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# Using COTS Electronic Components in High Reliability Applications - Lessons Learned

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# Main Topics

- Summary of COTS Processes
  - What are COTS parts
  - Why are we using them
  - WRCIP (War Reserve COTS Insertion Process) Goals
- Production Status on First System
- Summary of Lessons Learned
  - Participant Feedback
  - Procurement Results
  - Qualification Results
  - Schedule Results
- Unique Capabilities Developed for COTS

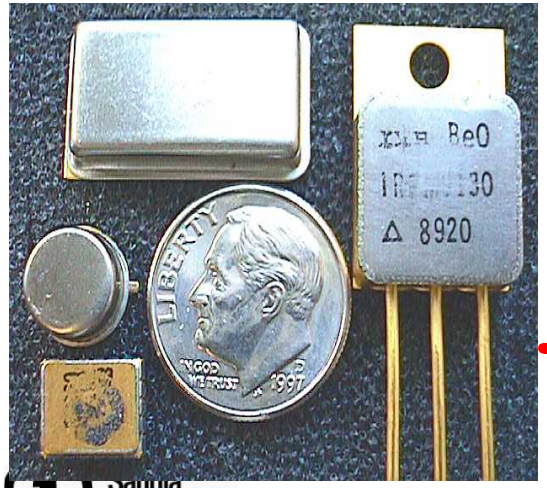
# Process Summary
# What are COTS Parts?

- Commercial Off The Shelf (COTS)

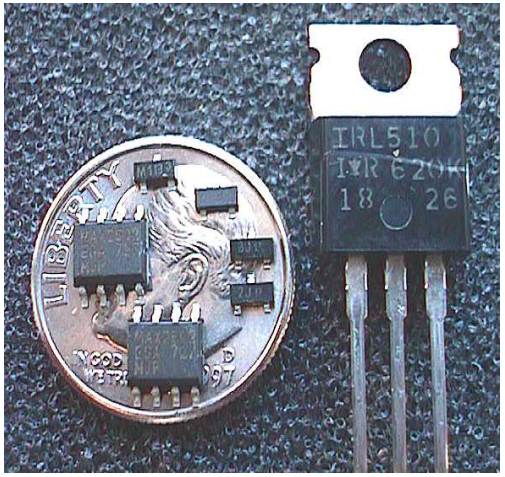
  *is not just a class of parts, also a procurement method*

  A definition for COTS is that the components are purchased with ***NO BUYER IMPOSED REQUIREMENTS PASSED TO THE SELLER***.

  - **The component is *purchased as the seller offers it in his catalog* with no special testing, handling, packaging, labeling, etc. required by the buyer**
  - **Both Commercial and Military grade components fit into this COTS category**




- **Commercial Grade: Plastic**
- **Industrial Grade: Plastic**
- **Military Grade: Ceramic packaged**
- **SA Grade: Custom versions of Mil Parts**

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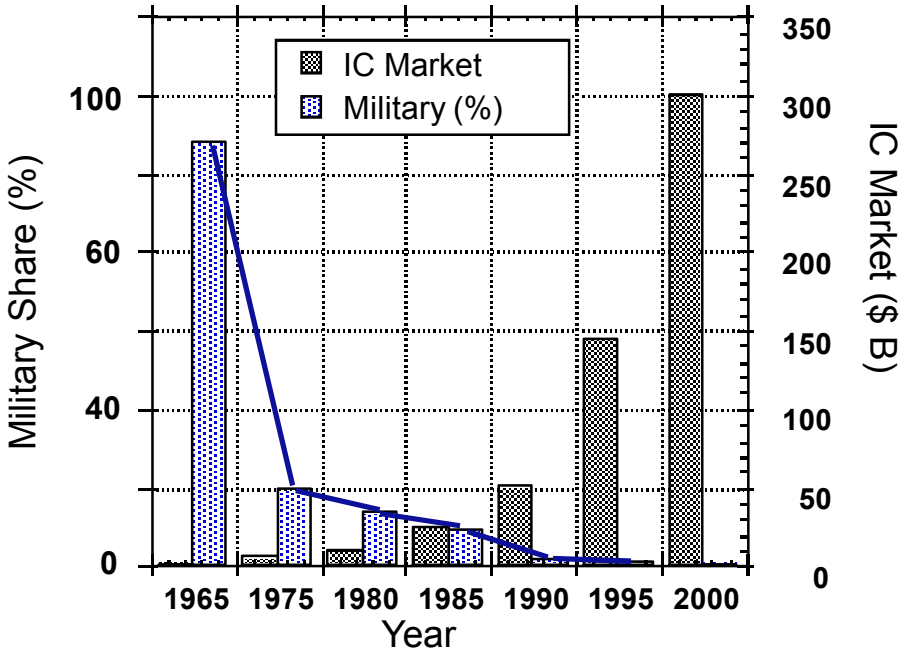
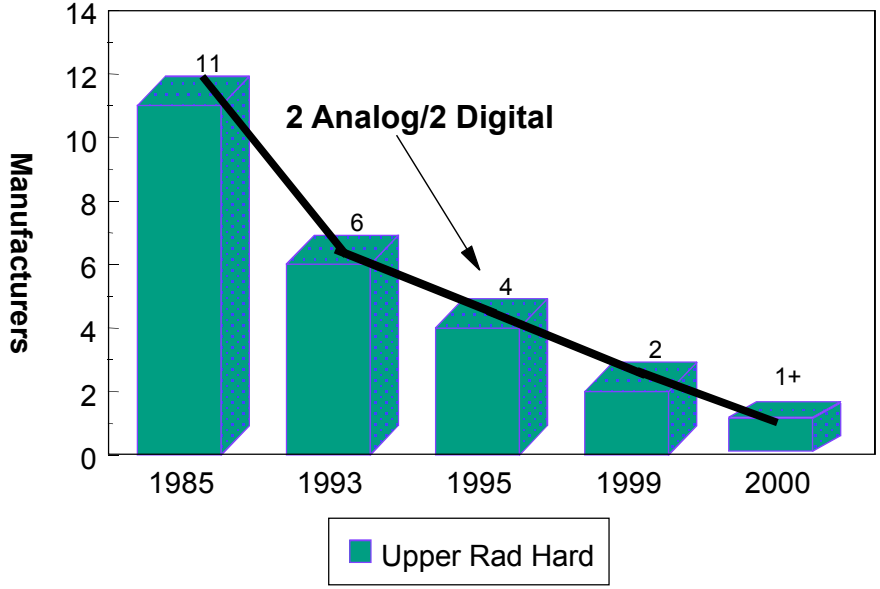
# Why COTS?: Microelectronics/Rad-Hard Industry Trends




- **Military market share is extremely small compared to commercial markets**
- **Manufactures have followed the market and have eliminated many military products**

- **Commercial Electronics Now Drive the Market**

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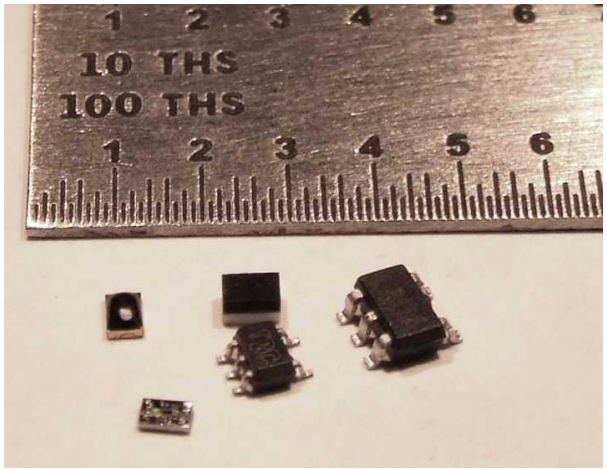
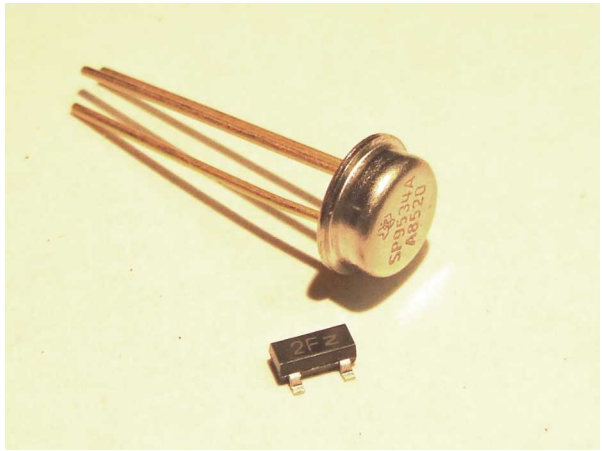
# Circuit designers find advantages with COTS Components

- Diminishing manufacturing sources, ***and in some cases no source***, (i.e., MIL-STD, ceramic, rad hard)
- **Lower cost of COTS components**
- **Rapid design capability**
- Smaller volume
- Greater functionality of COTS components
- Greater availability of COTS part types
- Greater design flexibility
- Produced to meet stringent requirements on high volume production lines using statistically controlled processes
- Include the latest technology
- Can exhibit higher reliability than low volume production parts



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# Examples of Potential Cost Savings in Using COTS Parts

- Lowers electronic part costs dramatically relative to mil-spec and source controlled (SC) parts
- Examples based on typical quantities and part types used in DOE systems

## Examples of Cost Savings

| | Part Type | Quantity Needed | Selection & Reliability Cost | Procurement & Qualfiication Cost | Purchase Price/part | Total Cost In Stores |
|---|---|---|---|---|---|---|
| BJT | COTS | 40000 | $120,000 | $80,000 | $0.05 | $202,000 |
| | Mil-Spec | 40000 | $20,000 | $40,000 | $15.00 | $660,000 |
| | SC | 40000 | $200,000 | $200,000 | $150.00 | $6,400,000 |
| | | | | | | |
| MOSFET | COTS | 20000 | $120,000 | $80,000 | $1.20 | $224,000 |
| | Mil-Spec | 20000 | $20,000 | $40,000 | $350.00 | $7,060,000 |
| | SC | 20000 | $200,000 | $200,000 | $362.00 | $7,640,000 |
| | | | | | | |
| 8051 | COTS | 2000 | $300,000 | $300,000 | $17.00 | $634,000 |
| | Mil-Spec | 2000 | $50,000 | $20,000 | $500.00 | $1,070,000 |
| | Mil-Spec(rad-hard) | 2000 | $50,000 | $40,000 | $1,700.00 | $3,490,000 |
| | SC | 2000 | $300,000 | $300,000 | $1,700.00 | $4,000,000 |

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# SNL Strategy is to Apply the BEST Electronic Parts Solution for System Application

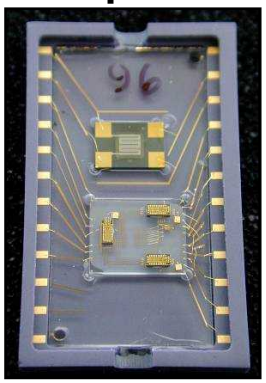
**Most cost effective solution:**

- Evaluate cost tradeoffs at every step of circuit design and part selection
- Meet requirements using
  -- COTS parts
  -- High level integration (e.g. ASIC)

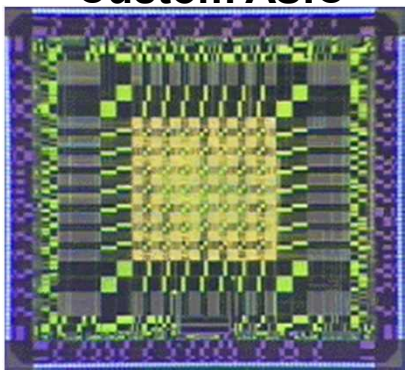
**Electronic part hierarchy:**

- Buy COTS parts and fully qualify them to meet mission requirements
- Design for industry fabrication and delivery
- Maintain in-house research, technology, and product capability - supply custom products to customers from internal fabrication facilities

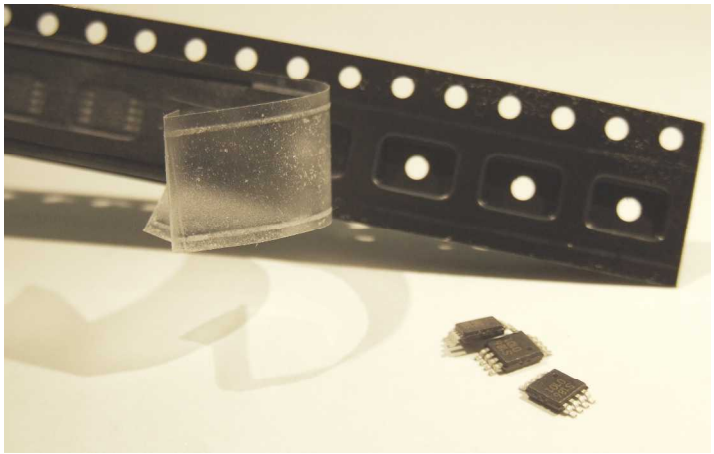
Multi-Chip Module



Custom ASIC



Qualified COTS



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# WR COTS Insertion Program Goal

## Goal:

**Develop a set of *standard processes and tools* that enable the selection and assessment of the BEST electronic component for a stated application.**

## Approaches include:

- **Developing the needed *knowledge, processes*, and *infrastructure***
- **Developing processes in 5 critical areas: *parts selection, procurement and acceptance, reliability, qualification, and surveillance***
- **Ensuring that our approach will serve the needs of future *DOE and DoD* programs**
- **Teaming with other knowledgeable groups to *pool information* and *accelerate learning***

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# Production Results

# First System Use of COTS

- **Utilized a Mix of Mil-Spec and Commercial PEMS**
  - Most resistors & small-signal capacitors are Mil-Spec
  - Most semiconductors are commercial PEMs
- **Status**
  - Procurement and Qualification testing are complete
  - Qualification Engineering Releases complete
  - Over 3 million parts in WR stores

**COTS Part Numbers**

| | |
|---|---|
| Diodes | 35 |
| Transistors | 10 |
| RF Devices | 17 |
| ICs (Dig + Analog) | 5 |
| FETs | 4 |
| Magnetics | 34 |
| Resistors | 163 |
| Capacitors | 71 |
| Other | 3 |
| Total | 342 |

# Board Electrical Test Results as of 12/8/06

| Board | Parts per Board | Boards Tested | Total Parts | COTS Failures |
|---|---|---|---|---|
| A | 741 | 37 | 27417 | 2 |
| B | 10 | 28 | 280 | 0 |
| C | 174 | 26 | 4524 | 0 |
| D | 302 | 30 | 9060 | 0 |
| E | 210 | 30 | 6300 | 0 |
| Total | | | 47581 | 2 |

<50 PPM Failure Rate

Board electrical test results meeting expectations of <75 PPM failure defect rate

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# Summary of Lessons Learned

# COTS Lessons Learned
# Participant Feedback

- **Contributors**
  - SNL (9+1) and KCP (6+1) component engineers and managers
  - Other key people
    - Design engineers (3)
    - Reliability engineers (1)
    - KCP buyer (1)
    - Third party test house (3)
- **Process**
  - Collect input on four questions via videoconference or surveys
    - What worked well (105)
    - What did not work well (97)
    - Suggested improvements (102)
    - General comments (39)
  - Perform affinity analysis on four questions and generate categories (25)
  - Reconcile suggested improvements with what did not work well
  - Validate candidate requirements (suggested improvements) with contributors
  - Prioritize candidate requirements

# Affinity Analysis Results

| Categories | What Worked Well | What Did Not Work Well | Suggested Improvements | General Comments |
|---|---|---|---|---|
| 3PTH = Third party test house | 21 | 12 | 7 | 3 |
| Communications | 16 | 3 | 2 | 0 |
| Design | 0 | 9 | 4 | 1 |
| Documentation | 5 | 2 | 1 | 4 |
| General | 4 | 6 | 2 | 14 |
| Institutionalization | 1 | 4 | 3 | 1 |
| Manufacturing | 0 | 1 | 1 | 0 |
| Moisture Sensitivity | 0 | 6 | 6 | 0 |
| Planning | 1 | 1 | 3 | 1 |
| Process | 5 | 11 | 12 | 3 |
| Product Definition | 0 | 5 | 4 | 0 |
| Purchasing | 2 | 5 | 6 | 0 |
| Requirements | 1 | 4 | 6 | 0 |
| Research | 0 | 0 | 3 | 0 |
| Results | 4 | 3 | 0 | 5 |
| Sampling | 0 | 3 | 3 | 0 |
| Scheduling | 0 | 7 | 5 | 3 |
| Status | 4 | 1 | 5 | 0 |
| Teamwork | 19 | 5 | 2 | 3 |
| Testing | 2 | 8 | 15 | 1 |
| Tools | 3 | 0 | 5 | 0 |
| Tools (eCATT) | 4 | 0 | 0 | 0 |
| Tools (eCIS) | 8 | 0 | 2 | 0 |
| Training | 1 | 1 | 3 | 0 |
| Workflow | 4 | 0 | 2 | 0 |
| Total | 105 | 97 | 102 | 39 |

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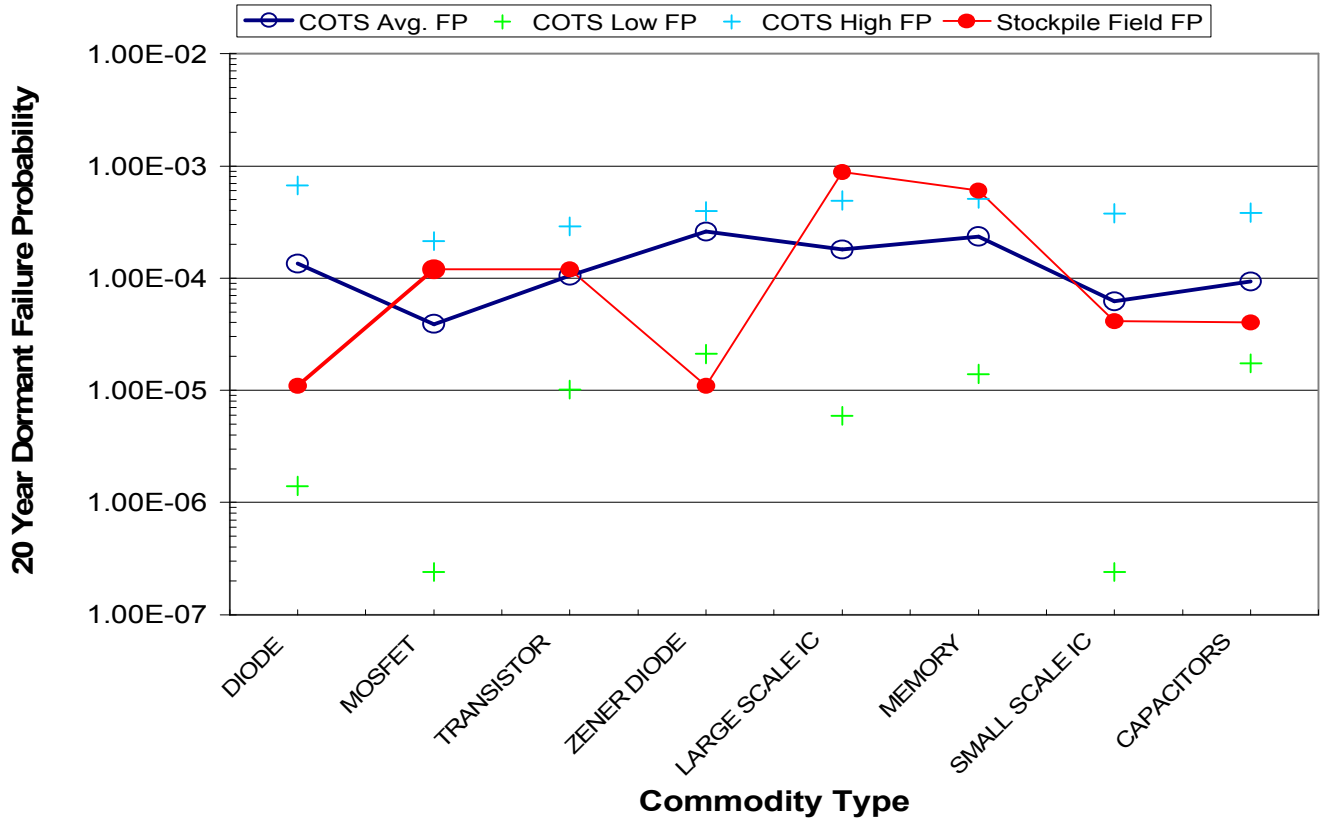
# Summary of Lessons Learned – Participant Feedback

- What worked well
  - Teamwork between design and production agencies
  - Communications
  - Third Party Test House and Workflow
- What did not work well
  - Third Party Test House scheduling and start-up (minimal high-frequency testing knowledge)
  - Process (some tests were too accelerated and moisture sensitivity had more effect on qualification than we expected)
  - Scheduling and execution (caused last minute accelerated efforts to finish qualification on time)
- Over 100 suggested improvements to a largely successful process

# Estimated Failure Probabilities of COTS vs Field Experience




During part selection data is gathered to estimate failure probability

- **The WRCIP Part Selection process is key to identifying reliable parts**
- **Most COTS parts exhibit estimated FPs similar to traditional SC parts**

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# Actual COTS Part Type Costs

| Part Type | | Part Type Qty | Procure Price Range Ea | Typical Price Ea | Qualification Lot Cost | Radiation Lot Cost | Total Cost for 10K Lot Size |
|---|---|---|---|---|---|---|---|
| Diodes | Commercial | 20 | 0.01 - 1.21 | $0.03 | $22,000 | $25,000 | $47,300 |
| | Mil-Spec | 15 | 4.22 - 47.65 | $7.50 | $8,000 | $25,000 | $108,000 |
| Transistors | Commercial | 6 | 0.01 - 0.17 | $0.03 | $38,000 | $25,000 | $63,300 |
| | Mil-Spec | 4 | 1.40 - 8.00 | $8.00 | $8,000 | $25,000 | $113,000 |
| MOSFET | Commercial | 2 | 0.34 - 0.86 | $0.86 | $31,000 | $25,000 | $64,600 |
| | Mil-Spec | 2 | 305.00 - 377.45 | $377.45 | $12,000 | $25,000 | $3,811,500 |
| RF Devices | Commercial | 17 | 0.22 - 10.00 | $1.80 | $57,000 | $25,000 | $100,000 |
| IC | Commercial | 5 | 0.10 - 3.45 | $2.60 | $45,000 | $25,000 | $96,000 |
| Inductors | Commercial | 34 | 0.09 - 4.45 | $0.09 | $5,000 | 0 | $5,900 |
| Resistors | Commercial | 10 | 0.71 -2.39 | $1.01 | $5,000 | 0 | $15,100 |
| | Mil-Spec | 153 | 0.41 - 5.30 | $0.58 | $1,000 | 0 | $6,800 |
| Capacitors | Commercial | 5 | 0.81 - 12.27 | $10.00 | $5,000 | 0 | $105,000 |
| | Mil-Spec | 66 | 0.77 - 9.80 | $2.37 | $1,000 | 0 | $24,700 |

**Saved >$35 Million on implementing COTS where we could on first application**

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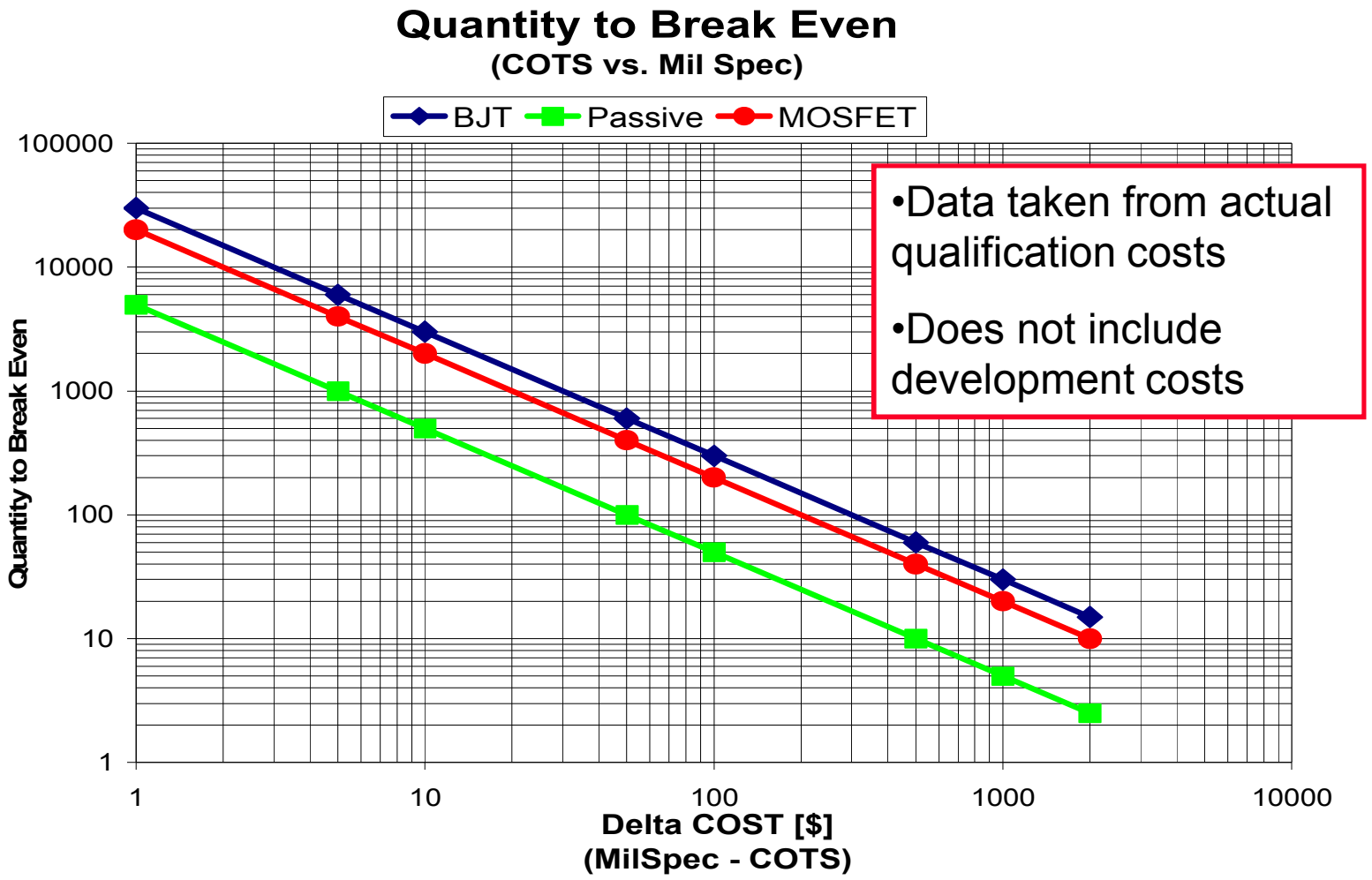
# Procurement Lessons Learned

- COTS parts can provide dramatic cost savings relative to mil-spec and source controlled (SC) parts
- COTS parts provide availability of part types not found in MIL-SPEC
- Low acquisition costs and times enable LoPB which mitigates obsolescence issues
- LoPB increases likelihood of single/consecutive date codes, thereby reducing risk associated with variability
- Minimum buy requirements often meet LoPB quantities
- LoPB reduces qualification costs
- Need to do life of program buys (LoPBs) earlier to use parts in QPA development evaluations

# Cost Savings is a Function of Quantity & Qualification Costs

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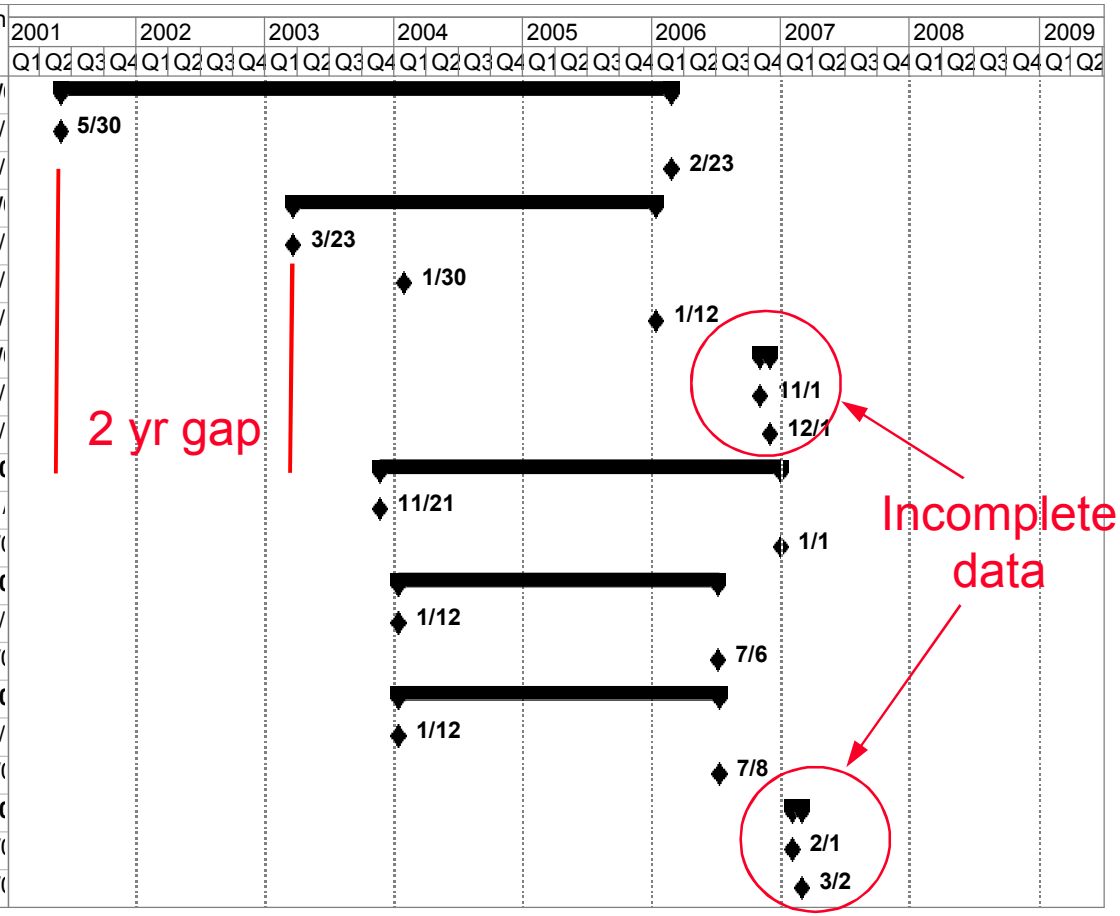
# Qualification Lessons Learned

37 First Qualification Failures

| Qty | Resolution | Example | Lessons Learned |
|---|---|---|---|
| 22 | Minor Limit Changes | Inductors with over specified lead pull strength | Need to fully understand part requirements |
| 6 | Qualify and handle parts at higher moisture sensitivity level | Part fails stress testing after MSL 1 preconditioning | Preconditioning affects reliability<br>Mfg. MSL rating is based on commercial reliability requirements not WR<br>COTS paradigm impacts next assembly techniques |
| 5 | Qualify using lower acceleration longer time tests | 130ºC/85%RH HAST overstresses eutectic die attach | Need to fully understand part construction relative to stress testing |
| 4 | Acquired new lot | True failures | COTS have lot-to-lot variability<br>Process was successful in identifying weak parts |

# WRCIP Cycle Time Evaluation

| ID | Task Name | Duratio | Start | Finish |
|---|---|---|---|---|
| 1 | **Development** | **1730 da** | **5/30/** | **2/23/** |
| 2 | 1st AFS Team Meeting | 0 day | 5/30/ | 5/30/ |
| 3 | Last User AER rev. | 0 day | 2/23/ | 2/23/ |
| 4 | **Procurement** | **1026 da** | **3/23/** | **1/12/** |
| 5 | Release First KCP ML | 0 mo | 3/23/ | 3/23/ |
| 6 | Production Funding | 0 day | 1/30/ | 1/30/ |
| 7 | Last part ordered | 0 day | 1/12/ | 1/12/ |
| 8 | **Part Received and Accept** | **30 da** | **11/1/** | **12/1/** |
| 9 | 1st Part Recevied | 0 day | 11/1/ | 11/1/ |
| 10 | Last Part Accepted | 0 day | 12/1/ | 12/1/ |
| 11 | **Qualification** | **1137 da** | **11/21/** | **1/1/(** |
| 12 | 1st Qual PO issued | 0 day | 11/21/ | 11/21/ |
| 13 | Last Part Qualified | 0 day | 1/1/( | 1/1/( |
| 14 | **Release QERs** | **906 da** | **1/12/** | **7/6/(** |
| 15 | 1st Part Qualified | 0 day | 1/12/ | 1/12/ |
| 16 | Last SNL QER Released | 0 day | 7/6/( | 7/6/( |
| 17 | **Receiving Inspection** | **908 da** | **1/12/** | **7/8/(** |
| 18 | First Part Arrives | 0 day | 1/12/ | 1/12/ |
| 19 | Last QER Promoted/ Par | 0 day | 7/8/( | 7/8/( |
| 20 | **Pre- Production Processin** | **29 da** | **2/1/(** | **3/2/(** |
| 21 | 1st Make from | 0 day | 2/1/( | 2/1/( |
| 22 | Last Make from | 0 day | 3/2/( | 3/2/( |

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# Evaluated Execution and Slack Times for 7 Major Part Tasks

| Task Name | Minimum Duration (days) | Maximum Duration (days) | Minimum Lag to succeeding task (days) | Maximum Lag to succeeding task (days) |
|---|---|---|---|---|
| **Prepare ML/ERs for Procurement** | **0** | **120** | **NA** | **NA** |
| **Finalize Definition** | **154** | **437** | **0** | **484** |
| **Qualification Development** | **0** | **384** | **94** | **516** |
| **Parts Procured** | **14** | **203** | **17** | **259** |
| **Qualification** | **210** | **586** | **0** | **80** |
| **Qualification to SNL QER Released** | **0** | **19** | **0** | **1** |
| **SNL QER to KCP Stores** | **5** | **95** | **NA** | **NA** |

# Summary of Lessons Learned on Cycle Time Evaluation

- Large variation in time to execute major tasks and large variation in slack time between tasks
- Need quicker response processes for failed items and changes that need to be made during qualification
- Need formal schedule plan with tracking and reporting process for each part from beginning
- Future: Need process to allow buying of parts (LoPB's) and establishing qualification capabilities during development for shortest schedule and less problems in qualification

# High Level Lessons Learned Summary

- Overall many of the WRCIP processes and tools were implemented successfully
- Many of the WRCIP processes and tools need to be refined or adapted
  - Customized qualification
  - Improved tracking and reporting tools
  - Quicker response processes during qualification
- Procurement and qualification activities need to be implemented earlier in the development cycle
- Use of COTS is a paradigm shift requiring changes in all areas
  - Design & Part Selection (e.g. design around post-rad performance)
  - Procurement and qualification (e.g. sample based qualification)
  - Manufacturing (e.g. working with MSL3)
  - Program management (e.g. early funding, LoPB, accelerated builds)
- Need systemic training (design through manufacturing)

# Unique Capabilities Developed for Utilizing COTS

- Virtual corporation among geographically separated sites
  - Integrates design agency, production agency and third party test houses
  - Concurrent engineering via web-based databases and workflow
- Cross-trained personnel highly leveraged using information technology
  - Web-based standard processes and tools
  - Enterprise Component Information System (eCIS) based on a commercial tool
  - Workflow enabled processes
  - Data and decisions saved electronically as generated in searchable databases
    - Parts data tracker
    - Electronic Component Analysis and Test Tracking (eCATT) tool
    - Test data tracker for third party test houses
    - Web-based document archiving (Docs2eCIS)

# SNL Strategy for Electronic Circuits in High Reliability Applications

- Fully qualify commercial off-the-shelf (COTS) electronic parts for high reliability, severe environment applications
  - Integrated databases, processes and tools
- Model and simulate very large, complex circuits to facilitate designs and skip builds
  - Have validated physics-based hostile environment models
  - Have already done circuits with 500K-750K components on 32 processors
- Jointly develop processes and tools for virtual rapid prototyping
- Build custom electronic parts to allow high level integration
  - Design and deliver custom ASICs and other custom components (e.g. RFICs, magnetics, capacitors)