Vulkan®

Antialiasing and Multisampling

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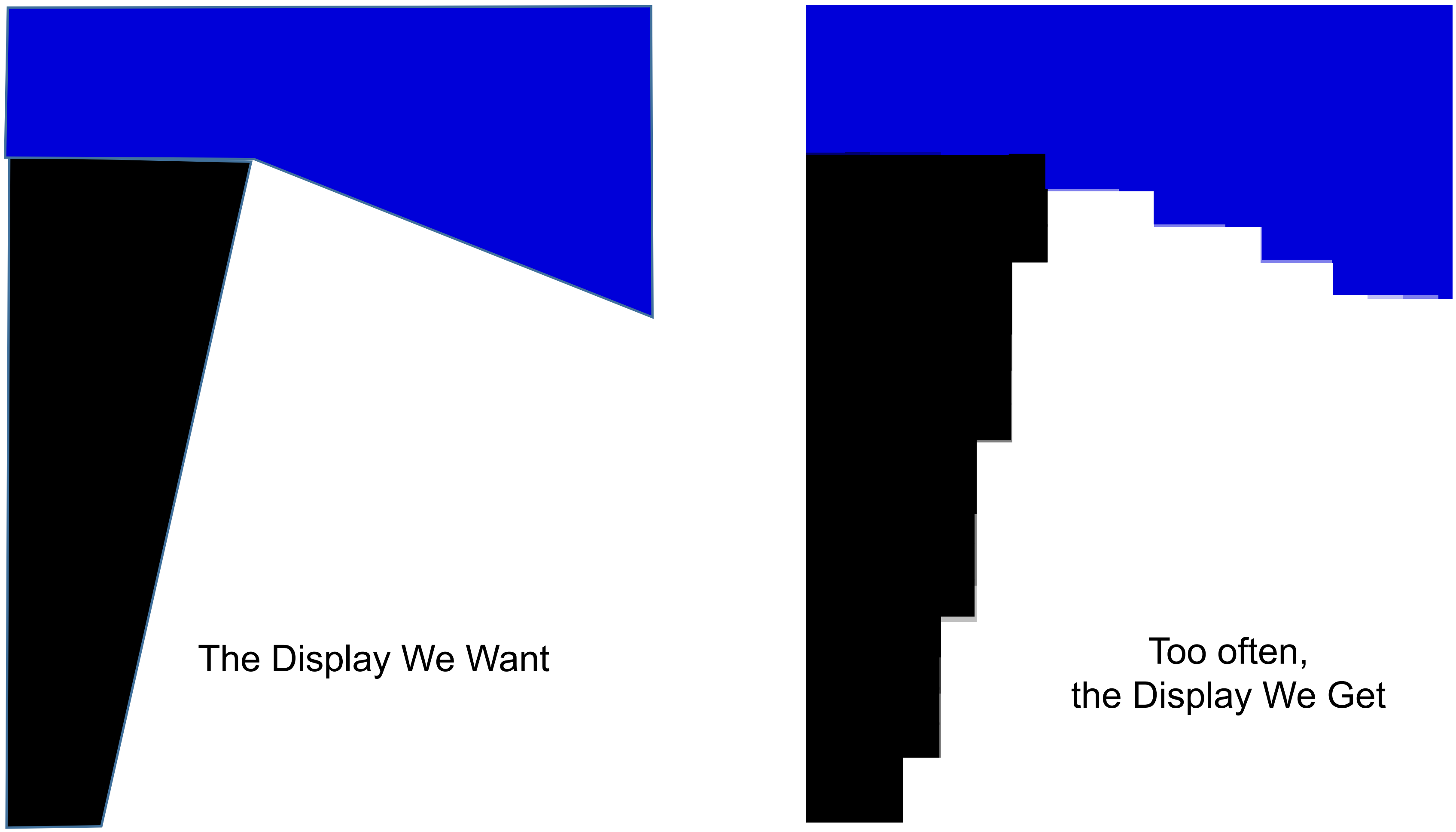
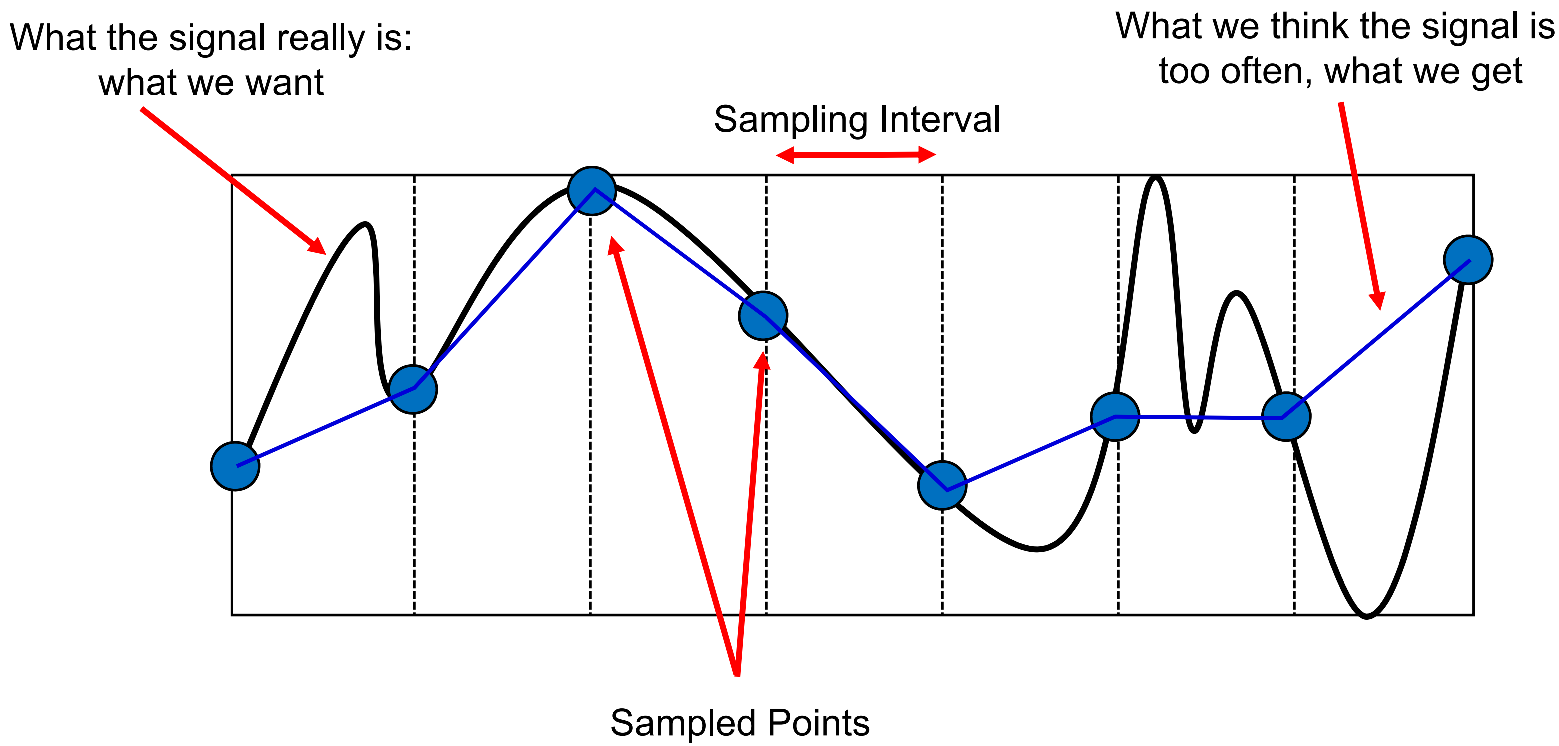
Aliasing

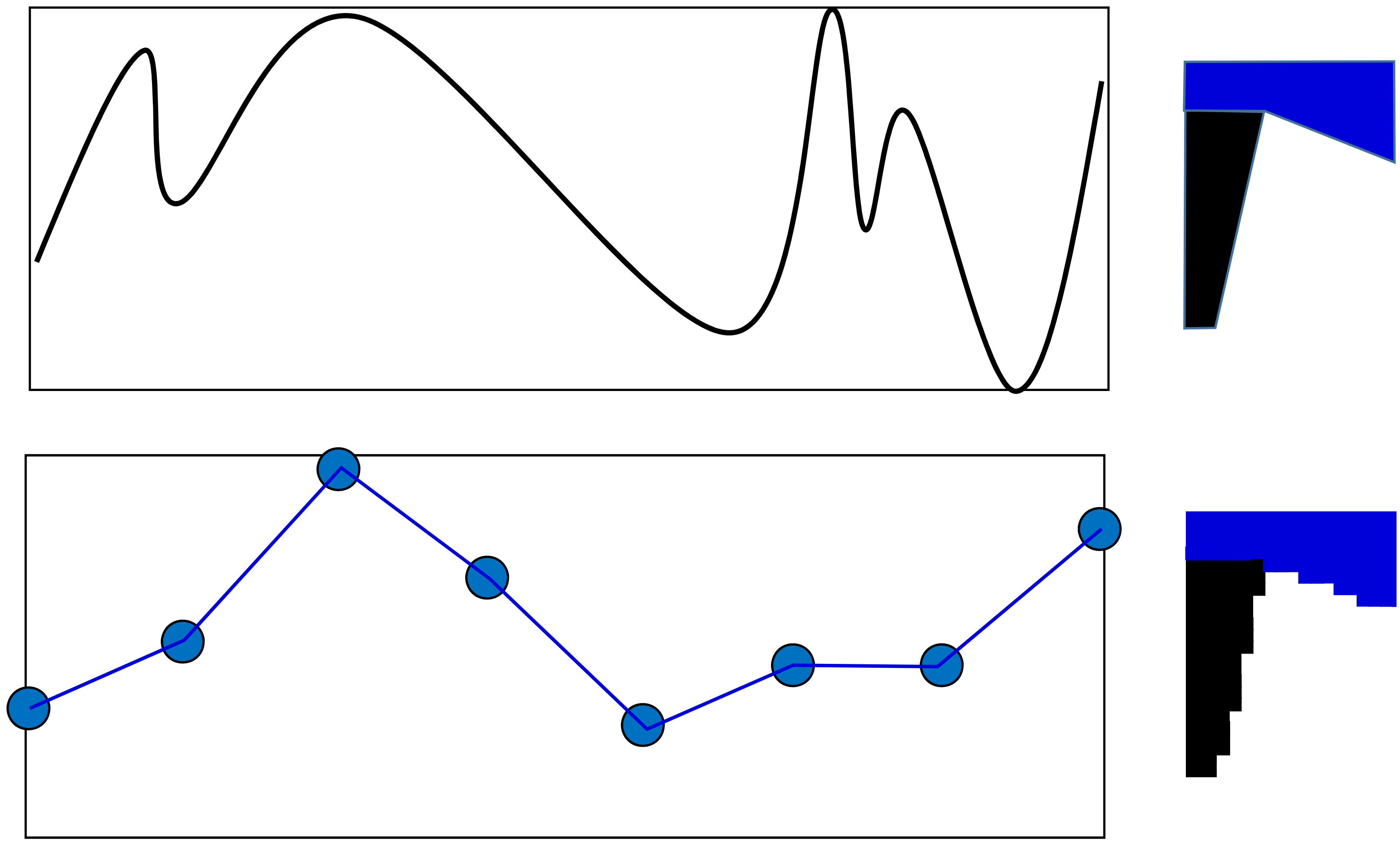


Aliasing

"Aliasing" is a signal-processing term for "under-sampled compared with the frequencies in the signal".

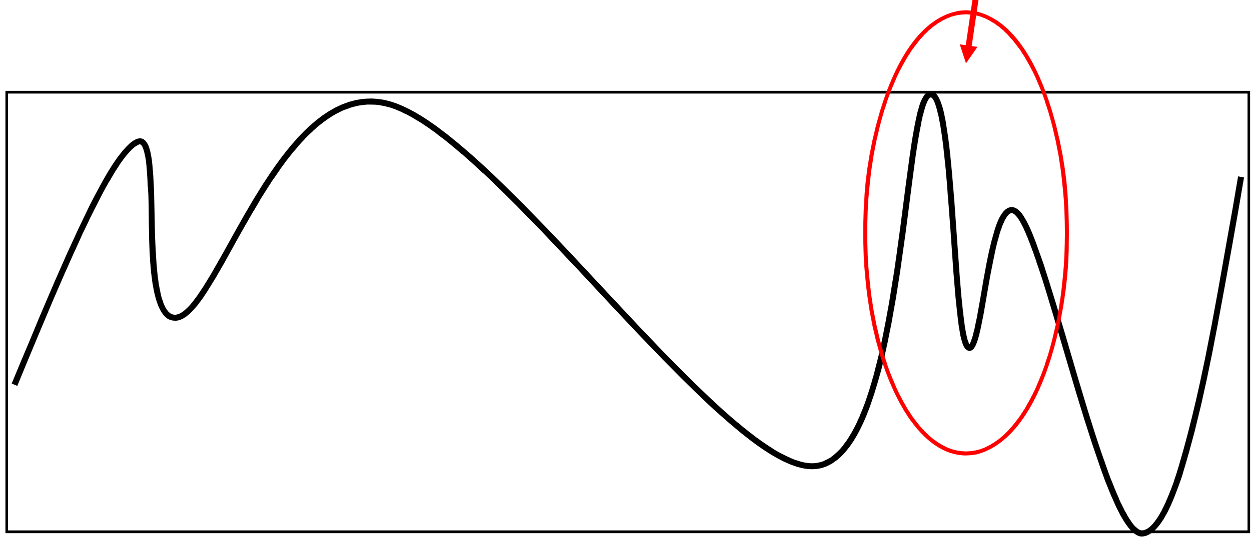


Aliasing

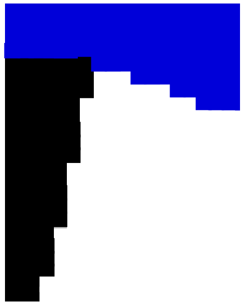


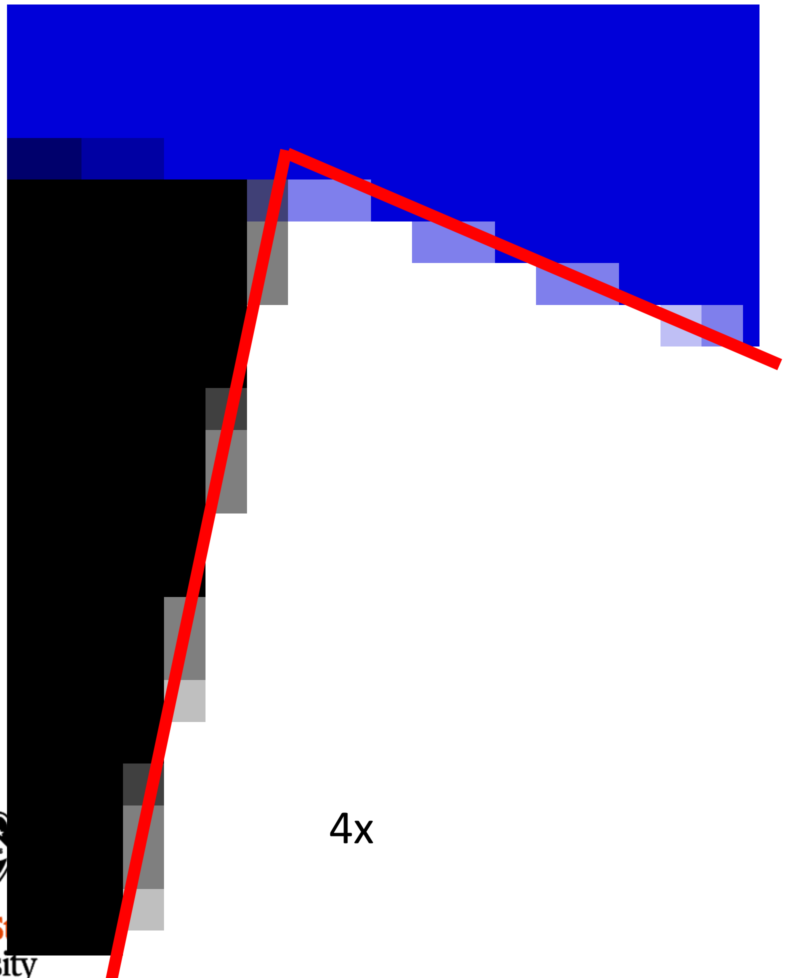
Nyquist Criterion

"The Nyquist [sampling] rate is twice the maximum component frequency of the function [i.e., signal] being sampled." -- WikiPedia

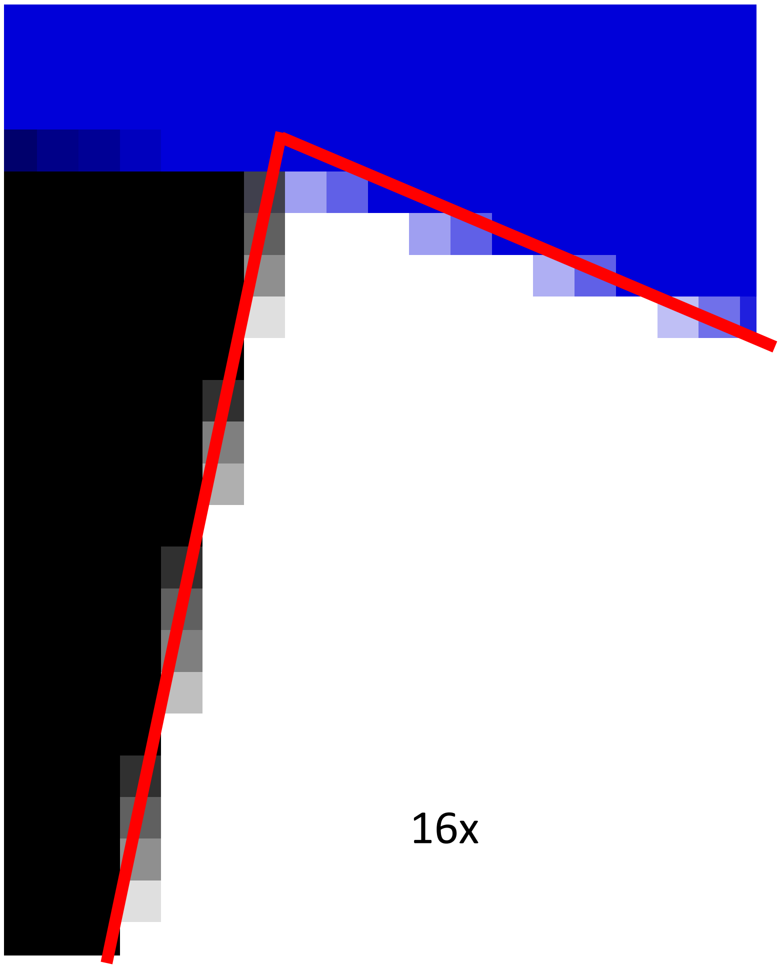


Anti-aliasing





4x



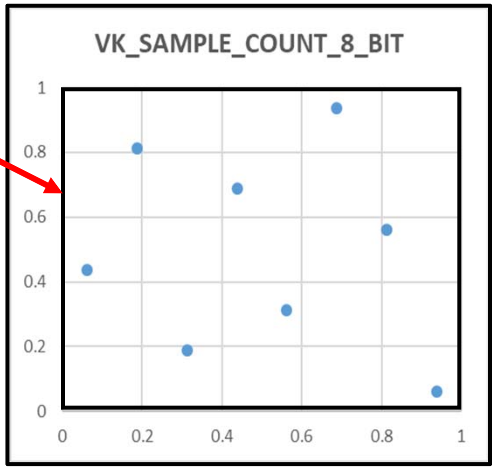
16x

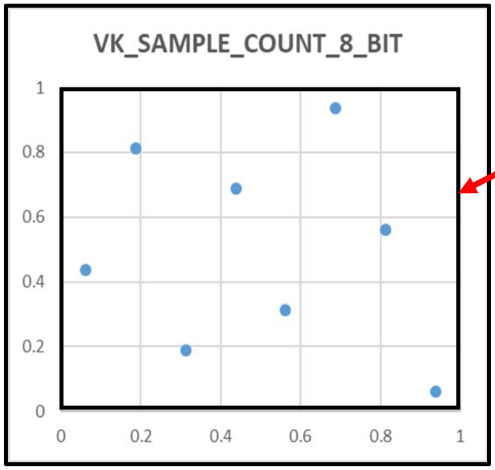
MultiSampling

Multisampling is a computer graphics technique to improve the quality of your output image by looking inside every pixel to see what the rendering is doing there. There are two approaches:

1. **Supersampling**: Pick some number of unique sub-pixels within a pixel, render the image at each of these individual sub-pixels (including depth and stencil tests), then average them together. This results in lots of renders.

One entire pixel



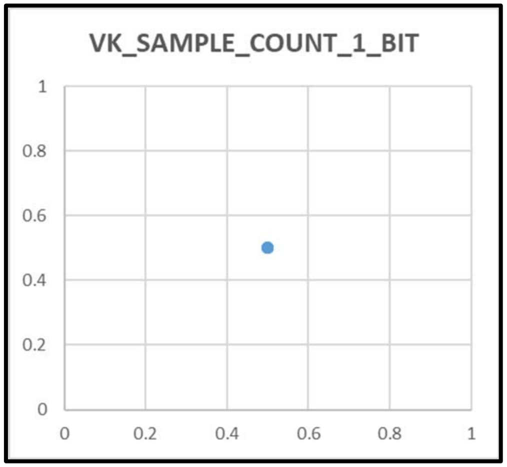


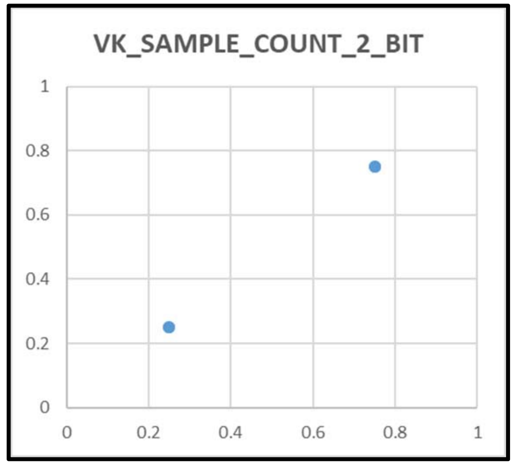
One entire pixel

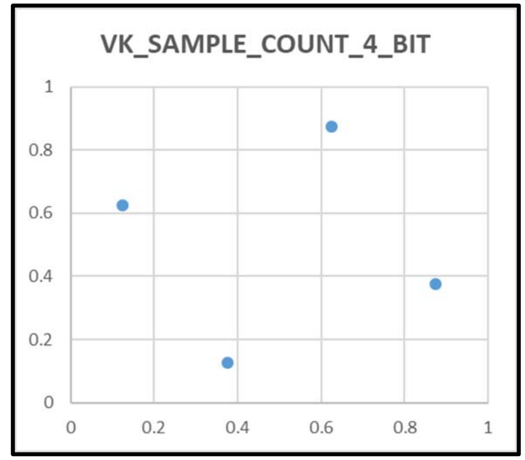
2. **Multisampling**: Perform a single color render for the one entire pixel. Then, pick some number of unique sub-pixels within that pixel and perform depth and stencil tests there. Assign the single color to all the sub-pixels that made it through the depth and stencil tests

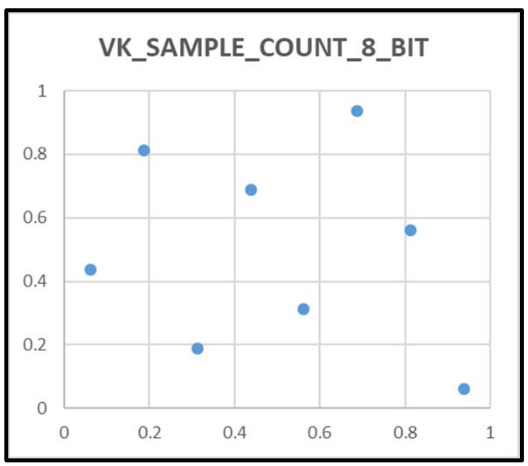
Note: per-sample depth and stencil tests are performed first to decide which color renders actually should be done

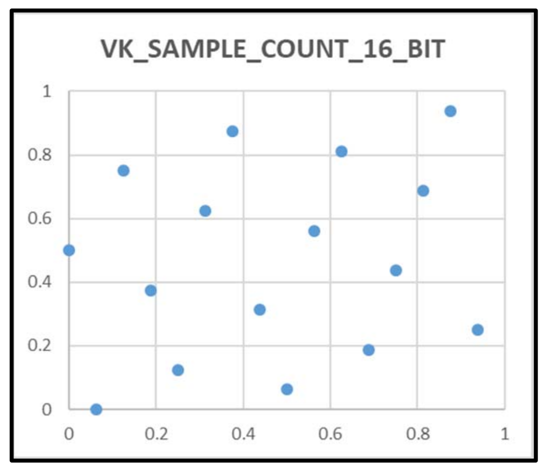
Vulkan Distribution of Sampling Points within a Pixel







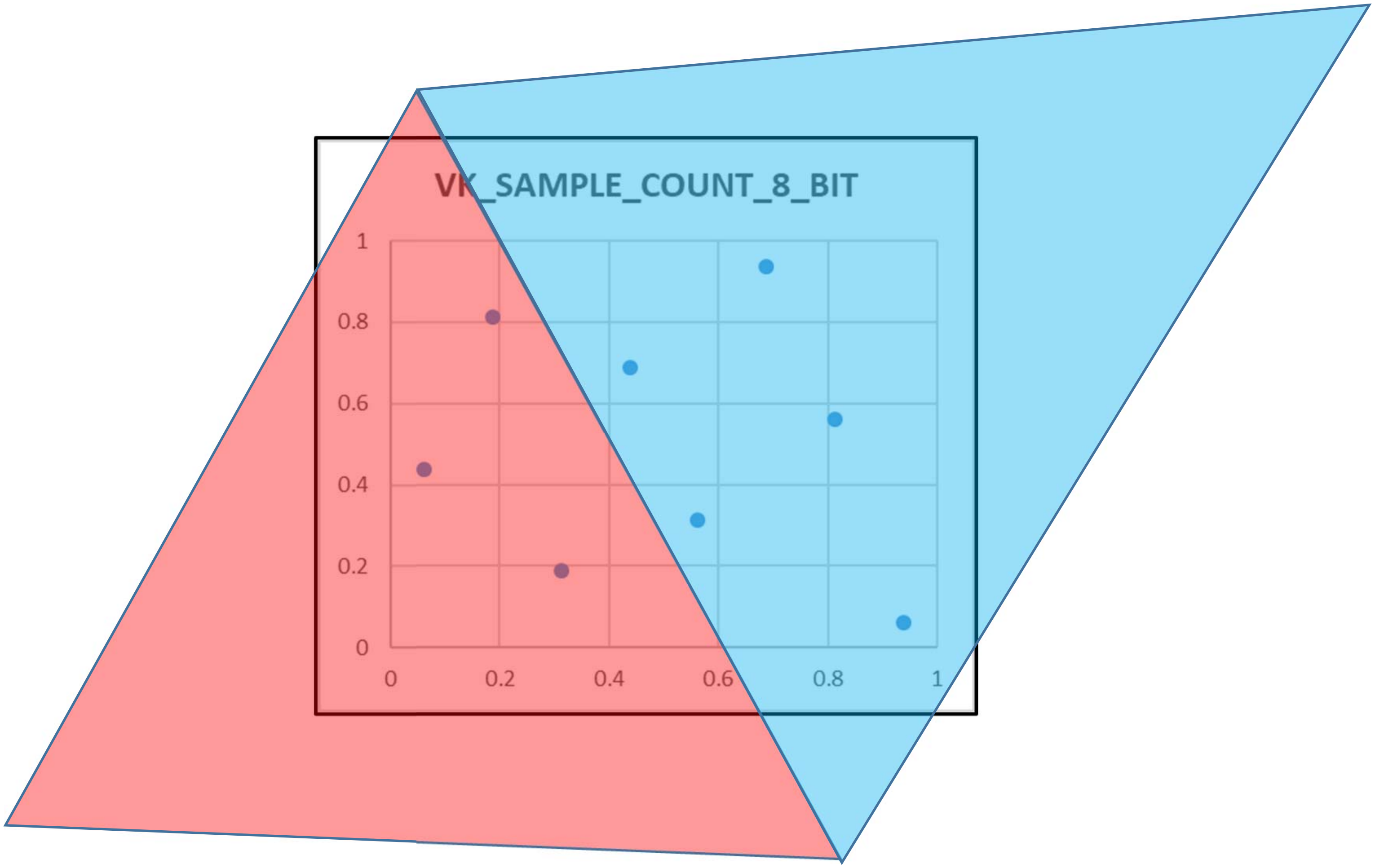




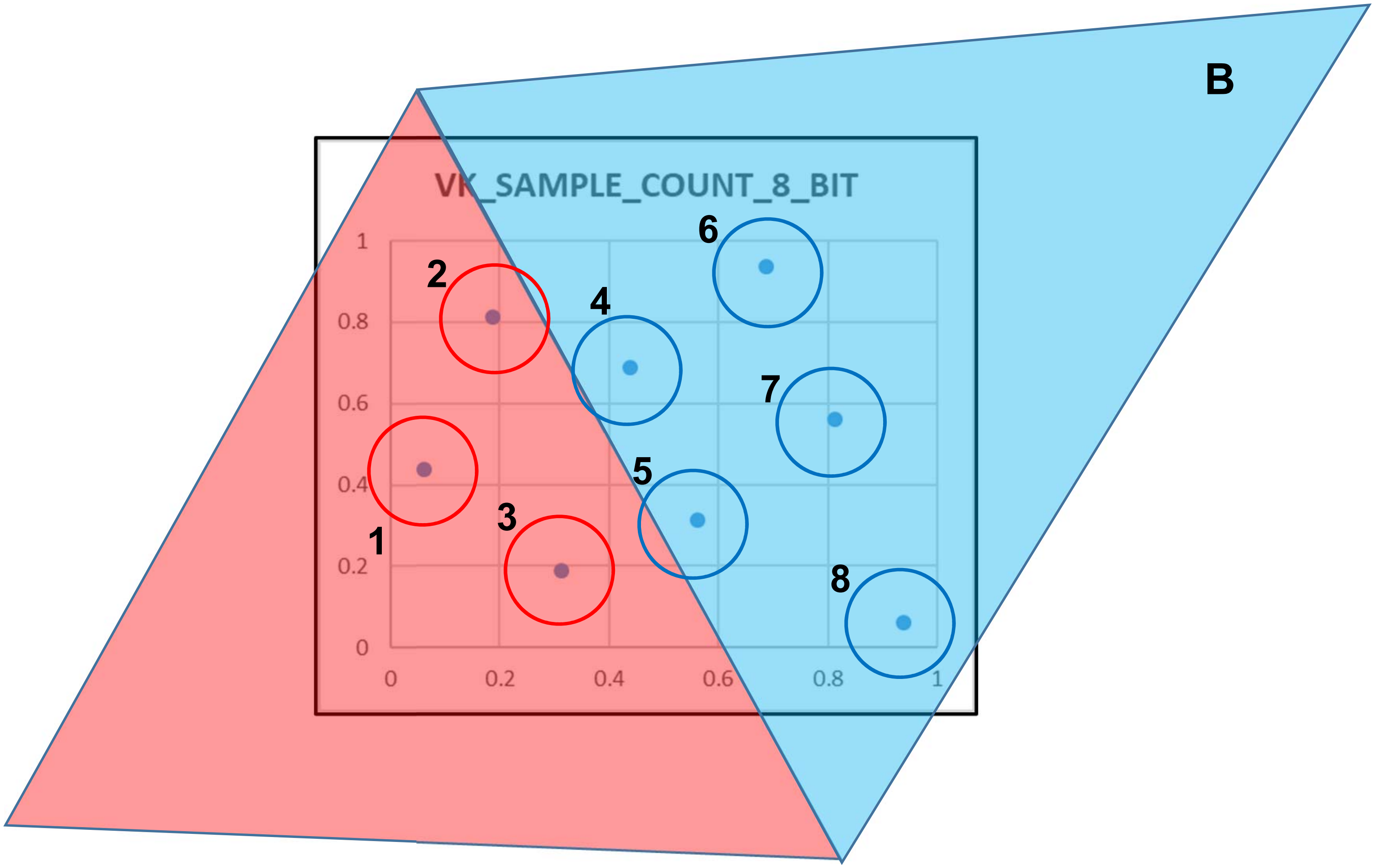
Vulkan Distribution of Sampling Points within a Pixel

VK_SAMPLE_COUNT_1_BIT	VK_SAMPLE_COUNT_2_BIT	VK_SAMPLE_COUNT_4_BIT	VK_SAMPLE_COUNT_8_BIT	VK_SAMPLE_COUNT_16_BIT
(0.5,0.5)	(0.25,0.25)	(0.375, 0.125)	(0.5625, 0.3125)	(0.5625, 0.5625)
	(0.75,0.75)	(0.875, 0.375)	(0.4375, 0.6875)	(0.4375, 0.3125)
		(0.125, 0.625)	(0.8125, 0.5625)	(0.3125, 0.625)
		(0.625, 0.875)	(0.3125, 0.1875)	(0.75, 0.4375)
			(0.1875, 0.8125)	(0.1875, 0.375)
			(0.0625, 0.4375)	(0.625, 0.8125)
			(0.6875, 0.9375)	(0.8125, 0.6875)
			(0.9375, 0.0625)	(0.6875, 0.1875)
				(0.375, 0.875)
				(0.5, 0.0625)
				(0.25, 0.125)
				(0.125, 0.75)
				(0.0, 0.5)
				(0.9375, 0.25)
				(0.875, 0.9375)
				(0.0625, 0.0)

Consider Two Triangles Whose Edges Pass Through the Same Pixel



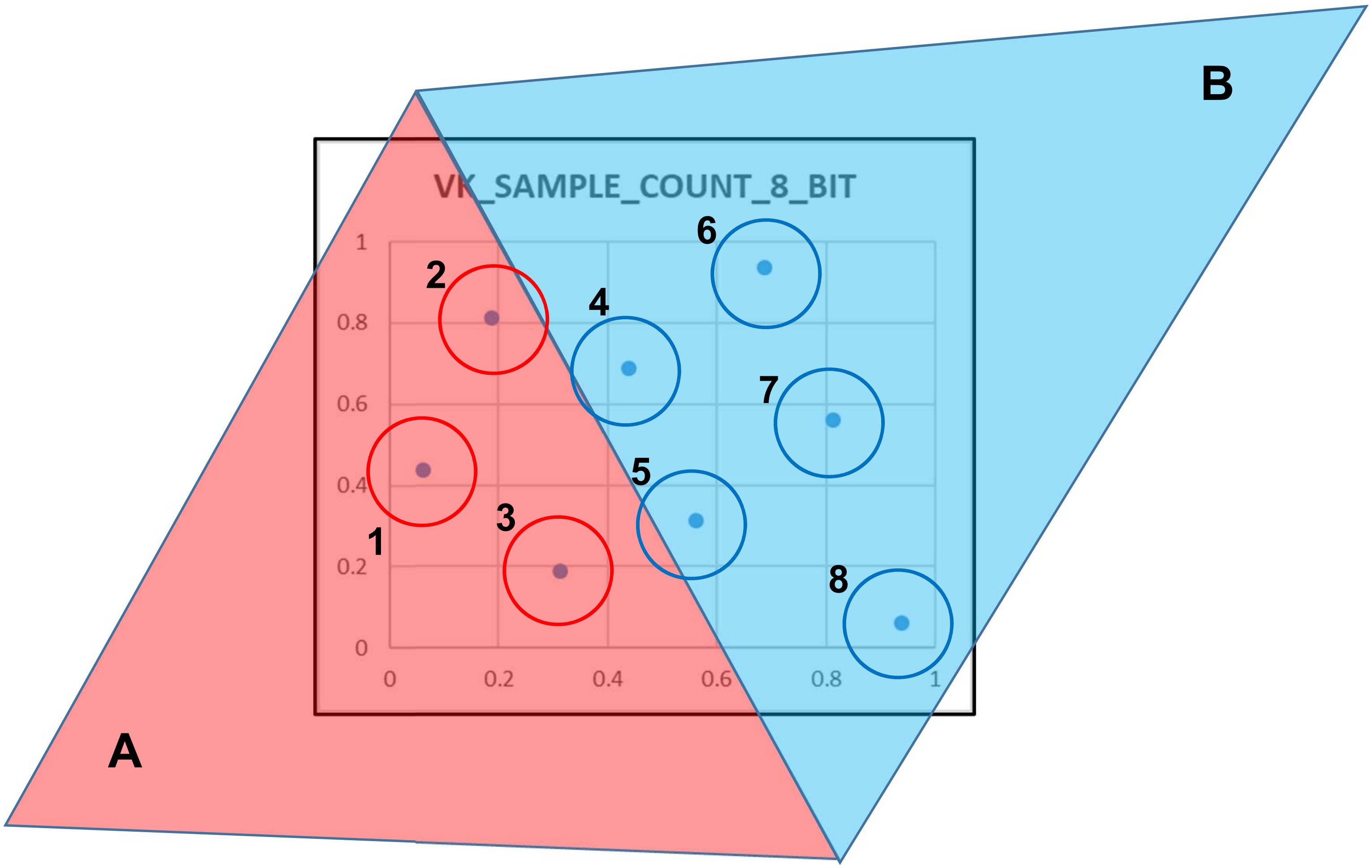
Supersampling



$$\mathit{Final\ Pixel\ Color} = \frac{\sum_{i=1}^{8} \mathit{Color\ sample\ from\ subpixel}_i}{8}$$

Fragment Shader calls = 8

Multisampling



$$\textit{Final Pixel Color} = \frac{3 * \textit{One color sample from } A \; + \; 5 * \textit{One color sample from } B}{8}$$

Fragment Shader calls = 2

Setting up the Image

```
VkPipelineMultisampleStateCreateInfo            vpmsci;
        vpmsci.sType = VK_STRUCTURE_TYPE_PIPELINE_MULTISAMPLE_STATE_CREATE_INFO;
        vpmsci.pNext = nullptr;
        vpmsci.flags = 0;
        vpmsci.rasterizationSamples = VK_SAMPLE_COUNT_8_BIT;
        vpmsci.sampleShadingEnable = VK_TRUE;
        vpmsci.minSampleShading = 0.5f;
        vpmsci.pSampleMask = (VkSampleMask *)nullptr;
        vpmsci.alphaToCoverageEnable = VK_FALSE;
        vpmsci.alphaToOneEnable = VK_FALSE;

VkGraphicsPipelineCreateInfo            vgpci;
        vgpci.sType = VK_STRUCTURE_TYPE_GRAPHICS_PIPELINE_CREATE_INFO;
        vgpci.pNext = nullptr;
    . . .
        vgpci.pMultisampleState = &vpmsci;

result = vkCreateGraphicsPipelines( LogicalDevice, VK_NULL_HANDLE, 1, IN &vgpci,\
                    PALLOCATOR, OUT pGraphicsPipeline );
```

How dense is the sampling

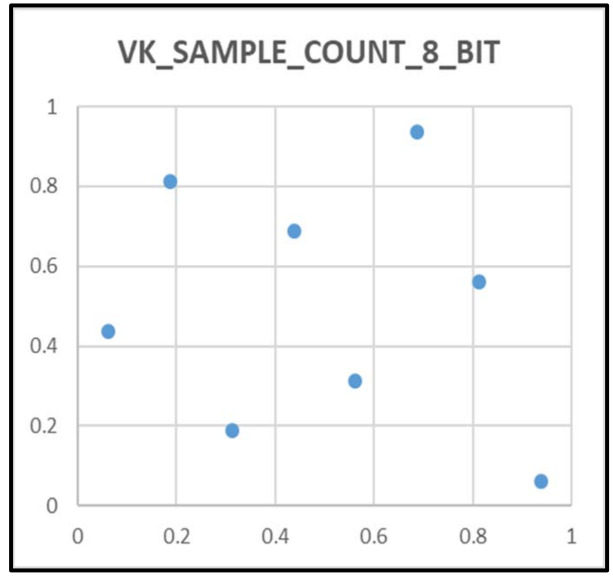
VK_TRUE means to allow some sort of multisampling to take place

Setting up the Image

```
VkPipelineMultisampleStateCreateInfo          vpmsci;
        . . .

        vpmsci.minSampleShading = 0.5;

        . . .
```



At least this fraction of samples will get their own fragment shader calls (as long as they pass the depth and stencil tests).

0. produces simple multisampling

(0.,1.) produces partial supersampling

1. Produces complete supersampling

Setting up the Image

```
VkAttachmentDescription                vad[2];
        vad[0].format = VK_FORMAT_B8G8R8A8_SRGB;
        vad[0].samples = VK_SAMPLE_COUNT_8_BIT;
        vad[0].loadOp = VK_ATTACHMENT_LOAD_OP_CLEAR;
        vad[0].storeOp = VK_ATTACHMENT_STORE_OP_STORE;
        vad[0].stencilLoadOp = VK_ATTACHMENT_LOAD_OP_DONT_CARE;
        vad[0].stencilStoreOp = VK_ATTACHMENT_STORE_OP_DONT_CARE;
        vad[0].initialLayout = VK_IMAGE_LAYOUT_UNDEFINED;
        vad[0].finalLayout = VK_IMAGE_LAYOUT_PRESENT_SRC_KHR;
        vad[0].flags = 0;

        vad[1].format = VK_FORMAT_D32_SFLOAT_S8_UINT;
        vad[1].samples = VK_SAMPLE_COUNT_8_BIT;
        vad[1].loadOp = VK_ATTACHMENT_LOAD_OP_CLEAR;
        vad[1].storeOp = VK_ATTACHMENT_STORE_OP_DONT_CARE;
        vad[1].stencilLoadOp = VK_ATTACHMENT_LOAD_OP_DONT_CARE;
        vad[1].stencilStoreOp = VK_ATTACHMENT_STORE_OP_DONT_CARE;
        vad[1].initialLayout = VK_IMAGE_LAYOUT_UNDEFINED;
        vad[1].finalLayout = VK_IMAGE_LAYOUT_DEPTH_STENCIL_ATTACHMENT_OPTIMAL;
        vad[1].flags = 0;

VkAttachmentReference                  colorReference;
        colorReference.attachment = 0;
        colorReference.layout = VK_IMAGE_LAYOUT_COLOR_ATTACHMENT_OPTIMAL;

VkAttachmentReference                  depthReference;
        depthReference.attachment = 1;
        depthReference.layout = VK_IMAGE_LAYOUT_DEPTH_STENCIL_ATTACHMENT_OPTIMAL;
```

Setting up the Image

```
VkSubpassDescription                    vsd;
        vsd.flags = 0;
        vsd.pipelineBindPoint = VK_PIPELINE_BIND_POINT_GRAPHICS;
        vsd.inputAttachmentCount = 0;
        vsd.pInputAttachments = (VkAttachmentReference *)nullptr;
        vsd.colorAttachmentCount = 1;
        vsd.pColorAttachments = &colorReference;
        vsd.pResolveAttachments = (VkAttachmentReference *)nullptr;
        vsd.pDepthStencilAttachment = &depthReference;
        vsd.preserveAttachmentCount = 0;
        vsd.pPreserveAttachments = (uint32_t *)nullptr;

VkRenderPassCreateInfo                  vrpci;
        vrpci.sType = VK_STRUCTURE_TYPE_RENDER_PASS_CREATE_INFO;
        vrpci.pNext = nullptr;
        vrpci.flags = 0;
        vrpci.attachmentCount = 2;          // color and depth/stencil
        vrpci.pAttachments = vad;
        vrpci.subpassCount = 1;
        vrpci.pSubpasses = &vsd;
        vrpci.dependencyCount = 0;
        vrpci.pDependencies = (VkSubpassDependency *)nullptr;


result = vkCreateRenderPass( LogicalDevice, IN &vrpci, PALLOCATOR, OUT &RenderPass );
```

Resolving the Image: Converting the multisampled image to a VK_SAMPLE_COUNT_1_BIT image

```
VlOffset3D                       vo3;
        vo3.x = 0;
        vo3.y = 0;
        vo3.z = 0;

VkExtent3D                       ve3;
        ve3.width = Width;
        ve3.height = Height;
        ve3.depth = 1;

VkImageSubresourceLayers         visl;
        visl.aspectMask = VK_IMAGE_ASPECT_COLOR_BIT;
        visl.mipLevel = 0;
        visl.baseArrayLayer = 0;
        visl.layerCount = 1;

VkImageResolve                   vir;
        vir.srcSubresource = visl;
        vir.srcOffset = vo3;
        vir.dstSubresource = visl;
        vir.dstOffset = vo3;
        vir.extent = ve3;

vkCmdResolveImage( cmdBuffer, srcImage, srcImageLayout,  dstImage, dstImageLayout, 1, &vir  );
```