

# A COMPENDIUM OF TOTAL DOSE DATA ON EEPROMs FOR NASA PROGRAMS

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## ABSTRACT

This paper reports on the variability of the TID radiation tolerance of SEEQ 32kX8 EEPROMs with lot date codes (LDCs) varying from 9052 to 9646. The EEPROMs were evaluated for various NASA programs using low dose rate exposures varying from 0.01 to 0.08Rads(Si)/sec, from a <sup>60</sup>Co source. The radiation tolerance of these parts varied from 3-40kRads(Si) depending upon the LDC. It was also found that the WRITE mode capability was generally lost at a lower TID level than the READ mode capability. With increasing radiation exposures, some increase was also observed in I<sub>CC</sub>. The parts also showed a higher radiation tolerance (by a factor of 2-3) when irradiated in an unbiased condition with only a READ functional test performed after each radiation step.

The paper also presents the results of TID evaluations of 1Mbit EEPROMs from Hitachi and AMD. The 1Mbit Hitachi parts showed higher radiation tolerance [50 - 100kRads(Si)]. The 1Mbit AMD parts showed a radiation tolerance of 7.5kRads(Si).

## 1. INTRODUCTION

A number of NASA programs are using non-radiation hardened (non-RH) 256k and 1Mbit EEPROMs. There are no radiation tolerance guarantees provided by the manufacturers of these parts. A number of evaluations were performed at GSFC to characterize the radiation tolerance of these EEPROMs with LDCs varying from 9052 to 9646 in the last eight years for ISTP, SMEX, TOMS, and other projects (see Table 1). The objective of these radiation evaluations was to determine the radiation tolerance of non-RH parts at low dose rates to see if they can meet the TID requirements for their intended mission application. An effort was made to identify the WRITE/READ functional failure levels versus the READ only failure level after different radiation exposures. The effect of biasing conditions on the radiation tolerance of the EEPROMs was also evaluated for some of the LDCs.

**Table 1: Parts Information**

| Part No. *              | Type of EEPROM | Package Type | Mfr.           | Project     | LDC     |
|-------------------------|----------------|--------------|----------------|-------------|---------|
| DM28C256-300/B          | 32k x 8        | 28 Pin DIP   | SEEQ           | ISTP/SOHO   | 9052B   |
| CJ28C256 (M38510/26104) | 32k x 8        | 28 Pin DIP   | SEEQ           | BCMS/GCMS   | 9136    |
| 28C256 (5962-8852503ZA) | 32k x 8        | 28 Pin FP    | SEEQ           | AXAF        | 9133A   |
| 28C256 (5962-8852503ZC) | 32k x 8        | 28 Pin FP    | SEEQ           | TOMS        | 9133B   |
| FM28C256                | 32k x 8        | 28 Pin FP    | SEEQ           | TOMS        | 9133B   |
| 28C256EF-25             | 32k x 8        | 28 Pin FP    | SEEQ           | AXAF/Gulton | 9526    |
| 28C256EFY-25            | 32k x 8        | 28 Pin FP    | SEEQ           | AXAF/Gulton | 9543    |
| 28C010TRPFE             | 125k x 8       | 32 Pin FP    | Hitachi/SEI    | AXAF/Gulton | 9530    |
| 58C1001F                | 125k x 8       | 32 Pin FP    | Hitachi/Austin | GPEP        | unknown |
| 58C1001SF               | 125k x 8       | 32 Pin FP    | Hitachi/Austin | SMEX LITE   | 9646    |
| AM29F016                | 16MBit Flash   | 48 Pin TSOP  | AMD            | GPEP        | unknown |

\* The manufacturer provided no radiation tolerance/ hardness guarantees for these parts.

## **2. TEST FACILITY AND PROCEDURES**

The radiation source used is a BNL Mk I Co<sup>60</sup> Irradiator located at the Radiation Effects Facility of NASA/Goddard Space Flight Center. Radiation dose rates vary from a maximum of  $\approx 1.0$  Rads(Si)/sec directly in front of the shutter to  $\approx 0.001$  Rads(Si)/sec in the rear corners of the room. A large number of different part types can be tested simultaneously at different dose rates simply by placing them at different locations within the irradiator room. This allows low dose rate testing to be done very cost-effectively.

The testing of parts initially and after each irradiation or annealing step was performed in the Microcircuit Test Facility at Unisys Federal Systems in Lanham, MD, using an S-50 digital tester.

The initial electrical measurements (prior to the first irradiation) included a minimum of three functional tests: WRITE/READ ZEROES, WRITE/READ ONES, WRITE/READ CHECKERBOARD. Before each radiation exposure, the parts were programmed with a checkerboard pattern. After each radiation exposure, the READ CHECKERBOARD test was performed. This was followed by WRITE/READ ZEROS, WRITE/READ ONES, and WRITE/READ CHECKERBOARD. However, on some lots, only the READ CHECKERBOARD test was performed after each radiation exposure to determine if the parts show higher radiation tolerance when no WRITE tests are performed.

During each radiation test, four to eight parts are irradiated under static bias and 1 or 2 parts are kept as unirradiated control samples. For some LDCs, a limited number of parts were tested with the parts in an unbiased condition to determine if the parts would show higher radiation tolerance. The irradiation steps for each series of tests are selected according to the anticipated radiation sensitivity of the parts and the projected total dose mission requirements. The dose rate is kept as low as possible within the limits of available time.

The typical radiation steps were 2.5, 5, 7.5, 10, 15, 20, 30, 50, 75 and 100kRads(Si). The dose rate varied from 0.01 to 0.08Rads(Si)/sec depending upon the part type and radiation level.

## **3. TEST RESULTS**

A brief description of the test results for each LDC is provided below and in Figures 1 through 5. Detailed test results for each part type are available in GSFC Radiation Reports, as identified in Table 2.

### **3.1 28C256 EEPROMs**

#### **3.1.1 LDC 9052B**

A total of ten parts were irradiated up to 50kRads(Si). Five parts were irradiated under bias and both READ and WRITE functional tests were performed after each radiation exposure. The other five parts were irradiated in the unbiased mode and only READ functional tests were performed.

All parts from both test groups passed all functional tests up to 5kRads(Si). After 10kRads(Si), four of the five parts in the biased group failed functionally and after 15kRads(Si), all biased parts failed functionally. However, the unbiased parts passed all functional tests up to 30kRads(Si). After 40kRads(Si), three parts in the unbiased group failed and after 50kRads(Si), all parts (biased and unbiased) failed functionally.

Both biased and unbiased parts showed degradation in  $I_{CC}$  after 10-50kRads(Si), but there was not much difference in the  $I_{CC}$  values for the two groups.

#### **3.1.2 LDC 9136**

Four parts were irradiated under bias to 15kRads(Si). All parts passed both READ and WRITE functional tests up to 10kRads. After 15kRads(Si), one part failed WRITE/READ CHECKERBOARD at  $V_{CC} = 4.5$  and  $5.5V$ . No failures were observed at  $V_{CC} = 5.0V$ . No significant degradation was observed in  $I_{CC}$ .

#### **3.1.3 LDC 9133A**

Four parts were irradiated under bias to 2.5kRads(Si). All parts passed the READ CHECKERBOARD functional test after the radiation step, but failed all functional WRITE tests (ZEROES, ONES and CHECKERBOARD). Significant degradation was observed in  $I_{CC}$ .

### **3.1.4 LDC 9133B**

Five parts were irradiated, three under bias and two unbiased up to 30kRads(Si). Only READ tests were performed after each radiation step for both the biased and unbiased parts. All biased parts passed all functional tests up to 20kRads(Si) and all parametric tests up to 8kRads(Si) but started showing degradation in  $I_{CC}$  at 9kRads(Si) and above. The unbiased parts passed functional and parametric tests up to 20kRads(Si). After 30kRads(Si), two biased parts failed the READ functional tests while both unbiased parts continued to pass all functional and parametric tests. The biased parts also showed increasing degradation in  $I_{CC}$  at 30kRads(Si). No significant recovery was observed in the biased parts after annealing for 168 hours at 25°C.

Four more parts were irradiated under bias, only the READ CHECKERBOARD functional tests were performed after each radiation step. All parts passed the READ CHECKERBOARD functional tests up to 30kRads(Si), however, the parts started to exceed the specification limit for  $I_{CC}$  after 15 through 30kRads(Si). Some recovery was observed in  $I_{CC}$  after annealing for 168 hours at 25°C.

### **3.1.5 LDC 9526**

Four parts were irradiated under bias and both READ and WRITE functional tests were performed after each step up to 20kRads(Si). All parts passed all functional tests up to 2kRads(Si). After 3kRads(Si), one part failed the READ/WRITE CHECKERBOARD functional test. The other three parts continued to pass all functional tests up to 14kRads(Si). All parts failed READ and WRITE functional tests after 16 to 20kRads(Si). No significant degradation was observed in  $I_{CC}$ .

### **3.1.6 LDC 9543**

Five parts were irradiated under bias, both READ and WRITE tests were performed after each radiation step up to 10kRads(Si). All parts passed all functional and parametric tests up to 7kRads(Si). Parts failed WRITE and READ functional tests after 8 to 10kRads(Si). No significant degradation was observed in  $I_{CC}$ .

## **3.2 1Mbit EEPROMs**

### **3.2.1 28C010 (LDC 9530)**

Four parts were irradiated under bias, all parts passed all WRITE and READ functional tests up to 100kRads(Si). Some parametric degradation was observed in  $I_{IL}$ .

### **3.2.2 58C1001**

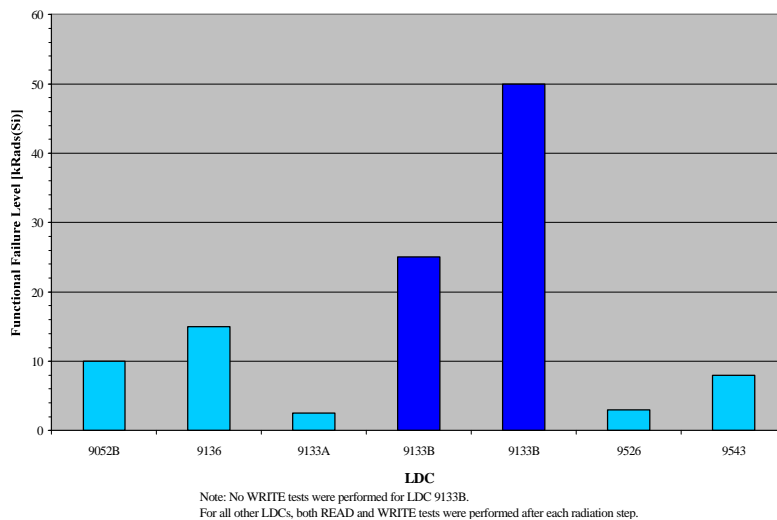
Two LDCs were tested, one was unknown and the other was 9646. For the first (unknown) lot, three parts were irradiated under bias to 100kRads(Si). All parts passed all WRITE and READ functional tests up to 50kRads(Si). The parts showed Read and Write functional failures at 75 and 100kRads(Si). Some degradation was also observed in  $I_{IL}$  after 30kRads(Si).

For LDC 9646, five parts were irradiated under bias. All parts passed all WRITE and READ functional tests up to 100kRads(Si). Some degradation was also observed in  $I_{IL}$  after 30kRads(Si).

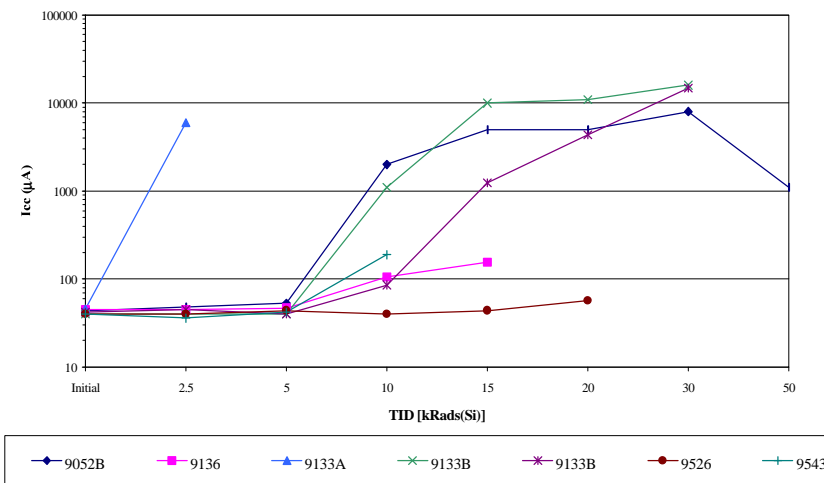
### **3.2.3 AM29F016 (LDC Unknown)**

Four parts were irradiated under bias to 10kRads(Si). All parts passed all WRITE and READ functional and parametric tests up to 7.5kRads(Si). After 10kRads(Si), all parts failed all functional tests as well as  $I_{CC}$ ,  $V_{OH}$  and  $V_{OL}$ .

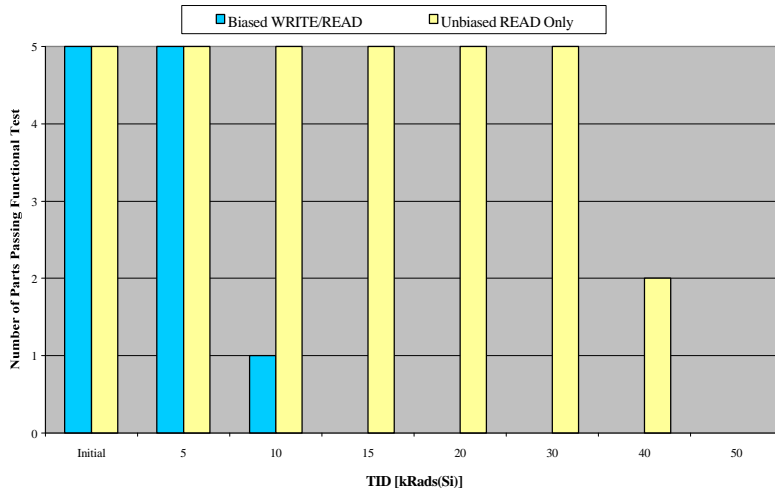
**Figure 1: Functional Failure Level for 28C256 EEPROMs**



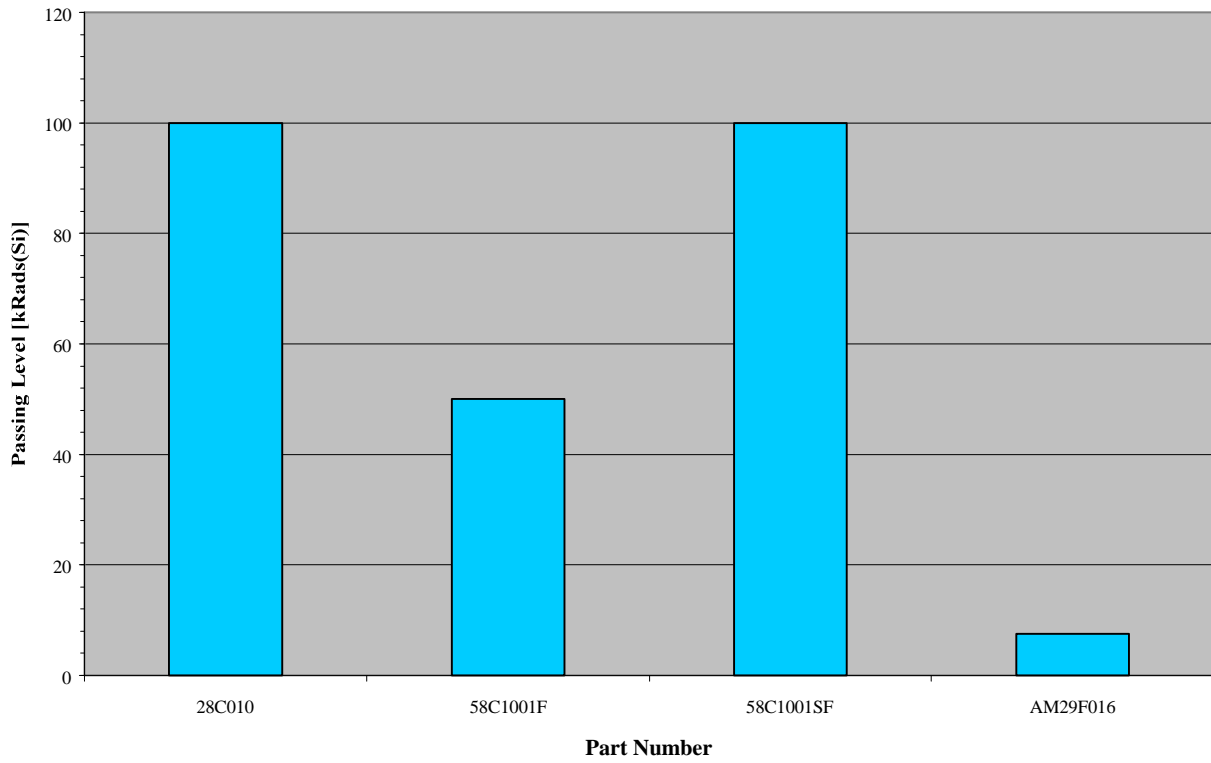
**Figure 2: Icc vs. Total Ionizing Dose [kRads(Si)] for 28C256 EEPROMs**



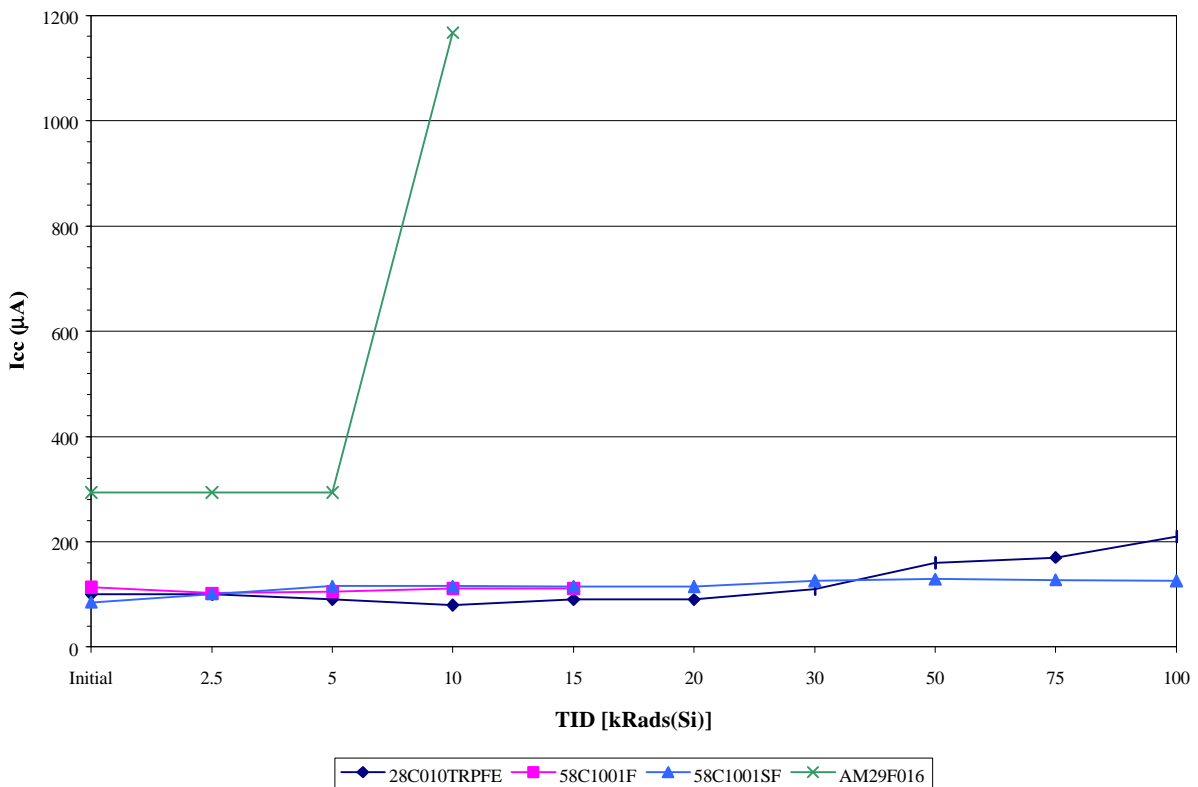
**Figure 3: Functional Test Results for Biased and Unbiased Parts vs Total Ionizing Dose for DM28C256 (LDC 9052B)**



**Figure 4: Functional Passing Level for 1Mbit EEPROMs**



**Figure 5: Icc vs. Total Ionizing Dose [kRads(Si)] for 1Mbit EEPROMs**



## 4.0 SUMMARY

A wide variation in the sensitivity of the SEEQ 32kX8 EEPROMs was observed with the radiation tolerance of these parts varying from 3 to 40kRads(Si). The WRITE mode capability was generally lost before the READ mode capability. There was an observable increase in I<sub>CC</sub> for several lots. The parts showed a higher radiation tolerance

(by a factor of 2-3) when irradiated in an unbiased condition with only a READ functional test performed after each radiation step.

The 1Mbit Hitachi parts showed higher radiation tolerance [50 - 100kRads(Si)]. The 1Mbit AMD parts showed a radiation tolerance of only 7.5kRads(Si).

**Table 2: Summary of Test Results**

| Generic Part No.        | Mfr.           | LDC     | Test Level, kRads(Si) | Dose Rate Rads(Si)/Sec | Funct. Read Failure Level kRads(Si) | Funct. Write Failure Level kRads(Si) | Radiation Sensitive DC Parameters                   | Report     |
|-------------------------|----------------|---------|-----------------------|------------------------|-------------------------------------|--------------------------------------|---|------------|
| DM28C256-300/B          | SEEQ           | 9052B   | 5-50                  | 0.06                   | 40-50                               | 10-15                                | I <sub>CC</sub>                                     | PPM-91-610 |
| CJ28C256 (M38510/26104) | SEEQ           | 9136    | 2.5-15                | 0.01                   | >15                                 | 15                                   | ---   | PPM-93-052 |
| 28C256 (5962-8525032A)  | SEEQ           | 9133A   | 2.5                   | 0.04                   | >2.5                                | 2.5                                  | I <sub>CC</sub>                                     | PPM-95-141 |
| 28C256 (5962-8852503ZC) | SEEQ           | 9133B   | 0.5-30                | 0.01                   | 25                                  | *                                    | I <sub>CC</sub>                                     | PPM-95-147 |
| FM28C256                | SEEQ           | 9133B   | 2.5-30                | 0.04                   | >30                                 | *                                    | I <sub>CC</sub>                                     | PPM-95-169 |
| 28C256EF-25             | SEEQ           | 9526    | 1-20                  | 0.01                   | 3-20                                | 3-20                                 | ---   | PPM-95-175 |
| 28C256EFY-25            | SEEQ           | 9543    | 1-10                  | 0.01                   | 8-10                                | 8-10                                 | ---   | PPM-95-187 |
| 28C010TRPFE             | Hitachi/SEI    | 9530    | 2.5-100               | 0.08                   | >100                                | >100                                 | I <sub>IL</sub>                                     | PPM-95-182 |
| 58C1001F                | Hitachi/Austin | Unknown | 2.5-100               | 0.06                   | 75-100                              | 75-100                               | I <sub>IL</sub>                                     | PPM-96-003 |
| 58C1001SF               | Hitachi/Austin | 9646    | 5-100                 | 0.05                   | >100                                | >100                                 | I <sub>IL</sub>                                     | PPM-97-034 |
| AM29F016                | AMD            | Unknown | 5-10                  | 0.01                   | 10                                  | 10                                   | I <sub>CC</sub> , V <sub>OH</sub> , V <sub>OL</sub> | PPM-97-011 |

\* Indicates that no WRITE tests were performed.

- The degradation level denotes the radiation exposure level at which one or more parts exceeded the specification limit for any of the functional tests or electrical parametric tests (since all the parts reported here are non-RH, no post-irradiation specification limits were provided by the manufacturer),
- The “radiation sensitive parameters” are those in which degradation beyond the specification limits was first observed during the radiation testing. This degradation does not necessarily represent a catastrophic failure of the part. In most cases, the part continued to remain functional.
- A copy of these reports can be obtained from the GSFC Office of Flight Assurance Library by calling (301) 286-7240.

## 5.0 RECOMMENDATIONS

Due to the large variance in the radiation tolerance of EEPROMs with LDC, as well as the test mode (READ/WRITE or READ ONLY), it is recommended that a sample from the flight LDC be tested to determine if the parts meet the radiation requirements for the specific mission application. Since the radiation tolerance of these parts generally improves when only READ tests are performed versus WRITE/READ, or if the parts are kept unbiased versus biased, the radiation evaluation should be custom tailored to the application of the part for each project.

## 6.0 ACKNOWLEDGEMENTS

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