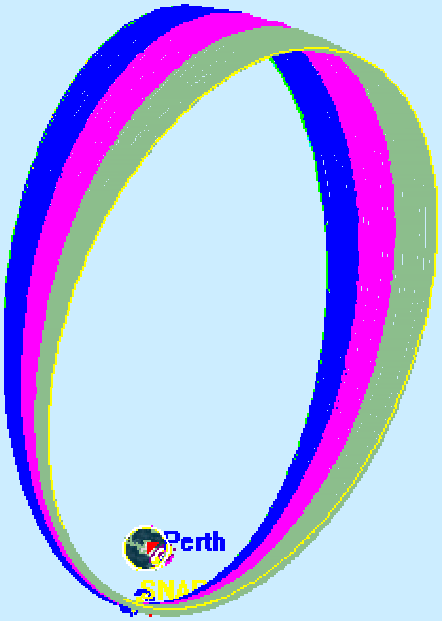
SNAP Data Recorder

- SNAP baseline
- Existing technologies
- Improvements needed for SNAP
- Scope of possible FNAL involvement
  - Highly elliptical orbit
    - 2.5 Re x 25 Re
    - 3 day cycle
    - 85% data collection
    - ~12 hrs in low orbit
      (5 hrs over Berkeley)



SNAP Baseline

- "A solid state recorder – a shoebox"
  - No moving (rotating) parts
  - Lots of memory
  - Radiation / space qualified
  - Low power

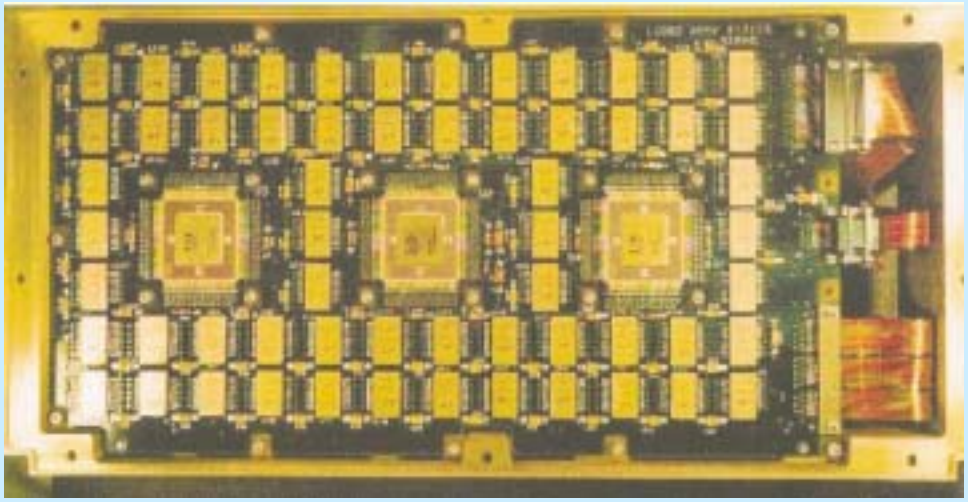
- SNAP plans to transmit data in Kα band @ 150-300 Mbs with 6W transmitter.
- 375 Gbyte (Levi, DOE talk) might grow to ~500 Gbyte storage (expanded science).

Memory technologies

- Memories
  - Dynamic RAM
    - Parasitic capacitance needs power to refresh
  - Static RAM
    - 2 transistors + 4 resistors FLIP-FLOP
  - FLASH memories
    - Floating gate with tunneling processes
  - FeRAM
    - Ferromagnetic crystal storage
  - Holographic and other technologies
- Tape and disk recorders are candidates

Some current missions

- Cassini
  - Two SSRs each of 2.5 Gbit
  - 640 4Mbit DRAMs
  - Early 90's technology => '97 launch
  - Multiple-bit upsets observed despite testing (architecture flaw)



-3 control ASICs
-120 DRAM/board
-Error detection and correction circuitry

Some current missions

- Hubble Space Telescope
  - Reel-to-reel tape replaced by SSR
    - 1.2 Gb -> 12 Gb
    - 1440 16 Mbit DRAM
    - Two stacks of 10 (+2 spare) for 320 Mb packages (still 12500 chips for 500 GB)

  - Single event upsets observed
    - EDAC (Reed-Solomon scheme)
    - Two events where memory corrected but damaged
- Kepler (earth size planets transiting stars)
  - Large CCD array, but only star's pixels Xmit'd

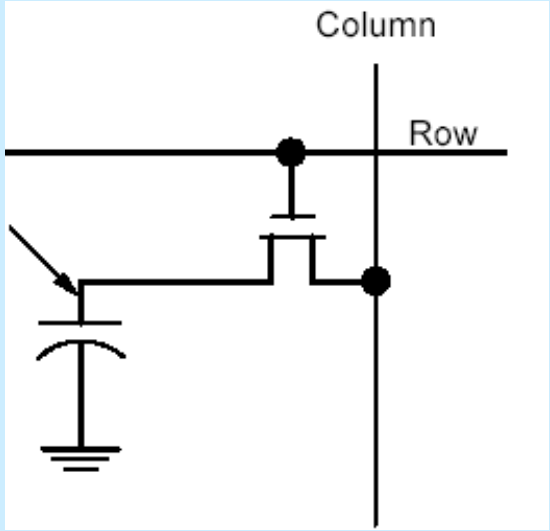
Challenges for SNAP

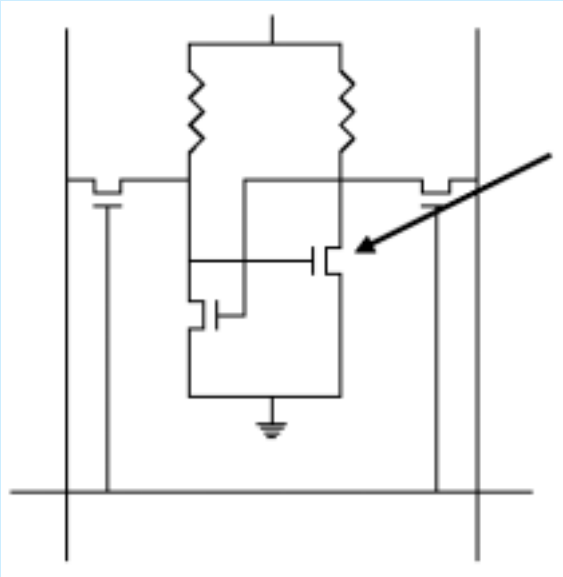
- Amount of memory
  - No examples of large (>>1 GB) SSRs found
  - Moore's Law growth. Need ~4000 x 1 Gbit
- Mass budget
  - Boards with 1000's of chips is several 10's lbs
- Power budget
  - Need more information
- Radiation tolerance
- Space qualification

Radiation Tolerance

- Ionizing radiation small (<50 Krad)
- SEE (Single Event Effects) include many failure mechanisms
- SEU (Single Event Upset) can change state of a bit

DRAM Sensitive area

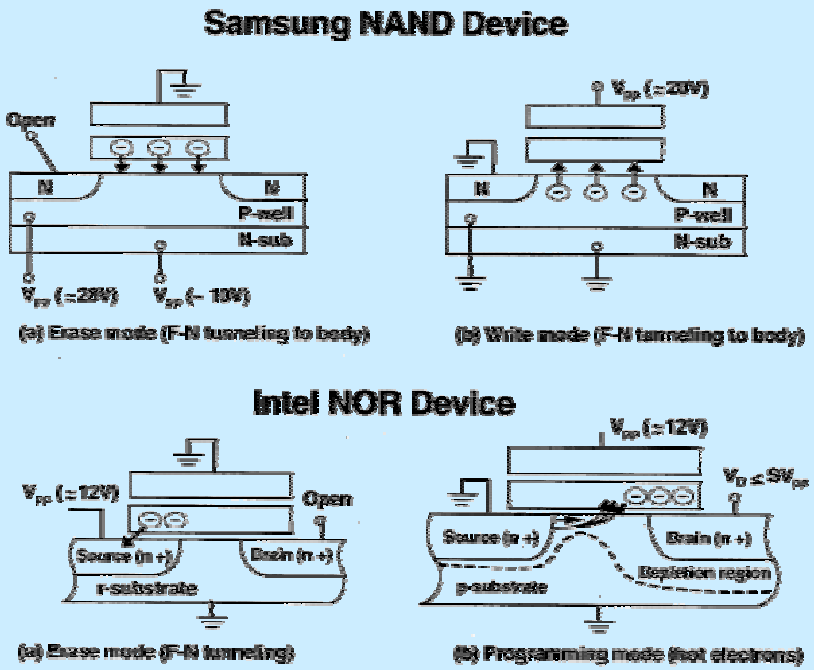


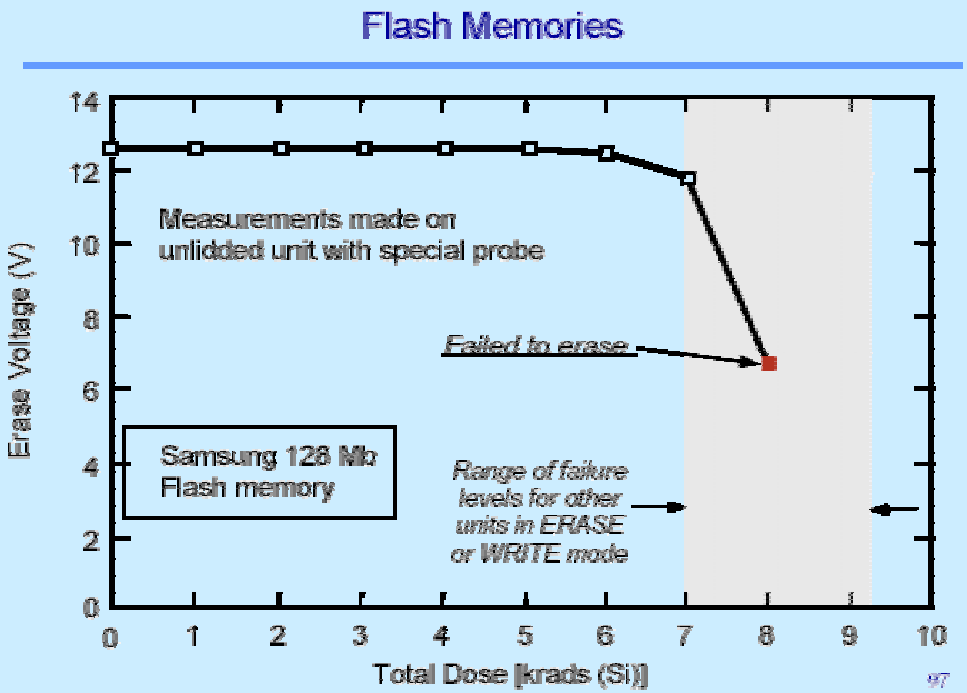


SRAM Sensitive area

Radiation Tolerance

- FLASH memories
  - Very thin oxides make FLASH susceptible
  - Charge pump is the suspect for many failures
  - Limited number of read/write cycles





Space qualification

- Thermal-Vac
  - Vacuum and Temperature extremes (-40 to +90 degC)

- Vibration facility
  - Hard shake

HST HOST Mission

- More Thermal-Vac and vibration testing after mount
  - Room filled with engine noise simulation

Space qualification

GSFC-S-480-89

PERFORMANCE ASSURANCE
REQUIREMENTS (PAR)
FOR THE
SOLID STATE
RECORDER

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

National Aeronautics and
Space Administration

CONTENTS

Para.		Page
1.	GENERAL REQUIREMENTS	1-1
1.1	BASIS AND SCOPE OF THE REQUIREMENTS	1-1
1.2	GENERAL REQUIREMENTS	1-1
1.3	MANAGEMENT OF THE ASSURANCE PROGRAM	1-1
1.4	PERFORMANCE ASSURANCE STATUS REPORT	1-2
1.6	SURVEILLANCE OF THE CONTRACTOR	1-2
1.6	GENERAL PROCUREMENT REQUIREMENTS	1-3
1.6.1	Selection of Sources	1-3
1.6.2	Requirements on Subcontractor and Suppliers	1-3
1.7	AUDITS	1-3
1.7.1	Subcontractor and Supplier Audits	1-3
1.7.2	Audit Report	1-4
1.8	APPLICABLE DOCUMENTS (APPENDIX A)	1-4
1.9	GLOSSARY (APPENDIX B)	1-4
2.	ASSURANCE REVIEW REQUIREMENTS	2-1
2.1	GENERAL REQUIREMENTS	2-1

Space qualification

CONTENTS (Continued)

Para.

2.2 POES FLIGHT ASSURANCE REVIEW REQUIREMENTS. . .

2.3 POES FLIGHT ASSURANCE REVIEW PROGRAM . . . . .

2.4 CONTRACTOR INTERNAL REVIEW REQUIREMENTS. . . .

3. PERFORMANCE VERIFICATION REQUIREMENTS. . . . .

3.1 GENERAL REQUIREMENTS . . . . . .

3.2 DOCUMENTATION REQUIREMENTS . . . . . .

3.2.1 Verification Plan.and Procedure. . .
3.2.3.1 Control of Unscheduled Activities
3.2.2 Verification Reports . . . . . .

3.3 ELECTRICAL FUNCTION TEST REQUIREMENTS . . . .

3.3.1 Electrical Interface Tests . . . . .
3.3.2 Performance Tests. . . . . .
3.3.2.1 Comprehensive Performance Tests. . .
3.3.2.2 Limited Performance Tests. . . . . .
3.3.2.4 Trouble-free Performance Testing . .

3.4 STRUCTURAL AND MECHANICAL REQUIREMENTS . . . .

3.4.1 General Requirements . . . . . .
3.4.2 Requirements Summary . . . . . .
3.4.3 Structural Loads . . . . . .
3.4.3.1 Verification . . . . . .
3.4.3.2 Acceptance Requirements. . . . . .
3.4.7 Pressure Profile. . . . . .
3.4.7.1 Verification. . . . . .
3.4.7.2 Acceptance Requirements. . . . . .
3.4.8 Mass Properties. . . . . .

3.5 ELECTROMAGNETIC COMPATIBILITY REQUIREMENTS . .

3.5.1 General Requirements . . . . . .
3.5.2 Specific Requirements. . . . . .
3.5.3 Magnetic Properties. . . . . .

3.6 VACUUM, THERMAL, AND HUMIDITY REQUIREMENTS . .

3.6.1 General Requirements . . . . . .
3.6.2 Requirements Summary . . . . . .
3.6.3 Thermal-Vacuum . . . . . .
3.6.3.1 General Requirements . . . . . .
3.6.3.2 Acceptance Requirements. . . . . .
3.6.3.3 Additional Report Requirements . . .

CONTENTS (Continued)

Para.

4. SYSTEM SAFETY REQUIREMENTS . . . . . .

4.1 GENERAL REQUIREMENTS . . . . . .
4.2 SYSTEM SAFETY PROGRAM PLAN . . . . . .
4.3 ANALYSES . . . . . .

4.3.1 System Hazard Analysis . . . . . .
4.3.2 Operations Hazard Analyses . . . .

4.4 HAZARD CONTROL VERIFICATION. . . . . .
4.5 WAIVERS. . . . . .
4.6 SAFETY DATA PACKAGE. . . . . .

5. PARTS CONTROL REQUIREMENTS. . . . . .

5.1 GENERAL REQUIREMENTS . . . . . .

5.2 ELECTRICAL, ELECTRONIC, AND ELECTROMECHANICA
PARTS .. . .

5.2.1 Parts Control Board . . . . . .
5.2.1.1 PCB Meetings. . . . . .
5.2.2 Parts Selection and Processing. . .
5.2.2.1 Custom Devices
5.2.3 Derating. . . . . .
5.2.4 Radiation Hardness. . . . . .
5.2.5 Verification Testing. . . . . .
5.2.6 Destructive Physical Analysis . . .
5.2.7 Parts Age Control . . . . . .

5.3 PARTS LIST . . . . . .

5.3.1 Program Approved Parts List . . . .

5.3.1.1 Parts Approved on Prior Programs. .

5.3.2. . Parts Identification List . . . . .

5.4 ALERTS. . . . . .

CONTENTS (Continued)

Para.

6. MATERIALS AND PROCESSES CONTROL REQUIREMENTS. . .

6.1 SELECTION REQUIREMENTS. . . . . .

6.1.1 Conventional Applications . . . . . .
6.1.2 Nonconventional Applications. . . . . .
6.1.3 Special Problem Areas . . . . . .
6.1.4 Organic Materials . . . . . .
6.1.5 Considerations in Process Selection . .
6.1.6 Shelf-Life Controlled Items . . . . . .

6.2 MATERIALS REVIEW . . . . . .
6.3 DOCUMENTATION . . . . . .

7. RELIABILITY REQUIREMENTS . . . . . .
7.1 GENERAL REQUIREMENTS. . . . . .

7.2 DESIGN ASSURANCE. . . . . .
7.2.1 Requirements. . . . . .
7.2.2 Contractor Support for Design Assurance
7.2.3 Specifications, Drawings, and Test
Procedures. . . . . .
7.2.3.1 Design Specifications . . . . . .
7.2.3.2 Specifications, Drawings, and Test
Procedure Reviews . . . . . .

7.3 RELIABILITY ANALYSES. . . . . .
7.3.1 Failure Mode, Effects, and Criticality
Analysis. . . . . .
7.3.2 Parts Devices Stress Analyses . . . . .
7.3.3 Worst Case Analyses . . . . . .
7.3.4 Trend Analyses. . . . . .

7.4 LIMITED-LIFE ITEMS. . . . . .

7.5 RELIABILITY OF GOVERNMENT-FURNISHED PROPERTY. . .

8. QUALITY ASSURANCE REQUIREMENTS. . . . . .

8.1 GENERAL REQUIREMENTS. . . . . .

Space qualification

CONTENTS (Continue

Para.

8.2 DOCUMENT CHANGE CONTROL . . . . . .

8.3 IDENTIFICATION AND TRACEABILITY . . . . . .

8.3.1 Requirements. . . . . .

8.4 PROCUREMENT CONTROLS. . . . . .

8.4.1 Product Changes . . . . . .
8.4.2 Purchased Raw Materials . . . . . .
8.4.3 Raw Materials Used in Purchased Products. . . . . .
8.4.4 Age Control and limited-life Products. . . . . .
8.4.5 Inspection and Test Records . . . . .
8.4.6 Government Source Inspection (GSA). .
8.4.7 Procurements That Do Not Require GSA .
8.4.8 Weld Filler Metal . . . . . .
8.4.9 Fasteners . . . . . .
8.4.10 Contractor QA Activity at Source. . .
8.4.11 Resubmission of Nonconforming Articles or Materials. . . . . .

8.5 REVIEW AND APPROVAL OF PROCUREMENT DOCUMENTS . .

8.6 GOVERNMENT SOURCE INSPECTION . . . . . .

8.7 CONTRACTOR SOURCE INSPECTION . . . . . .

8.8 CONTRACTOR RECEIVING INSPECTION. . . . . .

8.9 FABRICATION CONTROL. . . . . .

8.9.1 Fabrication and Assembly Flow Plan .
8.9.2 Documentation . . . . . .
8.9.3 Fabrication Requirements. . . . . .
8.9.4 Process Evaluation and Control. . . .

CONTENTS (Continued)

CONTAMINATION CONTROL. . . . . .

ELECTROSTATIC DISCHARGE CONTROL. . . . . .

NONCONFORMANCE CONTROL . . . . . .

8.12.1 Control, Disposition, and Reporting of Discrepancies. . . . . .
8.12.1.1 Documentation . . . . . .
8.12.1.2 Initial Review Dispositions. . . . . .
8.12.1.3 Material Review Board. . . . . .
8.12.1.4 Supplier Material Review Board . . . .
8.12.2 Control, Reporting, and Disposition of Failures. . . . . .
8.12. 2.1 Failure Reporting. . . . . .
8.12.2.2 Failure Review Board . . . . . .

ALERT INFORMATION. . . . . .

INSPECTION AND TESTS . . . . . .

8.14.1 Planning . . . . . .
8.14.2 Inspection and In-Process Test Procedures . . . . . .
8.14.3 Inspection Activity. . . . . .
8.14.3.1 In-Process Inspection. . . . . .
8.14.3.2 Final Inspection . . . . . .
8.14.3.3 End-Item Inspection. . . . . .
8.14.3.4 Printed-Wiring Board Inspections and Tests . . . . . .
8.14.4 QA Activities During Integration and Test Phase . . . . . .
8.14.4.1 Verification . . . . . .
8.14.4.2 Test Documentation . . . . . .
8.14.4.3 Post-Test Assurance Activity . . . . .
8.14.5 Inspection and Test Records (Component Level to End-Item). . . . .
8.14.5.1 General Requirements . . . . . .
8.14.5.2 Scope . . . . . .

CONTENTS (Continued)

CONFIGURATION VERIFICATION . . . . . .
METROLOGY. . . . . .

8.16.1 General Requirements . . . . . .
8.16.2 Instruments Used for Measuring . . . .
8.16.3 Product Measurement Process. . . . . .
8.16.4 Calibration Measurement Processes. . .

STAMP CONTROL SYSTEM . . . . . .

SAMPLING PLANS . . . . . .

TRAINING AND CERTIFICATION FOR MANUFACTURING AND INSPECTION PERSONNEL . . . . . .

8.19.1 Training . . . . . .
8.19.2 Certification and Recertification of Personnel. . . . . .
8.19.3 Records. . . . . .

HANDLING, STORAGE, PRESERVATION, MARRING, LABELING, PACKAGING, PACKING, AND SHIPPING . . . . . .

8.20.1 Handling . . . . . .
8.20.2 Preservation, Marking, Labeling, Packaging, and Packing . . . . . .
8.20.3 Shipping . . . . . .

GOVERNMENT PROPERTY CONTROL. . . . . .

8.21.1 Contractor's Responsibility. . . . . .
8.21.2 Unsuitable Government Property . . . . .

GOVERNMENT ACCEPTANCE. . . . . .

CONTAMINATION CONTROL REQUIREMENTS . . . . . .

APPLICABILITY AND DEFINITIONS. . . . . .

CONTAMINATION ALLOWANCE . . . . . .

CONTAMINATION CONTROL . . . . . .

FNAL Involvement

- Large robust memory is nicely associated with expanded science program of deep field sky survey
- Radiation issues (tie-in with shield) are already studied at FNAL
- Next steps
  - Continue to get working knowledge
  - Contact vendors
  - Narrow technologies to working concept
- ASIC resources are possible

Conclusions

- No clear technology solution
  - High density, low power, radiation hard
  - Flash memories x10 less power (big difference between 100 W and 1 kW)
  - New concepts not ready for 1 Gb scale
- Dense technologies use smaller feature sizes that are more prone to some failures
- ASIC solution is possible, but could memories be made dense enough with accessible minimal feature sizes