

# Accelerometer-Based Reliability & Condition-Based Maintenance System For Firearms

By:

**Howard D. Kent, Armor Development Group, LLC**

Forward By:

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US Army ARDEC, Joint Services Small Arms Program**

**Topic:**

**State Of The Art Maintenance For Firearms:**

**“A Synergy Of Cost Savings In Firearms Maintenance & Fleet Readiness Measures  
Which Increase The Warfighter’s Confidence In Their Weapon.”**

## Contents:

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2. Forward By: Lt.Col. Shawn P. Lucas, US Army ARDEC PM-IW
4. The Problem(s)
5. Introduction
10. Examples
16. Proposed Model Of Centralized Weapon Maintenance
17. Proposed Model Of PDM Weapon Survey
18. Proposed Measurement Procedure Of PDM Weapon Survey
19. Conclusion

## The Problems:

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Current Inventory Of War Weary Firearms In US Service >1.1 Million...  
Knowledge Of Inventory Weapon Condition: Low

Costs To Replace Or Rehabilitate Entire Fleet Too High...

User Confidence In Weapon Function Varies From High To None...

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***But How To Increase Readiness Within Current Maintenance Budgets And Raise User Confidence In Their Weapon?***

**Answer:** Adopt Commercial “***Predictive Maintenance***” Techniques...

## Introduction:

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“Who is this guy and why are we listening to this topic?”



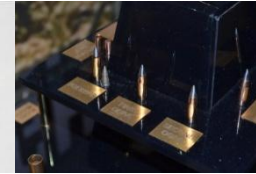
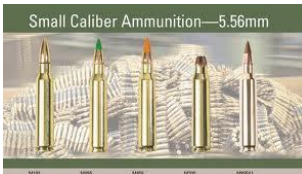
**Field Mechanical Engineer, Machinery Analyst:** Former CA/NV/Mexico Manager For **CSI- Emerson Process Control**, 20+ Years Experience In Industrial Construction, Commissioning, Operations & Maintenance: Utilities, Petro-Chemical, Nuclear, Electronics, Pharmaceutical & General Manufacturing For Over 200 Companies Throughout The Western United States, Test & Measurement Engineering, Product Development For Industry, Aerospace & Defense.

## Introduction:

“Look Toward The Weapon Because The **ATK** Ammo Is So Consistent”



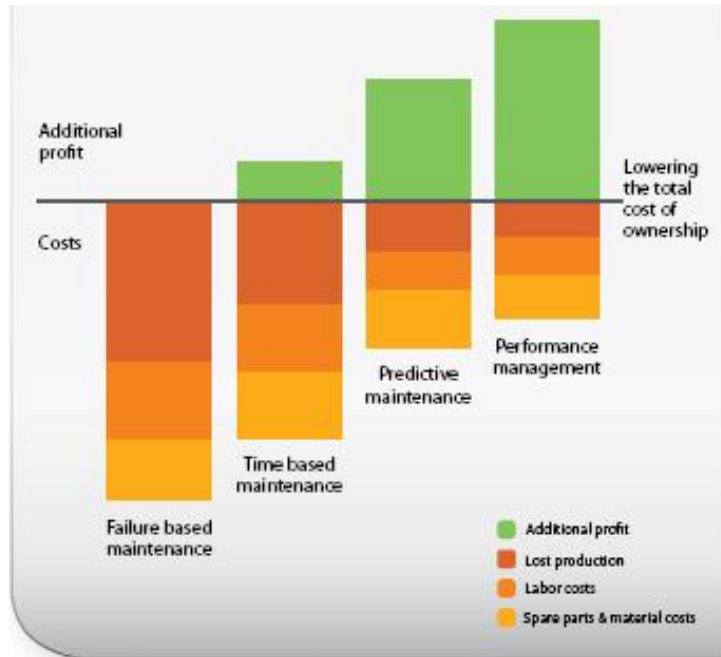
“Thousands Of Instrumented Rounds Were Fired Using **ATK Federal** Ammunition In Preparation For This Presentation. The Ammunition Was So Consistent And Repeatable For Influence On The Vibration Waveform, That We Treated It As A Constant And Varied Other Components Of The Weapon System.”



And Introducing America's **ATK Federal & Lake City Ammunition Division** To Address The Subject Of Quality Control For Military Ammunition...

## Introduction:

“Who uses Predictive Maintenance (PDM) and why do it to weapons?”



- 100% Of Energy Production Companies
- Over 90% Of Fortune 500 Industrial Companies
- Over 80% Of All Public Utilities
- US Army Corps Of Engineers
- US Navy Naval Facilities Command
- US Navy Fleet Maintenance Command
- US Air Force Intermediate Maintenance
- US Department Of Energy

Who Should Practice PDM:

Any Operator Of Critical Or High Value Equipment...

PDM Tools Include: Vibration Analysis, Infrared Thermography, High Speed Videography, Lubricant Analysis, Ultrasonic Microphones, Electrical Diagnostics, Non-Contact Instruments, And Other Advanced Testing Methods Which Focus On Machinery In Operational Use.

## Introduction:

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### The Three Basic Types Of Maintenance & Associated Costs:

#### **Preventative Maintenance:**

- \*Factory Scheduled Maintenance
- \*Operating Hours Or Time Basis

Prevents Many Faults By Inspection/Lubrication, Predicts None, Costs Very Little To Do...

#### **Reactive Maintenance:**

- \*Run Equipment To Failure
- \*Repair/Replace What's Left

Prevents Or Predicts Nothing, Costs A Tremendous Amount Of Capital & Lost Production...

#### **Predictive Maintenance:**

- \*Run Until Performance Drops
- \*Repair Only As Needed

Prevents Majority Of Faults, Saves A Tremendous Amount Of Capital & Lost Production...

### **Recommendation:**

#### **Preventative Maintenance:**

Use On Everything Regardless Of Cost Or Criticality

#### **Reactive Maintenance:**

Use On Low Cost & Non-Critical Equipment

#### **Predictive Maintenance:**

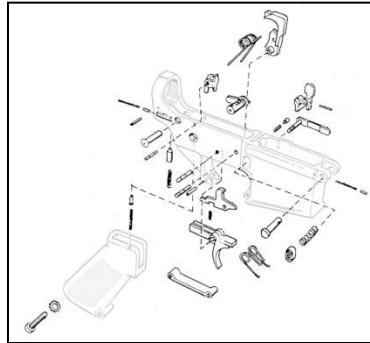
Use On Critical & High Value Equipment



## Introduction:

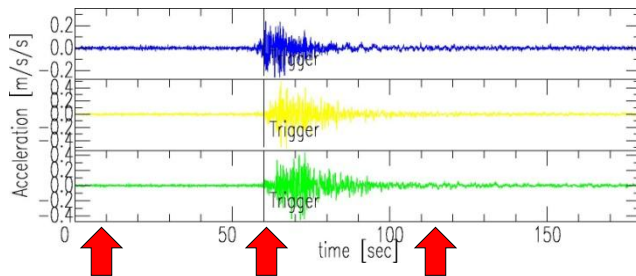
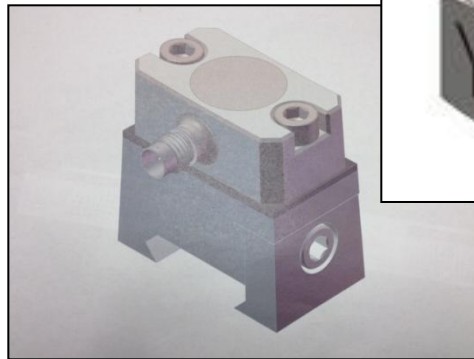
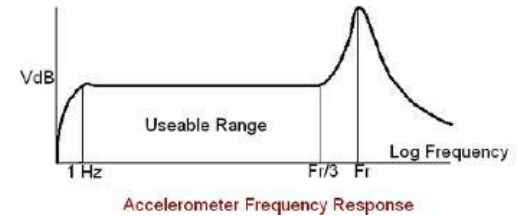
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“Why Vibration Analysis and how does it work?”

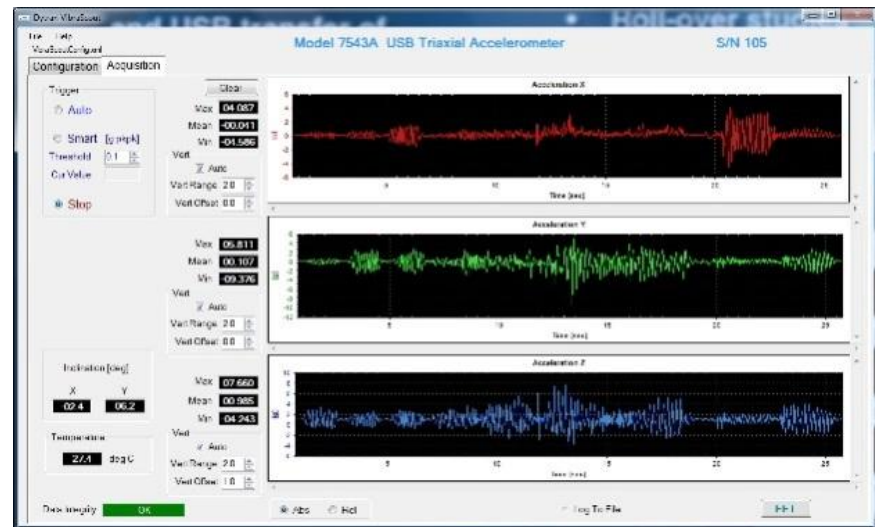


- 1) All Mechanical Components Of Firearms Are:
  - \* Different Sizes, Material Compositions And Weights
  - \* Mounted With Different Fasteners At Varying Orientations
  - \* Experiencing A Wide Range Of Stresses Over Time On Firing
- 2) All Mechanical Components Experience Wear With Use Differently
- 3) Damage And Wear Cause Easily Detectable Changes In Vibration

# Example: Accelerometers & Their Output



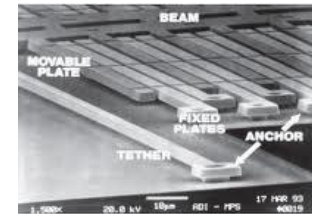
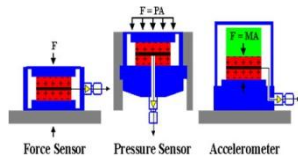
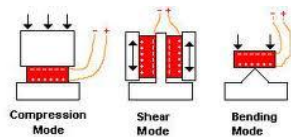
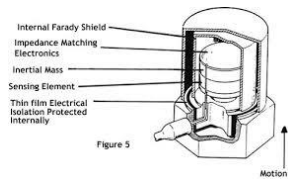
Monitor      Trigger      Capture



All Photos Above DYTRAN, Except Stanford University B-Y-G Triaxial In Lower Left, Upper Center: CSi 2400 Vibration Analyzer, Upper Right: Azimadli Generic Accelerometer F-R Showing Usable Measurement Range.

# Example: All Accelerometers Are Not Created Equal

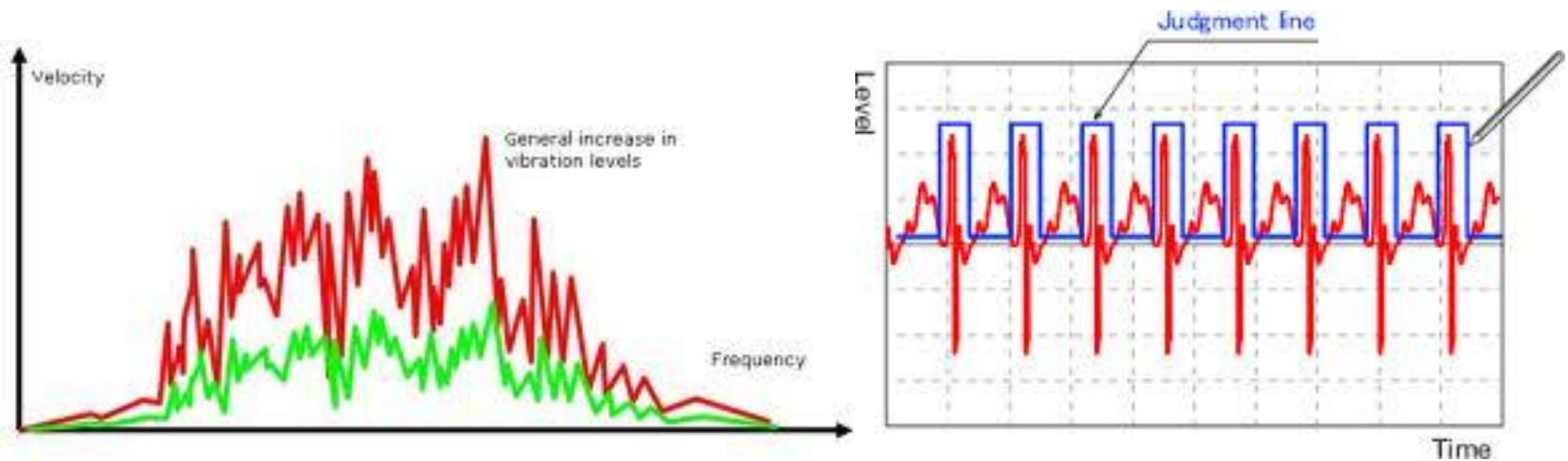
Two Basic Types: Piezo-Crystal Scientific & MEMS For Basic Control Sensing



Left Side, Clockwise From Upper Left: Wisdom Art Blog Crystals, DYTRAN Catalog, Accuvib Generic Cutaway, Debashish FR Photo, NI Photo, Berainian Instruments Photo. Right Side, Top: AD Photo, Below: ST Photos.

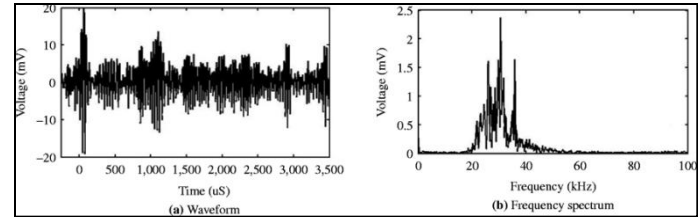
## Example: Signature Analysis Or “Deviations From Baseline Measures”

It Is Easier To See Changes In Machine Condition In Time Series...



Above Left: Spectrum Converted From Waveform Via FFT To Ease Analysis, Note Height Of Trace Line Differences, MH Mechanical Blogspot Photo. Above Right: Waveform Shaped Surrounded By “Judgement Line” Or Alarm Envelope Which Generates Warning Reports If Limit Is Ever Exceeded, Onnosoki Photo. NOTE: The Primary Measurement Is An Electrical Variation Of Force Exerted On A Piezo-Electric Crystal Called A “Sinusoidal Waveform” Created By Vibration Transmitted Through The Structure Of The Test Subject.

# Example: Time Series Analysis Cascade Comparison Or “Trending”

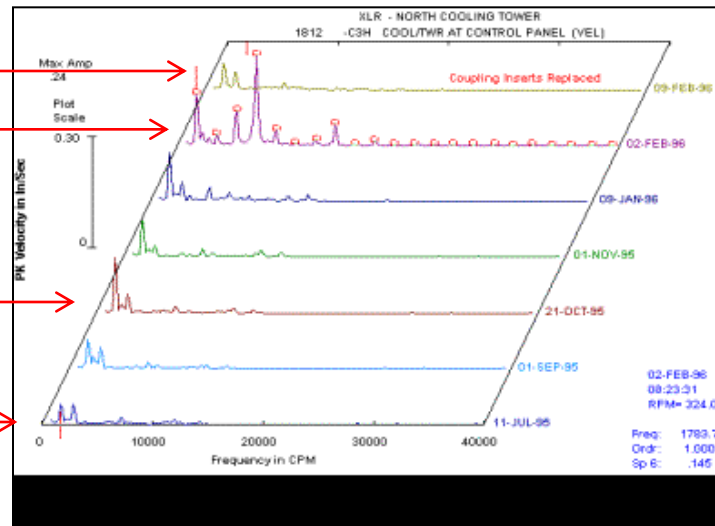


Post Repair Normal Reading

Critical Vibration Level Exceeded

Rising 1 x RPM Peak

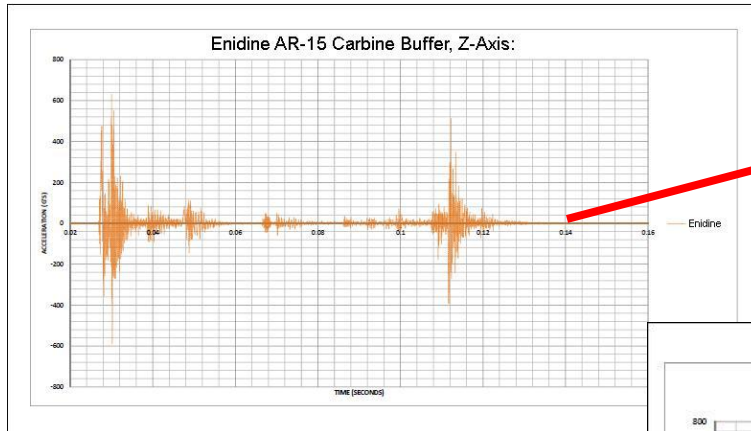
Baseline Measurement



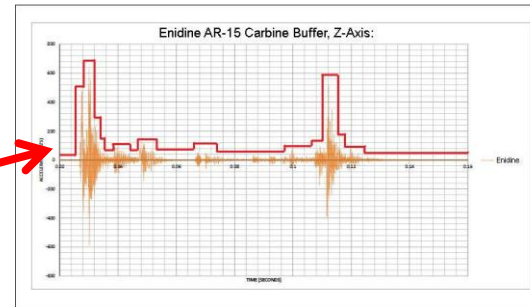
Top Row: US Army Photo, DLI Data Collector, Daid OCR, Emerald Insight Generic “One Time” Measurement. Below: Plant Maintenance Cascade Photo With Time Series Showing Deterioration, Failure And Verification Test After Repair.

# Example: Individual Weapon Firing Measurement

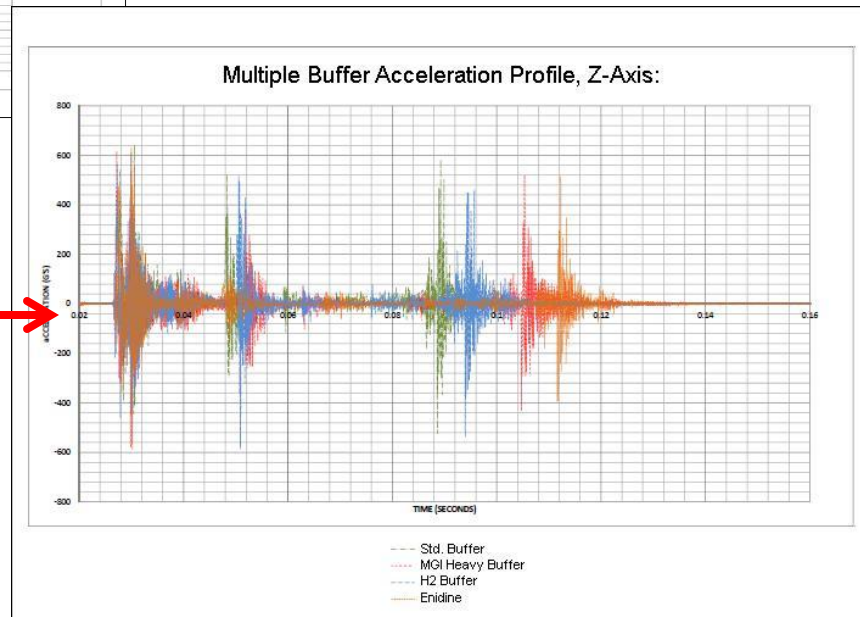
Enidine Buffer Individual Waveform



Alarm Envelope Applied



Overlay Of Multiple M4 Carbine Buffers With Cycle Rate Variations Due To Weight, Construction, Presence Or Absence Of Springs, Pads & Hydraulic Fluid Operation Shown...



## Example: Single Case Comparative Cost Structure

M4 Upper With PDM Work Order:

Diagnosis: Identified Rough Chamber

Shipped By User  
Received By Armory  
Disassembly  
Replacement Of Parts  
    Barrel Assembly  
    Barrel Extension  
    Barrel Extension Pin  
Reassemble  
Inspection  
Test Fire  
Automatic Reporting  
Clean & Package  
Ship To User

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**Cost = \$ "X"**

M4 With Unknown Function Problems:

Diagnosis: None, Overhaul

Shipped By User  
Received By Armory  
Inspection  
Test Fire  
Disassembly  
Gauging  
Replacement Of Parts  
    Barrel Assembly  
    Barrel Extension  
    Barrel Extension Pin  
    Bolt Assembly  
    Extractor, Spring, Pin  
    Ejector, Retainer  
    Firing Pin, Retainer  
    Carrier Assembly  
Reassemble  
Inspection  
Test Fire  
File Report  
Clean & Package  
Ship To User

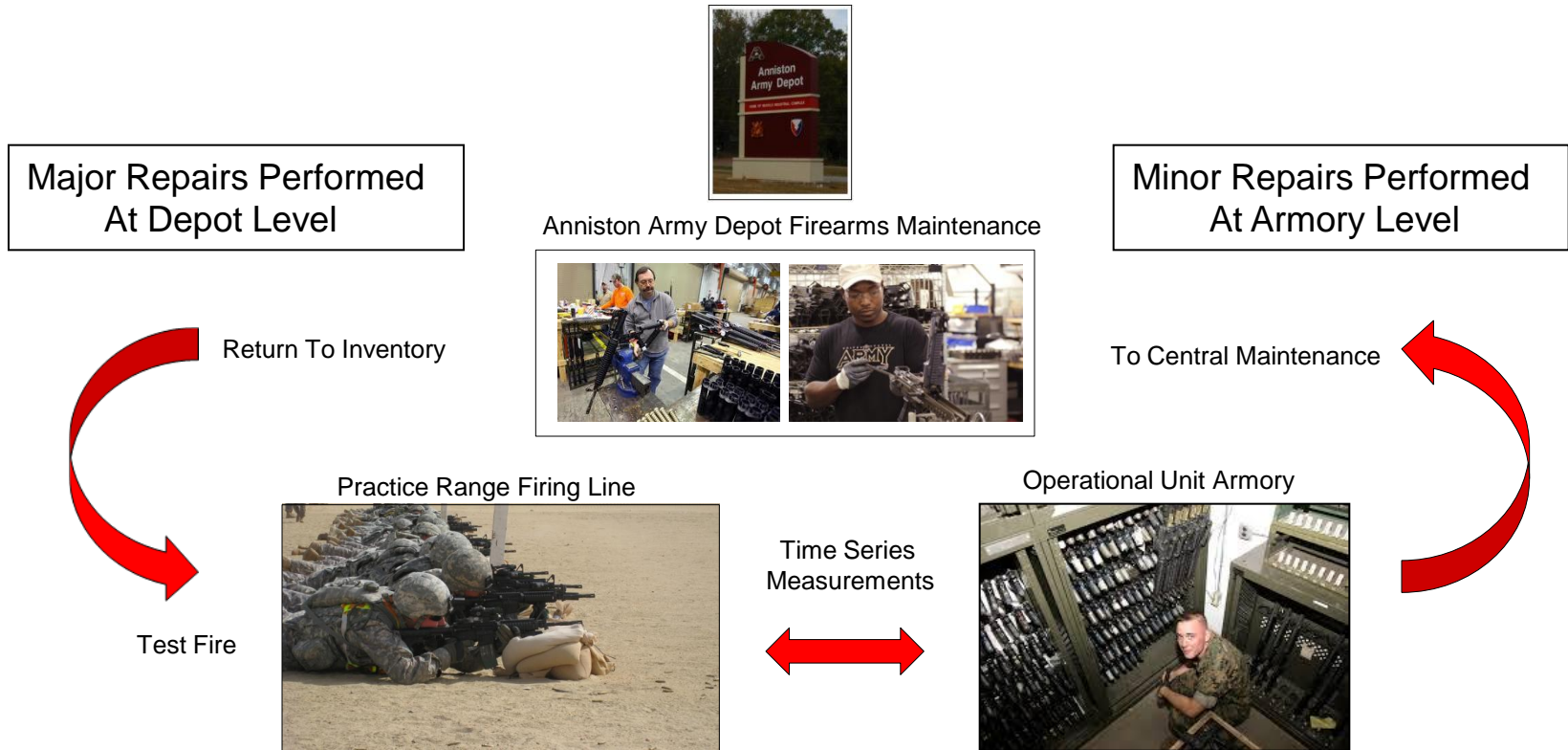
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**Cost = \$ "X" Times 2-3 !!!**

*And Remember, Sometimes Those  
Unnecessary Repairs Introduce New Faults  
To The Weapon!*

# Proposed Model Of Centralized Weapon Maintenance For Firearms:

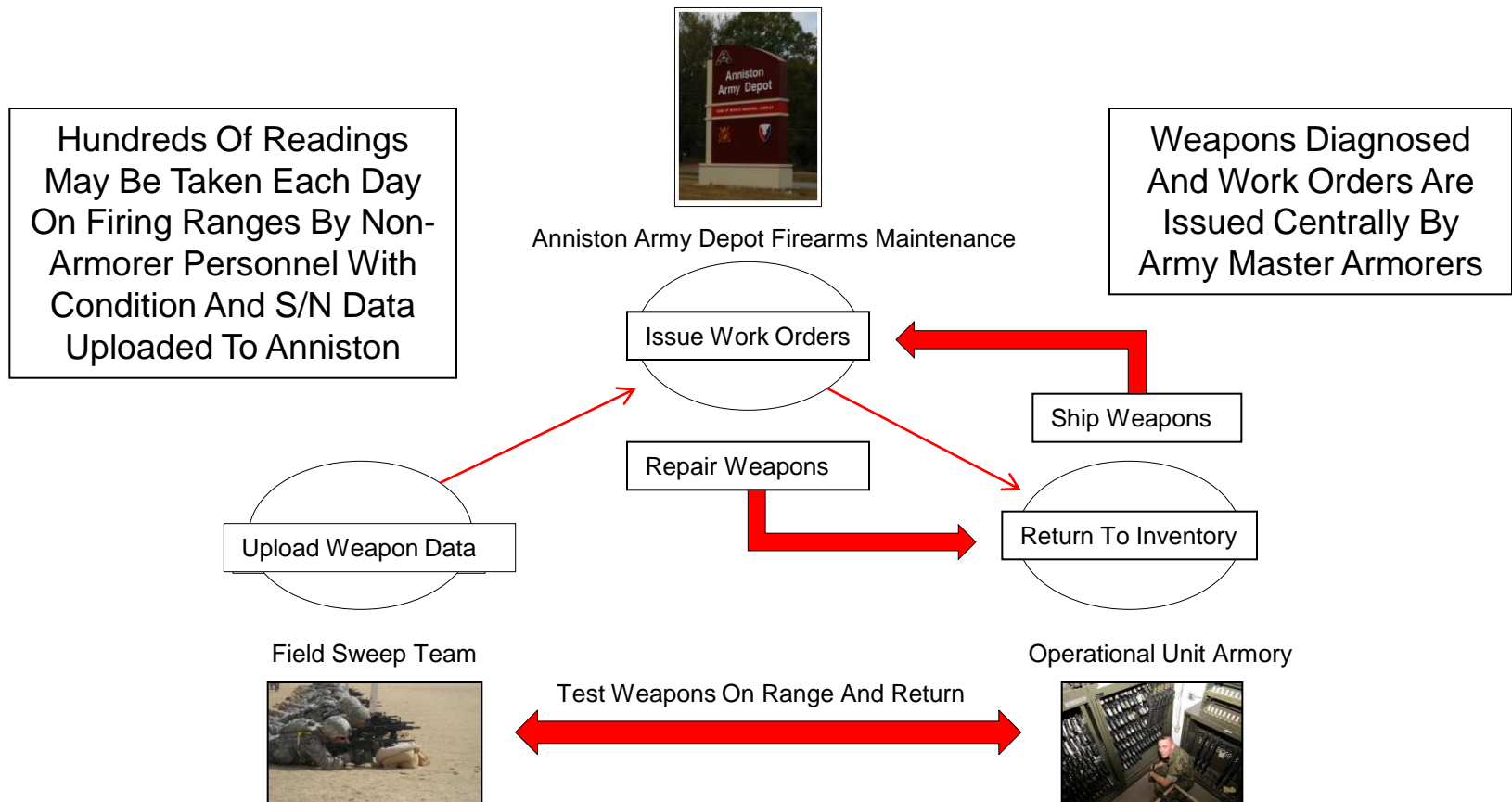
Concentrating Highly Trained Armorer Personnel & Specialized Equipment



Above: US Army Photos

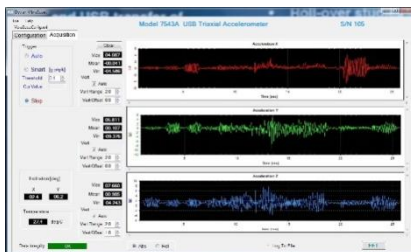
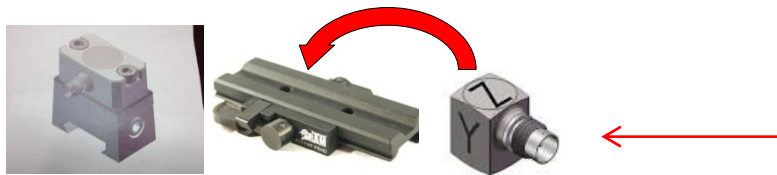


# Proposed Model Of PDM Weapon Survey For Firearms:



Above: US Army Photos

# Proposed Measurement Procedure Of PDM Weapon Survey For Firearms:



- 1) Scan Weapon Serial Number With OCR Gun
- 2) Attach QD Picatinny Mount Triaxial Accelerometer
- 3) Activate Data Collection Function & Fire Rounds
- 4) Verify Recording & Remove Triaxial Accelerometer



**SAMSON RAM** Advanced Adjustable QD Mount

Conclusion:

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Initiate ***Value Engineering Change Programs For Weapon Maintenance:***

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- The Various Services Can Increase Fleet Weapon Readiness Affordably...
- The Individual Weapon User Can Increase Confidence In Their Weapon...
- DoD Can Have A Weapon Knowledge Base & Retain Armorer Capacity...
- Existing Maintenance & Inventory Structures Can Remain Unchanged...

...All Through The Use Of ***Predictive Maintenance.***

Credits:



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With Special Thanks To:



&



With Problem Identification & Definition Co-Authored By:

MSgt. Craig LaMudge, USAF-Ret., **JSSAP** Special Projects Office & **NDIA** Hathcock Award Winner

*"He Who One Day Will Find Fault In Heaven"*

NDIA White Paper Series, Joint  
Small Arms Conference 2014