MK419 Mod 1
Multi-Function Fuze
Product Improvement Program

BY

Richard Chapman
Naval Surface Warfare Center
Dahlgren Division

# OUTLINE

- **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

Cycle Time
& Yield

Cost

PERFORMANCE:
Multi-Function Fuze (MFF) Operational Modes

Performance

Cycle Time & Yield   Cost
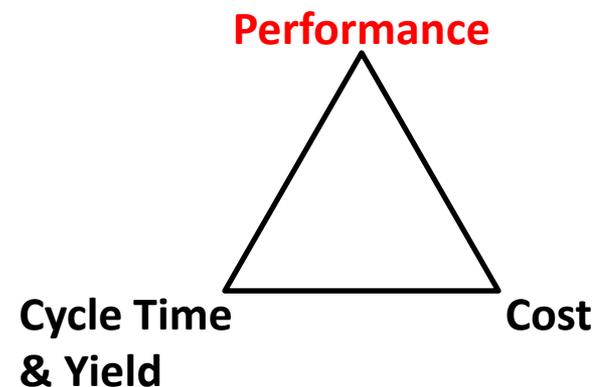
Multi-Function Fuze (MFF) Operational Modes
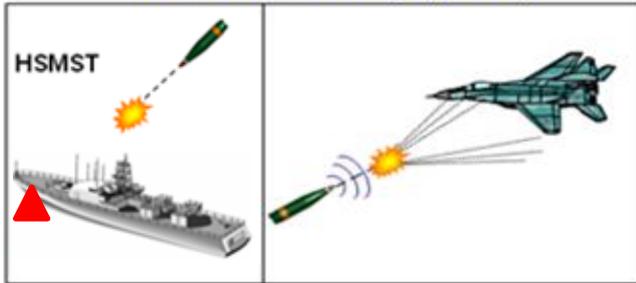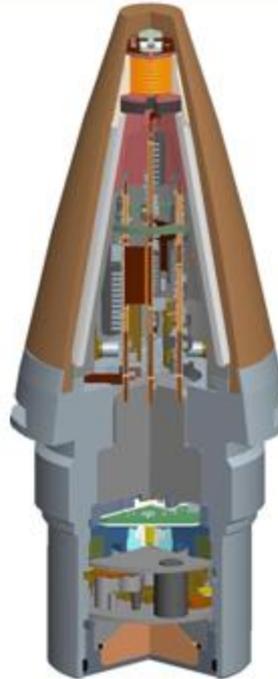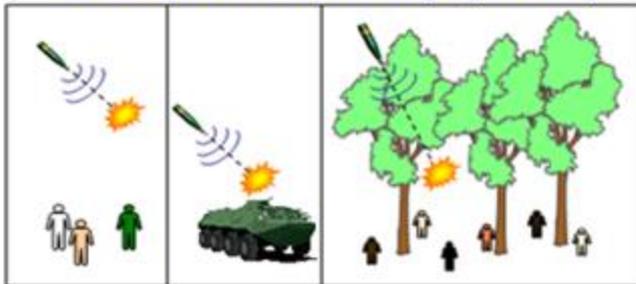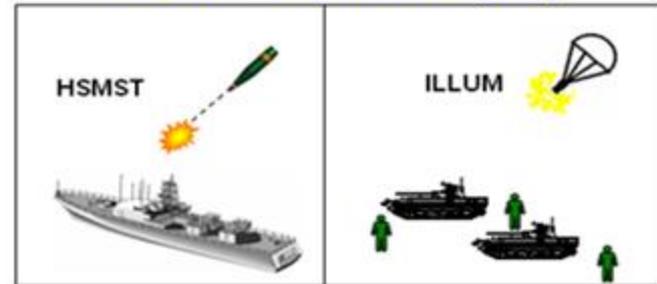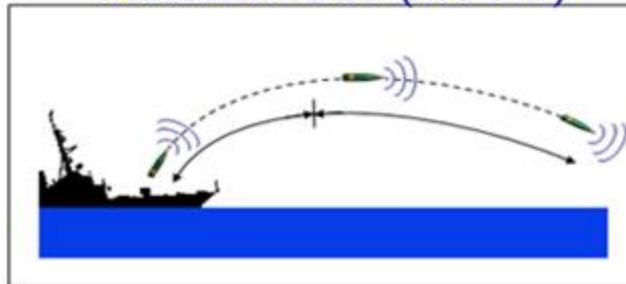
The MFF can fit 76mm and 5 inch rounds.

CYCLE TIME & YIELD:

Statistical Process Control

Handshake

for Cycle Time and Yield

Performance

**Cycle Time
& Yield**

Cost
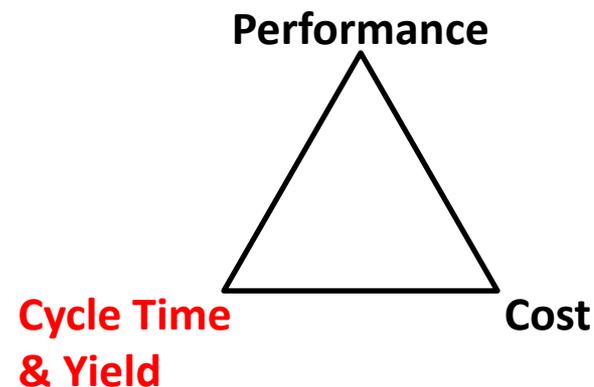
Statistical Process Control For Cycle Time Reduction
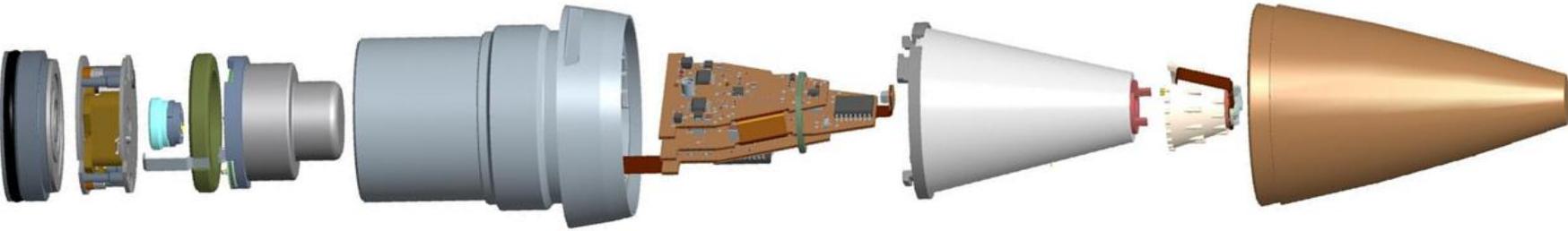
Mechanical Count Summary	MOD-0	MOD-1
Circuit Boards & Interconnect Flexes	6	3
Lap Solder Joints	16	0
Other Hand Soldered Connections	12	6
Custom Shimming Operations	1	0
Mechanical Parts*	37	31

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

Mod 1 Cycle Time is reduced by 65%

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

Statistical Process Control For Yield

- ## Initial Review of Product Parameters
  - FMEA Design
  - Technical Data Package

- ## Determine Process Capability
  - FMEA Manufacturing
  - Determine process capability
    - Cp = (USL-LSL)/(6*Sigma)
    - Cpl = (Mean-LSL)/(3*Sigma)
    - Cpu = (USL-Mean)/(3*Sigma)
    - Cpk = Min(Cpl,Cpu)
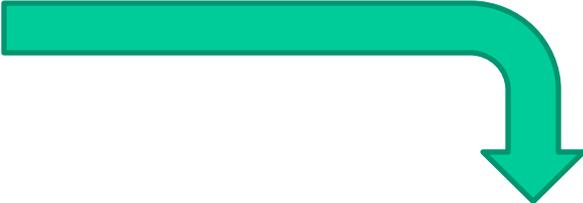
**CENTER TARGET
+
SMALL SIGMA
+
WIDE USL – LSL
=
GOOD CAPABILITY**

EXCELLENT YIELD

X Bar & S Statistical Process Control Shewhart Rules (Yield Consequence)
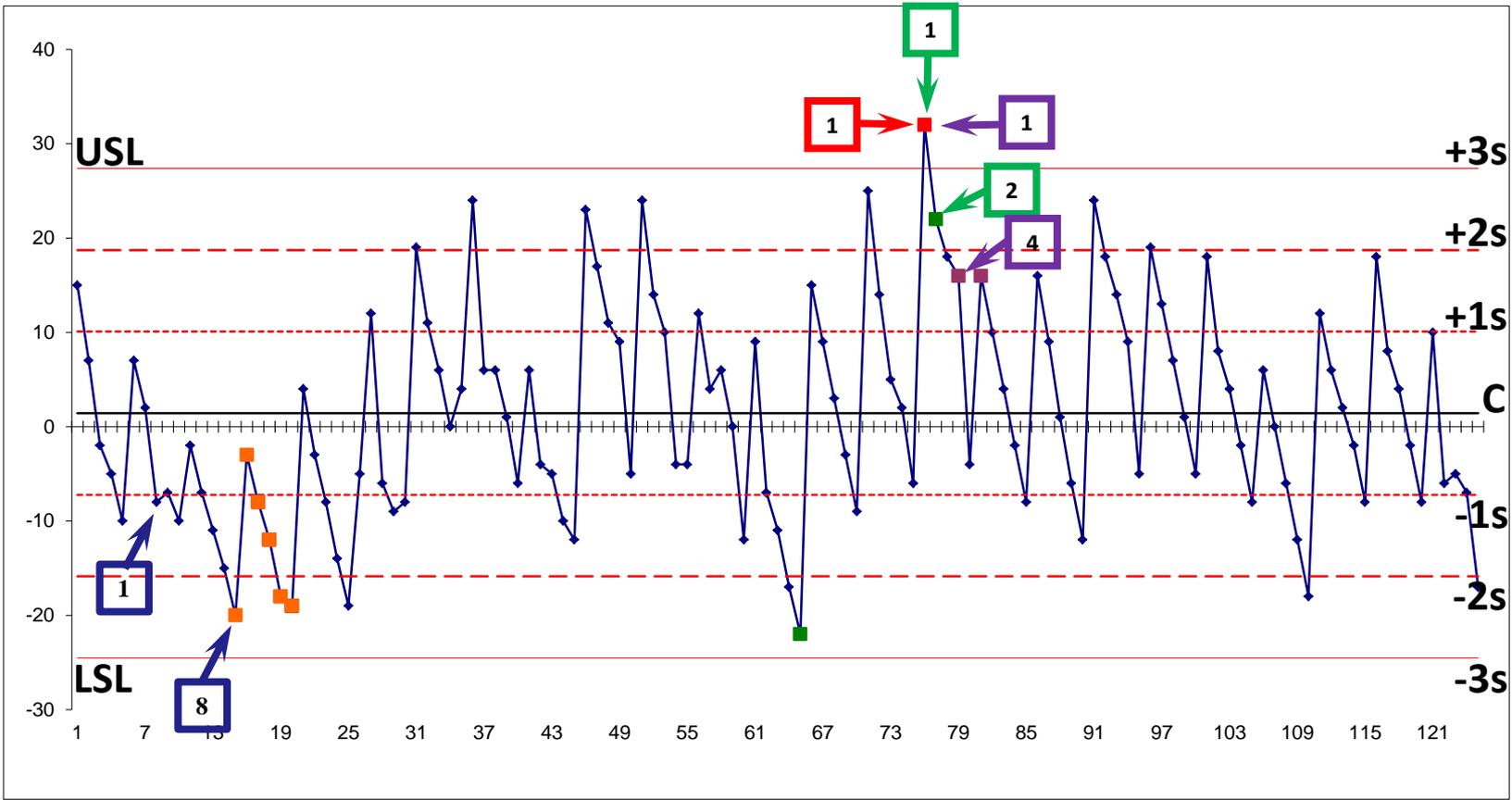
Legend:
- **Three** Sigma Limit
- **Two** Sigma Limit
- **One** Sigma Limit
- **Average**
- **A single point** outside the **three** sigma limit
- **Two of three pts** outside the **two** sigma limit
- **Four of Five pts** outside the **one** sigma limit
- **Eight** in a row on the same side of centerline

Statistical Process Control
Cycle Time and Yield Handshake

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

Spec Limit	Centered Yield (One Step)	Percent Yield (89 Steps)
1s > USL, LSL	68.27%	0.00%
2s > USL, LSL	95.45%	1.59%
3s > USL, LSL	99.73%	78.62%
4s > USL, LSL	99.99%	99.44%
5s > USL, LSL	100.00%	99.99%
6s > USL, LSL	100.00%	100.00%

← **95% Fuze Yield**
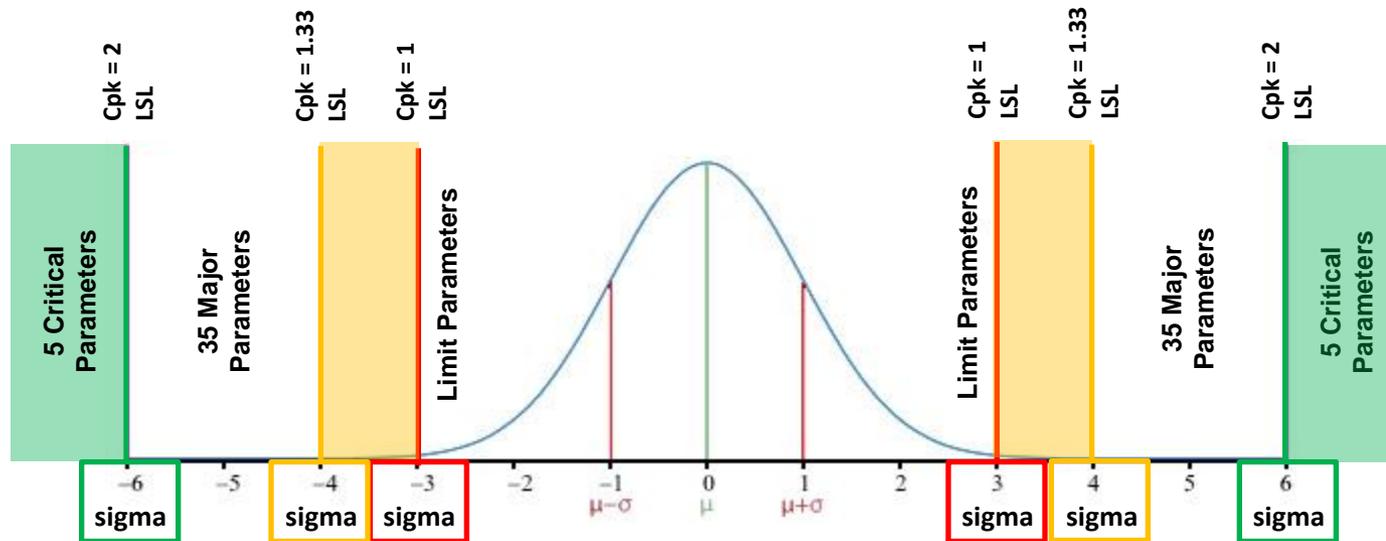
MOD 1 COMPONENT SUMMARY:
Performance, Cycle Time, Yield, and Cost
with Full Module Assembly

Performance

Cycle Time & Yield
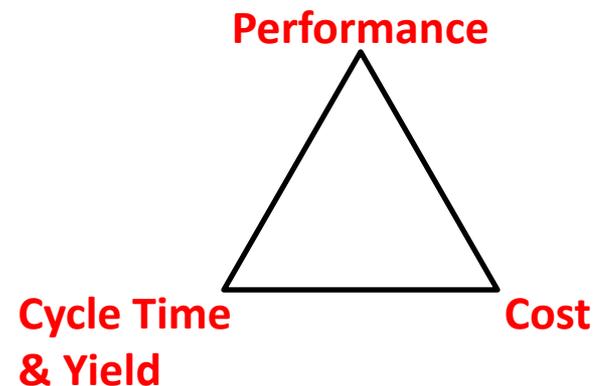
Cost

Major Subassemblies And Components

Mag Link Assembly

Controller CCA

Radome

Fuze Housing

Antenna Assembly

Detonator Plug Assembly

Booster

Battery Assembly

Retaining Ring Assembly

Safe and Arm
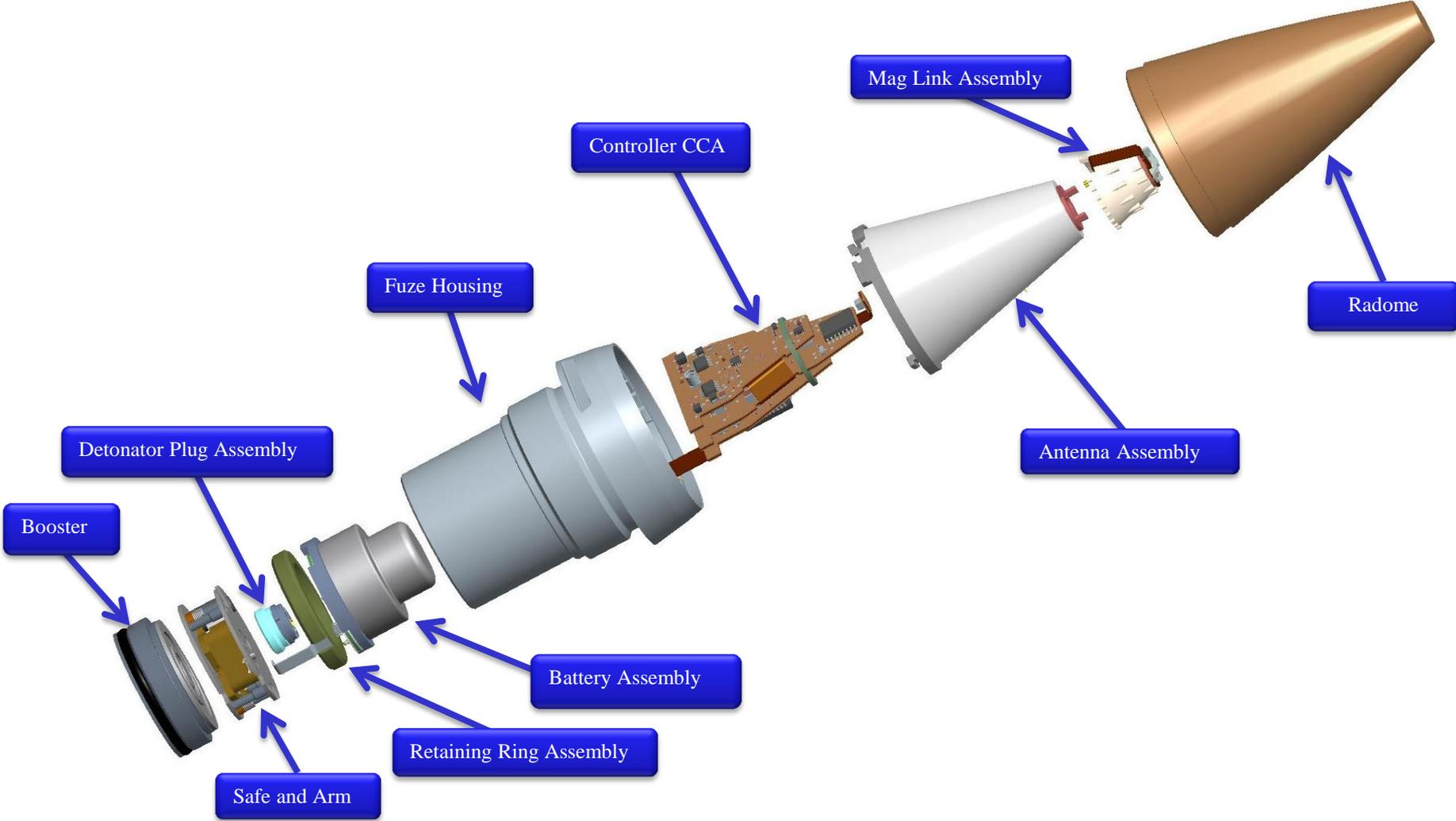
Radome And Mag Link Assembly

IMPROVEMENTS FOR MOD 1

▪ **Performance:**
N/A

▪ **Cycle Time:**
Simplified assembly

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

▪ **Cost:**
Component cost reduction

MOD-1	
✓ No change – No risk	
✓ Eliminated individual tuning costs	
✓ Automated reflow soldering process	
✓ Small, low cost capacitors	
✓ Alignment post assembly aids	
✓ Press interference fit	
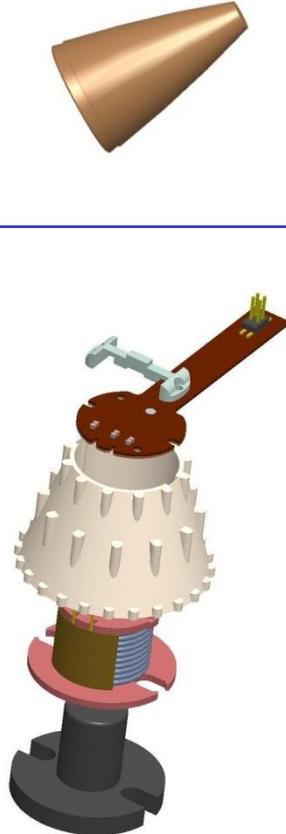
Mag Link Assembly Updates Simplify Assembly, Eliminate Tuning, And Reduces Cost

Antenna Assembly

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

| MOD-1 |
|---|
| ✓ Simplified geometry
✓ Improved quality process & controls |
| ✓ Standard coax cable connectors
✓ Consistent & repeatable performance |
| ✓ Excellent, proven dielectric control |
| Improved design margin on:
✓ Return loss
✓ Isolation
✓ 2-way gain |
| ✓ Autoclave bond film. |
| ✓ Survived extensive ATK air gun shock tests
✓ Rail gun test successful. |
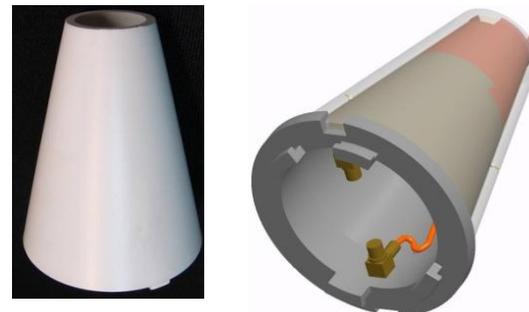
Antenna Assembly Updates Eliminate Tuning, Simplify Assembly, And Reduces Cost

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
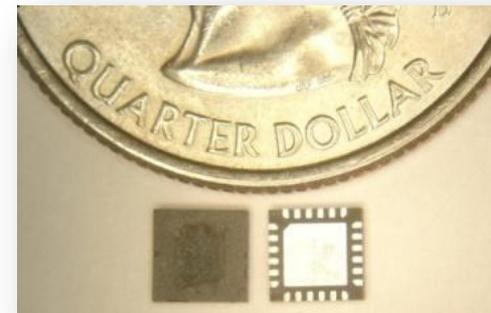
IMPROVEMENTS FOR MOD 1

▪ **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

MOD-1
✓ Miniaturized 4x4mm QFN
✓ Integrated onto Controller PWB
✓ Standard pick-n-place and reflow
✓ Added ESD protection diodes to improve reliability
✓ Unit to unit variations minimized
✓ Eliminates unit to unit tuning

Reduced Unit-to-Unit Variation Helps Eliminate Unit Tuning And Reduces Cost

# 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

| MOD-1 |
|---|
| ✓ Integrated into one PWB
✓ Panel fits twice as many PWBs |
| ✓ Obsolete parts resolved
✓ Miniaturized components |
| ✓ New potting eliminates component staking
✓ Improved component clearances for potting flow |
| ✓ Improved component clearances
✓ No taping required |
| ✓ Improved clearance and fitment |
| ✓ Standard connectors used for PWBs and Antenna |
| ✓ Standard re-flow process
✓ Repackaged and decreased power consumption |
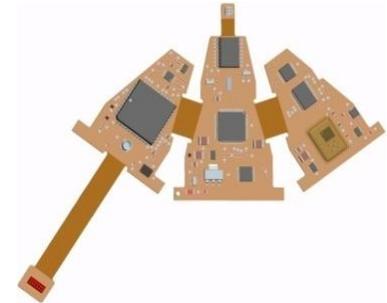
Controller Assembly Updates Simplify Assembly, Eliminate Tuning, And Reduces Cost

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

MOD-1	
✓ Integrated into one part ✓ Simplified assembly	
✓ Lithium-SOCl2 reserve battery ✓ Standard sockets ✓ Simple assembly done outside of fuze ✓ Eliminated shimming ✓ Miniaturized components ✓ Firing cap re-sized for M100	
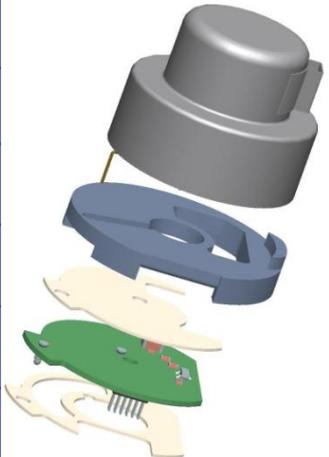
Fuze & Battery Assembly Design Updates Simplify Assembly And Reduces Cost

Detonator Assembly, S&A, And Booster

- M100 Detonator
- PBXN-5 Lead
- PBXN-5 Explosive
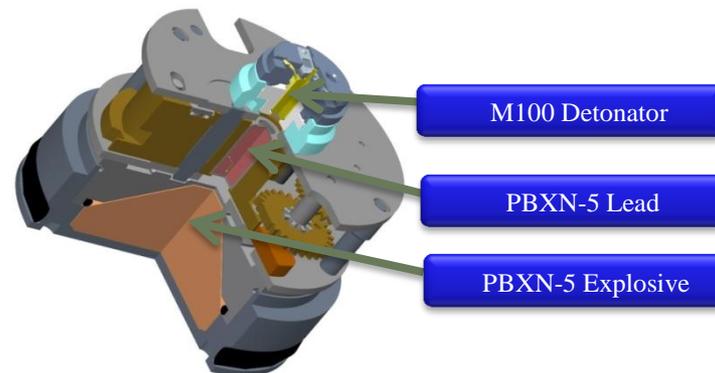
IMPROVEMENTS FOR MOD 1

- **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	

Detonator Assembly Simplifies Assembly And Reduces Cycle Time

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

MOD-0: MK44 Lead Acid Reserve Energizer

MOD-1 Lithium-SOCl2 Reserve Battery

PIP Design Results
✓ Batteries Procured
✓ Simplified Assembly
✓ Battery Tests Verify Battery Exceeds Goal
✓ Battery Tests Verify Rise Time Exceeds Threshold
✓ Simulation & Lab Tests Verify Functionality

Battery Characteristics Exceed Fuze Requirements and Reduces Cost

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
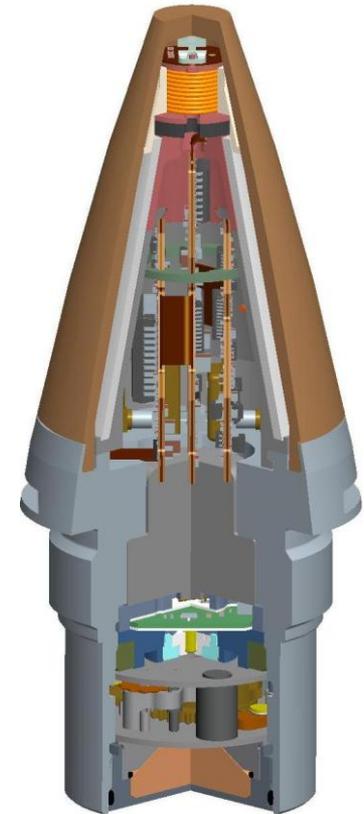
MOD-1 Design Updates Successfully Meets Performance, Cycle Time, Yield, and Cost