

A Radiation Hardened SONOS 1Mb EEPROM for Space Applications

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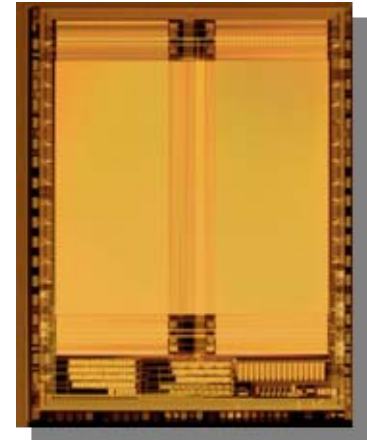
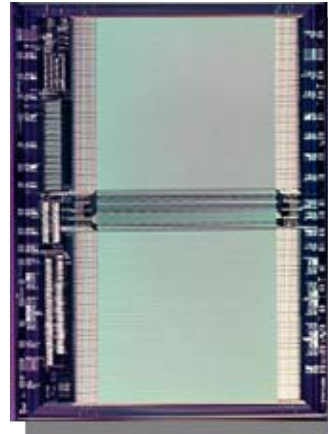
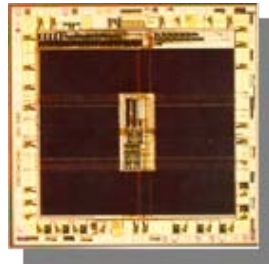
Outline

- **1Mb EEPROM Overview**
- **SONOS stack endurance cycling**
- **Memory retention study**
- **Qualification testing results**
- **Summary**

The NGC EEPROM Team

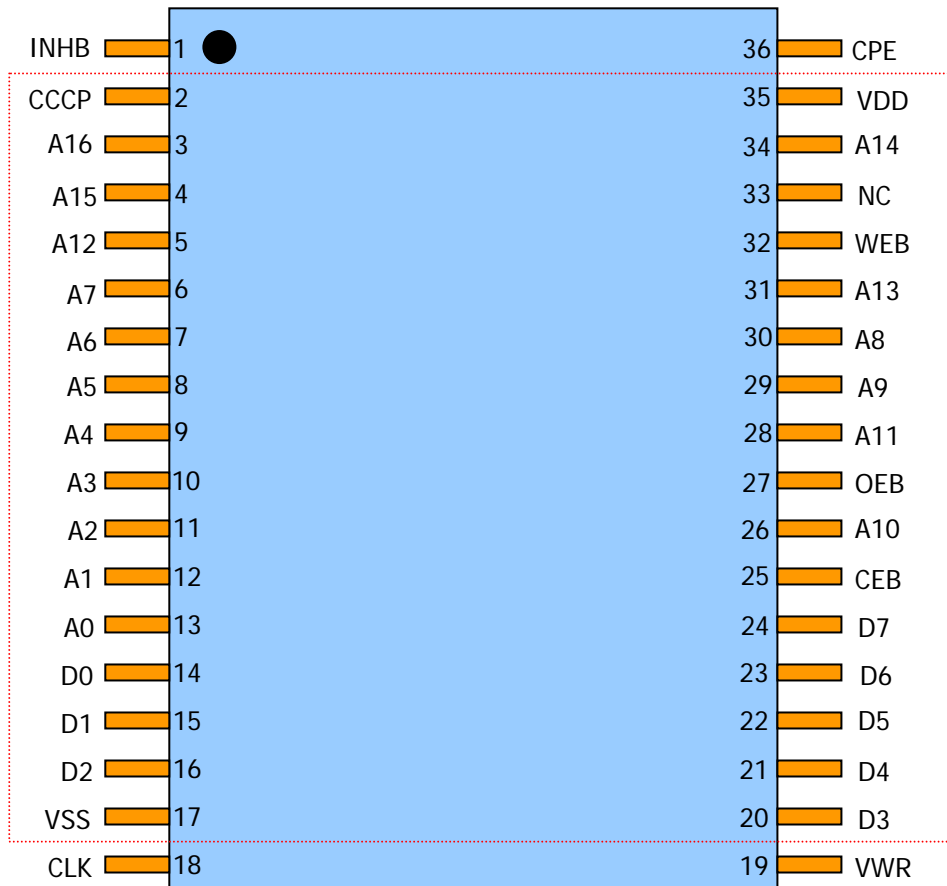
- **Northrop Grumman** (Baltimore,MD) – wafer fabrication; device screening & test; product sales
- **Amtec** (Huntsville,AL) – device radiation effects analysis & radiation test; program management
- **Sandia** (Albuquerque,NM) – EEPROM design
- **Lehigh University** (Bethlehem, PA) – SONOS “stack” analysis and characterization

Proven Rad Hard NVM Technology

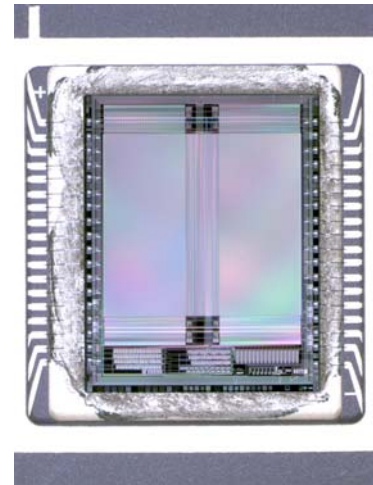


Part Number:	W28C64	W28C256	W28C0108
Organization:	8k x 8	32k x 8	128k x 8
Process:	1.25µm CMOS/SONOS	1.25µm CMOS/SONOS	0.8µm CMOS/SONOS
Memory Cell:	4T	4T	2T
Die Size:	6.5mm x 6.5 mm	8mm x 10.2 mm	8.3mm x 10.6 mm
Write Voltage:	10V	10V	7.5V
Write Time:	10 msec per page	10 msec per page	100 msec per page
Read Access:	250 nsec	250 nsec	250 nsec
Retention:	10 years @ 1E4 cycles	10 years @ 1E4 cycles	10 years @ 1E4 cycles
Production:	2Q93	2Q00	2Q08

Commercial Compatibility



36 Pin Flatpack

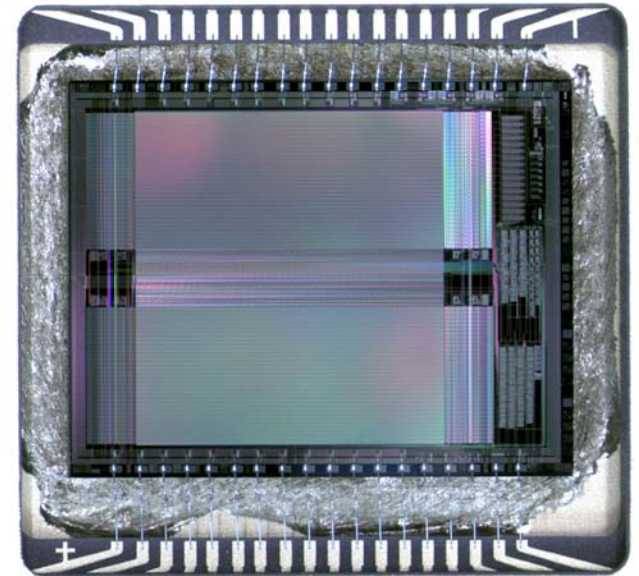


W28C0108F Rad Hard 1Mb EEPROM

The inner 32 pins are JEDEC compatible with commercial parts such as the Renesas HN58C1001

Rad Hard 1Mb EEPROM Characteristics

Parameter	Specification
Organization	128Kb x 8
Power Supplies	+3.3 V (Vdd), -4.2 V (Vwr)
Program Time (page)	100 ms
Endurance	
Write	1E4 cycles (min)
Read	Infinite cycles
Read Access Time	250 ns
Retention	>10 yrs @ +125° C
Temperature	-55 to +125C
Power Dissipation	
Standby	1 mW
Read	60 mW
Write	40 mW
Radiation	
Total Dose	300 krad(Si)
Prompt Dose Upset (logic)	>1E8 rad(Si)/s
Prompt Dose Upset (memory)	>1E12 rad(Si)/s
Prompt Dose Survivability	>1E12 rad(Si)/s
SEU (logic)	40 MeV-cm2/mg
SEU (memory)	>94 MeV-cm2/mg
Latch-up	None



▪ **NGC 1Mb EEPROM has been successfully characterized in all radiation environments and has successfully passed life testing (1000 hour @ +150° C).**

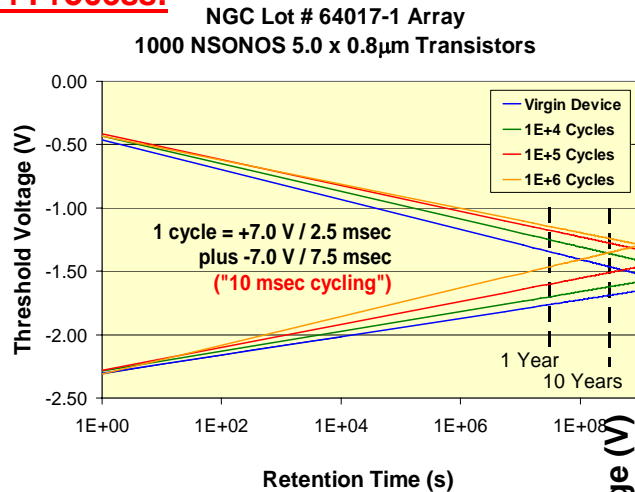
Summary of 1M EEPROM Radiation Test Results

Parameter	Specification	Measured
TID [krad(Si)]	300	>500
Prompt Dose -Transient [rad(Si)/s]	>1E8	2.9E8 Data recovered in one read cycle (1600 nsec)
Prompt Dose – Memory [rad(Si)/s]	>1E12	>6E12
Prompt Dose – Survivability [rad(Si)/s]	>1E12	>6E12
SEU – Logic (MeV-cm2/mg)	40	>122 (Au, 45 degree Angle)
SEU – Memory (MeV-cm2/mg)	>94	>122 (Au, 45 degree Angle)
Latch-up	None	None

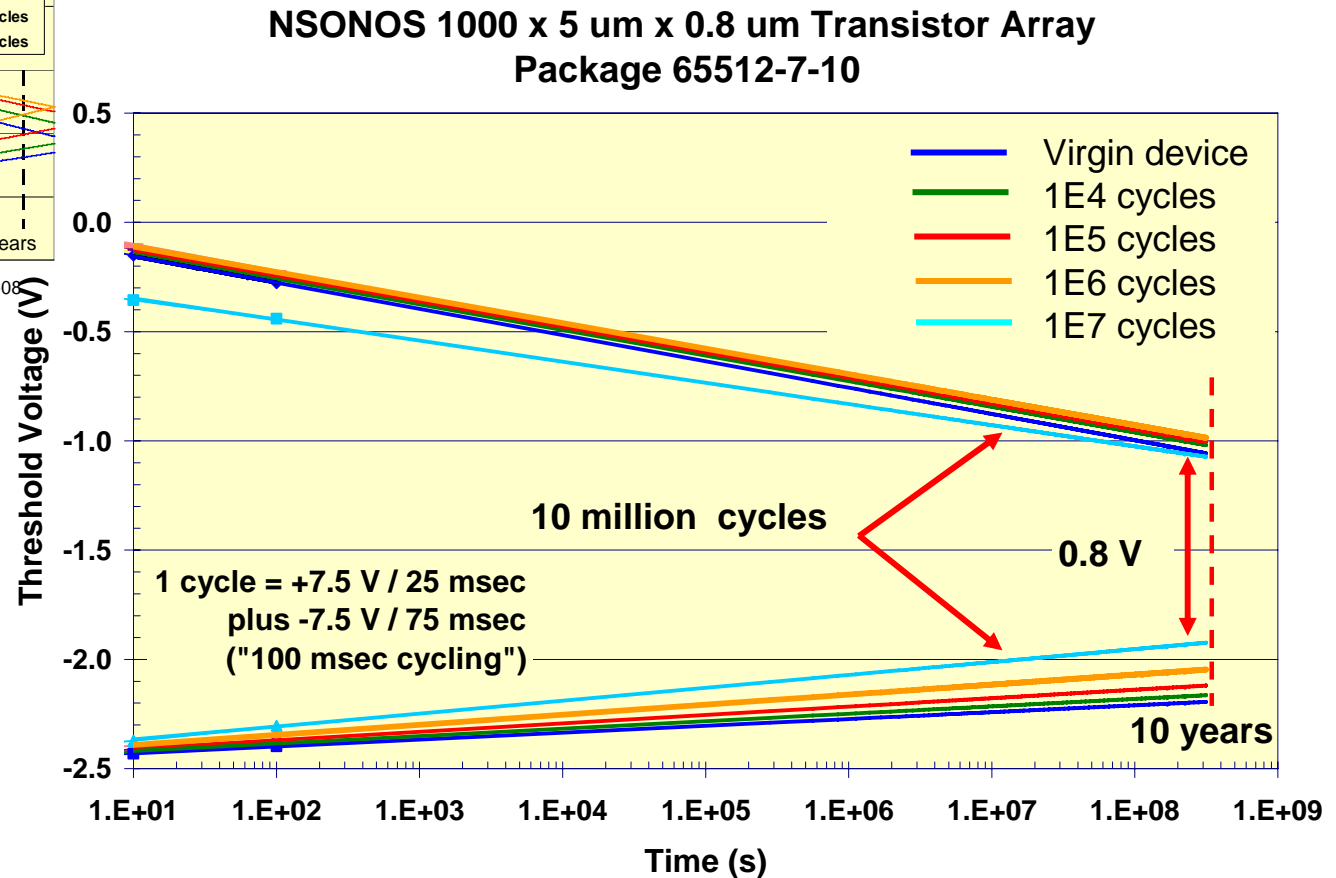
SONOS Stack Endurance Cycling

“Optimized Process”

2004 Process:



2007 process:



“Optimized process” has minimal degradation after 10 million cycles

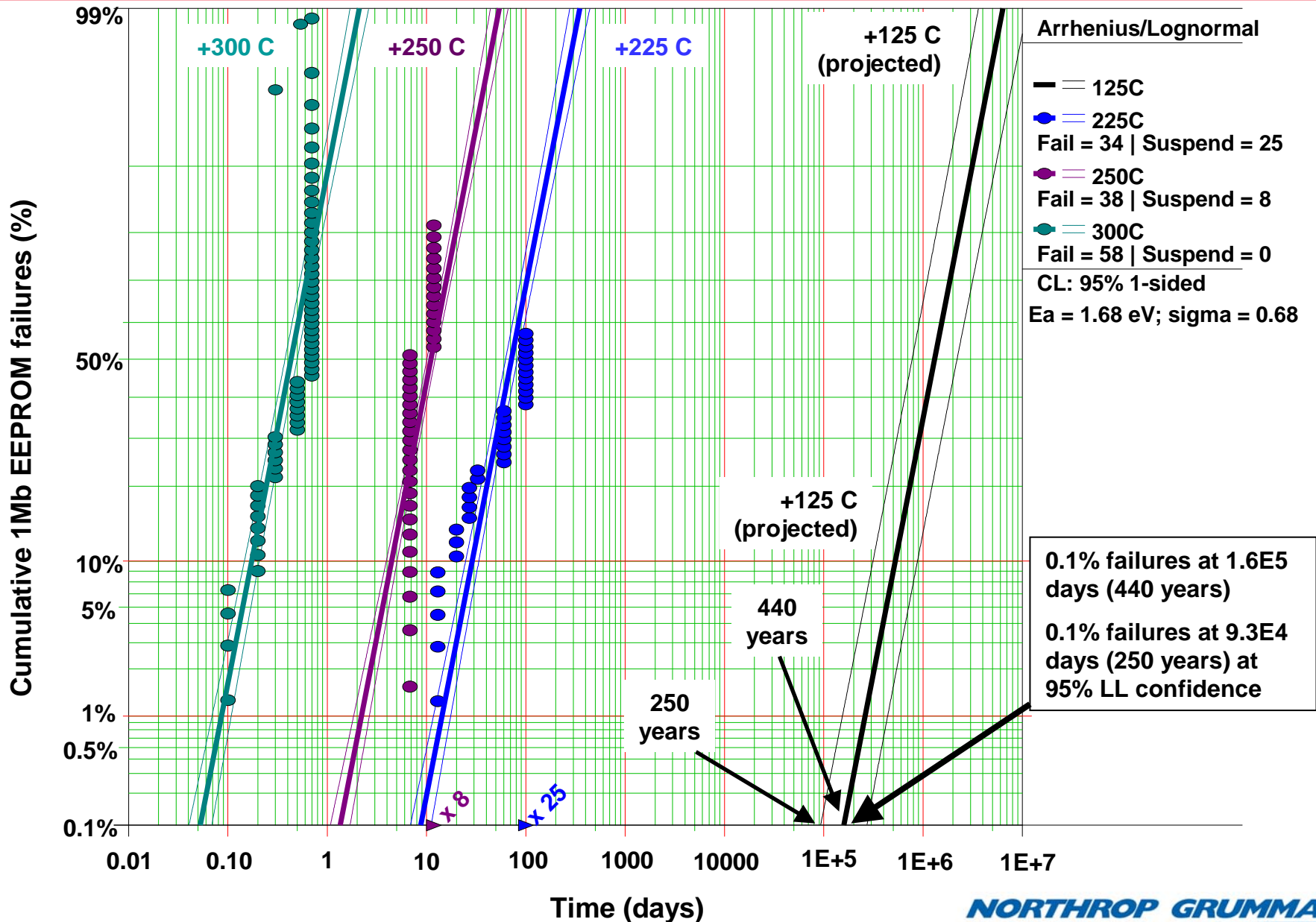
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1Mb EEPROM Activation Energy Study

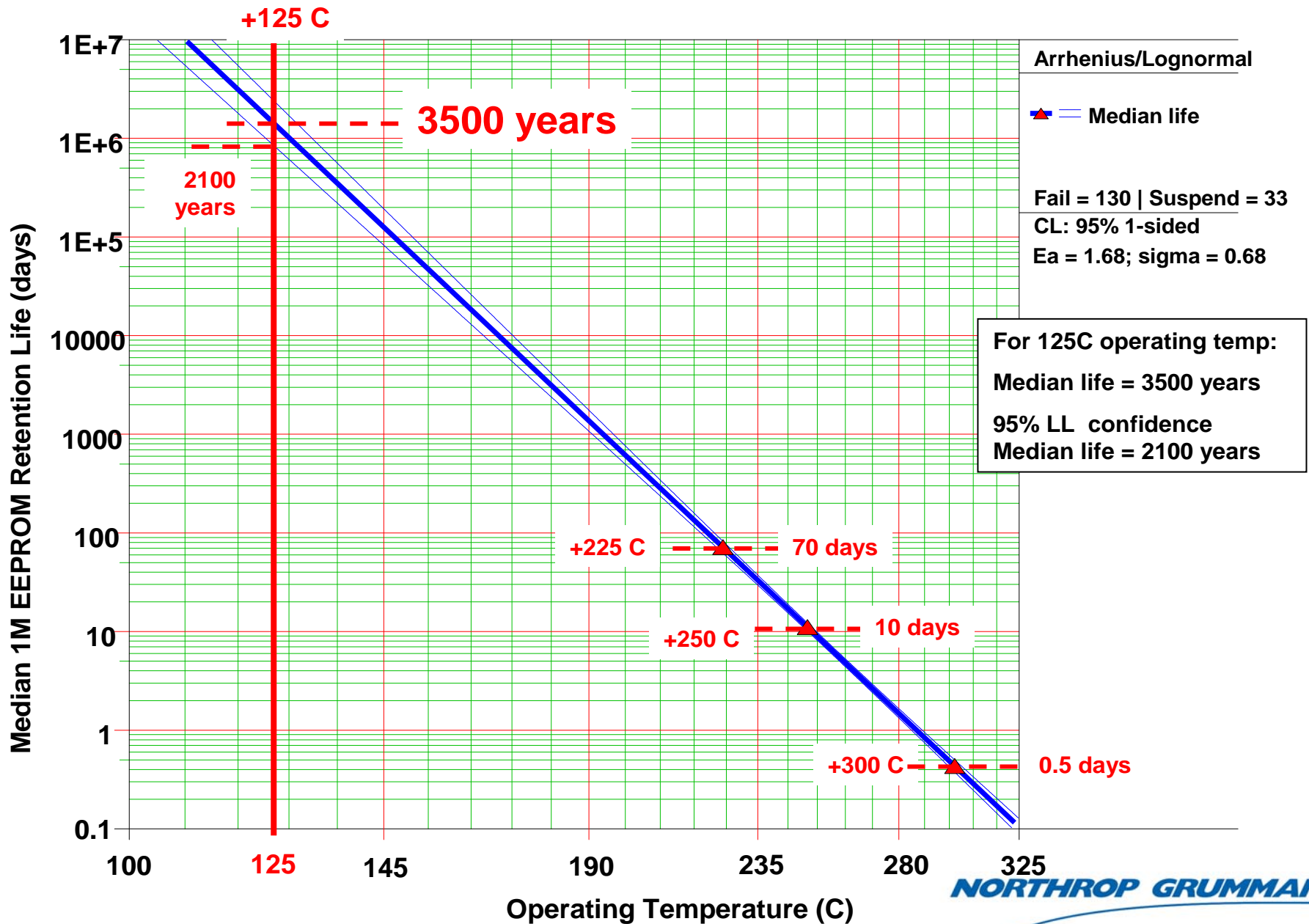
- 1M EEPROM parts (59) characterized @ +225/+250/+300° C for memory retention
- Parts programmed once at each temperature (+7.5 V / 25 msec, -7.5 V / 75 msec, topological checkerboard)
- Arrhenius equation calculations used to determine the 1M EEPROM retention activation energy
 - $MTF = k e^{E_a/kT}$
 - **$E_a = 1.68$ eV for NGC 1M EEPROM retention**
- NGC uses an aggressive screen to guarantee >10 year memory retention on all EEPROM products (2 days @ +250° C – all die)
 - NSONOS transistor data taken at +250° C to quantify SONOS transistor level retention acceleration effects
- **Key finding – Based on this data, NGC 1Mb EEPROM product will have >>100 year memory retention at +125° C**

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1Mb EEPROM Activation Energy Study

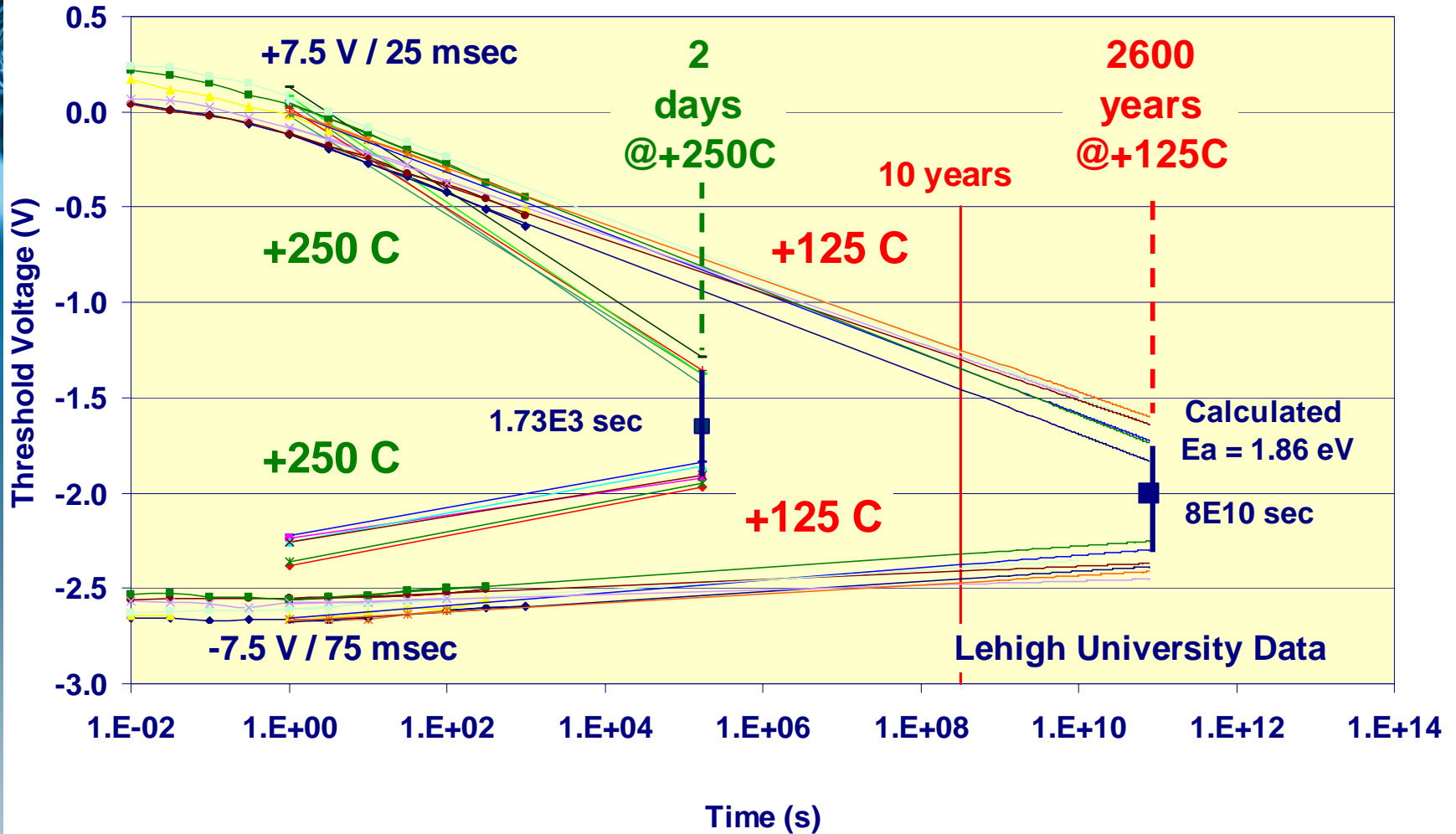


1Mb EEPROM Activation Energy Study



SONOS Memory Retention Screen Acceleration Effects

NSONOS transistor array - 1000 x 4 um x 0.8 um (7 parts)



2 days @ +250°C retention screen is equivalent to 2600 years @ +125°C

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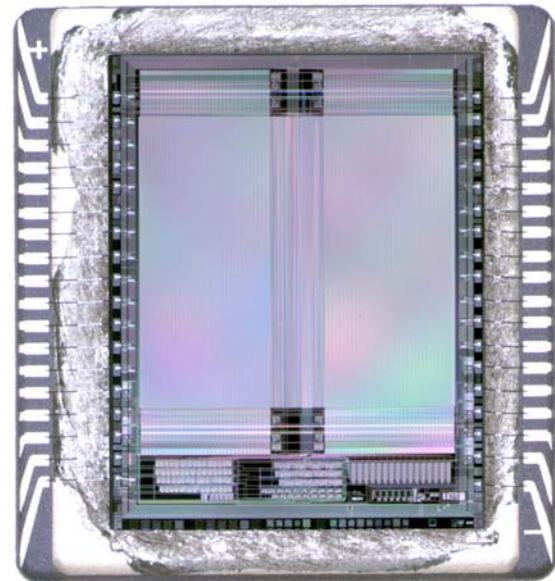
1Mb Qualification Testing Results

■ Life Test

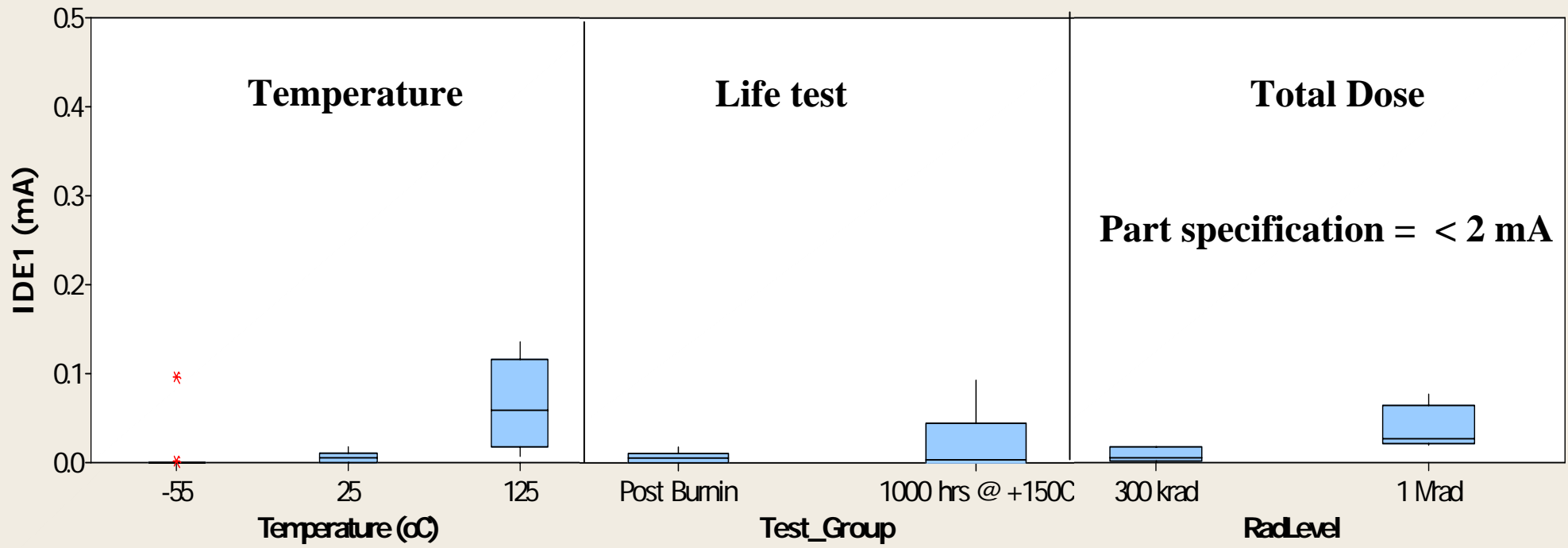
- 10 device sample (1Mbit EEPROM)
- 1000 hr burn-in at 150°C
- All devices passed post 1,000 hr electrical testing
- Tests were performed at 25°C, -55°C, and +125°C

■ Total Dose Radiation

- 6 device sample (1Mbit EEPROM)
- 3 devices 300 Krad
- 3 devices 1Mrad
- All devices passed post radiation testing

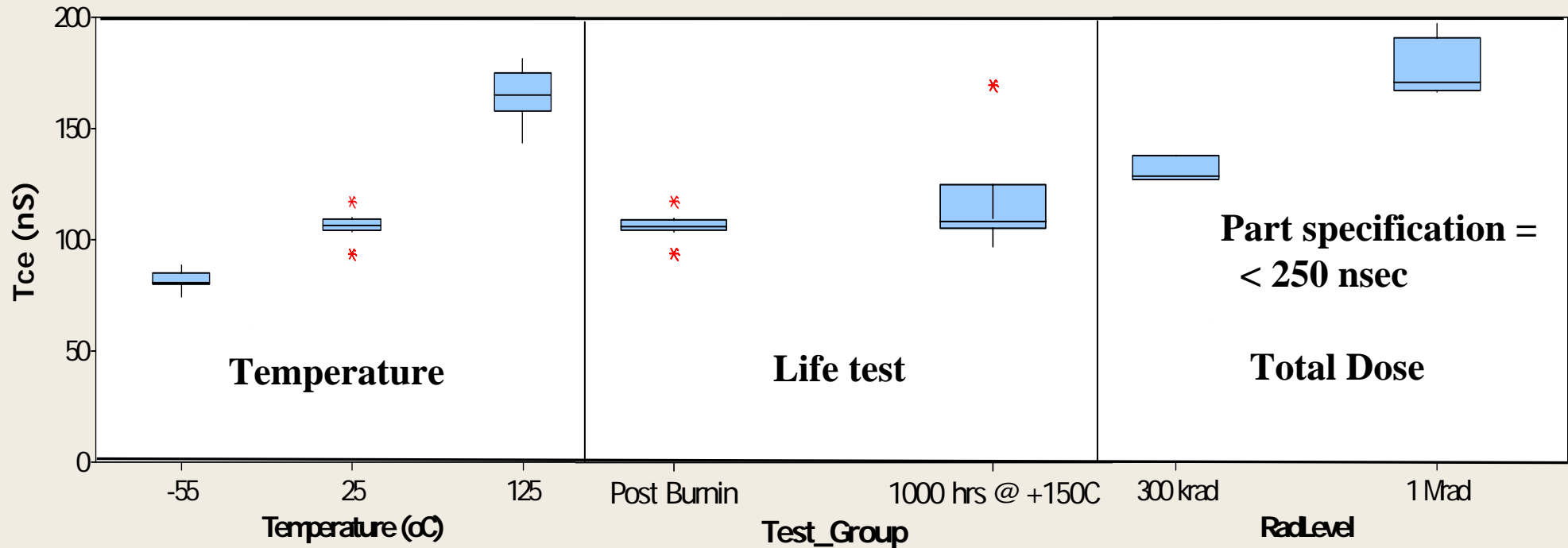


1Mb EEPROM Standby Supply Current



Negligible change with 1000 hour @ +150° C life test or 1 Mrad(Si) total ionizing dose for NGC 1Mb EEPROM

1M EEPROM Chip Enable Access Time



Minimal change in NGC 1Mb EEPROM access time with life test and with 300 krads

Summary

- **A 1Mb (128k x 8) SONOS EEPROM has completed qualification testing**
- **Recent process optimization has resulted in significant improvements in SONOS retention and endurance**
- **Extensive 1Mb activation energy characterization indicates >>100 year memory retention at +125° C**
- **Device has been fully characterized in all radiation environments**
- **Device has passed 1000 hour @ +150° C life tests;**
 - **no reliability issues seen with this part**
- **Engineering parts are available NOW;**
 - **Production parts available 2Q '08**

Acknowledgements

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U. S. Air Force Space and Missile Systems
Center,
NAVY Strategic Systems Program Office,
the Missile Defense Agency,
National Science Foundation and NASA GSFC
for their past and continued support of these
programs.**

“You can be sure if it’s



Northrop Grumman’s Rad-Hard EEPROM Technology

2Kb BORAM device programmed in December 1976

No dropped bits as of October 18, 2007 – 31 years of retention!!

NORTHROP GRUMMAN