

AD-A206 266

On-Orbit Observations of Single-Event Upset in Harris HM-6508 RAMs: An Update

Prepared by

J. B. BLAKE
Space Sciences Laboratory
The Aerospace Corporation
El Segundo, CA 90245

and

R. MANDEL
Lockheed Missiles and Space Corporation
Sunnyvale, CA 94088

16 February 1989

Prepared for

SPACE DIVISION
AIR FORCE SYSTEMS COMMAND
Los Angeles Air Force Station
P.O. Box 92960
Los Angeles, CA 90009-2960

APPROVED FOR PUBLIC RELEASE;
DISTRIBUTION UNLIMITED

DTIC
ELECTE
APR 05 1989
S & D
H

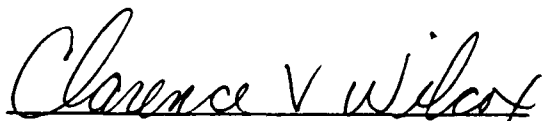
89 4 04 086

This report was submitted by The Aerospace Corporation, El Segundo, CA 90245, under Contract No. F04701-85-C-0086-P00019 with the Space Division, P.O. Box 92960, Los Angeles, CA 90009-2960. It was reviewed and approved for The Aerospace Corporation by H. R. Rugge, Director, Space Sciences Laboratory.

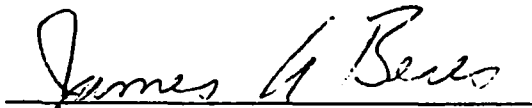
Lt Clarence V. Wilcox was the project officer for the Mission-Oriented Investigation and Experimentation (MOIE) Program.

This report has been reviewed by the Public Affairs Office (PAS) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nationals.

This technical report has been reviewed and is approved for publication. Publication of this report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas.



Clarence V. Wilcox, Lt, USAF
MOIE Project Officer
SD/CLTPC



JAMES A. BERES, Lt Col, USAF
Director, AFSTC West Coast Office
AFSTC/WCO

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified			1b. RESTRICTIVE MARKINGS	
2a. SECURITY CLASSIFICATION AUTHORITY			3. DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release; distribution unlimited.	
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE				
4. PERFORMING ORGANIZATION REPORT NUMBER(S) TR-0088(3940-05)-5			5. MONITORING ORGANIZATION REPORT NUMBER(S) SD-TR-89-07	
6a. NAME OF PERFORMING ORGANIZATION The Aerospace Corporation Laboratory Operations		6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION Space Division Air Force Systems Command	
6c. ADDRESS (City, State, and ZIP Code) 2350 E. El Segundo Blvd. El Segundo, CA 90245			7b. ADDRESS (City, State, and ZIP Code) Los Angeles Air Force Base P. O. Box 92960 Los Angeles, CA 90009-2960	
8a. NAME OF FUNDING / SPONSORING ORGANIZATION		8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER F04701-85-C-0086-P00019	
8c. ADDRESS (City, State, and ZIP Code)			10. SOURCE OF FUNDING NUMBERS	
			PROGRAM ELEMENT NO	PROJECT NO
11. TITLE (Include Security Classification) On-Orbit Observations of Single-Event Upset in Harris HM-6508 RAMs: An Update				
12. PERSONAL AUTHOR(S) J. Bernard Blake and R. Mandel				
13a. TYPE OF REPORT		13b. TIME COVERED FROM _____ TO _____	14. DATE OF REPORT (Year, Month, Day) 1989 February 16	15. PAGE COUNT 8
16. SUPPLEMENTARY NOTATION				
17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) Single event upset (SEU) Random access memories (RAMs) Radiation effects in space	
FIELD	GROUP	SUB-GROUP		
19. ABSTRACT (Continue on reverse if necessary and identify by block number) The observed single-event-upset rate of Harris HM-6508 RAMs in a low polar orbit is presented. These data were acquired during a four-year period from 1983 through 1986.				
20. DISTRIBUTION / AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT ☐ DTIC USERS			21. ABSTRACT SECURITY CLASSIFICATION	
22a. NAME OF RESPONSIBLE INDIVIDUAL			22b. TELEPHONE (Include Area Code)	22c. OFFICE SYMBOL

CONTENTS

I.	INTRODUCTION.....	3
II.	THE EXPERIMENT.....	5
III.	RESULTS.....	7

FIGURES

1.	Measured Upset Rate as a Function of Time.....	7
2.	Calculated Upset Rates as a Function of Shield Thickness.....	8

TABLE

1. SEU Multiplicity Distribution..... 9

Accession For
NTIS GRA&I ☒
DLE DAS ☐
Unannounced ☐
Distribution _____

For _____
Distribution / _____
Approved Entry Codes _____
_____ / or _____
Dist _____ Special _____

A-1

I. INTRODUCTION

The single event upset (SEU) phenomenon has continued to be of great interest to designers of spaceflight hardware. Although a great deal of ground testing has been and continues to be carried out, quantitative on-orbit measurements are very limited. Space measurements are a key part of the effort to ensure that the ground-based testing yields accurate predictions of on-orbit upset rates. Blake and Mandel¹ have published data from two years of flight observations from a subsystem consisting of 384 Harris HM-6508 1K RAMs. This report is an update of that study; the results of 2560 days of observation are presented.

¹J. B. Blake and R. Mandel, Proc. IEEE Trans. Nucl. Sci., 33 (6), 1616 (1986).

II. THE EXPERIMENT

The Harris HM-6508 1K x 1 RAMs are in a satellite subsystem in low, polar orbits. The memory module used in the subsystem containing the RAMs consists of three printed circuit cards with each card containing eight 2K byte memory hybrids for a total of 48K bytes. Thus, each memory hybrid contains 16 HM-6508 RAM chips.

On a regular basis, all but 256 bytes of the 48K bytes are examined for bit errors. Two different techniques are used for detecting bit errors. The first technique, a memory check sum, is capable of automatically detecting all single-bit and some double-bit errors that occurred within a page of memory. A memory page consists of 256 bytes. Memory check-sum tests are performed approximately every 90 minutes. To detect a multiple error or to determine the exact location of the bit error within the page, the entire contents of the memory are dumped and compared to the load file. Memory dumps are normally performed once a month, or immediately after the check sum routine detects an error. Once the location of the error is found, the correct value is reloaded into the memory. After the memory is reloaded, the contents of the memory location in question are verified to determine if the error was a soft error generated by an SEU, a hard error generated by a part failure, or a cosmic-ray-induced latchup.

III. RESULTS

A total of 234 SEUs were observed during 2560 days of observation. Thus, the average upset rate per day is

$$(2.62 \pm 0.17) \times 10^{-7} \text{ upsets/bit day.}$$

The distribution of upsets as a function of time is given in Figure 1.

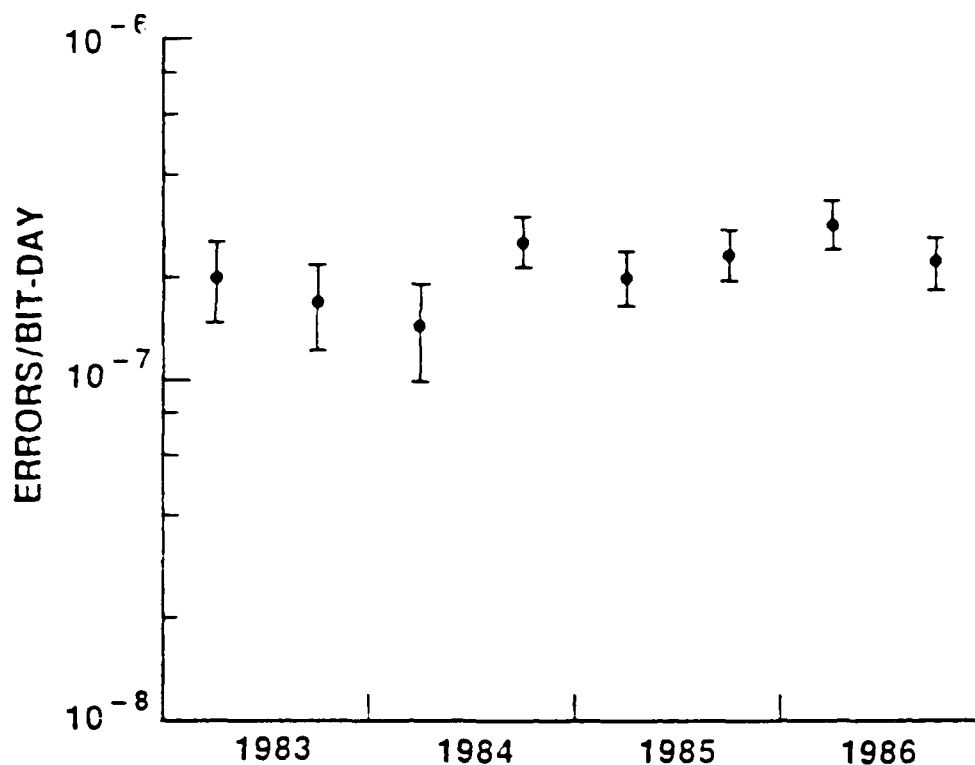


Figure 1. Measured Upset Rate as a Function of Time

The data have been grouped into six-month bins as a compromise between time resolution and counting statistics. Solar cycle modulation can be seen to be modest at best; a horizontal straight line is not a bad fit to

the data. A computer code written by Adams^{*} has been used to predict the on-orbit upset rate. The RAM input data are based on accelerator testing of the HM-6508 RAMs; the data were discussed by Blake and Mandel.² Some results of the calculation for shielding thicknesses of 1, 2, and 5 gm/cm² of aluminum are given in Figure 2.

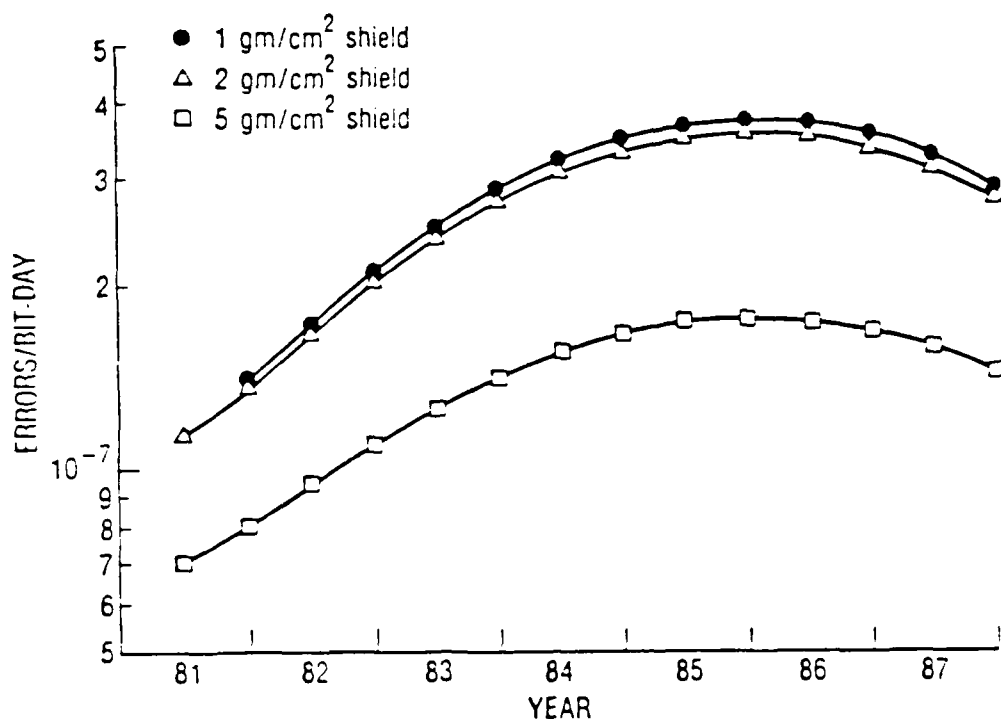


Figure 2. Calculated Upset Rates as a Function of Shield Thickness

It can be seen that the observed SEU rate, given above, is consistent with a shielding thickness of a few gm/cm², which is a reasonable value for the

^{*}J. H. Adams, Jr., private communication, 1985.

²See Ref. 1.

satellite in question. The predicted solar-cycle modulation may be greater than that observed, although the issue is unclear given the counting statistics.

Multiple events were observed in 14 percent of the upsets. The multiplicity distribution is given in Table 1.

Table 1. SEU Multiplicity Distribution

Number of Events	Multiplicity
202	1
27	2
3	3
1	4
1	All bits on chip

The relative location of the upsets in a multiple event is interesting. In many of the events, the multiple errors were adjacent, including the 4-fold error.³

However, in eight cases, the errors were not even on the same board. The obvious question arises: are these multiple SEU events really two independent events that occurred between verifications? As discussed in Blake and Mandel,¹ the probability of such an accidental event is less than once per decade, given the observed upset rate. Perhaps these separated multiple events were due to a single cosmic ray that creates a shower in the satellite vehicle due to a nuclear interaction. An understanding of multiple events will be an important consideration in the effective implementation of error detection and correction techniques in spaceflight hardware.

³See Ref. 1.

LABORATORY OPERATIONS

The Aerospace Corporation functions as an "architect-engineer" for national security projects, specializing in advanced military space systems. Providing research support, the corporation's Laboratory Operations conducts experimental and theoretical investigations that focus on the application of scientific and technical advances to such systems. Vital to the success of these investigations is the technical staff's wide-ranging expertise and its ability to stay current with new developments. This expertise is enhanced by a research program aimed at dealing with the many problems associated with rapidly evolving space systems. Contributing their capabilities to the research effort are these individual laboratories:

Aerophysics Laboratory: Launch vehicle and reentry fluid mechanics, heat transfer and flight dynamics; chemical and electric propulsion, propellant chemistry, chemical dynamics, environmental chemistry, trace detection; spacecraft structural mechanics, contamination, thermal and structural control; high temperature thermomechanics, gas kinetics and radiation; cw and pulsed chemical and excimer laser development including chemical kinetics, spectroscopy, optical resonators, beam control, atmospheric propagation, laser effects and countermeasures.

Chemistry and Physics Laboratory: Atmospheric chemical reactions, atmospheric optics, light scattering, state-specific chemical reactions and radiative signatures of missile plumes, sensor out-of-field-of-view rejection, applied laser spectroscopy, laser chemistry, laser optoelectronics, solar cell physics, battery electrochemistry, space vacuum and radiation effects on materials, lubrication and surface phenomena, thermionic emission, photo-sensitive materials and detectors, atomic frequency standards, and environmental chemistry.

Computer Science Laboratory: Program verification, program translation, performance-sensitive system design, distributed architectures for spaceborne computers, fault-tolerant computer systems, artificial intelligence, micro-electronics applications, communication protocols, and computer security.

Electronics Research Laboratory: Microelectronics, solid-state device physics, compound semiconductors, radiation hardening; electro-optics, quantum electronics, solid-state lasers, optical propagation and communications; microwave semiconductor devices, microwave/millimeter wave measurements, diagnostics and radiometry, microwave/millimeter wave thermionic devices; atomic time and frequency standards; antennas, rf systems, electromagnetic propagation phenomena, space communication systems.

Materials Sciences Laboratory: Development of new materials: metals, alloys, ceramics, polymers and their composites, and new forms of carbon; non-destructive evaluation, component failure analysis and reliability; fracture mechanics and stress corrosion; analysis and evaluation of materials at cryogenic and elevated temperatures as well as in space and enemy-induced environments.

Space Sciences Laboratory: Magnetospheric, auroral and cosmic ray physics, wave-particle interactions, magnetospheric plasma waves, atmospheric and ionospheric physics, density and composition of the upper atmosphere, remote sensing using atmospheric radiation; solar physics, infrared astronomy, infrared signature analysis; effects of solar activity, magnetic storms and nuclear explosions on the earth's atmosphere, ionosphere and magnetosphere; effects of electromagnetic and particulate radiations on space systems; space instrumentation.

. . .