Commercial Off-The-Shelf (COTS) Reliability Concerns for COTS Microelectronics in Space & Military Applications

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JPL COTS Program Objective:

Infusion of state-of-the-art COTS parts into JPL flight hardware & systems that meet the requirements of the mission they are used in

JPL COTS Infusion Process:

Developing new methodologies, performing evaluations, making risk assessments, and implementing tailored mitigation measures to insure reliable parts

Scope of COTS Microelectronics:

PEMs, KGD, Low Power/Temp., Advanced Microcircuits, FPGAs, ASICs, A/D, Memories, Microprocessors, Mixed Signal, among others
Reasons for Using COTS in Space:

1. The availability of COTS parts is proliferating.

2. COTS parts performance capabilities continue to increase (e.g. processing power & high density memories)

3. A new generation of leading COTS IC technologies is introduced every 3 years.

4. COTS acquisition cost is much less than radiation hardened counterparts; by using radiation tolerant parts the cost advantage can be preserved.

5. Some COTS parts (plastic) have been reported to demonstrate good to excellent reliability.
## COTS Concerns

<table>
<thead>
<tr>
<th>Concern</th>
<th>Military</th>
<th>Space</th>
<th>Why?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Very long term storage in a harsh environment (moisture sensitivity).</td>
<td><img src="/red.png" alt="Red" /></td>
<td><img src="/green.png" alt="Green" /></td>
<td>Typical Storage &lt;1-2 years (can be controlled)</td>
</tr>
<tr>
<td>2. Cannot upgrade to military temperature range.</td>
<td><img src="/red.png" alt="Red" /></td>
<td><img src="/yellow.png" alt="Yellow" /></td>
<td>Can tailor screens to mission profile</td>
</tr>
<tr>
<td>3. Supplier selection is critical to achieving low risk.</td>
<td><img src="/red.png" alt="Red" /></td>
<td><img src="/red.png" alt="Red" /></td>
<td>Suppliers vary considerably</td>
</tr>
<tr>
<td>4. Acquisition costs do not reflect total cost of ownership.</td>
<td><img src="/red.png" alt="Red" /></td>
<td><img src="/red.png" alt="Red" /></td>
<td>Depends highly on risk mitigation steps taken</td>
</tr>
<tr>
<td>5. Lack of high reliability</td>
<td><img src="/red.png" alt="Red" /></td>
<td><img src="/yellow.png" alt="Yellow" /></td>
<td>Apply risk assessment/methodology to meet mission requirements</td>
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</table>

- **High risk**
- **Moderate risk**
- **Low risk**
### COTS Concerns continued

<table>
<thead>
<tr>
<th>Concern</th>
<th>Military</th>
<th>Space</th>
<th>Why?</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. Lack of data</td>
<td><img src="image" alt="Red" /></td>
<td><img src="image" alt="Yellow" /></td>
<td>Rely on vendor’s data or generate as needed</td>
</tr>
<tr>
<td>7. Radiation sensitivity</td>
<td><img src="image" alt="Yellow" /></td>
<td><img src="image" alt="Red" /></td>
<td>Harsher/more variable radiation requirements</td>
</tr>
<tr>
<td>8. Obsolescence</td>
<td><img src="image" alt="Red" /></td>
<td><img src="image" alt="Green" /></td>
<td>Short design cycles</td>
</tr>
<tr>
<td>9. Stockpile reliability</td>
<td><img src="image" alt="Red" /></td>
<td><img src="image" alt="Green" /></td>
<td>Relatively short shelf life</td>
</tr>
<tr>
<td>10. Human life jeopardy</td>
<td><img src="image" alt="Red" /></td>
<td><img src="image" alt="Green" /></td>
<td>Unmanned missions for planetary exploration</td>
</tr>
<tr>
<td>11. Life cycle cost</td>
<td><img src="image" alt="Red" /></td>
<td><img src="image" alt="Green" /></td>
<td>Reparability is non-issue; one time use only!</td>
</tr>
</tbody>
</table>
Concern #2- Cannot Upgrade to Military Temperature Range

COTS SRAMS have been evaluated by JPL at military temperature range:

- +125°C
- +70°C
- +25°C
- 0°C
- -20°C
- -55°C

- +5.5V
- +4.5V
- +3.6V
- +3.0V

Sony CXK584000TM Pass
SS = 6/6

Motorola MCM6246 Pass
SS = 6/6

Hitachi HM628512 Pass
SS = 6/6

Results:

Three different parts from three different vendors passed.

Lesson: Some parts can be upscreened under careful evaluation.
Concern #3- Supplier Selection is Critical to Achieving Low Risk

JPL Experience:

Mars Pathfinder used a COTS hybrid converter because of cost & schedule constraints. They ordered to a military temperature range from a non-QML supplier. Early samples showed problems which were aggressively worked with the vendor. New builds were better and performed well.

Some subsequent JPL projects ordered converters from the same vendor without the same rigorous follow-up, we found:

- Corrective actions from Mars Pathfinder did not persist
- 11/13 DPA samples from different lots were rejected
- JPL source inspection led to many rejects (19/20 lots)
- 8 operational failures in hardware
- Extensive effort required to solve the problems proved very expensive

Lesson: Successful COTS infusion requires careful selection of suppliers.
Concern #4- Acquisition Costs do not Reflect Total Cost of Ownership

Total Cost of Ownership (TCO) = Acquisition + Inventory + Evaluation + Replacement

where Evaluation varies considerably for COTS based on risk mitigation taken.

Case Example for COTS Transistor Evaluation:

a. Upscreen per SCD spec - $4,600
b. Special electrical test with R/R at specified temperature range including Burn-in - $5,600
c. Life test on samples - $3,400
d. Destructive physical analysis/RGA - $400
e. SCD, Engineering Review, CSI, Acceptance - $10,000
f. Replacement - $0

COTS Acquisition cost was ~ $600; TCO ~ 40X (can vary to 50X)

COTS Yield = 58% (met our minimum Space reliability requirements & quantity needs).
Concern #5 - Lack of High Reliability:

JPL Applied Methodology for Selection of COTS is focused on:

- Detection, recognition, and elimination of potentially critical part problems that could lead to catastrophic mission failure.

- Performing risk assessment and risk mitigation for those parts that may seriously limit or compromise mission objectives.

- Establishing parts criteria that systematically generates data and requires critical decision making even when data/information gaps occur.

Lesson: High reliability is achieved by using incremental decision making.
**Concern #7 - Radiation Sensitivity:**

**JPL A/D COTS Radiation Data**

<table>
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<tr>
<th>P/N</th>
<th>Resolution</th>
<th>Process</th>
<th>VDD</th>
<th>Power</th>
<th>Speed</th>
<th>Total Dose</th>
<th>SEL</th>
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<tr>
<td>LTC1419</td>
<td>14-Bit</td>
<td>CMOS</td>
<td>+/- 5V</td>
<td>150 mW</td>
<td>800 Ksps</td>
<td>TBD</td>
<td>None, LET&gt;100 MeV/mg/cm²</td>
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<td>SPT7725</td>
<td>8-Bit</td>
<td>Bipolar</td>
<td>- 5.2V</td>
<td>2.2 W</td>
<td>300 Msps</td>
<td>&gt;100 Krad (Si)</td>
<td>None, LET&gt;100 MeV/mg/cm²</td>
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<td>HI1276</td>
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<td>Bipolar</td>
<td>- 5.2V</td>
<td>2.8 W</td>
<td>500 Msps</td>
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<td>None, LET&gt;100 MeV/mg/cm²</td>
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<td>AD7714-3</td>
<td>24-Bit</td>
<td>CMOS</td>
<td>+ 3V</td>
<td>2.6 mW</td>
<td>See data sheet</td>
<td>TBD</td>
<td>LET = 55 MeV/mg/cm²</td>
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<td>ADS7809</td>
<td>16-Bit</td>
<td>CMOS</td>
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<td>100 mW</td>
<td>100 Ksps</td>
<td>10 Krad (Si)</td>
<td>LET = 19.9 MeV/mg/cm²</td>
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**Lesson:** Each part must be evaluated on its own merit & per mission requirements before acceptance.
Moisture Absorption / Bake for Intel DA28F016SV in Plastic Package

(0.6 µm ETOX IV Process Technology)

Conditions: Test Temperature = 25°C, Vdd = 5.0V, Vpp = 5.0V

Figure 1

Jet Propulsion Laboratory
Electronic Parts Engineering Office
507
Data on PEMs

Moisture Absorption/Desorption for Intel 56 Ld SSOP Package

- 85°C/85%RH
- 70°C Bake
- 100°C Bake
- 125°C Bake

Preconditioned @ 105°C for 10 days

Weight Gain (%) = (Wt-Wi)/Wi*100
Weight Loss (%) = (Wtd-Wi)/(Wf-Wi)*100

No evidence of corrosion found on units 1 & 2. Minuscule evidence found on one lead for unit 3.
### Sample COTS Parts Evaluation Data

**Jet Propulsion Laboratory**

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<tr>
<th>Part No.</th>
<th>Mfg.</th>
<th>Process</th>
<th>Function</th>
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</table>
Internet Web Site is Developed at JPL for COTS

http://cots.jpl.nasa.gov/
Technical Solutions to Using COTS in Space:

- Ruggedize the compartment or enclosure if cost effective
- Upscreen using multiple qualified third parties
  - Upscreen using the OEM
- Use cooling fluids to meet military temperature range
- Buy ruggedized COTS if available
- Characterize for the application each & every time
  - Stay within the manufacture’s ratings
Conclusions:

The risks that must be ascertained when using COTS in Space must include:

1. Supplier selection to insure good product quality and reliability
2. Total Cost of Ownership including any upgrade screens/qualification
3. Radiation Sensitivity

To successfully infuse COTS in Space applications a complete characterization over the full environment intended is required.