SNIA DEVELOPER CONFERENCE



September 16-18, 2024 Santa Clara, CA

# **Computational Storage Service**

Analytical Data Platform with Intelligent Analytics Offload

Donpaul Stephens AirMettle, Inc.

# **Computational Storage**

Let's start with the devices...



# **Computational Storage?**

Erik Riedel's Ph.D. Dissertation 1999:

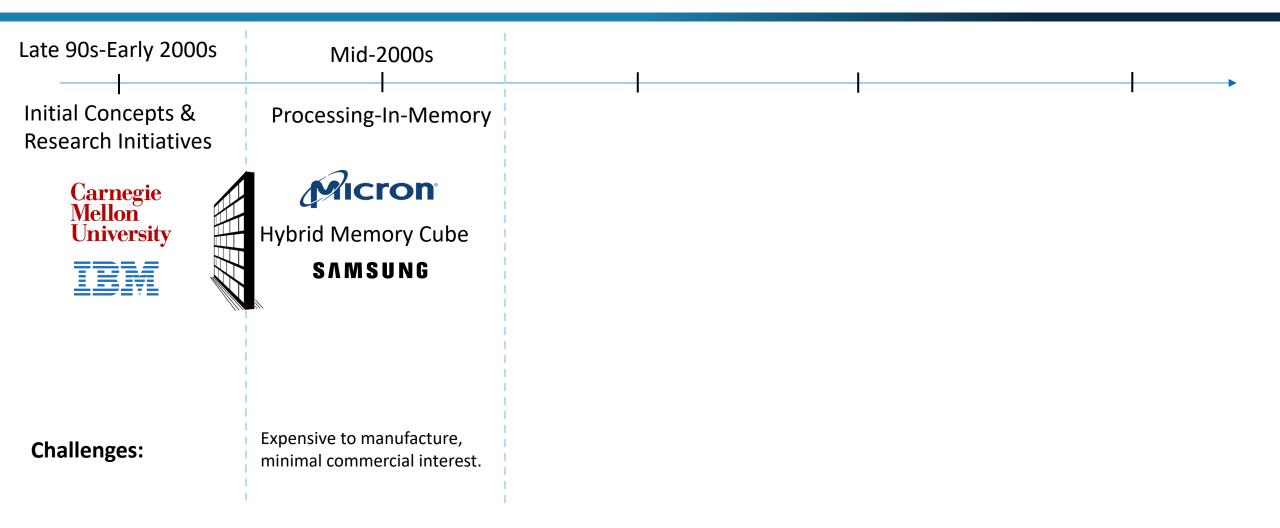
Active Disks – Remote Execution for Network-Attached Storage

Why didn't it take off? How we can put it to work.

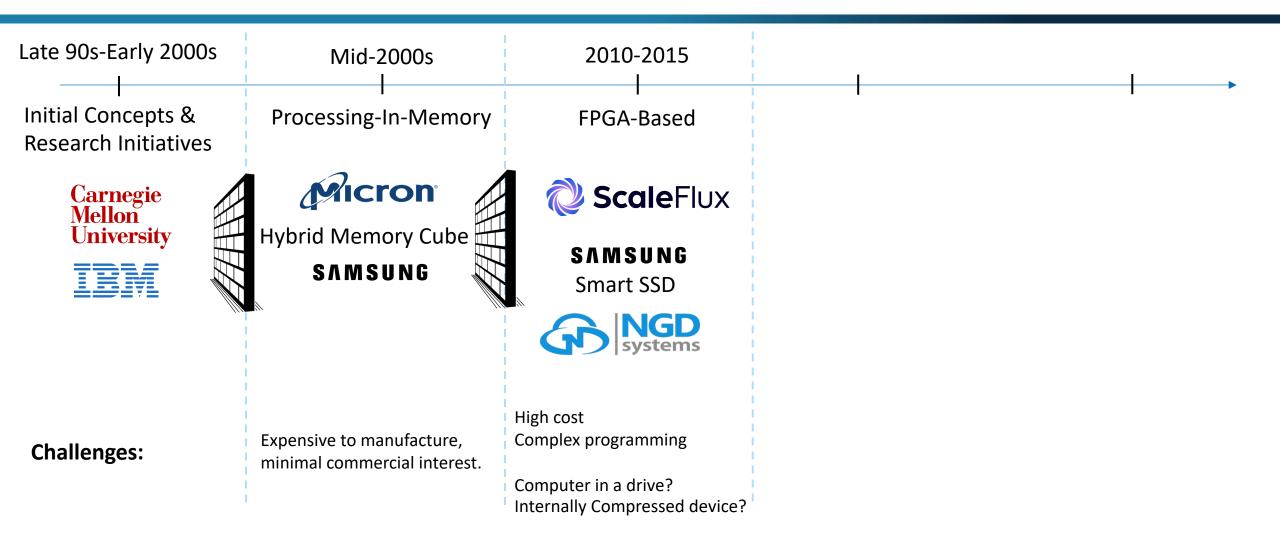


Late 90s-Early 2000s		1	1	
I Initial Concepts & Research Initiatives		Ι	Ι	
Carnegie Mellon University				

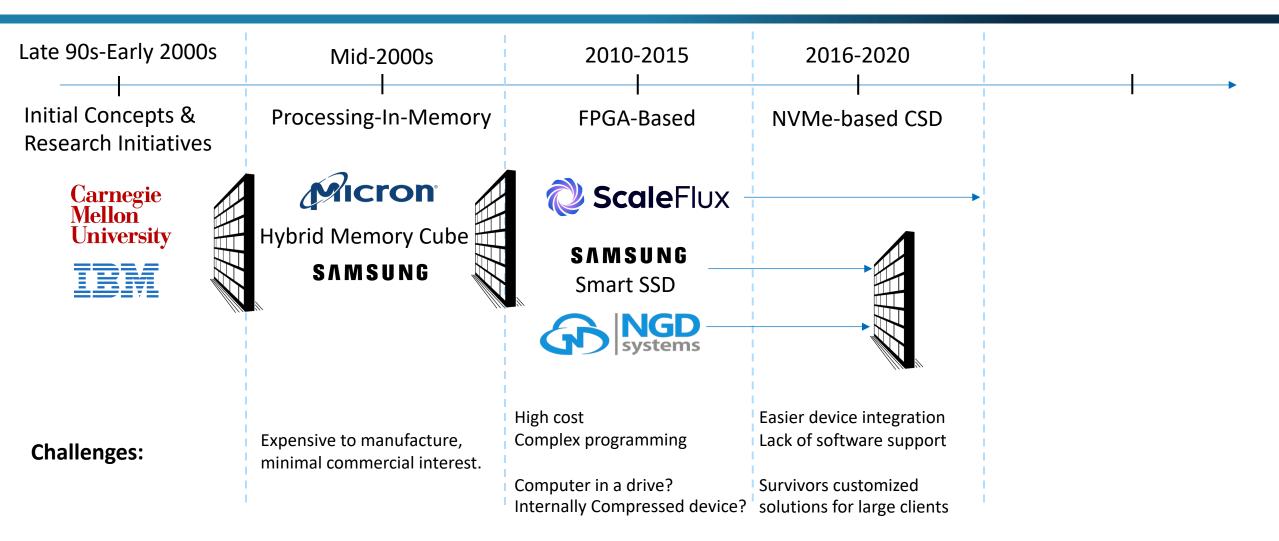




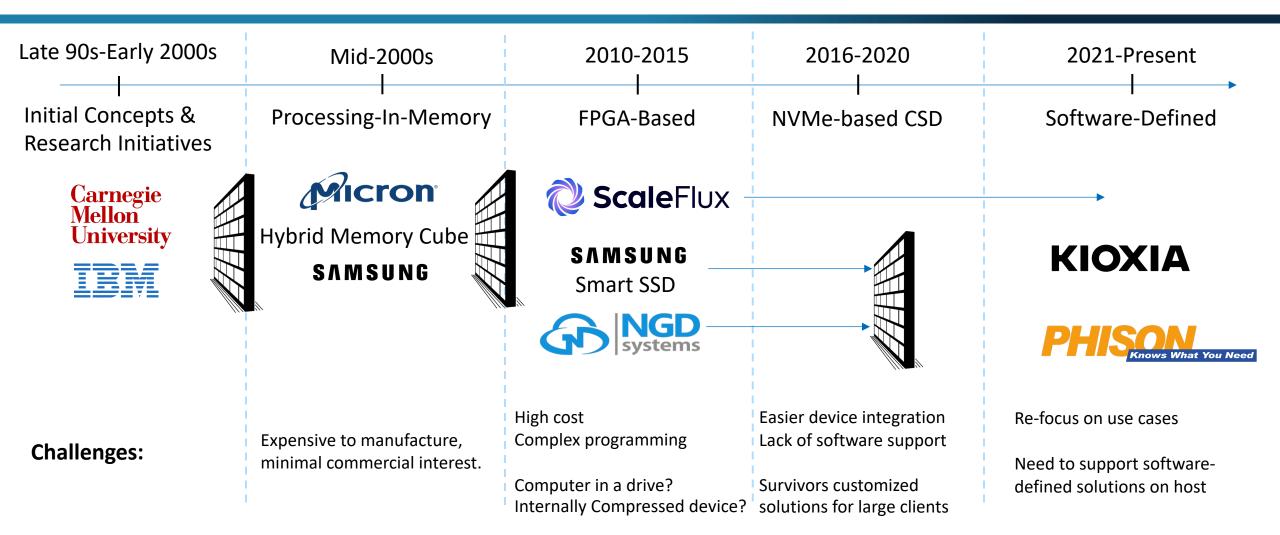




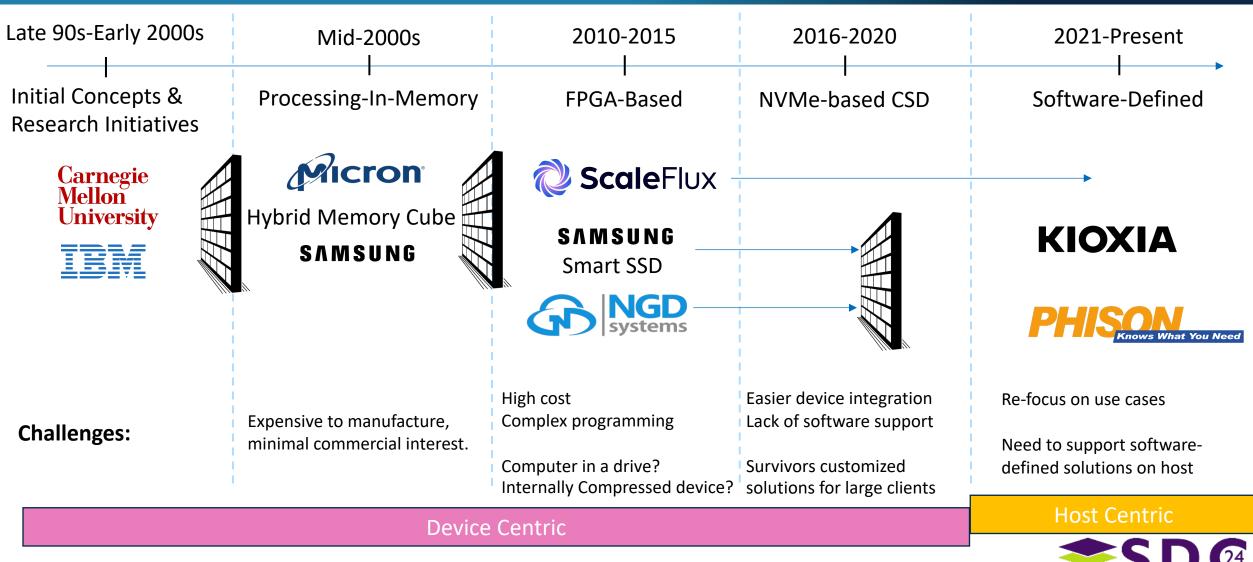










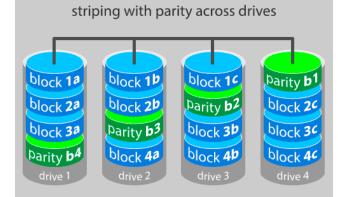


# **Host-level Approach**

Applications, with limitations

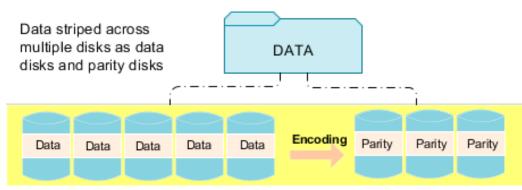


# How storage protects data

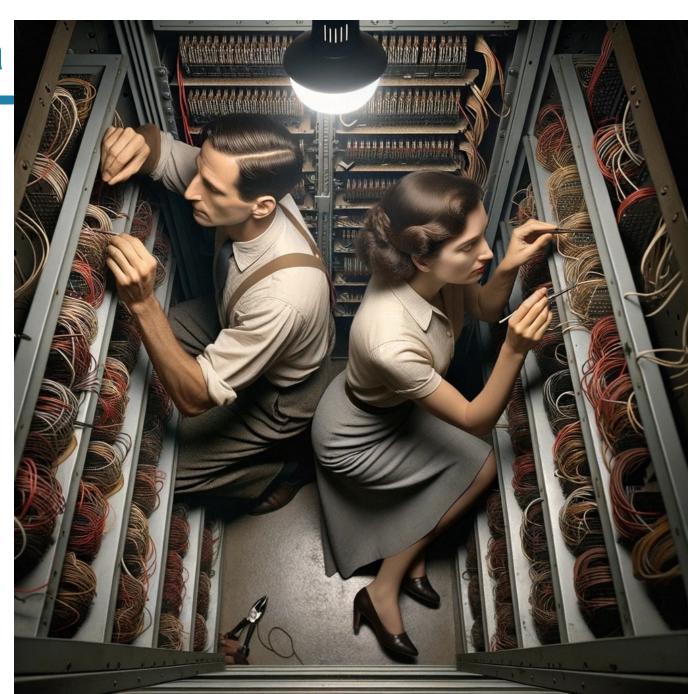


RAID 5

#### Erasure Coding:



**Designed way back... Then:** (logic was expensive, interconnect was relatively cheap



# Data reliably placed in storage: First 4 devices shown...

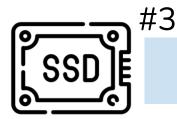
#### Simple Table:

1	155190	7706	1	17	21168.23	0.04	0.02 N	0	3/13/96	2/12/96	3/22/96	DELIVER_IN_PERSON	TRUCK	egular_courts_above_the
1	67310	7311	2	36	45983.16	0.09	0.06 N	0	4/12/96	2/28/96	4/20/96	TAKE_BACK_RETURN	MAIL	ly_final_dependencies:_slyly_bold_
1	63700	3701	3	8	13309.6	0.1	0.02 N	0	1/29/96	3/5/96	1/31/96	TAKE_BACK_RETURN	REG_AIR	riouslyregular _express_dep
1	2132	4633	4	28	28955.64	0.09	0.06 N	0	4/21/96	3/30/96	5/16/96	NONE	AIR	litesfluffily_even_de
1	24027	1534	5	24	22824.48	0.1	0.04 N	0	3/30/96	3/14/96	4/1/96	NONE	FOB	_pending_foxesslyly_re
1	15635	638	6	32	49620.16	0.07	0.02 N	0	1/30/96	2/7/96	2/3/96	DELIVER_IN_PERSON	MAIL	arefully_slyly_ex
2	106170	1191	1	38	44694.46	0	0.05 N	0	1/28/97	1/14/97	2/2/97	TAKE_BACK_RETURN	RAIL	ven_requestsdeposits_breach_a





#4



Bytes of data divided evenly across SSDs!



Data protection and streaming performance!



Supports data protection algorithms designed for HDD!

**KIOXIA** Talk this afternoon!



# Data reliably placed in storage: First 4 devices shown...

	1	155190	7706	1	17	21168.23	0.04	0.02 N	0	3/13/96	2/12/96	3/22/96 DELIVER_IN_P	PERSON T	RUCK	egular_courts_above_the
	/ 1	67310	7311	2	36	45983.16	0.09	0.06 N	0	4/12/96	2/28/96	4/20/96 TAKE_BACK_R	RETURN	MAIL	ly_final_dependencies:_slyly_bold_
	1	63700	3701	3	8	13309.6	0.1	0.02 N	0	1/29/96	3/5/96	1/31/96 TAKE_BACK_R	RETURN R	REG_AIR	riouslyregular _express_dep
Simple Table:	1	2132	4633	4	28	28955.64	0.09	0.06 N	0	4/21/96	3/30/96	5/16/96 NONE	A	AIR	litesfluffily_even_de
	1	24027	1534	5	24	22824.48	0.1	0.04 N	0	3/30/96	3/14/96	4/1/96 NONE	F	ОВ	_pending_foxesslyly_re
	1	15635	638	6	32	49620.16	0.07	0.02 N	0	1/30/96	2/7/96	2/3/96 DELIVER_IN_P	PERSON N	MAIL	arefully_slyly_ex
	2	106170	1191	1	38	44694.46	0	0.05 N	0	1/28/97	1/14/97	2/2/37 TAKE_BACK_R	RETURN R	RAIL	ven_requestsdeposits_breach_a



.,155190,7706,1,17,21168.23,0.04,0.02,N,0,1996-03-13 1996-02-12,1996-03-22,DELIVER\_IN\_PERSON,TRUCK egula \_\_courts\_above\_the, 1,67310,7311,2,36,45983.16,0.09, .06,N,0,1996-04-12,1996-02-28,1996-04-20,TAKE\_BACK

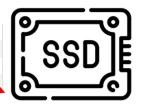
0.06,N,0,1996-04-21,1996-03-30,1996-05-16,NONE,AIR,l ites.\_fluffily\_even\_de, 1,24027,1534,5,24,22824.48,0 .10,0.04,N,0,1996-03-30,1996-03-14,1996-04-01,NONE,F OB,\_pending\_foxes.\_slyly\_re, 1,15635,638,6,32,49620.

Bytes of data divided evenly across SSDs!



Data protection and streaming performance!

RETURN,MAIL,ly\_final\_dependencies:\_slyly\_bold\_, 1,63
700,3701,3,8,13309.60,0.10,0.02,N,0,1996-01-29,199603-05,1996-01-31,TAKE\_BACK\_RETURN,REG\_AIR,riously.\_r
egularl\_express\_dep, 1,2132,4633,4,28,28955.64,0.09



#2

16,0.07,0.02,N,0,1996-01-30,1996-02-07,1996-02-03,DE LIVER\_IN\_PERSON,MAIL,arefully\_slyly\_ex, 2,106170,119 1,1,38,44694.46,0.00,0.05,N,0,1997-01-28,1997-01-14, 1997-02-02,TAKE\_BACK\_RETURN,RAIL,ven\_requests.\_depos

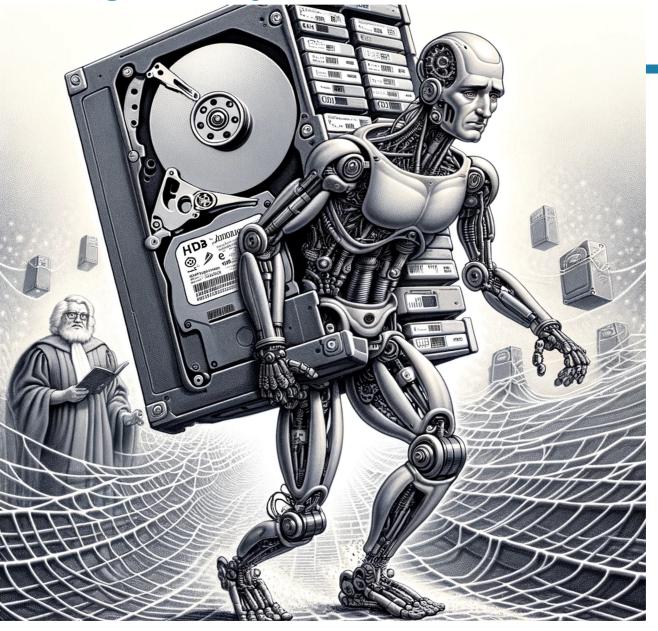




HDD-centric RAID/Erasure Coding prevent in-storage analytics



# Is Big Data just doomed to be SLOW?



# Systems-level Approach

Fast & Efficient Distributed Analytical Processing



## Took Occam's Razor to the Gordian's Knot of in-place analytics Computational Storage Service

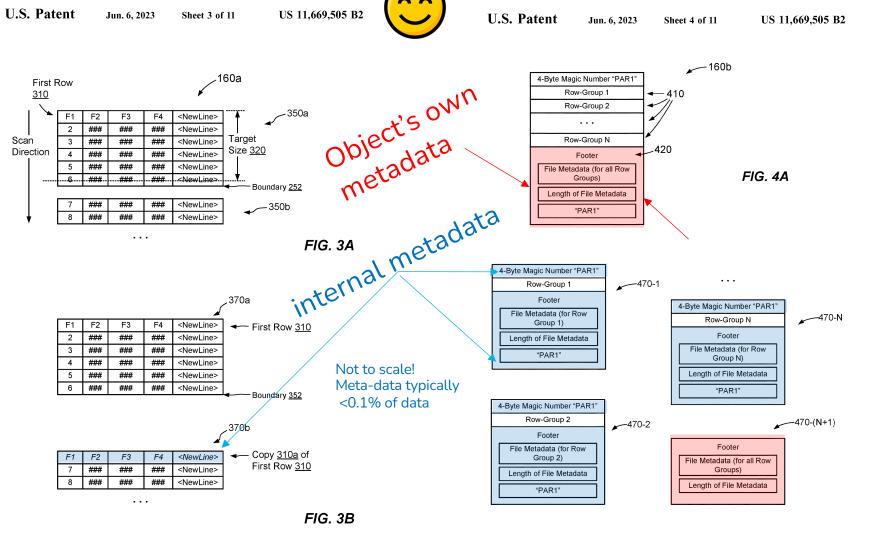




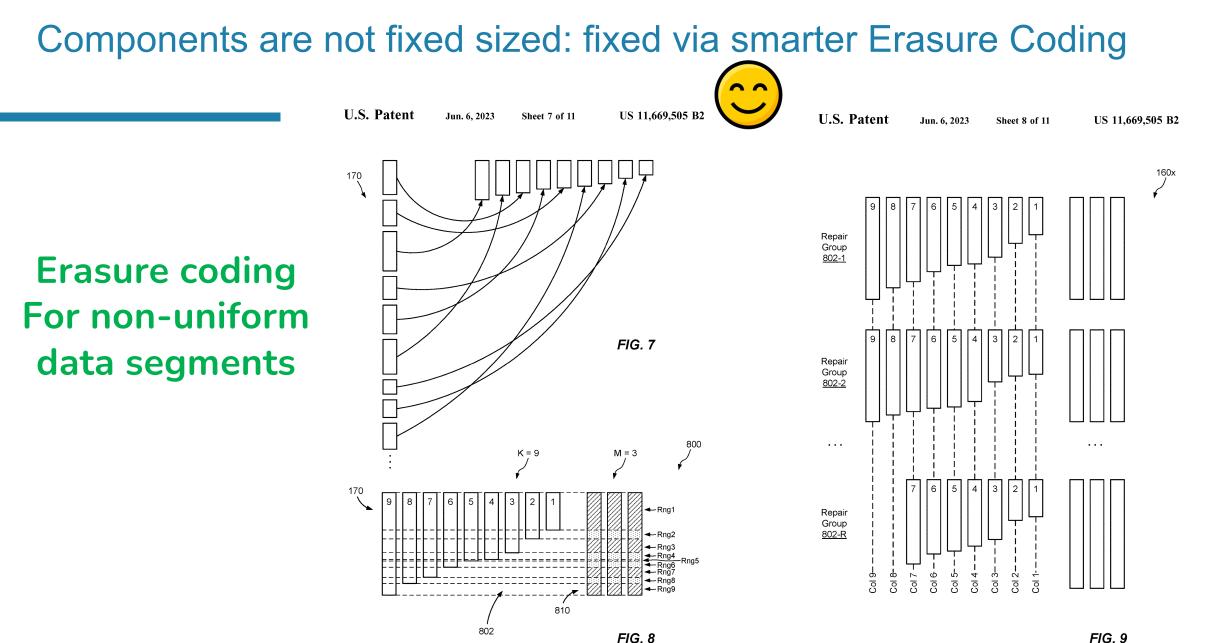
# Divide (transparently) to conquer common analytical needs



- Data file formats unchanged
- Each internal component can be processed separately in parallel in storage
- Overhead is typically <0.2%

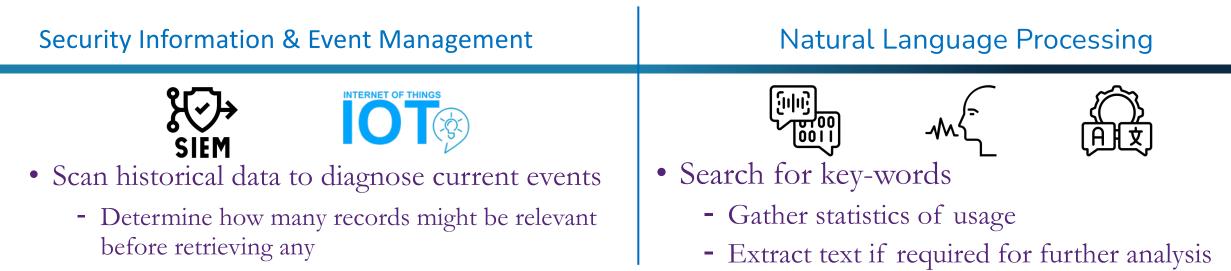


AirMettle internal metadata enables parallel in-storage analytics



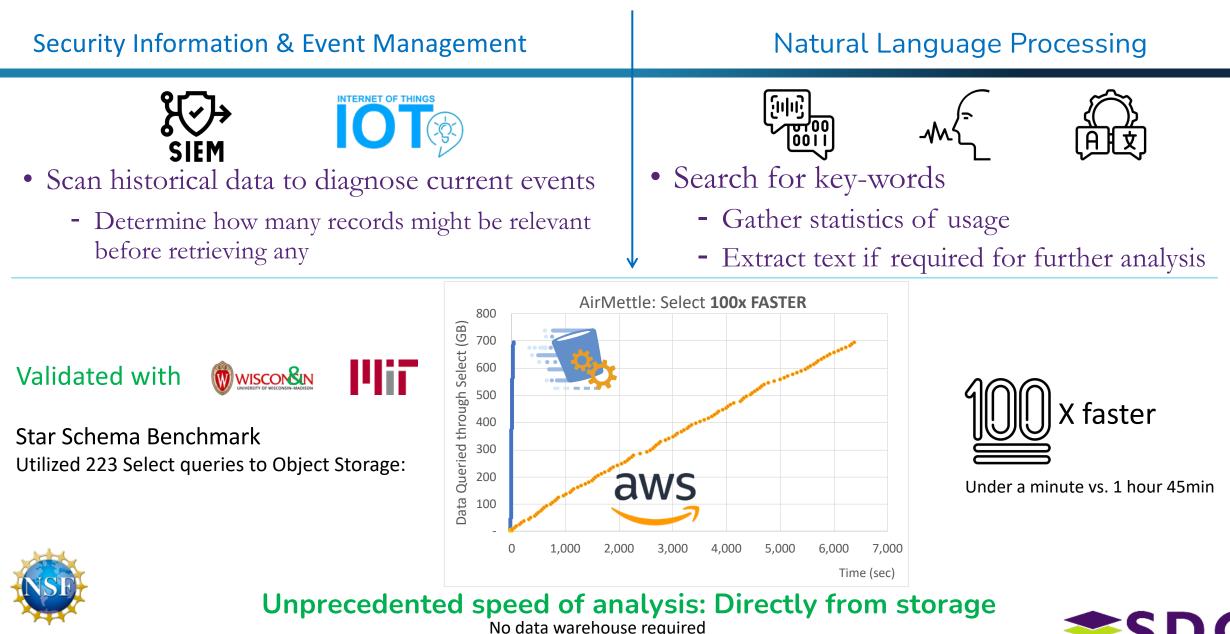


# Accelerated analytics of classic tabular data (S3 Select API)





# Accelerated analytics of classic tabular data (S3 Select API)



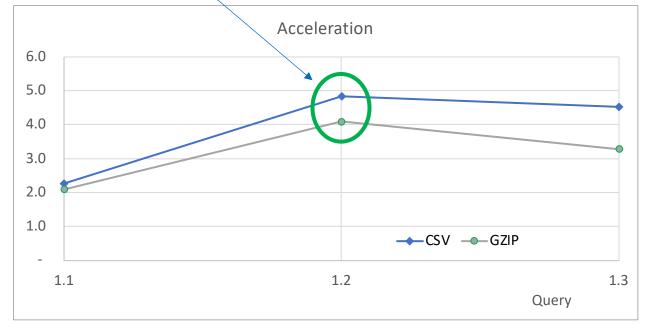
AirMettle Accelerates Spor

#### **5x Acceleration** on Complete Queries, today... just by using a different storage

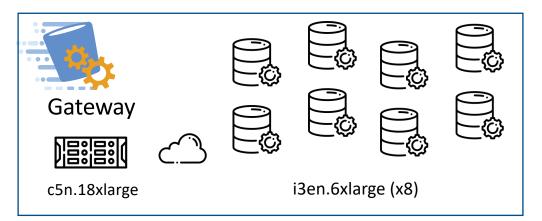


c5n.18xlarge





Star Schema Benchmark, Scale Factor 1 with 1 object per table



S3 Select API enables comparison vs. major cloud's object storage



# AirMettle: SQL needed for ad-hoc analysis of large objects well beyond "S3 Select", and with superior APIs to access it:

#### E.g., Security Information & Event Management

Collects sample measurements with certain flags and arguments and groups them by minute. Returns the number of samples, average duration, and standard deviation of duration for each group.

# SELECT TO\_STRING(event\_ts, 'yyyy-MM-dd HH24:mi') AS interval, COUNT(\*) AS event\_count, AVG(CAST(event\_dur AS INT)) AS avg\_event\_duration, STDDEV\_SAMP(CAST(event\_dur AS INT)) AS event\_duration\_stddev FROM events WHERE flgs LIKE 'C\_\_' AND REGEXP\_CONTAINS(args, 'JY.') AND event\_ts BETWEEN TO\_TIMESTAMP('2000-01-01 00') AND TO\_TIMESTAMP('2000-01-01 01') GROUP BY

interval;

- Data organization:
  - Aggregates within groups!
- Data characterization:

STDDEV SAMP

GROUP BY

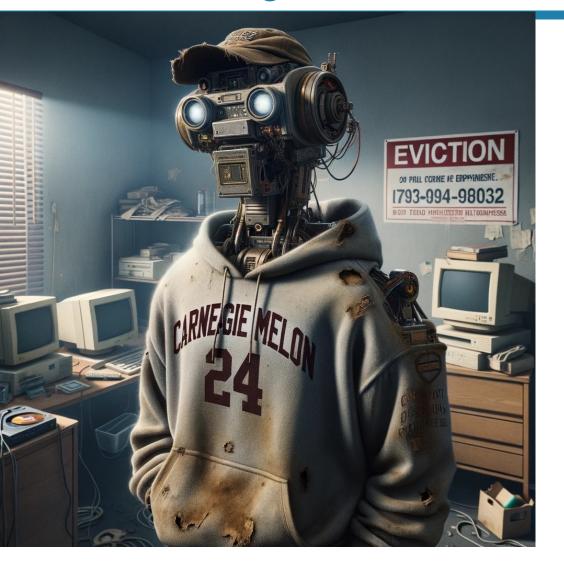




# **Device-level Processing?**



## But what about the SSD?!?!? How do we go from This:





## But what about the SSD?!?!? How do we go from This:



### to This:





# Target Use Cases: For whom

APPLICATIONS	Example Target Customers
Security Information & Event Management &	paloalto <sup>®</sup> Blumira BNY MELLON
Network Operations Management	PAIOAICO BIUMIRA BNY MELLON
Weather/climate	Bloomberg 🔛 CITADEL 🔅 AccuWeather 🤍
Semiconductor manufacturing	
Real-time Analytics (Security, e-commerce) Massive Multi-player On-line Games (MMOG)	ebay Microsoft SONY
	Security Information & Event Management & Network Operations Management Weather/climate Semiconductor manufacturing Real-time Analytics (Security, e-commerce)

Significant amount of Flash used in Public Cloud "object / Blob" storage is Array-based data formats



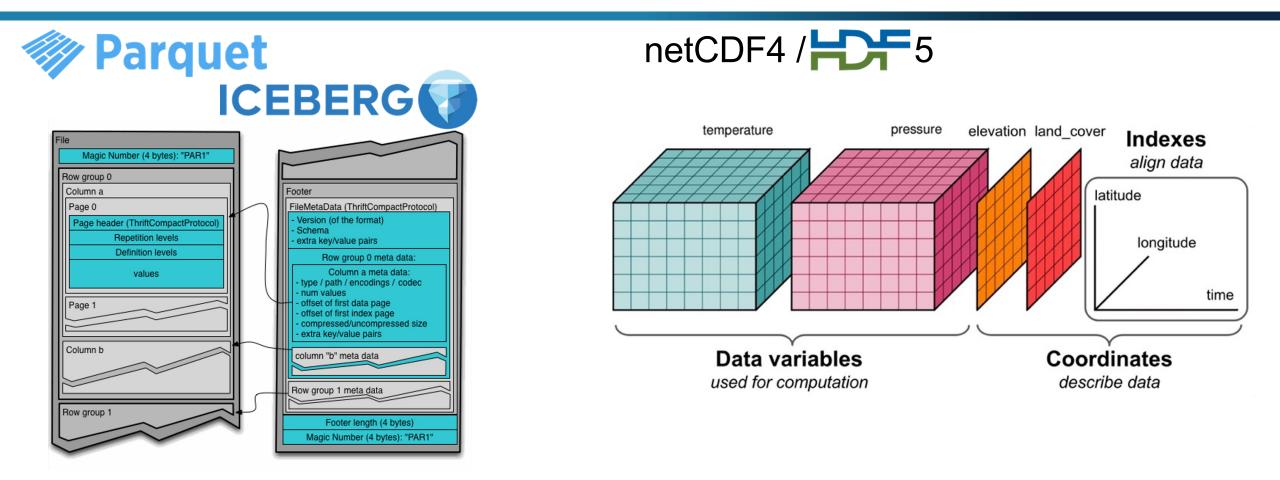


# Target Use Cases: Analytics $\rightarrow$ which we CAN address

APPLICATIONS	Select	Multi-dimensional Select
Security Information & Event Management &		
Network Operations Management	V	
Weather/climate		$\checkmark$
Semiconductor manufacturing		$\checkmark$
Real-time Analytics (Security, e-commerce) Massive Multi-player On-line Games (MMOG)	$\checkmark$	
	Security Information & Event Management & Network Operations Management Weather/climate Semiconductor manufacturing Real-time Analytics (Security, e-commerce)	Security Information & Event Management & Network Operations Management Weather/climate Semiconductor manufacturing Real-time Analytics (Security, e-commerce)



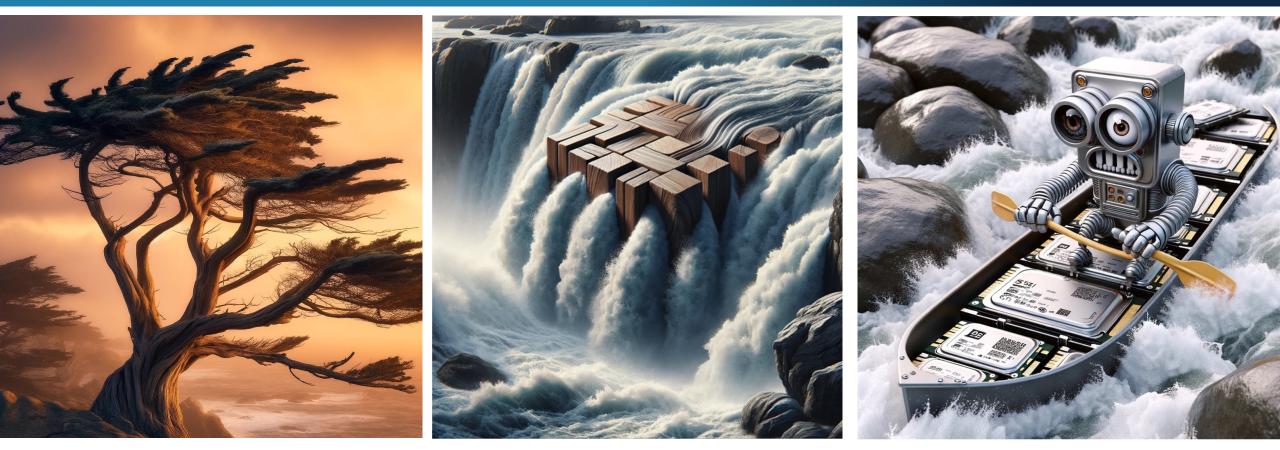
# Challenge: Array based data formats



• There many public data formats, which are complex & evolving



## Cram a modern processor & OS Into a hard real-time embedded controller?



Branches (prediction, memory management) Are HARD

Complex terrain (data formats)

Seemingly unbounded complexity



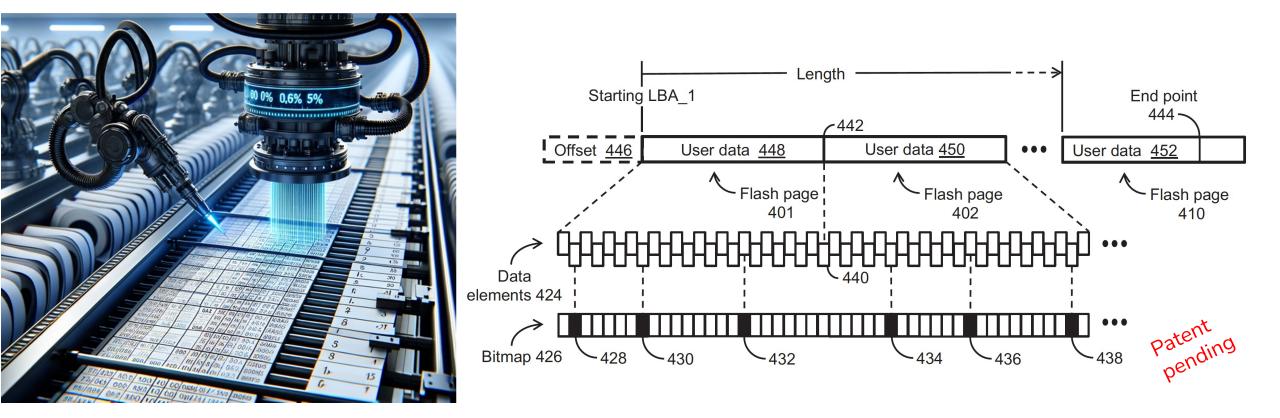
# Henry Youngman's classic

The Patient says, "Doctor, it hurts when I do this." •

#### "Then don't do that."



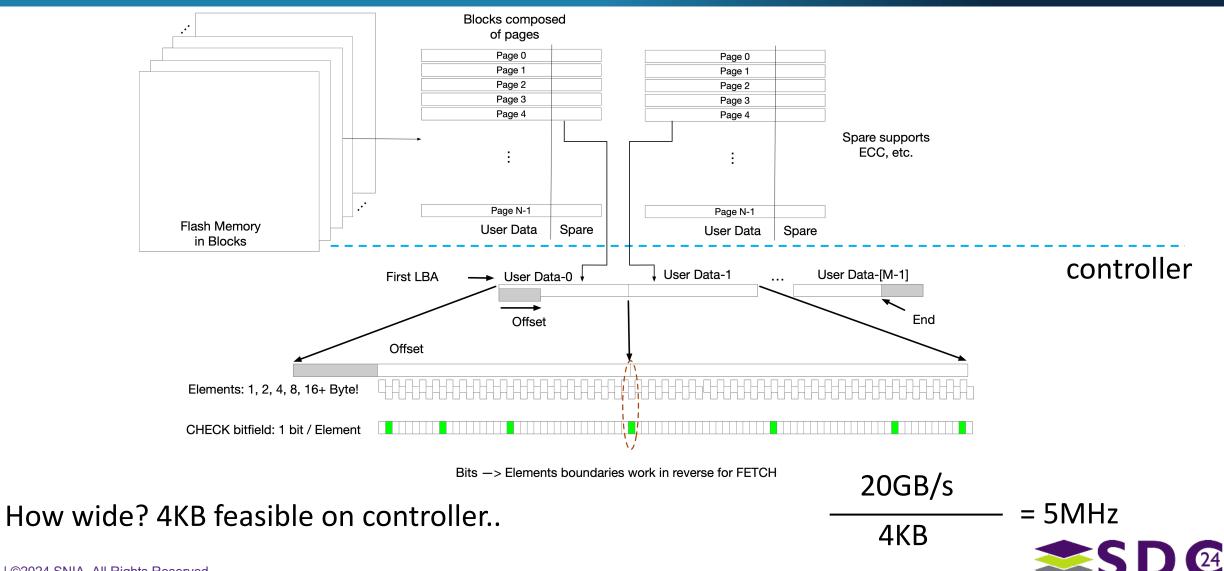
# New Paradigm: CHECK & FETCH User commands, NO administrative, NO Branches



"Inspection process"



# MASSIVELY Parallelizable: choice up to controller





**SELECT** 



WHERE

(lo\_quantity BETWEEN 11 AND 20)
AND (lo orderdate <= 20210116);</pre>

Retrieve required columns

- ~MB per column
- Process Data in CPU
- <0.1% for many queries!

O 0 LO\_ LO LO ORDERKEY LINENUMBER CUSTKEY PARTKEY SUPPKEY ORDERDATE ORDERPRIORITY SHIPPRIORITY QUANTITY EXTENDEDPRICE ORDTOTALPRICE DISCOUNT REVENUE SUPPLYCOST TAX COMMITDATE SHIPMODE 685 68 341 349 1/1/21 3-MEDIUM 34 2128.74 11861.44 0.04 9968.63 3995.22 0.1 2/1/21 TRUCK 0.05 20748.27 560 979 510 942 1/2/21 2-HIGH 3482.81 13217.61 3752.25 0.05 2/2/21 SHIP 18 630 772 515 283 1/3/21 5-LOW 6794.8 8005.41 0.03 37516.42 7694.96 0.12 2/3/21 RAIL 193 235 70 587 1/4/21 5-LOW 8804.42 19985.63 0.08 26818.47 3488.45 0.15 2/4/21 RAIL 13 836 717 358 821 1/5/21 5-LOW 5482.41 7102.67 0.08 24896.14 6744.53 0.05 2/5/21 AIR 764 434 1/6/21 1-URGEN 2898.73 14455.99 0.09 1026.75 5414.6 0.12 2/6/21 AIR 999 909 708 292 557 220 1/7/21 1-URGENT 399.33 12787.9 0 21844.68 5107.17 0.13 2/7/21 SHIP 360 727 886 820 1/8/21 3-MEDIUM 7132.33 16279.77 0.09 4114.13 9061.04 0.19 2/8/21 MAIL 10 702 766 740 1/9/21 1-URGENT 178.05 19526.89 0.04 11204.41 5769.13 0.16 2/9/21 AIR 724 710 323 874 1/10/21 4-NOT SPECIFIED 47 3789.52 17806.89 0.09 46687.3 8355.19 0.17 2/10/21 AIR 278 728 624 787 1/11/21 4-NOT SPECIFIED 5352.32 15314.78 0.07 11554.51 7392.95 0.1 2/11/21 SHIP 755 374 1/12/21 5-LOW 9228.9 13995.14 0.1 43058.54 866.29 0.04 2/12/21 AIR 556 92 805 1/13/21 2-HIGH 986 6776.41 0.08 40341.78 7844.55 0.2 2/13/21 SHIP 33 291 600 424 1/14/21 5-LOW 4118.83 3038.94 0.04 8798.17 2560.27 0.03 2/14/21 REG AIF 12 71 617 552 671 1/15/21 4-NOT SPECIFIED 340.7 1346.46 0.05 30679.89 9079.92 0.09 2/15/21 SHIP 473 213 972 438 1/16/21 4-NOT SPECIFIED 3491.85 4913.84 0.04 6667.43 907.78 0.01 2/16/21 AIR 601 139 827 1/17/21 4-NOT SPECIFIED 6260.09 8702.4 0.04 36666.52 3664.18 0.19 2/17/21 MAIL 663 397 1/18/21 5-LOW 0.03 32235.65 695 415 940 2862.77 10487.73 1447.46 0.19 2/18/21 TRUCK 315 422 824 1/19/21 3-MEDIUM 2176.52 15484.36 5018.1 0.14 2/19/21 TRUCK 658 0.05 40784.99 706 638 711 509 1/20/21 2-HIGH 1245.46 19178.94 0.07 24489.84 8290.21 0.07 2/20/21 SHIP 487 787 669 968 1/21/21 3-MEDIUM 5813.69 2434.68 0.03 45828.29 3332.78 0.05 2/21/21 MAIL 1/22/21 3-MEDIUM 552 624 275 942 6983.17 2229.38 0.05 3418.1 1933.88 0.05 2/22/21 TRUCK 88 489 861 856 1/23/21 2-HIGH 6752.38 11834.92 0.01 15351.54 3637.54 0.03 2/23/21 MAIL 175 450 1/24/21 4-NOT SPECIFIED 9493.72 14933.42 0.02 36037.58 8231.86 0.11 2/24/21 TRUCK 771 44 601 327 1/25/21 4-NOT SPECIFIED 126.76 16978.19 0 21487.35 1833.65 0.03 2/25/21 AIR 540 84 850 980 434 491 1/26/21 5-LOW 6507.25 18723.06 0.1 9474.62 2659.94 0.06 2/26/21 REG AIR 678 218 810 54 1/27/21 5-LOW 6043.88 19670.18 0 6253.33 1154.09 0.13 2/27/21 REG AIR 19 538 664 94 817 1/28/21 3-MEDIUM 5928.52 8056.05 0.02 41049.62 7204.25 0.15 2/28/21 AIR

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SD @







FROM

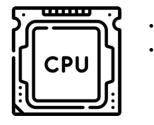
s30bject

SELECT

WHERE (lo quantity BETWEEN 11 AND 20) AND (lo orderdate <= 20210116); Retrieve required columns

- ~MB per column
- Process Data in CPU
  - <0.1% for many queries!

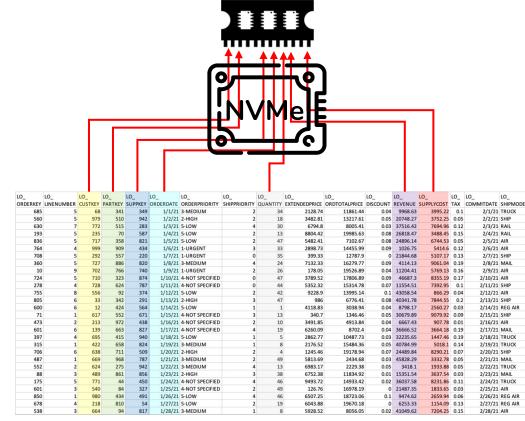
#### With CHECK-FETCH



Perform basic filtering in device

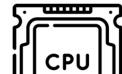
Scratchpad can eliminate returning intermediate results

				ļ				′M								
	LO_ LINENUMBER		LO_ PARTKEY		LO_ ORDERDATE	LO_ ORDERPRIORITY		.0_ QUANTITY		LO_ ORDTOTALPRICE	LO_ DISCOUNT	LO_ REVENUE	LO_ SUPPLYCOST		LO_ COMMITDATE	LO_ E SHIPMODE
685						3-MEDIUM	2	34								1 TRUCK
560			510	942	1/2/21	2-HIGH	2	18	3482.81	13217.61	0.05	20748.27	3752.25	0.05	5 2/2/2	1 SHIP
630	7	772	515	283	1/3/21	5-LOW	4	30	6794.8	8005.41	0.03	37516.42	7694.96	0.12	2/3/2	1 RAIL
193	5	235	70	587	1/4/21	5-LOW	2	13	8804.42	19985.63	0.08	26818.47	3488.45	0.15	5 2/4/2:	1 RAIL
836	5	5 717	358	821	1/5/21	5-LOW	2	47	5482.41	7102.67	0.08	24896.14	6744.53	0.05	2/5/2	1 AIR
764			909	434	1/6/21	1-URGENT	3	33	2898.73	14455.99	0.09	1026.75	5414.6	0.12	2/6/2	1 AIR
708	5	292	557	220	1/7/21	1-URGENT	0	35	399.33	12787.9	0	21844.68	5107.17	0.13	3 2/7/2	1 SHIP
360	5	5 727	886	820	1/8/21	3-MEDIUM	4	24	7132.33	16279.77	0.09	4114.13	9061.04	0.19	2/8/2	1 MAIL
10			766	740	1/9/21	1-URGENT	2	26		19526.89	0.04	11204.41	5769.13	0.16	5 2/9/2	1 AIR
724	5	5 710	323	874	1/10/21	4-NOT SPECIFIED	0	47	3789.52	17806.89	0.09	46687.3	8355.19	0.17	2/10/2	1 AIR
278			624			4-NOT SPECIFIED	0	44								
755					1/12/21		2	42								
805						2-HIGH	3	47								
					1/14/21		1	1								1 REG AIR
600			552			4-NOT SPECIFIED	3	13								
71			972			4-NOT SPECIFIED	2	10								
71 473	2		663	827		4-NOT SPECIFIED	4	19								
71 473 601	2								2862.77						2/18/2:	
71 473 601 397	2 6 4	695				5-LOW	1	5				32235.65				
71 473 601 397 315	2 6 4	695 422	658	824	1/19/21	3-MEDIUM	1	8	2176.52	15484.36	0.05	40784.99	5018.1	0.14	2/19/2	1 TRUCK
71 473 601 397 315 706	2 6 4 1	695 422 6 638	658 711	824 509	1/19/21 1/20/21	3-MEDIUM 2-HIGH	1	8	2176.52 1245.46	15484.36 19178.94	0.05	40784.99 24489.84	5018.1 8290.21	0.14	2/19/2	1 TRUCK 1 SHIP
71 473 601 397 315 706 487	2 6 4 1 6 6	695 422 6 638 6 669	658 711 968	824 509 787	1/19/21 1/20/21 1/21/21	3-MEDIUM 2-HIGH 3-MEDIUM	1 2 2	8 4 49	2176.52 1245.46 5813.69	15484.36 19178.94 2434.68	0.05 0.07 0.03	40784.99 24489.84 45828.29	5018.1 8290.21 3332.78	0.14	2/19/2 2/20/2 2/21/2	1 TRUCK 1 SHIP 1 MAIL
71 473 601 397 315 706 487 552	2 6 4 1 6 1 2	695 422 6 638 6 669 8 624	658 711 968 275	824 509 787 942	1/19/21 1/20/21 1/21/21 1/22/21	3-MEDIUM 2-HIGH 3-MEDIUM 3-MEDIUM	1 2 2 4	4 4 49 13	2176.52 1245.46 5813.69 6983.17	15484.36 19178.94 2434.68 2229.38	0.05 0.07 0.03 0.05	40784.99 24489.84 45828.29 3418.1	5018.1 8290.21 3332.78 1933.88	0.14	2/19/2 2/20/2 2/21/2 2/21/2	1 TRUCK 1 SHIP 1 MAIL 1 TRUCK
71 473 601 397 315 706 487 552 88	2 6 4 1 6 6 1 1 2 3	695 4222 6638 669 2624 8489	658 711 968 275 861	824 509 787 942 856	1/19/21 1/20/21 1/21/21 1/22/21 1/23/21	3-MEDIUM 2-HIGH 3-MEDIUM 3-MEDIUM 2-HIGH	1 2 2 4 3	8 49 13 38	2176.52 1245.46 5813.69 6983.17 6752.38	15484.36 19178.94 2434.68 2229.38 11834.92	0.05 0.07 0.03 0.05 0.01	40784.99 24489.84 45828.29 3418.1 15351.54	5018.1 8290.21 3332.78 1933.88 3637.54	0.14	2/19/2 2/20/2 2/21/2 2/22/2 2/22/2 2/22/2	1 TRUCK 1 SHIP 1 MAIL 1 TRUCK 1 MAIL
71 473 601 397 315 706 487 552 88 175	2 6 4 1 6 1 1 2 2 3 3 5	4 695 4 422 5 638 4 669 2 624 8 489 5 771	658 711 968 275 861 44	824 509 787 942 856 450	1/19/21 1/20/21 1/21/21 1/22/21 1/23/21 1/23/21 1/24/21	3-MEDIUM 2-HIGH 3-MEDIUM 3-MEDIUM 2-HIGH 4-NOT SPECIFIED	1 2 2 4 3 4	8 49 13 38 46	2176.52 1245.46 5813.69 6983.17 6752.38 9493.72	15484.36 19178.94 2434.68 2229.38 11834.92 14933.42	0.05 0.07 0.03 0.05 0.01 0.02	40784.99 24489.84 45828.29 3418.1 15351.54 36037.58	9 5018.1 4 8290.21 9 3332.78 1 1933.88 4 3637.54 8 8231.86	0.14	4 2/19/2 7 2/20/2 5 2/21/2 5 2/22/2 8 2/23/2 1 2/24/2	1 TRUCK 1 SHIP 1 MAIL 1 TRUCK 1 MAIL 1 TRUCK
71 473 601 397 315 706 487 552 88 175 601	2 6 4 1 6 1 1 2 2 3 3 5 5 3	4 695 4 422 5 638 1 669 2 624 8 489 5 771 8 540	658 711 968 275 861 44 84	824 509 787 942 856 450 327	1/19/21 1/20/21 1/21/21 1/22/21 1/23/21 1/23/21 1/24/21 1/25/21	3-MEDIUM 2-HIGH 3-MEDIUM 3-MEDIUM 2-HIGH 4-NOT SPECIFIED 4-NOT SPECIFIED	1 2 2 4 3 4 2	8 49 13 38 46 49	2176.52 1245.46 5813.69 6983.17 6752.38 9493.72 126.76	15484.36 19178.94 2434.68 2229.38 11834.92 14933.42 16978.19	0.05 0.07 0.03 0.05 0.01 0.02 0	40784.99 24489.84 45828.29 3418.1 15351.54 36037.58 21487.35	9 5018.1 8290.21 9 3332.78 1 1933.88 8 3637.54 8 8231.86 5 1833.65	0.14 0.07 0.05 0.05 0.03 0.11 0.03	2/19/2 2/20/2 2/21/2 2/21/2 2/22/2 2/22/2 2/23/2 2/24/2 2/25/2	1 TRUCK 1 SHIP 1 MAIL 1 TRUCK 1 MAIL 1 TRUCK 1 AIR
71 473 601 397 315 706 487 552 88 175	2 6 4 1 6 1 2 3 3 5 3 3 5 3 3	4 695 4 422 5 638 4 669 2 624 8 489 5 771 8 540 4 980	658 711 968 275 861 44	824 509 787 942 856 450 327 491	1/19/21 1/20/21 1/21/21 1/22/21 1/23/21 1/24/21 1/25/21 1/26/21	3-MEDIUM 2-HIGH 3-MEDIUM 3-MEDIUM 2-HIGH 4-NOT SPECIFIED 4-NOT SPECIFIED	1 2 2 4 3 4	8 49 13 38 46	2176.52 1245.46 5813.69 6983.17 6752.38 9493.72 126.76 6507.25	15484.36 19178.94 2434.68 2229.38 11834.92 14933.42 16978.19 18723.06	0.05 0.07 0.03 0.05 0.01 0.02 0 0	40784.99 24489.84 45828.29 3418.1 15351.54 36037.58 21487.35 9474.62	9 5018.1 8 290.21 9 3332.78 1 1933.88 8 3637.54 8 8231.86 5 1833.65 2 659.94	0.14 0.07 0.05 0.05 0.03 0.11 0.03 0.06	4 2/19/2 7 2/20/2 5 2/21/2 5 2/22/2 8 2/23/2 4 2/24/2 8 2/25/2 5 2/26/2	1 TRUCK 1 SHIP 1 MAIL 1 TRUCK 1 MAIL 1 TRUCK









lo revenue

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lo	suppkey,
lo	supplycost
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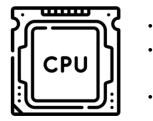
FROM s30bject

SELECT

WHERE (lo quantity BETWEEN 11 AND 20) AND (lo orderdate <= 20210116); Retrieve required columns

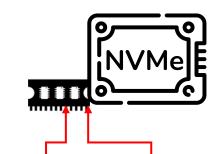
- ~MB per column
- Process Data in CPU
  - <0.1% for many queries!

#### With CHECK-FETCH

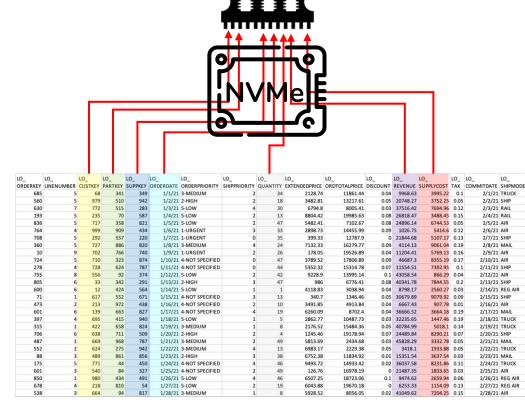


Perform basic filtering in device

- Scratchpad can eliminate returning intermediate results
- Bitwise operators: combine results



.0_	LO_	LO_	LO_	LO_	LO_	LO_	LO_	LO_	LO_	LO_	LO_	LO_	LO_	LO_	LO_	LO_
ORDERKEY	LINENUMBER	CUSTKEY	PARTKEY	SUPPKEY	ORDERDATE	ORDERPRIORITY	SHIPPRIORITY	QUANTITY	EXTENDEDPRICE	ORDTOTALPRICE	DISCOUNT	REVENUE	SUPPLYCOST	TAX	COMMITDATE	SHIPMODE
685	5	68				3-MEDIUM	2	34			0.04					TRUCK
560	5					2-HIGH	2					20748.27				
630	7	772				5-LOW	4					37516.42				
193	5					5-LOW	2					26818.47				
836	5					5-LOW	1					24896.14				
764	4	999				1-URGENT	3				0.09					
708	5	292				1-URGENT	(				0					
360	5					3-MEDIUM	4	24			0.09					
10	9					1-URGENT	2				0.04					
724	5	710			1/10/21	4-NOT SPECIFIED	(	47	3789.52	17806.89	0.09				2/10/21	AIR
278	4	728				4-NOT SPECIFIED	(	44			0.07					
755	8					5-LOW	2				0.1					
805	6	33				2-HIGH	3	47			0.08					
600	6	12	424	564	1/14/21	5-LOW	1	1	4118.83	3038.94	0.04	8798.17	2560.27	0.03	2/14/21	REG AIR
71	1	617	552	671		4-NOT SPECIFIED		13				30679.89				
473	2					4-NOT SPECIFIED		10			0.04					
601	6					4-NOT SPECIFIED	4	19			0.04					
397	4	695				5-LOW	1	. 5			0.03					
315	1	422	658	824	1/19/22	3-MEDIUM	1	. 8	2176.52	15484.36	0.05	40784.99	5018.1	0.14	2/19/21	TRUCK
706	6	638			1/20/21	2-HIGH	2	4	1245.46	5 19178.94	0.07	24489.84	8290.21	0.07	2/20/21	SHIP
487	1	669			1/21/22	3-MEDIUM	2				0.03					
552	2	624			1/22/23	3-MEDIUM	4	13			0.05					
88	3					2-HIGH	3				0.01					
175	5			450	1/24/21	4-NOT SPECIFIED	4	46	9493.72	14933.42	0.02	36037.58	8231.86	0.11	2/24/21	TRUCK
601	3	540	84	327	1/25/21	4-NOT SPECIFIED	2	49	126.76	6 16978.19	0	21487.35	1833.65	0.03	2/25/21	AIR
850	1	980	434	491	1/26/23	5-LOW	4	46	6507.25	18723.06	0.1	9474.62	2659.94	0.06	2/26/21	REG AIR
678	4	218			1/27/23	5-LOW	2	19			0	0200100		0.13		REG AIR
538	3	664	94	817	1/28/23	3-MEDIUM	1	. 8	5928.52	8056.05	0.02	41049.62	7204.25	0.15	2/28/21	AIR









FROM

lo supplycost s30bject

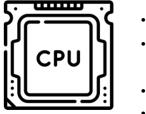
WHERE

SELECT

(lo quantity BETWEEN 11 AND 20) AND (lo orderdate <= 20210116); Retrieve required columns

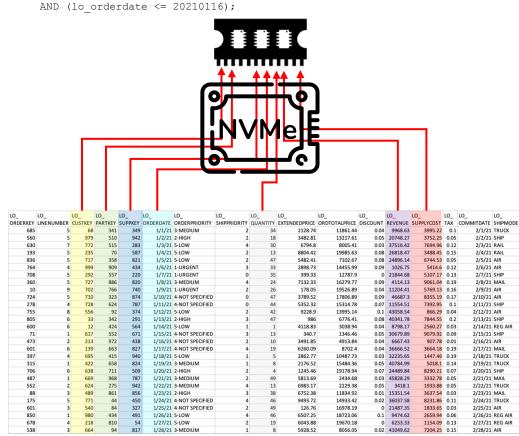
- ~MB per column
- Process Data in CPU
  - <0.1% for many queries!

#### With CHECK-FETCH



- Perform basic filtering in device
- Scratchpad can eliminate returning • intermediate results
- Bitwise operators: combine results ٠
- Extract only desired data

		Γ	Г	끧							7	7		
	LO	LO_ L	.0_	LO	LO_	LO	LO_	LO	LO_	LO_	LO_	LO_	LO_	LOLO
														COMMITDATE SHIPMODE
5	68	341	349		3-MEDIUM	2			11861.44		9968.63	3995.22		2/1/21 TRUCK
5		510	942	1/2/21		2			13217.61		20748.27	3752.25		2/2/21 SHIP
7		515	283			4					37516.42	7694.96	_	2/3/21 RAIL
5	235	70	587	1/4/21		2			19985.63		26818.47	3488.45		2/4/21 RAIL
5		358 909	821 434	1/5/21	1-URGENT	3			7102.67	0.08	24896.14 1026.75	6744.53 5414.6		2/5/21 AIR 2/6/21 AIR
4		557	220		1-URGENT	0			14455.99	0.09		5107.17		2/7/21 AIR
5		886	820		3-MEDIUM	4			16279.77	0.09	4114.13	9061.04		2/8/21 MAIL
9	702	766	740		1-URGENT	2			19526.89	0.04		5769.13		2/9/21 AIR
5	710	323	874		4-NOT SPECIFIED				17806.89	0.09	46687.3	8355.19		2/10/21 AIR
4	728	624	787	1/11/21	4-NOT SPECIFIED	0	44	5352.32	15314.78	0.07	11554.51	7392.95	0.1	2/11/21 SHIP
8	556	92	374	1/12/21		2			13995.14	0.1		866.29		2/12/21 AIR
6	33	342	291	1/13/21		3			6776.41	0.08		7844.55		2/13/21 SHIP
6		424	564	1/14/21		1			3038.94	0.04	8798.17	2560.27		2/14/21 REG AIR
1	617	552 972	671 438		4-NOT SPECIFIED 4-NOT SPECIFIED		20		1346.46 4913.84	0.05	30679.89	9079.92		2/15/21 SHIP 2/16/21 AIR
2		972	438		4-NOT SPECIFIED 4-NOT SPECIFIED				4913.84 8702.4	0.04	6667.43 36666.52	907.78		2/16/21 AIR 2/17/21 MAIL
4	695	415	940	1/1//21					10487.73	0.04		1447.46		2/18/21 TRUCK
1	422	658	824		3-MEDIUM	1			15484.36	0.05	40784.99	5018.1		2/19/21 TRUCK
6	638	711	509	1/20/21		2			19178.94	0.07	24489.84	8290.21		2/20/21 SHIP
1	669	968	787	1/21/21	3-MEDIUM	2	49	5813.69	2434.68	0.03	45828.29	3332.78	0.05	2/21/21 MAIL
2		275	942						2229.38	0.05	3418.1			2/22/21 TRUCK
3		861	856						11834.92					2/23/21 MAIL
	771	44	450				-10		14933.42					2/24/21 TRUCK
3														2/25/21 AIR
														2/26/21 REG AIR
1														2/27/21 REG AIR 2/28/21 AIR
	1 2 3 5 3	1 669 2 624 3 489 5 771 3 540 1 980 4 218	1         669         968           2         624         275           3         489         861           5         771         44           3         540         844           1         980         434           4         218         810	1         669         968         787           2         624         275         942           3         449         861         856           5         771         44         450           3         540         84         327           1         980         434         491           4         218         810         54	1         669         968         787         1/21/21           2         624         275         942         1/22/21           3         449         861         865         1/3/321           5         771         44         450         1/24/21           3         540         84         327         1/25/21           1         980         434         491         1/26/21           4         218         810         54         1/2/71	1         669         968         787         1/21/21         3-MEDIUM           2         624         275         942         1/22/21         3-MEDIUM           3         489         861         856         1/32/21         2-HGH           5         771         44         50         1/24/21         4-HGT SPECIFIED           3         540         84         327         1/26/21         4-HGT SPECIFIED           1         980         434         491         1/26/21         5-LOW           4         218         810         54         1/27/21         5-LOW	1         669         968         787         1/21/21         3-MEDIUM         2           2         624         275         942         1/22/21         3-MEDIUM         4           3         489         861         856         1/23/21         2-HIGH         3           5         771         44         450         1/24/21         4-NOT SPECIFIED         4           3         540         84         27         1/27/21         4-NOT SPECIFIED         2           1         580         434         491         1/26/21         5-LOW         4           4         218         810         54         1/27/21         5-LOW         4	1         669         968         787         1/21/21         3-MEDUM         2         493           2         624         275         942         1/22/13         3-MEDUM         4         13           3         489         861         856         1/23/21         2-MGH         3         38           5         771         44         450         1/24/21         4-NOT 5PECIFIED         4         46           3         540         84         327         1/25/21         5-LOW         2         49           1         980         434         431         1/26/21         5-LOW         2         49           4         218         810         5 L/27/21         5-LOW         2         49	1         669         968         767         1/21/21         3-MEDUM         2         49         5813.69           2         624         275         942         1/22/13         3-MEDUM         4         13         6983.17           3         489         861         856         1/23/21         2-MGH         3         38         6752.38           5         771         44         450         1/24/21         4-NOT 5PECIFIED         4         46         9493.72           3         540         84         327         1/25/21         5-LOW         2         649         12676           1         980         434         491         1/26/21         5-LOW         4         46         6507.25           4         218         810         5 L         1/27/21         5-LOW         4         46         6507.25	1         669         968         787         1/21/21.3-MEDUM         2         49         581.69         2434.68           2         624         275         942         1/22/21.3-MEDUM         4         13         6981.7         2229.88           3         489         861         856         1/23/21.2-MGH         3         38         6752.38         11834.92           5         771         44         450         1/24/21.4-NOT 5PECHED         4         46         9493.72         1933.42           3         540         84         327         1/25/21.4-NOT 5PECHED         2         49         12.676         16783.19           1         980         434         41         1/26/21.5-LOW         4         46         5607.25         1972.30           2         128         810         5/4         1/27/21.5-LOW         4         46         5607.25         1972.30	1         669         968         787         1/21/21         3-MEDUM         2         49         5813.69         2434.68         0.03           2         624         275         942         1/22/21         3-MEDUM         4         13         6981.7         2228         0.05           3         489         861         856         1/23/21         2-HGH         3         38         6752.38         11834.92         0.01           5         771         44         450         1/24/21         4NOT 5FCCHED         4         46         9493.72         14933.42         0.01           3         540         84         327         1/25/21         NOT 5FCCHED         2         49         12.676         16938.42         10           1         980         434         491         1/26/21         5-LOW         4         46         6507.25         1872.306         0.1           4         218         810         5-LOW         2         19         6043.88         1970.08         0	1         669         968         787         J/22/21         J-MEDIUM         2         49         5813.69         2434.68         0.00         4528.29           2         624         275         942         1/22/21         J-MEDIUM         4         13         698.17         2228.8         0.05         3418.1           3         489         861         856         1/22/21         2.HIGH         3         38         6752.38         11834.92         0.01         1551.54           5         771         44         450         1/2/21.2         HIGH         46         9493.72         14933.42         0.02         36037.63           3         540         84         327         1/2/21.1         HOT SPECIFED         2         49         126.76         16978.19         0.2         16037.85           1         980         84         327         1/2/21.15         HOW         4         46         6507.25         16978.16         0         9474.24           4         218         810         5 4         1/27/21.5 LOW         2         46         6507.25         1572.306         0         9474.82	1         669         968         767         1/21/21         3-MEDUM         2         49         581.69         2434.68         0.03         4582.89         332.78           2         624         275         994         1/22/21         3-MEDUM         4         13         6981.7         222.88         0.05         3418.1         133.88           3         489         861         856         1/23/21         2-HGH         3         38         6752.38         11834.92         0.01         15351.54         3637.54           5         771         44         450         1/2/21.21         HOH         4         46         9493.72         1493.42         0.01         15351.54         3637.54           3         540         84         327         1/2/21.41         HOT SPECIFIED         2         49         12.676         1978.19         0         24437.8         183.85         1473.54         1363.54           1         980         434         491         1/2/2/11.5-LOW         4         46         6507.25         1978.108         0         6253.33         154.00           4         218         810         54         1/2/7/21.5-LOW         2	1         669         968         787         1/1/2/1 3-MEDIUM         2         49         581 69         2434 68         0.03         45828.29         3332.78         0.05           2         624         275         942         1/3/2/1         3-MEDIUM         4         13         6698.17         222.83         0.05         3181.1         1933.88         0.05           3         489         861         656         1/2/2/1 2-HIGH         3         38         6752.38         11834.92         0.01         15351.54         3637.54         0.03           5         771         44         450         1/2/2/1 2-HIGH         4         46         9493.72         1433.42         0.01         15351.54         3637.54         0.03           3         540         84         327         1/2/2/1 4-HOT SPECIFIED         2         49         126.76         16978.19         0.02         36037.54         0.03         4845.85         0.03           1         980         84         491         1/2/6/11 5-LOW         4         46         6507.25         1872.36         0.1         9/47.42         265.94         0.6           4         218         810         1/2/7/11 5-LOW









lo suppkey,

lo supplycost FROM s30bject

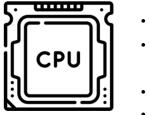
WHERE

SELECT

(lo quantity BETWEEN 11 AND 20) AND (lo orderdate <= 20210116); Retrieve required columns

- ~MB per column •
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  - <0.1% for many queries!

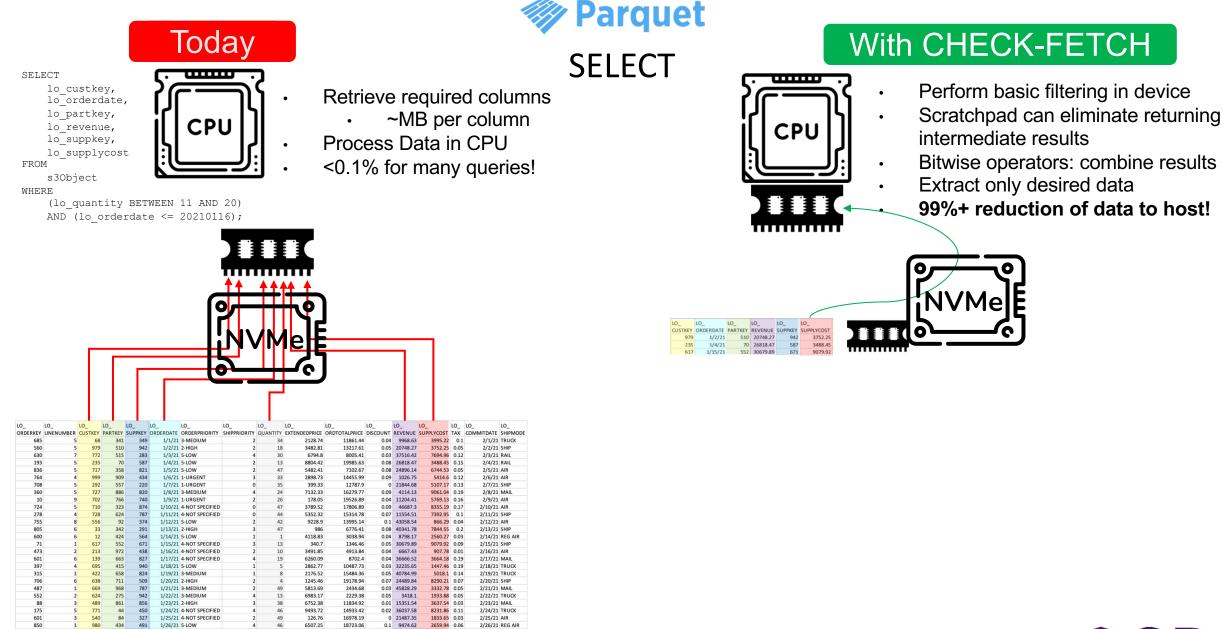
#### With CHECK-FETCH



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											٦	٦		
	LO_	LO_ LO		0	LO	LO	LO	.o_ L	0_ I	.0_	LO_	LO	LO_ L	0 L0
														OMMITDATE SHIPMOD
5	68	341	349		3-MEDIUM	2	34	2128.74	11861.44	0.04	9968.63	3995.22		2/1/21 TRUCK
5		510	942		2-HIGH	2	18	3482.81	13217.61		20748.27	3752.25	0.05	2/2/21 SHIP
7			283	1/3/21		4	30	6794.8	8005.41		37516.42			2/3/21 RAIL
5		70	587	1/4/21		2	13	8804.42	19985.63		26818.47	3488.45		2/4/21 RAIL
5		358	821 434	1/5/21		2	47	5482.41 2898.73	7102.67 14455.99	0.08	24896.14 1026.75	6744.53		2/5/21 AIR
4		557	220		1-URGENT 1-URGENT	3	33	2898.73	14455.99		21844.68	5414.6 5107.17		2/6/21 AIR 2/7/21 SHIP
5		886	820		3-MEDIUM	4	24	7132.33	16279.77	0.09	4114.13	9061.04		2/8/21 MAIL
9	702	766	740		1-URGENT	2	26	178.05	19526.89		11204.41	5769.13		2/9/21 AIR
5		323	874		4-NOT SPECIFIED	0	47	3789.52	17806.89	0.09	46687.3	8355.19		2/10/21 AIR
4	728	624	787	1/11/21	4-NOT SPECIFIED	0	44	5352.32	15314.78	0.07	11554.51	7392.95	0.1	2/11/21 SHIP
8	556	92	374	1/12/21	5-LOW	2	42	9228.9	13995.14		43058.54	866.29	0.04	2/12/21 AIR
6		342	291	1/13/21		3	47	986	6776.41		40341.78	7844.55		2/13/21 SHIP
6		424	564	1/14/21		1	1	4118.83	3038.94	0.04	8798.17	2560.27	_	2/14/21 REG AIR
1		552	671		4-NOT SPECIFIED	3	13	340.7	1346.46		30679.89	9079.92		2/15/21 SHIP
2		972	438 827		4-NOT SPECIFIED 4-NOT SPECIFIED	2	10	3491.85 6260.09	4913.84 8702.4	0.04	6667.43 36666.52	907.78 3664.18		2/16/21 AIR 2/17/21 MAIL
4	695	415	940	1/17/21		4	19	2862.77	10487.73		32235.65	1447.46		2/18/21 TRUCK
1	422	658	824			1	8	2176.52	15484.36					2/19/21 TRUCK
6		711	509			2	4	1245.46	19178.94					2/20/21 SHIP
1	669	968	787	1/21/21	3-MEDIUM	2	49	5813.69	2434.68	0.03	45828.29	3332.78	0.05	2/21/21 MAIL
2		275	942			4	13	6983.17	2229.38	0.05	3418.1			2/22/21 TRUCK
3		861	856			3	38	6752.38	11834.92					2/23/21 MAIL
														2/24/21 TRUCK
														2/25/21 AIR
														2/26/21 REG AIR 2/27/21 REG AIR
1														2/28/21 AIR
	6 1 2 3 5 3 1 4	6         638           1         669           2         624           3         489           5         771           3         540           1         980	6         638         711           1         669         968           2         624         275           3         489         861           5         771         44           3         540         84           1         980         434           4         218         810	6         638         711         509           1         669         968         787           2         624         275         942           3         489         861         856           5         771         44         450           3         540         84         327           1         980         434         491           4         218         810         54	6         638         711         509         1/20/21           1         669         968         787         1/21/21           2         664         275         942         1/22/21           3         489         861         856         1/23/21           5         771         44         450         1/24/21           3         540         64         327         1/25/21           1         980         434         491         1/26/21           4         218         810         54         1/27/21	6         638         711         509         1/20/21 2-HIGH           1         669         968         787         1/21/21 3-MEDIUM           2         624         275         942         1/22/21 3-MEDIUM           3         489         861         856         1/23/21 2-HIGH           5         771         44         4405         1/24/21 4-MOT SPECIFIED           3         540         64         327         1/25/21 4-MOT SPECIFIED           1         980         444         491         1/26/21 5-LOW           4         218         810         54         1/27/21 5-LOW	6         638         711         509         1/20/21         2-HGH         2           1         669         968         787         1/21/21         3-MEDIUM         2           2         624         275         942         1/22/21         3-MEDIUM         4           3         489         861         856         1/23/21         2-HGH         3           5         771         44         450         1/2/4/21         4-NOT SPECIFIED         4           3         540         84         327         1/25/21         4-NOT SPECIFIED         2           1         960         434         491         1/26/21         5-LOW         4           218         810         54         1/27/21         5-LOW         2	6         638         711         509         1/20/21         2-HiGH         2         44           1         669         968         787         1/21/21         3-MEDUM         2         49           2         624         275         942         1/22/21         3-MEDUM         4         13           3         489         861         856         1/23/21         2-HiGH         3         38           5         771         44         450         1/24/21         4-NOT SPECIFIED         4         466           3         540         84         327         1/25/21         4-NOT SPECIFIED         2         49           1         960         434         491         1/26/21         5-LOW         4         466           4         218         810         54         1/27/21         5-LOW         4         46	6         638         711         509         1/20/21         2-10(H)         2         4         1245.46           1         669         968         787         1/21/21         3-MEDIUM         2         49         5813.69           2         624         275         942         1/22/21         3-MEDIUM         4         13         6693.17           3         489         861         856         1/23/21         2-HIGH         3         38         6752.38           5         771         44         450         1/24/21         4-NOT SPECIFIED         4         69993.72           3         540         64         327         1/25/21         4-NOT SPECIFIED         2         49         1226.76           4         218         810         54         1/27/21         5-LOW         4         46         6507.25           4         218         810         54         1/27/21         5-LOW         4         46         6507.25	6         638         711         509         1/20/21         2-10(H)         2         4         1245.46         19178.48           1         669         968         787         1/21/21         3-MEDUM         2         49         5813.69         2434.68           2         624         275         942         1/22/21         3-MEDUM         4         13         6698.17         2223.38           3         489         861         856         1/23/21         2-HIGH         3         38         6752.38         1183492           5         771         44         450         1/24/21.4 + NOT SPECIFIED         4         69993.72         14933.42           3         540         84         327         1/25/21.4 + NOT SPECIFIED         2         49         126.76         16978.19           1         960         434         401         1/26/11.5 + LOW         4         46         6507.25         1872.306           4         218         810         54         1/27/21.5 + LOW         2         19         6643.88         19670.18	6         638         711         509         1/20/21         2-HiGH         2         4         1245.46         19178.94         0.07           1         669         968         787         1/21/21         3-MEDIUM         2         49         5813.69         2434.68         0.03           2         624         275         942         1/22/21         3-MEDIUM         4         13         6698.17         2229.38         0.05           3         489         861         856         1/23/21         2-HIGH         3         38         6752.38         11834.92         0.01           5         771         44         450         1/24/21         4-HOT SPECIFIED         4         46         690.372         14933.42         0.02           3         540         84         327         1/25/21         4-HOT SPECIFIED         2         49         126.76         16978.19         0           1         960         434         491         1/26/21         5-LOW         4         46         690.73.8         10872.06         0.1           4         218         810         54         1/27/21.5-LOW         2         19         66043.88	6         638         711         509         1/20/21 2-HGH         2         4         1245.46         1917.84         0.07         2488.94           1         669         968         787         1/21/21         3-HEDIUM         2         49         5813.69         2434.68         0.03         45828.29           2         664         275         942         1/2/21         3-HEDIUM         4         13         6698.17         222.93         0.05         3418.1           3         489         861         856         1/2/21.2         1-HEDIUM         4         38         6752.38         1.00.1         15351.54           5         777         44         405         1/2/21.4         1-4075 SPCIFED         4         46         993.72         1439.34         0.02         5037.58           5         577.1         44         405         1/2/21.4         1407 SPCIFED         2         49         126.76         16978.19         0         2187.35           1         580         8.4         327         1/2/21.4         407 SPCIFED         2         49         126.76         16978.19         0         2187.35           1         580         8.	6         638         711         509         1/20/21         2-10(H)         2         4         1245.46         19178.94         0.07         2448.94         8290.21           1         669         968         787         1/21/21         3-MEDIUM         2         49         5813.69         2434.68         0.03         4582.29         3332.78           2         624         275         942         1/22/21         3-MEDIUM         4         13         6698.17         2229.38         0.05         348.1         1933.88           3         489         861         856         1/23/21         2-HIGH         3         38         6752.38         11834.92         0.01         1535.15         3607.58         8231.68           5         771         44         450         1/42/41         407 SPECIFIED         2         49         126.76         16978.19         0         21487.35         1833.65           5         507         14         426         126.76         16978.19         0         21487.35         1833.65           5         500         43         12/25/21         FLOW         4         46         6507.25         1073.06         0 <td< td=""><td>6         638         711         509         1/20/21 2-HIGH         2         4         1/24546         19178.94         0.07         24489.84         8290.21         0.07           1         669         968         787         1/2/21         3-MEDIUM         2         49         5813.69         2434.68         0.03         45828.29         332.78         0.05           2         624         275         942         1/22/21         3-MEDIUM         4         13         6698.17         222.93         0.05         4348.1         9488.0         0.55         363.77         44         405         1/2/21.2 -HIGH         3         38         6752.38         11834.92         0.001         15351.54         0.61         363.75.8         0.316         0.11         363.75.8         0.316         0.11         363.75.8         0.316         0.11         363.75.8         0.315.8         0.11         354.0         0.37         1/25/21.4         4/05 FPCIFIED         4         46         6507.25         16978.19         0         2487.85         0.03         1.351.94         0.03         354.0         0.13         374.0         265.94         0.06         3.33         1.54.0         0.13         374.02         26</td></td<>	6         638         711         509         1/20/21 2-HIGH         2         4         1/24546         19178.94         0.07         24489.84         8290.21         0.07           1         669         968         787         1/2/21         3-MEDIUM         2         49         5813.69         2434.68         0.03         45828.29         332.78         0.05           2         624         275         942         1/22/21         3-MEDIUM         4         13         6698.17         222.93         0.05         4348.1         9488.0         0.55         363.77         44         405         1/2/21.2 -HIGH         3         38         6752.38         11834.92         0.001         15351.54         0.61         363.75.8         0.316         0.11         363.75.8         0.316         0.11         363.75.8         0.316         0.11         363.75.8         0.315.8         0.11         354.0         0.37         1/25/21.4         4/05 FPCIFIED         4         46         6507.25         16978.19         0         2487.85         0.03         1.351.94         0.03         354.0         0.13         374.0         265.94         0.06         3.33         1.54.0         0.13         374.02         26

												_				
.0_	LO_	LO_	LO_	LO_	LO_	LO_	LO_	LO_	LO_	LO_	LO_	LO_	LO_	LO_	LO_	LO_
						ORDERPRIORITY										
685			341			3-MEDIUM	2	34			0.04					TRUCK
560 630			510			2-HIGH 5-LOW	2	18								
193			70			5-LOW	4	13								
836			358			5-LOW	2	47			0.08					
764			909			1-URGENT	3	33								
708			557			1-URGENT	0									
360	5	727	886	5 8	20 1/8/21	3-MEDIUM	4	24	7132.33	16279.77	0.09	4114.13	9061.04	0.19		
10	9	702	766	5 7	40 1/9/21	1-URGENT	2	26	178.05	19526.89	0.04	11204.41	5769.13	0.16	2/9/21	AIR
724			323			4-NOT SPECIFIED	0	47								
278			624			4-NOT SPECIFIED	0	44				11554.51				
755			92			5-LOW	2	42								
0.05			342			2-HIGH	3	47								
805		12	424			5-LOW		13								
600		617	553	6	71 1/15/21									0.03		
600 71	. 1		552			4-NOT SPECIFIED 4-NOT SPECIFIED	3							0.01		AIR
600 71 473	1	213	972	2 4	38 1/16/21	4-NOT SPECIFIED	3	10	3491.85	4913.84	0.04	6667.43	907.78			
600 71	. 1 2 . 6	213 139		2 4 8 8	38 1/16/21 27 1/17/21		2		3491.85 6260.09	4913.84 8702.4	0.04	6667.43 36666.52	907.78 3664.18	0.19	2/17/21	MAIL
600 71 473 601	1 2 6	213 139 695	972 663	4 8 8 9	38 1/16/21 27 1/17/21 40 1/18/21	4-NOT SPECIFIED 4-NOT SPECIFIED	2	10 19	3491.85 6260.09 2862.77	4913.84 8702.4 10487.73	0.04	6667.43 36666.52 32235.65	907.78 3664.18 1447.46	0.19	2/17/21 2/18/21	MAIL TRUCK
600 71 473 601 397	1 2 6 4	213 139 695 422	972 663 415	2 4 8 8 9 9 8 8	38         1/16/21           27         1/17/21           40         1/18/21           24         1/19/21	4-NOT SPECIFIED 4-NOT SPECIFIED 5-LOW	2 4	10 19 5	3491.85 6260.09 2862.77 2176.52	4913.84 8702.4 10487.73 15484.36	0.04 0.04 0.03 0.05	6667.43 36666.52 32235.65 40784.99	907.78 3664.18 1447.46 5018.1	0.19	2/17/21 2/18/21 2/19/21	MAIL TRUCK
600 71 473 601 397 315 706 487	1 2 6 4 1 6 6	213 139 695 422 638 669	972 663 415 658 711 968	2 4 8 8 9 9 8 8 1 5 8 7	38         1/16/21           27         1/17/21           40         1/18/21           24         1/19/21           09         1/20/21           87         1/21/21	4-NOT SPECIFIED 4-NOT SPECIFIED 5-LOW 3-MEDIUM 2-HIGH 3-MEDIUM	2 4 1 1 2 2 2	10 19 5 8 4 49	3491.85 6260.09 2862.77 2176.52 1245.46 5813.69	4913.84 8702.4 10487.73 15484.36 19178.94 2434.68	0.04 0.04 0.03 0.05 0.07 0.03	6667.43 36666.52 32235.65 40784.99 24489.84 45828.29	907.78 3664.18 1447.46 5018.1 8290.21 3332.78	0.19 0.19 0.14 0.07 0.05	2/17/21 2/18/21 2/19/21 2/20/21 2/20/21 2/21/21	MAIL TRUCK TRUCK SHIP MAIL
600 71 473 601 397 315 706 487 552	1 2 6 4 1 1 6 7 1 2	213 139 695 422 638 669 624	972 663 415 658 711 968 275	2 4 8 8 9 9 8 8 1 5 8 7 9 9	38         1/16/21           27         1/17/21           40         1/18/21           24         1/19/21           09         1/20/21           87         1/21/21           42         1/22/21	4-NOT SPECIFIED 4-NOT SPECIFIED 5-LOW 3-MEDIUM 2-HIGH 3-MEDIUM 3-MEDIUM	2 4 1 1 2 2 2 4	10 19 5 8 4 4 9 13	3491.85 6260.09 2862.77 2176.52 1245.46 5813.69 6983.17	4913.84 8702.4 10487.73 15484.36 19178.94 2434.68 2229.38	0.04 0.03 0.05 0.07 0.03 0.03	6667.43 36666.52 32235.65 40784.99 24489.84 45828.29 3418.1	907.78 3664.18 1447.46 5018.1 8290.21 3332.78 1933.88	0.19 0.19 0.14 0.07 0.05 0.05	2/17/21 2/18/21 2/19/21 2/20/21 2/21/21 2/22/21	MAIL TRUCK TRUCK SHIP MAIL TRUCK
600 71 473 601 397 315 706 487 552 88	1 2 6 4 1 1 6 7 1 2 2 3	213 139 695 422 638 669 624 489	972 663 415 658 711 968 275 861	2 4 8 8 5 9 8 8 8 8 8 8 8 7 5 9 1 8	38         1/16/21           27         1/17/21           40         1/18/21           24         1/19/21           09         1/20/21           87         1/21/21           42         1/22/21           56         1/23/21	4-NOT SPECIFIED 4-NOT SPECIFIED 5-LOW 3-MEDIUM 2-HIGH 3-MEDIUM 3-MEDIUM 2-HIGH	2 4 1 1 2 2 2 4 3	10 19 5 8 4 4 9 13 38	3491.85 6260.09 2862.77 2176.52 1245.46 5813.69 6983.17 6752.38	4913.84 8702.4 10487.73 15484.36 19178.94 2434.68 2229.38 11834.92	0.04 0.03 0.05 0.07 0.03 0.05 0.05	6667.43 36666.52 32235.65 40784.99 24489.84 45828.29 3418.1 15351.54	907.78 3664.18 1447.46 5018.1 8290.21 3332.78 1933.88 3637.54	0.19 0.19 0.14 0.07 0.05 0.05 0.05	2/17/21 2/18/21 2/19/21 2/20/21 2/21/21 2/22/21 2/22/21 2/23/21	MAIL TRUCK TRUCK SHIP MAIL TRUCK MAIL
600 71 473 601 397 315 706 487 552 88 175	1 2 6 4 1 6 1 1 2 2 3 3 5	213 139 695 422 638 669 624 489 771	972 663 419 658 711 968 275 861 44	2 4 8 8 5 9 8 8 1 5 8 7 5 9 1 8 4 4	38         1/16/21           27         1/17/21           40         1/18/21           24         1/19/21           09         1/20/21           87         1/21/21           42         1/22/21           56         1/23/21           50         1/24/21	4-NOT SPECIFIED 4-NOT SPECIFIED 5-LOW 3-MEDIUM 2-HIGH 3-MEDIUM 2-HIGH 4-NOT SPECIFIED	2 4 1 1 2 2 2 4 4 3 4	10 19 5 8 4 49 13 38 46	3491.85 6260.09 2862.77 2176.52 1245.46 5813.69 6983.17 6752.38 9493.72	4913.84 8702.4 10487.73 15484.36 19178.94 2434.68 2229.38 11834.92 14933.42	0.04 0.03 0.05 0.07 0.03 0.05 0.01 0.01	6667.43 36666.52 32235.65 40784.99 24489.84 45828.29 3418.1 15351.54 36037.58	907.78 3664.18 1447.46 5018.1 8290.21 3332.78 1933.88 3637.54 8231.86	0.19 0.19 0.14 0.07 0.05 0.05 0.05 0.03 0.11	2/17/21 2/18/21 2/19/21 2/20/21 2/21/21 2/22/21 2/23/21 2/23/21 2/24/21	MAIL TRUCK TRUCK SHIP MAIL TRUCK MAIL TRUCK
600 71 473 601 397 315 706 487 552 88 175 601	1 2 6 4 1 6 1 1 2 3 3 5 5 3	213 139 695 422 638 669 624 489 771 540	972 663 419 658 711 968 275 861 44 84	2 4 8 8 5 9 8 8 1 5 5 9 1 5 5 9 1 8 4 4 4 3	38         1/16/21           27         1/17/21           40         1/18/21           24         1/19/21           09         1/20/21           87         1/21/21           56         1/23/21           50         1/24/21           27         1/25/21	4-NOT SPECIFIED 4-NOT SPECIFIED 5-LOW 3-MEDIUM 2-HIGH 3-MEDIUM 3-MEDIUM 2-HIGH 4-NOT SPECIFIED 4-NOT SPECIFIED	2 4 1 1 2 2 4 3 4 2 2 4 2 2 2 2 2 2 2 2 2 2 2 2	10 19 5 8 4 49 13 38 46 49	3491.85 6260.09 2862.77 2176.52 1245.46 5813.69 6983.17 6752.38 9493.72 126.76	4913.84 8702.4 10487.73 15484.36 19178.94 2434.68 2229.38 11834.92 14933.42 16978.19	0.04 0.03 0.05 0.07 0.03 0.05 0.01 0.02 0.02	6667.43 36666.52 32235.65 40784.99 24489.84 45828.29 3418.1 15351.54 36037.58 21487.35	907.78 3664.18 1447.46 5018.1 8290.21 3332.78 1933.88 3637.54 8231.86 1833.65	0.19 0.19 0.14 0.07 0.05 0.05 0.05 0.03 0.11	2/17/21 2/18/21 2/19/21 2/20/21 2/21/21 2/22/21 2/23/21 2/23/21 2/24/21 2/25/21	MAIL TRUCK TRUCK SHIP MAIL TRUCK AIR
600 71 473 601 397 315 706 487 552 88 175 601 850	1 2 6 4 1 6 1 1 2 3 3 5 5 3 3 1	213 139 695 422 638 669 624 489 771 540 980	972 663 419 658 711 968 275 861 44 84 84 84	2 4 8 8 5 9 8 8 1 5 5 9 1 5 5 9 1 8 1 4 4 3 4 4	38         1/16/21           27         1/17/21           40         1/18/21           24         1/19/21           09         1/20/21           87         1/21/21           42         1/22/21           56         1/23/21           50         1/24/21           27         1/25/21           91         1/26/21	4-NOT SPECIFIED 4-NOT SPECIFIED 5-LOW 3-MEDIUM 2-HIGH 3-MEDIUM 2-HIGH 4-NOT SPECIFIED 4-NOT SPECIFIED 5-LOW	2 4 1 1 2 2 2 4 3 3 4 2 2 4 4 2 4	10 19 5 8 4 49 13 38 46 49 49 46	3491.85 6260.09 2862.77 2176.52 1245.46 5813.69 6983.17 6752.38 9493.72 126.76 6507.25	4913.84 8702.4 10487.73 15484.36 19178.94 2434.68 2229.38 11834.92 14933.42 16978.19 18723.06	0.04 0.03 0.05 0.07 0.03 0.05 0.01 0.02 0.02 0.01	6667.43 36666.52 32235.65 40784.99 24489.84 45828.29 3418.1 15351.54 36037.58 21487.35 9474.62	907.75 3664.18 1447.46 5018.1 8290.21 3332.75 1933.88 3637.54 8231.86 1833.65 2659.94	0.19 0.19 0.14 0.07 0.05 0.05 0.05 0.05 0.03 0.11 0.03	2/17/21 2/18/21 2/19/21 2/20/21 2/21/21 2/22/21 2/23/21 2/23/21 2/24/21 2/25/21 2/25/21	MAIL TRUCK TRUCK SHIP MAIL TRUCK MAIL TRUCK AIR REG A
600 71 473 601 397 315 706 487 552 88 175 601	1 2 6 4 1 1 2 3 3 5 5 3 3 1 1	213 139 695 422 638 669 624 489 771 540 980 218	972 663 419 658 711 968 275 861 44 84	2 4 8 8 5 9 5 8 8 8 1 5 5 9 1 8 4 4 4 3 4 4 4 0	38         1/16/21           27         1/17/21           40         1/18/21           24         1/19/21           9         1/20/21           87         1/21/21           42         1/22/21           56         1/23/21           50         1/24/21           27         1/25/21           91         1/26/21           54         1/27/21	4-NOT SPECIFIED 4-NOT SPECIFIED 5-LOW 3-MEDIUM 2-HIGH 3-MEDIUM 3-MEDIUM 2-HIGH 4-NOT SPECIFIED 4-NOT SPECIFIED	2 4 1 1 2 2 4 3 4 2 2 4 2 2 2 2 2 2 2 2 2 2 2 2	10 19 5 8 4 49 13 38 46 49	3491.85 6260.09 2862.77 2176.52 1245.46 5813.69 6983.17 6752.38 9493.72 126.76 6507.25 6607.25	4913.84 8702.4 10487.73 15484.36 19178.94 2434.68 2229.38 11834.92 14933.42 16978.19 18723.06 19670.18	0.04 0.03 0.05 0.07 0.03 0.05 0.01 0.02 0.01 0.01 0.01	6667.43 36666.52 32235.65 40784.99 24489.84 45828.29 3418.1 15351.54 36037.58 21487.35 9474.62	907.75 3664.18 1447.46 5018.1 8290.21 3332.75 1933.85 3637.54 8231.86 1833.65 2659.94 1154.05	0.19 0.19 0.14 0.07 0.05 0.05 0.05 0.03 0.03 0.03 0.03 0.03	2/17/21 2/18/21 2/19/21 2/20/21 2/22/21 2/22/21 2/22/21 2/24/21 2/25/21 2/25/21 2/26/21	MAIL TRUC TRUC SHIP MAIL TRUC MAIL TRUC AIR REG REG



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94

1/27/21 5-LOW

817 1/28/21 3-MEDIUN

6043.88

5928.52

19670.18

8056.05

6253.33

0.02 41049.62

0

1154.09 0.13

7204.25 0.15

2/27/21 REG AIR

2/28/21 AIR

218 810 54

678

538



AirMettle's methodology for enabling in-device analytical offloads can be implemented in both the firmware and the hardware of our commercial enterprise SSDs.

- Sebastien Jean , CTO





This work was supported with government support under

- 2135007 awarded by the National Science Foundation
- NA22OAR0210591 awarded by the National Oceanic and Atmospheric Administration
- NA23OAR0210342 awarded by the National Oceanic and Atmospheric Administration
- DE-SC0024750 awarded by the US Department of Energy









**SNIA DEVELOPER CONFERENCE** 



September 16-18, 2024 Santa Clara, CA

# **Computational Storage Service**

Analytical Data Platform with Intelligent Analytics Offload Donpaul Stephens AirMettle, Inc. donpaul@airmettle.com



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