Sed at ante. Sed vitae mauris non ante egestas hendrerit. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. In venenatis facilisis magna. Phasellus purus. Cras quis mauris. Aliquam eget magna. Donec rutrum sagittis mi. Morbi elementum, est sit amet sollicitudin feugiat, orci magna semper risus, eu congue nulla metus vel elit. Nunc tempor ornare mi. Integer justo odio, suscipit tincidunt, fermentum eu, tincidunt et, libero. Vestibulum vestibulum, urna et suscipit imperdiet, nulla ante fermentum erat, at laoreet lorem lectus sed metus. Fusce ante sem, posuere in, vehicula a, posuere sed, ante. Phasellus magna. Maecenas sit amet diam. Nunc at nibh sit amet augue tristique gravida.

Aenean adipiscing auctor est. Morbi quam arcu, malesuada sed, volutpat et, elementum sit amet, libero. Duis accumsan. Curabitur urna. In sed ipsum. Donec lobortis nibh. Duis mattis. Sed cursus lectus quis odio. Phasellus arcu. Praesent imperdiet dui in sapien. Vestibulum tellus pede, auctor a, pellentesque sit amet, vulputate sed, purus. Nunc pulvinar, dui at eleifend adipiscing, tellus nulla placerat massa, sed condimentum nulla tellus sed ligula. Nulla vitae odio sit amet leo imperdiet blandit. In vel massa. Maecenas varius dui at turpis. Sed odio.

Quisque aliquam ipsum sed turpis. Pellentesque laoreet velit nec justo. Nam sed augue. Maecenas rutrum quam eu dolor. Fusce consectetuer. Proin tellus est, luctus vitae, molestie a, mattis et, mauris. Donec tempor. Pellentesque habitant morbi tristique senectus et netus

et malesuada fames ac turpis egestas. Duis ante felis, dignissim id, blandit in, suscipit vel, dolor. Pellentesque tincidunt cursus felis. Proin rhoncus semper nulla. Ut et est. Vivamus ipsum erat, gravida in, venenatis ac, fringilla in, quam. Nunc ac augue. Fusce pede erat, ultrices non, consequat et, semper sit amet, urna.

Fusce adipiscing justo nec ante. Nullam in enim. Pellentesque felis orci, sagittis ac, malesuada et, facilisis in, ligula. Nunc non magna sit amet mi aliquam dictum. In mi. Curabitur sollicitudin justo sed quam. Aenean imperdiet. Vestibulum ante ipsum primis in faucibus orci luctus et ultrices posuere cubilia Curae; Donec lacinia nonummy lectus. Proin vel urna. Fusce sit amet orci ac magna iaculis pharetra. Duis sagittis massa in tellus. Aenean vel velit vel felis consectetuer pharetra.

7.1 What Do These Findings Mean?

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Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

Quisque ullamcorper placerat ipsum. Cras nibh. Morbi vel justo vitae lacus tincidunt ultrices. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. In hac habitasse platea dictumst. Integer tempus convallis augue. Etiam facilisis. Nunc elementum fermentum wisi. Aenean placerat. Ut imperdiet, enim sed gravida sollicitudin, felis odio placerat quam, ac pulvinar elit purus eget enim. Nunc vitae tortor. Proin tempus nibh sit amet nisl. Vivamus quis tortor vitae risus porta vehicula.

Fusce mauris. Vestibulum luctus nibh at lectus. Sed bibendum, nulla a faucibus semper, leo velit ultricies tellus, ac venenatis arcu wisi vel nisl. Vestibulum diam. Aliquam pellentesque, augue quis sagittis posuere, turpis lacus congue quam, in hendrerit risus eros eget felis. Maecenas eget erat in sapien mattis porttitor. Vestibulum porttitor. Nulla facilisi. Sed a turpis eu lacus commodo facilisis. Morbi fringilla, wisi in dignissim interdum, justo lectus

sagittis dui, et vehicula libero dui cursus dui. Mauris tempor ligula sed lacus. Duis cursus enim ut augue. Cras ac magna. Cras nulla. Nulla egestas. Curabitur a leo. Quisque egestas wisi eget nunc. Nam feugiat lacus vel est. Curabitur consectetuer.

Suspendisse vel felis. Ut lorem lorem, interdum eu, tincidunt sit amet, laoreet vitae, arcu. Aenean faucibus pede eu ante. Praesent enim elit, rutrum at, molestie non, nonummy vel, nisl. Ut lectus eros, malesuada sit amet, fermentum eu, sodales cursus, magna. Donec eu purus. Quisque vehicula, urna sed ultricies auctor, pede lorem egestas dui, et convallis elit erat sed nulla. Donec luctus. Curabitur et nunc. Aliquam dolor odio, commodo pretium, ultricies non, pharetra in, velit. Integer arcu est, nonummy in, fermentum faucibus, egestas vel, odio.

Sed commodo posuere pede. Mauris ut est. Ut quis purus. Sed ac odio. Sed vehicula hendrerit sem. Duis non odio. Morbi ut dui. Sed accumsan risus eget odio. In hac habitasse platea dictumst. Pellentesque non elit. Fusce sed justo eu urna porta tincidunt. Mauris felis odio, sollicitudin sed, volutpat a, ornare ac, erat. Morbi quis dolor. Donec pellentesque, erat ac sagittis semper, nunc dui lobortis purus, quis congue purus metus ultricies tellus. Proin et quam. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Praesent sapien turpis, fermentum vel, eleifend faucibus, vehicula eu, lacus.

Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Donec odio elit, dictum in, hendrerit sit amet, egestas sed, leo. Praesent feugiat sapien aliquet odio. Integer vitae justo. Aliquam vestibulum fringilla lorem. Sed neque lectus, consectetuer at, consectetuer sed, eleifend ac, lectus. Nulla facilisi. Pellentesque eget lectus. Proin eu metus. Sed porttitor. In hac habitasse platea dictumst. Suspendisse eu lectus. Ut mi mi, lacinia sit amet, placerat et, mollis vitae, dui. Sed ante tellus, tristique ut, iaculis eu, malesuada ac, dui. Mauris nibh leo, facilisis non, adipiscing quis, ultrices a, dui.

Morbi luctus, wisi viverra faucibus pretium, nibh est placerat odio, nec commodo wisi enim eget quam. Quisque libero justo, consectetuer a, feugiat vitae, porttitor eu, libero. Suspendisse sed mauris vitae elit sollicitudin malesuada. Maecenas ultricies eros sit amet ante. Ut venenatis velit. Maecenas sed mi eget dui varius euismod. Phasellus aliquet volutpat odio. Vestibulum ante ipsum primis in faucibus orci luctus et ultrices posuere cubilia Curae; Pellentesque sit amet pede ac sem eleifend consectetuer. Nullam elementum, urna vel imperdiet sodales, elit ipsum pharetra ligula, ac pretium ante justo a nulla. Curabitur tristique arcu eu metus. Vestibulum lectus. Proin mauris. Proin eu nunc eu urna hendrerit faucibus. Aliquam auctor, pede consequat laoreet varius, eros tellus scelerisque quam, pellentesque hendrerit ipsum dolor sed augue. Nulla nec lacus.

Suspendisse vitae elit. Aliquam arcu neque, ornare in, ullamcorper quis, commodo eu, libero. Fusce sagittis erat at erat tristique mollis. Maecenas sapien libero, molestie et, lobortis in, sodales eget, dui. Morbi ultrices rutrum lorem. Nam elementum ullamcorper leo. Morbi dui. Aliquam sagittis. Nunc placerat. Pellentesque tristique sodales est. Maecenas imperdiet lacinia velit. Cras non urna. Morbi eros pede, suscipit ac, varius vel, egestas non, eros. Praesent malesuada, diam id pretium elementum, eros sem dictum tortor, vel consectetuer odio sem sed wisi.

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Etiam euismod. Fusce facilisis lacinia dui. Suspendisse potenti. In mi erat, cursus id, nonummy sed, ullamcorper eget, sapien. Praesent pretium, magna in eleifend egestas, pede

pede pretium lorem, quis consectetuer tortor sapien facilisis magna. Mauris quis magna varius nulla scelerisque imperdiet. Aliquam non quam. Aliquam porttitor quam a lacus. Praesent vel arcu ut tortor cursus volutpat. In vitae pede quis diam bibendum placerat. Fusce elementum convallis neque. Sed dolor orci, scelerisque ac, dapibus nec, ultricies ut, mi. Duis nec dui quis leo sagittis commodo.

Aliquam lectus. Vivamus leo. Quisque ornare tellus ullamcorper nulla. Mauris porttitor pharetra tortor. Sed fringilla justo sed mauris. Mauris tellus. Sed non leo. Nullam elementum, magna in cursus sodales, augue est scelerisque sapien, venenatis congue nulla arcu et pede. Ut suscipit enim vel sapien. Donec congue. Maecenas urna mi, suscipit in, placerat ut, vestibulum ut, massa. Fusce ultrices nulla et nisl.

Etiam ac leo a risus tristique nonummy. Donec dignissim tincidunt nulla. Vestibulum rhoncus molestie odio. Sed lobortis, justo et pretium lobortis, mauris turpis condimentum augue, nec ultricies nibh arcu pretium enim. Nunc purus neque, placerat id, imperdiet sed, pellentesque nec, nisl. Vestibulum imperdiet neque non sem accumsan laoreet. In hac habitasse platea dictumst. Etiam condimentum facilisis libero. Suspendisse in elit quis nisl aliquam dapibus. Pellentesque auctor sapien. Sed egestas sapien nec lectus. Pellentesque vel dui vel neque bibendum viverra. Aliquam porttitor nisl nec pede. Proin mattis libero vel turpis. Donec rutrum mauris et libero. Proin euismod porta felis. Nam lobortis, metus quis elementum commodo, nunc lectus elementum mauris, eget vulputate ligula tellus eu neque. Vivamus eu dolor.

Nulla in ipsum. Praesent eros nulla, congue vitae, euismod ut, commodo a, wisi. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Aenean nonummy magna non leo. Sed felis erat, ullamcorper in, dictum non, ultricies ut, lectus. Proin vel arcu a odio lobortis euismod. Vestibulum ante ipsum primis in faucibus orci luctus et ultrices posuere cubilia Curae; Proin ut est. Aliquam odio. Pellentesque massa turpis, cursus eu, euismod nec, tempor congue, nulla. Duis viverra gravida mauris. Cras tincidunt. Curabitur eros ligula, varius ut, pulvinar in, cursus faucibus, augue.

Nulla mattis luctus nulla. Duis commodo velit at leo. Aliquam vulputate magna et leo. Nam vestibulum ullamcorper leo. Vestibulum condimentum rutrum mauris. Donec id mauris. Morbi molestie justo et pede. Vivamus eget turpis sed nisl cursus tempor. Curabitur mollis sapien condimentum nunc. In wisi nisl, malesuada at, dignissim sit amet, lobortis in, odio. Aenean consequat arcu a ante. Pellentesque porta elit sit amet orci. Etiam at turpis nec elit ultricies imperdiet. Nulla facilisi. In hac habitasse platea dictumst. Suspendisse viverra aliquam risus. Nullam pede justo, molestie nonummy, scelerisque eu, facilisis vel, arcu.

Curabitur tellus magna, porttitor a, commodo a, commodo in, tortor. Donec interdum. Praesent scelerisque. Maecenas posuere sodales odio. Vivamus metus lacus, varius quis, imperdiet quis, rhoncus a, turpis. Etiam ligula arcu, elementum a, venenatis quis, sollicitudin sed, metus. Donec nunc pede, tincidunt in, venenatis vitae, faucibus vel, nibh. Pellentesque wisi. Nullam malesuada. Morbi ut tellus ut pede tincidunt porta. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam congue neque id dolor.

Donec et nisl at wisi luctus bibendum. Nam interdum tellus ac libero. Sed sem justo, laoreet vitae, fringilla at, adipiscing ut, nibh. Maecenas non sem quis tortor eleifend fermentum. Etiam id tortor ac mauris porta vulputate. Integer porta neque vitae massa. Maecenas tempus libero a libero posuere dictum. Vestibulum ante ipsum primis in faucibus orci luctus et ultrices posuere cubilia Curae; Aenean quis mauris sed elit commodo placerat. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Vivamus rhoncus tincidunt libero. Etiam elementum pretium justo. Vivamus est. Morbi a tellus eget pede tristique commodo. Nulla nisl. Vestibulum sed nisl eu sapien cursus rutrum.

Nulla non mauris vitae wisi posuere convallis. Sed eu nulla nec eros scelerisque pharetra. Nullam varius. Etiam dignissim elementum metus. Vestibulum faucibus, metus sit amet mattis rhoncus, sapien dui laoreet odio, nec ultricies nibh augue a enim. Fusce in ligula. Quisque at magna et nulla commodo consequat. Proin accumsan imperdiet sem. Nunc porta. Donec feugiat mi at justo. Phasellus facilisis ipsum quis ante. In ac elit eget ipsum pharetra faucibus. Maecenas viverra nulla in massa.

7.2 Where Do We Go From Here?

Nulla ac nisl. Nullam urna nulla, ullamcorper in, interdum sit amet, gravida ut, risus. Aenean ac enim. In luctus. Phasellus eu quam vitae turpis viverra pellentesque. Duis feugiat felis ut enim. Phasellus pharetra, sem id porttitor sodales, magna nunc aliquet nibh, nec blandit nisl mauris at pede. Suspendisse risus risus, lobortis eget, semper at, imperdiet sit amet, quam. Quisque scelerisque dapibus nibh. Nam enim. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Nunc ut metus. Ut metus justo, auctor at, ultrices eu, sagittis ut, purus. Aliquam aliquam.

Etiam pede massa, dapibus vitae, rhoncus in, placerat posuere, odio. Vestibulum luctus commodo lacus. Morbi lacus dui, tempor sed, euismod eget, condimentum at, tortor. Phasellus aliquet odio ac lacus tempor faucibus. Praesent sed sem. Praesent iaculis. Cras rhoncus tellus sed justo ullamcorper sagittis. Donec quis orci. Sed ut tortor quis tellus euismod tincidunt. Suspendisse congue nisl eu elit. Aliquam tortor diam, tempus id, tristique eget, sodales vel, nulla. Praesent tellus mi, condimentum sed, viverra at, consectetuer quis, lectus. In auctor vehicula orci. Sed pede sapien, euismod in, suscipit in, pharetra placerat, metus. Vivamus commodo dui non odio. Donec et felis.

Etiam suscipit aliquam arcu. Aliquam sit amet est ac purus bibendum congue. Sed in eros. Morbi non orci. Pellentesque mattis lacinia elit. Fusce molestie velit in ligula. Nullam et orci vitae nibh vulputate auctor. Aliquam eget purus. Nulla auctor wisi sed ipsum. Morbi porttitor tellus ac enim. Fusce ornare. Proin ipsum enim, tincidunt in, ornare venenatis, molestie a, augue. Donec vel pede in lacus sagittis porta. Sed hendrerit ipsum quis nisl. Suspendisse quis massa ac nibh pretium cursus. Sed sodales. Nam eu neque quis pede dignissim ornare. Maecenas eu purus ac urna tincidunt congue.

Donec et nisl id sapien blandit mattis. Aenean dictum odio sit amet risus. Morbi purus. Nulla a est sit amet purus venenatis iaculis. Vivamus viverra purus vel magna. Donec in justo sed odio malesuada dapibus. Nunc ultrices aliquam nunc. Vivamus facilisis pellentesque velit. Nulla nunc velit, vulputate dapibus, vulputate id, mattis ac, justo. Nam mattis elit dapibus purus. Quisque enim risus, congue non, elementum ut, mattis quis, sem. Quisque elit.

Maecenas non massa. Vestibulum pharetra nulla at lorem. Duis quis quam id lacus dapibus interdum. Nulla lorem. Donec ut ante quis dolor bibendum condimentum. Etiam egestas tortor vitae lacus. Praesent cursus. Mauris bibendum pede at elit. Morbi et felis a lectus interdum facilisis. Sed suscipit gravida turpis. Nulla at lectus. Vestibulum ante ipsum primis in faucibus orci luctus et ultrices posuere cubilia Curae; Praesent nonummy luctus nibh. Proin turpis nunc, congue eu, egestas ut, fringilla at, tellus. In hac habitasse platea dictumst.

Vivamus eu tellus sed tellus consequat suscipit. Nam orci orci, malesuada id, gravida nec, ultricies vitae, erat. Donec risus turpis, luctus sit amet, interdum quis, porta sed, ipsum. Suspendisse condimentum, tortor at egestas posuere, neque metus tempor orci, et tincidunt urna nunc a purus. Sed facilisis blandit tellus. Nunc risus sem, suscipit nec, eleifend quis, cursus quis, libero. Curabitur et dolor. Sed vitae sem. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Maecenas ante. Duis ullamcorper

enim. Donec tristique enim eu leo. Nullam molestie elit eu dolor. Nullam bibendum, turpis vitae tristique gravida, quam sapien tempor lectus, quis pretium tellus purus ac quam. Nulla facilisi.

Duis aliquet dui in est. Donec eget est. Nunc lectus odio, varius at, fermentum in, accumsan non, enim. Aliquam erat volutpat. Proin sit amet nulla ut eros consectetuer cursus. Phasellus dapibus aliquam justo. Nunc laoreet. Donec consequat placerat magna. Duis pretium tincidunt justo. Sed sollicitudin vestibulum quam. Nam quis ligula. Vivamus at metus. Etiam imperdiet imperdiet pede. Aenean turpis. Fusce augue velit, scelerisque sollicitudin, dictum vitae, tempor et, pede. Donec wisi sapien, feugiat in, fermentum ut, sollicitudin adipiscing, metus.

Donec vel nibh ut felis consectetuer laoreet. Donec pede. Sed id quam id wisi laoreet suscipit. Nulla lectus dolor, aliquam ac, fringilla eget, mollis ut, orci. In pellentesque justo in ligula. Maecenas turpis. Donec eleifend leo at felis tincidunt consequat. Aenean turpis metus, malesuada sed, condimentum sit amet, auctor a, wisi. Pellentesque sapien elit, bibendum ac, posuere et, congue eu, felis. Vestibulum mattis libero quis metus scelerisque ultrices. Sed purus.

Donec molestie, magna ut luctus ultrices, tellus arcu nonummy velit, sit amet pulvinar elit justo et mauris. In pede. Maecenas euismod elit eu erat. Aliquam augue wisi, facilisis congue, suscipit in, adipiscing et, ante. In justo. Cras lobortis neque ac ipsum. Nunc fermentum massa at ante. Donec orci tortor, egestas sit amet, ultrices eget, venenatis eget, mi. Maecenas vehicula leo semper est. Mauris vel metus. Aliquam erat volutpat. In rhoncus sapien ac tellus. Pellentesque ligula.

Cras dapibus, augue quis scelerisque ultricies, felis dolor placerat sem, id porta velit odio eu elit. Aenean interdum nibh sed wisi. Praesent sollicitudin vulputate dui. Praesent iaculis viverra augue. Quisque in libero. Aenean gravida lorem vitae sem ullamcorper cursus. Nunc adipiscing rutrum ante. Nunc ipsum massa, faucibus sit amet, viverra vel, elementum semper, orci. Cras eros sem, vulputate et, tincidunt id, ultrices eget, magna. Nulla varius ornare odio. Donec accumsan mauris sit amet augue. Sed ligula lacus, laoreet non, aliquam sit amet, iaculis tempor, lorem. Suspendisse eros. Nam porta, leo sed congue tempor, felis est ultrices eros, id mattis velit felis non metus. Curabitur vitae elit non mauris varius pretium. Aenean lacus sem, tincidunt ut, consequat quis, porta vitae, turpis. Nullam laoreet fermentum urna. Proin iaculis lectus.

Sed mattis, erat sit amet gravida malesuada, elit augue egestas diam, tempus scelerisque nunc nisl vitae libero. Sed consequat feugiat massa. Nunc porta, eros in eleifend varius, erat leo rutrum dui, non convallis lectus orci ut nibh. Sed lorem massa, nonummy quis, egestas id, condimentum at, nisl. Maecenas at nibh. Aliquam et augue at nunc pellentesque ullamcorper. Duis nisl nibh, laoreet suscipit, convallis ut, rutrum id, enim. Phasellus odio. Nulla nulla elit, molestie non, scelerisque at, vestibulum eu, nulla. Ut odio nisl, facilisis id, mollis et, scelerisque nec, enim. Aenean sem leo, pellentesque sit amet, scelerisque sit amet, vehicula pellentesque, sapien.

Sed consequat tellus et tortor. Ut tempor laoreet quam. Nullam id wisi a libero tristique semper. Nullam nisl massa, rutrum ut, egestas semper, mollis id, leo. Nulla ac massa eu risus blandit mattis. Mauris ut nunc. In hac habitasse platea dictumst. Aliquam eget tortor. Quisque dapibus pede in erat. Nunc enim. In dui nulla, commodo at, consectetuer nec, malesuada nec, elit. Aliquam ornare tellus eu urna. Sed nec metus. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas.

Phasellus id magna. Duis malesuada interdum arcu. Integer metus. Morbi pulvinar

pellentesque mi. Suspendisse sed est eu magna molestie egestas. Quisque mi lorem, pulvinar eget, egestas quis, luctus at, ante. Proin auctor vehicula purus. Fusce ac nisl aliquam ante hendrerit pellentesque. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Morbi wisi. Etiam arcu mauris, facilisis sed, eleifend non, nonummy ut, pede. Cras ut lacus tempor metus mollis placerat. Vivamus eu tortor vel metus interdum malesuada.

Sed eleifend, eros sit amet faucibus elementum, urna sapien consectetuer mauris, quis egestas leo justo non risus. Morbi non felis ac libero vulputate fringilla. Mauris libero eros, lacinia non, sodales quis, dapibus porttitor, pede. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Morbi dapibus mauris condimentum nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Etiam sit amet erat. Nulla varius. Etiam tincidunt dui vitae turpis. Donec leo. Morbi vulputate convallis est. Integer aliquet. Pellentesque aliquet sodales urna.

Nullam eleifend justo in nisl. In hac habitasse platea dictumst. Morbi nonummy. Aliquam ut felis. In velit leo, dictum vitae, posuere id, vulputate nec, ante. Maecenas vitae pede nec dui dignissim suscipit. Morbi magna. Vestibulum id purus eget velit laoreet laoreet. Praesent sed leo vel nibh convallis blandit. Ut rutrum. Donec nibh. Donec interdum. Fusce sed pede sit amet elit rhoncus ultrices. Nullam at enim vitae pede vehicula iaculis.

Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Aenean nonummy turpis id odio. Integer euismod imperdiet turpis. Ut nec leo nec diam imperdiet lacinia. Etiam eget lacus eget mi ultricies posuere. In placerat tristique tortor. Sed porta vestibulum metus. Nulla iaculis sollicitudin pede. Fusce luctus tellus in dolor. Curabitur auctor velit a sem. Morbi sapien. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Donec adipiscing urna vehicula nunc. Sed ornare leo in leo. In rhoncus leo ut dui. Aenean dolor quam, volutpat nec, fringilla id, consectetuer vel, pede.

Nulla malesuada risus ut urna. Aenean pretium velit sit amet metus. Duis iaculis. In hac habitasse platea dictumst. Nullam molestie turpis eget nisl. Duis a massa id pede dapibus ultricies. Sed eu leo. In at mauris sit amet tortor bibendum varius. Phasellus justo risus, posuere in, sagittis ac, varius vel, tortor. Quisque id enim. Phasellus consequat, libero pretium nonummy fringilla, tortor lacus vestibulum nunc, ut rhoncus ligula neque id justo. Nullam accumsan euismod nunc. Proin vitae ipsum ac metus dictum tempus. Nam ut wisi. Quisque tortor felis, interdum ac, sodales a, semper a, sem. Curabitur in velit sit amet dui tristique sodales. Vivamus mauris pede, lacinia eget, pellentesque quis, scelerisque eu, est. Aliquam risus. Quisque bibendum pede eu dolor.

Donec tempus neque vitae est. Aenean egestas odio sed risus ullamcorper ullamcorper. Sed in nulla a tortor tincidunt egestas. Nam sapien tortor, elementum sit amet, aliquam in, porttitor faucibus, enim. Nullam congue suscipit nibh. Quisque convallis. Praesent arcu nibh, vehicula eget, accumsan eu, tincidunt a, nibh. Suspendisse vulputate, tortor quis adipiscing viverra, lacus nibh dignissim tellus, eu suscipit risus ante fringilla diam. Quisque a libero vel pede imperdiet aliquet. Pellentesque nunc nibh, eleifend a, consequat consequat, hendrerit nec, diam. Sed urna. Maecenas laoreet eleifend neque. Vivamus purus odio, eleifend non, iaculis a, ultrices sit amet, urna. Mauris faucibus odio vitae risus. In nisl. Praesent purus. Integer iaculis, sem eu egestas lacinia, lacus pede scelerisque augue, in ullamcorper dolor eros ac lacus. Nunc in libero.

Fusce suscipit cursus sem. Vivamus risus mi, egestas ac, imperdiet varius, faucibus quis, leo. Aenean tincidunt. Donec suscipit. Cras id justo quis nibh scelerisque dignissim. Aliquam sagittis elementum dolor. Aenean consectetuer justo in pede. Curabitur ullamcorper ligula nec orci. Aliquam purus turpis, aliquam id, ornare vitae, porttitor non, wisi. Maecenas luctus

porta lorem. Donec vitae ligula eu ante pretium varius. Proin tortor metus, convallis et, hendrerit non, scelerisque in, urna. Cras quis libero eu ligula bibendum tempor. Vivamus tellus quam, malesuada eu, tempus sed, tempor sed, velit. Donec lacinia auctor libero.

Praesent sed neque id pede mollis rutrum. Vestibulum iaculis risus. Pellentesque lacus. Ut quis nunc sed odio malesuada egestas. Duis a magna sit amet ligula tristique pretium. Ut pharetra. Vestibulum imperdiet magna nec wisi. Mauris convallis. Sed accumsan sollicitudin massa. Sed id enim. Nunc pede enim, lacinia ut, pulvinar quis, suscipit semper, elit. Cras accumsan erat vitae enim. Cras sollicitudin. Vestibulum rutrum blandit massa.

Sed gravida lectus ut purus. Morbi laoreet magna. Pellentesque eu wisi. Proin turpis. Integer sollicitudin augue nec dui. Fusce lectus. Vivamus faucibus nulla nec lacus. Integer diam. Pellentesque sodales, enim feugiat cursus volutpat, sem mauris dignissim mauris, quis consequat sem est fermentum ligula. Nullam justo lectus, condimentum sit amet, posuere a, fringilla mollis, felis. Morbi nulla nibh, pellentesque at, nonummy eu, sollicitudin nec, ipsum. Cras neque. Nunc augue. Nullam vitae quam id quam pulvinar blandit. Nunc sit amet orci. Aliquam erat elit, pharetra nec, aliquet a, gravida in, mi. Quisque urna enim, viverra quis, suscipit quis, tincidunt ut, sapien. Cras placerat consequat sem. Curabitur ac diam. Curabitur diam tortor, mollis et, viverra ac, tempus vel, metus.

Curabitur ac lorem. Vivamus non justo in dui mattis posuere. Etiam accumsan ligula id pede. Maecenas tincidunt diam nec velit. Praesent convallis sapien ac est. Aliquam ullamcorper euismod nulla. Integer mollis enim vel tortor. Nulla sodales placerat nunc. Sed tempus rutrum wisi. Duis accumsan gravida purus. Nunc nunc. Etiam facilisis dui eu sem. Vestibulum semper. Praesent eu eros. Vestibulum tellus nisl, dapibus id, vestibulum sit amet, placerat ac, mauris. Maecenas et elit ut erat placerat dictum. Nam feugiat, turpis et sodales volutpat, wisi quam rhoncus neque, vitae aliquam ipsum sapien vel enim. Maecenas suscipit cursus mi.

Quisque consectetuer. In suscipit mauris a dolor pellentesque consectetuer. Mauris convallis neque non erat. In lacinia. Pellentesque leo eros, sagittis quis, fermentum quis, tincidunt ut, sapien. Maecenas sem. Curabitur eros odio, interdum eu, feugiat eu, porta ac, nisl. Curabitur nunc. Etiam fermentum convallis velit. Pellentesque laoreet lacus. Quisque sed elit. Nam quis tellus. Aliquam tellus arcu, adipiscing non, tincidunt eleifend, adipiscing quis, augue. Vivamus elementum placerat enim. Suspendisse ut tortor. Integer faucibus adipiscing felis. Aenean consectetuer mattis lectus. Morbi malesuada faucibus dolor. Nam lacus. Etiam arcu libero, malesuada vitae, aliquam vitae, blandit tristique, nisl.

Maecenas accumsan dapibus sapien. Duis pretium iaculis arcu. Curabitur ut lacus. Aliquam vulputate. Suspendisse ut purus sed sem tempor rhoncus. Ut quam dui, fringilla at, dictum eget, ultricies quis, quam. Etiam sem est, pharetra non, vulputate in, pretium at, ipsum. Nunc semper sagittis orci. Sed scelerisque suscipit diam. Ut volutpat, dolor at ullamcorper tristique, eros purus mollis quam, sit amet ornare ante nunc et enim.

Phasellus fringilla, metus id feugiat consectetuer, lacus wisi ultrices tellus, quis lobortis nibh lorem quis tortor. Donec egestas ornare nulla. Mauris mi tellus, porta faucibus, dictum vel, nonummy in, est. Aliquam erat volutpat. In tellus magna, porttitor lacinia, molestie vitae, pellentesque eu, justo. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Sed orci nibh, scelerisque sit amet, suscipit sed, placerat vel, diam. Vestibulum nonummy vulputate orci. Donec et velit ac arcu interdum semper. Morbi pede orci, cursus ac, elementum non, vehicula ut, lacus. Cras volutpat. Nam vel wisi quis libero venenatis placerat. Aenean sed odio. Quisque posuere purus ac orci. Vivamus odio. Vivamus varius, nulla sit amet semper viverra, odio mauris consequat lacus, at vestibulum neque arcu eu tortor. Donec iaculis tincidunt tellus. Aliquam erat volutpat. Curabitur magna lorem,

dignissim volutpat, viverra et, adipiscing nec, dolor. Praesent lacus mauris, dapibus vitae, sollicitudin sit amet, nonummy eget, ligula.

Cras egestas ipsum a nisl. Vivamus varius dolor ut dolor. Fusce vel enim. Pellentesque accumsan ligula et eros. Cras id lacus non tortor facilisis facilisis. Etiam nisl elit, cursus sed, fringilla in, congue nec, urna. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Integer at turpis. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Duis fringilla, ligula sed porta fringilla, ligula wisi commodo felis, ut adipiscing felis dui in enim. Suspendisse malesuada ultrices ante. Pellentesque scelerisque augue sit amet urna. Nulla volutpat aliquet tortor. Cras aliquam, tellus at aliquet pellentesque, justo sapien commodo leo, id rhoncus sapien quam at erat. Nulla commodo, wisi eget sollicitudin pretium, orci orci aliquam orci, ut cursus turpis justo et lacus. Nulla vel tortor. Quisque erat elit, viverra sit amet, sagittis eget, porta sit amet, lacus.

In hac habitasse platea dictumst. Proin at est. Curabitur tempus vulputate elit. Pellentesque sem. Praesent eu sapien. Duis elit magna, aliquet at, tempus sed, vehicula non, enim. Morbi viverra arcu nec purus. Vivamus fringilla, enim et commodo malesuada, tortor metus elementum ligula, nec aliquet est sapien ut lectus. Aliquam mi. Ut nec elit. Fusce euismod luctus tellus. Curabitur scelerisque. Nullam purus. Nam ultricies accumsan magna. Morbi pulvinar lorem sit amet ipsum. Donec ut justo vitae nibh mollis congue. Fusce quis diam. Praesent tempus eros ut quam.

Donec in nisl. Fusce vitae est. Vivamus ante ante, mattis laoreet, posuere eget, congue vel, nunc. Fusce sem. Nam vel orci eu eros viverra luctus. Pellentesque sit amet augue. Nunc sit amet ipsum et lacus varius nonummy. Integer rutrum sem eget wisi. Aenean eu sapien. Quisque ornare dignissim mi. Duis a urna vel risus pharetra imperdiet. Suspendisse potenti.

Morbi justo. Aenean nec dolor. In hac habitasse platea dictumst. Proin nonummy porttitor velit. Sed sit amet leo nec metus rhoncus varius. Cras ante. Vestibulum commodo sem tincidunt massa. Nam justo. Aenean luctus, felis et condimentum lacinia, lectus enim pulvinar purus, non porta velit nisl sed eros. Suspendisse consequat. Mauris a dui et tortor mattis pretium. Sed nulla metus, volutpat id, aliquam eget, ullamcorper ut, ipsum. Morbi eu nunc. Praesent pretium. Duis aliquam pulvinar ligula. Ut blandit egestas justo. Quisque posuere metus viverra pede.

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