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On Managing LTO-10 for AI Applications

Includes a summary on a Misunderstood Topic: UBER vs Data Operational Durability

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UBER vs. Data Durability “Nines”

- **Uncorrectable Bit Error Rate (UBER)** is a foundational technology defining **theoretical reliability metric** that quantifies the probability of an unrecoverable error after error correction decoding in ideal conditions. It is used to measure the strength of the **deeply interleaved two-dimensional ECC architecture** in LTO formats, which enables extremely low probabilities of uncorrectable errors (e.g., one bit error per ~10^{20} user bits transferred for LTO-9) under assumptions of independent random errors.
- However, **UBER does not represent full real-world data durability** on its own. It does not account for additional failure modes encountered in operational environments—such as load/unload failures, media handling damage, environmental stress, mechanical wear, correlated errors, or debris-related effects—which can contribute to data loss even when the underlying ECC performance is excellent. Because the theoretical UBER calculation assumes random and uncorrelated bit errors, it cannot fully capture these operational risks.
- As a result, standalone LTO systems typically provide roughly **four nines of operational durability** when all real-world factors are considered. To attain significantly higher effective durability (e.g., 10–15 nines), additional protection mechanisms such as **object-level replication or erasure coding** are required.
- **QTM’s ASCS with 2DEC (Two-Dimensional Erasure Coding)** architecture extends operational durability to **up to 15 nines** while maintaining efficient protection overhead (<~40%), providing **substantially stronger resilience** in practical use cases. This broader durability reflects the combined effect of format-level ECC plus system-level protection against a wide range of real-world faults.

https://www.lto.org/wp-content/uploads/2022/08/LTO-UBER-Technical-Paper-August-2022.pdf

ASCS + 2DEC RAIL Configuration –

Real-World Field Results

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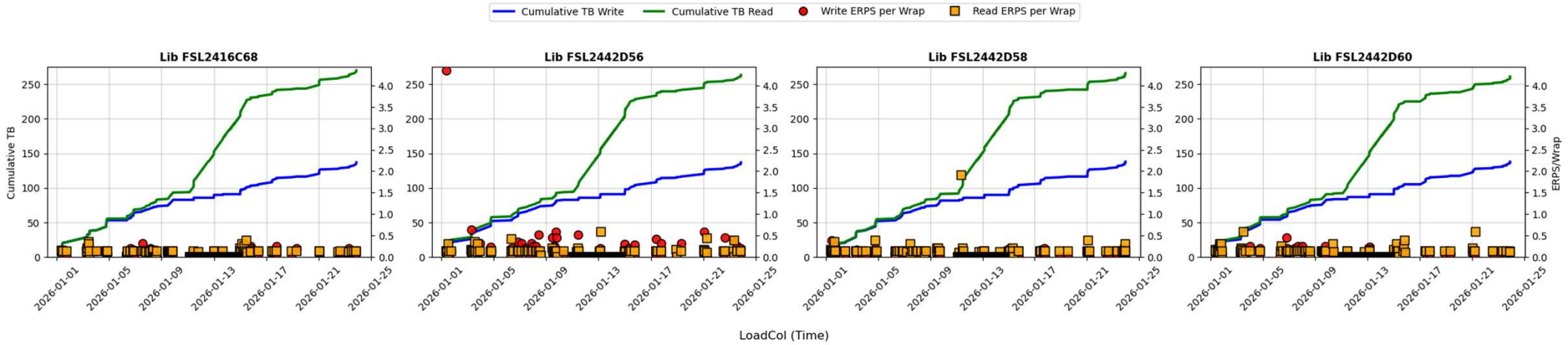
Overall ASCS Performance using 2DEC and RAIL Concept

RAIL Libraries	# of Loads	PB Written	PB Read	Xfer Rate MB/s per Drive	Rewrite Rate %	ReadErr Rate %	Write ERP/Wrap	Read ERP/Wrap	# of Hard Errors
Library #1	1,987	4.047	4.103	374	0.818	0.210	0.08	0.14	6
Library #2	1,816	3.872	3.898	375	0.800	0.203	0.08	0.14	2
Library #3	1,841	3.865	3.917	376	0.982	0.239	0.03	0.14	0
Library #4	1,796	3.831	3.841	374	0.922	0.348	0.08	0.14	2
Library #5	1,842	3.922	3.951	374	0.954	0.261	0.03	0.14	2
Grand Total	9,282	19.538	19.711	374	0.894	0.251	0.06	0.14	12

- 5 Library each 5 LTO-9 FH drives operating in 2DEC Erasure code architecture
- Over 14 months, ~20 PB data writes with full Fixity Checks
- Aggregated Xfer rate per Library is 1.870 GB/s
- Aggregated RAIL Xfer Rate is 9.350 GB/s

ASCS with 2DEC using RAIL based Flash + LTO-9



	Total TB_Write	Total TB_Read	Average write_erps_ perWrap	Average of read_erps_ perWrap	Xfer MB/s
FSL2416C68	137	270	0.075	0.039	389
FSL2442D56	137	263	0.197	0.043	388
FSL2442D58	138	266	0.037	0.049	392
FSL2442D60	138	261	0.092	0.044	391
Grand Total	138	270	0.100	0.044	392

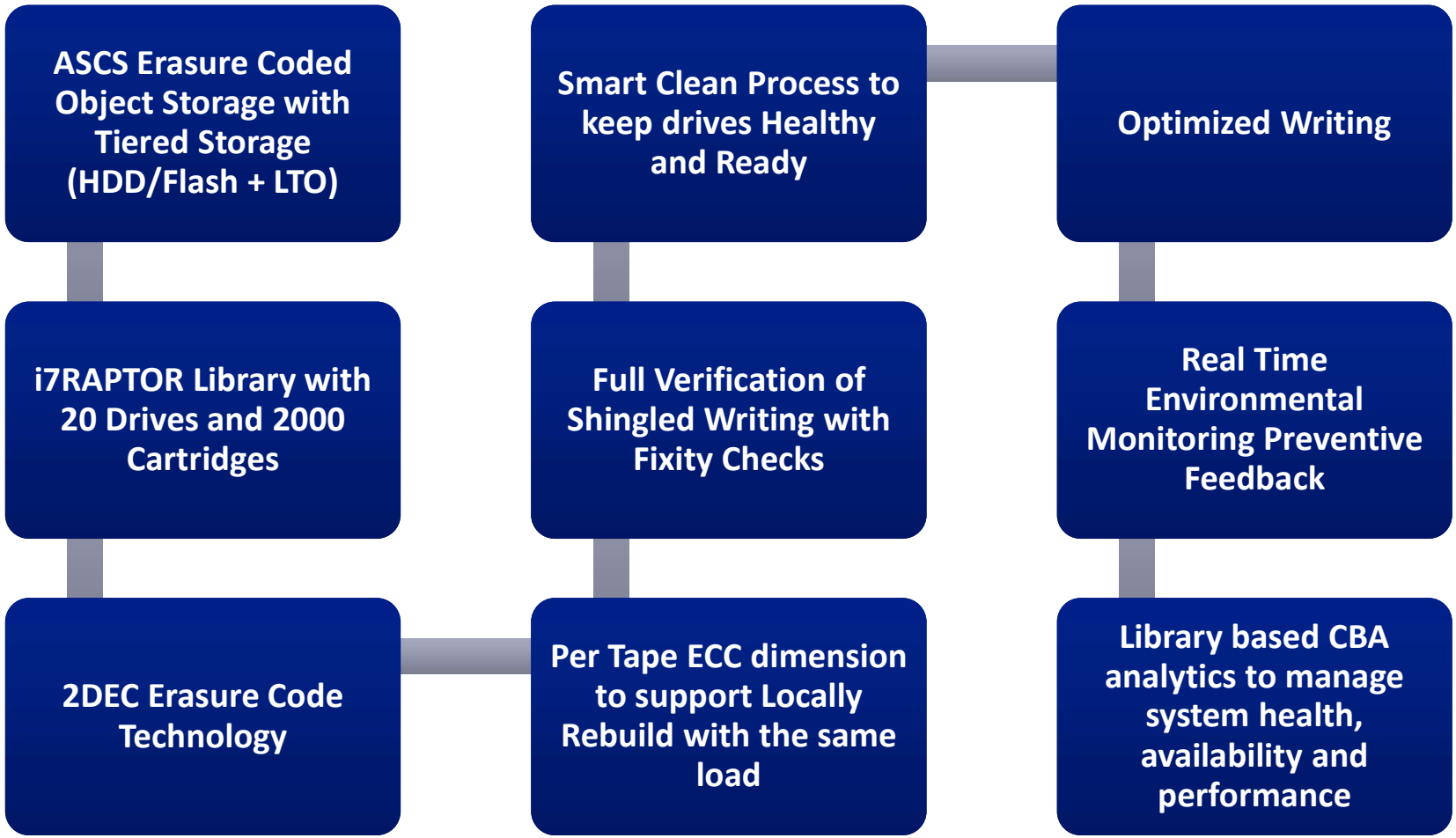
- Only last 2 months of data
- 100% Fixity Checks by separate Reads
- Cumulative Writes (blue traces)
- Cumulative Read (green traces)
- Write Mode ERP events (blue dots)
- Read Mode ERP events (Orange dots)
- **Overall Tape Motion Efficiency is 87%**

- Don’t be misled by theoretical “Uber Nines” (e.g., 12 nines).
- What truly matters is operational NINES; it is extremely good however still only ~4 NINES
- LTO-10 small sample shows dominated by Tracking and Loads

Tape Alert											
Error Type	**No Alert**	**3**	**4**	**11**	**18**	**21**	**33**	**35**	**58**	**Grand Total**	**NINES**
No Error	34552			235	1	239		208		35235	
Firmware									1	1	4.5
LOAD			10				16			26	3.1
Read		3								3	4.1
Tracking		3								3	4.1
Grand Total	**34552**	**6**	**10**	**235**	**1**	**239**	**16**	**208**	**1**	**35268**	

- TA 3 - Hard Error
- TA 4 Media
- TA 11: Cleaning tape present
- 18: Tape Directory Corrupted - 21: Periodic leaning Required
- 33: Eject Media – can't tread
- 35: Humidity Alert
- 58: FW problem

QTM Strategy for AI and LTO



QTM's Strategy and Vision
w/ LTO-10 Test Sample

From Carl Watts LinkedIn Post on The Migration Tax:

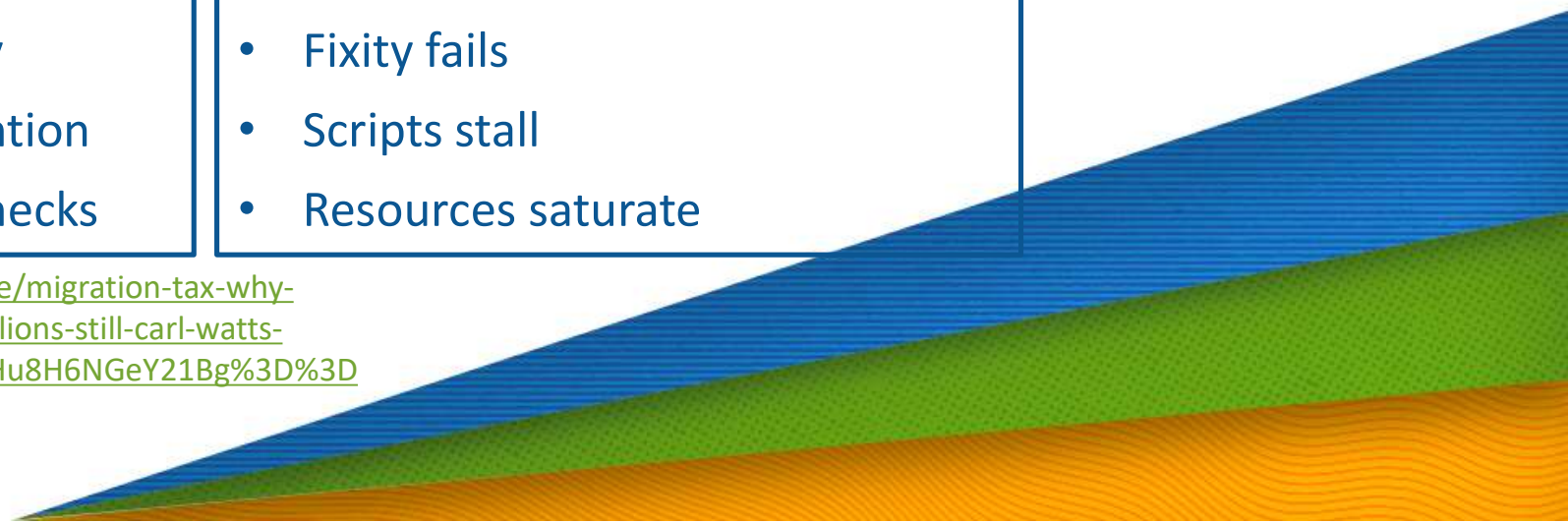
Assume Ideal Conditions.

- All tapes readable
- All files intact
- All drives healthy
- No queue contention
- No ingest bottlenecks

That's not real life. In production:

- Drives fail
- Mounts timeout
- Fixity fails
- Scripts stall
- Resources saturate

https://www.linkedin.com/pulse/migration-tax-why-moving-34pb-shouldnt-cost-millions-still-carl-watts-m1o0c/?trackingId=xnh72sUiSHu8H6NGeY21Bg%3D%3D



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LTO-10 Drive & Media Sniff Test using 19 drives and 19 Media

Overall great performance with excellent rewrites and read error performance

Drives	# of Loads	GB Data written	GB data Read	Write ERP/Wrap	Read ERP/Wrap	ReWrite /FWD	ReWrite /REV	Read Error Rate	Tracking Metric	XFER MB/s	Hard Err Events	Max Meter tape Moved
1	14	14,902.7	14,817.9	0.02	0.27	19.2%	0.4%	0.1%	0.19	328	0	491,870
2	11	4,639.6	4,650.0	0.11	0.44	1.5%	1.2%	0.1%	0.00	380	0	148,042
3	10	8,769.9	8,778.2	0.01	0.30	1.1%	0.5%	0.1%	0.00	192	0	273,419
4	8	13,823.0	13,824.2	0.00	0.22	1.0%	0.5%	0.1%	0.00	279	0	424,928
5	12	15,247.1	16,345.5	0.01	0.23	1.0%	0.5%	0.1%	0.00	176	0	507,688
6	7	4,641.5	5,664.1	0.01	0.32	0.3%	0.4%	0.1%	0.00	324	0	161,919
7	20	13,931.2	13,889.5	0.04	0.26	1.0%	0.5%	0.1%	0.01	290	0	492,121
8	10	12,328.8	12,342.2	0.01	0.24	1.0%	0.4%	0.1%	0.00	195	0	397,334
9	11	22,815.3	24,925.7	0.01	0.19	1.0%	0.5%	0.1%	0.01	264	0	738,089
10	4	1,074.4	1,437.4	0.00	1.47	0.5%	0.5%	0.1%	0.00	348	0	53,096
11	9	6,539.7	6,546.9	0.07	0.35	1.0%	0.4%	0.1%	0.00	250	0	212,551
12	19	14,920.2	15,016.2	0.05	0.23	1.0%	0.4%	0.1%	0.01	285	0	495,426
13	10	11,403.5	11,413.0	0.02	0.25	1.0%	0.4%	0.1%	0.00	287	0	363,458
14	9	21,700.0	26,028.0	0.01	0.18	1.0%	0.5%	0.1%	0.01	251	0	746,396
15	16	14,902.2	14,849.6	0.01	0.25	0.5%	0.5%	0.1%	0.02	362	0	490,384
16	14	8,478.2	9,905.9	0.78	0.81	10.8%	3.9%	1.0%	6.41	311	2	481,485
17	17	14,895.1	16,029.1	0.02	0.22	0.4%	0.4%	0.1%	0.01	376	0	509,450
18	4	13,879.8	13,630.3	0.02	0.15	0.3%	0.3%	0.1%	0.01	149	0	441,138
19	11	3,792.3	3,686.0	0.00	0.50	0.9%	0.4%	0.1%	0.10	236	0	122,378

Drive #1 → Debris or a Cartridge issue

Cartridge	Cart Type	Max Tape Motion,m	Clean NOW	Data Written GB	Data Read GB	ReWrite /FWD	ReWrite/ REV	Read ErrorRate	Tracking Metric	XFER MB/s	Hard Err Events
Cart #4	LA	955	0	0.020	0.000	19.2%	0.0%	0.0%	0.00	1	0
Cart #2	LA	1,255	0	7.873	0.000	1.5%	0.0%	0.0%	0.19	88	0
Cart #3	LA	32,596	0	1,020.515	1,020.319	0.4%	0.4%	0.1%	0.00	385	0
Cart #3	LA	64,459	0	1,020.466	1,020.417	0.4%	0.4%	0.1%	0.00	376	0
Cart #4	LA	126,701	0	2,040.932	2,040.736	0.4%	0.4%	0.1%	0.00	390	0
Cart #3	LA	189,246	0	2,040.932	2,040.745	0.4%	0.4%	0.1%	0.00	388	0
Cart #1	LA	251,679	0	2,041.049	2,040.863	0.4%	0.4%	0.1%	0.00	386	0
Cart #3	LA	283,738	0	1,020.466	1,020.417	0.4%	0.4%	0.1%	0.00	375	0
Cart #2	LA	345,927	0	2,041.049	2,040.853	0.4%	0.4%	0.1%	0.00	390	0
Cart #4	LA	407,678	0	2,040.932	2,040.745	0.4%	0.4%	0.1%	0.00	392	0
Cart #3	LA	449,155	0	554.115	0.098	0.4%	0.4%	0.1%	0.00	339	0
Cart #4	LA	458,013	0	537.192	0.078	0.4%	0.4%	0.1%	0.00	358	0
Cart #5	LA	466,858	0	537.192	0.078	0.4%	0.4%	0.1%	0.00	358	0
Cart #6	LA	491,870	0	0.000	1,552.598	0.0%	0.0%	0.1%	0.00	362	0

Drive #16 → is it Drive, Debris, Cartridge?

Cartridge	Cart Type	Max Meter Tape Motion	Clean NOW	Data Written GB	Data Read GB	ReWrite /FWD	ReWrite/ REV	Read ErrorRate	Tracking Metric	XFER MB/s	Hard Err Events
Cart #4	LA	1,318	0	0.000	0.000	0.0%	0.0%	0.0%	0.00	0	0
Cart #8	LA	1,877	0	0.000	0.000	0.0%	0.0%	0.0%	0.00	0	1
Cart #10	LA	2,396	0	0.000	0.000	0.0%	0.0%	0.0%	0.00	0	1
Cart #9	LA	35,376	0	1,020.515	1,020.319	0.8%	0.6%	0.1%	0.25	350	0
Cart #4	LA	35,376	0	0.000	0.000	0.0%	0.0%	0.0%	0.00	0	0
UCC	L1	35,376	1	0.000	0.000	0.0%	0.0%	0.0%	0.00	0	0
Cart #9	LA	124,388	0	2,040.932	3,175.576	3.1%	3.1%	0.2%	0.47	337	0
Cart #8	LA	160,080	0	1,020.525	1,020.515	3.8%	2.2%	0.2%	0.55	325	0
Cart #10	LA	194,049	0	1,020.525	1,020.485	2.5%	2.0%	1.0%	0.22	338	0
Cart #7	LA	264,223	0	2,040.932	2,040.726	1.5%	1.3%	0.6%	0.26	329	0
Cart #5	LA	437,530	0	369.469	0.098	10.8%	3.3%	0.2%	6.41	186	0
Cart #6	LA	447,322	0	472.146	0.078	4.0%	2.0%	0.2%	2.43	265	0
Cart #1	LA	456,788	0	493.128	0.078	1.2%	3.9%	0.1%	1.51	281	0
Cart #2	LA	481,485	0	0.000	1,628.057	0.0%	0.0%	0.1%	0.00	389	0

- Note when checking Cartridges 47LA and 49LA, the problem stays with drive
- Debris case with 48LA also stay with drive

Is it Drive or Media or Combination?

Not Cart & Not drive but random transient debris

Row Labels	Cart #1	Cart #2	Cart #3	Cart #4	Cart #5	Cart #6	Cart #7	Cart #8	Cart #9	Cart #10	Cart #11	Cart #12	Cart #13	Cart #14	Cart #15	Cart #16	Cart #17	Cart #18	Cart #19
Drive 1	0.4	1.5	0.4	19.2	0.4	0													
Drive 2				1.5	0.8	0.7	0						0			0.6		0.6	
Drive 3							0	1.1	0.5	0.5	0								
Drive 4	0.4	0	0		0.5						1	0.4							
Drive 5			1	0.5	0.5	0								0		0			
Drive 6	0.3	0.3	0.3	0		0.4													
Drive 7	1	0.4	0.4	0									0.5	0.5	0.5	0.5			
Drive 8							0		1	0.4	0.4	0							
Drive 9						1	0.4	0.5	0				0		0.4	0	0.5		
Drive 10		0	0.5	0.5	0														
Drive 11	0.4	0.4	0	0.4								1							
Drive 12		1	0.4	0.4	0								0.4	0.4	0.4	0.4			
Drive 13							1	0.4	0.4	0	0.4	0							
Drive 14	0	0	0.4	0						1	0.4	0.4							
Drive 15	0.5	0.5	0.5	0.5	0.5	0.4													
Drive 16	2.5	0		0	6	2.9	1.4	3	3.1	2.3									0
Drive 17	0.4	0.4	0	0		0.4	0.4	0.4	0.4	0.4									
Drive 18							0.3		0										
Drive 19					0.9	0.4	0.4	0					0.3		0	0.4			

This is Drive; cart #9 is OK. Questions Why right after UCC and can it be still cleanable? Even though the drive is not requesting Cleaning best to clean this again

Your difference is in your data.