MK419 Mod 1
Multi-Function Fuze
Product Improvement Program

BY

Richard Chapman
Naval Surface Warfare Center
Dahlgren Division
• PERFORMANCE:
Multi-Function Fuze (MFF) Operational Modes

• CYCLE TIME & YIELD:
Statistical Process Control Handshake for Cycle Time and Yield

• MOD 1 COMPONENT SUMMARY:
Performance, Cycle Time, Yield, and Cost with Full Module Assembly
PERFORMANCE:
Multi-Function Fuze (MFF)
Operational Modes
Multi-Function Fuze (MFF)
Operational Modes

The MFF can fit 76mm and 5 inch rounds.
CYCLE TIME & YIELD: Statistical Process Control Handshake for Cycle Time and Yield
Statistical Process Control
For Cycle Time Reduction

Decreased Mechanical Part Count Simplifies Assembly (Reduces Cycle Time) And Improves Yield

**Mechanical Count Summary**

<table>
<thead>
<tr>
<th>Component</th>
<th>MOD-0</th>
<th>MOD-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circuit Boards &amp; Interconnect Flexes</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Lap Solder Joints</td>
<td>16</td>
<td>0</td>
</tr>
<tr>
<td>Other Hand Soldered Connections</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>Custom Shimming Operations</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Mechanical Parts*</td>
<td>37</td>
<td>31</td>
</tr>
</tbody>
</table>

*CCAs and purchased assemblies (Booster, S&A, Det, etc.) are considered a single mechanical part*

**Mod 1 Cycle Time is reduced by 65%**
Statistical Process Control
For Yield

• Initial Review of Product Parameters
  • FMEA Design
  • Technical Data Package

• Determine Process Capability
  • FMEA Manufacturing
  • Determine process capability
    • $C_p = \frac{(USL-LSL)}{(6*\text{Sigma})}$
    • $C_{pl} = \frac{(\text{Mean}-LSL)}{(3*\text{Sigma})}$
    • $C_{pu} = \frac{(USL-\text{Mean})}{(3*\text{Sigma})}$
    • $C_{pk} = \text{Min}(C_{pl},C_{pu})$

CENTER TARGET
+ SMALL SIGMA
+ WIDE USL – LSL
= GOOD CAPABILITY

EXCELLENT YIELD
### Statistical Process Control

#### Cycle Time and Yield Handshake

Fewer steps not only reduce Cycle Time, but increases Yield due to reduced manipulative errors.

<table>
<thead>
<tr>
<th>Spec Limit</th>
<th>Centered Yield (One Step)</th>
<th>Percent Yield (89 Steps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1σ &gt; USL, LSL</td>
<td>68.27%</td>
<td>0.00%</td>
</tr>
<tr>
<td>2σ &gt; USL, LSL</td>
<td>95.45%</td>
<td>1.59%</td>
</tr>
<tr>
<td>3σ &gt; USL, LSL</td>
<td>99.73%</td>
<td>78.62%</td>
</tr>
<tr>
<td>4σ &gt; USL, LSL</td>
<td>99.99%</td>
<td>99.44%</td>
</tr>
<tr>
<td>5σ &gt; USL, LSL</td>
<td>100.00%</td>
<td>99.99%</td>
</tr>
<tr>
<td>6σ &gt; USL, LSL</td>
<td>100.00%</td>
<td>100.00%</td>
</tr>
</tbody>
</table>

95% Fuze Yield

Distribution Statement A – Approved for Public Release; Distribution is unlimited
MOD 1 COMPONENT SUMMARY: Performance, Cycle Time, Yield, and Cost with Full Module Assembly
Major Subassemblies And Components

- Mag Link Assembly
- Radome
- Controller CCA
- Antenna Assembly
- Booster
- Fuze Housing
- Detonator Plug Assembly
- Battery Assembly
- Retaining Ring Assembly
- Safe and Arm

Distribution Statement A – Approved for Public Release; Distribution is unlimited
Radome And Mag Link Assembly

IMPROVEMENTS FOR MOD 1

- **Performance:**
  N/A

- **Cycle Time:**
  Simplified assembly

- **Yield:**
  Automation increases yield
  Cpk increase

- **Cost:**
  Component cost reduction

<table>
<thead>
<tr>
<th>MOD-1</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>✔ No change – No risk</td>
<td></td>
</tr>
<tr>
<td>✔ Eliminated individual tuning costs</td>
<td></td>
</tr>
<tr>
<td>✔ Automated reflow soldering process</td>
<td></td>
</tr>
<tr>
<td>✔ Small, low cost capacitors</td>
<td></td>
</tr>
<tr>
<td>✔ Alignment post assembly aids</td>
<td></td>
</tr>
<tr>
<td>✔ Press interference fit</td>
<td></td>
</tr>
</tbody>
</table>
Antenna Assembly Updates Eliminate Tuning, Simplify Assembly, And Reduces Cost

IMPROVEMENTS FOR MOD 1

- **Performance:**
  Dielectric improvement
  ESD protection improvement

- **Cycle Time:**
  Simplified assembly

- **Yield:**
  Automation increases yield
  Cp better on target
  Cpk increase

- **Cost:**
  Component cost reduction

<table>
<thead>
<tr>
<th>MOD-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ Simplified geometry</td>
</tr>
<tr>
<td>✓ Improved quality process &amp; controls</td>
</tr>
<tr>
<td>✓ Standard coax cable connectors</td>
</tr>
<tr>
<td>✓ Consistent &amp; repeatable performance</td>
</tr>
<tr>
<td>✓ Excellent, proven dielectric control</td>
</tr>
<tr>
<td>Improved design margin on:</td>
</tr>
<tr>
<td>✓ Return loss</td>
</tr>
<tr>
<td>✓ Isolation</td>
</tr>
<tr>
<td>✓ 2-way gain</td>
</tr>
<tr>
<td>✓ Autoclave bond film.</td>
</tr>
<tr>
<td>✓ Survived extensive ATK air gun shock tests</td>
</tr>
<tr>
<td>✓ Rail gun test successful.</td>
</tr>
</tbody>
</table>

Distribution Statement A – Approved for Public Release; Distribution is unlimited
MMIC Receiver

- MOD1 Receiver successfully designed, repackaged, built, and tested
- Increased LO drive range helps eliminate expensive unit tuning
- Successfully integrated and tested Receiver MMIC

IMPROVEMENTS FOR MOD 1

- **Performance:**
  - ESD protection improvement
  - Design margin improvement

- **Cycle Time:**
  - Eliminate unit to unit tuning

- **Yield:**
  - Cp better on target
  - Cpk increase

- **Cost:**
  - Reduced chip size

MOD-1

- Miniaturized 4x4mm QFN
- Integrated onto Controller PWB
- Standard pick-n-place and reflow
- Added ESD protection to improve reliability
- Significantly improved design margin
- Eliminates unit to unit tuning

Significantly Improved Design Margin Helps Eliminate Unit Tuning And Reduces Cost
MMIC Transmitter

PIP planned two Transmitter MMIC design iterations

1st Design Iteration
- Vendor modeling error resulted in faulty ESD cells
- Vendor fused cells open, resulting in spec compliant MMICs
- Successful integration testing

2nd Design Iteration
✓ Updated design for ESD cell
✓ Updated core design to re-center frequency & increase output power (yield improvements)
✓ Modulation Port Sensitivity Pulling reduced range and opened specification. Reduced resistor binning.

IMPROVEMENTS FOR MOD 1

▪ Performance:
  ESD protection improvement

▪ Cycle Time:
  Eliminate unit to unit tuning

▪ Yield:
  Cp better on target
  Cpk increase

▪ Cost:
  Reduced chip size

Distribution Statement A – Approved for Public Release; Distribution is unlimited
Controller Circuit Card Assembly

IMPROVEMENTS FOR MOD 1

- **Performance:**
  Reduced power consumption

- **Cycle Time:**
  Reduced soldering
  Standard reflow

- **Yield:**
  Automation increases yield
  Cp better on target
  Cpk increase

- **Cost:**
  Reduced chip size
  Integrate PWBs

<table>
<thead>
<tr>
<th>MOD-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ Integrated into one PWB</td>
</tr>
<tr>
<td>✓ Panel fits twice as many PWBs</td>
</tr>
<tr>
<td>✓ Obsolete parts resolved</td>
</tr>
<tr>
<td>✓ Miniaturized components</td>
</tr>
<tr>
<td>✓ New potting eliminates component staking</td>
</tr>
<tr>
<td>✓ Improved component clearances for potting flow</td>
</tr>
<tr>
<td>✓ Improved component clearances</td>
</tr>
<tr>
<td>✓ No taping required</td>
</tr>
<tr>
<td>✓ Improved clearance and fitment</td>
</tr>
<tr>
<td>✓ Standard connectors used for PWBs and Antenna</td>
</tr>
<tr>
<td>✓ Standard re-flow process</td>
</tr>
<tr>
<td>✓ Repackaged and decreased power consumption</td>
</tr>
</tbody>
</table>

Controller Assembly Updates Simplify Assembly, Eliminate Tuning, And Reduces Cost
Fuze Housing And Battery Assembly

**IMPROVEMENTS FOR MOD 1**

- **Performance:**
  Improved battery

- **Cycle Time:**
  Integrated fuze housing

- **Yield:**
  Reduced steps increases yield

- **Cost:**
  Reduced chip size
  Integrate PWBs

<table>
<thead>
<tr>
<th>MOD-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ Integrated into one part</td>
</tr>
<tr>
<td>✓ Simplified assembly</td>
</tr>
<tr>
<td>✓ Lithium-SOCl2 reserve battery</td>
</tr>
<tr>
<td>✓ Standard sockets</td>
</tr>
<tr>
<td>✓ Simple assembly done outside of fuze</td>
</tr>
<tr>
<td>✓ Eliminated shimming</td>
</tr>
<tr>
<td>✓ Miniaturized components</td>
</tr>
<tr>
<td>✓ Firing cap re-sized for M100</td>
</tr>
</tbody>
</table>

---

*Fuze & Battery Assembly Design Updates Simplify Assembly And Reduces Cost*

Distribution Statement A – Approved for Public Release; Distribution is unlimited
Detonator Assembly, S&A, And Booster

**IMPROVEMENTS FOR MOD 1**

- **Performance:**
  Improved detonator

- **Cycle Time:**
  Easy Detonator Assembly

- **Yield:**
  Reduced steps increases yield

- **Cost:**
  N/A

---

**MOD-1**

- M100
- Detonator test points accessible
- Simple assembly done outside of fuze
- Redundant positive and ground contacts
- Unchanged from MOD-0
- Unchanged from MOD-0
Battery

• MOD0 MK44 Lead Acid Reserve Energizer is obsolete
• Previous MFF studies identified and tested a replacement battery:

Lithium-SOCl2 Reserve Battery

IMPROVEMENTS FOR MOD 1

▪ Performance:
  Improved rise time

▪ Cycle Time:
  N/A

▪ Yield:
  N/A

▪ Cost:
  Battery cost reduced

<table>
<thead>
<tr>
<th>PIP Design Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ Batteries Procured</td>
</tr>
<tr>
<td>✓ Simplified Assembly</td>
</tr>
<tr>
<td>✓ Battery Tests Verify Battery Exceeds Goal</td>
</tr>
<tr>
<td>✓ Battery Tests Verify Rise Time Exceeds Threshold</td>
</tr>
<tr>
<td>✓ Simulation &amp; Lab Tests Verify Functionality</td>
</tr>
</tbody>
</table>

Distribution Statement A – Approved for Public Release; Distribution is unlimited
Summary

✓ **PERFORMANCE:**
  - Going forward for HSMSTs
  - New hardware has improved tolerance

✓ **CYCLE TIME:**
  - 72 parts for Mod 0 compared to 40 parts for Mod 1
  - Mod 1 Cycle Time is reduced by 65%

✓ **YIELD:**
  - Less steps for Mod 1 than Mod 0, less manipulation error
  - Automation means better Cp and increased Cpk (better yield)

✓ **COST:**
  - Electrical component cost less due to Moore’s Law
  - Moore’s Law: in 10 years same component price drops by 100x

**Acknowledgements:**
Mr. James Ring – ATK Technical Lead
Mr. Marty Davis – ATK Program Manager