Vulkan.

Queues and Command Buffers

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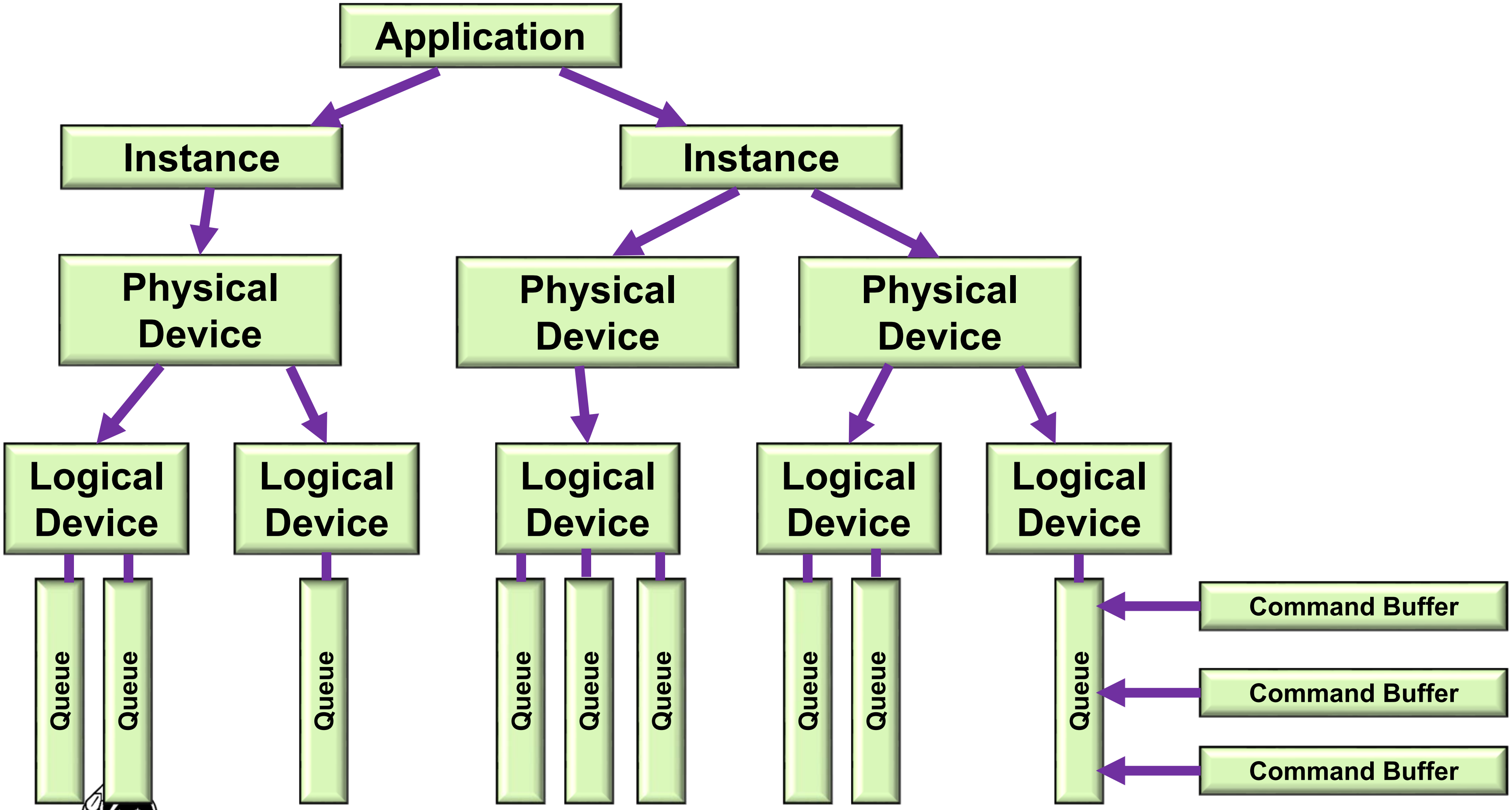
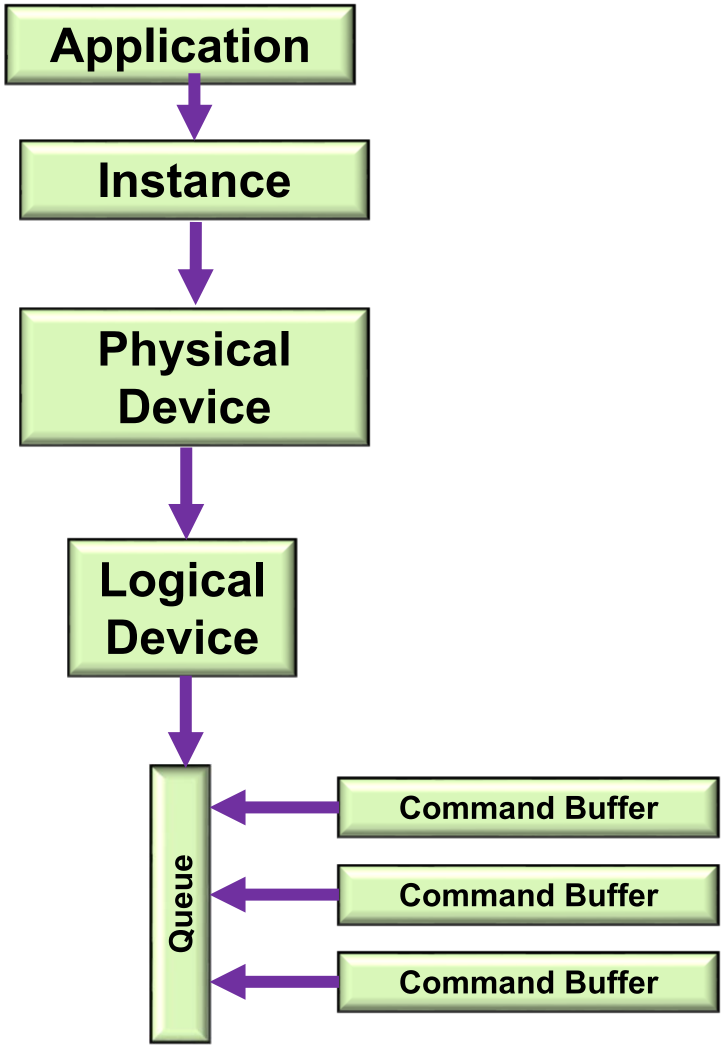
Vulkan: Overall Block Diagram



Vulkan: a More Typical (and Simplified) Block Diagram



Application

Instance

Physical Device

Logical Device

Queue

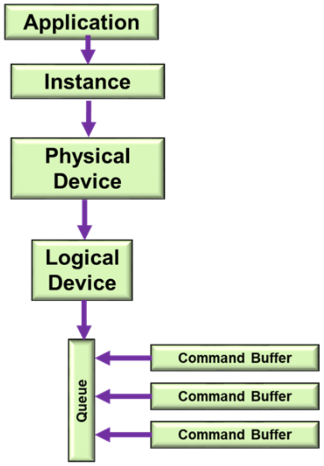
Command Buffer

Command Buffer

Command Buffer

Vulkan Queues and Command Buffers

- Graphics commands are recorded in command buffers, e.g., *vkCmdDoSomething(cmdBuffer, …);*
- You can have as many simultaneous Command Buffers as you want
- Each command buffer can be filled from a different thread
- Command Buffers record our commands, but no work takes place until a Command Buffer is submitted to a Queue
- We don't create Queues – the Logical Device has them already
- Each Queue belongs to a Queue Family
- We don't create Queue Families – the Physical Device already has them


Application
Instance
Physical Device
Logical Device
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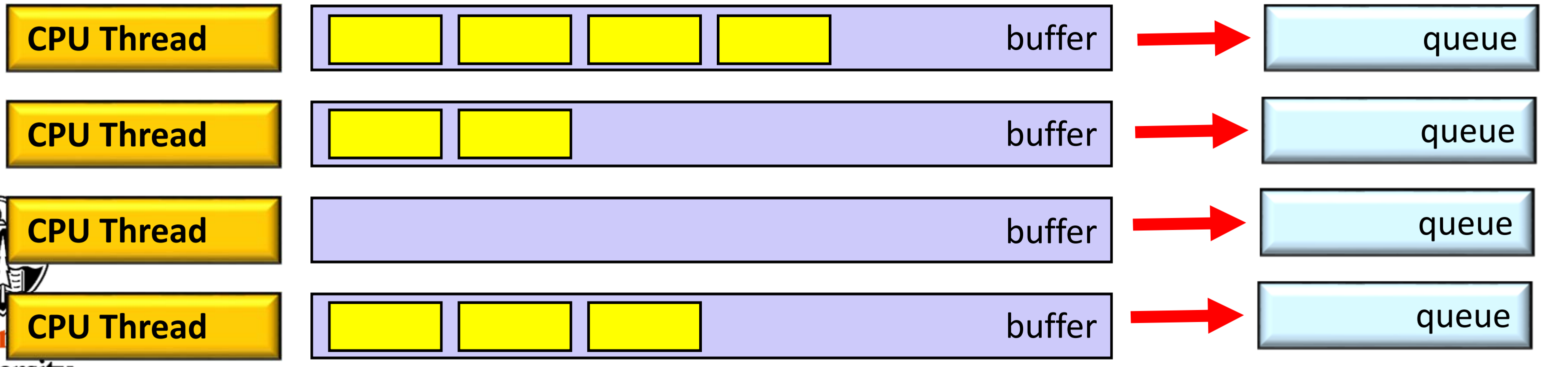
Command Buffer
Command Buffer


CPU Thread
buffer
queue
CPU Thread
buffer
queue
CPU Thread
buffer
queue
CPU Thread
buffer
queue

Querying what Queue Families are Available

```
uint32_t  count;
vkGetPhysicalDeviceQueueFamilyProperties( IN PhysicalDevice, &count, OUT (VkQueueFamilyProperties *) nullptr );

VkQueueFamilyProperties *vqfp = new VkQueueFamilyProperties[ count ];
vkGetPhysicalDeviceFamilyProperties(  PhysicalDevice, &count, OUT &vqfp, );

for( unsigned int i = 0; i < count; i++ )
{
	fprintf( FpDebug, "\t%d: Queue Family Count = %2d  ;   ", i, vqfp[i].queueCount );
	if( ( vqfp[i].queueFlags & VK_QUEUE_GRAPHICS_BIT ) != 0 )       fprintf( FpDebug, " Graphics" );
	if( ( vqfp[i].queueFlags & VK_QUEUE_COMPUTE_BIT  ) != 0 )       fprintf( FpDebug, " Compute " );
	if( ( vqfp[i].queueFlags & VK_QUEUE_TRANSFER_BIT ) != 0 )       fprintf( FpDebug, " Transfer" );
	fprintf(FpDebug, "\n");
}
```

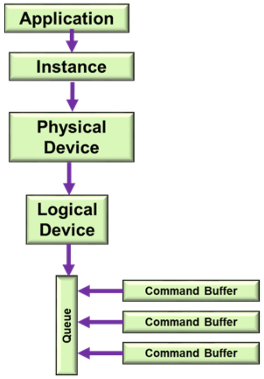
```
Found 3 Queue Families:
	0: Queue Family Count = 16  ;    Graphics Compute Transfer
	1: Queue Family Count =   1  ;    Transfer
	2: Queue Family Count =   8  ;    Compute
```

Similarly, we Can Write a Function that Finds the Proper Queue Family

```
int
FindQueueFamilyThatDoesGraphics( )
{
        uint32_t count = -1;
        vkGetPhysicalDeviceQueueFamilyProperties( IN PhysicalDevice, &count, OUT (VkQueueFamilyProperties *)nullptr )
;
        VkQueueFamilyProperties *vqfp = new VkQueueFamilyProperties[ count ];
        vkGetPhysicalDeviceQueueFamilyProperties( IN PhysicalDevice, &count, OUT vqfp );

        for( unsigned int i = 0; i < count; i++ )
        {
                if( ( vqfp[i].queueFlags & VK_QUEUE_GRAPHICS_BIT ) != 0 )
                        return i;
        }
        return -1;
}
```

“These are not the Queue Families you’re looking for.”

Creating a Logical Device Queue Needs to Know Queue Family Information



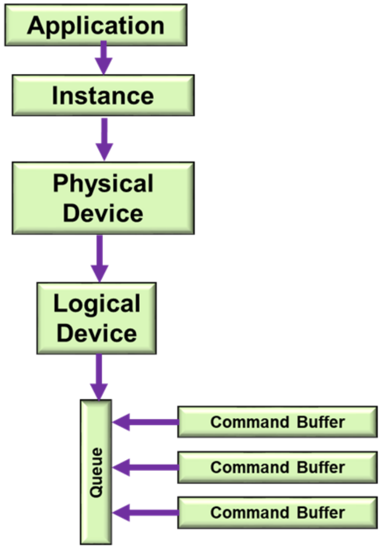
```
 float   queuePriorities[ ] =
{
                1.                    // one entry per queueCount
};

VkDeviceQueueCreateInfo  vdqci[1];
        vdqci.sType = VK_STRUCTURE_TYPE_QUEUE_CREATE_INFO;
        vdqci.pNext = nullptr;
        vdqci.flags = 0;
        vdqci.queueFamilyIndex = FindQueueFamilyThatDoesGraphics( );
        vdqci.queueCount = 1;
        vdqci.queuePriorities = (float *) queuePriorities;

 VkDeviceCreateInfo   vdci;
            vdci.sType = VK_STRUCTURE_TYPE_DEVICE_CREATE_INFO;
            vdci.pNext = nullptr;
            vdci.flags = 0;
            vdci.queueCreateInfoCount = 1;                   // # of device queues wanted
            vdci.pQueueCreateInfos = IN &vdqci[0];           // array of VkDeviceQueueCreateInfo's
            vdci.enabledLayerCount = sizeof(myDeviceLayers) / sizeof(char *);
            vdci.ppEnabledLayerNames = myDeviceLayers;
            vdci.enabledExtensionCount = sizeof(myDeviceExtensions) / sizeof(char *);
            vdci.ppEnabledExtensionNames = myDeviceExtensions;
            vdci.pEnabledFeatures = IN &PhysicalDeviceFeatures;     // already created

result = vkCreateLogicalDevice( PhysicalDevice, IN &vdci, PALLOCATOR, OUT &LogicalDevice );

VkQueue Queue;
uint32_t  queueFamilyIndex = FindQueueFamilyThatDoesGraphics( );
uint32_t  queueIndex = 0;

result = vkGetDeviceQueue ( LogicalDevice, queueFamilyIndex, queueIndex,  OUT &Queue );
```

Creating the Command Pool as part of the Logical Device

```
VkResult
Init06CommandPool( )
{
	VkResult result;

	VkCommandPoolCreateInfo			vcpci;
		vcpci.sType = VK_STRUCTURE_TYPE_COMMAND_POOL_CREATE_INFO;
		vcpci.pNext = nullptr;
		vcpci.flags =	VK_COMMAND_POOL_CREATE_RESET_COMMAND_BUFFER_BIT
				| VK_COMMAND_POOL_CREATE_TRANSIENT_BIT;
#ifdef CHOICES
VK_COMMAND_POOL_CREATE_TRANSIENT_BIT
VK_COMMAND_POOL_CREATE_RESET_COMMAND_BUFFER_BIT
#endif
		vcpci.queueFamilyIndex = FindQueueFamilyThatDoesGraphics( );

	result = vkCreateCommandPool( LogicalDevice, IN &vcpci, PALLOCATOR, OUT &CommandPool );

	return result;
}
```

Creating the Command Buffers

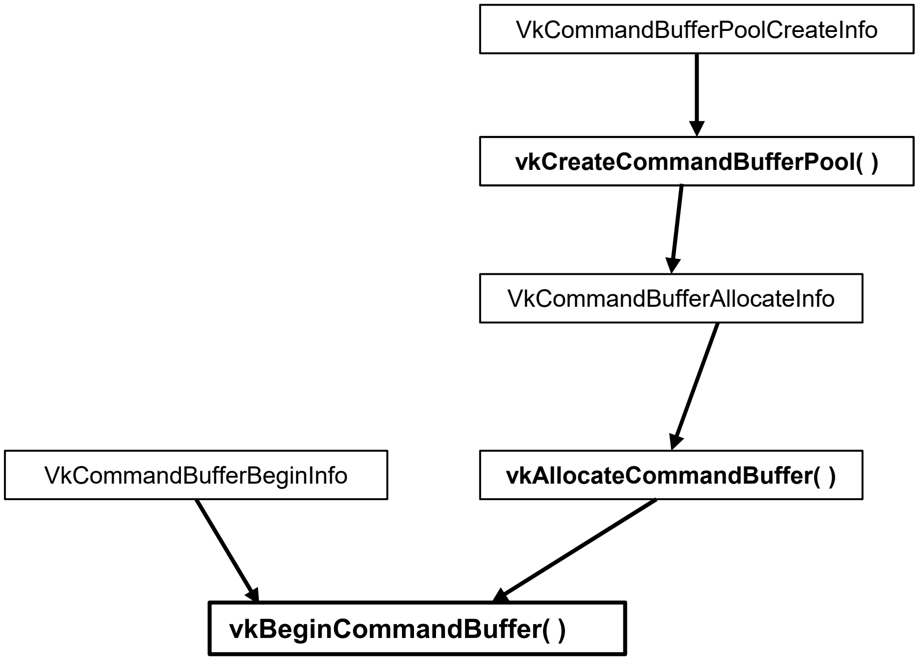
```
VkResult
Init06CommandBuffers( )
{
	VkResult result;

	// allocate 2 command buffers for the double-buffered rendering:

	{
		VkCommandBufferAllocateInfo			vcbai;
			vcbai.sType = VK_STRUCTURE_TYPE_COMMAND_BUFFER_ALLOCATE_INFO;
			vcbai.pNext = nullptr;
			vcbai.commandPool = CommandPool;
			vcbai.level = VK_COMMAND_BUFFER_LEVEL_PRIMARY;
			vcbai.commandBufferCount = 2;		// 2, because of double-buffering

		result = vkAllocateCommandBuffers( LogicalDevice, IN &vcbai, OUT &CommandBuffers[0] );
	}


	// allocate 1 command buffer for the transferring pixels from a staging buffer to a texture buffer:

	{
		VkCommandBufferAllocateInfo			vcbai;
			vcbai.sType = VK_STRUCTURE_TYPE_COMMAND_BUFFER_ALLOCATE_INFO;
			vcbai.pNext = nullptr;
			vcbai.commandPool = CommandPool;
			vcbai.level = VK_COMMAND_BUFFER_LEVEL_PRIMARY;
			vcbai.commandBufferCount = 1;

		result = vkAllocateCommandBuffers( LogicalDevice, IN &vcbai, OUT &TextureCommandBuffer );
	}

	return result;
}
```



Beginning a Command Buffer

```
VkSemaphoreCreateInfo                vsci;
        vsci.sType = VK_STRUCTURE_TYPE_SEMAPHORE_CREATE_INFO;
        vsci.pNext = nullptr;
        vsci.flags = 0;

VkSemaphore  imageReadySemaphore;
result = vkCreateSemaphore( LogicalDevice, IN &vsci, PALLOCATOR, OUT &imageReadySemaphore );

uint32_t  nextImageIndex;
vkAcquireNextImageKHR( LogicalDevice, IN SwapChain, IN UINT64_MAX,
                                        IN imageReadySemaphore, IN VK_NULL_HANDLE, OUT &nextImageIndex );


VkCommandBufferBeginInfo             vcbbi;
            vcbbi.sType = VK_STRUCTURE_TYPE_COMMAND_BUFFER_BEGIN_INFO;
            vcbbi.pNext = nullptr;
            vcbbi.flags = VK_COMMAND_BUFFER_USAGE_ONE_TIME_SUBMIT_BIT;
            vcbbi.pInheritanceInfo = (VkCommandBufferInheritanceInfo *)nullptr;

result = vkBeginCommandBuffer( CommandBuffers[nextImageIndex], IN &vcbbi );

        . . .

vkEndCommandBuffer( CommandBuffers[nextImageIndex] );
```

Beginning a Command Buffer



These are the Commands that could be entered into the Command Buffer, I

```
vkCmdBeginQuery( commandBuffer, flags );
vkCmdBeginRenderPass( commandBuffer, const contents );
vkCmdBindDescriptorSets( commandBuffer, pDynamicOffsets );
vkCmdBindIndexBuffer( commandBuffer, indexType );
vkCmdBindPipeline( commandBuffer, pipeline );
vkCmdBindVertexBuffers( commandBuffer, firstBinding, bindingCount, const pOffsets );
vkCmdBlitImage( commandBuffer, filter );
vkCmdClearAttachments( commandBuffer, attachmentCount, const pRects );
vkCmdClearColorImage( commandBuffer, pRanges );
vkCmdClearDepthStencilImage( commandBuffer, pRanges );
vkCmdCopyBuffer( commandBuffer, pRegions );
vkCmdCopyBufferToImage( commandBuffer, pRegions );
vkCmdCopyImage( commandBuffer, pRegions );
vkCmdCopyImageToBuffer( commandBuffer, pRegions );
vkCmdCopyQueryPoolResults( commandBuffer, flags );
vkCmdDebugMarkerBeginEXT( commandBuffer, pMarkerInfo );
vkCmdDebugMarkerEndEXT( commandBuffer );
vkCmdDebugMarkerInsertEXT( commandBuffer, pMarkerInfo );
vvkCmdDispatch( commandBuffer, groupCountX, groupCountY, groupCountZ );
vkCmdDispatchIndirect( commandBuffer, offset );
vkCmdDraw( commandBuffer, vertexCount, instanceCount, firstVertex, firstInstance );
vkCmdDrawIndexed( commandBuffer, indexCount, instanceCount, firstIndex, int32_t vertexOffset, firstInstance );
vkCmdDrawIndexedIndirect( commandBuffer, stride );
vkCmdDrawIndexedIndirectCountAMD( commandBuffer, stride );
vkCmdDrawIndirect( commandBuffer, stride );
vkCmdDrawIndirectCountAMD( commandBuffer, stride );
vkCmdEndQuery( commandBuffer, query );
vkCmdEndRenderPass( commandBuffer );
vkCmdExecuteCommands( commandBuffer, commandBufferCount, const pCommandBuffers );
```

These are the Commands that could be entered into the Command Buffer, II

```
vkCmdFillBuffer( commandBuffer, dstBuffer, dstOffset, size, data );
vkCmdNextSubpass( commandBuffer, contents );
vkCmdPipelineBarrier( commandBuffer, srcStageMask, dstStageMask, dependencyFlags, memoryBarrierCount, VkMemoryBarrier* pMemoryBarriers,
bufferMemoryBarrierCount, pBufferMemoryBarriers, imageMemoryBarrierCount, pImageMemoryBarriers );
vkCmdProcessCommandsNVX( commandBuffer, pProcessCommandsInfo );
vkCmdPushConstants( commandBuffer, layout, stageFlags, offset, size, pValues );
vkCmdPushDescriptorSetKHR( commandBuffer, pipelineBindPoint, layout, set, descriptorWriteCount, pDescriptorWrites );
vkCmdPushDescriptorSetWithTemplateKHR( commandBuffer, descriptorUpdateTemplate, layout, set, pData );
vkCmdReserveSpaceForCommandsNVX( commandBuffer, pReserveSpaceInfo );
vkCmdResetEvent( commandBuffer, event, stageMask );
vkCmdResetQueryPool( commandBuffer, queryPool, firstQuery, queryCount );
vkCmdResolveImage( commandBuffer, srcImage, srcImageLayout, dstImage, dstImageLayout, regionCount, pRegions );
vkCmdSetBlendConstants( commandBuffer, blendConstants[4] );
vkCmdSetDepthBias( commandBuffer, depthBiasConstantFactor, depthBiasClamp, depthBiasSlopeFactor );
vkCmdSetDepthBounds( commandBuffer, minDepthBounds, maxDepthBounds );
vkCmdSetDeviceMaskKHX( commandBuffer, deviceMask );
vkCmdSetDiscardRectangleEXT( commandBuffer, firstDiscardRectangle, discardRectangleCount, pDiscardRectangles );
vkCmdSetEvent( commandBuffer, event, stageMask );
vkCmdSetLineWidth( commandBuffer, lineWidth );
vkCmdSetScissor( commandBuffer, firstScissor, scissorCount, pScissors );
vkCmdSetStencilCompareMask( commandBuffer, faceMask, compareMask );
vkCmdSetStencilReference( commandBuffer, faceMask, reference );
vkCmdSetStencilWriteMask( commandBuffer, faceMask, writeMask );
vkCmdSetViewport( commandBuffer, firstViewport, viewportCount, pViewports );
vkCmdSetViewportWScalingNV( commandBuffer, firstViewport, viewportCount, pViewportWScalings );
vkCmdUpdateBuffer( commandBuffer, dstBuffer, dstOffset, dataSize, pData );
vkCmdWaitEvents( commandBuffer, eventCount, pEvents, srcStageMask, dstStageMask, memoryBarrierCount, pMemoryBarriers,
                    bufferMemoryBarrierCount, pBufferMemoryBarriers, imageMemoryBarrierCount, pImageMemoryBarriers );
vkCmdWriteTimestamp( commandBuffer, pipelineStage, queryPool, query );
```

```
VkResult
RenderScene( )
{
        VkResult result;
        VkSemaphoreCreateInfo                   vsci;
            vsci.sType = VK_STRUCTURE_TYPE_SEMAPHORE_CREATE_INFO;
            vsci.pNext = nullptr;
            vsci.flags = 0;

        VkSemaphore  imageReadySemaphore;
        result = vkCreateSemaphore( LogicalDevice, IN &vsci, PALLOCATOR, OUT &imageReadySemaphore );

        uint32_t nextImageIndex;
        vkAcquireNextImageKHR( LogicalDevice,    IN SwapChain, IN UINT64_MAX, IN VK_NULL_HANDLE,
                                                IN VK_NULL_HANDLE, OUT &nextImageIndex );

        VkCommandBufferBeginInfo              vcbbi;
                vcbbi.sType = VK_STRUCTURE_TYPE_COMMAND_BUFFER_BEGIN_INFO;
                vcbbi.pNext = nullptr;
                vcbbi.flags = VK_COMMAND_BUFFER_USAGE_ONE_TIME_SUBMIT_BIT;
                vcbbi.pInheritanceInfo = (VkCommandBufferInheritanceInfo *)nullptr;

        result = vkBeginCommandBuffer( CommandBuffers[nextImageIndex], IN &vcbbi );
```

```
VkClearColorValue                       vccv;
        vccv.float32[0] = 0.0;
        vccv.float32[1] = 0.0;
        vccv.float32[2] = 0.0;
        vccv.float32[3] = 1.0;

VkClearDepthStencilValue                vcdsv;
        vcdsv.depth = 1.f;
        vcdsv.stencil = 0;

VkClearValue                            vcv[2];
        vcv[0].color = vccv;
        vcv[1].depthStencil = vcdsv;

VkOffset2D o2d = { 0, 0 };
VkExtent2D e2d = { Width, Height };
VkRect2D r2d = { o2d, e2d };

VkRenderPassBeginInfo                   vrpbi;
        vrpbi.sType = VK_STRUCTURE_TYPE_RENDER_PASS_BEGIN_INFO;
        vrpbi.pNext = nullptr;
        vrpbi.renderPass = RenderPass;
        vrpbi.framebuffer = Framebuffers[ nextImageIndex ];
        vrpbi.renderArea = r2d;
        vrpbi.clearValueCount = 2;
        vrpbi.pClearValues = vcv;            // used for VK_ATTACHMENT_LOAD_OP_CLEAR

vkCmdBeginRenderPass( CommandBuffers[nextImageIndex], IN &vrpbi, IN VK_SUBPASS_CONTENTS_INLINE );
```

```
VkViewport viewport =
{
	0.,			// x
	0.,			// y
	(float)Width,
	(float)Height,
	0.,			// minDepth
	1.			// maxDepth
};

vkCmdSetViewport( CommandBuffers[nextImageIndex], 0, 1, IN &viewport );		// 0=firstViewport, 1=viewportCount

VkRect2D scissor =
{
	0,
	0,
	Width,
	Height
};

vkCmdSetScissor( CommandBuffers[nextImageIndex], 0, 1, IN &scissor );

vkCmdBindDescriptorSets( CommandBuffers[nextImageIndex], VK_PIPELINE_BIND_POINT_GRAPHICS,
				GraphicsPipelineLayout, 0, 4, DescriptorSets, 0, (uint32_t *)nullptr );
								// dynamic offset count, dynamic offsets
vkCmdBindPushConstants( CommandBuffers[nextImageIndex], PipelineLayout, VK_SHADER_STAGE_ALL, offset, size, void *values );

VkBuffer buffers[1] = { MyVertexDataBuffer.buffer };

VkDeviceSize offsets[1] = { 0 };

vkCmdBindVertexBuffers( CommandBuffers[nextImageIndex], 0, 1, buffers, offsets );		// 0, 1 = firstBinding, bindingCount

const uint32_t vertexCount = sizeof(VertexData) / sizeof(VertexData[0]);
const uint32_t instanceCount = 1;
const uint32_t firstVertex = 0;
const uint32_t firstInstance = 0;
vkCmdDraw( CommandBuffers[nextImageIndex], vertexCount, instanceCount, firstVertex, firstInstance );

vkCmdEndRenderPass( CommandBuffers[nextImageIndex] );

vkEndCommandBuffer( CommandBuffers[nextImageIndex] );
```

Submitting a Command Buffer to a Queue for Execution

```
VkSubmitInfo                              vsi;
            vsi.sType = VK_STRUCTURE_TYPE_SUBMIT_INFO;
            vsi.pNext = nullptr;
            vsi.commandBufferCount = 1;
            vsi.pCommandBuffers = &CommandBuffer;
            vsi.waitSemaphoreCount = 1;
            vsi.pWaitSemaphores = imageReadySemaphore;
            vsi.signalSemaphoreCount = 0;
            vsi.pSignalSemaphores = (VkSemaphore *)nullptr;
            vsi.pWaitDstStageMask = (VkPipelineStageFlags *)nullptr;
```

The Entire Submission / Wait / Display Process

```
VkFenceCreateInfo                    vfci;
        vfci.sType = VK_STRUCTURE_TYPE_FENCE_CREATE_INFO;
        vfci.pNext = nullptr;
        vfci.flags = 0;

VkFence  renderFence;
vkCreateFence( LogicalDevice, &vfci, PALLOCATOR, OUT &renderFence );
result = VK_SUCCESS;

VkPipelineStageFlags waitAtBottom = VK_PIPELINE_STAGE_BOTTOM_OF_PIPE_BIT;
VkQueue presentQueue;
vkGetDeviceQueue( LogicalDevice, FindQueueFamilyThatDoesGraphics( ), 0, OUT &presentQueue );\
                                                     // 0 =, queueIndex

VkSubmitInfo                         vsi;
        vsi.sType = VK_STRUCTURE_TYPE_SUBMIT_INFO;
        vsi.pNext = nullptr;
        vsi.waitSemaphoreCount = 1;
        vsi.pWaitSemaphores = &imageReadySemaphore;
        vsi.pWaitDstStageMask = &waitAtBottom;
        vsi.commandBufferCount = 1;
        vsi.pCommandBuffers = &CommandBuffers[nextImageIndex];
        vsi.signalSemaphoreCount = 0;
        vsi.pSignalSemaphores = &SemaphoreRenderFinished;

result = vkQueueSubmit( presentQueue,   1, IN &vsi, IN renderFence );    // 1 = submitCount
result = vkWaitForFences( LogicalDevice, 1, IN &renderFence, VK_TRUE, UINT64_MAX );    // waitAll, timeout

vkDestroyFence( LogicalDevice, renderFence, PALLOCATOR );

VkPresentInfoKHR                         vpi;
        vpi.sType = VK_STRUCTURE_TYPE_PRESENT_INFO_KHR;
        vpi.pNext = nullptr;
        vpi.waitSemaphoreCount = 0;
        vpi.pWaitSemaphores = (VkSemaphore *)nullptr;
        vpi.swapchainCount = 1;
        vpi.pSwapchains = &SwapChain;
        vpi.pImageIndices = &nextImageIndex;
        vpi.pResults = (VkResult *)nullptr;

result = vkQueuePresentKHR( presentQueue, IN &vpi );
```

Create fence

Get the queue

Fill in the queue information

Submit the queue

Wait for the fence