Wrong Way: Successes, Failures, and Lessons Learned from Using the “Wrong” Programming Approach for Summit

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Mid-2020 DOE Landscape

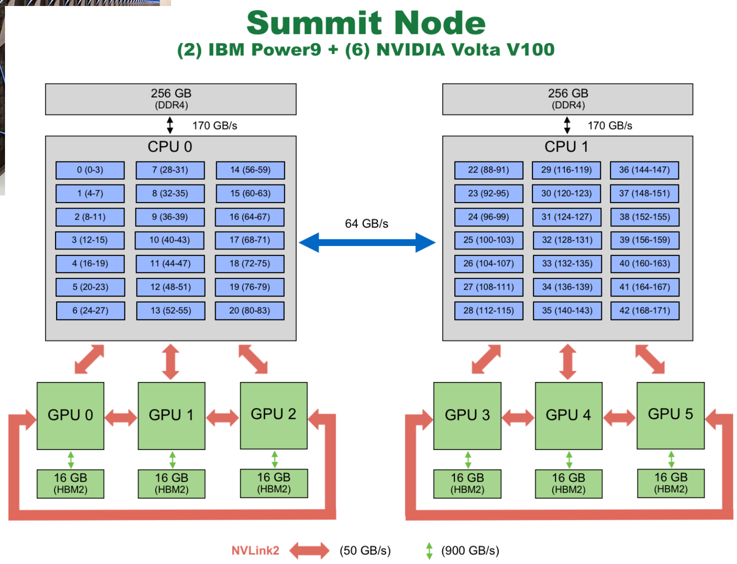
- Department of Energy (DOE) computing centers exhibit variety
  - Accelerators vs. no accelerators
    - Variety of accelerator vendors
    - Variety in CPU/GPU ratios, connectivity
  - Interconnect type, topology, capabilities
  - On-node NVM vs. near-node NVM vs. no NVM
- DOE Centers epitomize need for ***Performance, Portability, and Productivity***

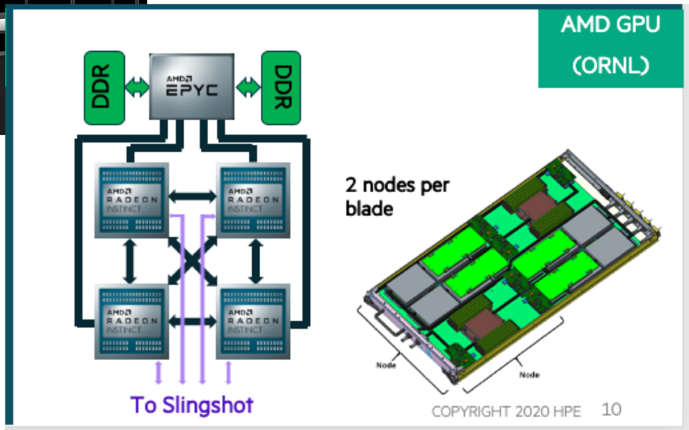
The DOE Landscape: OLCF

- Oak Ridge Leadership Computing Facility (OLCF) currently fields Summit
  - Each node contains six NVIDIA V100 GPUs and two POWER9 CPUs

- OLCF will soon deploy Frontier
  - Each node will contain four AMD Radeon Instinct GPUs and one AMD EPYC CPU

- ***<u>90%+ of OLCF systems' computational capability comes from GPUs</u>***
  - Other systems have/will have similar characteristics
  - ***<u>I will focus on GPUs in this talk</u>***





“Right Way” vs. “Wrong Way”

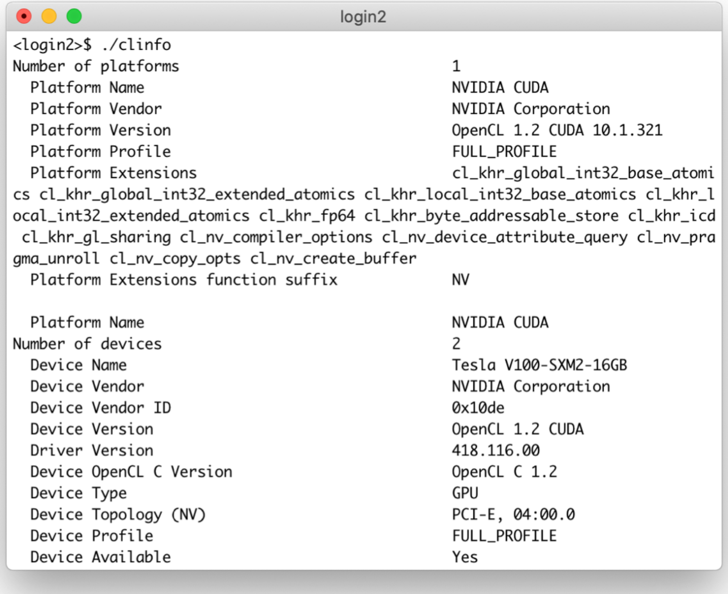
- GPU type suggests “right” or “natural” approach
  - Summit:
    - CUDA
    - OpenACC
    - OpenMP offload
  - Frontier
    - HIP
    - OpenMP offload
  - Also portability libraries (e.g., Kokkos, RAJA) with these backends
- ***Sometimes fun to consider what is possible, especially when it is “natural” on some other interesting system(s)***
  - Open source options
  - Functionality rather than performance
- ***Definitely NOT a criticism about vendor(s) choices!***

OLCF: Some Possible “Wrong Ways”

- What “wrong ways” are theoretically possible on Summit?
  - OpenCL
  - HIP
  - SYCL
  - DPC++
- And on Frontier?
  - OpenCL
  - SYCL
  - DPC++

Summit: OpenCL

- OpenCL: Khronos standard, C-based, **very** mature – and might even be performance portable
- CUDA installation includes some OpenCL-related files
  - Installable Client Driver (ICD) with config file
  - OpenCL loader library (libOpenCL.so) – but it is for X86_64
  - No OpenCL headers
  - ***To reiterate: I am not criticizing NVIDIA for not supporting OpenCL on POWER9***
- Two possible “wrong ways”
  - For both: Download Khronos headers, build Khronos ICD loader library
  - Option 1: use NVIDIA ICD
    - Platform/device queries and data transfer OK, can’t do OpenCL JIT compile
  - Option 2: use Portable Computing Language (POCL) open source OpenCL implementation



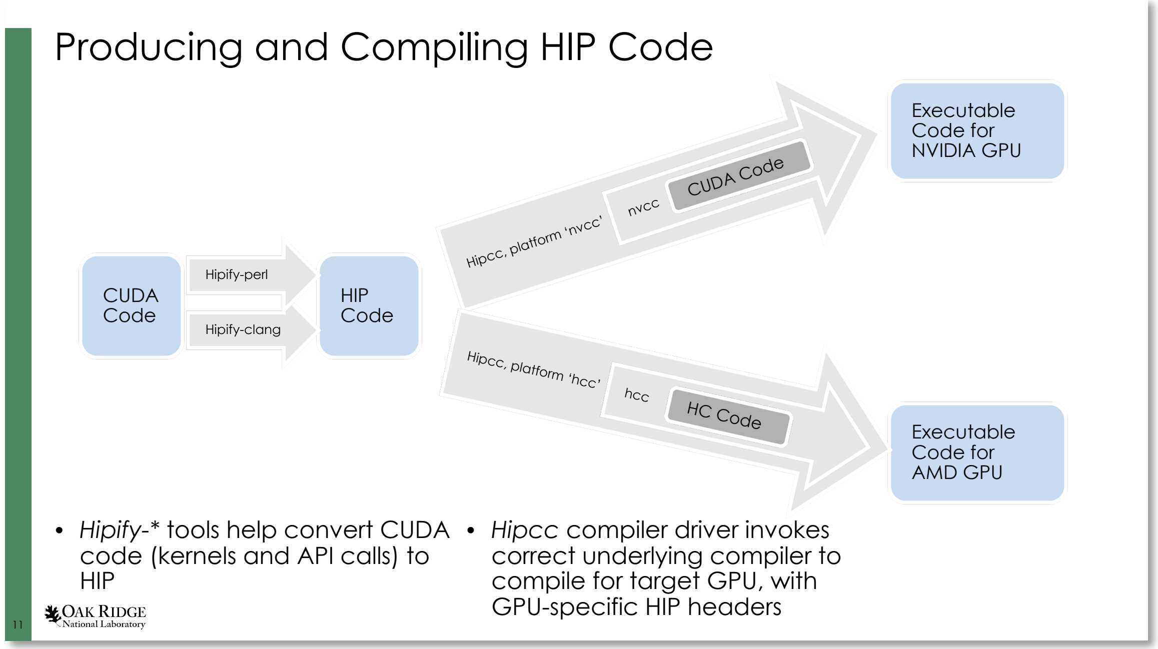
```
<login2>$ ./clinfo
Number of platforms                               1
  Platform Name                                   NVIDIA CUDA
  Platform Vendor                                 NVIDIA Corporation
  Platform Version                                OpenCL 1.2 CUDA 10.1.321
  Platform Profile                                FULL_PROFILE
  Platform Extensions                             cl_khr_global_int32_base_atomi
cs cl_khr_global_int32_extended_atomics cl_khr_local_int32_base_atomics cl_khr_l
ocal_int32_extended_atomics cl_khr_fp64 cl_khr_byte_addressable_store cl_khr_icd
 cl_khr_gl_sharing cl_nv_compiler_options cl_nv_device_attribute_query cl_nv_pra
gma_unroll cl_nv_copy_opts cl_nv_create_buffer
  Platform Extensions function suffix             NV

  Platform Name                                   NVIDIA CUDA
Number of devices                                 2
  Device Name                                     Tesla V100-SXM2-16GB
  Device Vendor                                   NVIDIA Corporation
  Device Vendor ID                                0x10de
  Device Version                                  OpenCL 1.2 CUDA
  Driver Version                                  418.116.00
  Device OpenCL C Version                         OpenCL C 1.2
  Device Type                                     GPU
  Device Topology (NV)                            PCI-E, 04:00.0
  Device Profile                                  FULL_PROFILE
  Device Available                                Yes
```

CLInfo with NVIDIA ICD

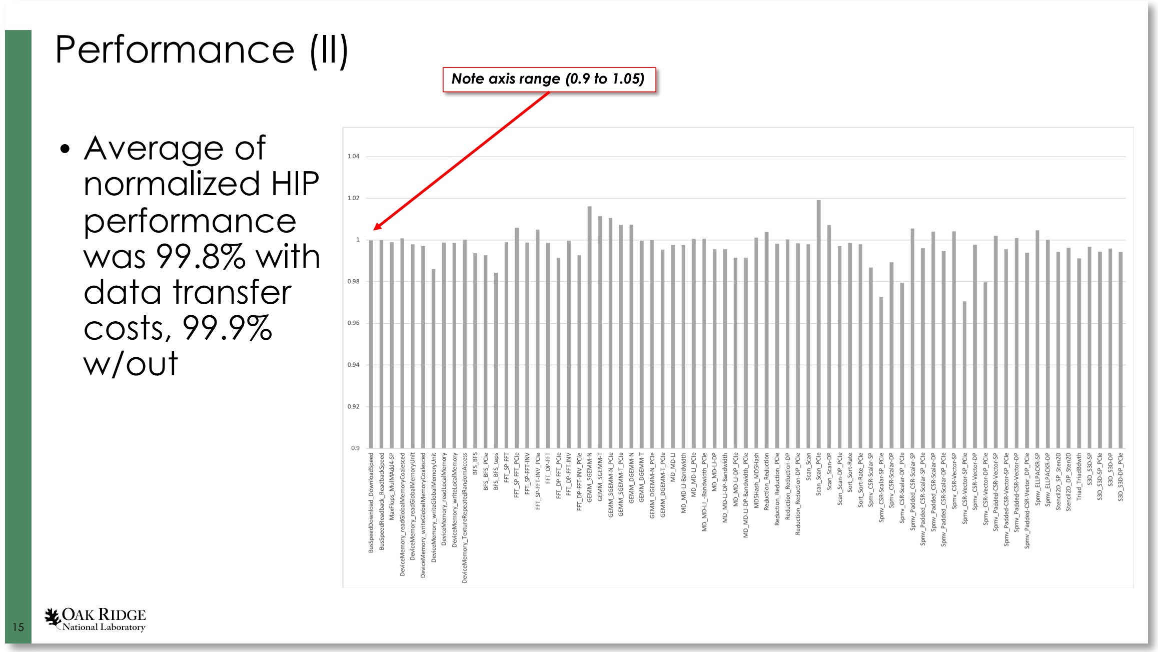
Summit: HIP

- Heterogeneous-compute Interface for Portability (HIP)
- Not really a “wrong way” on Summit
    - HIP designed as portability layer with AMD ROCm and NVIDIA CUDA backends
- OLCF provides a module for HIP but not (yet) any of the hip* libraries
    - HIP can be installed by user as header-only library
    - HIP libraries can be built for CUDA backend and installed by user



Producing and Compiling HIP Code

- *Hipify-** tools help convert CUDA code (kernels and API calls) to HIP
- *Hipcc* compiler driver invokes correct underlying compiler to compile for target GPU, with GPU-specific HIP headers



Performance (II)

- Average of normalized HIP performance was 99.8% with data transfer costs, 99.9% w/out

Note axis range (0.9 to 1.05)

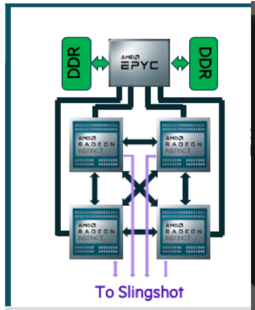
Summit: SYCL

- SYCL: Khronos standard, C++-based, OpenCL’s spiritual successor
- Some options for this “wrong way”:
  - hipSYCL: a SYCL 1.2 implementation built on HIP
    - CUDA for GPU, OpenMP for CPU
    - Have demonstrated this running on Summit with simple examples, e.g., matrix aX+Y
  - Tried using CodePlay’s Community Edition to compile kernels to PTX code on spare x86_64 system, transferring to Summit, and using them via POCL – not successful

DPC++

- Intel’s oneAPI C++-based programming approach
  - Several useful extensions to SYCL 1.2 (some appearing in SYCL 2020)
- A “wrong way” for Summit:
  - Intel LLVM staging repository includes DPC++ compiler sources
  - Found small number of build problems, e.g., reliance on CPUID instruction that isn’t supported on POWER9
- Others have reported some success in working around for other non-x86_64 platforms, so may be possible soon on Summit

Frontier: OpenCL, SYCL, and DPC++



- Have less experience trying these “wrong way” approaches on pre-Frontier systems so far
- AMD has traditionally supported OpenCL
  - But SPIR/SPIR-V support varies by product line - not supported on MI25/MI60
  - Options: POCL, “manual” conversion of SPIR-V to AMDGCN
- SYCL and DPC++
  - CodePlay’s community edition
    - Earlier versions had some undocumented support for AMDGCN, missing from more recent versions
  - Intel LLVM repository
    - CPUID not an issue here
    - Still reliant on SPIR-V tools/translator to convert to AMDGCN?

Acknowledgements

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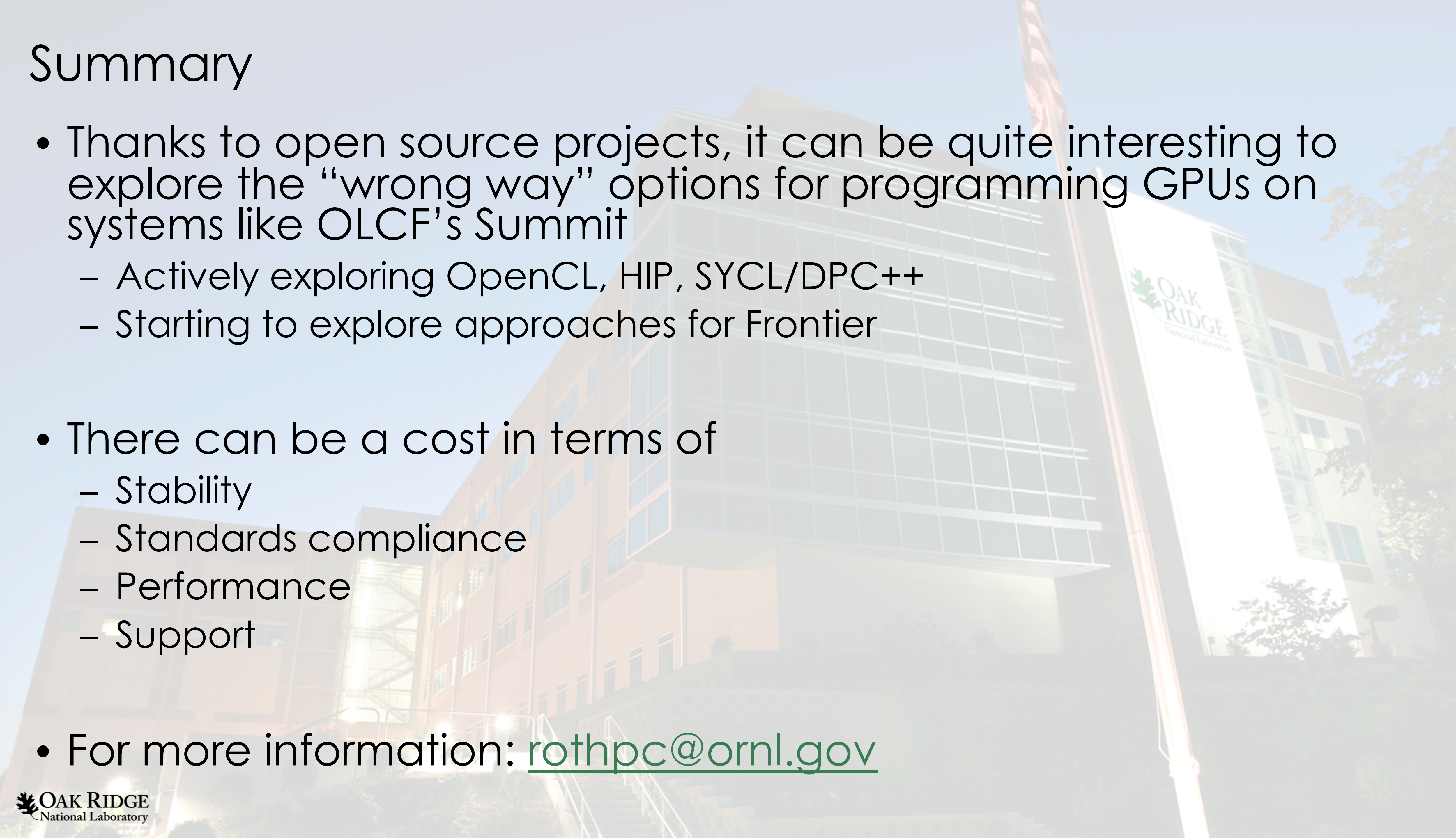
Summary



- Thanks to open source projects, it can be quite interesting to explore the “wrong way” options for programming GPUs on systems like OLCF’s Summit
  - Actively exploring OpenCL, HIP, SYCL/DPC++
  - Starting to explore approaches for Frontier

- There can be a cost in terms of
  - Stability
  - Standards compliance
  - Performance
  - Support

- For more information: rothpc@ornl.gov