Specialization Constants

Remember the Compute Pipeline?

- VkPipelineLayoutCreateInfo
- VkPipelineShaderStageCreateInfo
- VkSpecializationInfo
- VkShaderModule
- vkCreateComputePipelines
- Compute Pipeline
What Are Specialization Constants?

In Vulkan, all shaders get halfway-compiled by SPIR-V and then the rest-of-the-way compiled by the Vulkan driver.

Normally, the half-way compile fixes all constant values and compiles the code that uses them.

But, it would be nice every so often to have your Vulkan program sneak into the halfway-compiled binary and manipulate some constants at runtime. This is what Specialization Constants are for. A Specialization Constant is a way of injecting an integer, Boolean, uint, float, or double constant into an halfway-compiled version of a shader right before the rest-of-the-way compilation.

That final compilation happens when you call `vkCreateComputePipelines()`.

Without Specialization Constants, you would have to commit to a final value before the SPIR-V compile was done, which could have been a long time ago.

Why Do We Need Specialization Constants?

Specialization Constants could be used for:

- Setting the work-items per work-group in a compute shader
- Setting a Boolean flag and then eliminating the if-test that used it
- Setting an integer constant and then eliminating the switch-statement that looked for it
- Making a decision to unroll a for-loop because the number of passes through it are small enough
- Collapsing arithmetic expressions into a single value
- Collapsing trivial simplifications, such as adding by zero or multiplying by 1
Specialization Constants are Described in the Compute Pipeline

In the compute shader

```cpp
layout( constant_id = 7 ) const int ASIZE = 32;
int array[ASIZE];
```

In the Vulkan C/C++ program:

```cpp
int asize = 64;
VkSpecializationMapEntry vsme[1]; // one array element for each Specialization Constant
    vsme[0].constantID = 7; // # bytes into the Specialization Constant
    vsme[0].offset = 0; // array this one item is
    vsme[0].size = sizeof(asize); // size of just this Specialization Constant

VkSpecializationInfo vsi;
    vsi.mapEntryCount = 1;
    vsi.pMapEntries = &vsme[0];
    vsi.dataSize = sizeof(asize); // size of all the Specialization Constants together
    vsi.pData = &asize; // array of all the Specialization Constants
```

Specialization Constant Example -- Setting an Array Size
## Linking the Specialization Constants into the Compute Pipeline

```cpp
int asize = 64;

VkSpecializationMapEntry vsme[1];
    vsme[0].constantID = 7;
    vsme[0].offset = 0;
    vsme[0].size = sizeof(asize);

VkSpecializationInfo vsi;
    vsi.mapEntryCount = 1;
    vsi.pMapEntries = &vsme[0];
    vsi.dataSize = sizeof(asize);
    vsi.pData = &asize;

VkPipelineShaderStageCreateInfo vpssci;
    vpssci.sType = VK_STRUCTURE_TYPE_PIPELINE_SHADER_STAGE_CREATE_INFO;
    vpssci.pNext = nullptr;
    vpssci.flags = 0;
    vpssci.stage = VK_SHADER_STAGE_COMPUTE_BIT;
    vpssci.module = computeShader;
    vpssci.pName = "main";
    vpssci.pSpecializationInfo = &vsi;

VkSpecializationMapEntry vsme[1];
    vsme[0].constantID = 7;
    vsme[0].offset = offsetof(abc, a);
    vsme[0].size = sizeof(abc.a);

VkSpecializationInfo vsi;
    vsi.mapEntryCount = 1;
    vsi.pMapEntries = &vsme[0];
    vsi.dataSize = sizeof(asize);
    vsi.pData = &asize;

VkPipelineShaderStageCreateInfo vpssci;
    vpssci.sType = VK_STRUCTURE_TYPE_PIPELINE_SHADER_STAGE_CREATE_INFO;
    vpssci.pNext = nullptr;
    vpssci.flags = 0;
    vpssci.stage = VK_SHADER_STAGE_COMPUTE_BIT;
    vpssci.module = computeShader;
    vpssci.pName = "main";
    vpssci.pSpecializationInfo = &vsi;

VkComputePipelineCreateInfo vcpci[1];
    vcpci[0].sType = VK_STRUCTURE_TYPE_COMPUTE_PIPELINE_CREATE_INFO;
    vcpci[0].pNext = nullptr;
    vcpci[0].flags = 0;
    vcpci[0].stage = vpssci;
    vcpci[0].layout = ComputePipelineLayout;
    vcpci[0].basePipelineHandle = VK_NULL_HANDLE;
    vcpci[0].basePipelineIndex = 0;

result = vkCreateComputePipelines(LogicalDevice, VK_NULL_HANDLE, 1, &vcpci[0], PALLOCATOR, OUT &ComputePipeline);
```

## Specialization Constant Example – Setting Multiple Constants

In the compute shader:

```cpp
layout( constant_id = 9 ) const int a = 1;
layout( constant_id = 10 ) const int b = 2;
layout( constant_id = 11 ) const float c = 3.14;
```

In the C/C++ program:

```cpp
struct abc { int a, int b, float c; } abc;

VkSpecializationMapEntry vsme[3];
    vsme[0].constantID = 9;
    vsme[0].offset = offsetof(abc, a);
    vsme[0].size = sizeof(abc.a);
    vsme[1].constantID = 10;
    vsme[1].offset = offsetof(abc, b);
    vsme[1].size = sizeof(abc.b);
    vsme[2].constantID = 11;
    vsme[2].offset = offsetof(abc, c);
    vsme[2].size = sizeof(abc.c);

VkSpecializationInfo vsi;
    vsi.mapEntryCount = 3;
    vsi.pMapEntries = &vsme[0];
    vsi.dataSize = sizeof(abc); // size of all the Specialization Constants together
    vsi.pData = &abc; // array of all the Specialization Constants
```
In the compute shader:

```glsl
layout( local_size_x_id=12 ) in;
layout( local_size_x = 32, local_size_y = 1, local_size_z = 1 ) in;
```

In the C/C++ program:

```c
int numXworkItems = 64;

VkSpecializationMapEntry vsme[1];
vsme[0].constantID = 12;
vsme[0].offset = 0;
vsme.size = sizeof(int);

VkSpecializationMapEntry vsme[1];
vsme[0].constantID = 12;
vsme[0].offset = 0;
vsme.size = sizeof(int);

VkSpecializationInfo vsi;
vsi.mapEntryCount = 1;
vsi.pMapEntries = &vsme[0];
vsi.dataSize = sizeof(int); 
vsi.pData = &numXworkItems;
```