

Bryce Graves

Professor Mike Bailey

CS 475

2020 5 30 (ISO 8601)

Project: 6

Bryce Graves

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Hardware: desktop still haven't changed the OS ͇͇(ツ)͇͇

- **OS:** Linux Mint 19.3 Cinnamon
- **Kernel:** 5.3
- **CPU:** Intel© Core™ i7-6700K CPU
 - **Cores:** 4
 - **Threads:** 8
 - **Core Clock:** 4 GHz
 - **Boost Clock:** 4.2 GHz
 - **L1 Cache:**
 - 4 x 32 kB Instruction
 - 4 x 32 kB Data
 - **L2 Cache:** 4 x 256 kB
 - **L3 Cache:** 1 x 8 MB
 - **Simultaneous Multithreading:** yes - Hyper-Threading
- **GPU:** Gigabyte Radeon RX 480 8 GB G1 Gaming Video Card X 2
 - **Memory:** 8 GB GDDR5
 - **Core Clock:** 1120 MHz
 - **Boost Clock:** 1290 MHz
 - **Effective Memory Clock:** 8100 MHz
- **Memory:** 32 GB DDR4 overclocked to 3200 MHz from base 2133 MHz

Hardware: laptop

- **OS:** Ubuntu 20.04

- **Kernel:** 5.4
- **CPU:** Intel(R) Core(TM) i5-6200U CPU
 - **Cores:** 2
 - **Threads:** 4
 - **Core Clock:** 2.30 GHz
 - **Boost Clock:** 2.80 GHz
 - **L1 Cache:** 64KiB
 - **L2 Cache:** 512KiB
 - **L3 Cache:** 3MiB
 - **Simultaneous Multithreading:** yes - Hyper-Threading
- **GPU:** Intel® HD Graphics 520
 - **Core Clock:** 300 MHz
 - **Boost Clock:** 1.00 GHz
- **Memory:** 8GB DDR3 1600 MHz

Print Info Output:

Laptop:

Desktop:

```
Number of Platforms = 1
Platform #0:
  Name = 'Intel Gen OCL Driver'
  Vendor = 'Intel'
  Version = 'OpenCL 2.0 beignet 1.3'
  Profile = 'FULL_PROFILE'
  Number of Devices = 1
  Device #0:
    Type = 0x0004 = CL_DEVICE_TYPE_GPU
    Device Vendor ID = 0x8086 (Intel)
    Device Maximum Compute Units = 24
    Device Maximum Work Item Dimensions = 3
    Device Maximum Work Item Sizes = 512 x 512 x 512
    Device Maximum Work Group Size = 512
    Device Maximum Clock Frequency = 1000 MHz

Device Extensions:
cl_khr_global_int32_base_atomics
cl_khr_global_int32_extended_atomics
cl_khr_local_int32_base_atomics
cl_khr_local_int32_extended_atomics
cl_khr_byte_addressable_store
cl_khr_3d_image_writes
cl_khr_image2d_from_buffer
cl_khr_depth_images
cl_khr_spir
cl_khr_icd
cl_intel_accelerator
cl_intel_subgroups
cl_intel_subgroups_short
cl_khr_fp16

Number of Platforms = 1
Platform #0:
  Name = 'Clover'
  Vendor = 'Mesa'
  Version = 'OpenCL 1.1 Mesa 19.2.8'
  Profile = 'FULL_PROFILE'
  Number of Devices = 2
  Device #0:
    Type = 0x0004 = CL_DEVICE_TYPE_GPU
    Device Vendor ID = 0x1002 (AMD)
    Device Maximum Compute Units = 36
    Device Maximum Work Item Dimensions = 3
    Device Maximum Work Item Sizes = 256 x 256 x 256
    Device Maximum Work Group Size = 256
    Device Maximum Clock Frequency = 1290 MHz
  Device #1:
    Type = 0x0004 = CL_DEVICE_TYPE_GPU
    Device Vendor ID = 0x1002 (AMD)
    Device Maximum Compute Units = 36
    Device Maximum Work Item Dimensions = 3
    Device Maximum Work Item Sizes = 256 x 256 x 256
    Device Maximum Work Group Size = 256
    Device Maximum Clock Frequency = 1290 MHz

Device Extensions:
cl_khr_byte_addressable_store
cl_khr_global_int32_base_atomics
cl_khr_global_int32_extended_atomics
cl_khr_local_int32_base_atomics
cl_khr_local_int32_extended_atomics
cl_khr_int64_base_atomics
cl_khr_int64_extended_atomics
cl_khr_fp64
cl_khr_fp16
```

Thoughts:

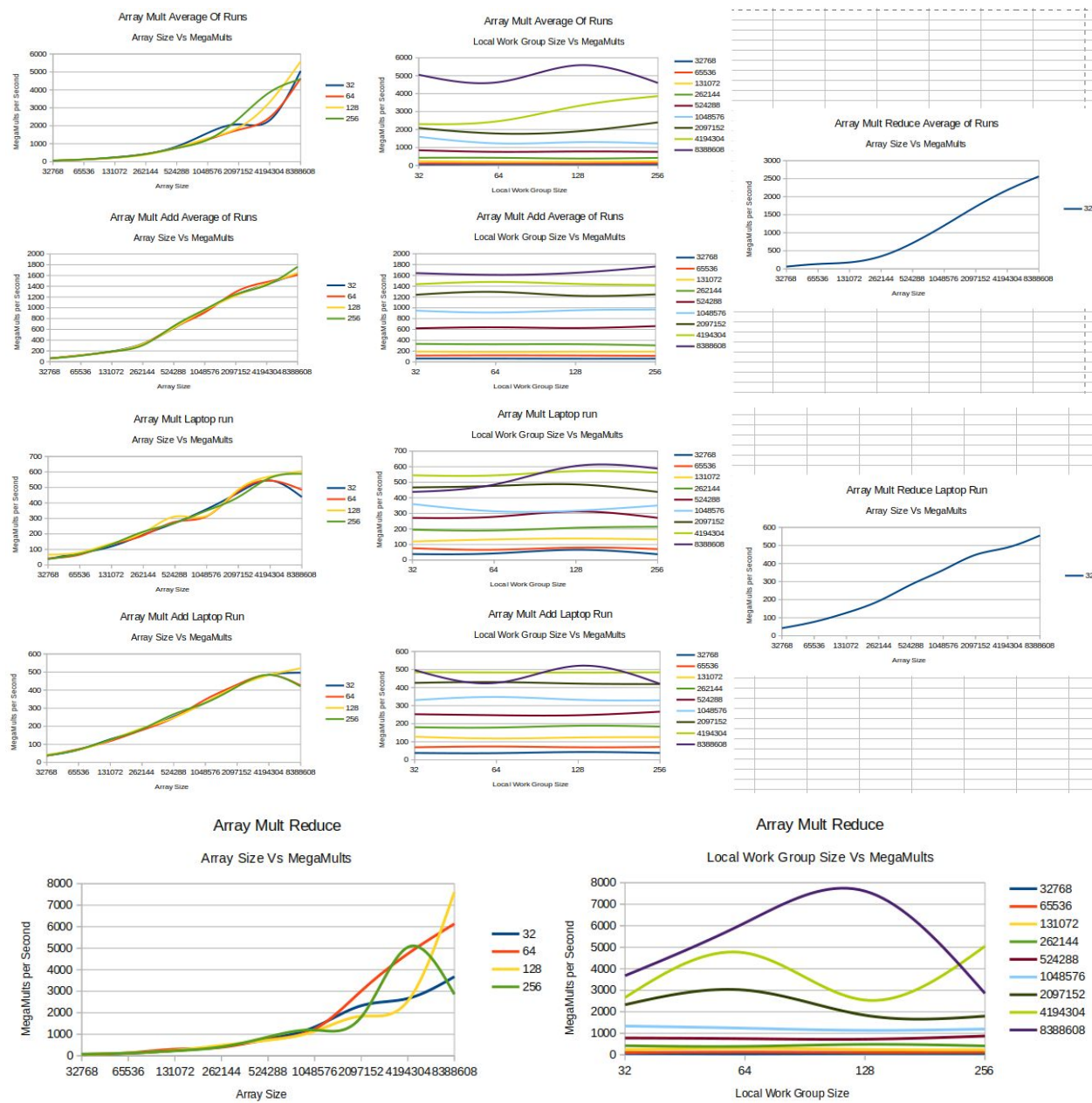
When I first ran timing tests it was with very very large array sizes that were close to the max size of my desktop graphics. Those speeds were much slower than expected and I saw a decrease in speed as I approached these sizes. I figure that this slow down is due to the requirement that the entire work global work group size is available before the graphics card. I was also surprised at how quickly my laptop ran the tests. I felt like the tests completed faster on my laptop but the megamults data contradicted this feeling. I am guessing the difference in response time comes down to the differences in terminals and Linux distros between the two systems.

Conclusion:

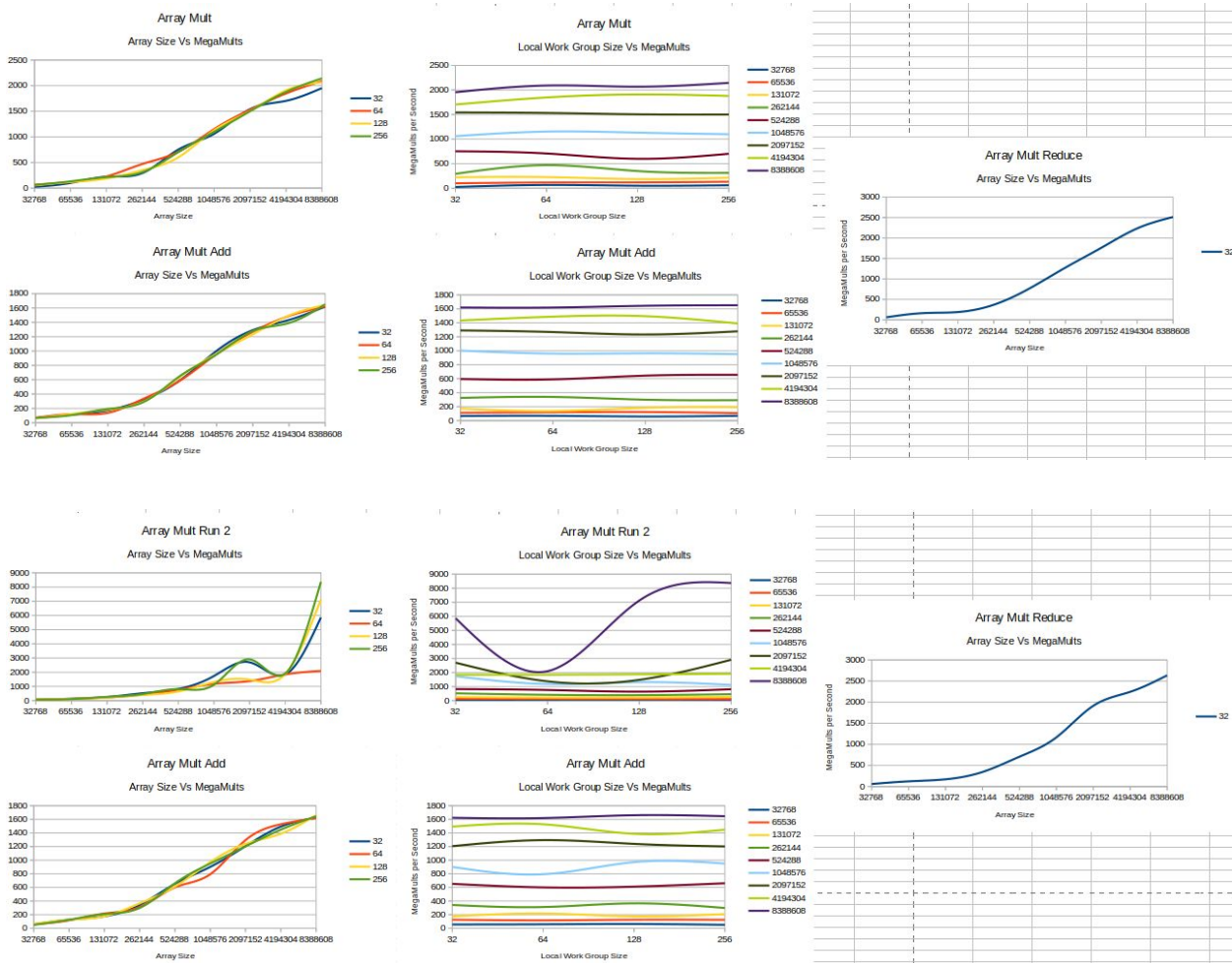
The data seems to suggest that larger jobs have better performance due to the card being able to churn through more calculations once the overhead of setting up the calculations is complete. I would assume that if I tested with larger and larger array sizes that this speed increase would continue to increase until it reaches the cap of how many calculations the card can complete.

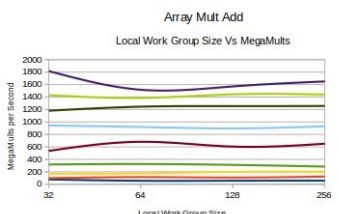
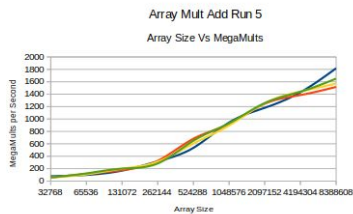
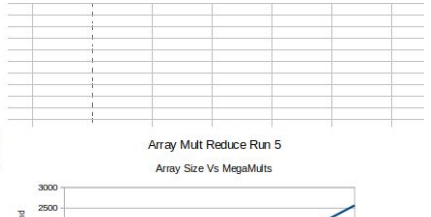
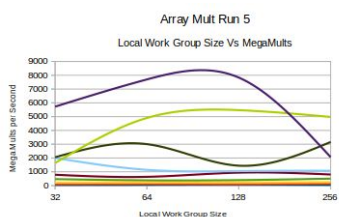
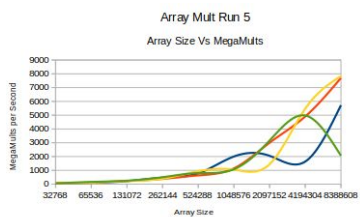
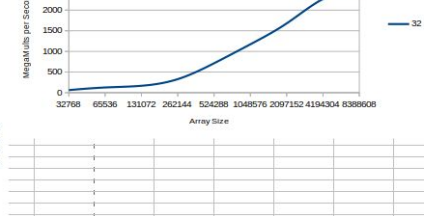
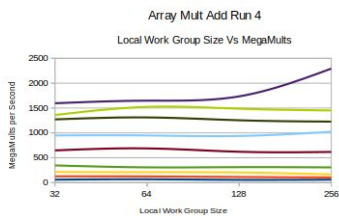
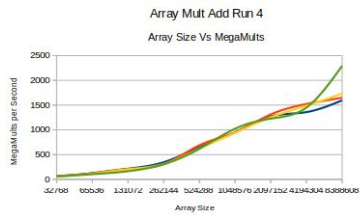
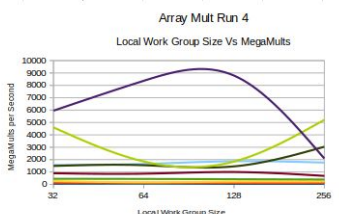
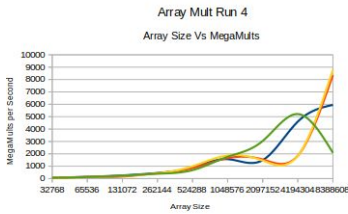
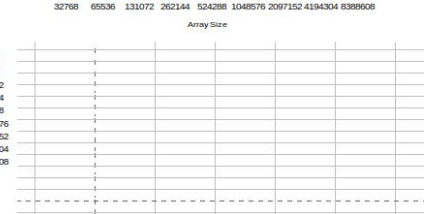
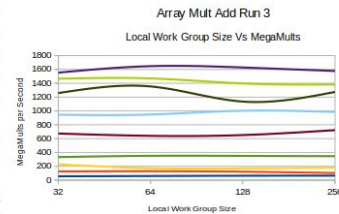
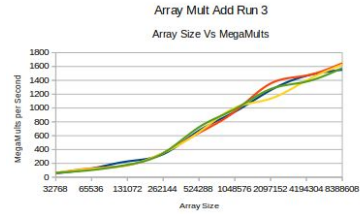
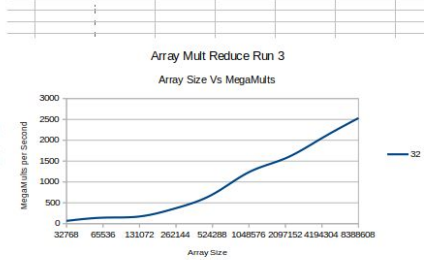
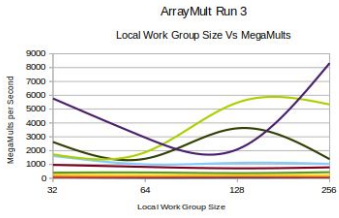
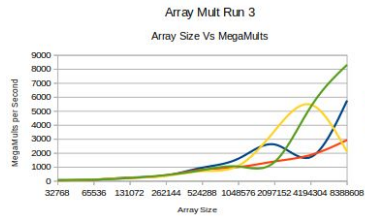
After rereading the directions I realized that the ArrayMultReduce was meant to be run like the other two tests so I went and reran the testing and added the graphs below. It seems that the amount of megamults increases as the size increases in all group sizes besides 256. I am not sure if this could be due to random variance or if 32, 64, and 128 are more likely to better fit into the array size and thus have a faster reduction time. I was also amazed at how quickly these reductions could be done. Being able to reduce as the calculations are done was much more efficient than I expected it to be but it makes sense that having a fraction of the total elements to sum at the end leads to a large speed increase. On a last sort of side tangent I run these last ArrayMultReduce on a fresh cool card which might explain why there was an increase to the megamult results do the the unthrottled core frequency. It would be really interesting to graph the card temperature in relation to these scores in the future.

Data & Graphs:



All desktop run graph:





Desktop Runs:

Method	Global Size	Local Work Group Size	Speedup
ArrayMult	65536	32	99.5894
ArrayMult	131072	32	222.714985
ArrayMult	262144	32	292.048609
ArrayMult	524288	32	751.459453
ArrayMult	1048576	32	1060.09392
ArrayMult	2097152	32	1542.248063
ArrayMult	4194304	32	1703.974393
ArrayMult	8388608	32	1953.016456
ArrayMult	32768	64	66.718791
ArrayMult	65536	64	116.385335
ArrayMult	131072	64	225.745671
ArrayMult	262144	64	470.204175
ArrayMult	524288	64	706.366742
ArrayMult	1048576	64	1153.191199
ArrayMult	2097152	64	1532.063987
ArrayMult	4194304	64	1847.605203
ArrayMult	8388608	64	2090.29583
ArrayMult	32768	128	51.04511
ArrayMult	65536	128	118.361833
ArrayMult	131072	128	186.170447
ArrayMult	262144	128	349.28456
ArrayMult	524288	128	598.803052
ArrayMult	1048576	128	1131.54788
ArrayMult	2097152	128	1503.626869
ArrayMult	4194304	128	1908.58391
ArrayMult	8388608	128	2066.184543
ArrayMult	32768	256	60.103927
ArrayMult	65536	256	131.360994

ArrayMult	131072	256	213.338195
ArrayMult	262144	256	311.432193
ArrayMult	524288	256	700.620056
ArrayMult	1048576	256	1099.40017
ArrayMult	2097152	256	1500.292239
ArrayMult	4194304	256	1878.324391
ArrayMult	8388608	256	2143.824671
ArrayMultAdd	32768	32	65.377786
ArrayMultAdd	65536	32	111.271843
ArrayMultAdd	131072	32	172.855266
ArrayMultAdd	262144	32	324.918195
ArrayMultAdd	524288	32	594.827391
ArrayMultAdd	1048576	32	1002.210725
ArrayMultAdd	2097152	32	1291.399851
ArrayMultAdd	4194304	32	1433.298363
ArrayMultAdd	8388608	32	1619.468664
ArrayMultAdd	32768	64	68.024189
ArrayMultAdd	65536	64	119.262399
ArrayMultAdd	131072	64	137.908395
ArrayMultAdd	262144	64	338.784947
ArrayMultAdd	524288	64	589.556636
ArrayMultAdd	1048576	64	959.716783
ArrayMultAdd	2097152	64	1267.95198
ArrayMultAdd	4194304	64	1488.175645
ArrayMultAdd	8388608	64	1619.163578
ArrayMultAdd	32768	128	58.255879
ArrayMultAdd	65536	128	122.80133
ArrayMultAdd	131072	128	183.2219
ArrayMultAdd	262144	128	299.383061
ArrayMultAdd	524288	128	643.04883

ArrayMultAdd	1048576	128	963.801911
ArrayMultAdd	2097152	128	1233.208963
ArrayMultAdd	4194304	128	1494.759988
ArrayMultAdd	8388608	128	1644.179677
ArrayMultAdd	32768	256	68.15648
ArrayMultAdd	65536	256	106.701748
ArrayMultAdd	131072	256	192.736785
ArrayMultAdd	262144	256	292.663866
ArrayMultAdd	524288	256	655.035757
ArrayMultAdd	1048576	256	951.791207
ArrayMultAdd	2097152	256	1278.564113
ArrayMultAdd	4194304	256	1390.787645
ArrayMultAdd	8388608	256	1651.506901
ArrayMultReduce	32768	32	61.921049
ArrayMultReduce	65536	32	162.760895
ArrayMultReduce	131072	32	190.59335
ArrayMultReduce	262144	32	368.664942
ArrayMultReduce	524288	32	769.047301
ArrayMultReduce	1048576	32	1277.820904
ArrayMultReduce	2097152	32	1760.547619
ArrayMultReduce	4194304	32	2233.927566
ArrayMultReduce	8388608	32	2512.977534
ArrayMult	32768	32	65.634189
ArrayMult	65536	32	135.486979
ArrayMult	131072	32	253.255737
ArrayMult	262144	32	521.84784
ArrayMult	524288	32	824.845033
ArrayMult	1048576	32	1736.605014
ArrayMult	2097152	32	2701.679893
ArrayMult	4194304	32	1847.468482

ArrayMult	8388608	32	5857.811036
ArrayMult	32768	64	72.874782
ArrayMult	65536	64	127.217809
ArrayMult	131072	64	216.330768
ArrayMult	262144	64	416.904957
ArrayMult	524288	64	759.989679
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ArrayMult	2097152	64	1375.476578
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ArrayMult	32768	128	77.822084
ArrayMult	65536	128	117.237715
ArrayMult	131072	128	217.298392
ArrayMult	262144	128	391.763732
ArrayMult	524288	128	641.109733
ArrayMult	1048576	128	1316.610185
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ArrayMult	4194304	128	1871.669204
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ArrayMult	32768	256	66.919084
ArrayMult	65536	256	107.935222
ArrayMult	131072	256	265.55909
ArrayMult	262144	256	461.185793
ArrayMult	524288	256	813.937386
ArrayMult	1048576	256	1120.45067
ArrayMult	2097152	256	2908.990028
ArrayMult	4194304	256	1913.141288
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ArrayMultAdd	65536	32	125.480825

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ArrayMult	262144	128	416.654481
ArrayMult	524288	128	998.978705
ArrayMult	1048576	128	1872.87185
ArrayMult	2097152	128	1454.173286
ArrayMult	4194304	128	1844.563878

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ArrayMult	2097152	256	3040.972577
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ArrayMult	8388608	256	2088.598666
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ArrayMultAdd	65536	32	125.517115
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ArrayMultAdd	131072	64	208.779866
ArrayMultAdd	262144	64	306.547748
ArrayMultAdd	524288	64	688.338287
ArrayMultAdd	1048576	64	948.246752
ArrayMultAdd	2097152	64	1310.946958
ArrayMultAdd	4194304	64	1522.51021
ArrayMultAdd	8388608	64	1648.112598
ArrayMultAdd	32768	128	55.349949
ArrayMultAdd	65536	128	113.093523

ArrayMultAdd	131072	128	203.640205
ArrayMultAdd	262144	128	310.672984
ArrayMultAdd	524288	128	620.966233
ArrayMultAdd	1048576	128	938.343195
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ArrayMultAdd	4194304	128	1486.826727
ArrayMultAdd	8388608	128	1734.708151
ArrayMultAdd	32768	256	59.565402
ArrayMultAdd	65536	256	104.044389
ArrayMultAdd	131072	256	163.985332
ArrayMultAdd	262144	256	305.83747
ArrayMultAdd	524288	256	617.357771
ArrayMultAdd	1048576	256	1022.697658
ArrayMultAdd	2097152	256	1226.815052
ArrayMultAdd	4194304	256	1451.129474
ArrayMultAdd	8388608	256	2292.612709
ArrayMultReduce	32768	32	62.596709
ArrayMultReduce	65536	32	125.76497
ArrayMultReduce	131072	32	167.014954
ArrayMultReduce	262144	32	328.131591
ArrayMultReduce	524288	32	712.871826
ArrayMultReduce	1048576	32	1172.687367
ArrayMultReduce	2097152	32	1679.345863
ArrayMultReduce	4194304	32	2271.833259
ArrayMultReduce	8388608	32	2571.937438
ArrayMult	32768	32	53.825861
ArrayMult	65536	32	105.629626
ArrayMult	131072	32	219.173318
ArrayMult	262144	32	468.600459
ArrayMult	524288	32	785.412535

ArrayMult	1048576	32	2003.630541
ArrayMult	2097152	32	2053.191125
ArrayMult	4194304	32	1636.567811
ArrayMult	8388608	32	5723.894641
ArrayMult	32768	64	64.117967
ArrayMult	65536	64	122.900355
ArrayMult	131072	64	227.469465
ArrayMult	262144	64	379.263649
ArrayMult	524288	64	633.032164
ArrayMult	1048576	64	1141.885145
ArrayMult	2097152	64	3004.41676
ArrayMult	4194304	64	4906.536896
ArrayMult	8388608	64	7698.160027
ArrayMult	32768	128	76.367687
ArrayMult	65536	128	112.469152
ArrayMult	131072	128	226.162458
ArrayMult	262144	128	395.655613
ArrayMult	524288	128	938.215578
ArrayMult	1048576	128	1051.328378
ArrayMult	2097152	128	1442.480694
ArrayMult	4194304	128	5471.435541
ArrayMult	8388608	128	7833.839022
ArrayMult	32768	256	59.896505
ArrayMult	65536	256	160.353121
ArrayMult	131072	256	250.523229
ArrayMult	262144	256	501.716766
ArrayMult	524288	256	802.477129
ArrayMult	1048576	256	1077.708619
ArrayMult	2097152	256	3160.084263
ArrayMult	4194304	256	4977.587054

ArrayMult	8388608	256	2061.565767
ArrayMultAdd	32768	32	77.190718
ArrayMultAdd	65536	32	98.683636
ArrayMultAdd	131072	32	168.295195
ArrayMultAdd	262144	32	317.833903
ArrayMultAdd	524288	32	535.476241
ArrayMultAdd	1048576	32	942.908065
ArrayMultAdd	2097152	32	1180.461264
ArrayMultAdd	4194304	32	1430.61687
ArrayMultAdd	8388608	32	1817.208331
ArrayMultAdd	32768	64	55.685843
ArrayMultAdd	65536	64	114.977052
ArrayMultAdd	131072	64	175.693609
ArrayMultAdd	262144	64	325.417939
ArrayMultAdd	524288	64	681.883566
ArrayMultAdd	1048576	64	919.538133
ArrayMultAdd	2097152	64	1245.264981
ArrayMultAdd	4194304	64	1386.282352
ArrayMultAdd	8388608	64	1516.973665
ArrayMultAdd	32768	128	57.127416
ArrayMultAdd	65536	128	107.754914
ArrayMultAdd	131072	128	199.369669
ArrayMultAdd	262144	128	311.319018
ArrayMultAdd	524288	128	604.607019
ArrayMultAdd	1048576	128	896.093197
ArrayMultAdd	2097152	128	1254.468083
ArrayMultAdd	4194304	128	1443.180024
ArrayMultAdd	8388608	128	1570.389851
ArrayMultAdd	32768	256	58.132892
ArrayMultAdd	65536	256	123.638134

ArrayMultAdd	131072	256	200.456361
ArrayMultAdd	262144	256	284.336769
ArrayMultAdd	524288	256	650.602469
ArrayMultAdd	1048576	256	931.605479
ArrayMultAdd	2097152	256	1256.568947
ArrayMultAdd	4194304	256	1439.925901
ArrayMultAdd	8388608	256	1650.663267
ArrayMultReduce	32768	32	56.691453
ArrayMultReduce	65536	32	109.90312
ArrayMultReduce	131072	32	188.55835
ArrayMultReduce	262144	32	323.244679
ArrayMultReduce	524288	32	690.700557
ArrayMultReduce	1048576	32	1148.593199
ArrayMultReduce	2097152	32	1695.505417
ArrayMultReduce	4194304	32	2119.791372
ArrayMultReduce	8388608	32	2567.63599

Laptop run data:

Method	Global Size	Local Work Group Size	Speedup
ArrayMult	32768	32	38.206817
ArrayMult	65536	32	75.742271
ArrayMult	131072	32	119.302672
ArrayMult	262144	32	194.98451
ArrayMult	524288	32	271.056332
ArrayMult	1048576	32	359.7799
ArrayMult	2097152	32	466.87727
ArrayMult	4194304	32	544.889524
ArrayMult	8388608	32	438.120855
ArrayMult	32768	64	42.211464
ArrayMult	65536	64	65.975795

ArrayMult	131072	64	132.522592
ArrayMult	262144	64	190.117163
ArrayMult	524288	64	277.926766
ArrayMult	1048576	64	313.792711
ArrayMult	2097152	64	476.482077
ArrayMult	4194304	64	544.213916
ArrayMult	8388608	64	484.928757
ArrayMult	32768	128	66.029638
ArrayMult	65536	128	79.91893
ArrayMult	131072	128	138.15216
ArrayMult	262144	128	207.245005
ArrayMult	524288	128	312.380761
ArrayMult	1048576	128	317.210181
ArrayMult	2097152	128	486.132324
ArrayMult	4194304	128	571.347618
ArrayMult	8388608	128	604.831131
ArrayMult	32768	256	37.07987
ArrayMult	65536	256	70.497471
ArrayMult	131072	256	132.604376
ArrayMult	262144	256	213.869225
ArrayMult	524288	256	271.198504
ArrayMult	1048576	256	350.334489
ArrayMult	2097152	256	437.970845
ArrayMult	4194304	256	561.727864
ArrayMult	8388608	256	588.190485
ArrayMultAdd	32768	32	38.023581
ArrayMultAdd	65536	32	69.534144
ArrayMultAdd	131072	32	127.899829
ArrayMultAdd	262144	32	180.534101
ArrayMultAdd	524288	32	252.452476

ArrayMultAdd	1048576	32	330.428962
ArrayMultAdd	2097152	32	425.760609
ArrayMultAdd	4194304	32	484.885311
ArrayMultAdd	8388608	32	496.540186
ArrayMultAdd	32768	64	37.081758
ArrayMultAdd	65536	64	73.729484
ArrayMultAdd	131072	64	117.958548
ArrayMultAdd	262144	64	178.778509
ArrayMultAdd	524288	64	246.863054
ArrayMultAdd	1048576	64	347.992427
ArrayMultAdd	2097152	64	430.103946
ArrayMultAdd	4194304	64	483.99343
ArrayMultAdd	8388608	64	425.927606
ArrayMultAdd	32768	128	43.166965
ArrayMultAdd	65536	128	69.514304
ArrayMultAdd	131072	128	123.641982
ArrayMultAdd	262144	128	188.723147
ArrayMultAdd	524288	128	246.769867
ArrayMultAdd	1048576	128	332.419155
ArrayMultAdd	2097152	128	421.712794
ArrayMultAdd	4194304	128	482.945677
ArrayMultAdd	8388608	128	520.636548
ArrayMultAdd	32768	256	38.107554
ArrayMultAdd	65536	256	71.224641
ArrayMultAdd	131072	256	125.368126
ArrayMultAdd	262144	256	184.243078
ArrayMultAdd	524288	256	266.386065
ArrayMultAdd	1048576	256	329.200081
ArrayMultAdd	2097152	256	419.204533
ArrayMultAdd	4194304	256	484.622497

ArrayMultAdd	8388608	256	420.718978
ArrayMultReduce	32768	32	42.279545
ArrayMultReduce	65536	32	77.170266
ArrayMultReduce	131072	32	127.065621
ArrayMultReduce	262144	32	192.05167
ArrayMultReduce	524288	32	283.099598
ArrayMultReduce	1048576	32	364.334688
ArrayMultReduce	2097152	32	447.868051
ArrayMultReduce	4194304	32	489.028952
ArrayMultReduce	8388608	32	555.188362