A. JAMES CLARK
SCHOOL OF ENGINEERING

A Standalone Package for Bringing Graphics Processor Acceleration to GNU Radio: *GRGPU*

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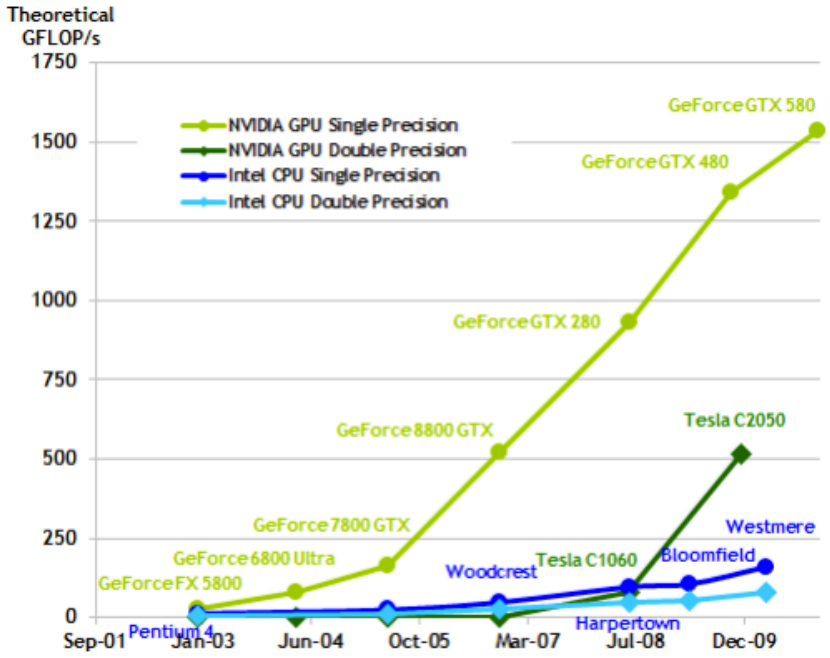
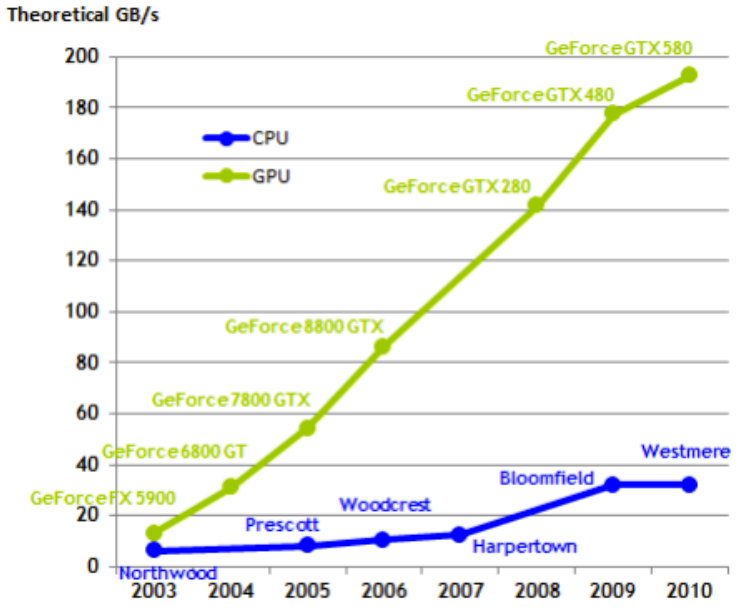
Outline

- Introduction
- GPU Background
- Graphics Processor Integration with GNU Radio
- Evaluation
- Summary

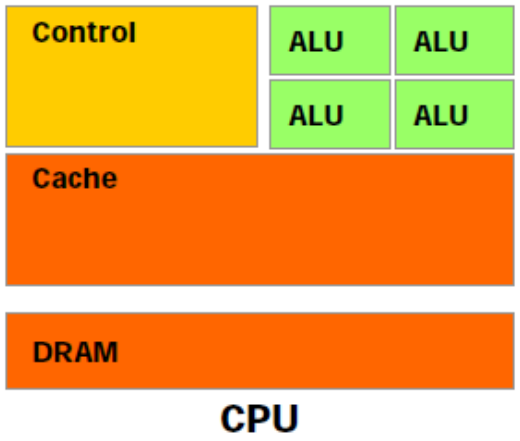
Motivation

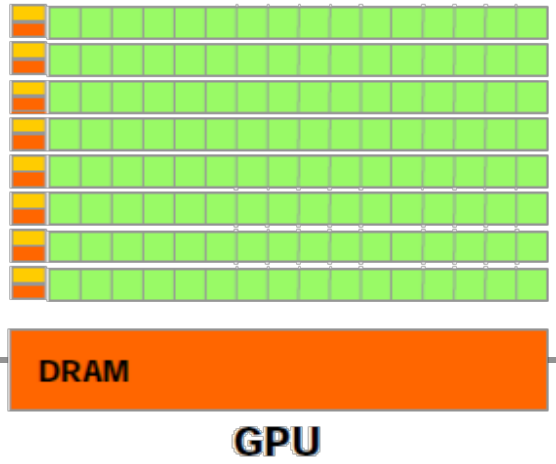
- High-Performance prototyping with GPUs is tempting…
  - *Potentially* fast design times
  - Flop/$
- …but hard.
  - Learn a new language
  - Expose or refactor parallelism



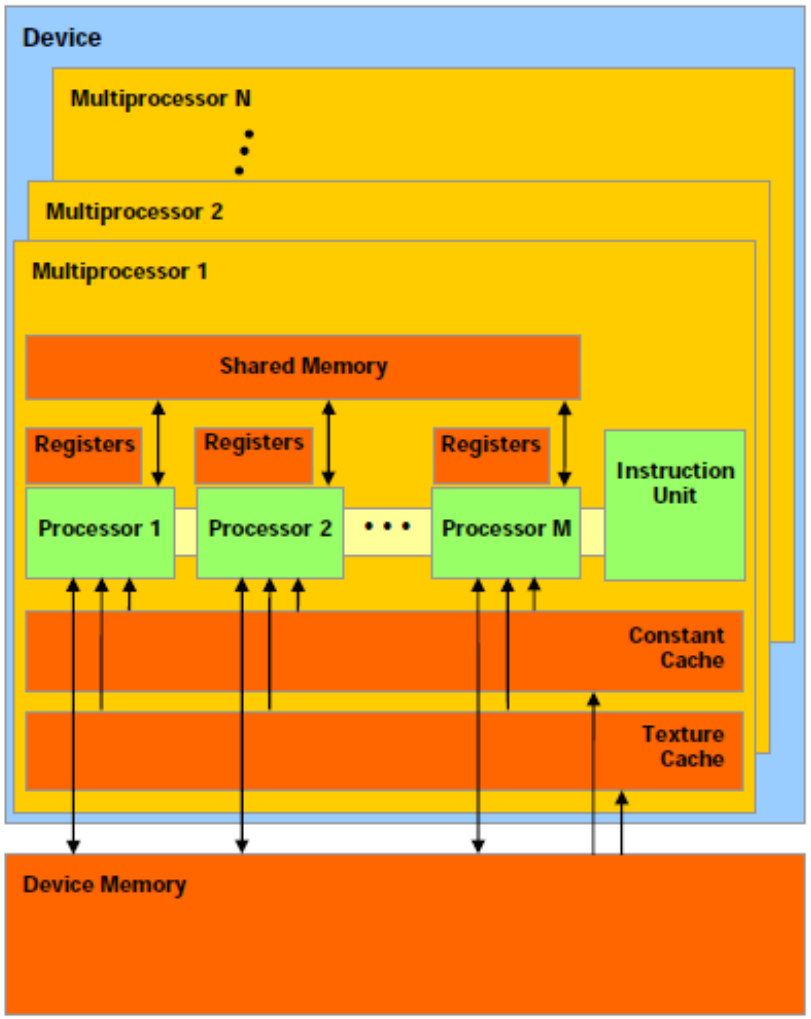


The GPU Difference





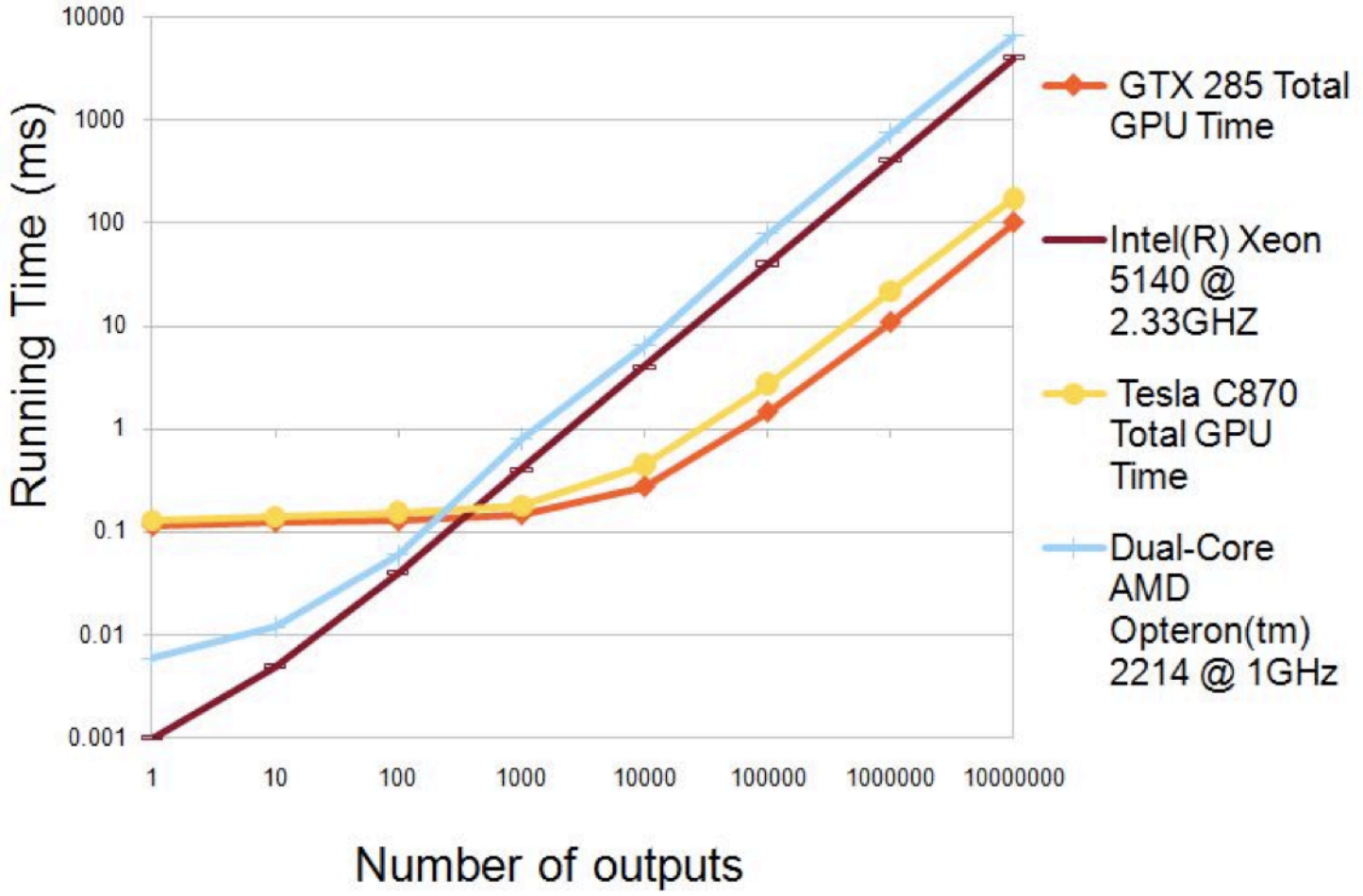
Detailed GPU



A typical high end modern GPU: GTX 580

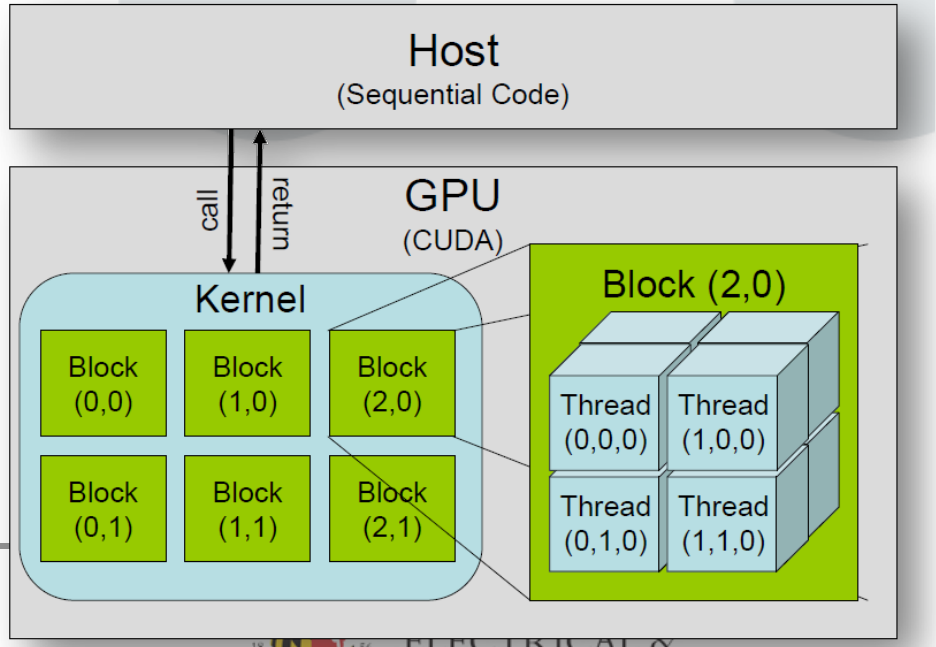
- Released 10/2010
- 3B transistors, 40nm
- 512 Cores @700MHz
- 1.5 TFLOPs
- 192 GB/s Memory BW
- 244W
- $500

CUDA FIR vs. Stock FIR

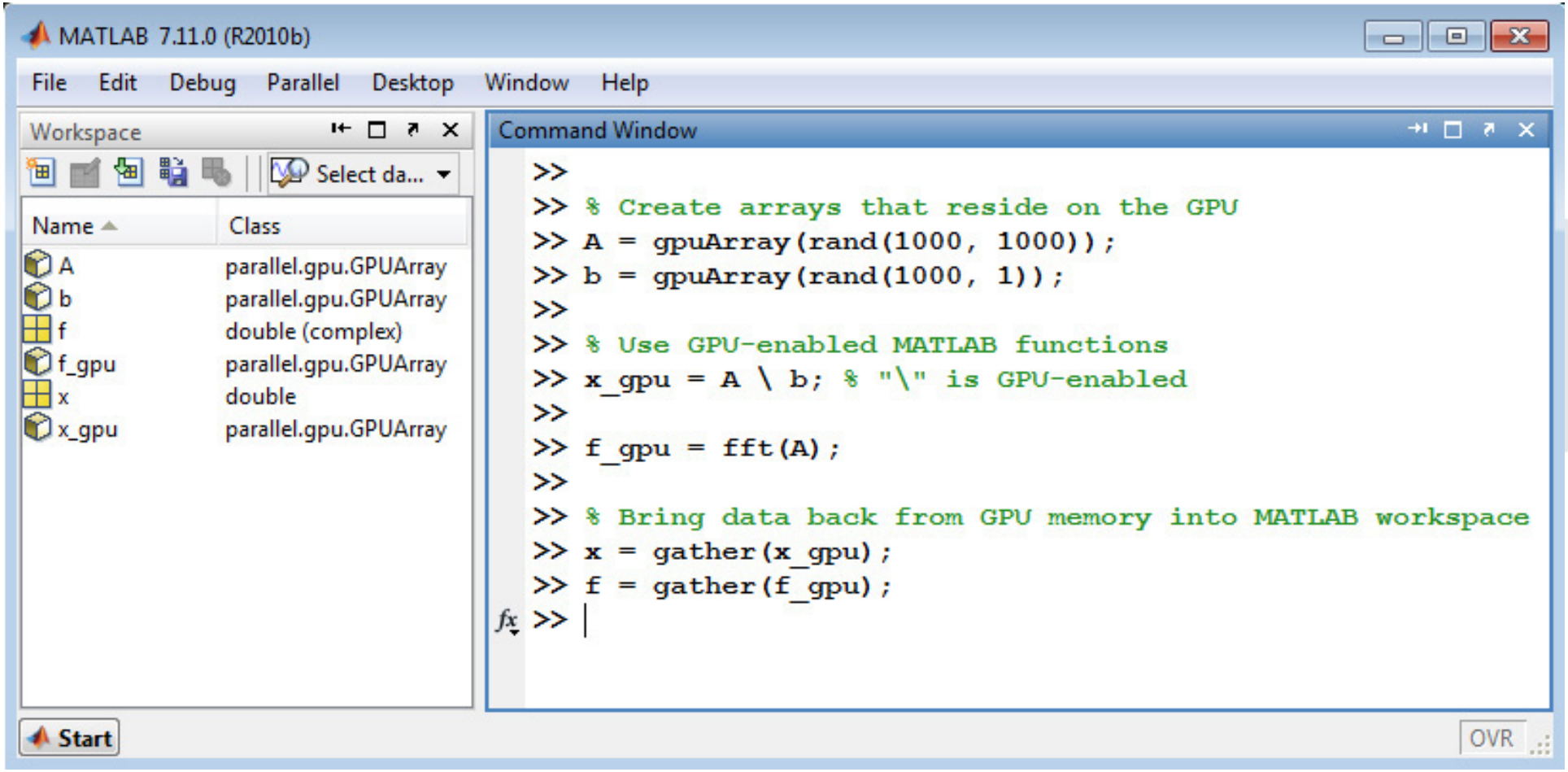


A brief history of GPU Programming

- OpenGL (1992)/DirectX(1995) + shader programming in assembly
- Cg, GLSL, HLSL (early 2000s)
- Sh, Brook (2004)
- CUDA (2006)
- OpenCL (2008)



Related Work – MATLAB

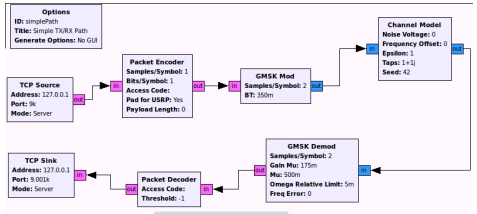


Related Work – PyCUDA

```
import pycuda.autoinit
import pycuda.driver as drv
import numpy

from pycuda.compiler import SourceModule
mod = SourceModule("""
__global__ void multiply_them(float *dest, float *a, float *b)
{
  const int i = threadIdx.x;
  dest[i] = a[i] * b[i];
}
""")

multiply_them = mod.get_function("multiply_them")

a = numpy.random.randn(400).astype(numpy.float32)
b = numpy.random.randn(400).astype(numpy.float32)

dest = numpy.zeros_like(a)
multiply_them(
        drv.Out(dest), drv.In(a), drv.In(b),
        block=(400,1,1), grid=(1,1))

print dest-a*b
```

Background – GNU Radio Design Flow

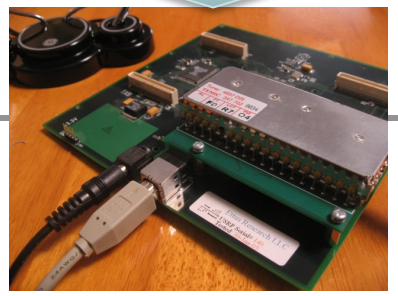
GNU Radio Companion (GRC)



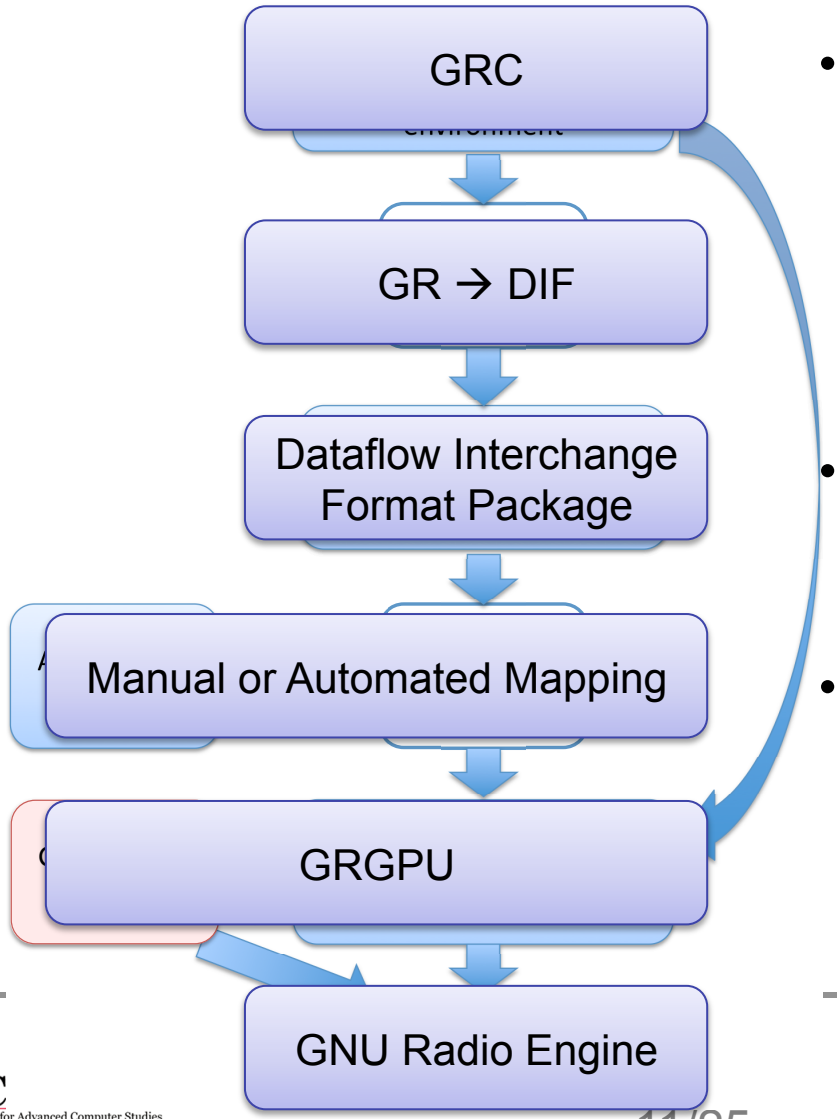
GNU Radio Python Flowgraph

```
class top(gr.top_block):
    def __init__(self):
        gr.top_block.__init__(self)
        ntaps = 256

        # Something vaguely like floating point ops
        self.flop = 2 * ntaps * options.npipelines

        src = gr.null_source(gr.sizeof_float)
        head = gr.head(gr.sizeof_float, int(options.nsamples))
        self.connect(src, head)

        for n in range(options.npipelines):
            self.connect(head, pipeline(options.nstages, ntaps))
```

Universal Software Radio Peripheral (USRP)

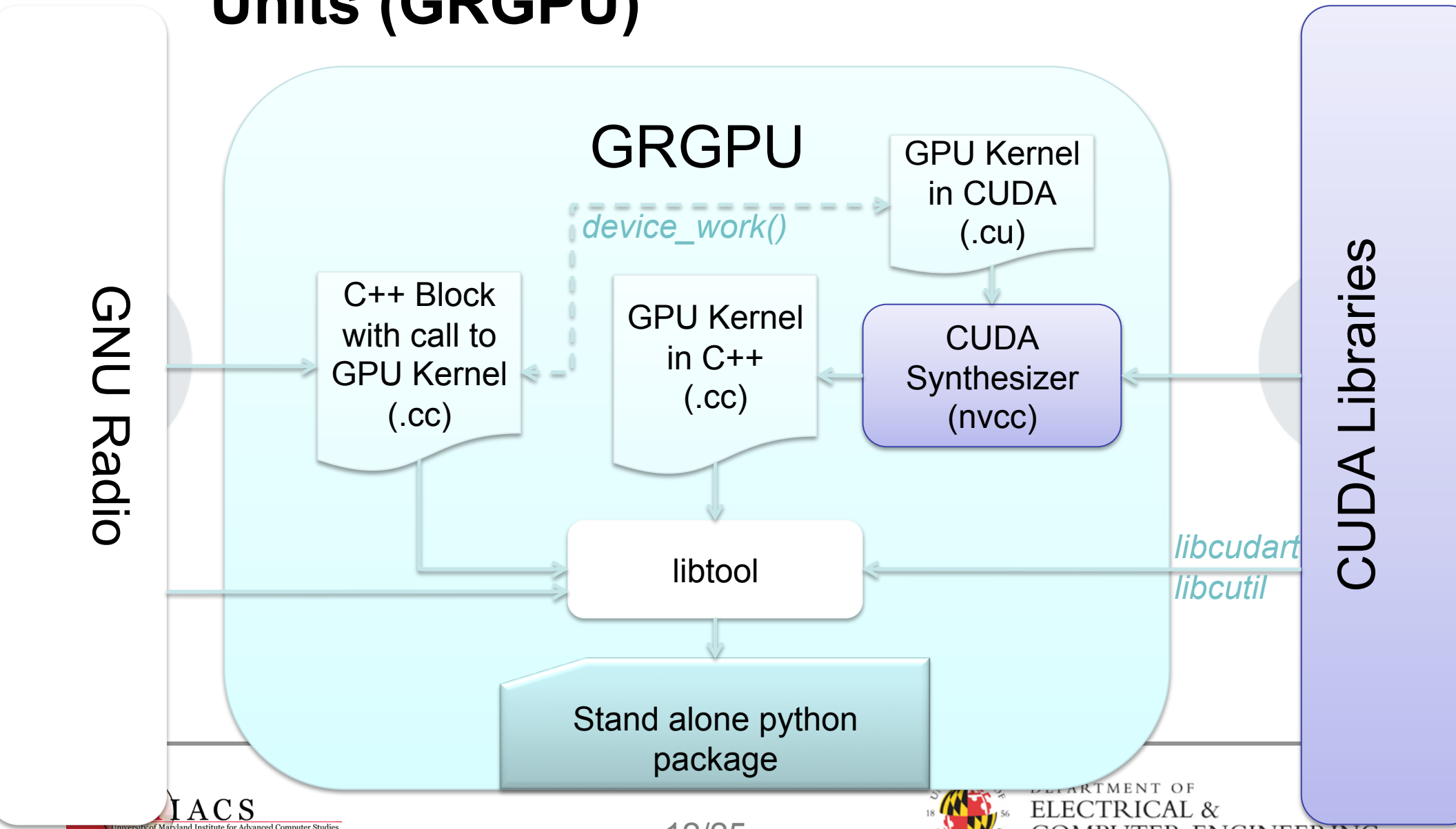


Proposed Design Flow



- Start from an unambiguous application description based on the application area itself
  - Dataflow
- Use tools to optimize scheduling, assignment
- Generate an accelerated functional description

GNU Radio for Graphics Processing Units (GRGPU)



Build Process

- make-cuda : .cu → .cc
  - nvcc as a software synthesizer
  - transform cuda code into target specific GPU code
  - wrap functions in extern “C”
- make
  - Resulting cc’s are just more inputs to existing build structure
  - link against CUDA runtime (cudart) and CUDA utils (cutil)

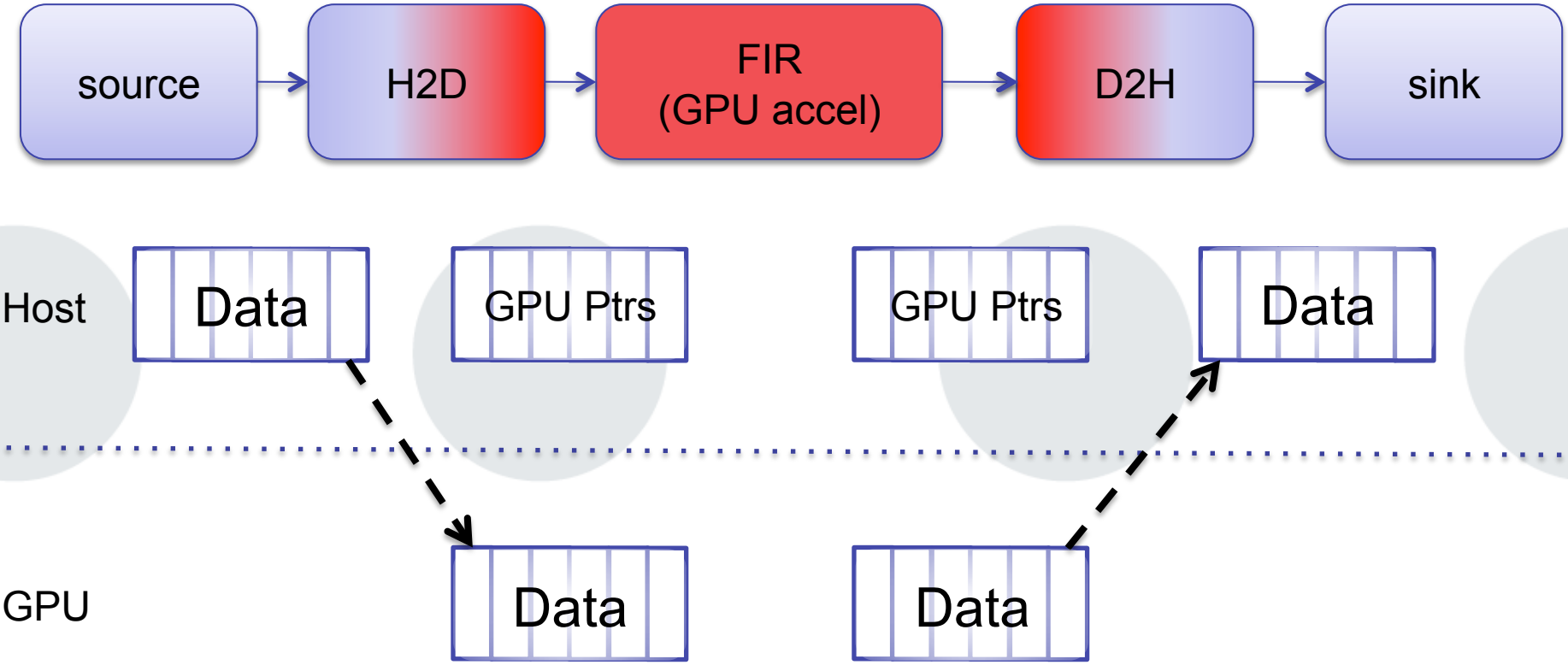
Using GRGPU

- Used just like gr in GNU Radio flowgraphs
  - import grgpu
  - op = grgpu.op_cuda()
- Dependent blocks
  - Host/device data movement handled by other blocks
  - Has device pointers as interface

GRGPU Example

```
class GPU_Thread(threading.Thread):
    """GPU Thread"""
    def init(self):
        self.tb = gr.top_block ()
        src_data = list(math.sin(x) for x in range(TOTAL_LENGTH))
        src = gr.vector_source_f (src_data)

        h2d = grgpu.h2d_cuda()
        taps = [0.1]*60
        op  = grgpu.fir_filter_fff_cuda(taps)
        d2h = grgpu.d2h_cuda()

        self.dst = gr.vector_sink_f ()
        self.tb.connect(src, h2d)
        self.tb.connect(h2d, op)
        self.tb.connect(op, d2h)
        self.tb.connect(d2h, self.dst)
```

GRGPU Example



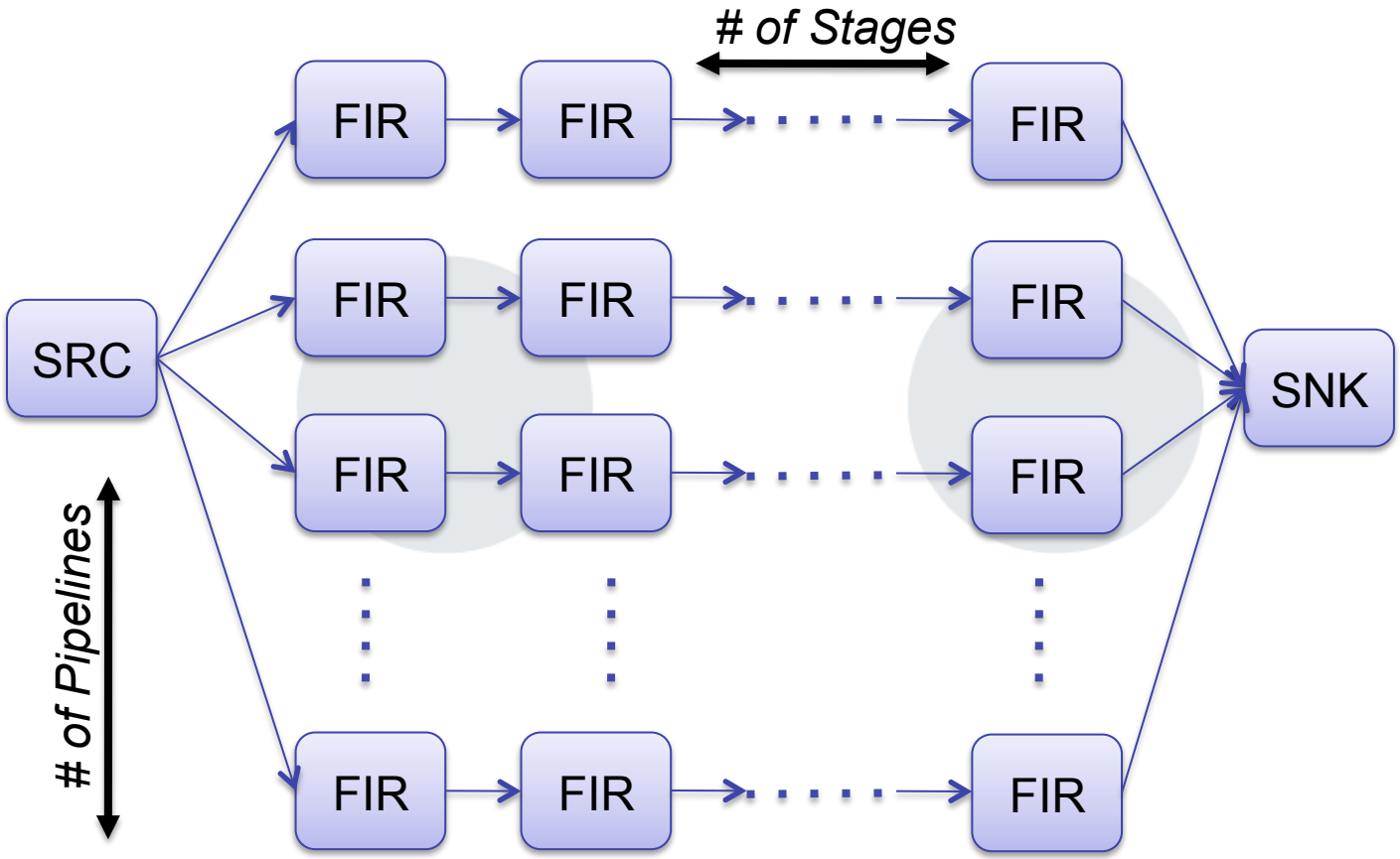
Other GRGPU features

- Fifo reads/writes are chunky and have history
  - Designed to make use of burst transfers
  - Creates in data contiguous memory for kernels
- Growing library
  - add_const, mul_const, FIR, resampler, FFT
  - floats, complexes
- Typical GR conveniences
  - Create new GRGPU block script
  - Doxygen, unit tests, GR build process

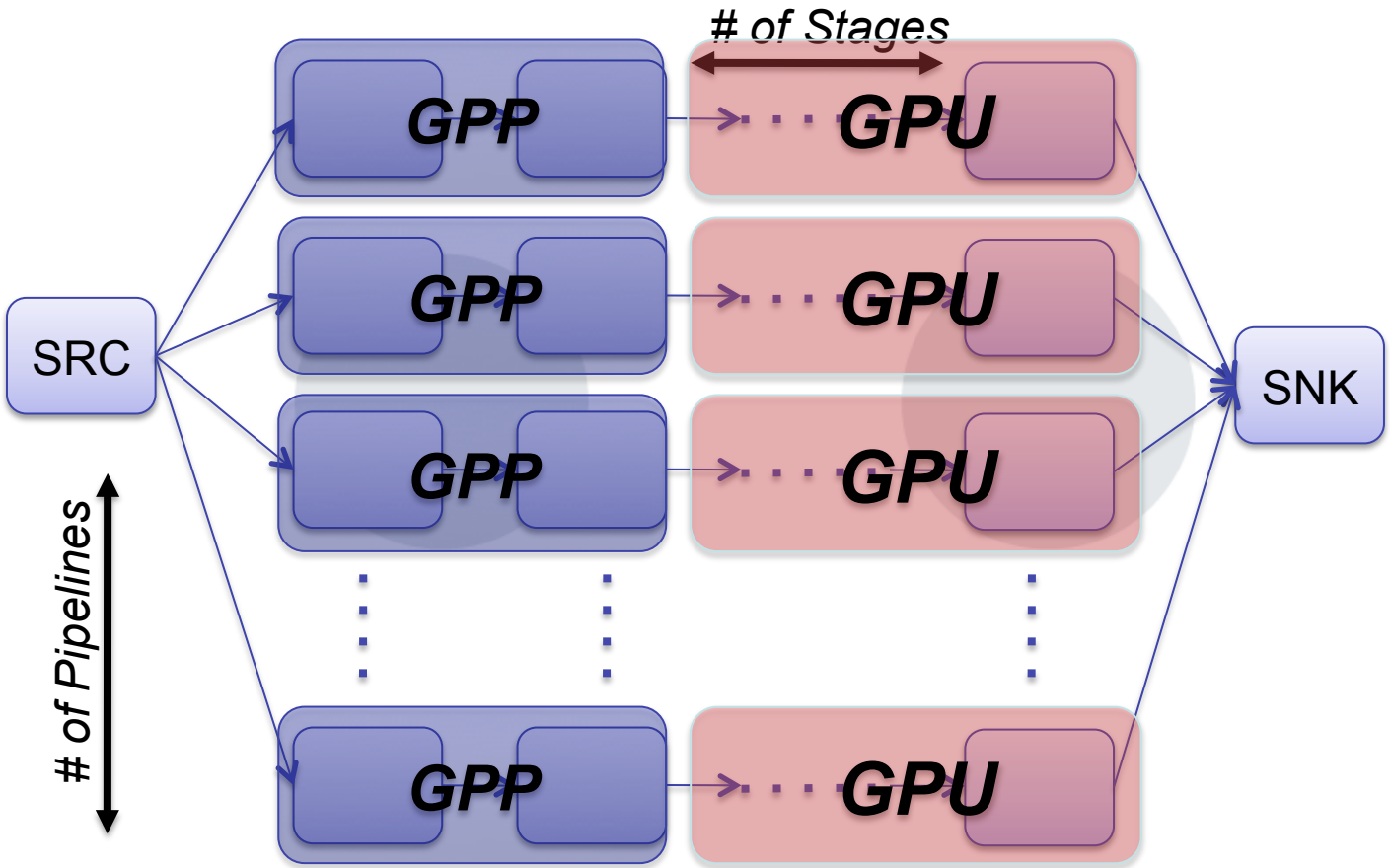
Evaluation

- Benchmark GPU options with GNU Radio multicore benchmark (mp-sched)
  - 2 Intel Xeons (3GHz) and 1 GTX 260
- GPU and GPP accelerated FIR
  - CUDA and SSE acceleration
- Vary: size and assignment
- Measure: total execution time

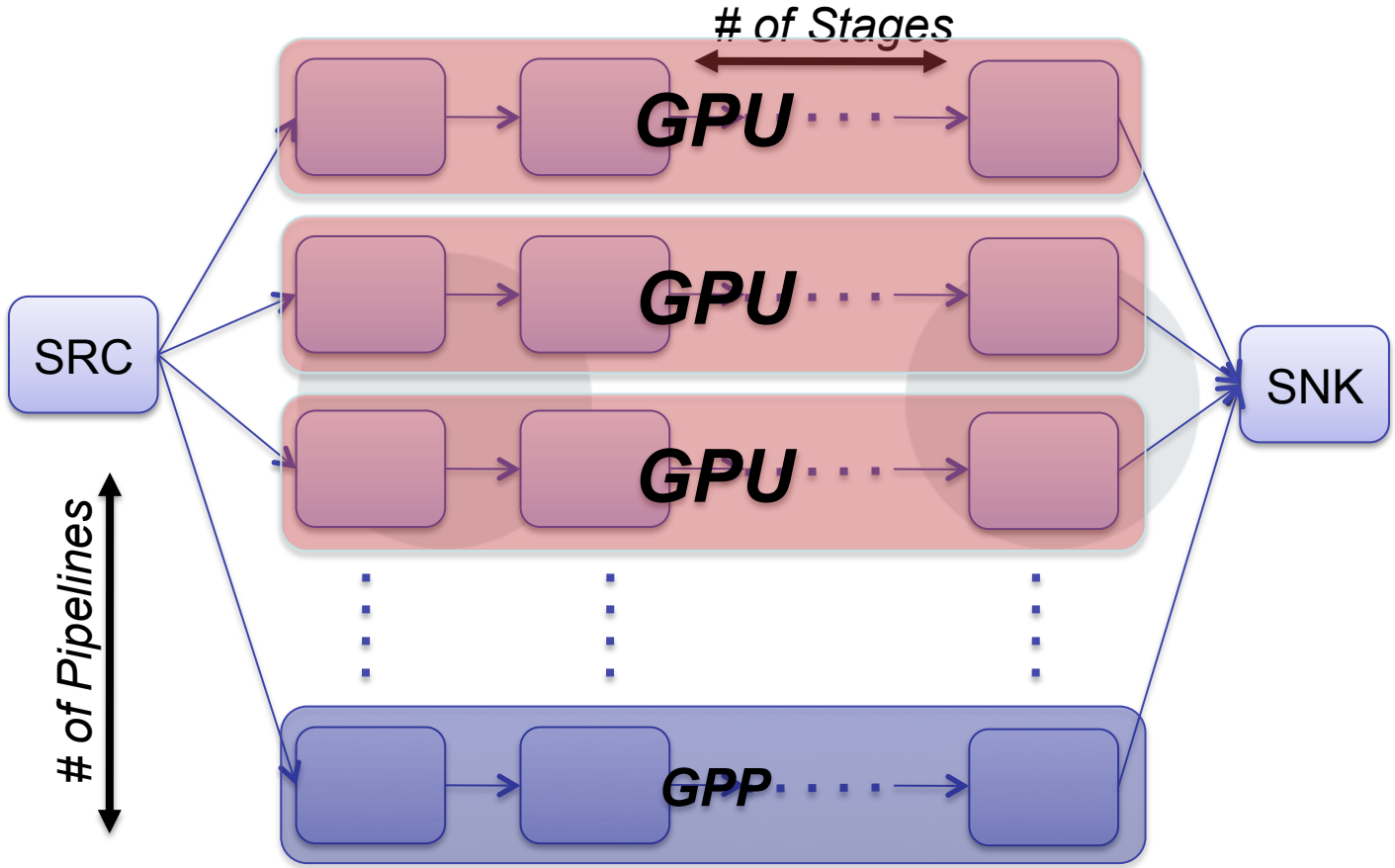
Evaluation Application



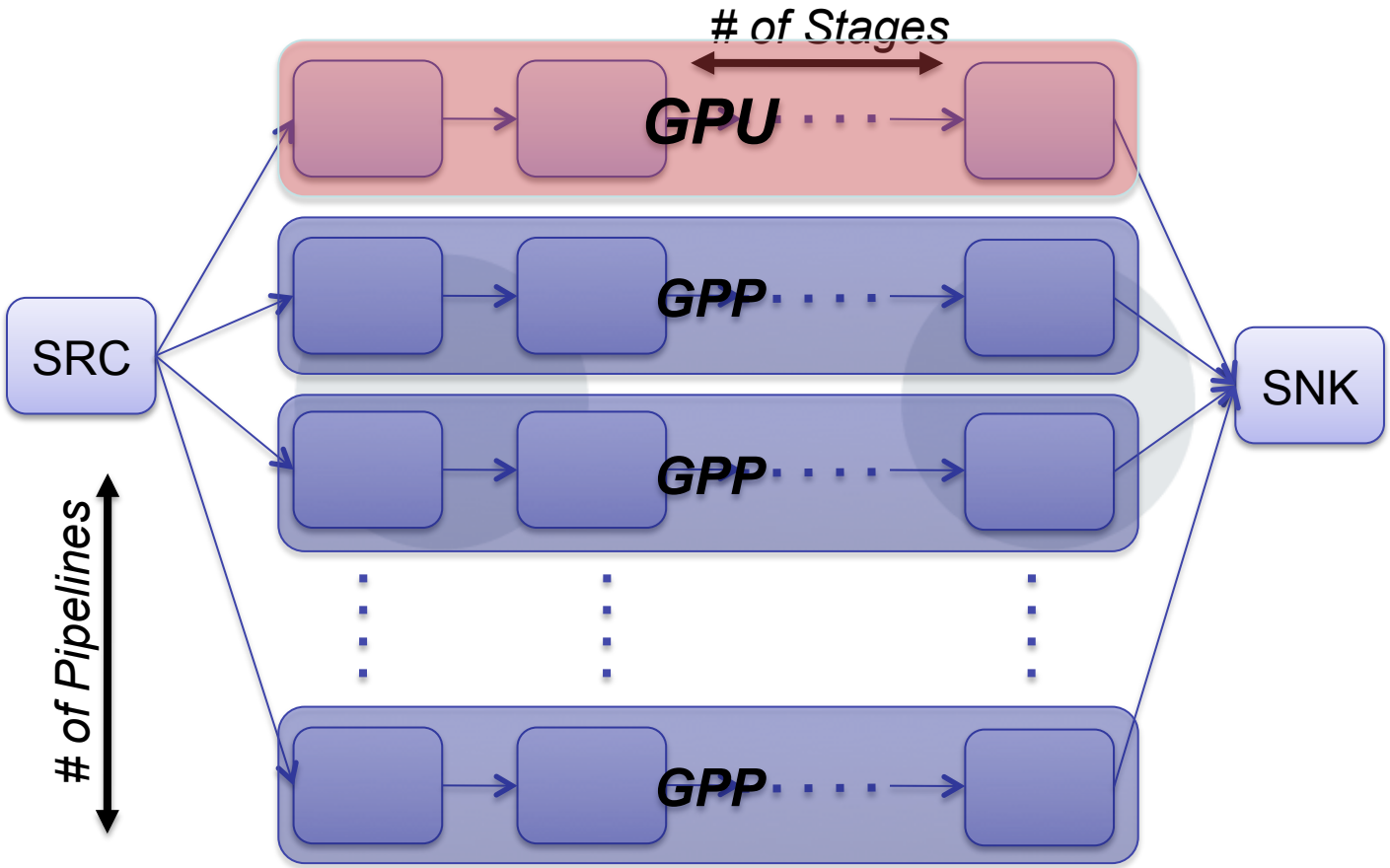
Evaluation Application – "Half CPU"



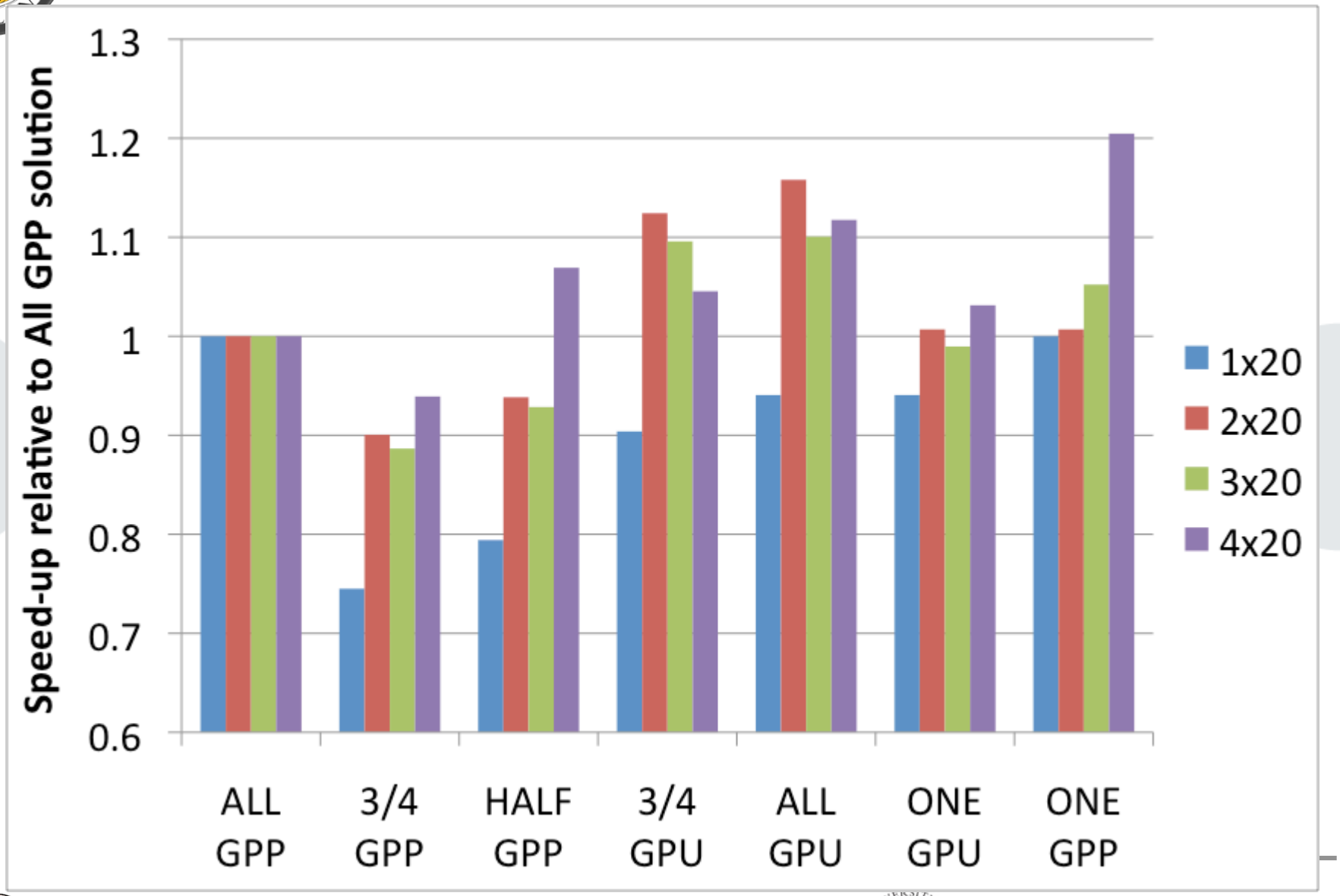
Evaluation Application – "One GPP"



Evaluation Application – "One GPU"



Results


Speed-up relative to All GPP solution
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
ALL GPP
3/4 GPP
HALF GPP
3/4 GPU
ALL GPU
ONE GPU
ONE GPP
1x20
2x20
3x20
4x20

Conclusions

- GRGPU provides GPU acceleration to GNU Radio as a stand alone library
  - Facilitates design space exploration
- Status
  - Planned to be contributed back
  - Few but growing number of CUDA accelerated blocks
- Ongoing Work
  - Automated Mapping
  - MultiGPU

Questions?

Citations:

W. Plishker, G. Zaki, S. S. Bhattacharyya, C. Clancy, and J. Kuykendall. Applying graphics processor acceleration in a software defined radio prototyping environment. In *Proceedings of the International Symposium on Rapid System Prototyping, pages 67-72, Karlsruhe, Germany, May 2011.*

G. Zaki, W. Plishker, T. OShea, N. McCarthy, C. Clancy, E. Blossom, and S. S. Bhattacharyya. Integration of dataflow optimization techniques into a software radio design framework. In *Proceedings of the IEEE Asilomar Conference on Signals, Systems, and Computers, pages 243-247, Pacific Grove, California, November 2009.*