

Finding Flash Features: bigger, better, faster... stronger ECC

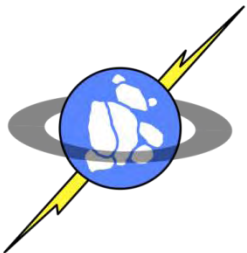
Laura M. Grupp^{*}, Hung-Wei Tseng^{*}, Adrian M. Caulfield^{*}, Joel Coburn^{*},
Eitan Yaakobi[†], Paul H. Siegel[†], Jack K. Wolf[†], Steven Swanson^{*}

^{*}Non-volatile Systems Laboratory, Department of Computer Science and Engineering

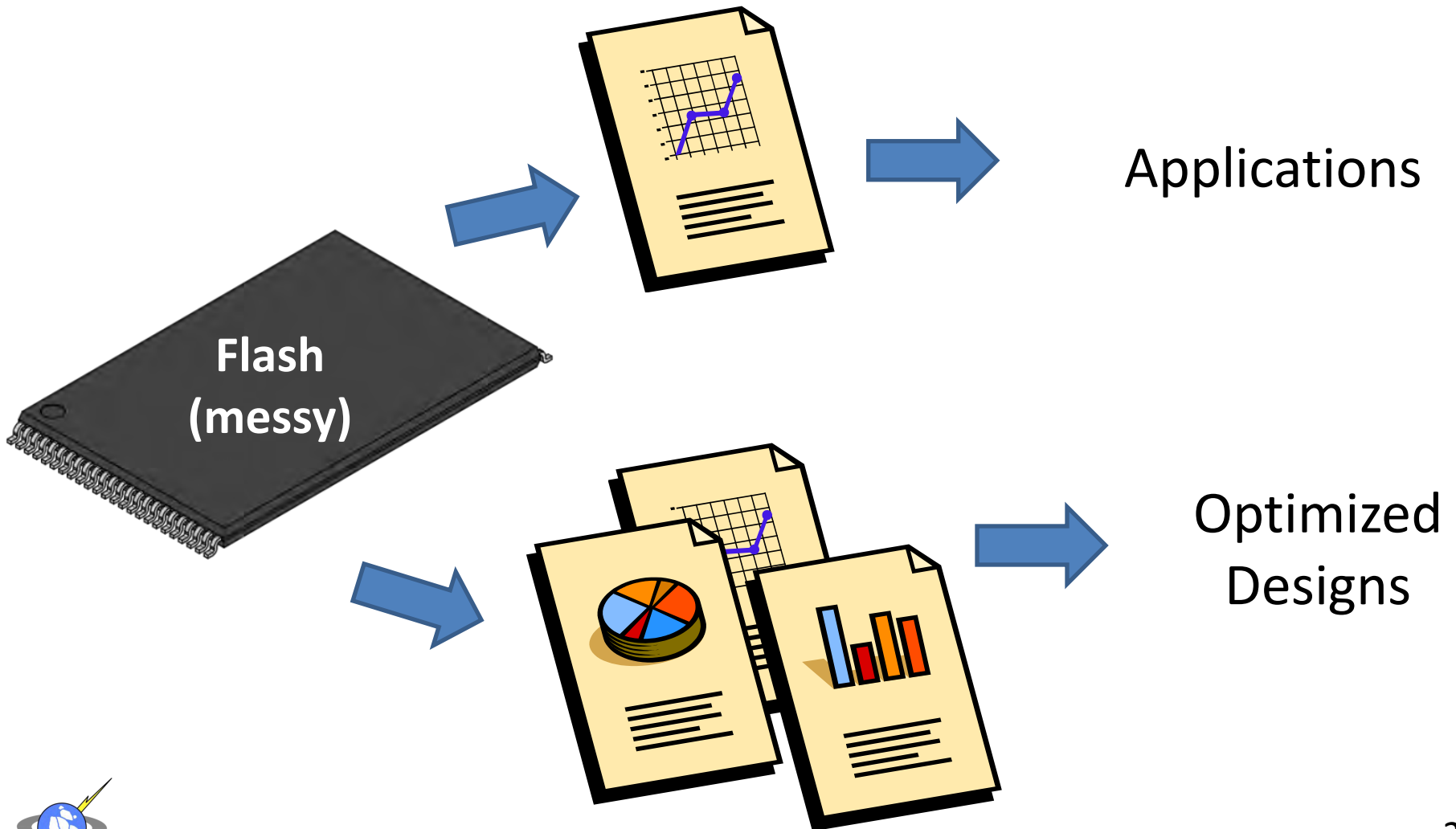
[†]Center for Magnetic Recording Research

Jacob's School of Engineering

University of California, San Diego

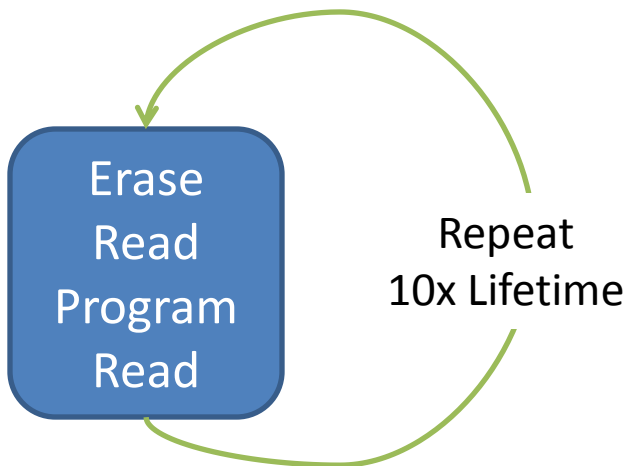
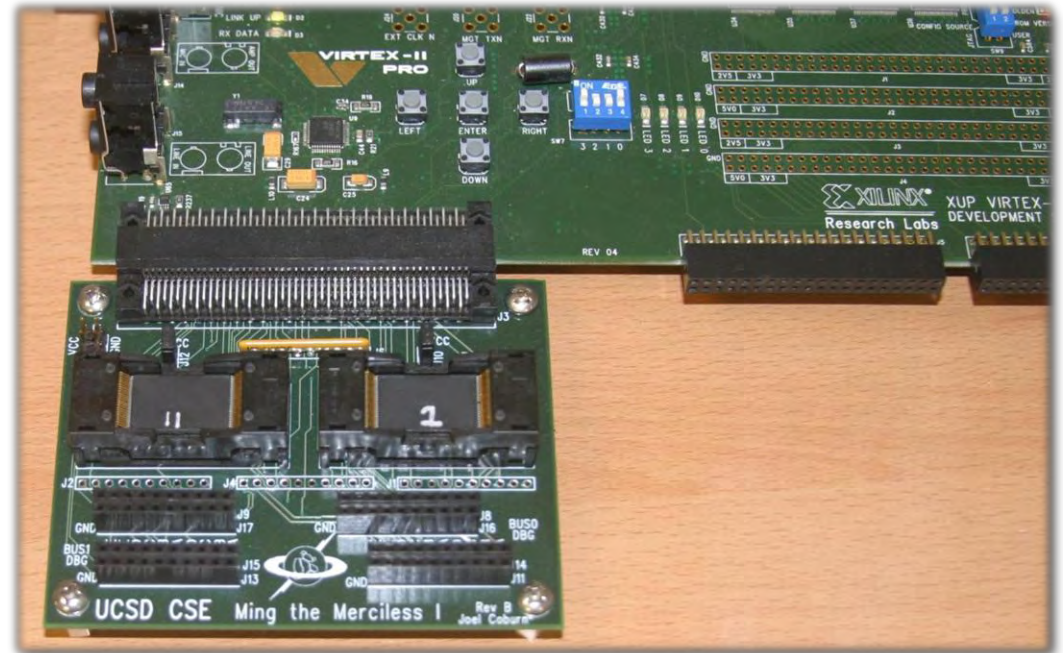


Ultimate Goal



Test Setup

- Custom-Built Daughter Board
- Xilinx XUP Board
- Full-fledge Linux
- Kernel module



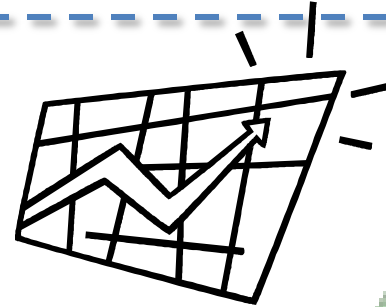


The Test Subjects

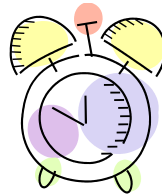
Chip Name	Max PE Cycles	Tech Node	Capacity (Gb)	Bytes Page	Pages Block	Blocks Plane	Planes Die	Dies
B-MLC128-2	5,000	34nm	128	4096	256	2048	2	4
B-MLC32-2	5,000	34nm	32	4096	256	2048	2	1
B-MLC128	5,000	34nm	128	4096	128	4096	2	4
F-MLC16	5,000	41nm	16	4096	128	2048	2	1
C-MLC64	10,000	43nm	64	8192	128	4096	1	2
A-MLC16	10,000		16	4096	128	2048	2	1
B-MLC32	10,000	50nm	32	4096	128	2048	2	2
D-MLC32	10,000		32	4096	128	4096	1	2
B-MLC8	10,000	72nm	8	2048	128	4096	1	1
E-MLC8	10,000		8	4096	128	1024	1	2
B-SLC4	100,000	72nm	4	2048	64	2048	2	1

Outline

- MLC Device Trends



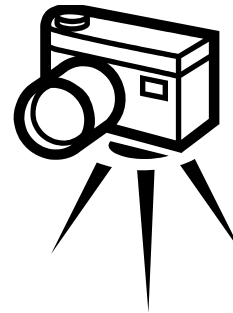
- Data Lifetime



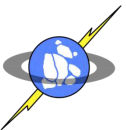
- Benefits of Relaxation



- Modeling Flash

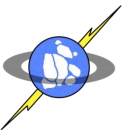
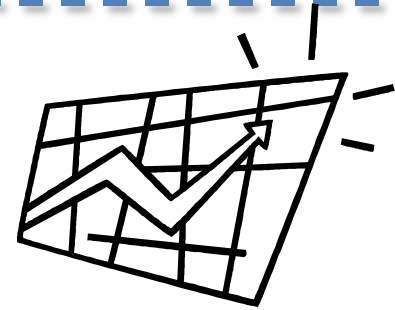


- New Application



Outline

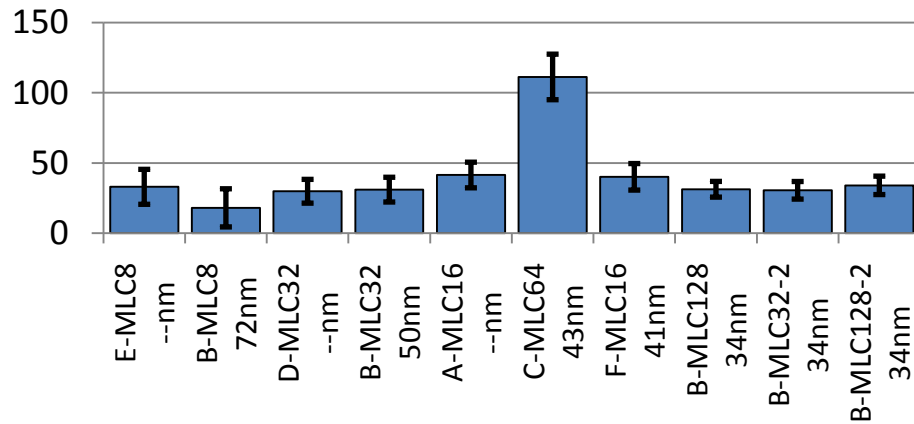
- MLC Device Trends
- Data Lifetime
- Benefits of Relaxation
- Modeling Flash
- New Application



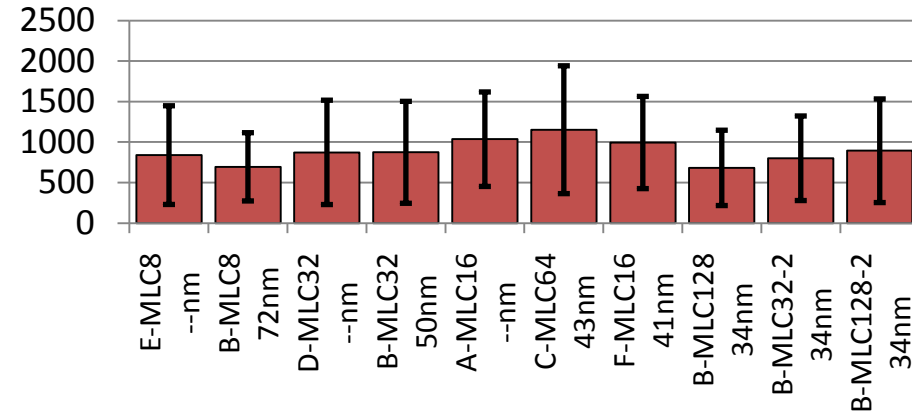
Latencies

Decreasing Technology Node

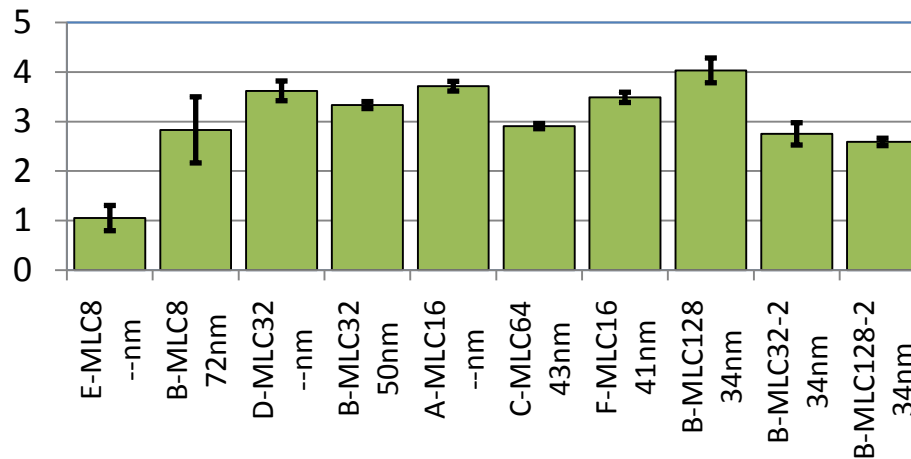
Read Latency (μs)



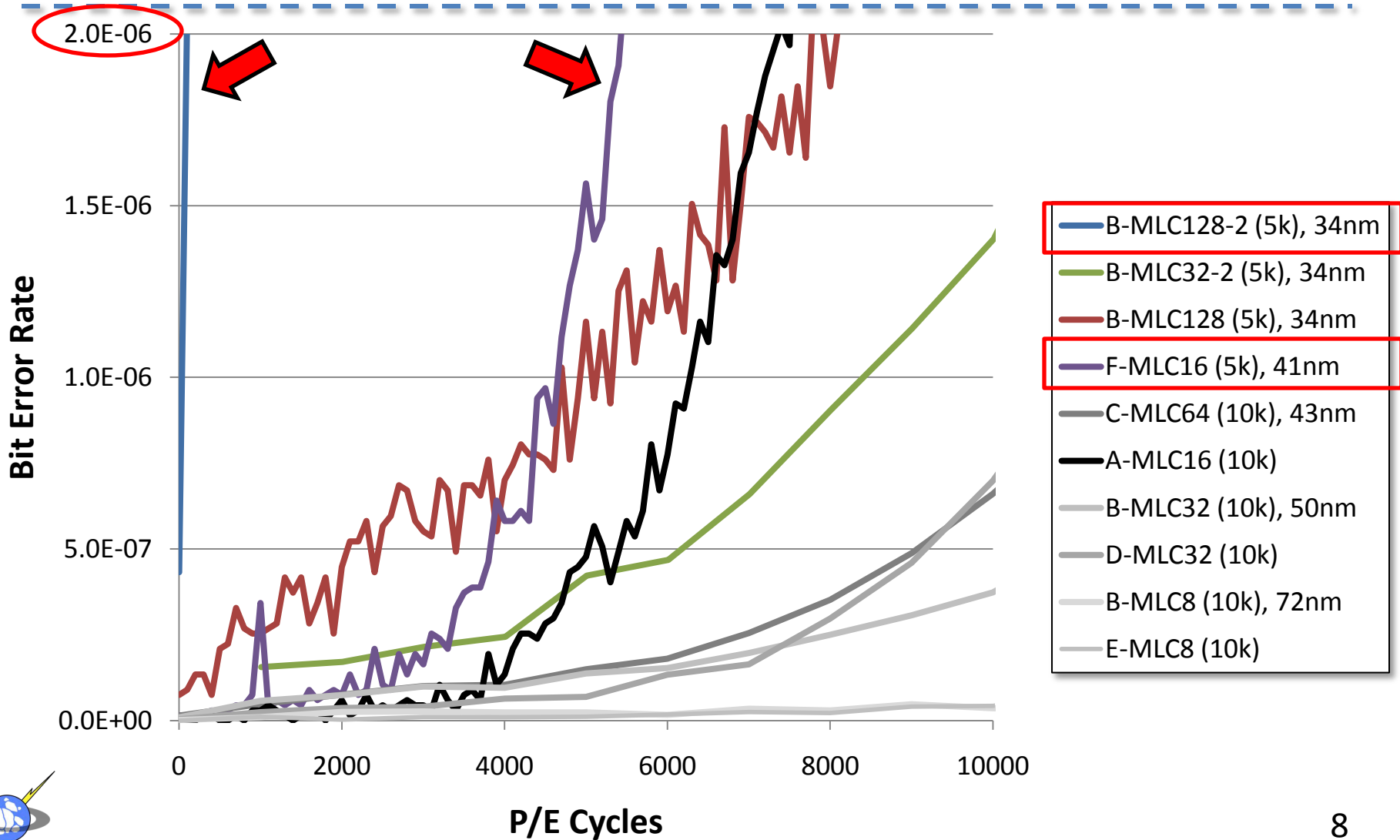
Program Latency (μs)



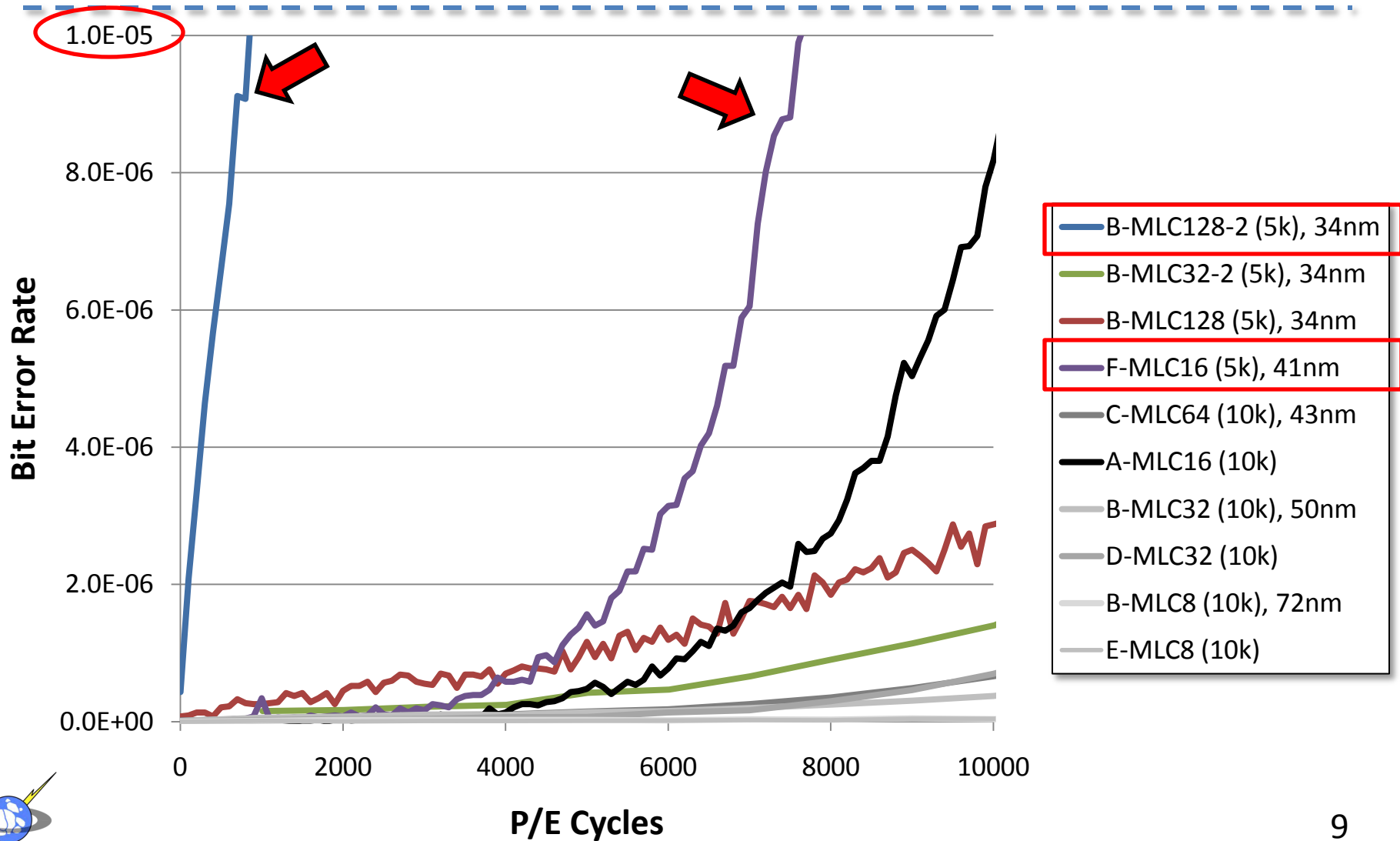
Erase Latency (ms)



BER over Cycles

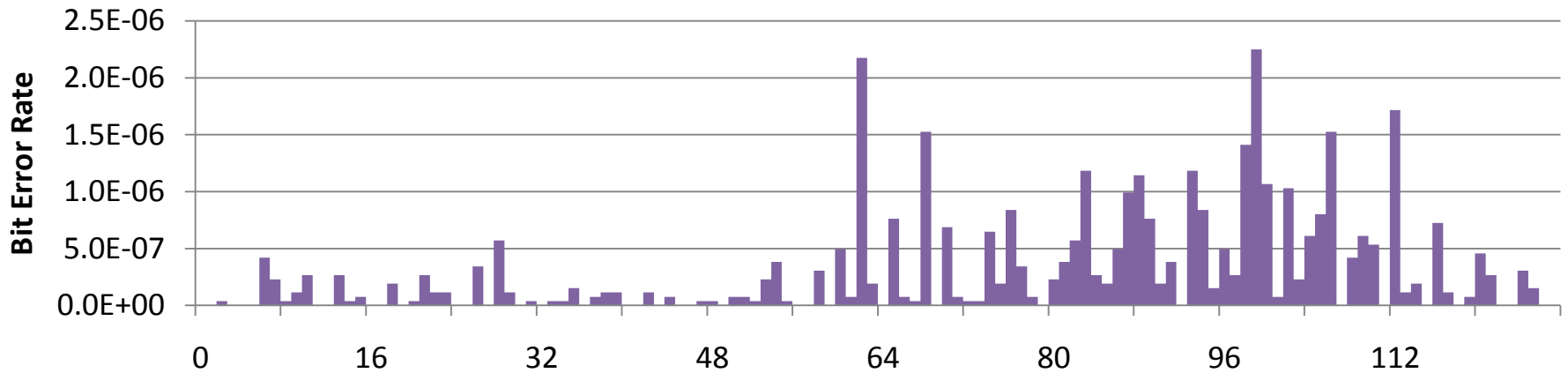


BER over Cycles

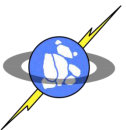
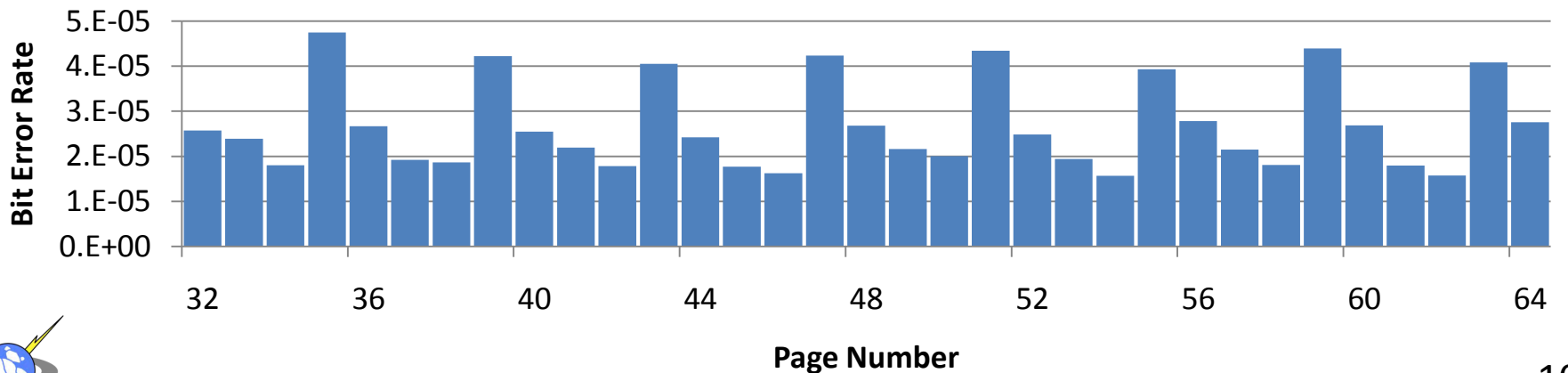


Patterns in BER

F-MLC16

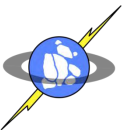
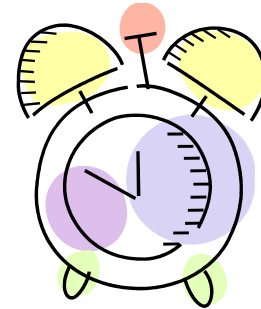


B-MLC32-2, 32nm



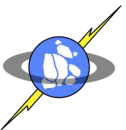
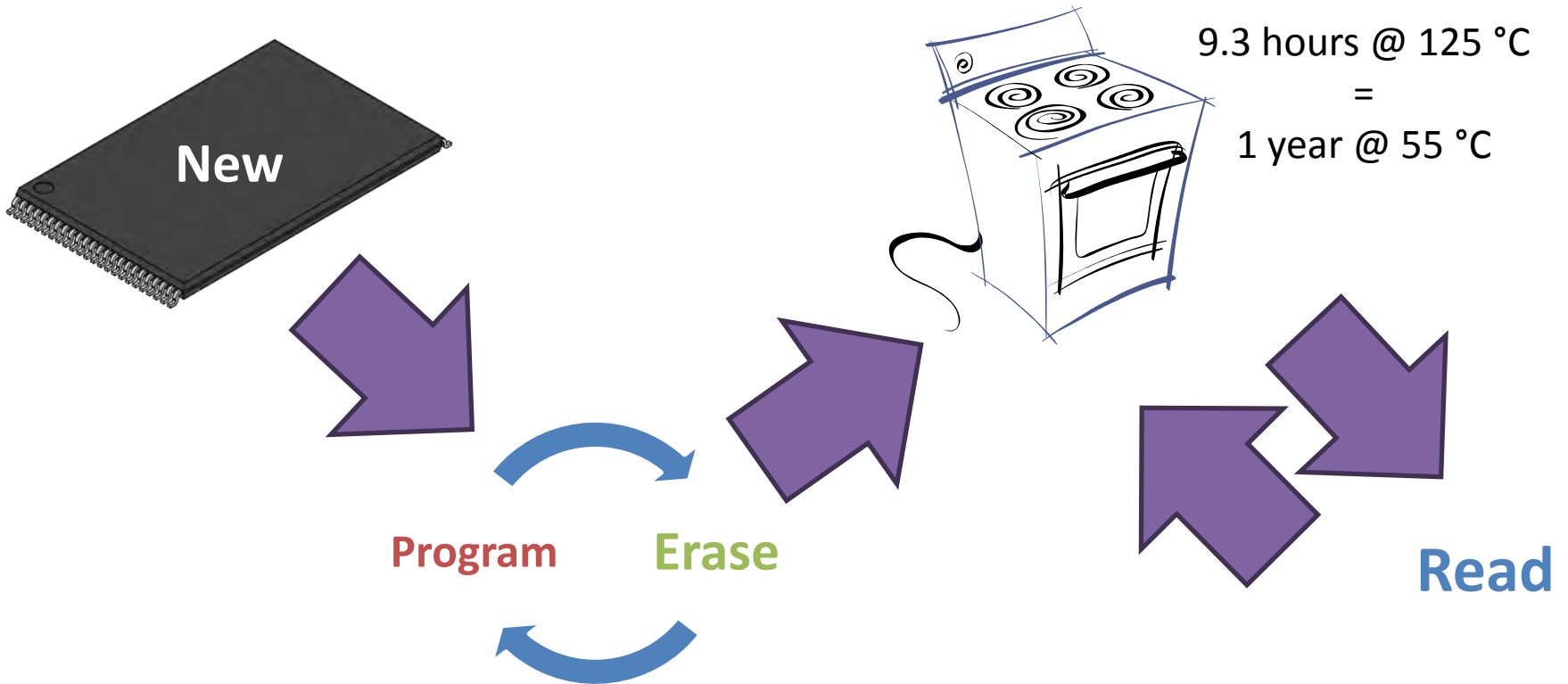
Outline

- MLC Device Trends
- **Data Lifetime**
- Benefits of Relaxation
- Modeling Flash
- New Application



Data Retention

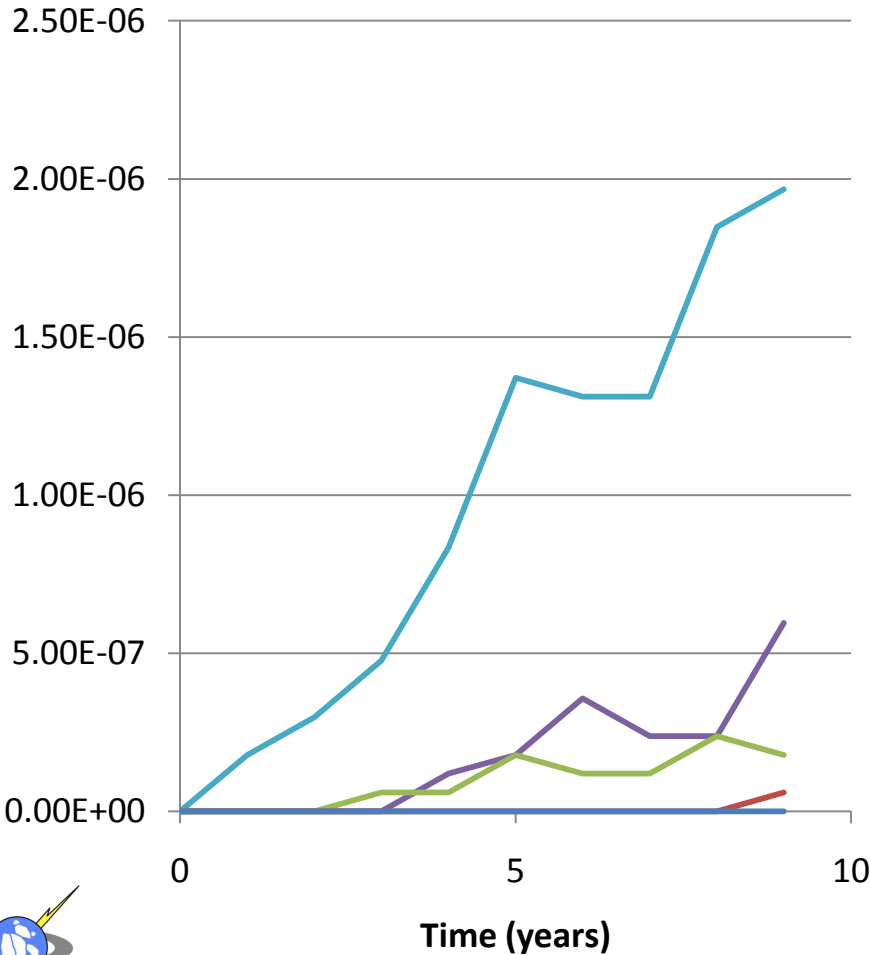
How long does flash store data?



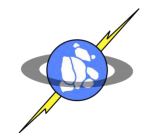
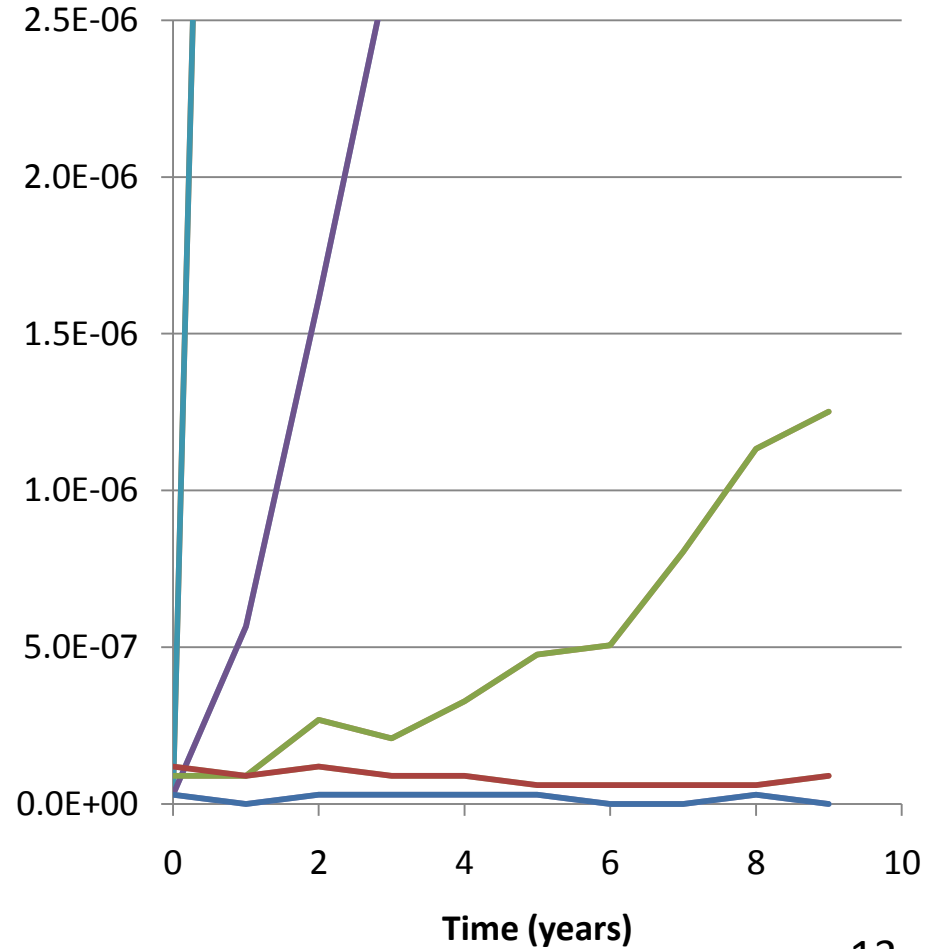
Data Retention

- 400% of Max Cycles
- 200% of Max Cycles
- 100% of Max Cycles
- 50% of Max Cycles
- 25% of Max Cycles

B-SLC4, 72nm

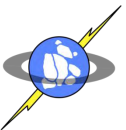


B-MLC8, 72nm

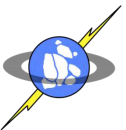
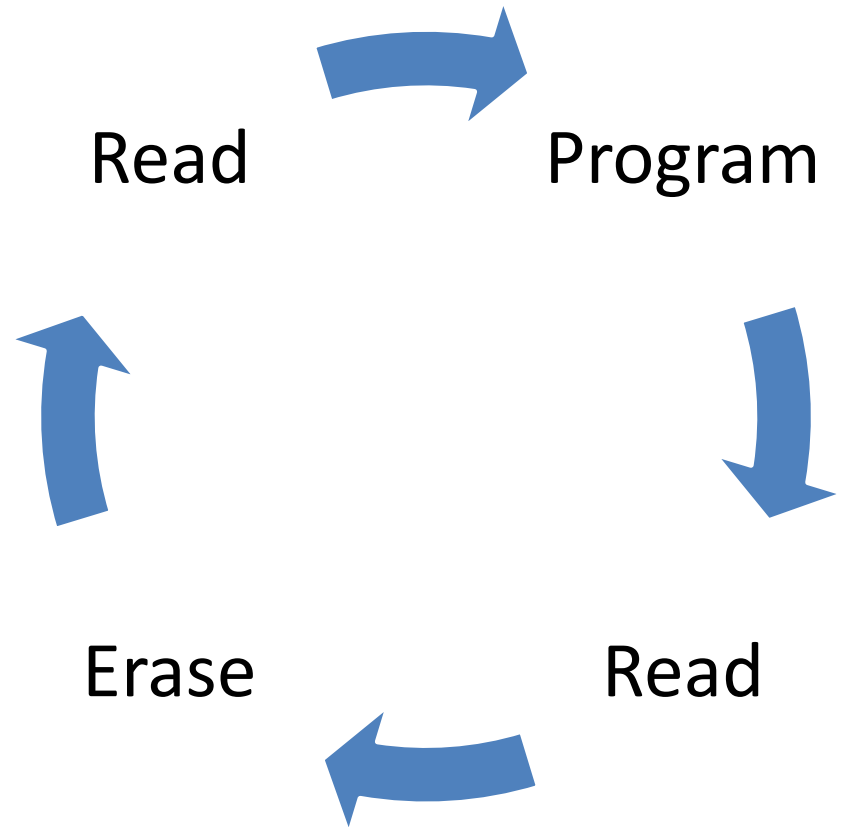
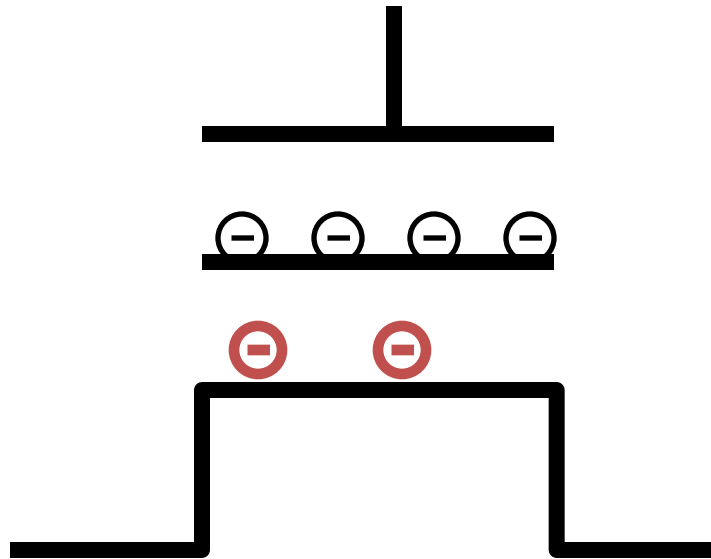


Outline

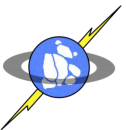
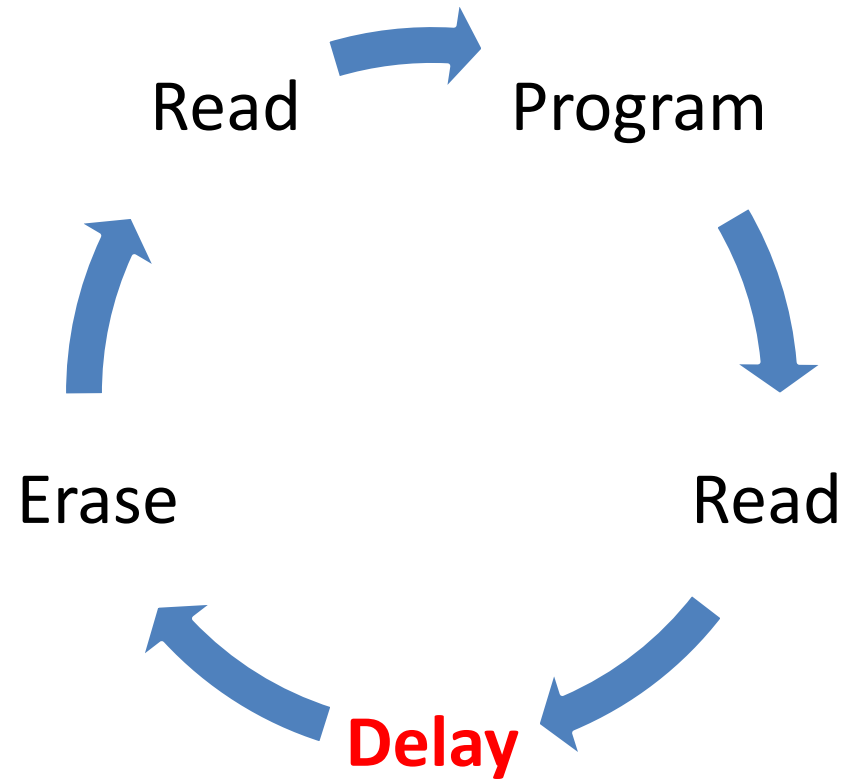
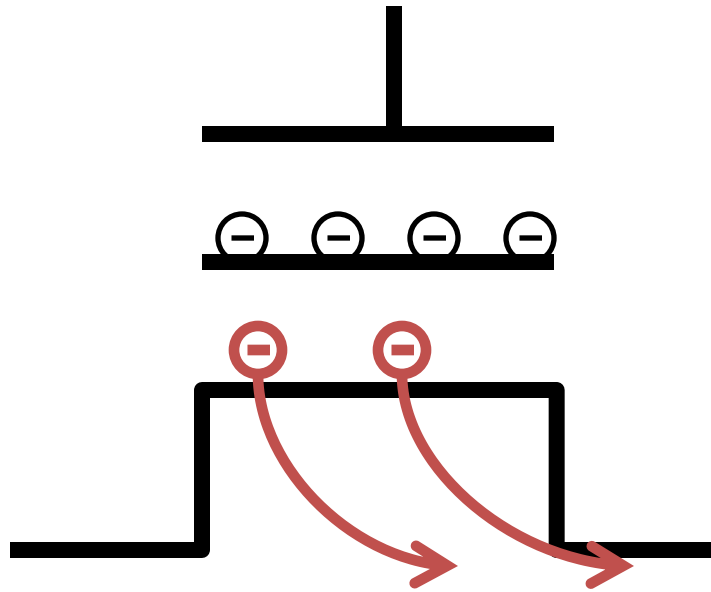
- MLC Device Trends
- Data Lifetime
- **Benefits of Relaxation**
- Modeling Flash
- New Application



Delay

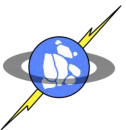
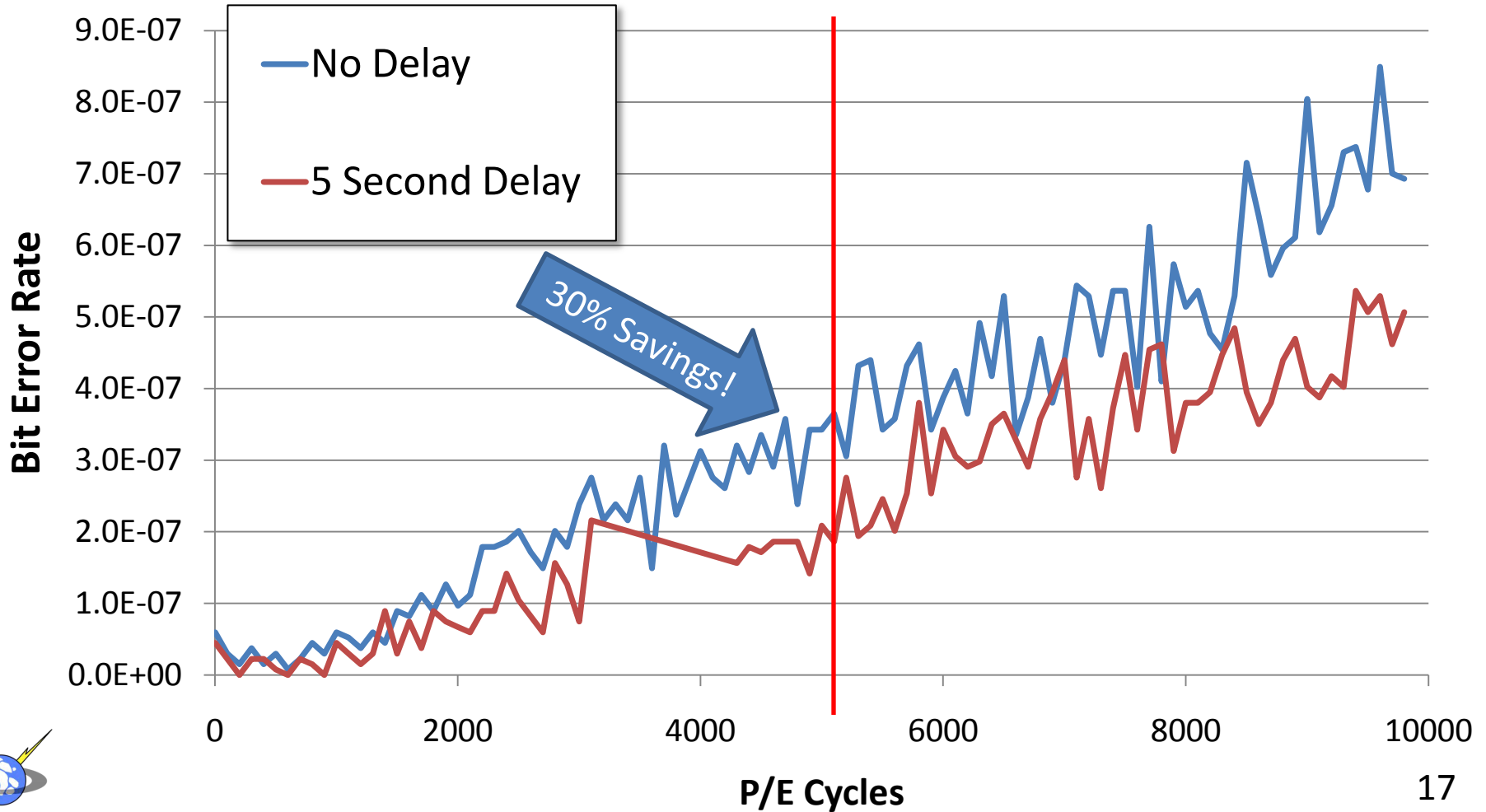


Delay



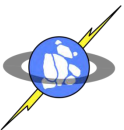
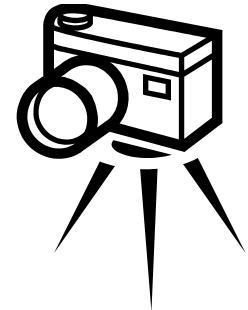
Delay

B-MLC32-2, 34nm



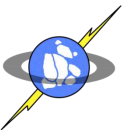
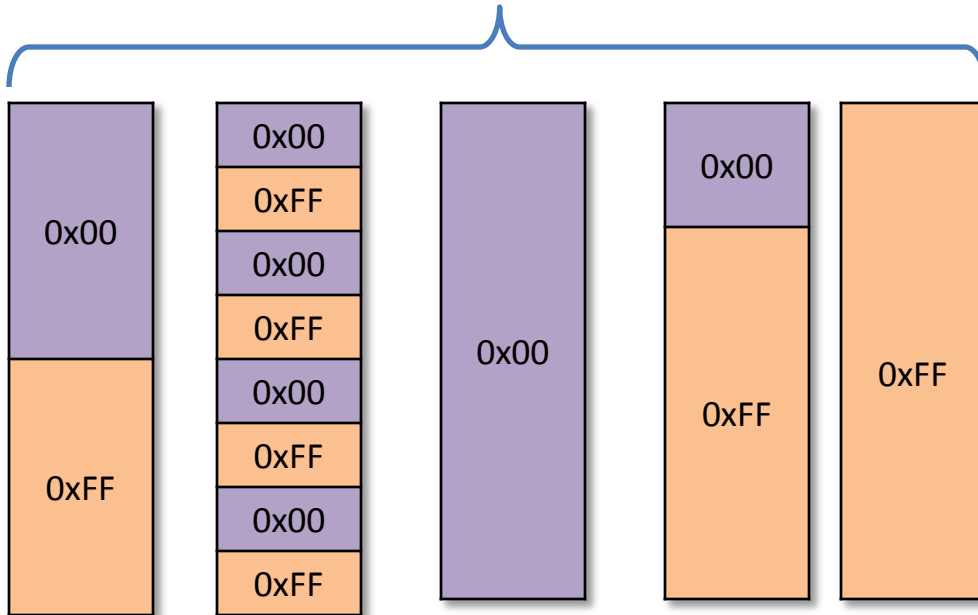
Outline

- MLC Device Trends
- Data Lifetime
- Benefits of Relaxation
- **Modeling Flash**
- New Application

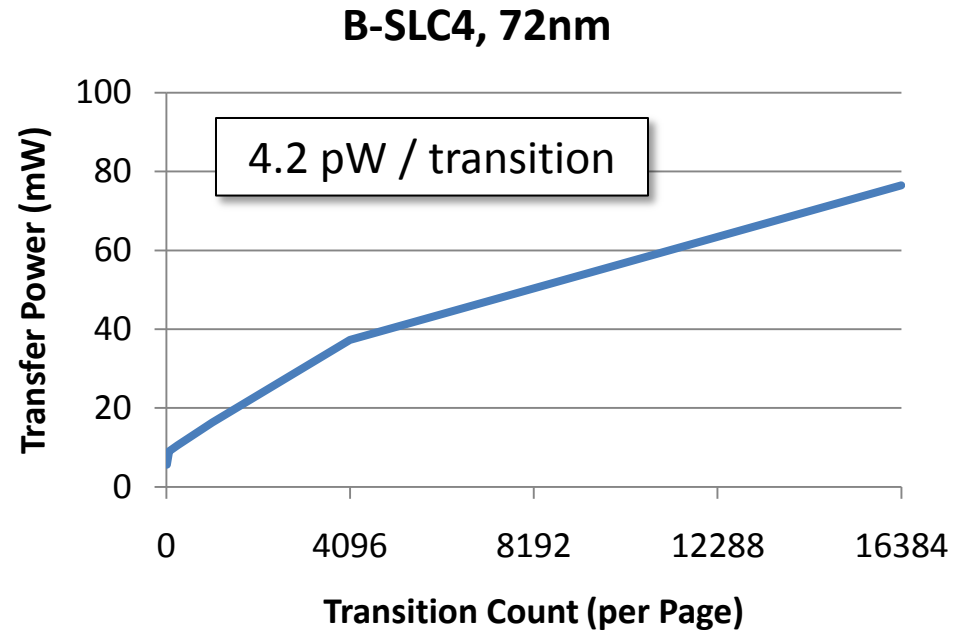
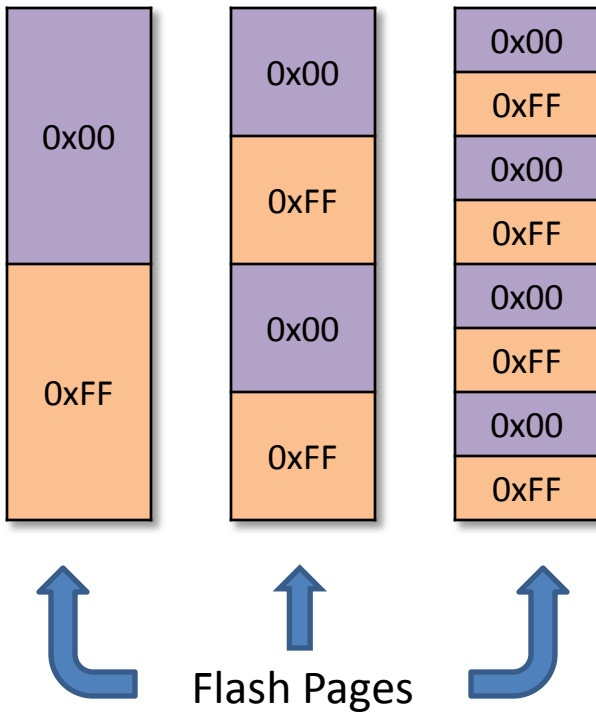


Validation of Power Model

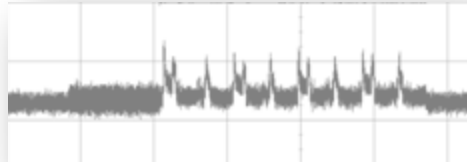
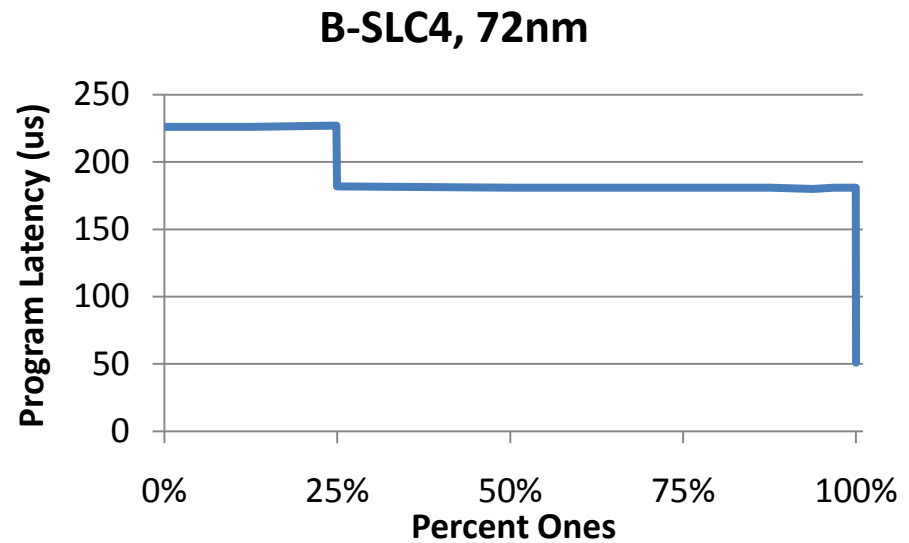
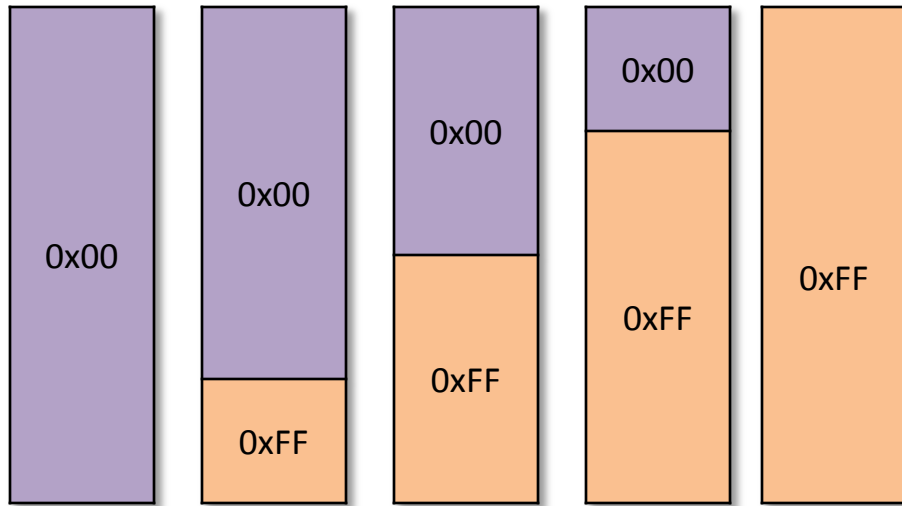
Flash Pages



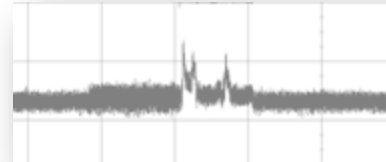
Data Dependence - Transfer



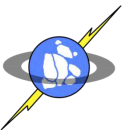
Data Dependence - Cells



50% Ones

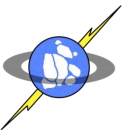


100% Ones



Outline

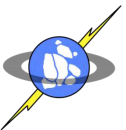
- MLC Device Trends
- Data Lifetime
- Benefits of Relaxation
- Modeling Flash
- New Application



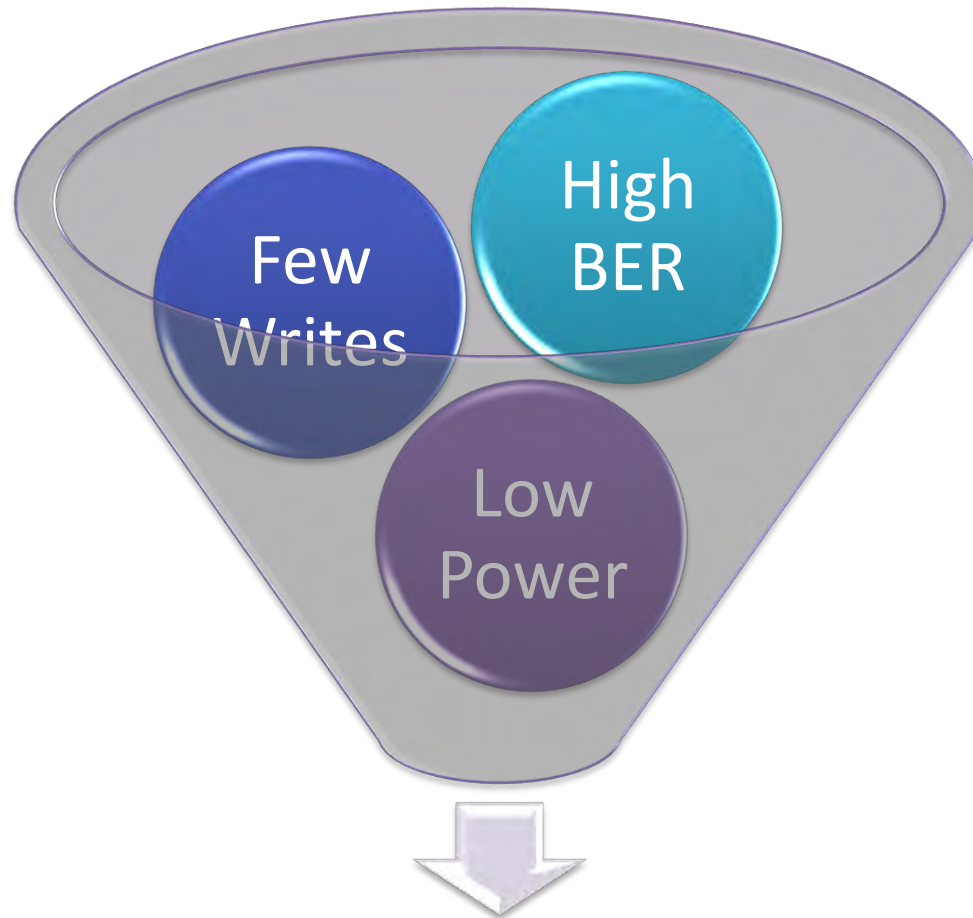
Flash in Space



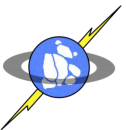
- Goals
 - Short-term: Earth-Orbiting Mission
 - Long-term: Space Flight Domination!
- Constraints
 - Low power
 - High Density
 - Limited ECC
 - High Radiation
- Advantages
 - Specified BERs
 - Full System Design



Specialized Storage

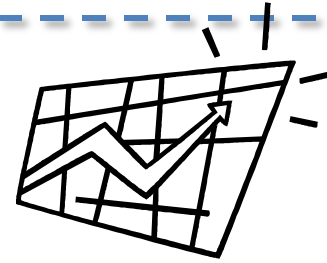


Personalized SSD

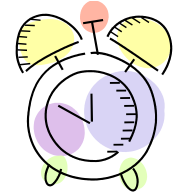


Conclusion

- MLC Trends: Sophisticated ECC



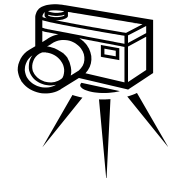
- Data's Shelf Life: Cycling Matters



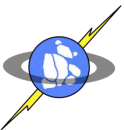
- Low Overhead ECC: Delay



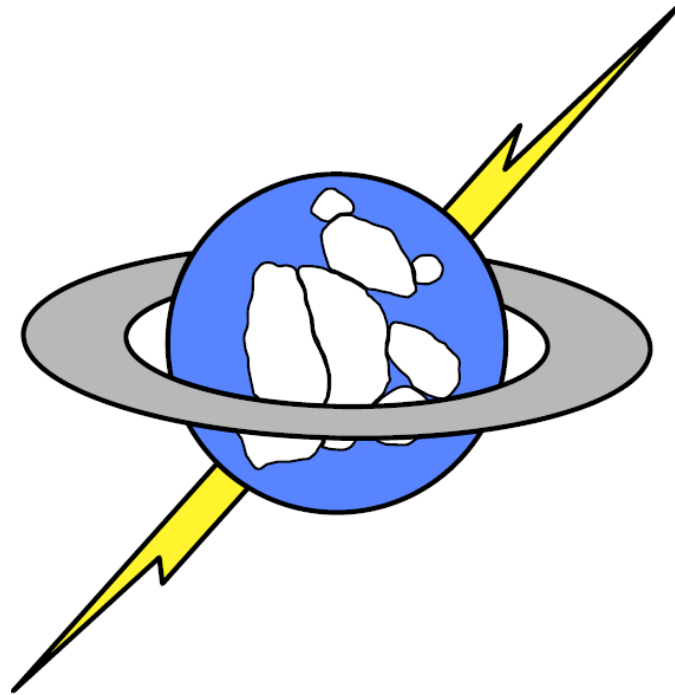
- Rapid Development: Flash Model



- Well Specified: Well Optimized



Thank You



Non-volatile Systems Laboratory

