#### Benchmarking Groth16 Proving System

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This serves as a guide for navigating the excel sheets containing the benchmarks. Each benchmark (representing each excel sheet) has colors (representing the machine each workload was run on), and a tag on the upper right side (representing the repository benchmarked).

#### **Benchmarks**

- \* Parameter and Preprocessing Generation
- \* CPU Proof Generation
- \* GPU Proof Generation

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#### **Colors**

\* Pink = 28-core Intel(R) Xeon(R) Gold 5120 CPU @ 2.20GHz, NVIDIA P100 (Pascal Architecture) with 12 GB HBM2, 192 GB DDR4 DRAM, 128 GB SSD.

\* Purple = 64-core Intel(R) Xeon(R) Platinum 8358 CPU @ 2.60GHz, NVIDIA A10 (Ampere Architecture) with 24 GB GDDR6, 1024 GB DDR4 DRAM, 2 TB SSD.

\*Green = NVIDIA A40 (Ampere Architecture) with 48 GB GDDR6.

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#### <u>Tags</u>

FIGURE 1 = snark-challenge-prover-reference repository:

<a href="https://github.com/TalDerei/snark-challenge-prover-reference">https://github.com/TalDerei/snark-challenge-prover-reference</a>

**FIGURE 2 and FIGURE 3 =** gpu-groth16-prover-3x:

https://github.com/TalDerei/gpu-groth16-prover-3x

FIGURE 4 = ZPrize (test-msm-gpu): <a href="https://github.com/TalDerei/test-msm-gpu">https://github.com/TalDerei/test-msm-gpu</a>

# PARAMETER AND PREPROCESSING GENERATION

	nce repository: ht		/TaiDerei/snark-challenge-prover-			FIGURE 1	Parameter Generation Be snark-challenge-prover-r	reference repository: h	ttps://github.com/TalDerei/snark-challenge-prover	r-reference			Formation Time
(R) Xeon(R) Gold 5120 CPL	U @ 2.20GHz		inputs on CPU (there isn't a GPU o			Execution Time = seconds CPU Utilization = percent	Intel(R) Xeon(R) Platinum	n 8358 CPU @ 2.60GHz					CPU Utilization =
Count: 28	Memory (GB):	192 GB	Network bandwidth (Gbps): 50	Boot Disk: 128 GB Year: Q3 2	017	Memory Utilization = GB	Core Count: 128	Memory (GB):	1024 GB Network bandwidth (Gbps): 50	Boot Disk: 128 GB	Year: Q2 2021		Memory Utilization
	2^15			Parameter Generation (Memory Utilization)	Input File Size	Parameter File Size		2^15	Parameter Generation (Execution Time)	Parameter Generation (Memory U	tilization)	Input File Size	Parameter File S
		30.33		0					8.62 9.16	0			
:		30.195		0	13M	37M	Total:		8.89	0		13M	37M
						B 4 51 01							
	2^16	Parameter Gen		Parameter Generation (Memory Utilization) 0.192	Input File Size	Parameter File Size		2^16	Parameter Generation (Execution Time) 18.68	Parameter Generation (Memory U 0.512	tilization)	Input File Size	Parameter File S
		43.53		0.192					18.52	0.512			
		43.5		0.192	25M	73M	Total:		18.6	0.512		25M	73M
	2^17	Parameter Gen	eration (Execution Time)	Parameter Generation (Memory Utilization)	Input File Size	Parameter File Size		2^17	Parameter Generation (Execution Time)	Parameter Generation (Memory U	tilization)	Input File Size	Parameter File S
	- "	53.39		1.426944	input i ne oize	T distinctor T no Olec		- "	24.89	1.02	unzation	input i ne oize	r drameter r ne o
		53.75		1.425792	49M	145M			25.07	1.02		49M	145M
		53.57		1.426368			Total:		24.98	1.02			
	2^18	Parameter Gen	eration (Execution Time)	Parameter Generation (Memory Utilization)	Input File Size	Parameter File Size		2^18	Parameter Generation (Execution Time)	Parameter Generation (Memory U	tilization)	Input File Size	Parameter File S
		98.93		2.153522765					58.76	2.46			
		98.34 98.635		2.1736512 2.163586982	97M	289M	Total:		58.54 58.65	2.46 2.46		97M	289M
		90.033		2.163506902	97W	209M	Total:		30.03	2.40		97M	209W
	2^19			Parameter Generation (Memory Utilization)	Input File Size	Parameter File Size		2^19	Parameter Generation (Execution Time)	Parameter Generation (Memory U	tilization)	Input File Size	Parameter File S
		147.74		4.6699008 4.7122944					95.13 95.21	4.71 4.81			
		148.33		4.7122944 4.6910976	193M	577M	Total:		95.21 95.17	4.81 4.76		193M	577M
	2^20			Parameter Generation (Memory Utilization)	Input File Size	Parameter File Size		2^20	Parameter Generation (Execution Time)	Parameter Generation (Memory U	tilization)	Input File Size	Parameter File S
		270.99 272.45		9.312 9.039017414					171.57 172.42	8.8 8.91			
		271.72		9.175508707	385M	1.2G	Total:		171.995	8.855		385M	1.2G
				T.									
	2^21	Parameter Gen	eration (Execution Time)	Parameter Generation (Memory Utilization) 19.0272	Input File Size	Parameter File Size		2^21	Parameter Generation (Execution Time)	Parameter Generation (Memory U 19.15	tilization)	Input File Size	Parameter File S
		581.79		19.2					393.98	19.25			
		583.14		19.1136	769M	2.3G	Total:		393.605	19.2		769M	2.3G
	2^22	D	eration (Execution Time)	Parameter Generation (Memory Utilization)	land File Clas	Parameter File Size		2^22	Parameter Generation (Execution Time)	Parameter Generation (Memory U	*!!!==#!==\	land File Clas	Parameter File S
	2-22	1115.58		36,9408	input File Size	Parameter File Size		222	761.85	36.86	unzation)	input rile Size	Parameter File 5
		1113.57		36.8832					757.56	36.97			
		1114.575		36.912	1.6G	4.6G	Total:		759.705	36.915		1.6G	4.6G
	2^23	Parameter Gen	eration (Execution Time)	Parameter Generation (Memory Utilization)	Innut File Size	Parameter File Size		2^23	Parameter Generation (Execution Time)	Parameter Generation (Memory U	tilization)	Innut File Size	Parameter File S
	- 20	2016.29		62.4768	input i ne oize	T distinctor T no Olec			1358.07	61.92	unzuuon,	input i ne oize	r drameter r ne c
		2014.33		61.92					1362.01	61.19			
		2015.31		62.1984	3.	1 9.1	Total:		1360.04	61.555		3.1G	9.1G
	2^24	Parameter Gen	eration (Execution Time)	Parameter Generation (Memory Utilization)	Input File Size	Parameter File Size		2^24	Parameter Generation (Execution Time)	Parameter Generation (Memory U	tilization)	Input File Size	Parameter File S
		3568.72		124.9536					2231.07	120.52			
		3563.53 3566.125		124.8576 124.9056			Total:		2235.06	120.55		6.1G	19G
		3566.125		124.9056			lotai:		2233.065	120.535		6.1G	196
	2^25	Parameter Gen	eration (Execution Time)	Parameter Generation (Memory Utilization)	Input File Size	Parameter File Size		2^25	Parameter Generation (Execution Time)	Parameter Generation (Memory U	tilization)	Input File Size	Parameter File S
									3907.86	240.438			
		Process killed	due to insufficient memory (192 G	SB)			Total:		3901.12 3904.49	214.52 227.479		12.2G	40G
					_		Total.		3304.43	221.418		12.20	
eter Preprocessing Gene						FIGURE 3	Parameter Generation Be						
challenge-prover-referen	ce repository: ht	ttps://github.com	TalDerei/snark-challenge-prover- inputs on CPU (there isn't a GPU o	reference otion)		Execution Time = seconds	ZPrize (test-msm-gpu): h		erei/test-msm-gpu n on CPU (there isn't a GPU option) this is not com	parable to running a fully complete tru	stad catus cara	mony required by	n prover
) Xeon(R) Platinum 8358	CPU @ 2.60GHz					CPU Utilization = percent	Intel(R) Xeon(R) Platinum	n 8358 CPU @ 2.60GHz				mony required by	a prover
ount: 128	Memory (GB):	1024 GB	Network bandwidth (Gbps): 50	Boot Disk: 128 GB Year: Q2 2	021	Memory Utilization = GB	Core Count: 128	Memory (GB):	1024 GB Network bandwidth (Gbps): 50	Boot Disk: 128 GB	fear: Q2 2021		
	2^15	Parameter Gen	eration (Execution Time)	Parameter Generation (Memory Utilization)	Input File Size	Preprocessing File Size		2^15	Parameter Generation (Execution Time)	Parameter Generation (Memory U	tilization)		
		34.11		0					0.051	Neglible			
		34.12		0					0.046				
		34.115		0	13M	745M	Total:		0.0485				
	2^16			Parameter Generation (Memory Utilization)	Input File Size	Preprocessing File Size		2^16	Parameter Generation (Execution Time)	Parameter Generation (Memory U	tilization)		
		62.28		1.02					0.06	Neglible			
		62.29 62.285		1.02	25M	1.50	Total:		0.061				
		62.285		1.02	20W	1.00	Total:		0.0005				
				Parameter Generation (Memory Utilization)	Input File Size	Preprocessing File Size		2^17	Parameter Generation (Execution Time)	Parameter Generation (Memory U	tilization)		
	2^17			2.46					0.08	Neglible			
	2^17	104.38		2.46	49M	3.0G	Total:		0.076				
	2^17			2.46									
	2^17	104.38 104.32		2.46									
	2^17	104.38 104.32 104.35 Parameter Gene	eration (Execution Time)	Parameter Generation (Memory Utilization)		Preprocessing File Size		2^18	Parameter Generation (Execution Time)	Parameter Generation (Memory U	tilization)		
		104.38 104.32 104.35 Parameter Gene 199.55	eration (Execution Time)	Parameter Generation (Memory Utilization) 4.92		Preprocessing File Size		2^18	0.11	Parameter Generation (Memory U Neglible	tilization)		
		104.38 104.32 104.35 Parameter Gene	eration (Execution Time)	Parameter Generation (Memory Utilization)		Preprocessing File Size	Total:	2^18			tilization)		
	2^18	104.38 104.35 104.35 Parameter Gen 199.55 199.65	eration (Execution Time)	Parameter Generation (Memory Utilization) 4.92 4.81 4.865	Input File Size	5.9G	Total:		0.11 0.111 0.1105	Neglible	,		
		104.38 104.32 104.35 Parameter Gen 199.55 199.65	eration (Execution Time)	Parameter Generation (Memory Utilization) 4.92 4.81 4.865  Parameter Generation (Memory Utilization)	Input File Size		Total:	2^18	0.11 0.111 0.1105  Parameter Generation (Execution Time)	Neglible Parameter Generation (Memory U	,		
	2^18	104.38 104.35 104.35 Parameter Gen 199.55 199.65	eration (Execution Time)	Parameter Generation (Memory Utilization) 4.92 4.81 4.865	Input File Size	5.9G	Total:		0.11 0.111 0.1105	Neglible	,		

	Parameter Generation (Ex	ecution rime)	Parameter Gene	ration (Memory	Othization)	Input File Size	rieprocessing	rile Size	
	754.57		20.07						
	755.43		20.17						
	755		20.12			385M	24G		
2^21	Parameter Generation (Ex	ecution Time)	Parameter Gene	ration (Memory	Utilization)	Input File Size	Preprocessing File Size		
	1499.83		38.71						
	1503.98		38.6						
	1501.91		38.655			769M	47G		
2^22	Parameter Generation (Ex	recution Time)	Parameter Gene	ration (Memory	Utilization)	Input File Size	Preprocessing File Size		
	3063.88		78.03						
	3065.65		77.93						
	3064.765		77.98			1.6G	94G		
2^23		recution Time)		ration (Memory	Utilization)	Input File Size	Preprocessing	File Size	
	6143.93		156.085			3.1G	187G		
2^24	Parameter Generation (Ex	recution Time)	Parameter Gene	ration (Memory	Input File Size	Prennocessing File Size			
	11913.42	,	311 78	,					
	11917.11		310.26						
	11915.265		311.02			6.1G	373G		
2^25		recution Time)		ration (Memory	Utilization)	Input File Size	Preprocessing	File Size	
	23239.12		621.42						
	2^22 2^23	785.43 775  2*21 Parameter Generation (E) 1499.83 1503.98 1501.91  2*22 Parameter Generation (E) 3963.88 3065.85 3064.785  2*23 Parameter Generation (E) 6142.21 6145.65 6143.93  2*24 Parameter Generation (E) 11917.11 11915.265	755.43 755  2*21 Parameter Generation (Execution Time) 1490.83 1503.98 1503.98 1503.98 3065.65 3064.765  2*22 Parameter Generation (Execution Time) 6142.21 6146.55 6143.93  2*24 Parameter Generation (Execution Time) 11915.28 11917.11 11915.285  2*25 Parameter Generation (Execution Time) 11917.11 11915.285	755.43   20.17   755   20.12   2*21   Parameter Generation (Execution Time)   Parameter Generation (Execution Time)   1499.83   38.71   1590.99   38.65   1590.191   38.655   2*22   Parameter Generation (Execution Time)   Parameter Generation (Execution Time)   77.93   3064.765   77.93   3064.765   77.93   3064.765   77.93   3064.765   77.93   3064.765   77.93   3064.765   77.93   3064.765   77.93   3064.765   77.93   3064.765   77.93   3064.765   77.93   3064.765   3	755.43 20.17 755 20.12  2*21 Parameter Generation (Execution Time) 1409.63 38.71 1503.98 38.65 1501.91 38.655  2*22 Parameter Generation (Execution Time) 9 38.65 30.665 77.98 3063.88 77.93 3064.765 77.98  2*23 Parameter Generation (Execution Time) 156.04 614.656 156.13 156.08 614.33 156.085  2*24 Parameter Generation (Execution Time) 9 156.04 614.656 156.13 156.085  2*24 Parameter Generation (Execution Time) 156.04 614.55 156.13 156.085  2*25 Parameter Generation (Execution Time) 156.08  2*26 Parameter Generation (Execution Time) 19 110.28 11917.11 31.28 311.78 11917.11 310.28 2*25 Parameter Generation (Execution Time) 22324.77  2*25 Parameter Generation (Execution Time) 23234.77	785.43   20.17   755   20.12	755.43   20.17   385M   20.17   385M   20.12	755.43   20.17   385M   24G   24C   24C	

	2^20	Parameter Generation (I	Execution Time)	Parameter Gene	eration (Memory L	Itilization)		
		0.316		Neglible				
		0.304						
otal:		0.31						
	2^21	Parameter Generation (I	Evecution Time)	Parameter Gone	eration (Memory L	Itilization)	 	
	2 21	0.568	Execution rime;	Neglible	ration (weinory c	dilizationij		
		0.563		Neglible				
Total:		0.566						
		0.000					 	
	2^22	Parameter Generation (I	Execution Time)	Parameter Gene	eration (Memory L	Jtilization)		
		1.09		Neglible				
		1.09						
Total:		1.09						
	2^23	Parameter Generation (I	Execution Time)		eration (Memory L	Itilization)		
		2.02		Neglible				
		2.19						
Total:		2.105						
	2^24 Parameter Generation (Execution Time)				eration (Memory L	Itilization)		
		3.82		Neglible				
		3.63						
Total:		3.725						
		Parameter Generation (I	Evecution Time)	Parameter Gene	eration (Memory L	Itilization)		
	2^25		Excountion mine;					
	2^25	6.33	Execution Time;	Neglible				
	2^25		Excession Time;					

# **CPU PROOF GENERATION**

PU Benchmar	king				on Time = seconds	FIGURE 1 CPU Ben	hmarking_			m.m	hallan an ann		Execution Time = second	
k-challeng	e-prover-reference repository: http://doi.org/10.1001/j.j.j.j.j.j.j.j.j.j.j.j.j.j.j.j.j.j.j.	ps://github.com/TalDerei/snark-c	challenge-prover-referen	Execut	on Time = seconds	snark-ch	illenge-prover-referei	ice repository: ht	ttps://github.com/	TalDerei/snark-c	challenge-prover-reference	2	CPU Utilization = percent Memory Utilization = GB	
I(R) Yoon/B	Gold 5120 CPU @ 2.20GHz				lization = percent Utilization = GB	[piel/D) )	eon(R) Platinum 8358	CBIT @ 3 euch-					memory utilization = GB	
U count: 2		92 GB Network bandw	vidth (Gbps): 50 Boot D		Otilization - GB	Core Cou		Memory (GB):		Network bandy	vidth (Gbps): 50 Boot Dis	sk: 128 GB	Year: Q2 2021	
	, (,-		(											
(2^15)						Size (2^1	5)							
	CPU Program (Execution Time)		CPU Utilization)	CPU Program (Memory	Jtilization)			(Execution Time)			CPU Utilization)	CPU Program (	Memory Utilization)	
	5.36	100		0			4.4			100		0		
	5.37	100		0			4.5			100		0		
	5.37	100		0			4.4			100		0		
al:	5.366666667	100	)	0		Total:	4.4	6		100	)	0		
		CPU FFT (Execution Time)					CPU MSM (Ex		CPU FFT (Execu					
	4.81	0.54					3.8		0.52					
	4.77	0.58					3.9		0.53					
	4.76	0.57					3.9		0.52					
al:	4.78	0.5633333333				Total:	3.92333333	3	0.5233333333					
e (2^16)						Size (2^1								
e (2^16)						Size (2"1	9)							
	CPU Program (Execution Time)	CPU Program (	CDII I Hillingtian)	CPU Program (Memory	Miliantian)		CDII December	(Execution Time)		CDII Dramon /	CPU Utilization)	CDU Drowsom (	Memory Utilization)	
	9.53	100		CPO Program (Memory	Junzauonij		68			100		CPO Program (	wemory dunzation)	
	9.67	100		0			6.8			100		0		
	9.65	100		0			6.6			100		0		
ıl:	9.616666667	100		0		Total:	6.85333333			100		0		
						Totali						· ·		
	CPU MSM (Execution Time)	CPU FFT (Execution Time)					CPU MSM (Ex	ecution Time)	CPU FFT (Execu	ution Time)				
	8.54	0.95					5.8		0.99					
	8.61	1.02					5.7		1.05					
	8.6	1.02					5.7		1.04					
ıl:	8.583333333	0.9966666667				Total:	5.79333333		1.026666667					
e (2^17)						Size (2^1	7)							
	CPU Program (Execution Time)	CPU Program (	CPU Utilization)	CPU Program (Memory	Jtilization)		CPU Program	(Execution Time)		CPU Program (	CPU Utilization)	CPU Program (	Memory Utilization)	
	18.3	100	)	0.48			12.1			100	)	0.52		
	17.76	100	)	0.48			12.1	5		100		0.53		
	17.85	100	)	0.48			12.			100		0.52		
tal:	17.97	100		0.48		Total:	12.1733333	3		100		0.5233333333		
		CPU FFT (Execution Time)					CPU MSM (Ex		CPU FFT (Execu					
	15.79	2.42					9.9		2.16					
	15.77	1.9					9.9		2.14					
	15.76	2.1					9.9		2.17					
otal:	15.77333333	2.14				Total:	9.94666666	7	2.156666667					
te (2^18)						Size (2^1	3)							
			CPU Utilization)											
	CPU Program (Execution Time) 32.43	CPU Program (		CPU Program (Memory 1.05	Jtilization)		CPU Program 21.3	(Execution Time)		CPU Program (	CPU Utilization)	CPU Program (I	Memory Utilization)	
	32.43	100		1.05			21.3			100		0.92		
	32.33	100		1.05			20.5			100		0.93		
al:	32.33	100		1.07		Total:	20.8766666			100		0.9266666667		
	52.4033333	100		1.00000007		iotal:	20.0700000			100		0.3200000667		
	CPU MSM (Execution Time)	CPU FFT (Execution Time)					CPU MSM (Ex	ecution Time)	CPU FFT (Execu	ution Time)				
	28.94	3.29					17.3		3.86					
	28.64	3.62					16.6		3.72					
	28.75	3.43					16.9		3.75					
:	28.77666667	3.446666667				Total:	16.9866666		3.776666667					
e (2^19)						Size (2^1	9)							
	CPU Program (Execution Time)	CPU Program (	CPU Utilization)	CPU Program (Memory	Jtilization)		CPU Program	(Execution Time)		CPU Program (	CPU Utilization)	CPU Program (	Memory Utilization)	
	60.96	100		2.13			34.6			100		1.74		
	61.05	100	)	2.15			34.7	3		100		1.74		
	61.03	100	)	2.13			34.5	3		100		1.74		
al:	61.01333333	100		2.136666667		Total:	34.6266666			100		1.74		
		CPU FFT (Execution Time)					CPU MSM (Ex		CPU FFT (Execu					
	53.83	6.67					27.0		7.38					
	53.74	6.85					26.9		7.53					
	53.8	6.84					26.9	9	7.45					
ıl:	53.79	6.786666667				Total:	26.9866666		7.453333333					
(2^20)						Size (2^2	0)							
		CRII Program (	CPU Utilization)	CPU Program (Memory	Jtilization)			(Execution Time)			CPU Utilization)	CPU Program (	Memory Utilization)	
	CPU Program (Execution Time)	CFO Flogram (												
	CPU Program (Execution Time) 113.94	100		3.93			63.1	2		100		3.48		
	113.94 113.4	100 100		3.93 3.93			63.7	2		100	)	3.38		
	113.94 113.4 114.06	100 100 100		3.93 3.93 3.96			63.7 63.4	2 3		100		3.38 3.48		
l:	113.94 113.4	100 100		3.93 3.93		Total:	63.7	2 3		100		3.38		

CPU MSM (Execution of	12.94 13.5 12.97 13.13866667  Execution Time)  CPU FFT (Execution 23.94 23.77 24.17 23.96  Execution Time)  CPU	Program (CPU Utilization) 100 100 100 100	CPU Program (Memory Utilization) 7.85 7.83 7.87 7.85  CPU Program (Memory Utilization) 16.90 16.86	Total:  Size (2^21)  Total:  Total:  Size (2^22)	CPU MSM (Execution Time 48.38 49.3 48.67 48.7833333   CPU Program (Execution 1 113.34 115.41 112.93 113.893333   CPU MSM (Execution Time 88.25 88.14 88.74 88.71	14.29 13.96 14.14 14.13	CPU Program (CPU Utilization) 100 100 100 100 100 100 100	CPU Program (M 6.94 6.96 7.07 6.99	lemory Utilization)	
98.97 Total: 99.76 Size (2^21)  CPU Program (Es 213.86 212.34 Total: 212.6086667  CPU MSM (Execu 168.84 188.23 186.3 Total: 186.79  CPU Program (Es 401.58 401.58 401.40 Total: 401.686667  CPU MSM (Execu 168.84) 300.43 Total: 350.43 Total: 350.933333	13.5 12.97 13.13866667  Lixecution Time) CPU FFT (Execution 23.94 23.77 24.17 23.96  Lixecution Time) CPU FFT (Execution 46.87 48.13	100 100 100 100 100 100 100 100 100 100	7.85 7.83 7.87 7.85  CPU Program (Memory Utilization)	Size (2^21)  Total:	49.3 48.67 48.7833333  CPU Program (Execution 1 113.34 115.41 112.93 113.893333 113.893333 CPU MSM (Execution Time 88.25 88.14 89.74	13.96 14.14 14.13  Firme)  CPU FFT (Executed 24.2 24.31 24.74	CPU Program (CPU Utilization) 100 100 100 100 100 100 July Stion Time)	6.94 6.96 7.07	emory Utilization)	
Total: 99.75  Size (2^21)  CPU Program (Expure 10.21	12.97 13.1366667  Execution Time)  CPU FFT (Execution 23.94 23.77 24.17 23.96  Execution Time)  CPU FFT (Execution 46.87 46.87 48.13	100 100 100 100 100 100 100 100 100 100	7.85 7.83 7.87 7.85  CPU Program (Memory Utilization)	Size (2^21)  Total:	48.7833333  CPU Program (Execution 1 113.34 115.41 112.93 113.893333   CPU MSM (Execution Time 88.25 88.14 88.74	14.14 14.13 Time) cPU FFT (Exect 24.2 24.31 24.74	CPU Program (CPU Utilization) 100 100 100 100 100 100 100 Ution Time)	6.94 6.96 7.07	emory Utilization)	
Total: 99.76  Size (2^21)  CPU Program (Excupance) 211.62 213.86 212.34  Total: 212.608667  CPU MSM (Execupance) 185.84 188.23 186.3  Total: 186.79  CPU Program (Excupance) 401.05 401.58 401.34  Total: 401.6566667  CPU MSM (Execupance) 350.43 350.43 340.68 350.17  Total: 350.0933333	13.1366667	100 100 100 100 100 100 100 100 100 100	7.85 7.83 7.87 7.85  CPU Program (Memory Utilization)	Size (2^21)  Total:	CPU Program (Execution 1 113.34 115.41 112.93 113.8933333 CPU MSM (Execution Time 88.25 88.14 89.74	14.13  (a) CPU FFT (Exect (24.2 (24.3) (24.74	CPU Program (CPU Utilization) 100 100 100 100 100 100 100	6.94 6.96 7.07	emory Utilization)	
CPU Program (Ex-   213.86     212.34     213.86     212.34     212.6066667     212.6066667     212.6066667     212.6066667     212.6066667     212.6066667     212.6066667     212.6066667     212.6066667     212.6066667     212.6066667     212.6066667     212.6066667     212.6066667     212.6066667     212.606667     212.606667     212.6066667     212.6066667     212.6066667     212.6066667     212.6066667     212.606667     212.606667     212.606667     212.606667     212.606667     212.606667     212.606667     212.606667     212.606667     212.606667     212.606667     212.6067     212.6067     212.6067     212.6067     212	vecution Time)	100 100 100 100 100 100 100 100 100 100	7.85 7.83 7.87 7.85  CPU Program (Memory Utilization)	Size (2^21)  Total:	CPU Program (Execution 1 113.34 115.41 112.93 113.893333 CPU MSM (Execution Time 88.25 88.14 88.74	CPU FFT (Exect 24.2 24.31 24.74	CPU Program (CPU Utilization) 100 100 100 100 100 tion	6.94 6.96 7.07	emory Utilization)	
CPU Program (Es 211.62 213.86 212.34 Total: 212.6086667 212.34 188.23 188.39 188.79 Size (2^22) CPU Program (Es 401.05 401.05 401.58 402.34 7otal: 401.886667 CPU MSM (Execu 350.43 340.68 350.17 Total: 350.0933333	ution Time)	100 100 100 100 100 100 100 100 100 100	7.85 7.83 7.87 7.85  CPU Program (Memory Utilization)	Total:	113.34 115.41 112.93 113.8933333 CPU MSM (Execution Time 88.25 88.14 89.74	24.2 24.31 24.74	100 100 100 100 100	6.94 6.96 7.07	emory Utilization)	
CPU Program (Es 211.62 213.86 212.34 Total: 212.6086667 212.34 188.23 188.39 188.79 Size (2^22) CPU Program (Es 401.05 401.05 401.58 402.34 7otal: 401.886667 CPU MSM (Execu 350.43 340.68 350.17 Total: 350.0933333	ution Time)	100 100 100 100 100 100 100 100 100 100	7.85 7.83 7.87 7.85  CPU Program (Memory Utilization)	Total:	113.34 115.41 112.93 113.8933333 CPU MSM (Execution Time 88.25 88.14 89.74	24.2 24.31 24.74	100 100 100 100 100	6.94 6.96 7.07	emory Utilization)	
CPU Program (Es 211.62 213.86 212.34 Total: 212.6086667 212.34 188.23 188.39 188.79 Size (2*22) CPU Program (Es 401.05 401.58 402.34 Total: 401.886667 CPU MSM (Execu 350.43 340.68 350.17 Total: 350.0933333	ution Time)	100 100 100 100 100 100 100 100 100 100	7.85 7.83 7.87 7.85  CPU Program (Memory Utilization)	Total:	113.34 115.41 112.93 113.8933333 CPU MSM (Execution Time 88.25 88.14 89.74	24.2 24.31 24.74	100 100 100 100 100	6.94 6.96 7.07	emory Utilization)	
211.62 213.68 212.34 Total: 212.606667  CPU MSM (Execution 188.23 186.3 Total: 186.79  Size (2^22)  CPU Program (Execution 188.23 401.55 401.58 402.34 Total: 401.6566667  CPU MSM (Execution 188.23 350.17 Total: 350.093333	ution Time)	100 100 100 100 100 100 100 100 100 100	7.85 7.83 7.87 7.85  CPU Program (Memory Utilization)	Total:	113.34 115.41 112.93 113.8933333 CPU MSM (Execution Time 88.25 88.14 89.74	24.2 24.31 24.74	100 100 100 100 100	6.94 6.96 7.07	lemory Utilization)	
211.62 213.68 212.34 Total: 212.606667  CPU MSM (Execution 188.23 186.3 Total: 186.79  Size (2^22)  CPU Program (Execution 188.23 401.55 401.58 402.34 Total: 401.6566667  CPU MSM (Execution 350.43 350.43 340.68 350.17 Total: 350.0933333	ution Time)	100 100 100 100 100 100 100 100 100 100	7.85 7.83 7.87 7.85  CPU Program (Memory Utilization)	Total:	113.34 115.41 112.93 113.8933333 CPU MSM (Execution Time 88.25 88.14 89.74	24.2 24.31 24.74	100 100 100 100 100	6.94 6.96 7.07	emory utilization)	
213.86 212.34 Total: 212.606667  CPU MSM (Execu 188.84 188.23 186.3 Total: 186.79 Size (2^22)  CPU Program (Execu 401.58 401.58 402.34 Total: 401.656667  CPU MSM (Execu 350.43 349.68 350.17 Total: 350.0933333	ution Time)	100 100 100 100 100 100 100 100 100 100	7.83 7.87 7.85  CPU Program (Memory Utilization) 15.9	Total:	115.41 112.93 113.8933333 CPU MSM (Execution Time 88.25 88.14 89.74	24.2 24.31 24.74	100 100 100 100 ution Time)	6.96 7.07		
212.34   212.6086667   CPU MSM (Execution 188.23   186.3   186.79   CPU Program (Execution 188.24   186.79   CPU Program (Execution 188.24   CPU Program (Execution 188.24   CPU Program (Execution 188.24   CPU MSM (Execution 189.48   350.17   CPU MSM (Execution 189.48   350.17   Cotal: 350.0933333	23.94 23.77 24.17 23.96  Execution Time)  CPU FFT (Execution 46.87 48.13	100 100 100 (ime) Program (CPU Utilization) 100 100	7.87 7.85  CPU Program (Memory Utilization) 15.9	Total:	112.93 113.8933333 CPU MSM (Execution Time 88.25 88.14 89.74	24.2 24.31 24.74	100 100 ution Time)	7.07		
Total: 212.606667  CPU MSM (Execu 188.84 188.23 186.3 186.79  Size (2^22)  CPU Program (Execu 198.84 198.23 186.3 186.79  CPU Program (Execu 198.84 198.35 198.3 1	23.94 23.77 24.17 23.96  Execution Time)  CPU FFT (Execution 46.87 48.13	Program (CPU Utilization) 100 100	7.85 CPU Program (Memory Utilization) 16.9	Total:	113.8933333 CPU MSM (Execution Time 88.25 88.14 89.74	24.2 24.31 24.74	100 ation Time)			
CPU MSM (Execu 185.84 188.23 186.3 186.3 186.3 186.79 Size (2^22) CPU Program (Execu 401.55 401.58 402.34 Total: 401.656667 CPU MSM (Execu 350.43 349.68 350.17 Total: 350.0933333	23.94 23.77 24.17 23.96  Execution Time)  CPU FFT (Execution 46.87 48.13	Program (CPU Utilization) 100 100	CPU Program (Memory Utilization) 15.9	Total:	CPU MSM (Execution Time 88.25 88.14 89.74	24.2 24.31 24.74	ation Time)	6.99		
CPU MSM (Execu 185.84 188.23 186.3 186.3 186.3 186.79 Size (2^22) CPU Program (Execu 401.55 401.58 402.34 Total: 401.656667 CPU MSM (Execu 350.43 349.68 350.17 Total: 350.0933333	23.94 23.77 24.17 23.96  Execution Time)  CPU FFT (Execution 46.87 48.13	Program (CPU Utilization) 100 100	CPU Program (Memory Utilization) 15.9	Total:	CPU MSM (Execution Time 88.25 88.14 89.74	24.2 24.31 24.74	ation Time)			
185.84 188.23 186.3 Total: 186.79 Size (2^22)  CPU Program (E) 401.05 401.58 402.34 Total: 29.04 CPU MSM (Execution 350.43 349.68 350.17 Total: 350.0933333	23.94 23.77 24.17 23.96  Execution Time)  CPU FFT (Execution 46.87 48.13	Program (CPU Utilization) 100 100	16.9		88.25 88.14 89.74	24.2 24.31 24.74				
185.84 188.23 186.3 Total: 186.79 Size (2^22)  CPU Program (E) 401.05 401.58 402.34 Total: 29.04 CPU MSM (Execution 350.43 349.68 350.17 Total: 350.0933333	23.94 23.77 24.17 23.96  Execution Time)  CPU FFT (Execution 46.87 48.13	Program (CPU Utilization) 100 100	16.9		88.25 88.14 89.74	24.2 24.31 24.74				
188.23 186.3 Total: 186.79 Size (2^22)  CPU Program (Example of the control of th	23.77 24.17 23.96  Execution Time) CPU FFT (Execution 46.67 46.87 48.13	100 100 100	16.9		88.14 89.74	24.31 24.74				
Total: 186.3  Total: 186.79  CPU Program (Es 401.58  401.58  402.34  Total: 401.886667  CPU MSM (Execu 350.43  340.68  350.17  Total: 350.0933333	24.17 23.96  Execution Time) CPU FFT (Execution 46.87 48.13	100 100 100	16.9		89.74	24.74				
Total: 186.79  Size (2^22)  CPU Program (E) 401.05 401.58 402.34  Total: 401.656667  CPU MSM (Execusion 350.43) 350.43 349.68 350.17  Total: 350.0933333	23.96  Execution Time) CPU  ution Time) CPU FFT (Execution 46.87  48.13	100 100 100	16.9							
CPU Program (E) 401.05 401.58 402.34 Total: 401.858667 CPU MSM (Execu 304.68 350.17 Total: 350.0933333	ution Time) CPU FFT (Execution 46.87 48.13	100 100 100	16.9			24.41666667				
CPU Program (E) 401.05 401.58 402.34 Total: 401.858667 CPU MSM (Execu 304.68 350.17 Total: 350.0933333	ution Time) CPU FFT (Execution 46.87 48.13	100 100 100	16.9							
CPU Program (Es 401.05 401.58 402.34 Total: 401.6566667 CPU MSM (Execu 350.43 349.68 350.17 Total: 350.0933333	ution Time) CPU FFT (Execution 46.87 48.13	100 100 100	16.9	Size (2^22)						
CPU Program (Es 401.05 401.58 402.34 Total: 401.6566667 CPU MSM (Execu 350.43 349.68 350.17 Total: 350.0933333	ution Time) CPU FFT (Execution 46.87 48.13	100 100 100	16.9	Size (2*22)						
401.05 401.58 402.34 Total: 401.658667  CPU MSM (Execu 350.43 349.68 350.17 Total: 350.0933333	ution Time) CPU FFT (Execution 46.87 48.13	100 100 100	16.9							
401.05 401.58 402.34 Total: 401.658667  CPU MSM (Execu 350.43 349.68 350.17 Total: 350.0933333	ution Time) CPU FFT (Execution 46.87 48.13	100 100 100	16.9							
401.58 402.34 Total: 401.886667  CPU MSM (Execusion 350.43 340.68 350.17 Total: 350.0933333	46.87 48.13	100 100			CPU Program (Execution 1	Time)	CPU Program (CPU Utilization)		lemory Utilization)	
401.58 402.34 Total: 401.886667  CPU MSM (Execusion 350.43 340.68 350.17 Total: 350.0933333	46.87 48.13	100 100			211.37		100	13.4		
402.34 Total: 401.856667  CPU MSM (Execu 350.43 349.68 350.17 Total: 350.0933333	46.87 48.13	100			211.42		100	13.31		
Total: 401.6566667  CPU MSM (Execu 350.43 349.68 350.17  Total: 350.0933333	46.87 48.13		16.88		211.34		100	13.31		
CPU MSM (Execu 350.43 349.68 350.17 Total: 350.0933333	46.87 48.13	100								
350.43 349.68 350.17 Total: 350.0933333	46.87 48.13		16.88	Total:	211.3766667		100	13.34		
350.43 349.68 350.17 Total: 350.0933333	46.87 48.13									
350.43 349.68 350.17 Total: 350.0933333	46.87 48.13	ime)			CPU MSM (Execution Time	e) CPU FFT (Execu	ution Time)			
350.17 Total: 350.0933333					160.21	49.4				
350.17 Total: 350.0933333					158.76	50.84				
Total: 350.0933333					159.86	50.32				
Size (2^23)	47.81333333			Total:	159.61	50.18666667				
Size (2^23)										
				Size (2^23)						
CPU Program (Ex	vesution Time) CDU	Program (CPU Utilization)	CPU Program (Memory Utilization)	_	CPU Program (Execution 1	Firm a)	CPU Program (CPU Utilization)	CDU Drowsom (M	lemory Utilization)	
	xecution nine)					illie)			amory ounzation)	
773.43		100	30.85		361.82		100	26.73		
777.78		100	30.8		361.16		100	26.93		
774.68		100	30.82		361.73		100	26.73		
Total: 775.2966667		100	30.82333333	Total:	361.57		100	26,79666667		
CPU MSM (Execu		ime)			CPU MSM (Execution Time					
667.2					258.73	99.61				
670.35	99.87				258.78	98.81				
672.33	98.5				258.75	99.52				
Total: 669.96	99.01			Total:	258.7533333	99.31333333				
Size (2^24)				Size (2^24)						
Size (2"24)				Size (2*24)						
CPU Program (Ex	xecution Time) CPU	Program (CPU Utilization)	CPU Program (Memory Utilization)		CPU Program (Execution 1	Time)	CPU Program (CPU Utilization)		lemory Utilization)	
1490.77		100	61.54		770.81		100	53.84		
1492.15		100	61.67		771.35		100	53.81		
1493.25		100	61.86		773.21		100	53.71		
Total: 1492.056667		100	61.69	Total:	771.79		100	53.78666667		
1492.00067		100	01.03	Total.	111.19		100	53.70000067		
CPU MSM (Execu		ime)			CPU MSM (Execution Time					
1275.43	200.85				552.75	210.78				
1270.87	206.05				553.21	211.72				
1250.37	205.75				554.32	209.34				
Total: 1265.556667	204.2166667			Total:	553.4266667	210.6133333				
1200.550007	204.2100007			Total.	555,4200001	210.0133333				
Size (2^25)				Size (2^25)						
CPU Program (Ex	xecution Time) CPU	Program (CPU Utilization)	CPU Program (Memory Utilization)		CPU Program (Execution 1	Time)	CPU Program (CPU Utilization)	CPU Program (M	lemory Utilization)	
5 ,					1542.21		100	110.32		
					1539.59		100	110.92		
	Process killed due to	insufficient memory (192 GB)			1541.24		100	109.34		
				Total:	1541.013333		100	110.1933333		
Total:										
Total:					CPU MSM (Execution Time	e) CPU FFT (Execu				
	ution Time) CPU FFT (Execution	ime)					ution Time)			
Total:	ution Time) CPU FFT (Execution	īme)			1110 12					
	ution Time) CPU FFT (Execution	īme)			1110.12	425.32				
	ution Time) CPU FFT (Execution	ime)			1113.43	425.32 425.42				
CPU MSM (Execu	ution Time) CPU FFT (Execution	ime)			1113.43 1114.24	425.32 425.42 422.35				
	ution Time) CPU FFT (Execution	ime)		Total:	1113.43	425.32 425.42				

# **GPU PROOF GENERATION**

Company	GPU Benchmarking	Cal Decembers, profit for recover, by	Francisco Visco a con-	Note: MSM and FFTs over in manifel	FIGURE 1	GPU Benchma gpu-groth16-pr	king	hub com/TelDereitens.proft-16 assess 2-		Execution Time a seconds Note 1991	FIGURE 2
March   Marc	Shape: BM.GPU2.2		GPU Utilization = percent Memory Utilization = GR	and the same of th				Tomorphism Comment		GPU Utilization = percent Memory Utilization = GB	
March   Marc	GPUs Architecture GPU Interest NVIDIA P100 Pascal N/A	nased GPU Memory GPU Cores System Memory Network 16 GB HBM2 3584 192 GB 2x 25 Gbps	.,			GPUs Nvida A10	Architecture C	DPU Interconne GPU Messary GPU Ceres Sys NA 24 GB GDDRS 9216 102	em Memory Network GB 2x 25 Gbps		
March   Marc	Size (2*15)										
March   Marc	GPU Program (Execution T	ime) GPU Program (GPU Utilization)	GPU Program (VRAM Memory Utilization)	GPU Program (System Memory Utilization)			GPU Program (Ex	secution Time) GPU Program (GPU	Jtilization)	GPU Program (VRAM Memory Utilization)	GPU Program (System Memory Utilization)
March   Marc	3.46 3.47	100	1.09				1.48	100		1.09	0
	Total: 3.463333333	100	1.09	0		Total:	1.48	100		1.09	•
	GPU MSM (Execution Time)	GPU FFT (Execution Time)			_		GPU MSM (Execu	ation Time) GPU FFT (Execution Time)			
	3.42 3.43	0.67					1.47	0.54			
Martin	Total: 3.43	0.66				Total:	1.463333333	0.5366666667			
14   15   15   15   15   15   15   15						Size (2^16)					
14   15   15   15   15   15   15   15	GPU Program (Execution T 6.82	ime) GPU Program (GPU Utilization)	GPU Program (VRAM Memory Utilization) 1.9	GPU Program (System Memory Utilization) 1.86			GPU Program (Ex	secution Time) GPU Program (GPU	Jtilization)	GPU Program (VRAM Memory Utilization) 1.9	GPU Program (System Memory Utilization) 1.02
14   15   15   15   15   15   15   15	6.85 6.83	100 100	1.9	1.42 1.44			2.15 2.13	100 100		1.9 1.9	1.02 1.02
	Total: 6.833333333	100	1.9	1.573333333		Total:	2.123333333	100		1.9	1.02
	GPU MSM (Execution Time 6.79	GPU FFT (Execution Time) 1.31					GPU MSM (Execu 2.07	tion Time) GPU FFT (Execution Time)			
	6.75 6.73	1.3 1.31					2.12 2.1	0.98			
Part		1.306666667				Total:	2.096666667	0.99			
March   Marc	Size (2*17)					Size (2^17)					
Second   S	GPU Program (Execution T	me) GPU Program (GPU Utilization)	GPU Program (VRAM Memory Utilization)	GPU Program (System Memory Utilization) 3.57			GPU Program (Ex	secution Time) GPU Program (GPU	Jtilization)	GPU Program (VRAM Memory Utilization) 3.51	GPU Program (System Memory Utilization) 3.07
Marie	14.31 14.22	100	3.51	355 355		Total	3.58	100		3.51	3.07
	GPU MSM (Exerction Time)	GPU FFT (Execution Time)	-			NA.	GPU MSM (Every	tion Time) GPU FFT (Execution Time)			
	13.88 14.25	1.97					3.61	1.94			
	13.92 Total: 14.0168667	1.93				Total:	3.56	1.96 1.96			
Part						Size (2^18)					
Part		ime) GPU Program (GPU Utilization)	GPU Program (VRAM Memory Utilization)	GPU Program (System Memory Utilization)		12 1.5	GPU Program (Ex	secution Time) GPU Program (GPU	Jtilization)	GPU Program (VRAM Memory Utilization)	GPU Program (System Memory Utilization)
Part	24.37 24.21	100 100	6.6	6.80			6.61 6.43	100 100		6.6	6.96 6.76
Part	24.12 Total: 24.23333333	100	6.6	6.67 6.676666667		Total:	6.45 6.496666667	100 100		6.6	6.86
Part	GPU MSM (Execution Time	GPU FFT (Execution Time)					GPU MSM (Execu	ation Time) GPU FFT (Execution Time)			
Part	24.2 24.04	3.91 3.45					6.52 6.33	3.65 100 3.9 100			
Part	24.01 Total: 24.08333333	3.606666667				Total:	6.43 6.426666667	3.74 100 3.763333333 100			
1	Size (2*19)					Size (2^15)					
Column   C	GPU Program (Execution T	ime) GPU Program (GPU Utilization)	GPU Program (VRAM Memory Utilization)	GPU Program (System Memory Utilization)			GPU Program (Ex	secution Time) GPU Program (GPU	Jtilization)	GPU Program (VRAM Memory Utilization)	GPU Program (System Memory Utilization)
Column   C	47 47	100	129	13.77			12.13	100		12.9	13.72
Company   Product   Prod	Total: 46.85	100	129	13.77666667		Total:	12.19333333	100		12.9	13.68666667
Company   Product   Prod	GPU MSM (Execution Time) 46.33	GPU FFT (Execution Time) 6.94					GPU MSM (Execu	ation Time) GPU FFT (Execution Time)			
Company   Product   Prod	46.63 46.44	7.14 7.05					11.9 11.95	7.96 7.67			
Company   Section   Comp	Total: 46.46666657	7.045335533				Total:	11.96	7.660666667			
Out   Marie						Size (2^20)					
Column   C	GPU Program (Execution T	ime) GPU Program (GPU Utilization) 15.25 100	GPU Program (VRAM Memory Utilization) 16	GPU Program (System Memory Utilization) 26.84			GPU Program (Ex 23.26	secution Time) GPU Program (GPU 100	Jtilization)	GPU Program (VRAM Memory Utilization) 24	GPU Program (System Memory Utilization) 21.91
Out   Marie	1	5.71 100 5.65 100	16	26.82 26.67			23.32 23.29	100 100		24 24	22.01 22.01
Company   Comp	Total: 75.5360		16	26.77666667		Total:	23.29	100		24	21.97666667
Company   Comp	GPU MSM (Execution Time) 74.55	GPU FFT (Execution Time) 13.13					GPU MSM (Execu 22.81	tion Time) GPU FFT (Execution Time) 14.58			
## CP29    CP Propose Records Train   CP Propose	75.01 75.43	13.11					22.86 22.89	14.82 14.75			
OFF   Propose   Control   Table     OFF   Table	Rim (2*21)	13.12				Rire (2626)	22 00333333	14.71505557			
OF MARK Execution Temp)  173.21  173.22  173.22  173.23  173.23  173.24  173.25  173.2		me) GPU Program (CPU Hillington)	GPU Program (VRAM Memory Illitication)	GPU Program (System Memory Littlestics)		Grav (2"21)	GPU Promam (F)	secution Time) CBN Program (CBN	Jtilization)	GPU Program (VRAM Memory   Difference)	GPU Program (System Memory Utilization)
CPU   Program (Excusion Trans)   CPU PTF (Excusion Trans)   CPU Program (CPU Millerino)   CPU	178.28 176.69	100	16	54.66 53.47			43.33 43.48	100		24 24	53.86 52.63
CPU   Program (Excusion Trans)   CPU PTF (Excusion Trans)   CPU Program (CPU Millerino)   CPU	176.75 Total: 176.66667	100	16	53.78 53.97		Total-	43.48	100		24 24	53.25 53.24666667
## 12   Pages (Excelled Test)	GPU MEM (Francisco Torre	GPU FFT (Execution Time)				noval:	GPU MSM /Fy	tion Time) GPU FFT (Fraculty Time)			
See   1/23	174.71 175.16	26.2 25.54					42.38 42.84	25.53 25.55			
Sec   123	175.32 Total: 175.0633333	25.73 25.82333333				Total:	42.54 42.52	25.49 25.5233333			
Column   C	Size (2*22)					Size (2^22)					
Column   C	GPU Program (Execution T	ime) GPU Program (GPU Utilization)	GPU Program (VRAM Memory Utilization)	GPU Program (System Memory Utilization)			GPU Program (Ex	secution Time) GPU Program (GPU	Jtilization)	GPU Program (VRAM Memory Utilization)	GPU Program (System Memory Utilization)
Column   C	362.95 357.55	100	16	111.38 106.87			86.94 87.32	100 100		24 24	107.83 107.72
### CPU NEW (Excelor Tray)  ##	358.52 Total: 359.6733333	100	16	110.48 103.5766667		Total:	88.99 87.08333333	100 100		24 24	107.83
See (P-22)	GPU MSM (Execution Time)	GPU FFT (Execution Time)									
See (P-22)	337.35 338.29	49.85 51.23					85.06 85.4	51.91 50.45			
See (P-22)	338.53 Total: 338.056667	50.45 50.51				Total:	85.32 85.26	50.96 51.10868887			
### APP Program (Development Trees)  ### APP Pro						Size (2^23)					
OFU Wild (Execution Tree)  OFU Wild (Execution T	GPU Program (Execution T	ime) GPU Program (GPU Utilization)	GPU Program (VRAM Memory Utilization)	GPU Program (System Memory Utilization)			GPU Program (Ex	secution Time) GPU Program (GPU	Jtilization)	GPU Program (VRAM Memory Utilization)	GPU Program (System Memory Utilization)
OFU Wild (Execution Tree)  OFU Wild (Execution T		Failed to read all curve poinst – Aborted (core dumped)					180.58 180.35	100 100		24 24	215.24 213.91
OFU Wild (Execution Tree)  OFU Wild (Execution T	Total:	Not enough system memory to load in all the preprocessed curv	we points			Total:	180.23 180.3866667	100 100		24 24	214.53 214.56
Sin (2*34)	GPU MSM (Execution Time)	GPU FFT (Execution Time)					GPU MSM (Execu	stion Time) GPU FFT (Execution Time)			
Sin (2*34)							176.58 176.45	105.98 103.35			
Sin (2*34)	Total:					Total:	176.33 176.4533333	104.32 104.55			
OFU Program (Execution Time)	Size (2*24)					Size (2^24)					
313.25 100 24 429.07 377.36 100 24 429.37	GPU Program (Execution T	ime) GPU Program (GPU Utilization)	GPU Program (VRAM Memory Utilization)	GPU Program (System Memory Utilization)			GPU Program (Ex	secution Time) GPU Program (GPU	Jtilization)	GPU Program (VRAM Memory Utilization)	GPU Program (System Memory Utilization)
							378.29 377.38	100 100		24 24	429.47 429.26
Face to rea on a core primat - Adultie (cost dispute)  310.21 100 24 423 bit  Face: 377.86 100 24 423 bits  423 bits comply system memory a late of the purposses core points  Table: 377.86 100 24 423 bits comply system memory a late of the purposses of the points  Table: 377.86 100 24 423 bits comply system memory a late of the purposses of the points of the purposses of the purposs	Total:	Falled to read all curve poinst – Aborted (core dumped)  Not enough system memory to load in all the preprocessed curv	ve points			Total:	378.21 377.96	100 100		24 24	429.16 429.296667

	GPU MSM (E	xecution Time)	GPU FFT (Exec	cution Time)								GPU MSM (Exec	ution Time) GPU FF1	T (Execution Time)						
												358.29 357.32		210.05 210.21						
														211.24						
fotal:											Total:	358.31		210.5						
Size (2*25)											Size (2^25)									
	GPU Program	m (Execution Time)	0	GPU Program (GPU Utili	nation)	GPU Program (VR)	AM Memory Utilization)	GPU Program (System M	remory Utilization)			GPU Program (E 732.32	xecution Time)	GPU Program (GPU Util	ization)	GPU Program (VR 24	RAM Memory Utilization)	GPU Program (S 863.33	ystem Memory U	Utilizatio
												733.42		100		24		863.64		
			Failed to read a	all curve poinst – Aborted stem memory to load in all	(core dumped)							731.21 732.3166667		100		24 24		861.39 862.7866667		
fotal:			Not enough sys	stem memory to load in all	the preprocessed cu	rve points					Total:	732.3166667		100		24		862.7866667		
	GPU MSM (E	(xecution Time)	GPU FFT (Exec	cution Time)								GPU MSM (Exec		T (Execution Time)						
												700.21		421.24						
											_	700.11 701.24		421.82 420.45						
otal:											Total-	701.24		421.17						
Prize (test-m	am-ppu); https:	://github.com/TalDs	ereitest-mam-gp				Execution T	lime = seconds ory Utilization = GB		FIGRURE 4	ZPrize (test-m	sm-gpul; https://gi	thub.com/TelDereitest-m	wm-gou			Execution Tin	me = seconds ry Utilization = GB		FIGURE
hape: A10							VICAM MEETS	ory Unitration = GD			Shape: A40						VICAM MINISTER	y oneranon = GB		
hape: A10 PUs vidia A10	Architecture	GPU Interconne	24 GB GDDR6	Only me	asuring the MSM exec	cution time and memo	ory utilization in this reposi	itory			GPUs Nvidia A40	Architecture Ampere	GPU Interconnec GPU Mer N/A 48 GB G	mary Only m	easuring the MSM exe	cution time and men	nory utilization in this reposito	ory		
ridia A10	Ampere	N/A	24 GB GDDR6								Nvida A40	Ampere	N/A 48 GB G	DORS						
ize (2*15)											Size (2^15)									
	GPU MSM (E-	xecution Time)		GPU Program (VRAM Me	mory Utilization)						_	GPU MSM (Exec	ution Time)	GPU Program (VRAM M	emory Utilization)					
	0.5	194		1.67								0.24		2						
	0.40	527		1.67								0.25		2						
tal:	0.52266666	967		1.67							Total:	0.24		2						
tal: no (2*16)											Size (2^16)									
(2 10)											See (2 *10)									
	GPU MSM (E	execution Time)		GPU Program (VRAM Me 1.676 1.676	mory Utilization)							GPU MSM (Exec	ution Time)	GPU Program (VRAM M	emory Utilization)					
	0.5	336		1.676								0.24		2.05 2.05						
	0.5	146		1.676								0.24		2.05						
tal:	0.531333333	133		1.676							Total:	0.24 0.24		2.05 2.05						
	=								_											
no (2*17)											Size (2^17)									
	GPU MSM (E	xecution Time)		GPU Program (VRAM Mo 1.685	mory Utilization)							GPU MSM (Exec	ution Time)	GPU Program (VRAM M	emory Utilization)					
	0.5	536		1.685								0.25		2.08						
	0.50	533		1.685							_	0.25		2.08						
ital:	0.5	536		1.685							Total:	0.25		2.08 2.08						
ne (2*18)									_											
ne (2*18)											Size (2^18)									
	GPU MSM (E	(xecution Time)		GPU Program (VRAM Me	mory Utilization)						_	GPU MSM (Exec	ution Time)	GPU Program (VRAM M	emory Utilization)					
	0.50	155		GPU Program (VRAM Me 1.707								0.25		2.1						
	0.50	596		1.707								0.25		2.1 2.1						
otal:	0.68	333		1.707							Total:	0.26		2.1						
									_											
izo (2*19)											Size (2^19)									
	CRIL MOM (S	(xecution Time)		GPU Program (VRAM Me	many (Millerstian)						_	GPU MSM (Exec	otion Time)	GPU Program (VRAM M	omen (Hillastica)					
	0.6	348		1.75	mary dimension)							0.25 0.23	unun rame)	2.14 2.14	unitry contaction,					
	0.6	127		1.75 1.75								0.23		2.14						
otal:	0.50	597		1.75 1.75							Total:	0.23		2.14 2.14						
				1.79							iota.	0.130031031		2.19						
ize (2*20)											Size (2^20)									
					mory Utilization)						_	GPU MSM (Exec	at a March							
	0.0 0.0	execution Time)		GPU Program (VRAM Me 1.84	mory Utilization)							0.29	ution time)	GPU Program (VRAM N 2.23	amory Utilization)					
	0.60	333		1.84								0.25		2.23						
otal:	0.60	122		1.84							Total:	0.25		2.23 2.23						
	0.60	523		1.84								0.2633333333		2.23						
ne (2*21)											Size (2^21)									
		(xecution Time)			The state of the state of															
	0.8	112		GPU Program (VRAM Me	mory Utilization)							GPU MSM (Exec	word IITHE)	GPU Program (VRAM N	unity Utilization)					
	0.8	345		2.01								0.31		24 24 24						
	0.8	905		2.01								0.33		2.4						
tal: no (2*22)	0.82066666	101		2.01							Total:	0.33		2.4						
no (2*22)											Size (2^22)									
		(xecution Time)										GPU MSM (Fyar								
	GPU MSM (E:			GPU Program (VRAM Me 2.35	mory Utilization)									GPU Program (VRAM M	emory Utilization)					
	0.9	143		2.35								0.45 0.42		2.75 2.75						
	0.90	176		2.35								0.45		2.75						
tal:	0.95633333	133		2.35		بالسيان					Total:	0.44		2.75						
ne (2*23)											Size (2*23)									
	GPU MSM (E-	execution Time)		GPU Program (VRAM Me 3.04	mory Utilization)							GPU MSM (Exec	ution Time)	GPU Program (VRAM M 3.43	emory Utilization)					
	1.1	1.4		3.04								0.65		3.43						
		1.3		3.04 3.04								0.59		3.43 3.43						
at:	- 0	26		3.04							Total:	0.61		3.43						
(2*24)											Size (2^24)									
	GPU MSM (E:	(xecution Time)		GPU Program (VRAM Me 4.42	mory Utilization)							GPU MSM (Exec 0.96	ution Time)	GPU Program (VRAM N 4.81	emory Utilization)					
	1	51		4.42								0.96		4.81						
	1	.51 .64		4.42 4.42								1.01		4.81 4.81						
		.57		4.42							Total:	0.98		4.81						
at:	1.								-		Size (2*25)									
											Size (2*25)									
				GPU Program (VRAM Me	mory Utilization)							GPU MSM (Exec	ution Time)	GPU Program (VRAM N	emory Utilization)					
	GPU MSM (E:	(xecution Time)										1.75 1.74		7.58						
	GPU MSM (E:	(xecution Time)		7.17							_			1.44						
	GPU MSM (E:	execution Time)		7.17								1.74		7.56 7.56						
	GPU MSM (E:	(xecution Time)		7.17							Total:	1.74 1.71 1.733333333		7.56 7.56 7.56						
	GPU MSM (E:	execution Time)		7.17 7.17 7.17 7.17							Total:	1.71		7.56 7.56 7.56						
	GPU MSM (E:	execution Time)		7.17							Total:	1.71		7.56 7.56 7.56						
	GPU MSM (E:	execution Time)		7.17							Total:	1.71		7.56 7.56 7.56						
	GPU MSM (E:	execution Time)		7.17							Total:	1.71		7.56 7.56 7.56 7.86						
rtal: ze (2*25)	GPU MSM (E:	execution Time)		7.17						_	Total:	1.71		7.56 7.56 7.56						

# **CHARTS**



