TO: G. Swift
FROM: Logistics and Technical Information Division
SUBJECT: Notification of Clearance - CL#02-2164

The following title has been cleared by the Document Review Services, Section 274, for public release, presentation, and/or printing in the open literature:

Single-Event Upset in Power-PC Processors

This clearance is issued for the full paper and is valid for U.S. and foreign release.

Clearance issued by Mary Sue O'Brien
Document Review Services
Section 644

(Over)
The Document Review approval process applies to all JPL information intended for unrestricted external release via print or electronic media. See explanations on page 3 of this form and the Distribute Knowledge documents available through http://dmie.

**I. DOCUMENT AND PROJECT IDENTIFICATION - To be completed by Author/Originator**

<table>
<thead>
<tr>
<th>Title</th>
<th>OTHER AUTHORS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Event Upset in Power PC Processors</td>
<td>A. H. Johnston, F. Irom</td>
</tr>
</tbody>
</table>

**KEY WORDS FOR INDEXING (Separate terms with commas)**

**THIS WORK: □ Covers new technology not previously reported □ Covers work previously reported in New Technology Report (NTR) No. □ Provides more information for earlier NTR No(s). □ Contains no new technology**

**LEAD JPL AUTHOR'S SIGNATURE**

**DATE**

**8/19/02**

**SECTION OR PROJECT LEVEL APPROVAL - I attest to the technical accuracy of this document/web site.**

**DATE**

**8/19/02**

**ORIGINATING ORGANIZATION (Section, Project, or Element Number)**

**PERFORMING ORGANIZATION (If different)**

**ACCOUNT CODE OR TASK ORDER (For tracking purposes only)**

**DOCUMENT NUMBER(S), RELEASE DATE(S)**

**DATE RECEIVED**

**DATE DUE**

For presentations, documents, or other scientific/technical information to be externally published (including via electronic media), enter information—such as name, place, and date of conference; periodical or journal name; or book title and publisher—in the area below.

**Web Site: Preclearance URL (JPL internal)**


**Postclearance URL (external)**

**Meeting Title**

**RADECs**

**Meeting Date**

Sept. 19-20

**Location**

Italy

**Sponsoring Society**

**RADECs Basel**

**Book/Book Chapter**

**Assigned JPL Task**

**Private Venture Publisher**

If your document will not be part of a journal, meeting, or book publication (including a web-based publication), can we post the cleared, final version on the JPL worldwide Technical Report Server (TRS) and send it to the NASA Center for Aerospace Information (CASI)? □ Yes □ No

(For more information on TRS/CASI, see [http://techreports.jpl.nasa.gov](http://techreports.jpl.nasa.gov) and [http://www.sti.nasa.gov](http://www.sti.nasa.gov)). If your document will be published, the published version will be posted on the TRS and sent to CASI.

**II. NATIONAL SECURITY CLASSIFICATION**

**CHECK ONE (One of the five boxes denoting Security Classification must be checked.)**

**SECRET**

**SECRET RD**

**CONFIDENTIAL**

**CONFIDENTIAL RD**

□ UNCLASSIFIED

**NASA EXPORT-CONTROLLED PROGRAM STI**

| □ International Traffic in Arms Regulations (ITAR) | □ Export Control Classification Number (ECCN) from the Commerce Control List (CCL) |

**CONFIDENTIAL COMMERCIAL STI**

(Check appropriate box below and indicate the distribution limitation if applicable.)

| □ TRADE SECRET | □ Limited until (date) |
| □ SBIR | □ Limited until (date) |
| □ COPYRIGHTED | □ Limited until (date) |

| □ COPYRIGHT | □ Publicly available (but subject to copying restrictions) |

**ADDITIONAL INFORMATION**

(Provide additional information if applicable.)

- □ U.S. Government agencies only
- □ NASA contractors and U.S. Government only
- □ NASA personnel and NASA contractors only
- □ Available only with the approval of issuing office

**PUBLICLY AVAILABLE STI**

Publicly available means it is unlimited and unclassified, is not export-controlled, does not contain confidential commercial data, and has cleared any applicable patent application.

**Alan Johnston 4-6425**
<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
</tr>
</thead>
</table>
| IV. DOCUMENT DISCLOSING AN INVENTION (For SIAMO Use Only) ROUTED ON | □ If STI discloses an invention, send this box and send to SIAMO. 
□ This document may be released on (date) | 
□ STRATEGIC INTELLECTUAL ASSETS MANAGEMENT OFFICE (SIAMO) SIGNATURE DATE |
| V. BLANKET AVAILABILITY AUTHORIZATION (Optional) | □ All documents issued under the following contract/grant/project number may be processed as checked in Sections II and III. 
This blanket availability authorization is granted on (date) 
□ Check one: □ Contract □ Grant □ Project Number 
□ The blanket availability authorization granted on (date) 
□ is RESCINDED - Future documents must have individual availability authorizations. 
□ is MODIFIED - Limitations for all documents processed in the STI system under the blanket release should be changed to conform to blocks as checked in Sections II and III. |
| SIGNATURE MAIL STOP DATE |
| VI. PROJECT OFFICER/TECHNICAL MONITOR/DIVISION CHIEF REVIEW OF I THROUGH V | □ Approved for distribution as marked above 
□ Not approved |
| NAME OF PROJECT OFFICER OR TECH. MONITOR MAIL STOP SIGNATURE DATE |
| VII. EXPORT CONTROL REVIEW/CONFIRMATION ROUTED ON | □ Public release is approved 
□ Export-controlled limitation is approved 
□ Public release not approved due to export control 
□ Export-controlled limitation is not applicable |
| USML CATEGORY NUMBER (ITAR) CCL NUMBER, ECCN NUMBER (EAR) JPL EXPORT CONTROL ADMIN. REPRESENTATIVE SIGNATURE DATE |
| COMMENTS |
| VIII. OTHER APPROVALS ROUTED ON | □ LAUNCH APPROVAL 
□ OFFICE OF COMMUNICATIONS AND EDUCATION 
□ GENERAL COUNSEL 
□ Budgetary/Cost Data 
□ Vendor Data 
□ Copyrights 
□ Other |
| SIGNATURE DATE |
| IX. FINAL VERIFICATION, APPROVAL, AND DISPOSITION BY DOCUMENT REVIEW | □ I have determined that this publication: 
□ DOES contain ITAR/export-controlled, confidential commercial information, and/or discloses an invention and the appropriate limitation is checked in Sections III and/or IV. 
□ Does NOT contain ITAR/export-controlled, confidential commercial information, nor does it disclose an invention and may be released as indicated above. |
| USML CATEGORY NUMBER (ITAR) CCL NUMBER, ECCN NUMBER (EAR) |
| □ Public release is approved for U.S. and foreign distribution 
□ Public release is not approved |
| COMMENTS Oral only? Call author - Yes 2785 will be furnished |
| SIGNATURE MAIL STOP DATE | Mary Lee O'Brien 11/12/02 8/26/02 |
| □ Obtained published version Date 
☑ Obtained final JPL version Date |
Single-Event Upset in Power-PC Processors

G. M. Swift, A. H. Johnston, and F. Irom

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, CA 91109 USA

The research in this paper was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration (NASA), under the NASA Electronics Parts and Packaging Program, Code AE.
Outline

• Background
  • Processor Testing
  • PowerPC family

• Proton Tests

• Heavy Ion Tests

• Discussion
  • Hangs and Crashes
  • Effects of Scaling

• Conclusions
Overview of “Pin Wiggler” Method

- DUT running self-inspection program
- SEU counter from register comparison
- LOOP counter from self-inspection program
- INIT counter (indicates processor reset)

Record with "strip chart" at regular intervals
Test Approach Using “Yellowknife” Development Board

Diagram showing the connection between various components including power supplies, interface driver, probe, AI heat sink, JTAG, and the vacuum chamber.
Proton Upsets of PowerPC Cache

![Graph showing cross section vs LETeff for MPC-7400 (0.20 μm) and MPC-750 (0.29 μm).]
Proton Upset Results for FPRs

![Graph showing proton upset results for FPRs with different energy levels for Motorola MPC-750 and MPC-7400.](image-url)
Outline

• Background
  • Processor Testing
  • PowerPC family

• Proton Tests

• Heavy Ion Tests

• Discussion
  • Hangs and Crashes
  • Effects of Scaling

• Conclusions
Proton Upsets of PowerPC Cache

![Graph showing the relationship between LET_{eff} and Cross Section (cm²/bit) for MPC-7400 (0.20 μm) and MPC-750 (0.29 μm).]
TAM In-Air Irradiation Facility
TAM In-Air Irradiation Facility
Dealing with Thermal Problems
Heavy Ions Used

![Graph showing LET vs. Travel Distance in Si (μm) for different ions.]

- 3,200 MeV Xe
- 2,100 MeV Kr
- 1,000 MeV Ar
- 546 MeV Ne
Hang Comparison: PowerPCs and Pentiums

![Graph showing cross section vs. proton energy for Pentium II (after Hiemstra) and MMX (after Hiemstra). The graph also includes an estimated hang rate for Power PC tests.]
Scaling: Alpha Simulation Results

Lines correspond to model
Points are for 3-D simulation
Trench isolation (0.3 micron)

Conclusion

- Processor Test Techniques
  - Hand coded assembly test programs
  - Simple or no operating system

- Upset Results
  - Cache and register upsets dominate at present
  - Hangs and crashes expected to increase

- Scaling Results
  - Cross sections lower with smaller feature sizes
  - Consistent with charge collection simulations
References