Pipeline Barriers: 
A case of Gate-ing and Wait-ing

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From the Command Buffer Notes:
These are the Commands that can be entered into the Command Buffer, I

```c
vCmdBeginQuery(commandBuffer, flags);
vCmdBeginRenderPass(commandBuffer, contents);
vCmdBeginQuerycentaje(commandBuffer, pDynamicOffsets);
vCmdBindDescriptorSets(commandBuffer, indexType);
vCmdBindPipeline(commandBuffer, pipeline);
vCmdBindVertexBuffer(commandBuffer, firstBinding, bindingCount, pOffsets);
vCmdBlitImage(commandBuffer, firstRendering, bindingCount, const pOffsets);
vCmdClearAttachments(commandBuffer, attachmentCount, const pRects);
vCmdClearColorImage(commandBuffer, pRanges);
vCmdClearDepthStencilImage(commandBuffer, pRanges);
vCmdCopyBufferToBuffer(commandBuffer, pRegions);
vCmdCopyImageToBuffer(commandBuffer, pRegions);
vCmdCopyQueryPoolResults(commandBuffer, flags);
vCmdDebugMarkerBeginEXT(commandBuffer, pMarkerInfo);
vCmdDebugMarkerEndEXT(commandBuffer);
vCmdDebugMarkerInsertEXT(commandBuffer, pMarkerInfo);
vCmdDispatch(commandBuffer, groupCountX, groupCountY, groupCountZ);
vCmdDispatchIndirect(commandBuffer, offset);
vCmdDraw(commandBuffer, vertexCount, instanceCount, firstVertex, firstInstance);
vCmdDrawIndexed(commandBuffer, indexCount, instanceCount, firstIndex, int32_t vertexOffset, firstInstance);
vCmdDrawIndexedIndirect(commandBuffer, pOffsets);
vCmdDrawIndirect(commandBuffer, pOffsets);
vCmdDrawIndirectCount(commandBuffer, pOffsets);
vCmdEndQuery(commandBuffer, query);
vCmdEndRenderPass(commandBuffer);
vCmdExecuteCommands(commandBuffer, commandBufferCount, const pCommandBuffers);
```

We don't any one of these commands to have to wait on a previous command unless you say so. In general, we want all of these commands to be able to run "flat-out".

But, if we do that, surely there will be nasty race conditions!
From the Command Buffer Notes:
These are the Commands that can be entered into the Command Buffer, II

vkCmdFillBuffer(commandBuffer, dstBuffer, dstOffset, size, data);
vkCmdNextSubpass(commandBuffer, contents);
vkCmdPipelineBarrier(commandBuffer, srcStageMask, dstStageMask, dependencyFlags, memoryBarrierCount, pMemoryBarriers, bufferMemoryBarrierCount, pBufferMemoryBarriers, imageMemoryBarrierCount, pImageMemoryBarriers);
vkCmdProcessCommandNVX(commandBuffer, pProcessCommandInfo);
vkCmdPushConstants(commandBuffer, layout, stageFlags, offset, size, pValues);
vkCmdPushDescriptorSetKHR(commandBuffer, pipelineBindPoint, layout, set, descriptorWriteCount, pDescriptorWrites);
vkCmdPushDescriptorSetWithTemplateKHR(commandBuffer, descriptorUpdateTemplate, layout, set, pData);
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);
vkCmdWriteTimestamp(commandBuffer, pipelineStage, queryPool, query);

We don’t any one of these commands to have to wait on a previous command unless you say so. In general, we want all of these commands to be able to run “flat-out”.

But, if we do that, surely there will be nasty race conditions!

Potential Memory Race Conditions that Pipeline Barriers can Prevent

1. Write-then-Read (WtR) – the memory write in one operation starts overwriting the memory that another operation’s read needs to use

2. Read-then-Write (RtW) – the memory read in one operation hasn’t yet finished before another operation starts overwriting that memory

3. Write-then-Write (WtW) – two operations start overwriting the same memory and the end result is non-deterministic

Note: there is no problem with Read-then-Read (RtR) as no data has been changed
**vkCmdPipelineBarrier() Function Call**

*Pipeline Barrier* is a way to establish a memory dependency between commands that were submitted before the barrier and commands that are submitted after the barrier.

```c
vkCmdPipelineBarrier( commandBuffer,
    srcStageMask,         // Guarantee that this pipeline stage has completely generated one set of data before ...
    dstStageMask,         // ... allowing this pipeline stage to consume it
    VK_DEPENDENCY_BY_REGION_BIT,
    memoryBarrierCount,   // Defines what data we will be blocking/un-blocking on
    pMemoryBarriers,
    bufferMemoryBarrierCount,  // memoryBarrierCount,   // Defines what data we will be blocking/un-blocking on
    pBufferMemoryBarriers,
    imageMemoryBarrierCount, // memoryBarrierCount,   // Defines what data we will be blocking/un-blocking on
    pImageMemoryBarriers
    );
```

---

**The Scenario**

- *src cars*:
  - TOP_OF_PIPE Street
  - VERTEX_INPUT Street
  - VERTEX_SHADER Street

- *dst cars*:
  - FRAGMENT_SHADER Street
  - COLOR_ATTACHMENT_OUTPUT Street
  - TRANSFER_BIT Street
  - BOTTOM_OF_PIPE Street
1. The cross-streets are named after pipeline stages
2. All traffic lights start out green ("we want all of these commands to be able to run flat-out")
3. There are special sensors at all intersections that will know when the first car in the src group enters that intersection
4. There are connections from those sensors to the traffic lights so that when the first car in the src group enters its intersection, the dst traffic light will be turned red
5. When the last car in the src group completely makes it through its intersection, the dst traffic light can be turned back to green
6. The Vulkan command pipeline ordering is this: (1) the src cars get released, (2) the pipeline barrier is invoked (which turns some lights red), (3) the dst cars get released (which end up being stopped by a red light somewhere), (4) the src cars clear their intersection, (5) the dst cars get released

Pipeline Stage Masks –
Where in the Pipeline is this Memory Data being Generated or Consumed?

- VK_PIPELINE_STAGE_TOP_OF_PIPE_BIT
- VK_PIPELINE_STAGE_DRAW_INDIRECT_BIT
- VK_PIPELINE_STAGE_VERTEX_INPUT_BIT
- VK_PIPELINE_STAGE_VERTEX_SHADER_BIT
- VK_PIPELINE_STAGE_TESSELLATION_CONTROL_SHADER_BIT
- VK_PIPELINE_STAGE_TESSELLATION_EVALUATION_SHADER_BIT
- VK_PIPELINE_STAGE_GEOMETRY_SHADER_BIT
- VK_PIPELINE_STAGE_FRAGMENT_SHADER_BIT
- VK_PIPELINE_STAGE_EARLY_FRAGMENT_TESTS_BIT
- VK_PIPELINE_STAGE_LATE_FRAGMENT_TESTS_BIT
- VK_PIPELINE_STAGE_COLOR_ATTACHMENT_OUTPUT_BIT
- VK_PIPELINE_STAGE_COMPUTE_SHADER_BIT
- VK_PIPELINE_STAGE_TRANSFER_BIT
- VK_PIPELINE_STAGE_BOTTOM_OF_PIPE_BIT
- VK_PIPELINE_STAGE_HOST_BIT
- VK_PIPELINE_STAGE_ALL_GRAPHICS_BIT
- VK_PIPELINE_STAGE_ALL_COMMANDS_BIT
Pipeline Stages

VK_PIPELINE_STAGE_TOP_OF_PIPE_BIT
VK_PIPELINE_STAGE_DRAW_INDIRECT_BIT
VK_PIPELINE_STAGE_VERTEX_INPUT_BIT
VK_PIPELINE_STAGE_VERTEX_SHADER_BIT
VK_PIPELINE_STAGE_TESSELLATION_CONTROL_SHADER_BIT
VK_PIPELINE_STAGE_TESSELLATION_EVALUATION_SHADER_BIT
VK_PIPELINE_STAGE_GEOMETRY_SHADER_BIT
VK_PIPELINE_STAGE_FRAGMENT_SHADER_BIT
VK_PIPELINE_STAGE_EARLY_FRAGMENT_TESTS_BIT
VK_PIPELINE_STAGE_LATE_FRAGMENT_TESTS_BIT
VK_PIPELINE_STAGE_COLOR_ATTACHMENT_OUTPUT_BIT
VK_PIPELINE_STAGE_COMPUTE_SHADER_BIT
VK_PIPELINE_STAGE_TRANSFER_BIT
VK_PIPELINE_STAGE_BOTTOM_OF_PIPE_BIT
VK_PIPELINE_STAGE_HOST_BIT
VK_PIPELINE_STAGE_ALL_GRAPHICS_BIT
VK_PIPELINE_STAGE_ALL_COMMANDS_BIT

Access Masks –
What are you Interested in Generating or Consuming this Memory for?

VK_ACCESS_INDIRECT_COMMAND_READ_BIT
VK_ACCESS_INDEX_READ_BIT
VK_ACCESS_VERTEX_ATTRIBUTE_READ_BIT
VK_ACCESS_UNIFORM_READ_BIT
VK_ACCESS_INPUT_ATTACHMENT_READ_BIT
VK_ACCESS_SHADER_READ_BIT
VK_ACCESS_SHADER_WRITE_BIT
VK_ACCESS_COLOR_ATTACHMENT_READ_BIT
VK_ACCESS_COLOR_ATTACHMENT_WRITE_BIT
VK_ACCESS_DEPTH_STENCIL_ATTACHMENT_READ_BIT
VK_ACCESS_DEPTH_STENCIL_ATTACHMENT_WRITE_BIT
VK_ACCESS_TRANSFER_READ_BIT
VK_ACCESS_TRANSFER_WRITE_BIT
VK_ACCESS_HOST_READ_BIT
VK_ACCESS_HOST_WRITE_BIT
VK_ACCESS_MEMORY_READ_BIT
VK_ACCESS_MEMORY_WRITE_BIT
### Pipeline Stages and what Access Operations can Happen There

| Pipeline Stage                  | VK Access Indirect Command Read Bit | VK Access Index Read Bit | VK Access Vertex Attribute Read Bit | VK Access Uniform Read Bit | VK Access Input Attachment Read Bit | VK Access Shader Read Bit | VK Access Shader Write Bit | VK Access Color Attachment Read Bit | VK Access Color Attachment Write Bit | VK Access Depth Stencil Attachment Read Bit | VK Access Depth Stencil Attachment Write Bit | VK Access Transfer Read Bit | VK Access Transfer Write Bit | VK Access Host Read Bit | VK Access Host Write Bit | VK Access Memory Read Bit | VK Access Memory Write Bit |
|--------------------------------|-------------------------------------|--------------------------|------------------------------------|----------------------------|-------------------------------------|---------------------------|--------------------------|-------------------------------------|----------------------------------------|---------------------------------------------|-----------------------------------------|------------------------|-------------------------|------------------------|-------------------------|------------------------|
| 1 VK_PIPELINE_STAGE_TOP_OF_PIPE_BIT | ×                                   |                          |                                    |                           |                                     | ×                         | ×                       |                                    | ×                                      | ×                                            | ×                                       | ×                      | ×                      | ×                      |
| 2 VK_PIPELINE_STAGE_DRAW_INDIRECT_BIT |                                     |                          |                                    |                           |                                     |                          | ×                       |                                    | ×                                      | ×                                            | ×                                       | √                      | ×                      | ×                      |
| 3 VK_PIPELINE_STAGE_VERTEX_INPUT_BIT | ×                                   |                          |                                    |                           |                                     | ×                         | ×                       |                                    | ×                                      | ×                                            | ×                                       | √                      | ×                      | ×                      |
| 4 VK_PIPELINE_STAGE_VERTEX_SHADER_BIT | ×                                   | ×                       |                                    | ×                           |                                     | ×                         | ×                       |                                    | ×                                      | ×                                            | ×                                       | √                      | ×                      | ×                      |
| 5 VK_PIPELINE_STAGE_TESSELLATION_CONTROL_SHADER_BIT | ×                                   | ×                       |                                    | ×                           |                                     | ×                         | ×                       |                                    | ×                                      | ×                                            | ×                                       | √                      | ×                      | ×                      |
| 6 VK_PIPELINE_STAGE_TESSELLATION_EVALUATION_SHADER_BIT | ×                                   | ×                       |                                    | ×                           |                                     | ×                         | ×                       |                                    | ×                                      | ×                                            | ×                                       | √                      | ×                      | ×                      |
| 7 VK_PIPELINE_STAGE_GEOMETRY_SHADER_BIT | ×                                   | ×                       |                                    | ×                           |                                     | ×                         | ×                       |                                    | ×                                      | ×                                            | ×                                       | √                      | ×                      | ×                      |
| 8 VK_PIPELINE_STAGE_EARLY_FRAGMENT_TESTS_BIT | ×                                   | ×                       |                                    | ×                           |                                     | ×                         | ×                       |                                    | ×                                      | ×                                            | ×                                       | √                      | ×                      | ×                      |
| 9 VK_PIPELINE_STAGE_FRAGMENT_SHADER_BIT | ×                                   | ×                       |                                    | ×                           |                                     | ×                         | ×                       |                                    | ×                                      | ×                                            | ×                                       | √                      | ×                      | ×                      |
| 10 VK_PIPELINE_STAGE_LATE_FRAGMENT_TESTS_BIT | ×                                   | ×                       |                                    | ×                           |                                     | ×                         | ×                       |                                    | ×                                      | ×                                            | ×                                       | √                      | ×                      | ×                      |
| 11 VK_PIPELINE_STAGE_COLOR_ATTACHMENT_OUTPUT_BIT | ×                                   | ×                       |                                    | ×                           |                                     | ×                         | ×                       |                                    | ×                                      | ×                                            | ×                                       | √                      | ×                      | ×                      |
| 12 VK_PIPELINE_STAGE_BOTTOM_OF_PIPE_BIT | ×                                   | ×                       |                                    | ×                           |                                     | ×                         | ×                       |                                    | ×                                      | ×                                            | ×                                       | √                      | ×                      | ×                      |
| 13 VK_PIPELINE_STAGE_COMPUTE_SHADER | ×                                   | ×                       |                                    | ×                           |                                     | ×                         | ×                       |                                    | ×                                      | ×                                            | ×                                       | √                      | ×                      | ×                      |
| 14 VK_PIPELINE_STAGE_TRANSFER_BIT | ×                                   | ×                       |                                    | ×                           |                                     | ×                         | ×                       |                                    | ×                                      | ×                                            | ×                                       | √                      | ×                      | ×                      |
| 15 VK_PIPELINE_STAGE_HOST_BIT | ×                                   | ×                       |                                    | ×                           |                                     | ×                         | ×                       |                                    | ×                                      | ×                                            | ×                                       | √                      | ×                      | ×                      |

### Access Operations and what Pipeline Stages they can be used In

| Access Operation                  | Pipeline Stage Top of Pipe Bit | Pipeline Stage Draw Indirect Bit | Pipeline Stage Vertex Input Bit | Pipeline Stage Vertex Shader Bit | Pipeline Stage Tesselation Control Shader Bit | Pipeline Stage Tesselation Evaluation Shader Bit | Pipeline Stage Geometry Shader Bit | Pipeline Stage Early Fragment Tests Bit | Pipeline Stage Fragment Shader Bit | Pipeline Stage Late Fragment Tests Bit | Pipeline Stage Color Attachment Output Bit | Pipeline Stage Bottom of Pipe Bit | Pipeline Stage Compute Shader | Pipeline Stage Transfer Bit | Pipeline Stage Host Bit | Pipeline Stage Memory Bit |
|----------------------------------|--------------------------------|----------------------------------|---------------------------------|-----------------------------------|-----------------------------------------------|--------------------------------------|-------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|------------------------------------------|----------------------------------|-----------------------------|--------------------------|--------------------------|
| VK_ACCESS_INDIRECT_COMMAND_READ_BIT | ×                              | ×                                | ×                                | ×                                 | ×                                              | ×                                     | ×                                   | ×                                    | ×                                    | ×                                    | ×                                         | ×                                  | ×                            | ×                        | ×                        |
| VK_ACCESS_INDEX_READ_BIT         | ×                              | ×                                | ×                                | ×                                 | ×                                              | ×                                     | ×                                   | ×                                    | ×                                    | ×                                    | ×                                         | ×                                  | ×                            | ×                        | ×                        |
| VK_ACCESS_VERTEX_ATTRIBUTE_READ_BIT | ×                              | ×                                | ×                                | ×                                 | ×                                              | ×                                     | ×                                   | ×                                    | ×                                    | ×                                    | ×                                         | ×                                  | ×                            | ×                        | ×                        |
| VK_ACCESS_UNIFORM_READ_BIT       | ×                              | ×                                | ×                                | ×                                 | ×                                              | ×                                     | ×                                   | ×                                    | ×                                    | ×                                    | ×                                         | ×                                  | ×                            | ×                        | ×                        |
| VK_ACCESS_INPUT_ATTACHMENT_READ_BIT | ×                              | ×                                | ×                                | ×                                 | ×                                              | ×                                     | ×                                   | ×                                    | ×                                    | ×                                    | ×                                         | ×                                  | ×                            | ×                        | ×                        |
| VK_ACCESS_SHADER_READ_BIT        | ×                              | ×                                | ×                                | ×                                 | ×                                              | ×                                     | ×                                   | ×                                    | ×                                    | ×                                    | ×                                         | ×                                  | ×                            | ×                        | ×                        |
| VK_ACCESS_SHADER_WRITE_BIT       | ×                              | ×                                | ×                                | ×                                 | ×                                              | ×                                     | ×                                   | ×                                    | ×                                    | ×                                    | ×                                         | ×                                  | ×                            | ×                        | ×                        |
| VK_ACCESS_COLOR_ATTACHMENT_READ_BIT | ×                              | ×                                | ×                                | ×                                 | ×                                              | ×                                     | ×                                   | ×                                    | ×                                    | ×                                    | ×                                         | ×                                  | ×                            | ×                        | ×                        |
| VK_ACCESS_COLOR_ATTACHMENT_WRITE_BIT | ×                              | ×                                | ×                                | ×                                 | ×                                              | ×                                     | ×                                   | ×                                    | ×                                    | ×                                    | ×                                         | ×                                  | ×                            | ×                        | ×                        |
| VK_ACCESS_DEPTH_STENCIL_ATTACHMENT_READ_BIT | ×                              | ×                                | ×                                | ×                                 | ×                                              | ×                                     | ×                                   | ×                                    | ×                                    | ×                                    | ×                                         | ×                                  | ×                            | ×                        | ×                        |
| VK_ACCESS_DEPTH_STENCIL_ATTACHMENT_WRITE_BIT | ×                              | ×                                | ×                                | ×                                 | ×                                              | ×                                     | ×                                   | ×                                    | ×                                    | ×                                    | ×                                         | ×                                  | ×                            | ×                        | ×                        |
| VK_ACCESS_TRANSFER_READ_BIT      | ×                              | ×                                | ×                                | ×                                 | ×                                              | ×                                     | ×                                   | ×                                    | ×                                    | ×                                    | ×                                         | ×                                  | ×                            | ×                        | ×                        |
| VK_ACCESS_TRANSFER_WRITE_BIT     | ×                              | ×                                | ×                                | ×                                 | ×                                              | ×                                     | ×                                   | ×                                    | ×                                    | ×                                    | ×                                         | ×                                  | ×                            | ×                        | ×                        |
| VK_ACCESS_HOST_READ_BIT          | ×                              | ×                                | ×                                | ×                                 | ×                                              | ×                                     | ×                                   | ×                                    | ×                                    | ×                                    | ×                                         | ×                                  | ×                            | ×                        | ×                        |
| VK_ACCESS_HOST_WRITE_BIT         | ×                              | ×                                | ×                                | ×                                 | ×                                              | ×                                     | ×                                   | ×                                    | ×                                    | ×                                    | ×                                         | ×                                  | ×                            | ×                        | ×                        |
| VK_ACCESS_MEMORY_READ_BIT        | ×                              | ×                                | ×                                | ×                                 | ×                                              | ×                                     | ×                                   | ×                                    | ×                                    | ×                                    | ×                                         | ×                                  | ×                            | ×                        | ×                        |
| VK_ACCESS_MEMORY_WRITE_BIT       | ×                              | ×                                | ×                                | ×                                 | ×                                              | ×                                     | ×                                   | ×                                    | ×                                    | ×                                    | ×                                         | ×                                  | ×                            | ×                        | ×                        |
Example: Be sure we are done writing an output image before using it for something else

Stages

VK_PIPELINE_STAGE_TOP_OF_PIPE_BIT
VK_PIPELINE_STAGE_DRAW_INDIRECT_BIT
VK_PIPELINE_STAGE_VERTEX_INPUT_BIT
VK_PIPELINE_STAGE_VERTEX_SHADER_BIT
VK_PIPELINE_STAGE_TESSELLATION_CONTROL_SHADER_BIT
VK_PIPELINE_STAGE_TESSELLATION_EVALUATION_SHADER_BIT
VK_PIPELINE_STAGE_GEOMETRY_SHADER_BIT
VK_PIPELINE_STAGE_FRAGMENT_SHADER_BIT
VK_PIPELINE_STAGE_EARLY_FRAGMENT_TESTS_BIT
VK_PIPELINE_STAGE_LATE_FRAGMENT_TESTS_BIT
VK_PIPELINE_STAGE_COLOR_ATTACHMENT_OUTPUT_BIT
VK_PIPELINE_STAGE_COMPUTE_SHADER_BIT
VK_PIPELINE_STAGE_TRANSFER_BIT
VK_PIPELINE_STAGE_BOTTOM_OF_PIPE_BIT
VK_PIPELINE_STAGE_HOST_BIT
VK_PIPELINE_STAGE_ALL_GRAPHICS_BIT
VK_PIPELINE_STAGE_ALL_COMMANDS_BIT

The Scenario

src cars are generating the image
dst cars are doing something with that image
Example: Don’t read a buffer back to the host until a shader is done writing it

<table>
<thead>
<tr>
<th>Stages</th>
<th>Access types</th>
</tr>
</thead>
<tbody>
<tr>
<td>VK_PIPELINE_STAGE_TOP_OF_PIPE_BIT</td>
<td>VK_ACCESS_INDIRECT_COMMAND_READ_BIT</td>
</tr>
<tr>
<td>VK_PIPELINE_STAGE_DRAW_INDIRECT_BIT</td>
<td>VK_ACCESS_INDEX_READ_BIT</td>
</tr>
<tr>
<td>VK_PIPELINE_STAGE_VERTEX_SHADER_BIT</td>
<td>VK_ACCESS_VERTEX_ATTRIBUTE_READ_BIT</td>
</tr>
<tr>
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<td>VK_ACCESS_UNIFORM_READ_BIT</td>
</tr>
<tr>
<td>VK_PIPELINE_STAGE_TESSELLATION_EVALUATION_SHADER_BIT</td>
<td>VK_ACCESS_INPUT_ATTACHMENT_READ_BIT</td>
</tr>
<tr>
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<tr>
<td>VK_PIPELINE_STAGE_LATE_FRAGMENT_TESTS_BIT</td>
<td>VK_ACCESS_DEPTH_STENCIL_ATTACHMENT_READ_BIT</td>
</tr>
<tr>
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<td>VK_ACCESS_DEPTH_STENCIL_ATTACHMENT_WRITE_BIT</td>
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<td>VK_ACCESS_HOST_READ_BIT</td>
</tr>
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<td>VK_PIPELINE_STAGE_HOST_BIT</td>
<td>VK_ACCESS_HOST_WRITE_BIT</td>
</tr>
<tr>
<td>VK_PIPELINE_STAGE_ALL_GRAPHICS_BIT</td>
<td>VK_ACCESS_MEMORY_READ_BIT</td>
</tr>
<tr>
<td>VK_PIPELINE_STAGE_ALL_COMMANDS_BIT</td>
<td>VK_ACCESS_MEMORY_WRITE_BIT</td>
</tr>
</tbody>
</table>

The Scenario

src cars

dst cars

OCR State University Computer Graphics
VKImageLayout – How an Image gets Laid Out in Memory depends on how it will be Used

| VK_IMAGE_LAYOUT_UNDEFINED          | Used as a color attachment       |
| VK_IMAGE_LAYOUT_COLOR_ATTACHMENT_Optimal | Read into a shader as a texture |
| VK_IMAGE_LAYOUT_DEPTH_STENCIL_ATTACHMENT_Optimal | Copy from |
| VK_IMAGE_LAYOUT_SHADER_READ_ONLY_Optimal         | Copy to                        |
| VK_IMAGE_LAYOUT_TRANSFER_SRC_Optimal             | Show image to viewer            |

Here, the use of vkCmdPipelineBarrier() is to simply change the layout of an image.