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55th ANNUAL FUZE CONFERENCE

"Fuzing's Evolving Role in Smart Weapons"

Salt Lake City, UT

May 24 - 26, 2011

Agenda (Brochure)
On-Site Agenda

WEDNESDAY, MAY 25, 2011

GENERAL SESSION
SESSION I

A Soldiers Perspective

- CSM Lance Lehr, US Army

SESSION II
DTRA S&T Strategy

- Danny Hayles, Defense Threat Reduction Agency

Navy S&T Strategy

- Randall Cope, US Navy, NAVAIR China Lake

OSD Perspective/ Fuze IPT

- Charles Kelly, OUSD (AT&L) Land Warfare and Munitions

Joint Fuze Technology Program

- Lawrence Fan, US Navy, NSWC Indian Head Division

Army Safety Approval Process

- Chris Janow, Chief, Army Fuze Management Office

Navy Safety Approval Process

- Gabe Soto, Chairman, Fuze and Initiation System Technical Review Panel

Air Force Safety Approval Process

- Matt Bridge

OPEN SESSIONS
Session IIIA

- Use of Charge Based Programmable Logic Devices to Perform Fuze Safety Functions, Robert Hubal, US Army, ARDEC
- Evolving Requirements for the Use of Logic Devices in the Implementation of Safety Features, John Hughes, US Navy, NAVAIR China Lake

- Ceramic Capacitor Failures & Lessons Learned, Patrick O'Malley, Sandia National Laboratories
- Enhanced Weapon Arming Safety by Controlled Accumulation of Arming Energy, Thomas Harward, Raytheon Missile Systems
- Pyro-MEMS, Renaud Lafont, NEXTER Munitions
- Universal Fuze Monitoring Test Systems, Jason Koonts, NSWCDD, Computer Engineer
- Simple Optical Sensors for Firing Tests, Michael Connolly, US Army, AMRDEC
- Scalable Software Evaluation Methodology and Tools, Jeffrey Fornoff, US Army, ARDEC
- FIPS 140-2 Tamper Detection to protect Fuze Technology, John Ambrose, Mixed Signal Integration
- Void Sensing Fuze Product (VSF) Improvement Program, Transition of German Technology to Meet American Warfighter Needs, Dale Spencer, Kaman Precision Products

THURSDAY, MAY 26, 2011

OPEN SESSIONS
Session IVA

- Fuze Power - Quo Vadis?, Harald Wich, Diehl & Eagle Picher
- New Data Recorder for Gun Launch and Impact Test with Options for Built-in High G Accelerometers and Angular Rate Sensors, Stephen Pruitt, DTS
- Smart Materials for Fuzing, Dr. Daniel Peairs, L-3 Fuzing & Ordnance Systems
- Generation and Measurement of Long Duration High-g Acceleration Profiles, Siegfried Nau, Fraunhofer Ernst-Mach-Institut
- Development of a new MEMS High-g Accelerometer, Robert Kuells, Fraunhofer Ernst-Mach-Institut
- Course Correction Fuze - Integration Technologies, Max Perrin, JUNGHANS Microtec GmbH|
- MK419 Mod 1 Multi-Function Fuze Product Improvement Program, Richard Chapman, US Navy, NSWC Dalhgren Division
- Fuze for Tiger Helicopter Rocket - Inductive Setting and Motor Ignition, Max Perrin, JUNGHANS Microtec
- Multifunction Fuze Capability Against High Speed Mobile Water Attack Craft, James Ring, ATK

55th Annual Fuze Conference

May 24-26, 2011

Grand America Hotel

Salt Lake City, UT

NDIA National Defense Industrial Association

55th Annual Fuze Conference

May 25, 2011 - General Session (AM)

Session I

- **8:00** Introduction/Admin Remarks – Dr. Barry Neyer
- **8:05** A Soldier's Perspective – CSM Lance Lehr, USA

Session II **(Chair: Eric Roach, Asst: Dr. Barry Neyer)**

- **8:40** DTRA Overview – Danny Hayles
- **9:00** Navy S&T Strategy – Randall Cope
- **9:20** ~~Air Force S&T Strategy – Tim Tobik~~
- **9:40** Break
- **10:00** OSD Perspective/Fuze IPT – Charles Kelly
- **10:15** Joint Fuze Technology Program – Lawrence Fan
- **10:30** Army Safety Approval Process – Chris Janow
- **11:00** Navy Safety Approval Process – Gabe Soto
- **11:30** Air Force Safety Approval Process – Matt Bridge
- **11:50** Harry Diamond Fuzing Excellence Award Ceremony
- **12:00** Lunch

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55th Annual Fuze Conference

May 25, 2011 - OPEN Session (PM)

Session IIIA **(Chair: Ed Cooper, Asst: Dave Lawson)**

- **1:00** Use of Charge Based Programmable Logic… – R. Hubal
- **1:20** Evolving Requirements for the Use of Logic… – J. Hughes
- **1:40** 40mm MEMS Fuze Integration Update – C. Robinson
- **2:00** Ceramic Capacitor Failures & Lessons… – P. O'Malley
- **2:20** Enhanced Weapon Arming Safety by… – T. Harward
- **2:40** ~~Developments in Target Detection Device… – G. Buzzard~~
- **3:00** Break
- **3:20** Pyro-MEMS – R. Lafont
- **3:40** Universal Fuze Monitoring Test System – J. Koonts
- **4:00** Simple Optical Sensors for Firing Tests – M. Connolly
- **4:20** Scalable Software Evaluation Methodology… – J. Fornoff
- **4:40** FIPS 140-2 Tamper Detection to Protect… – J. Ambrose
- **5:00** Void Sensing Fuze Product (VSF)… – D. Spencer/Dr. Muthig
- **5:30** Grand Reception

55th Annual Fuze Conference

May 26, 2011 - OPEN Session (AM)

Session IVA (**Chair**: Eric Roach, **Asst**: Lawrence Fan)

8:00	Fuze Power – Quo Vadis? – H. Wich
8:20	New Data Recorder for Gun Launch and… – S. Pruitt
8:40	Smart Materials for Fuzing – Dr. D. Peairs
9:00	Generation and Measurement of Long… – S. Nau
9:20	Development of a new MEMS High-G Acc… – R. Kulls
9:40	OPEN
10:00	Break
10:20	Course Correction Fuze – Integration Tech… – M. Perrin
10:40	MK419 Mod 1 Multi-Function Fuze Prod… – R. Chapman
11:00	Fuze for Tiger Helicopter Rocket-Inductive… – M. Perrin
11:20	Multifunction Fuze Capability Against High… – J. Ring
11:40	~~TDW's 2-inch Full Electronic Void Sens… – Dr. H. Muthig~~
12:00	Open Session Adjournment
12:05	Lunch

Event # 1560

PROMOTING NATIONAL SECURITY SINCE 1919

55TH ANNUAL FUZE CONFERENCE

"Fuzing's Evolving Role in Smart Weapons"

PLAN TO ATTEND……

- Participate in technical presentations on the latest advances in fuzing
- Learn about emerging trends in fuze technology
- Network with other professionals who share your interests

SHOWCASE YOUR COMPANY……

- Represent your company before a broad base of potential customers and partners
- Maximize your company's visibility through sponsorship opportunities & table top displays

May 24-26, 2011

www.ndia.org/meetings/1560

SALT LAKE CITY, UT

AGENDA

HOTEL INFORMATION

The Grand America
555 South Main Street
Salt Lake City, Utah 84111

Reservations:

Tel:1-800-304-8696

A limited block of rooms has been reserved at The Grand America and Little America (Gov Per Diem Rate offered here). To ensure the negotiated NDIA rate, please make your reservations early and ask for the NDIA room block - Industry or Government Per Diem. Rooms will not be held after Sunday, May 1, 2011 and may sell out before then. Rates are also subject to increase after this date. The government per diem rate is available only to active duty or civilian government employees.

Attire:

The proper attire for this conference is business casual or military ACUs.

Inquiries:

For more information, contact Mary Katherine Saladino, Meeting Planner at (703) 247-2540 or via e-mail at: msaladino@ndia.org.

TUESDAY, MAY 24, 2011

3:00-6:30 pm - Onsite Registration

5:00-6:30 pm - Opening Reception

WEDNESDAY, MAY 25, 2011

GENERAL SESSION

Session I

7:00 am Onsite Registration/Continental Breakfast

8:00 am Introduction/Administrative Remarks
Barry Neyer, Chair, Fuze Division
Chief Technology Officer, Defense, Excelitas Technologies Corp.

8:05 am NDIA Opening Remarks
MG Barry Bates, Vice President, Operations
National Defense Industrial Association

8:10 am A Soldiers Perspective
CSM Lance Lehr, US Army

Session II

CHAIR: ERIC ROACH ASSISTANT: BARRY NEYER

8:40 am DTRA S&T Strategy
Danny Hayles, Defense Threat Reduction Agency

9:00 am Navy S&T Strategy
Randall Cope, US Navy, NAVAIR China Lake

9:20 am Air Force S&T Strategy
Tim Tobik, Chief, Fuze Branch, Air Force Research Laboratory

9:40 am BREAK

10:00 am OSD Perspective/ Fuze IPT
Charles Kelly, OUSD (AT&L) Land Warfare and Munitions

10:15 am Joint Fuze Technology Program
Lawrence Fan, US Navy, NSWC Indian Head Division

10:30 am Army Safety Approval Process
Chris Janow, Chief, Army Fuze Management Office

11:00 am Navy Safety Approval Process
Gabe Soto, Chairman, Fuze and Initiation System Technical Review Panel

11:30 am Air Force Safety Approval Process
Mel Duval, Acting Chief, Air Force System Safety Office

11:50 am Harry Diamond Fuzing Excellence Award Ceremony

12:00 pm LUNCH

WEDNESDAY, MAY 25, 2011 (PM)

OPEN SESSIONS

Session IIIA

CHAIR: ED COOPER **ASSISTANT:** DAVE LAWSON

1:00 pm Use of Charge Based Programmable Logic Devices to Perform Fuze Safety Functions
Robert Hubal, US Army, ARDEC

1:20 pm Evolving Requirements for the Use of Logic Devices in the Implementation of Safety Features
John Hughes, US Navy, NAVAIR China Lake

1:40 pm Independence and Partitioning for Fuze Safety
Michael Connolly, US Army, AMRDEC

2:00 pm Capacitor Failures: A Continuing Plague for Electronic Systems
Patrick O'Malley, Sandia National Laboratories

2:20 pm Enhanced Weapon Arming Safety by Controlled Accumulation of Arming Energy
Thomas Harward, Raytheon Missile Systems

2:40 pm Developments in Target Detection Device Clutter Discrimination Algorithms
Gary Buzzard, Thales

3:00 pm BREAK

3:20 pm Pyro-MEMS
Renaud Lafont, NEXTER Munitions

3:40 pm 40mm MEMS Fuze Integration Update
Charles Robinson, US Army, ARDEC

4:00 pm Simple Optical Sensors for Firing Tests
Michael Connolly, US Army, AMRDEC

4:20 pm Scalable Software Evaluation Methodology and Tools
Jeffrey Fornoff, US Army, ARDEC

4:40 pm FIPS 140-2 Tamper Detection to protect Fuze Technology
John Ambrose, Mixed Signal Integration

5:00 pm Void Sensing Fuze Product (VSF) Improvement Program, Transition of German Technology to Meet American Warfighter Needs
Dale Spencer, Kaman Precision Products

5:20 pm Adjourned for the Day

5:30 pm - 7:00 pm Grand Reception

US ONLY SESSIONS

Session IIIB

CHAIR: TOM BAGINSKI **ASSISTANT:** FRAN MATTIA

1:00 pm Piezoelectric Generation in the Fuze Environment
Dr. Daniel Peairs, L-3 Fuzing & Ordnance Systems

1:20 pm FMCW Target Classification
Charles Overman, University of Florida Electronic Communications Lab

1:40 pm Integrating Direct Write Technologies for Explosives Systems
Dr. Brian Fuchs, US Army, ARDEC

2:00 pm Anti Tamper Technologies in Fuze Environments
Bobby Zienowicz, US Army, ARDEC &
Stephen Redington, US Army, ARDEC

2:20 pm Development of a Direct Write Exploding Foil Initiator
Dr. Ann Marie Petrock , US Army, ARDEC

2:40 pm High Reliability Fuzing Architecture for Cluster Munitions
David Gudjohnsen, US Army, ARDEC

3:00 pm BREAK

3:20 pm Enabling Technologies for Miniature Firing Systems
Charles Treu, NNSA Kansas City Plant

3:40 pm System Integration of Miniature Fuze Technologies
Kenneth Jensen, NNSA Kansas City Plant

4:00 pm A Compact MIL-STD-1901A Compliant Rocket Motor Initiator to Replace Current Initiators
Paul Moore, Excelitas Technologies Corp

4:20 pm High Power & Energy Supercapacitors Fabricated with Inherently Conductive Polymers for Improved Performance
Hai-Long Nguyen, US Army, ARDEC

4:40 pm Dual Load Exploding Foil Initiator Detonator
Don Warren, Excelitas Technologies Corp.

5:00 pm High Energy and High Power Thermal Battery Options for Weapons Applications
Dr. David Swanson, Enersys Advanced Systems Inc.

5:20 pm Adjourned for the Day

5:30 pm - 7:00 pm Grand Reception

THURSDAY, MAY 26, 2011 (AM)

REGISTRATION

7:00 am Onsite Registration/Continental Breakfast

OPEN SESSIONS

Session IVA

CHAIR: ERIC ROACH ASSISTANT: LAWRENCE FAN

8:00 am Fuze Power - Quo Vadis?
Harald Wich, Diehl & Eagle Picher

8:20 am New Data Recorder for Gun Launch and Impact Test with Options for Built-in High G Accelerometers and Angular Rate Sensors
Stephen Pruitt, DTS

8:40 am Smart Materials for Fuzing
Dr. Daniel Peairs, L-3 Fuzing & Ordnance Systems

9:00 am Generation and Measurement of Long Duration High-g Acceleration Profiles
Siegfried Nau, Fraunhofer Ernst-Mach-Institut

9:20 am Development of a new MEMS High-g Accelerometer
Robert Kuells, Fraunhofer Ernst-Mach-Institut

9:40 am Advanced Rapid Prototype Platform for Fuze Designers
Tracy Becker, National Nanotechnology Manufacturing Center, Inc.

10:00 am BREAK

10:20 am Course Correction Fuze - Integration Technologies
Max Perrin, JUNGHANS Microtec GmbH|

10:40 am MK419 Mod 1 Multi-Function Fuze Product Improvement Program
Richard Chapman, US Navy, NSWC Dalhgren Division

11:00 am Fuze for Tiger Helicopter Rocket - Inductive Setting and Motor Ignition
Max Perrin, JUNGHANS Microtec

11:20 am Multifunction Fuze Capability Against High Speed Mobile Water Attack Craft
James Ring, ATK

11:40 am TDW's 2-inch Full Electronic Void Sensing Penetrator Fuze is Ready
Dr. Helmut Muthig, TDW GmbH

12:00 pm LUNCH

US ONLY SESSIONS

Session IVB

CHAIR: CURT POWELL ASSISTANT: DON SHUTT

8:00 am The Fuze Environment of Boosted Penetrators
Dr. Jason Foley, US Air Force, AFRL Munitions Directorate

8:20 am Hard Target Void Sensing Fuze (HTVSF) Test Results
Jeremy Oligmueller, ATK

8:40 am Sub-Scale Fuze Survivability Protocol for Hard Target Fuzes
Stephen Szczepanski,US Air Force, AFRL Munitions Directorate

9:00 am Hardened Miniature Fuze Technology Progress
Jefferson Oliver, US Air Force, AFRL Munitions Directorate

9:20 am Mechanical Energy Propagation into Penetrating Weapon Fuzes
Dr. Jason Foley,US Air Force, AFRL Munitions Directorate

9:40 am Dynamic Impact Simulation of Deceleration Pulse for Layer Sensing Fuzes
Dr. Paul Glance, US Navy, NAVAIR China Lake

10:00 am BREAK

10:20 am Robust Fuzewell Instrumentation System (RFIS)
Kenneth Williamson, US Air Force, AFRL Munitions Directorate

10:40 am Development of the Design-a-Shock Methodology
Dr. Janet Wolfson, US Air Force, AFRL Munitions Directorate

11:00 am Hard Target Void Sensing (HTVSF) Update
Keith Thomas, Thales

11:20 am Improving Fuze Environment Prediction During Hard Target Penetration Using A Coupled-Code Erosion Technique
Reid McKeown, US Navy, NSWC Indian Head Division

11:40 am Fuze Diagnostic Recording
Darren Wang, Sandia National Labs

12:00 pm LUNCH

THURSDAY, MAY 26, 2011 (PM)

US ONLY SESSION

Session VA

CHAIR: DON SHUTT ASSISTANT: BOB HERTLEIN

1:00 pm A Low Voltage Command-Arm System for Distributed Fuzing
Mark Etheridge, US Army, AMRDEC

1:20 pm Target Detection Device and ESAD Designs for a KE Active Protection System
Nicholas Cali, US Army, ARDEC

1:40 pm Low-Cost Miniature Electronic Safe-Arm Device (ESAD)
Michael Haddon, US Navy, NAWC Weapons Division

2:00 pm Side Mount Height of Burst Sensor for the Laser Joint Direct Attack Munition
Brian Miracle, L3 Fuzing & Ordnance Systems

2:20 pm ATK Next Generation Proximity Sensor Test Results
Christopher Fuller, ATK

2:40 pm Detonation Phenomena in Deposited Explosives at Sub-Millimeter Dimensions
Alexander Tappan, Sandia National Laboratories

3:00 pm BREAK

3:20 pm Replaceable M213/228 Hand Grenade Electronic Fuze with Non-Inertial MEMS S&A
Ryan Knight, US Army, ARDEC

3:40 pm Enhanced Performance of MEMS Electric Initiators
Daniel Pines, US Navy, NSWC Indian Head Division

4:00 pm Nanoporous Energetic Silicon Initiators
Dr. Christopher Morris, US Army, Army Research Laboratory

4:20 pm Micro-Scale Firetrain Explosive Inks Manufacturing Technology Development
Tim Hoang, US Army, ARDEC

4:40 pm Wafer Level Packaging for High Aspect Ratio MEMS
Kevin Cochran, US Navy, NSWC Indian Head Division

5:00 pm MEMS Safe and Arm – Facilitating Miniature Munitions
Dale Spencer, Kaman Precision Products

5:20 pm Wrap- Up & Conference Adjourned
Don Shutt, ATK

US ONLY SESSION

Session VB

CHAIR: BARRY NEYER ASSISTANT: TIM TOBIK

1:00 pm Thin Film Dielectric Breakdown Investigation for High Voltage Switch Applications
Bradley Hanna, US Navy, NSWC Dalhgren Division

1:20 pm The Design of Low or Ultra Low Energy Exploding Foil Initiation Devices
Michael Meadows, Reynolds Systems Inc.

1:40 pm The Use of Conventional Bridge Models to Predict Performance of Electrically Driven Flyers for EFI Devices
Edwin Wild, US Air Force, AFRL Munitions Directorate

2:00 pm State-of-the-Art of Reliability Methodologies for Munitions Fuzes
John Deep, US Air Force, AFRL Munitions Directorate

2:20 pm The Use of Conventional Bridge Models to Predict Performance of Electrically Driven Flyers for EFI Devices
Dr. Eric Welle, US Air Force, AFRL Munitions Directorate

2:40 pm Characterization of Initiation Phenomena for the Purpose of Warhead Design
Dr. Eric Welle, US Air Force, AFRL Munitions Directorate

3:00 pm BREAK

3:20 pm Piezoelectric Setback Generators for the 30mm STAR ATO Program
Alfredo Vazquez Carazo, Micromechatronics, Inc.

3:40 pm Conformal Antennas for Weapon Sensors
Dennis Jones, Mustang Technology Group

4:00 pm MEMS Retard and Impact Sensors
Walter Maurer, US Navy, NAVAIR China Lake

4:20 pm Passive Planar Setback Switch for Gunned Applications
Scott Rauscher, US Army, ARDEC

4:40 pm Low Cost Inertial Measurement Unit as Environment Sensor
Noah Desch, L-3 Fuzing & Ordnance Systems

5:00 pm HARM (High-Aspect Ratio Metal)-MEMS Very Low-G Viscously-Damped Inertial Switches
Ryan Knight, US Army, ARDEC

5:20 pm Wrap- Up & Conference Adjourned
Barry Neyer, Excelitas

Sponsorship Opportunities:

Fitness Center Sponsor
SOLD: Meggitt Sensing Systems
Benefits:
- One complimentary symposium registration
- Placement of your company's logo in the agenda handouts
- Signage at NDIA registration desk on May 24, 2011
- Sponsor ribbon on badge

Continental Breakfast Sponsor- Investment: $5,000 per breakfast (One opportunites remaining)
1 SOLD: Kaman Precision Products
Benefits:
- Two complimentary symposium registrations
- Placement of your company's logo in the agenda handouts and proceedings
- Signage outside the particular event sponsored
- Sponsor ribbon on badges

Break Sponsor- Investment: $4,000 per break (Two opportunites remaining)
2 SOLD: L-3
Benefits:
- One complimentary conference registration
- Placement of your company's logo in the agenda handouts and proceedings
- Company description (250 words) in onsite agenda
- Signage outside the particular event sponsored
- Sponsor ribbon on badges

Lunch Sponsor- Investment: $6,000 per lunch (One opportunity remaining)
1 SOLD: DSE, Inc.
Benefits:
- Three complimentary symposium registrations
- Company logo and link to your company on event web site
- Placement of your company's logo in the agenda handouts and proceedings
- Company description (300 words) in onsite agenda
- Signage outside the particular event sponsored
- Sponsor ribbon on badges

Opening Reception Sponsor- Investment:
SOLD: Lockheed Martin
Benefits:
- Three complimentary symposium registrations
- Company logo and link to your company on event web site
- Placement of your company's logo in the agenda handouts and proceedings
- Company description (300 words) in onsite agenda
- Company name on cocktail napkins at the reception

Sponsorship Opportunities CONT.:

Grand Reception Sponsor-
SOLD: ATK
Benefits:

- Four complimentary symposium registrations
- Company logo and link to your company on event web site
- Placement of your company's logo in the agenda handouts and proceedings
- Signage outside the particular event sponsored
- Opportunity to give a 10-minute company presentation at the reception
- Hosted bar and heavy hors d'ouvres for attendees
- Live musical entertainment provided
- Sponsor ribbon on badges

Create Your Own Opportunity!
Many of the NDIA events offer category exclusive sponsorships to fit your budget. By enhancing your brand with a sponsor ship at our events you'll build a stronger perception from the audience and stand out from the crowd. NDIA is open to custom sponsorship ideas.

Table Top Display Opportunities:

Interested in displaying your company's information? Register for a 6' table top display at the 2011 Fuze Conference!

This 6' table top display will give you an opportunity to have extra exposure to the Fuzing community at the 55th Annual Conference.

The cost to display is $750, registration form is on the next page.

*Included in the table top display registration is one conference registration for the exhibit-display personnel to attend the 55th Annual Fuze Conference. This also include attendance at all of the event food functions.

Hours of Operation:

Tuesday, May 24th
Set Up 2:00pm- 3:00pm
3:00pm - 6:30pm

Wednesday, May 25th
7:00am - 8:00am

Wednesday, May 25th cont.
10:00am - 10:20am
12:00pm - 1:00pm
3:00pm - 3:20pm
5:30pm - 7:00pm

Thursday, May 26th
7:00am - 8:00am
10:00am - 10:20am
12:00pm - 1:00pm
3:00pm - 3:20pm

GENERAL CONFERENCE INFORMATION

ATTENDEE ROSTER:

An attendance roster will be available at the conference registration desk. In order for your name to appear in the roster, you must be registered for this event by May 6, 2011. An updated roster will NOT be printed after the conference.

SPECIAL NEEDS:

NDIA supports the Americans with Disabilities Act of 1990. Attendees with special needs should call or email Mary Katherine Saladino, Meeting Planner at 703-247-2540 msaladino@ndia.org by May 3, 2011.

*US ONLY SESSIONS:

Certificate for Attendance will be the process to verify citizenship to attend this year's US Only Sessions. Please download the form at : www.ndia.org/meetings/1560 under the red 'Agenda or Registration' tab and complete section I & II before submitting.

QUESTIONS?

Please contact NDIA POC:
Mary Katherine Saladino, Meeting Planner at (703) 247-2540 or via email at msaladino@ndia.org.

REGISTRATION

NOTE: THERE ARE TWO SEPARATE REGISTRATION PROCESSES. ONE FOR CONFERENCE REGISTRATION AND ONE IF YOU PLAN TO ATTEND US ONLY SESSIONS. YOU MUST COMPLETE THE CERTIFICATE FOR ATTENDANCE.

ADDITIONAL DETAILS AND FORMS CAN BE FOUND AT WWW.NDIA.ORG/MEETINGS/1560 UNDER THE RED REGISTRATION TAB.

ONLINE:

Our preferred method of registration is online. Please go to www.ndia.org/meetings/1560 to register online.

FAX:

Register via fax by completing the Registration Form (PDF) and faxing it to (703) 522-1885. Please do not fax any registrations after May 10, 2011. After this date, please bring your completed registration form with you to the meeting to register on-site or register online.

MAIL:

Registration forms (PDF) may be mailed to: NDIA, Event #1560, 2111 Wilson Blvd., Suite 400, Arlington, VA 22201. Please do not mail any registrations after May 2, 2011. After this date, please bring your completed registration form with you to the meeting to register on-site or register online.

Registrations will not be taken over the phone and payment must be made at the time of registration.

CANCELLATIONS:

Cancellations until 05/6/11 receive a refund minus a $75 cancellation fee. No refunds for cancellations received on or after 05/7/11. Cancellations must be made in writing. Substitutions welcome in lieu of cancellations. Please e-mail your cancellations or substitutions to Mary Katherine Saladino via email:msaladino@ndia.org

	EARLY (UNTIL 3/29/11)	REGULAR (3/30/11-5/6/11)	LATE (AFTER 5/6/11)
GOVERNMENT ACADEMIA/ALLIED GOV.	$450	$495	$555
INDUSTRY NDIA MEMBER	$550	$605	$680
INDUSTRY NON-NDIA MEMBER	$625	$685	$775

55th Annual Fuze Conference

The Grand America, Salt Lake City, UT •
May 24-26, 2011 • Event #1560

National Defense Industrial Association
2111 Wilson Boulevard, Suite 400
Arlington, VA 22201-3061
(703) 522-1820 • (703) 522-1885 fax
www.ndia.org

NDIA National Defense Industrial Association

3 Ways to sign up:
1. Online with a credit card at www.ndia.org
2. By fax with a credit card — Fax: 703-522-1885
3. By mail with a check or credit card

☐Address change needed

NDIA Master ID/Membership # ____________________ Social Security # ____________________
(if known—hint: on mailing label above your name) *(last 4 digits – optional)*

Prefix ____________________
(e.g. RADM, COL, Mr., Ms., Dr., etc.)

Name First ____________________ MI ______ Last ____________________

Military Affiliation ____________________
(e.g. USMC, USA (Ret.) etc.)

Title ____________________

Organization ____________________

Street Address ____________________

Address *(Suite, PO Box, Mail Stop, Building, etc.)* ____________________

City ____________ State ______ Zip ______ Country ____________

Phone ____________ ext. ______ Fax ____________

E-Mail ____________________

Signature* ____________________ Date __________

Preferred way to receive information

Conference information ☐ address above ☐ Alternate *(print address below)* ☐ E-mail

Subscriptions ☐ address above ☐ Alternate *(print address below)*

Alternate Street Address ____________________

Alternate Address *(Suite, PO Box, Mail Stop, Building, etc.)* ____________________

City ____________ State ______ Zip ______ Country ____________

** By your signature above you consent to receive communications sent by or on behalf of NDIA, its Chapters, Divisions and affiliates (NTSA, AFEI, PSA, NCWG, WID) via regular mail, e-mail, telephone, or fax. NDIA, its Chapters, Divisions and affiliates do not sell data to vendors or other companies.*

By completing the following, you help us understand who is attending our meetings.

Primary Occupational Classification. *Check ONE.*

- ☐ A. Defense Business/Industry
- ☐ B. R&D/Laboratories
- ☐ C. Army
- ☐ D.Navy
- ☐ E. Air Force
- ☐ F.Marine Corps
- ☐ G. Coast Guard
- ☐ H.DOD/MOD Civilian
- ☐ I.Gov't Civilian (Non-DOD/ MOD)
- ☐ J. Trade/Professional Assn.
- ☐ K.Educator/Academia
- ☐ L. Professional Services
- ☐ M.Non-Defense Business
- ☐ N.Other ________

Current Job/Title/Position. *Check ONE.*

- ☐ A.Senior Executive
- ☐ B.Executive
- ☐ C.Manager
- ☐ D.Engineer/Scientist
- ☐ E.Professor/Instructor/Librarian
- ☐ F.Ambassador/Attaché
- ☐ G.Legislator/Legislative Aide
- ☐ H.General/Admiral
- ☐ I.Colonel/Navy Captain
- ☐ J.Lieutenant Colonel/ Commander/Major/ Lieutenant Commander
- ☐ K.Captain/Lieutenant/Ensign
- ☐ L.Enlisted Military
- ☐ O.Other

Year of birth
(Optional) ________

Registration Fees

	Early *(Until 3/29/11)*	**Regular** *(3/30/11-5/6/11)*	**Late** *(After 5/6/11)*
Industry Member	☐ $550	☐ $605	☐ $680
Industry Non-Member	☐ $625	☐ $685	☐ $775
Government/Academia	☐ $450	☐ $495	☐ $555

If you <u>plan** to attend</u> the DOD & US DOD Contractors Only Session please <u>check the box</u>. ☐US Only

**Did you submit your JPAS Visit Request or Certificate for Attendance? ☐Yes

Cancellations
Cancellations until 05/6/11 receive a refund minus a $75 cancellation fee. No refunds for cancellations received on or after 05/7/11. Cancellations must be made in writing.
Substitutions welcome in lieu of cancellations. Please e-mail your cancellations or substitutions to Mary Katherine Saladino via email:msaladino@ndia.org

Payment Options

- ☐ Check *(payable to NDIA)*
- ☐ Cash
- ☐ Government PO/Training Form # ____________
- ☐ VISA
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- ☐ F.Marine Corps
- ☐ G. Coast Guard
- ☐ H.DOD/MOD Civilian
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Air Armament Center

War-Winning Capabilities…On Time, On Cost

AF Nonnuclear Munitions Safety Approval Process

An Overview

U.S. AIR FORCE

This presentation is cleared for public release

AF Nonnuclear Munitions Safety Approval Process

- Who: Melvin Duval, Chief, AAC/SES
- Where: AF System Safety Office, Air Armament Center
- Experience: 20 + years in acquisition at Eglin, Chief Engineer several times, ~6 years in AAC/SES
- What: Overview of what is needed for a successful Nonnuclear Munitions Safety Board (NNMSB) evaluation

Background

- System Safety begins at the inception of the program
- Acquisition management authorities need to ensure system safety is an integral part of the acquisition strategy. (AFI 91-202, Chapter 9 and AFI 91-205)
- The AAC System Safety Office (AAC/SES) is primary AF source of conventional munition safety expertise
  - Ensuring program design safety requirements
  - Assisting in defining contractual system safety requirements
  - Supporting the systems engineering processes
  - Evaluating and documenting design as required for NNMSB safety approval/ certification actions for all conventional munition systems

Background

- NNMSB Core Mission
  - Review Authority and System Safety Group for All USAF Conventional Munitions
  - Advisor to Acquisition Authorities on Design Safety and Qualification Issues
  - Approval Authority for Airborne Flight Testing of Uncertified, Live-Loaded Munitions and Associated Subsystems
  - Design Safety Certification Authority for all Air Force Conventional Munitions
- AAC/SES, as NNMSB Executive Secretariat, assures execution of the Board's Core Mission

Background

- Authority rests with AFI 91-205
- Chairperson: Chief, Weapons Safety Division, Hq AF Safety Center
- Membership:

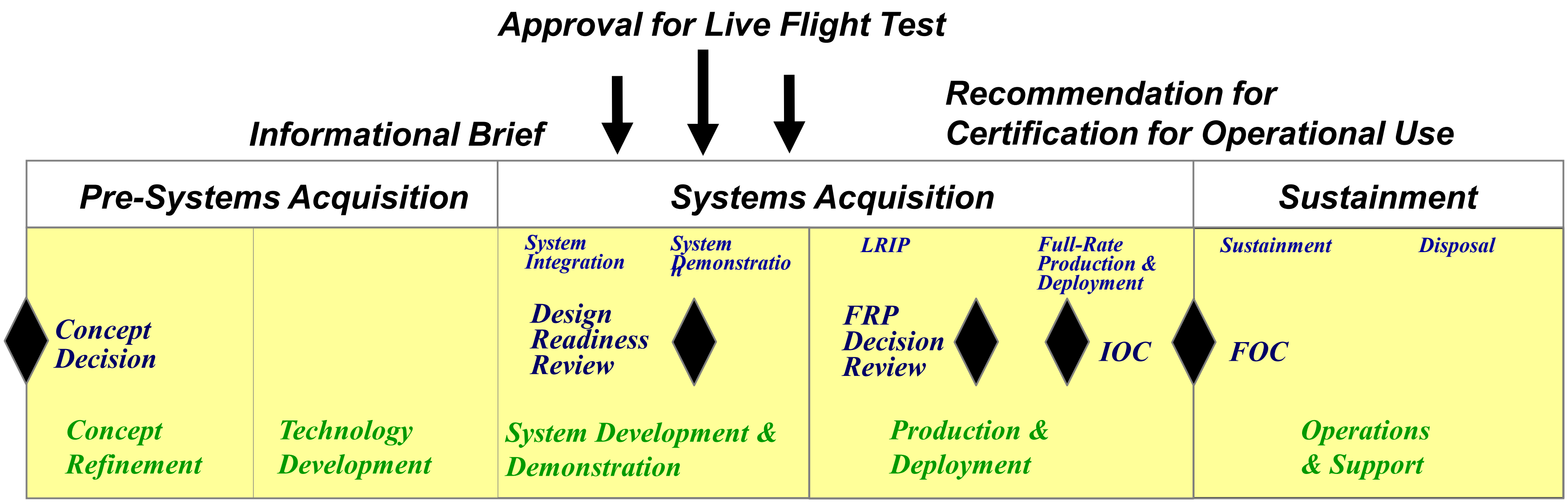
Air Combat Command	AF Materiel Command
Air Mobility Command	AF Operational T&E Center
AF Special Operations Command	Air Education & Training Cmd
Pacific Air Forces	Air National Guard
USAF Europe	AF Reserve Command
Air Force Space Command	Global Strike Command

- AFI 91-205 also designates AAC/SES, through Hq AFMC, as the agency to provide the Technical Support of the NNMSB

USAF Nonnuclear Munitions Safety Board AAC/SES Role

- AAC/SES is the Engineering Arm of the NNMSB
  - Performs Hazard Analyses
  - Performs Independent Fault Tree Analyses
  - Generates Safety Studies for assigned systems
  - Briefs the Safety Studies to the NNMSB
  - Obtains Approval for Live Flight Test/ Recommendation for Certification for Operational Use
- SES is part of the systems engineering team and will work with you from the start of the program through all milestones

USAF Nonnuclear Munitions Safety Approval Process



- Meeting the NNMSB is event driven, not milestone
- NNMSB scheduled Boards are April and October
- Special Boards can be held out of cycle if required
- Funding required for Board members' TDYs

USAF Nonnuclear Munitions Safety Approval Process

- First meeting with the Board is informational brief
- Scheduled 6 to 12 months before first live flight test
- Informational brief given by contractor in most cases
- Content is high level with specifics on safety aspects
- Feedback from the board will be comments on design, implementation, handling and storage
- Outcome will be concept agreement, subject to implementation

USAF Nonnuclear Munitions Safety Approval Process

- Second meeting with the Board is live flight test
- Live flight test includes live fuze, warhead, rocket motor, live Flight Termination System (FTS) or combination thereof
  - Live FTS has Range Safety and System Safety aspects
- Called Test Hazards Assessment Review (THAR)
  - THAR written by and presented to NNMSB by SES
  - THAR goes to NNMSB 30 days ahead of review
  - SES prep typically 30 days – Data in by 60 days ahead
  - Serial fashion is best – Don't wait for complete package
  - Must be approved by NNMSB for test to proceed

USAF Nonnuclear Munitions Safety Approval Process

- Third meeting with the Board is operational use
- Occurs after all testing is complete with no safety related failures – Can be held with minimal work left to conduct
- Documented by Technical Munitions Safety Study (TMSS) and in some cases by Munitions Safety Analysis for non-complex items – Time line is the same as THAR
- TMSS generated by and presented to NNMSB by SES
- Outcome is recommendation for certification for operational use by the NNMSB – May result in action items

USAF Nonnuclear Munitions Safety Approval Process

- For joint programs, SES will work with Service System Safety Counterparts to coordinate with and support review milestones, including formal Joint Meetings of the Boards
  - Key Distinction—There is no —Joint Board"
- Service Counterparts are invited to any review they have need to attend
- Can be informational or formal depending on requirements

USAF Nonnuclear Munitions Safety Approval Process

- What is important to know about the SES approach?
  - Primary desire is for concrete understanding of all safety critical elements of system, subsystem and components including:
    - Clear and detailed comprehension of design
    - What the hazards are to personnel/ property
    - Who will use the system and how they will use it
  - Is an iterative process - —Come Early, Come Often”
    - The earlier we understand your system, the better we can help you through the process

USAF Nonnuclear Munitions Safety Approval Process

- What is important to know about the SES approach? (cont)
- No formal submission guidelines or format requirements
- Emphasis is on technical content, not format
- Technical content is basically the same as for other service Boards and for a well prepared Safety Assessment Report – makes a good data transfer vehicle
  - Well defined/detailed physical/functional description
  - Full schematic diagrams of adequately mature design
  - Well defined/documented safety analyses
  - Well defined/documented safety specific testing
  - Well defined/documented system/subsystem testing

USAF Nonnuclear Munitions Safety Approval Process

- What to do to maximize your probability of a successful NNMSB?
  - Provide clear schedule requirements for program
  - Provide adequate information on system
  - Provide information in a timely manner
  - Provide technical support to Fault Tree Analysis
  - Provide support at the NNMSB Meeting
  - Respond to input from SES and the NNMSB
  - Notify AAC/SES of Program Changes ASAP
  - Work issues in real time -- No Surprises!!

USAF Nonnuclear Munitions Safety Approval Process

- As said before, our motto is —Come Early, Come Often”
  - Contact assigned engineer and set up informal and formal review times/dates
  - Be prepared to discuss the system at the lowest levels – Typically with the designer
  - Be prepared to discuss all hazards of the system
  - Be aware you are not the only one wanting a review, so plan ahead and have back-up dates ready

USAF Systems Safety Location

Questions…

NDIA's 55th Annual Fuze Conference
NAVY OVERVIEW

Randall Cope

Associate Department Head for Energetics

NAVAIR China Lake

Outline

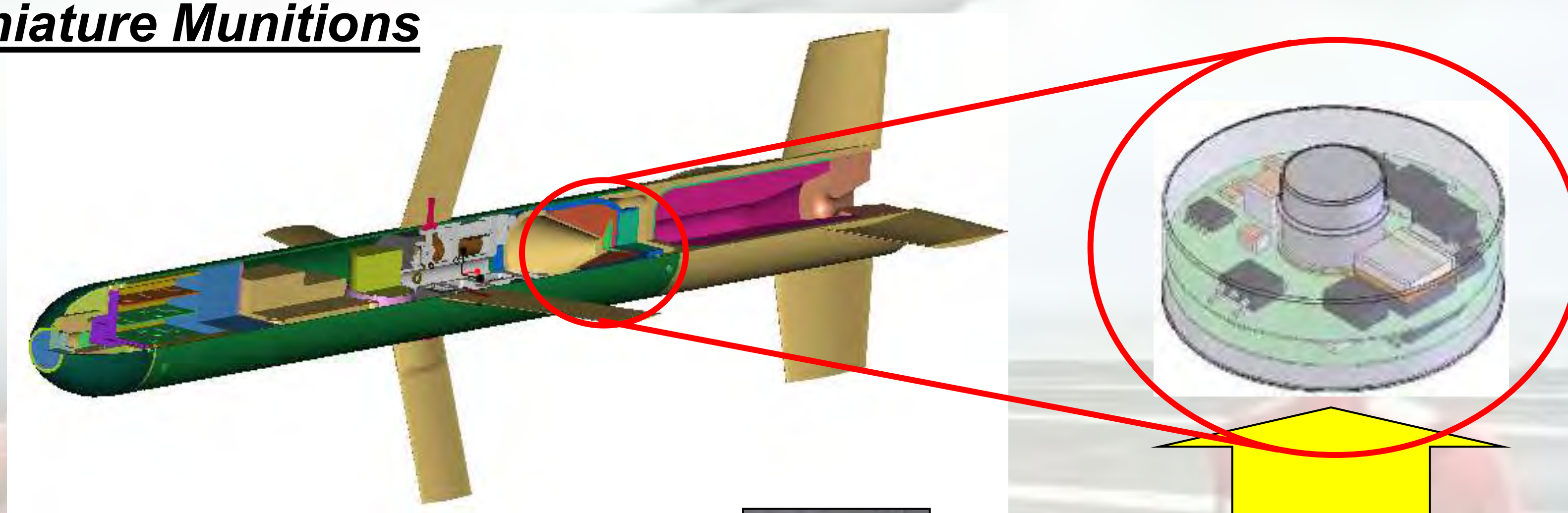
- Navy Fuze S&T Strategy
- Navy Fuzing Future Directions
- Navy Fuze Work Highlights
- Summary

Navy S&T Strategy

- **Less of a formal Strategy, but more of a fuzing path into the future**
  - ➢ **Smaller - We really see that fuzing is heading in the direction of smaller is better.**
    - **Weapons are getting smaller and smaller sizes allow for redundancy to help reliability.**
  - ➢ **Reliability - Higher reliability is also a big player for Navy fuzing. Sub-munitions have very high reliability expectations and more traditional fuzing is also wanting higher reliability.**
  - ➢ **Lower Cost - With budgets falling, the pressure is on to make all weapons and weapons systems cost less.**

Navy Future Directions

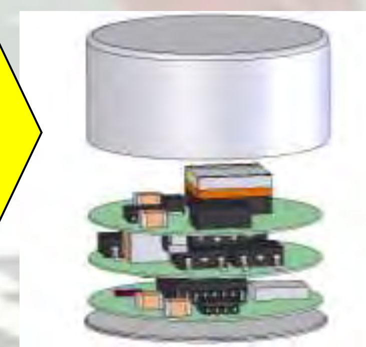
Miniature Munitions



State-of-the-Art
In-Line & Out-of-Line
Safe-Arm Devices

Large and bulky
Electro- Mechanical
Safe-Arm Devices

Complex Electro- Mechanical
Safe-Arm Devices

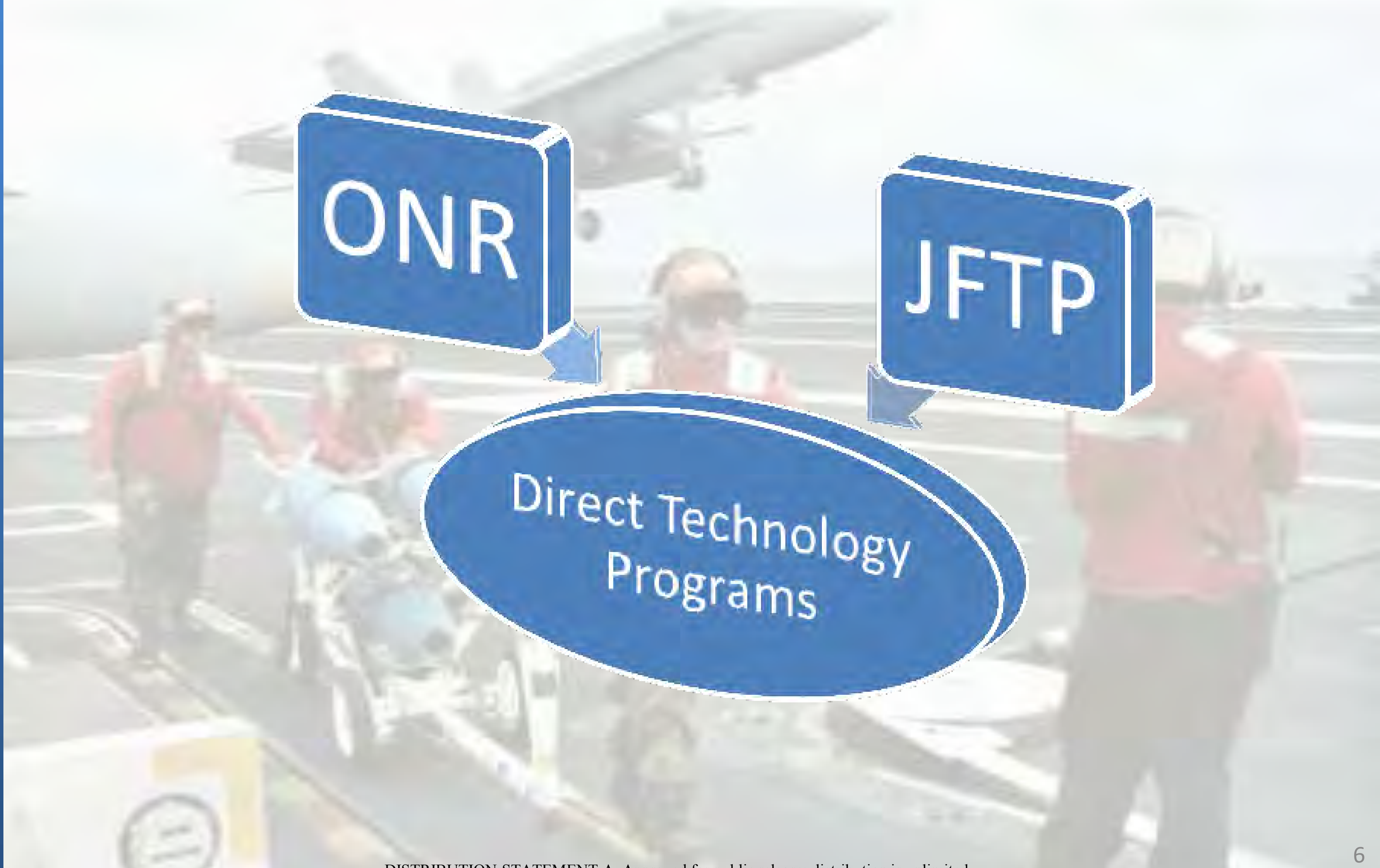


Advanced MEMS and
Electronic Technologies

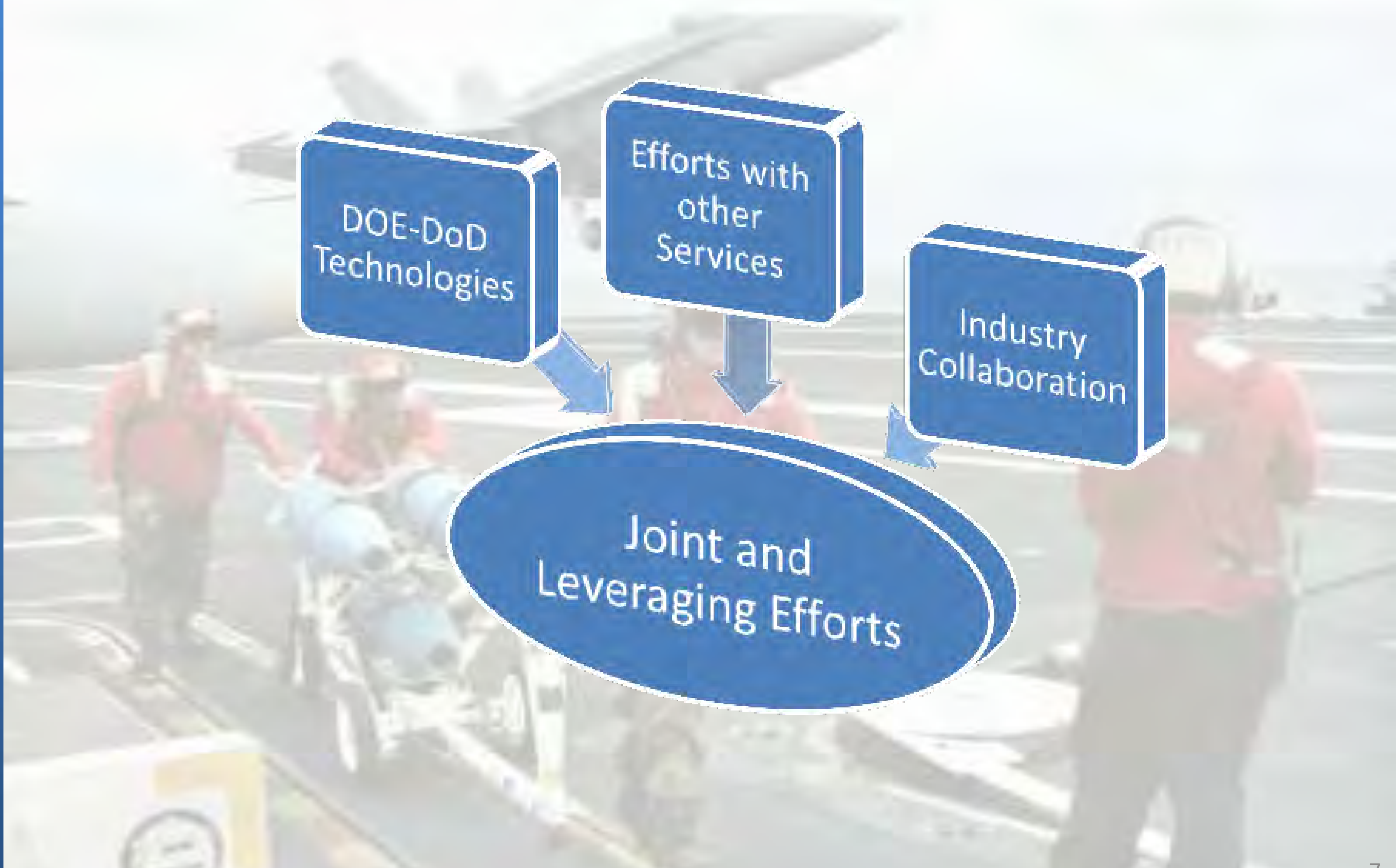
How Will We Get There?

- Smaller and more reliable and robust electronics and power conditioning technologies.
  - Improved reliability across all fuze applications.
- Improved detonator/initiator designs and components.
  - Improved IM and variable output weapons characteristics.
- Improved MEMS Technologies and producible MEMS designs.
  - Smaller and more robust fuzing application.
  - New families of contact sensors and fuzing devices
- Leverage spiral development of existing fuzes.
  - Improved reliability and capability.
  - Stop-gap to help support fuzing industry.
  - Demonstration beds for new technologies.
- Service life extension programs for existing fuze inventories.

Navy Tech Money Sources

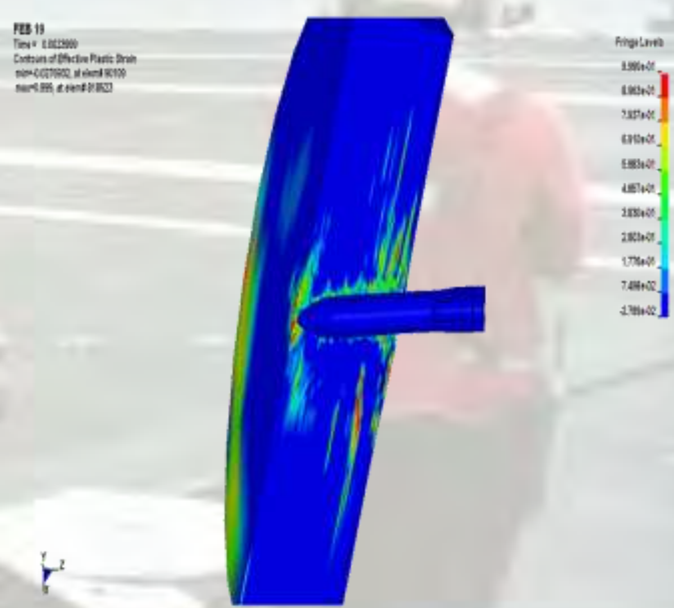


Navy Tech Money Sources



Dynamic Impact Simulation of Deceleration Pulse for Void Sensing Fuzes

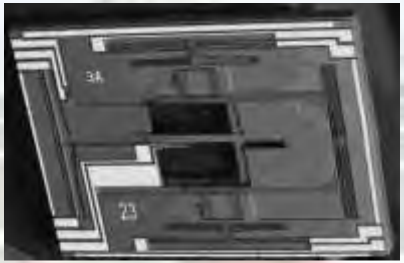
- Evaluation of latest LS-DYNA Impact Simulation Software
- Creating LS-DYNA input templates for hard target penetration application
- Impact deceleration, stress & strain calculated for penetrator Fuzes
- Results compared to NAVAIR cannon and sled test data

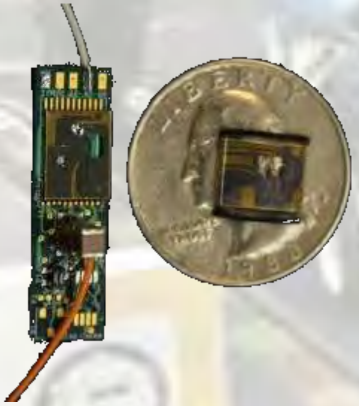


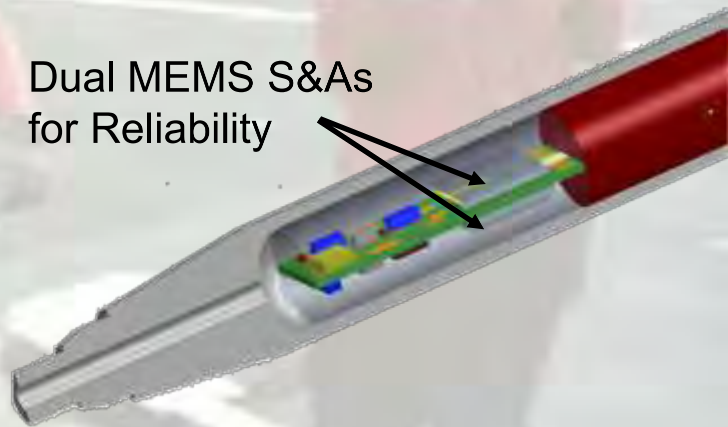
Open Session IVB Briefing provided by Dr. Paul Glance

MEMS Fuzing for High Reliability Systems

- Development of G-hardened miniature Fuze component technology mine defeat penetrator application
    - Silicon on Insulator (SOI) MEMS S&A
    - Micro detonator
    - MEMS initiator
    - Low-cost miniature fire-set





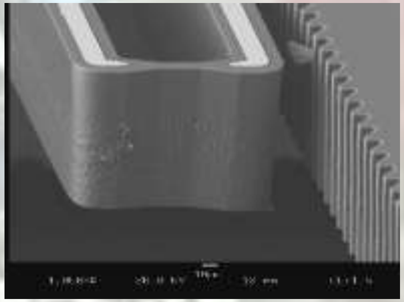


Dual MEMS S&As for Reliability

A Versatile Explosive Train Integrated into a MEMS S&A Device

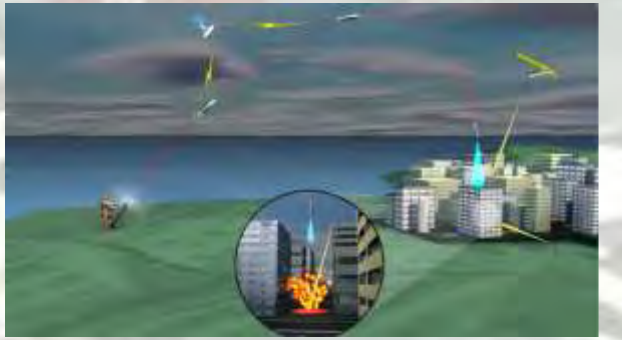
- Development of integrated initiation and explosive train component technology for MEMS based S&A application
- Developed for small volume applications turning tight corners
- Employs CI-20 based explosives RSI-007 & EDF-11 ink

Vaporization of an IHDIV MEMS initiator



Navy MEMS Fuze
For Marine Corp Flight Control Mortar

- S&A for 81 mm Precision Urban Mortar Attack (**PUMA**) – Future Naval Capability (FNC)
  - Joint Navy / Army S&T system development
  - Supports Marine Corps Conventional Weapons (CW) Science & Technology Objectives
  - System demonstration in FY14
- MEMS based S&A



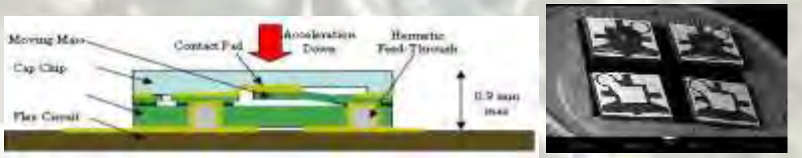
MEMS Retard & Impact Sensors

- ***Objective: Obtain DoD retard and impact sensors with precision, reliability, producibility and cost effectiveness by exploiting existing MEMS microfabrication and packaging technologies***
- ***Traditional coilspring-mass technology:***
  - *Wide performance variability per mechanical spring tolerances*
  - *Difficult to precisely sense low G's with "macro world" springs*

- ***MEMS technology appears well-suited for making improved low-G sensors per DoD exploratory work to date:***
  - *NAWCWD: precision-electroplated G-sensors*
  - *NSWCIH: silicon G-sensors and packaging*
  - *ARDEC: metal G-sensors and packaging*

Illustration and Photograph Courtesy of NAWCWD

- ***FY11 Focus: low-G impact sensors (<100G) & very low-G retard sensors (<5G)***



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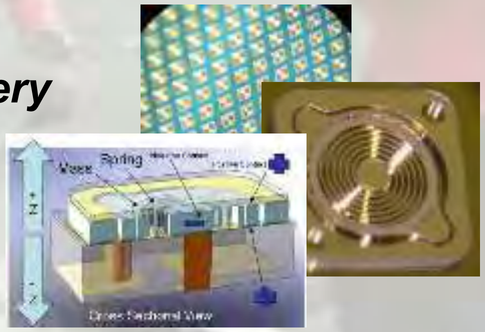
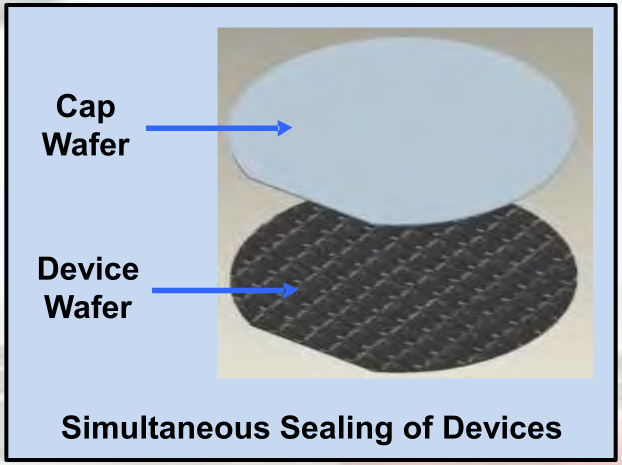


Illustration and Photographs Courtesy of ARDEC

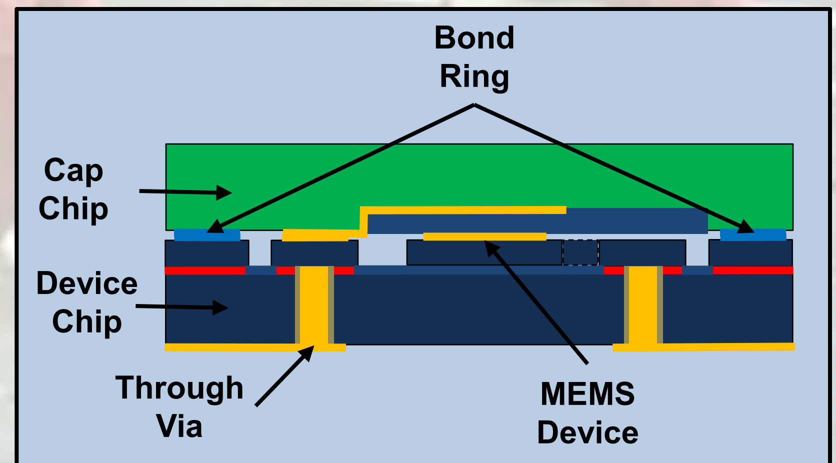
Closed Session VB Briefing provided by Mr. Walt Maurer

Wafer Level Packaging for High Aspect Ratio MEMS

- Develop wafer level packaging techniques that are applicable to high-aspect ratio MEMS devices
  - ➢Wafer bonding
  - ➢Through vias
- Improved reliability and safety of MEMS components in the fuze, including sensors and / or the MEMS S&A chip
- Increased throughput (2 orders of magnitude) and yield of the MEMS manufacturing process
- Lower cost components (submunition applications)



Simultaneous Sealing of Devices



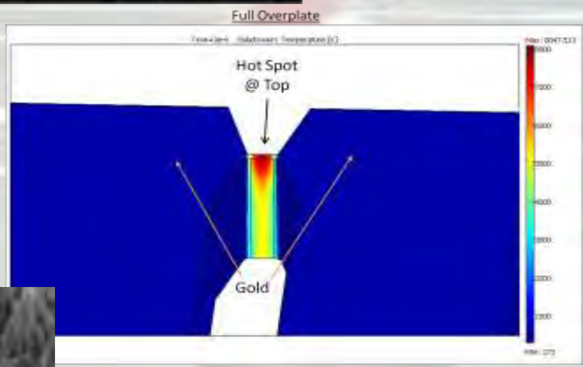
Sealed MEMS Device

Open Session VA Briefing provided by Mr. Kevin Cochran

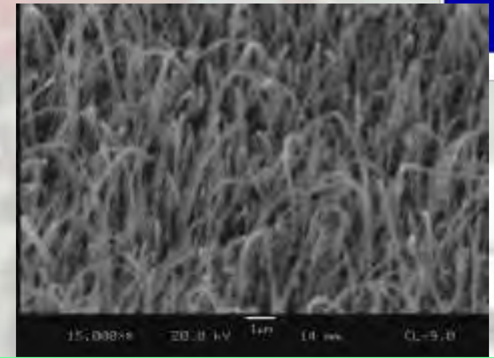
Enhanced Performance of MEMS Electric Initiators

- Increase the output of an initiator that can be easily integrated into a MEMS fuze to maximize micro-detonator output
  - ➢ Replaces low performance energetic
  - ➢ Prompt initiation (< 2μs)
  - ➢ Low power (< 1mJ)
  - ➢ Highly uniform fabrication
- Understand differences between reactive material bridge as compared to simple metal/silicon
- Provides compact, safe and low energy S&A for distributed multipoint initiation systems.

DRIE of Si Bridge



Model Hot Spots

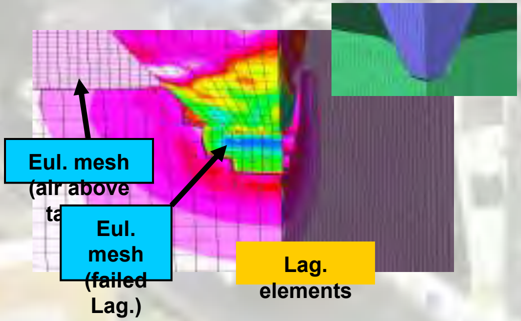


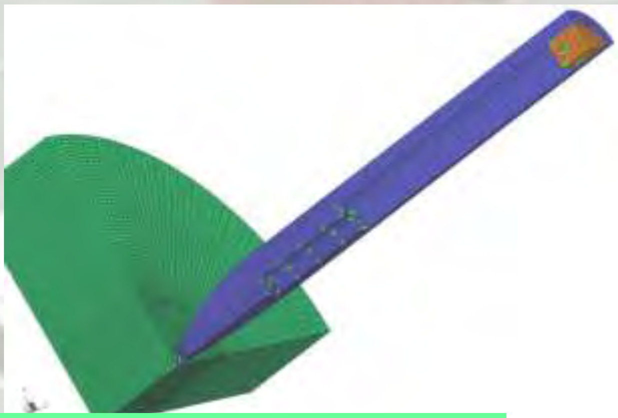
RM Nanowires

Open Session VA Briefing provided by Mr. Daniel Pines

Improving Fuze Environment Prediction During Hard Target Penetration Using A Coupled-Code Erosion Technique

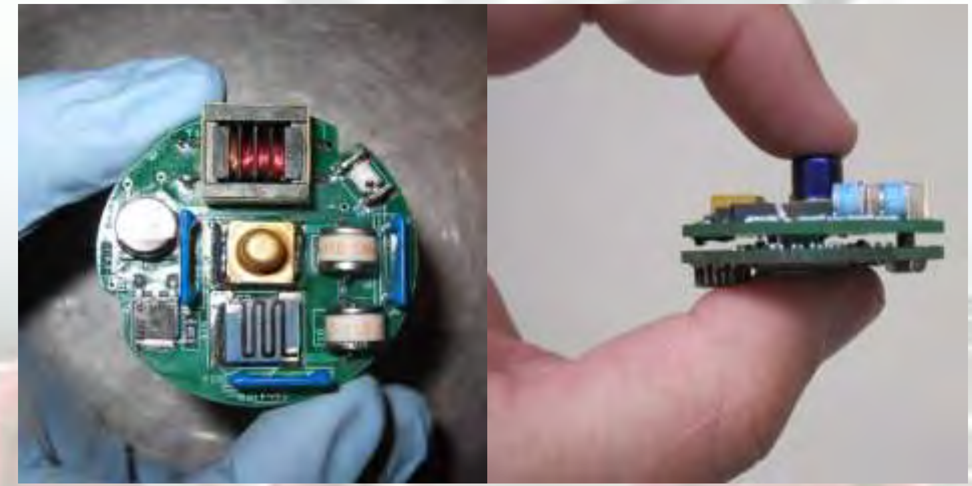
- Development of Element Deletion – Material Donation (EDMD) Erosion technique to improve prediction of forces experienced by fuzing components during hard target penetration
  - Replace artificial void with real target material
  - Reduce "numeric" noisy in fuze region
  - Prevent tensile failure of elements next to failed element
  - Avoid small time steps that stop the calculation
  - Overall improvement of HT Fuzing M & S

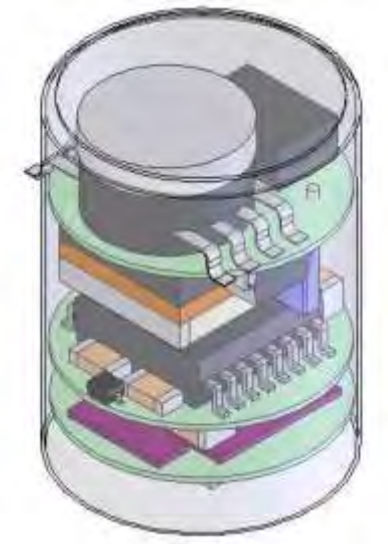




Closed Session IVB Briefing provided by Mr. Sean Tidwell

Low-Cost Miniature Electronic Safe-Arm Device (ESAD)





2.0 in^{3}*
(Demonstrated)

→ 1.1 in^{3} →

0.44 in^{3}
(Near Future)

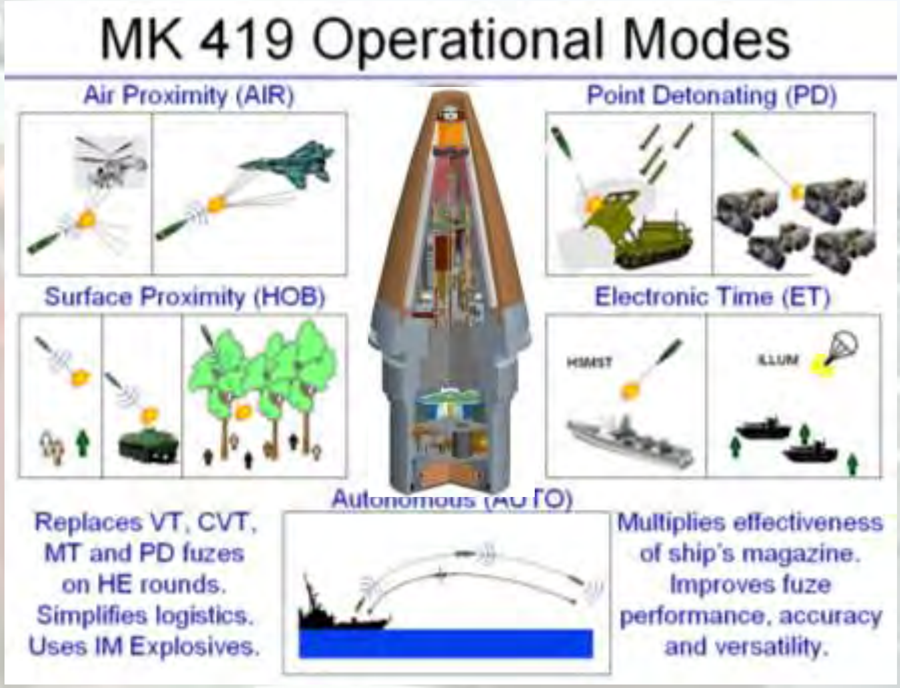
- All COTS components
- Production Low Energy Exploding Foil Initiator (LEEFI)
- Fuze safety board recommended 3-interrupter architecture
- Very low cost high-voltage switch
- Parts cost for this architecture ~ $260 (1000 unit pricing)

*has now had 4 successful flight tests where the ESAD functioned flawlessly

Open Session VA Briefing provided by Mr. Michael Haddon

MK419 Mod 1 Multi-Function Fuze Product Improvement Program

- The MK 419 Mod 1 Multi-Function Fuze fits 76 mm and 5 inch AURs.
- The PIP goal was to reduce cost.
- Major cost drivers:
  - Cheaper electronic components.
  - Smaller footprint of electronic devices.
  - Configuration modification for efficient manufacturing.
  - Sophisticated assembly techniques to reduce cycle time.



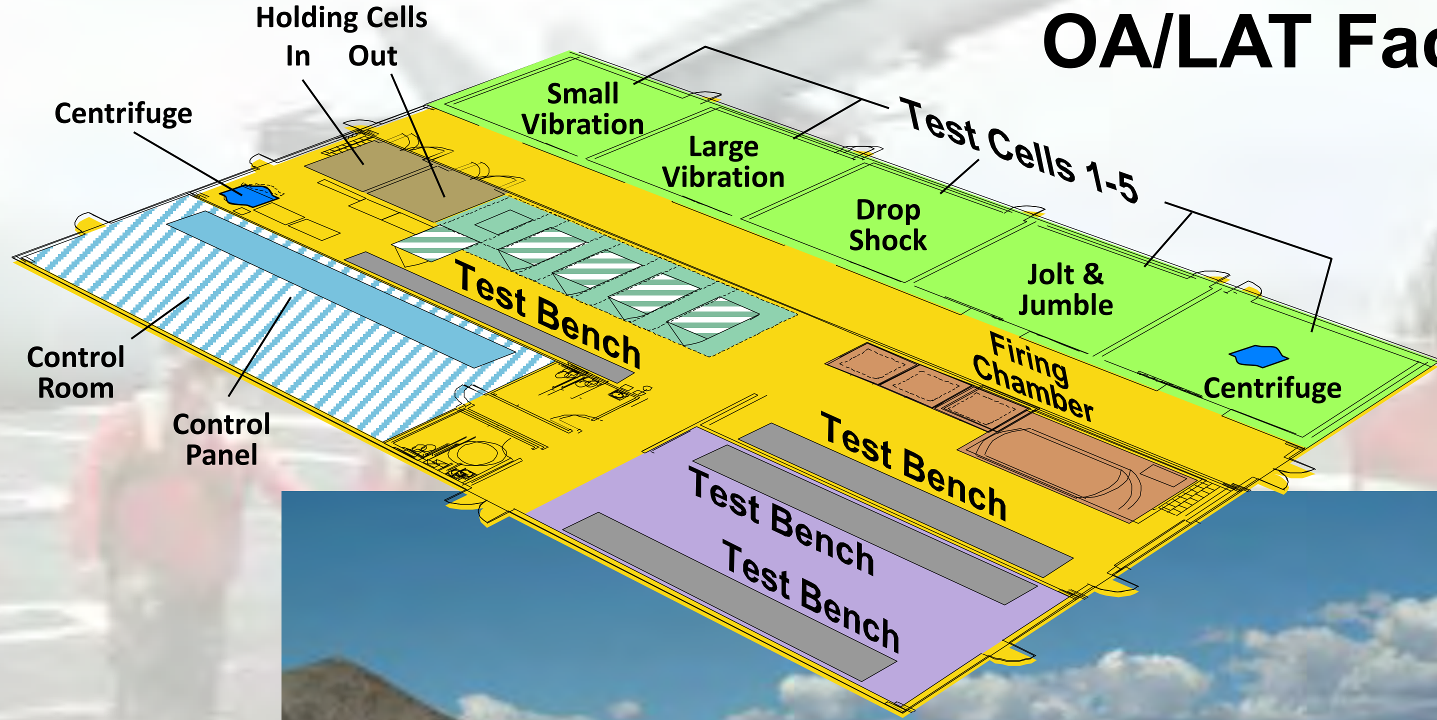
Open Session IVA Briefing provided by Mr. Richard Chapman

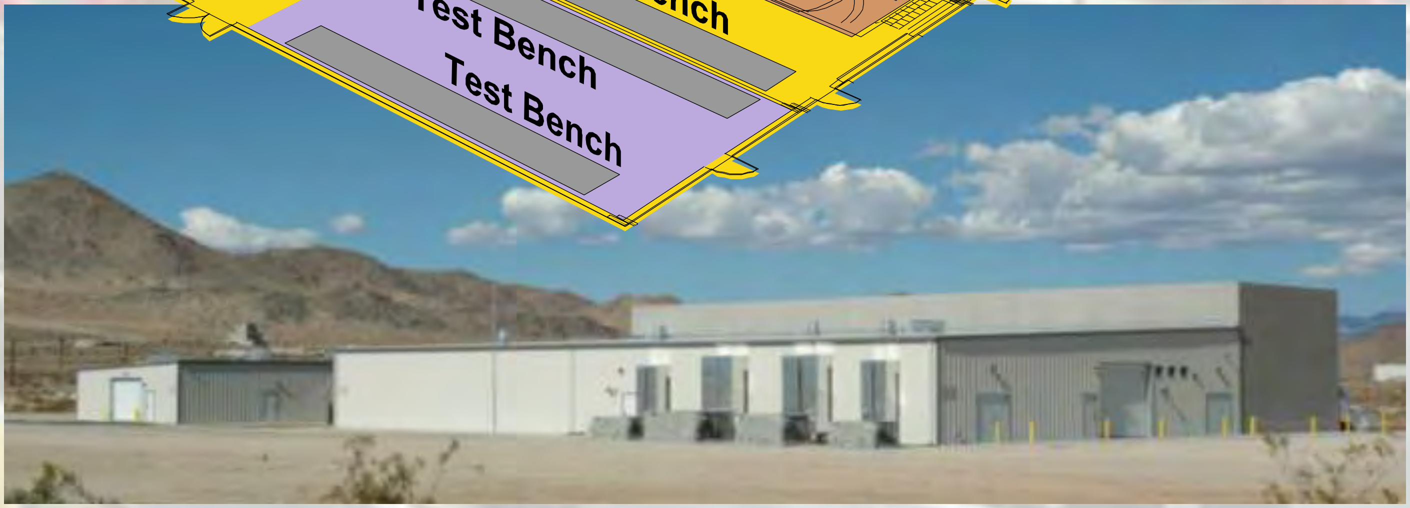
Near-Term Trends for Navy Fuzing

- Potential cost effective approaches for fuzes.
  - Leverage spiral development of existing fuzes.
  - Refurbish existing inventories.
  - Modify existing inventories to meet new requirements.
  - Demonstration beds for new technologies.
- Service life extension programs for existing fuze inventories.
  - Increase Ordnance Assessment (OA) Activities
  - Establish Ordnance Health Assessment program
- New State-of-the- Art Fuze Assessment Test Facilities
  - Modern multi-fuze test sets and data acquisition

New Navy Fuze Capabilities

OA/LAT Facility





Summary

Smaller, More Robust, Higher Reliability and Lower Cost fuze designs are future thrusts for future Navy Fuzing

Joint Fuze Technology Program (JFTP)
55th Annual NDIA Fuze Conference

25 May 2011

Joint Fuze Technology Panel
Charles Kelly (OUSD AT&L PSA LW&M)
Lawrence Fan (Navy)
Timothy Tobik (Air Force)
Philip Gorman (Army)

Lawrence Fan (Presenter)
Indian Head Division, Naval Surface Warfare Center
(301) 744-6157
lawrence.fan@navy.mil

JFTP Overview

- JFTP is a 6.2/6.3 national program established (FY10 start) to develop and mature technologies for improving future fuzing performance, survivability, and reliability
- JFTP governance and processes are modeled after the Joint Munitions Program (JMP) and the Joint Insensitive Munitions Technology Program (JIMTP)
  - Managers from Services and DTRA
- JFTP leverages and coordinates with projects in JMP, JIMTP and Service S&T
- Projects are selected based on evaluation of proposals from Gov't, Industry and Academia

Joint Fuze Technology Program Management Structure

OUSD(AT&L)/ PSA/LW&M

Technical Advisory Committee

JOINT FUZE TECH PANEL OVERSIGHT COMMITTEE

PROGRAM MANAGERS
Charles Kelly, Lawrence Fan, Phil Gorman, Tim Tobik

FUZE AREA TECHNOLOGY GROUPS

FATGI – Hard Target / Survivable Fuzing	FATGII – Tailorable Effects & Initiation	FATGIII – High Reliability Fuzing	FATGIV – Enabling Fuze Technologies
Chair Danny Hayles (DTRA)	Chair Gene Henderson (Army)	Chair John Hendershot (Navy)	Chair Chris Janow (Army)
Co-Chairs John Kandell (Navy) Bill Konick (Army) Howard White (AF)	Co-Chairs Daniel Lanterman (Navy) George Jolly (AF)	Co-Chairs Steve Smith (AF) Tom Crowley (Army)	Co-Chairs Matt Bridge (AF) Bruce Hornberger (Navy)
SME Participants	SME Participants	SME Participants	SME Participants

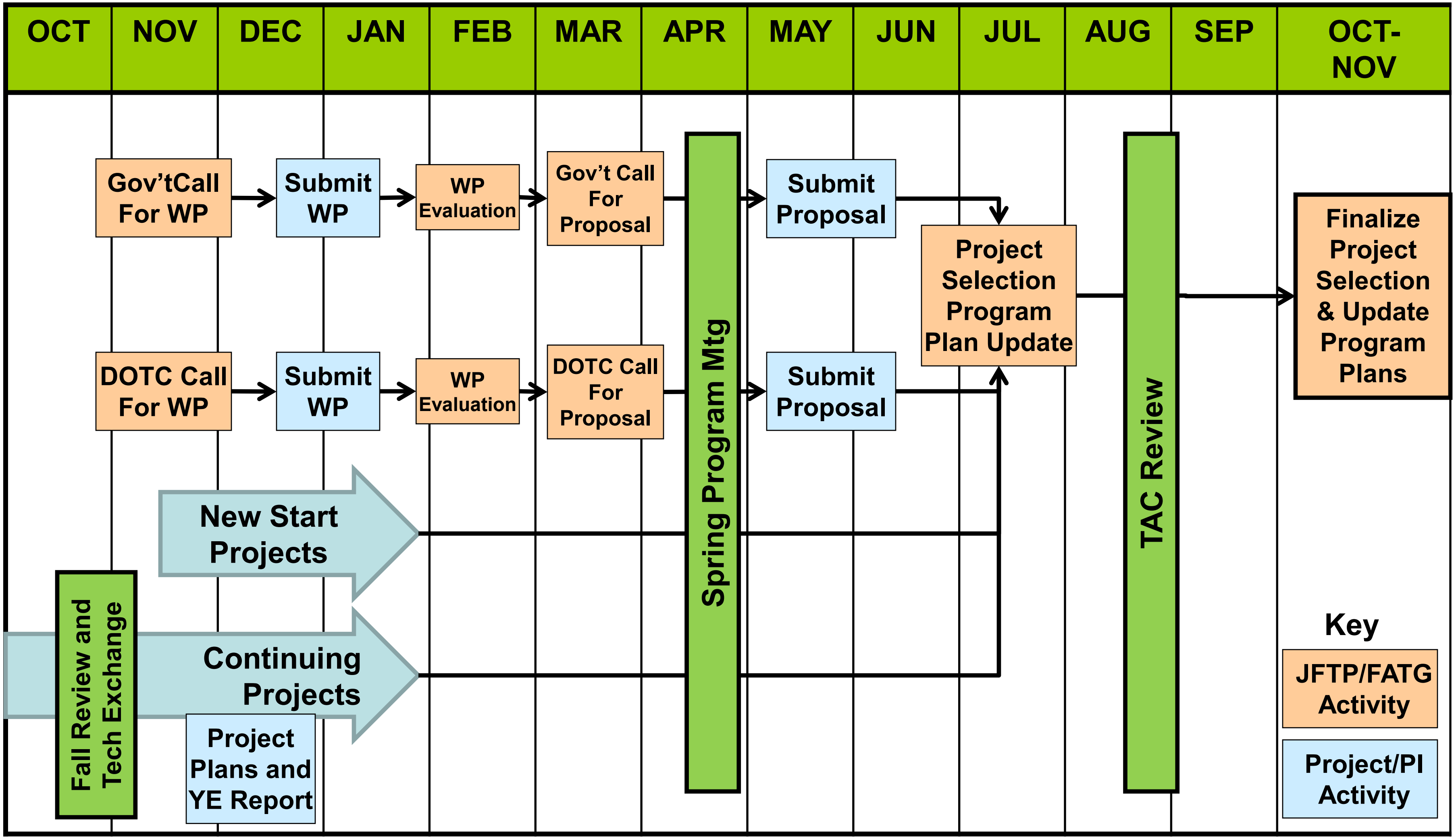
Fuze Area Technology Groups

FATG I – Hard Target / Survivable Fuzing	FATG II – Tailorable Effects	FATG III – High Reliability Fuzing	FATG IV – Enabling Fuze Technologies
1.1 Improved M&S 1.2 Fuze Environment 1.3 Next Generation Fuzing Hardware	2.1 Initiation & Multi-point 2.2 ESAD Based Multi-point Initiators 2.3 MEMS Based Multi-point Initiators 2.4 Smart Fuzing: Algorithms, timing and control 2.5 Adv Fuze Initiation	3.1 Fuzing Architecture 3.2 Fuzing Components 3.3 UXO reduction features	4.1 Common / Modular Fuze Architecture 4.2 Components Technologies 4.3 Proximity Sensors 4.4 Weapons Effects & Damage Assessment 4.5 Fuzing Power Sources

Funding

	FY 10	FY 11	FY 12 PBR	FY 13	FY 14	FY 15	FY16
JFTP 6.2	3.849	7.833 (requested) 5.400 (actual total)	7.167	5.656	6.604	7.312	7.520
JFTP 6.3	0	3.577 (requested) 1.077 (actual total)	4.889	6.098	6.835	8.350	8.606

JFTP Proposal and Review Annual Cycle



FY12 JFTP Summary

- Funding levels from FY12 submitted budget:
  - 6.2 - $7.167M total
  - 6.3 - $4.889M total
- Selection ongoing for FY12 new starts
  - Proposers receive final go/no-go when FY12 budget is released ~ Nov 12
- Industry involvement:
  - Conveyed FATG goals and higher priority goals via DOTC Fuze call for proposals
  - Additional details at DOTC General Membership meeting – July 11
- Program Plans (GOTChA charts) to link weapon requirements and needs to fuzing technologies to JFTP projects and gaps

Next Call for WP/Proposals

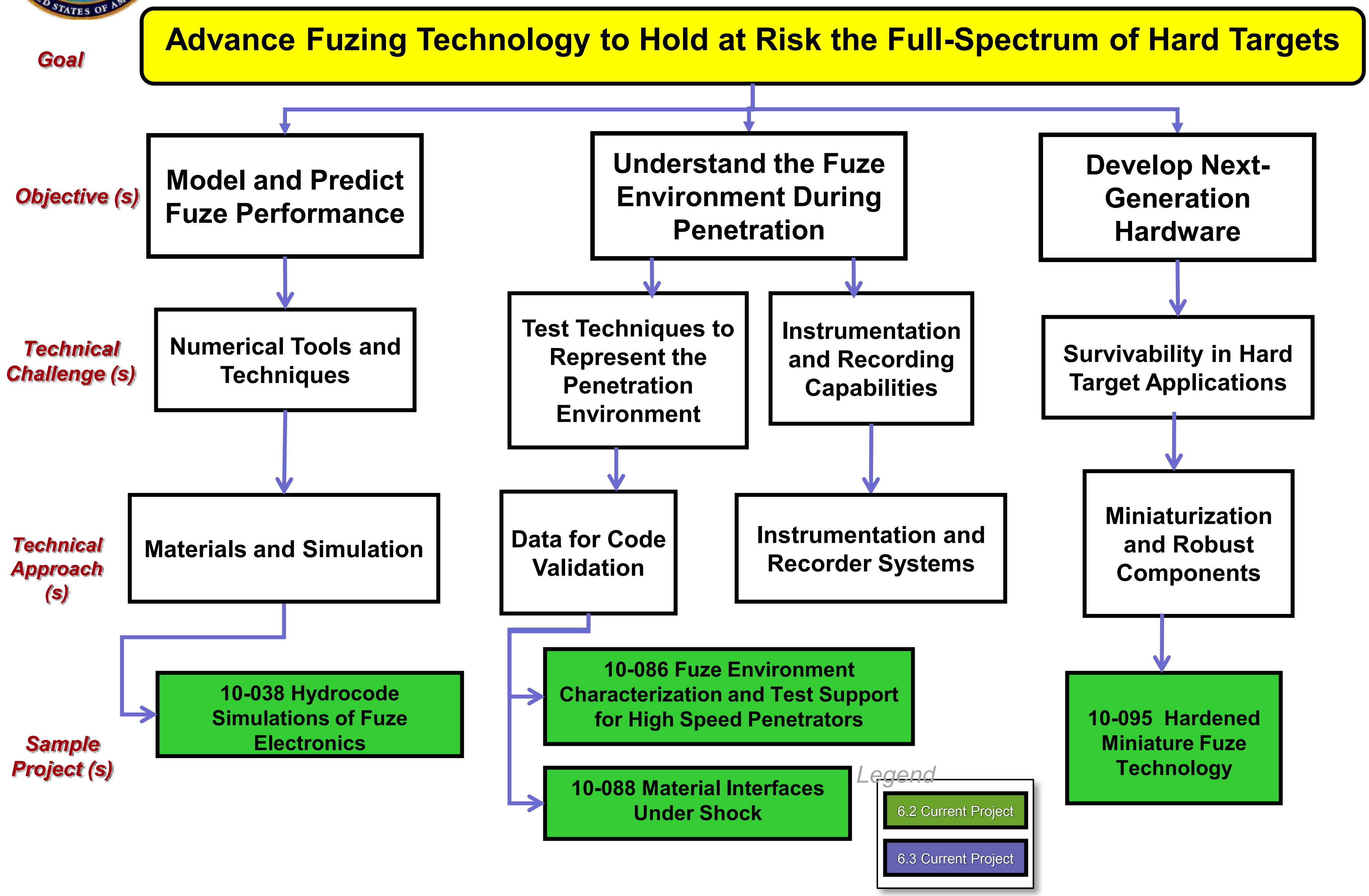
Call for White Papers

- FY13 cycle starts in Dec 11/Jan 12
- Call is distributed to DoD, DOE and TAC members and to NWEC/DOTC
- FATG goals and needs conveyed
  - Focus on specific gaps not currently addressed
- 6.2 and 6.3 projects solicited (3 pages)

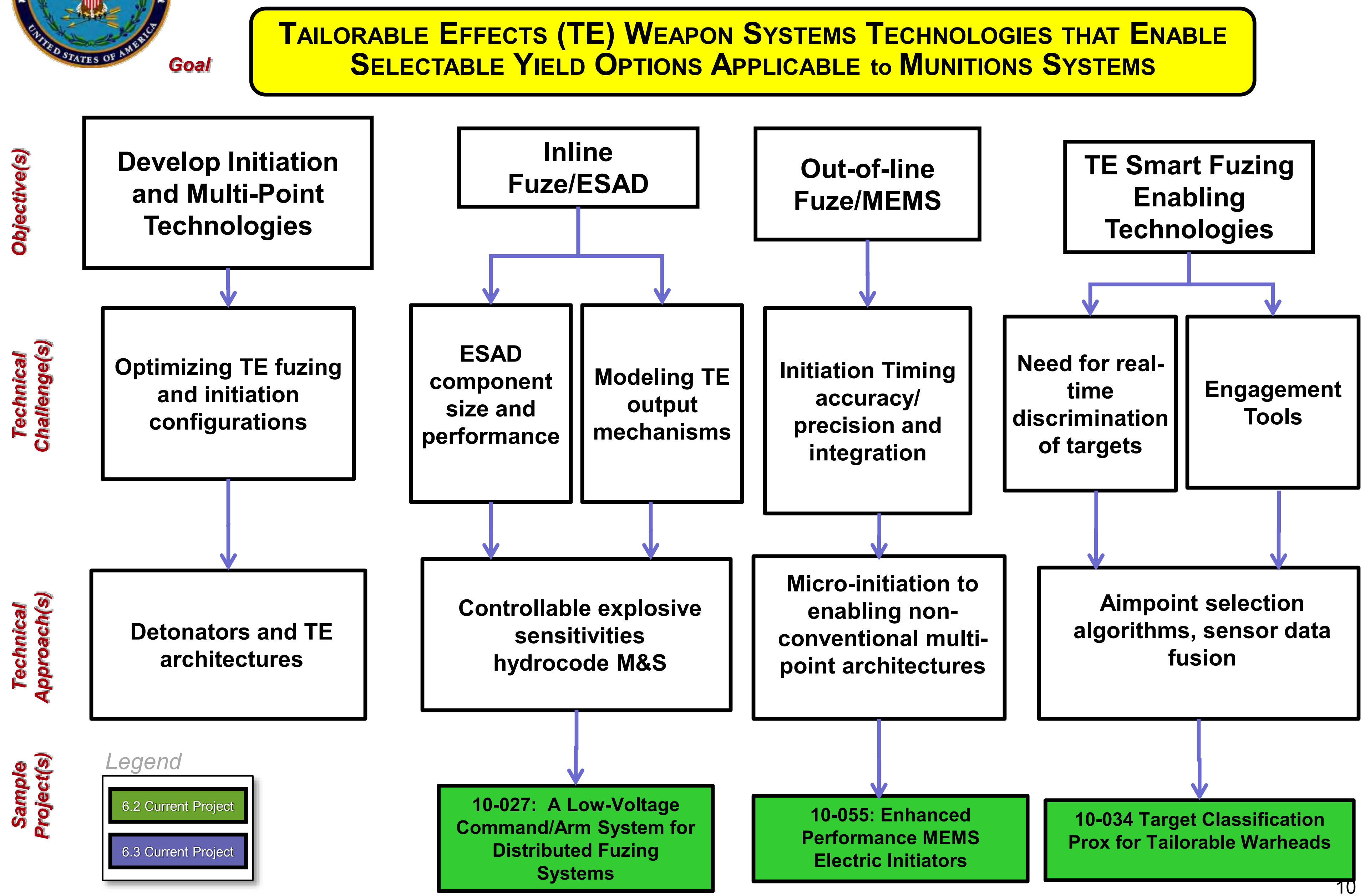
White Paper Content

- What FATG goals are being addressed
- Description of technology
- Statement of technology maturity
- Transitions (for 6.3 identify offices expected to provide endorsements and leveraging/cost sharing)
- Deliverables (what/when) and their relevance
- Yearly ROM costs and schedule

FATG I Hard Target Fuzing GOTChA



FATG II Tailorable Effect Fuzing GOTChA



FATG II Tailorable Effect Fuzing GOTChA

ADVANCE FUZE INITIATION TECHNOLOGIES for BROAD WEAPON APPLICATION *Goal*

Legend
- 6.2 Current Project
- 6.3 Current Project

Objective(s)

Improve Weapon System Fuze Train Performance O_4

Technical Challenge(s)

Overcome existing fireset limitations (volume, weight, cost).

Initiation of IM materials (main warhead, booster fills).

Technical Approach(s)

Develop improved/advanced fireset components.

Develop improved/advanced booster components.

Develop improved/advanced detonators and initiators.

Sample Project(s)

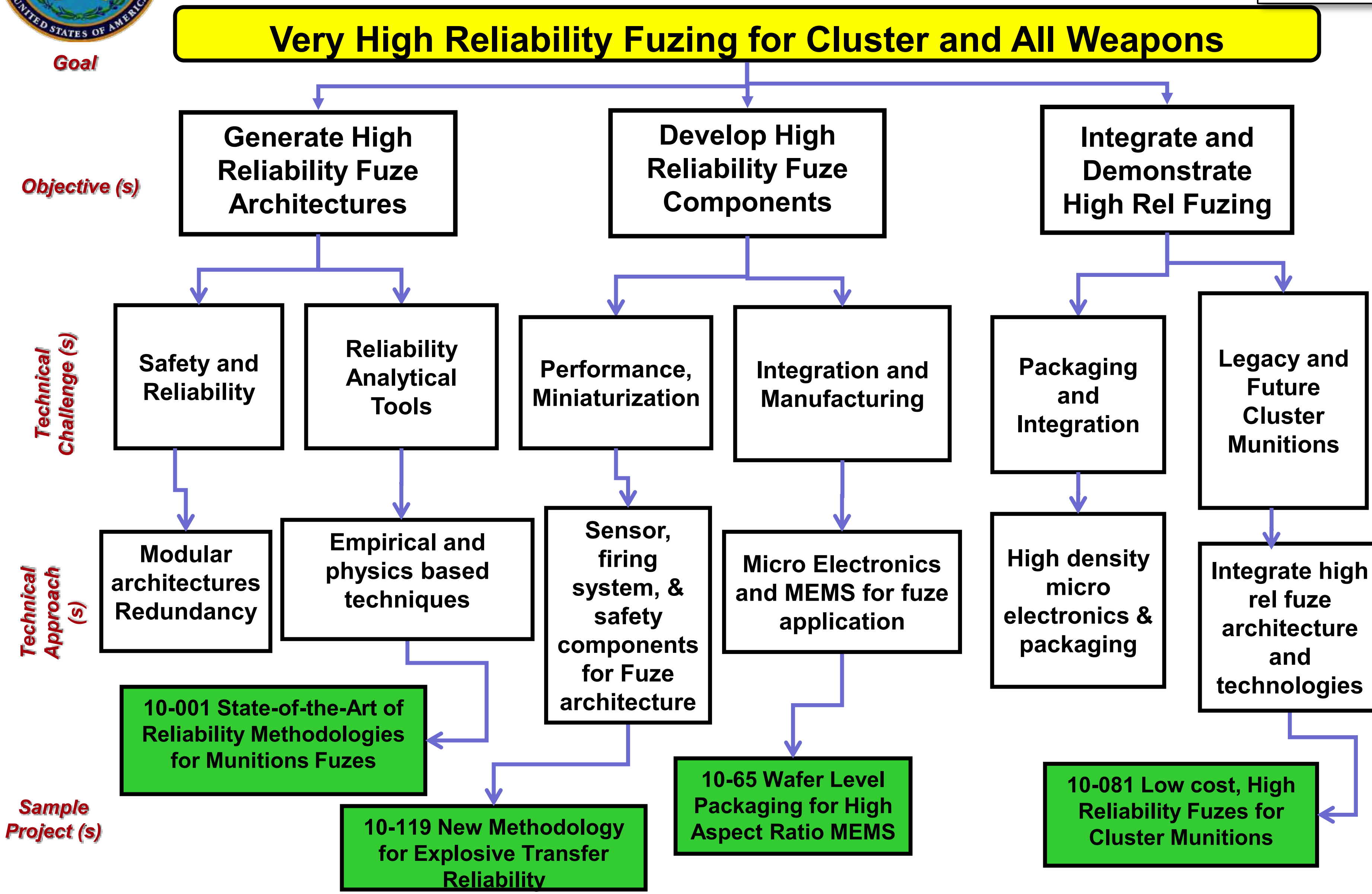
10-102: Integrated Switch Slapper

11-I-022: Maturation of a Smaller, Cheaper High Performance Monolithic Ceramic Flyback Transformer for High Reliability Firesets

11-G-015: PGK Explosive Train Redesign for IMX-101 Compatibility

FATG III High Reliability GOTChA

Legend
- 6.2 Current Project
- 6.3 Current Project



FATG IV Enabling Fuze Tech GOTChA

Goal

FATG IV Fuze Sensors and Power Sources

Objective (s)

- Develop Miniaturized, Robust and Affordable Fuzing Sensors
- Improved Fuzing Power Source Performance for a diverse range of applications
  Increased Output (Power & Energy Density Improvements for higher power needs)

Technical Challenge (s)

- Performance and technology development of proximity sensors, environmental safety sensors and retard / impact sensors
- Rise time improvements and Energy density
  Decrease time to set fuze

Technical Approach (s)

- Investigate RF, IR and optical sensors
  Develop advanced antennae, transceiver, and signal processing algorithms
- Apply advancements in power and materials technologies in compact form factors
  Develop Thermal Battery Materials
  Develop Electrolytes

Sample Project (s)

- 10-042 Next Generation Proximity Sensors
- 10-010: 6.3 MEMS Retard & Impact Sensor
- 10-070: Nanofoil-Heated Thin-Film/ Conformal Thermal Battery Construction
- 10-078: High Energy Density Super Capacitors

Legend
- 6.2 Current Project
- 6.3 Current Project

JFTP Calendar

10 Dec 10	Call for FY12 White papers (Gov't and DOTC)
18 March 11	Gov't and DOTC WP Feedback sent and Call for proposals
26-28 Apr 11	Spring JFTP Meeting (Booz Allen Hamilton – Arlington, VA)
15 Jun 11	FY12 JFTP NWEC and Gov't proposals due
13-14 July 11	DOTC General Membership Meeting
23-26 Aug 11	TAC review of JFTP program
Oct/Nov 11 (est)	FY12 JFTP Budget Determined
Nov 11 (est)	FY12 JFTP Project Selection Decision
Dec 11	Call for FY13 White Papers

55th Annual Fuze Conference
JFTP Project Briefs

- Session IIIB: High Reliability Fuzing Architecture for Cluster Munitions, David Gudjohnsen, US Army, ARDEC
- Session IVB: The Fuze Environment of Boosted Penetrators Dr. Jason Foley, US Air Force, AFRL Munitions Directorate
- Session IVB: Hardened Miniature Fuze Technology Progress Jefferson Oliver, US Air Force, AFRL Munitions Directorate
- Session IVB: Improving Fuze Environment Prediction During Hard Target Penetration Using A Coupled-Code Erosion Technique, Reid McKeown, US Navy, NSWC Indian Head Division
- Session VA: Wafer Level Packaging for High Aspect Ratio MEMS Kevin Cochran, US Navy, NSWC Indian Head Division
- Session VA: A Low Voltage Command-Arm System for Distributed Fuzing Mark Etheridge, US Army, AMRDEC
- Session VB: MEMS Retard and Impact Sensors, Walter Maurer, Naval Air Warfare Center Weapons Division

Questions?

"INITIATING EXCELLENCE"

An Overview Of The U.S. Army Fuze Safety Review Board (AFSRB)

55th NDIA Fuze Conference
Salt Lake City, UT

Presented By:
Chris Janow
Chief
US Army Fuze Management Office (AFMO)
973-724-5438
chris.janow@us.army.mil

- **Chairman of AFSRB was requested to brief conference on how to get a program through the AFSRB successfully.**
- **Answer……..**

- **Design and test the fuze properly!!!!**

AGENDA

- AFSRB Overview
- Generic Guidelines
- ESA Guidelines
- Command – Arm Fuzing
- Origin of the 500 Volt Requirement
- MIL-STD-1316F and STANAG 4187 Edition 4
- New ARSRB Guidelines

Army Fuze Safety Review Board

- **Charged with reviewing fuzing systems and hand emplaced munitions to assure acceptable safety exists and residual risks are properly described in system safety risk documents.**
- **In existence since late 1960s -**
- **Authority:**
  - **AR 385-10, Army Safety Program**
  - **AR 700-142, Type Classification, Materiel Release, Fielding & Transfer**
  - **Chartered by CG, Army Materiel Command (1995)**
  - **AFMO responsibility to operate in charter and AR 70-1, Army Acquisition Policy**

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AFSRB PERSONNEL

ARMY FUZE SAFETY REVIEW BOARD

Name	Organization
Larry Borshard Jeff Fornoff George Vinansky	SOFTWARE SAFETY
David Shigure	ARMY PUBLIC HEALTH CMD
Brian Travers	ENERGETICS
John Banks	ARDEC SAFETY
Frank Papano	ORDNANCE TESTING
Sean Bonney	TRADOC
Brian Mary	ARL
Chris Janow	CHAIRMAN
Homesh Lalbahadur	EXECUTIVE SECRETARY

Organization	Name
E^3	Dan Gutierrez
SYSTEM DESIGN	Tony DiGiacomo
AMCOM SAFETY	Bill Pottratz
ELECTRONIC DESIGN	Stew Genberg
EOD	Wilfred Cruz
HUMAN FACTORS	Keith Gunn
AMRDEC/ AMCOM	Gene Henderson
JMC	Dwaine Shaw
ARDEC	Bob Hubal
AMC	Ken Rose/Bill Edmonds

VOTING MEMBER (light blue boxes) — TECHNICAL ADVISOR (light yellow boxes)

Malcolm Baldrige National Quality Award 2007 Award Recipient

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

What Does The AFSRB Do?

- Performs a safety review of fuze designs by an independent panel of experts
  - Appraises level of safety inherent in the design
  - Ensures acceptable level of safety is present in final design
- Presents findings and recommendations to PM
- Issues Safety Certifications
  - Initial Safety Certification issued at request of test agency or project team (non mandatory)
  - Interim Safety Certification issued prior to Type Classification to allow beginning of initial production (mandatory)
  - Final Safety Certification issued prior to Materiel Release to allow fielding (mandatory)

AFSRB Certifications

- Safety Certifications
  - Only apply for the specific fuze configuration under review and for that specific application
  - Some contractor and DOD personnel guilty of implying to potential customers that a previously certified fuze design will “automatically” receive certification in a different application.
  - NOT NECESSARILY TRUE!!!!
  - There is no guarantee that a previously approved design will be acceptable for a new or different application.

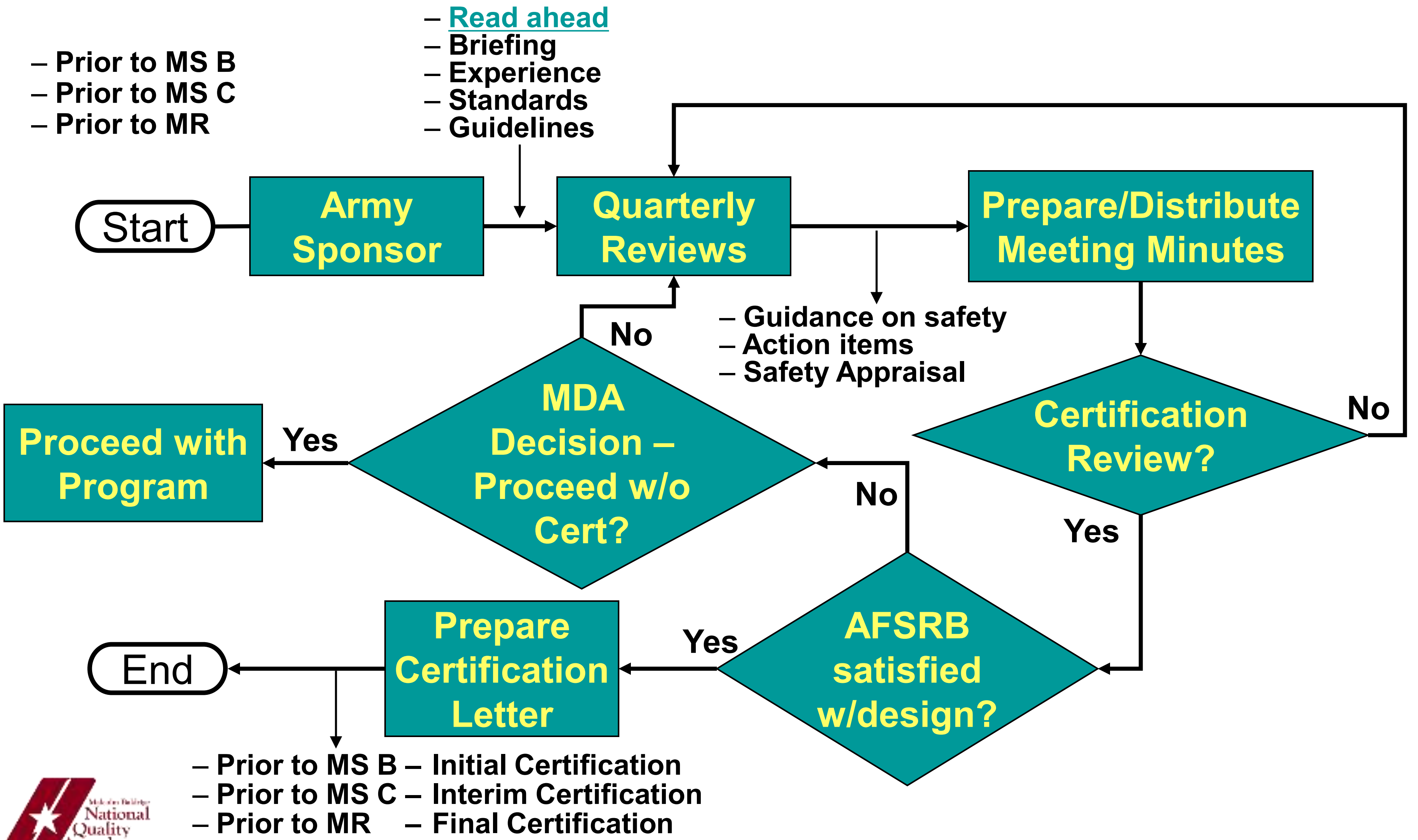
What Items Are Reviewed?

- Any new fuzing system design or fuze procured by the Army
- Any modification (product improvements or materiel changes) of existing fuzing system designs that affect the fuze safety system or a safety critical item
- A new application of an existing fuzing system
- Fuzes adapted for Army use from other U.S. Military Services
- Foreign fuzes for U.S. Army applications
- Fuzes for Non-Lethal Weapons as deemed necessary by the appropriate Safety Office (based on hazard/risk)
- All hand-emplaced ordnance as deemed necessary by the Chairman of the AFSRB

What Is The Basis For The AFSRB Review?

- STANAG 4187, Edition 4, Fuzing Systems - Safety Design Requirements
  – Mil-Std-1316F, Fuze Design, Safety Criteria For
- STANAG 4497, Hand-Emplaced Munitions (HEM), Principles for Safe Design
  – Mil-Std-1911A, Hand-Emplaced Ordnance Design, Safety Criteria For
- STANAG 4157, Edition 2, & AOP-20, Tests for the Safety Qualification of Fuzing Systems
  – Mil-Std-331C, Fuze and Fuze Components, Environmental and Performance Tests For
- Experience

AFSRB Process



Types of Testing

- Tests that simulate anticipated manufacturing, logistic and tactical usage environments
- Tests that exceed anticipated storage, transport and operational Fuze level tests
- System and component level tests
- Test types depend upon the fuze/ammunition/weapon
  - Some system level tests can substitute for some fuze level tests
- HAPPY 60th BIRTHDAY TO MIL-STD-331!!! First issued in 1951

Typical Tests & Quantities

AOP-20/MIL-STD-331 Fuze Level Tests

Environmental

- Jolt
- Jumble
- 1.5m Drop
- Salt Fog
- Temp/Humidity
- Extreme Temp Storage
- Thermal Shock
- Trans Vib & Secured Cargo
- E^3

Design

- Out of Line Safety
- Minimum Arming
- Explosive Component Safety

- Sequential testing is required by STANAG 4157, to demonstrate robustness against expected and typical life-cycle environments
- New FESWG Fuze Qualification Guideline specifies tests and quantities

GENERIC GUIDELINES

Generic Guidelines

- **Limit use of safety critical software**
  - **Raw data from guidance sensors (i. e., accelerometers) should be passed along to fuze logic devices for processing. This can be sent thru guidance computer, as long as data is not modified by this computer.**
  - **If processed in guidance computer, this becomes safety critical (it is expensive and cumbersome to safety certify guidance logic devices)**
  - **Having raw data processed by fuze logic is not considered cost driver or design complication**
  - **If using more than one logic device, should strive to implement in such a manner that only one is safety critical**
- **Preference is always to have separate environmental and guidance sensors**
- **BIT Checks:**
  - **AFSRB prefers that these be limited to continuity checks only – does not support exercising of safety features or powering up of logic beyond what is needed to verify continuity**

Generic Guidelines

- **Safety Features**
  - **Must be independent:**
    - **Independent means that the failure or subversion of one safety feature does not affect performance of the other safety feature(s)**
    - **Also means they must sense different environments (i.e., velocity and acceleration are not different)**
      - **Two physically independent setback locks would not be allowed (exception: multi-stage rockets or missiles where separate G-T profiles are gated with an interstagial time window)**
  - **Must be, where possible, environments instead of events that occur in munition or signals derived from events.**
    - **Events include reaching apogee, generation of "good guidance" signals, umbilical disconnect, deployment of control surfaces, firing of side thrusters, etc.**
    - **If events are used where a second environment is difficult at best to sense, they should be gated with some logic associated with the event (i. e., time window)**

Generic Guidelines

- Safe Separation
  - For the AFSRB:
  - Safe Separation is defined as the distance from the munition to the launch crew where there is a 1×10^{-4} probability of the crew taking a hit from a fragment that has a 50% chance of breaking exposed skin
  - Is based on munition fragmentation pattern and has nothing to do with fuze functioning
  - Is different than Safe Escape for an aircraft, the fuze arming distance, and the minimum engagement distance

ESA DESIGN GUIDELINES

ESA Design Guidelines

- With STANAG 4187 Ed 4, three switches (energy breaks) are now mandatory: two static and one dynamic
- No single environment or event signal can be used to enable more than one static switch
- Multiple signals can be used to enable more than one static switch
- The circuit which controls operation of the arming switches shall be physically partitioned into at least two elements, none of which are capable (by virtue of circuit architecture and partitioning, not element design) of independently arming the system.
- The functional partitioning shall be immune to being bypassed by electrical, mechanical, and thermal environmental hazards.

- A second safety feature (static switch) shall not be configured as the mechanical equivalent of a lock on a lock.

Dynamic Switch

- The circuit driving the dynamic switch shall be designed so that any failure modes of that circuit should not lead to a situation where the switch defaults to a gated fixed frequency free running oscillator
  - System clocks operating at frequencies that may drive the dynamic switch are not allowed to be part of the S&A design
- The dynamic arming switch, when configured as an integral part of the high voltage converter, should be so configured that any static failures disable the converter.

COMMAND-ARM FUZING

COMMAND ARM FUZING

- New capability driving fuze designs for use in urban combat environments, and to defeat enemy positioned behind obstacles
- Has become a more common fuze architecture
- Primarily medium caliber – is really implemented as command arming + functioning of a fuze
- Need precise bursting point due to relatively small warhead footprint, or to defeat target
- Probably will be firing over the heads of friendly forces

COMMAND ARM FUZING – CON'T

- Requires capability of air bursting anywhere along the projectile's trajectory beyond minimum engagement
- Minimum engagement distance can be within safe separation distance
- Target distance/setting info input to fuze via fire control system
- Preference is to protect friendly troops along trajectory and/or near target to the greatest degree possible
- Some traditional fuze solutions either not accurate enough or did not provide overhead safety

COMMAND ARM FUZING – CON'T

- Preferred solution is to incorporate an approach where fuze is arm-enabled by sensing launch environments and then command armed/functioned at burst point. For final arming, preferred approach is to release interrupter with stored energy device and use available flight environments to move interrupter into armed position.
- The AFSRB accepted the use of a piston actuator to move the interrupter into the armed condition, after the interrupter had been unlocked. The piston actuator defeats a shear tab that acts as a safety feature in the form of a blocking device.

COMMAND ARM FUZING – CON'T

- In the absence of a spin lock, the use of a piston actuator overcoming a shear tab violates a tenant and an objective of the safety standards:
  - Dual safety – shear tab is a block, not a lock
  - Use of stored energy in arming of the interrupter
- The acceptance by the Board was based on:
  - Rigorous testing of the shear tab, to include jolt and jumble with the setback lock missing
  - Historical evidence that piston actuators of this type do not fail by pre-firing without the correct signals and power

COMMAND ARM FUZING – CON'T

- The setback lock would prevent shearing of the tab and keep the interrupter safe if the P/A pre-fired with setback lock in place
- That under any credible environmental mishap or other accident at least two safety feature failures would be required in order for the interrupter to be released
- That testing to AOP-20/MIL-STD-331 environments indicated no safety issues

COMMAND ARM FUZING – CON'T

Challenge to the fuze community:

Is there a better way to do this?

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ORIGIN OF THE 500 VOLT REQUIREMENT

ORIGIN OF THE 500 VOLTS REQUIREMENT

MIL-STD-332 (MUCOM) 14 May 1969:

- **Paragraph 5.1.3.2 –**
  - **When the explosive train does not contain primary explosives, (e.g. EBW), interruption, shielding, and other protection, the initiation system must be designed to provide at least the same degree of fuze safety obtained with an interrupted train employing primary explosives.**

MIL-STD-1316 (Navy) 16 June 1967:

- **Paragraph 5.1.3 –**
  - **Electric initiators "in-line" – Electric initiators "in-line" (i.e., not followed by explosive train interruption) shall not be used in fuzes even though explosives employed are those listed in 5.1.2.**

ORIGIN OF THE 500 VOLTS REQUIREMENT

MIL-STD-1316A (17 September 1970)

- **4.2 Initiators "in-line". - Initiators "in-line" (i.e., not followed by explosive train interruption) shall not be used in fuzes, except as allowed by paragraph 4.2.2 below, even though explosives employed are those listed in 4.1.2. Where electrical type initiators or detonators are employed, a positive means (e.g., shorting or switching) of preventing fuze detonation prior to fuze arming shall be provided.**
- **4.2.1 When the explosive train does not contain primary explosives (e.g. Exploding Bridgewire (EBW) per MIL-I-23659), and has no provision for interruption, shielding, and other protection, then the initiation system shall be designed to provide at least the same degree of fuze safety, including a mechanical interruption in the electrical circuit, as is obtained with an interrupted train employing primary explosives.**

ORIGIN OF THE 500 VOLTS REQUIREMENT

MIL-STD-1316A (17 September 1970)

- **4.2.2 EBW Devices. – Exploding bridgewire (EBW) devices may be used may be used without subsequent explosive train interruption if the following conditions are met:**
  - **a. The explosive initiated by the exploding wire is an explosive listed in 4.1.2.**
  - **b. The arming and triggering signals for initiating the EBW device are switched by two independent features requiring independent sources of energy from an environmental force for operation.**
  - **c. One of the mechanisms in (b) above shall derive its energy from an environmental force after launch.**
  - **d. The sensitivity of the EBW device to electrical initiation is not greater than Group B per MIL-I-23659. The device cannot be initiated by any electrical signal at a peak potential of 500 volts, nor can a 500 volt discharge, especially from the firing circuit capacitor, initiate the device.**

ORIGIN OF THE 500 VOLTS REQUIREMENT

MIL-STD-1316B (15 February 1977)

- ***Eliminated Non-Interrupted Explosive Train discussion from the requirement sections***
- **Paragraph 7.2 In-Line Explosive Systems (in the NOTES section):**
  - **The use of an in-line explosive system which does not meet the requirements of explosive train interruption, may be necessary or very desirable for future systems to simplify an otherwise overly complex system or to solve a unique set of safing, arming and firing requirements. For in-line systems, the basic safety requirements and the methodology for demonstrating that an acceptable level of safety is achieved, HAVE NOT BEEN ESTABLISHED.**
  - **If in a future weapon, an in-line explosive is the preferred approach, the development of the system will include the establishment of safety requirements and procedures for demonstrating that the required safety is achieved. The following is a list of some of the major conditions which should be met if an in-line system is developed.**

ORIGIN OF THE 500 VOLTS REQUIREMENT

MIL-STD-1316C (3 January 1984)

- **Paragraph 4.3.4 Non-interrupted explosive train control. When the explosive train contains only those explosive materials allowed by 4.3.1, no explosive train interruption is required. One of the following methods of controlling function energy shall be employed to preclude arming before safe separation. Additionally, the fuze design shall include positive means to prevent the fuze from being assembled without its energy control feature(s). The combined probability of having minimum function energy in the fuze, having a failure of the energy control feature(s) and firing the initiator with minimum function energy must be compatible with the specified fuze safety system failure rate (see 4.6).**
  - **a. For fuzes containing minimum non-electrical function energy prior to safe separation, at least one energy interrupter directly and mechanically locked in the safe position by at least two independent safety features shall prevent the flow of energy to the initiator.**
  - **b. For fuzes containing minimum electrical function energy prior to safe separation, at least two energy interrupters directly and mechanically locked in the safe position, each by an independent safety feature, shall prevent the flow of energy to the initiator.**
  - **c. For systems using techniques for accumulating functioning energy from the post-launch environment, the fuze shall not permit any functioning energy to reach the initiator until verification, by the fuze, of a proper launch, and attainment of a safe separation distance. Additionally, any energy of the type required to function the initiator which exists in the fuze prior to safe separation shall be less than the minimum function energy.**

ORIGIN OF THE 500 VOLTS REQUIREMENT

MIL-STD-1316C (3 January 1984)

- **4.3.5 Electrical sensitivity. The initiator for an electrically fired non-interrupted explosive train shall meet the characteristics listed for Class B initiators of MIL-I-23659. *The initiator shall not be capable of being functioned by any electrical signal at a potential of less than 500 volts.* Electromagnetic emission sensitivity and susceptibility of the fuze shall not create a hazard. The requirements of MIL-STD-461 (and DOD-STD-1463 for the Army) shall apply.**

- **More severe requirement than MIL-STD-1316A**
- **Based on experience with EBWs?**

ORIGIN OF THE 500 VOLTS REQUIREMENT

MIL-STD-1316D (9 April 1991)

- **5.3.4.1 Electrical initiator sensitivity. The initiator for an electrically fired non-interrupted explosive train shall:**
  - **a. Meet the characteristics listed for Class B initiators of MIL-I-23659.**
  - ***b. Not exhibit unsafe degradation when tested in accordance with MIL-STD-1512.***
  - ***c. Not be capable of being detonated by any electrical potential of less than 500 volts.***
  - ***d. Not be capable of being initiated by any electrical potential of less than 500 volts, when applied to any accessible part of the fuzing system after installation into the munition or any munition subsystem.***

- **More severe requirement than MIL-STD-1316C**

ORIGIN OF THE 500 VOLTS REQUIREMENT

- Believe intent was to prevent use of EBW initiators in-line with secondary explosives.
- Due to low voltage sensitivity of these types of initiators.
- But, why 500?
- Believe nothing to do with 400 VDC available shipboard, as has been suggested.
- Lowest voltage everyone present could agree to.
- Should the 500 V requirement be left unchanged?

ORIGIN OF THE 500 VOLTS REQUIREMENT

- Should the 500 V requirement be changed?
  - To what?
  - No compelling argument to change it
  - Precedent to change it again
  - Need a threshold
  - If changed, no longer a threshold, but a variable

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MIL-STD-1316F & STANAG 4187 Ed 4

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MIL-STD-1316F

- In Tri-Service Approval process
- Will now be a supplement to STANAG 4187 Edition 4
- Will now have a dual-standard system for safety design guidelines
- Intend to brief at next year's conference
- Both documents will be available on ASSIST
- Similar situation for:
    - STANAG 4497 Edition 2 and MIL-STD-1911B
    - STANAG 4368 Edition 3 and MIL-STD-1901B

AFSRB Guidelines

- New version of Guidance for AFSRB Safety Certifications, dated April 2011
- For copies, contact:
  - Chris Janow at:

    chris.janow@us.army.mil

    973-724-5438

Summary

- AFSRB staffed for and focused on providing the "safest" fuzes for our Warfighters
- AFSRB is a "Gatekeeper" group that provides safety reviews of products going to the field
- Ultimately, safety is the responsibility of the MDA, the PM and the Project Team
- The AFSRB will work with the Project Team to assure safety is achieved
- The AFSRB will be integral part of joint weapon systems safety reviews

Summary

- Command – Arm fuzing is becoming a common type of fuze architecture
- Can't figure out a way to meet requirements without the use of a stored energy device
- AFSRB has accepted concept of using a piston actuator to overcome a blocking type of safety feature in these designs in order to provide overhead safety
- Origin of the 500 volt requirement as a threshold – used to prevent use of EBWs
- Do not think it should be modified
- Contact Info:
  - Chris Janow 973-724-5438
    chris.janow@us.army.mil

DTRA Counter WMD Technologies

Fuzing & Instrumentation Technology Overview

Presented at
55th Annual NDIA Fuze Conference
May 2011

Danny R. Hayles

Outline

- Mission
- Requirement for Hard Target Fuzing
- Current Fuzing and Instrumentation Technology Thrusts
- Summary

DTRA Mission

- Mission:
  - …reduce the threat to the United States and its allies from Weapons of Mass Destruction (CBRNE) by providing capabilities to reduce, eliminate, and counter the threat, and mitigate its effects.
- Functions:
  - Conduct RDT&E programs…in areas related to WMD and designated advanced weapons to include…WMD-related targets and the entire class of hard and deeply buried facilities.
- Vision:
  - Develop, test, and demonstrate to the Warfighters reliable and effective solutions to defeat WMD and WMD-related functions protected in Hard and Deeply Buried Targets

Hard & Deeply Buried Target (HDBT) Defeat Critical to Counter WMD Mission

- **Use of HDBTs is widespread among both hostile states and terrorists to protect WMD and WMD-related functions including:**
  - **Production, storage, research**
  - **Delivery systems**
  - **Command and control**
  - **National/terrorist leadership**

MOST VALUABLE ASSETS

You can't defeat WMDs, if you can't defeat HDBTs!!

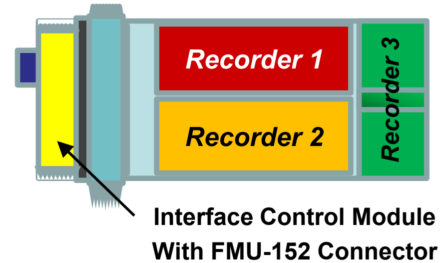
You can't defeat HDBTs, if the fuze does not survive!!

Fuzing and Instrumentation Technology Vision

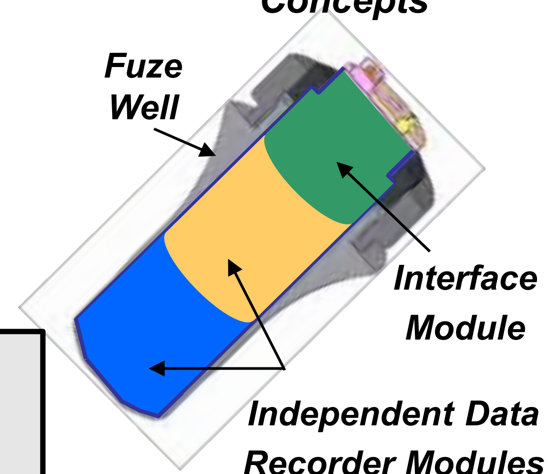
- Develop and demonstrate innovative **survivable** fuze and instrumentation technologies to support the defeat of **hard** WMD related facilities
  - Robust Fuzewell Instrumentation System (RFIS)
  - Sub-scale Survivability Test Protocol
  - FMU-152 Baseline Survivability Assessment (BSA)
  - 3-Axis DTRA Data Recorder Advanced Miniaturization (3DDR-AM) Universal Booster Cup Recorder

Robust Fuzewell Instrumentation System (RFIS)

- Collaborating with AFRL/RW to develop a shock survivable data recorder instrumentation package with redundant internal data recorders to fit in standard 3” fuzewell
    - 27 month contract awarded to ATK for prototype development and delivery concludes January 2013
    - Support CONOPS for laboratory, sub-scale cannon, and full scale sled and flight testing
    - Provide electrical/mechanical ICD for internal recorders
    - Successful System Requirements Review (SRR) and System Functional Review (SFR) , Preliminary Design Review in June 2011



Notional RFIS Concepts



RFIS Prototype Features

- Internal infrastructure supports up to 3 recorders
- To be delivered with modified commercially available recorders
- JPF compliant interface for external control of recorders
- Will provide battery power for internal recorders
- Modular design supports recorder installation and removal by trained technician

Sub-scale Survivability Test Protocol

- Joint research program with AFRL/RWMF to develop a Fuze Survivability Protocol (FSP)
  - Test series developed to replicate portions of full-scale impact environments using laboratory and field test equipment
  - FSP Version 1.0
    - Test protocol defined and tested in FY10
    - VHG and Drop Tower testing conducted
  - FSP Version 2.0
    - Refinement of initial FSP
    - Protocol tests based on impact data from multiple systems and targets
    - Initial testing began in early FY11

Notional Shock Spectrum

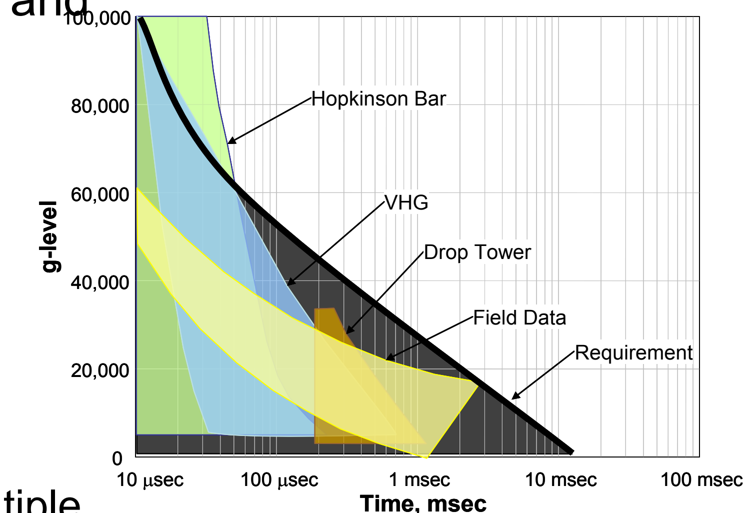


Photo Courtesy of AFRL/RWMF
Public Releasable: AAC/PA 03-496

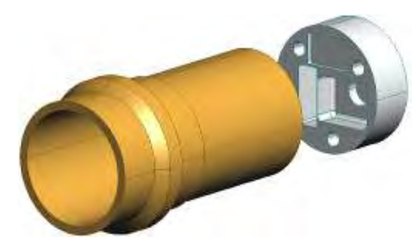
FMU-152A/B Baseline Survivability Assessment (BSA)

- Joint research program with AFRL/RWMF & Kaman Precision Products
  - FMU-152A/B fuze used to establish a survivability baseline for the Fuze Survivability Protocol (FSP)
- Phase 1 Survivability Testing
  - FMU-152A/B LAT units completed testing in 3rd & 4th qtr FY10
  - Tested using FSP version 1.0
- Phase 2 Survivability Testing
  - Testing to begin in 3rd qtr FY11
  - LAT units tested using FSP version 2.0
  - Baseline testing anticipated to be completed by 1st qtr FY12

Photo Courtesy of AFRL/RWMF
Public Releasable: AAC/PA 03-496

3DDR-AM Universal Booster Cup Recorder

- Collaborating with Sandia National Lab (SNL) to develop the 3-axis DTRA Data Recorder Advanced Miniaturization (3DDR-AM) shock survivable data recorder designed for the booster cups of legacy and developmental munitions
  - Design requirements based on a super set of hard target defeat inventory and EMD fuzes
  - Design based on 3DDR brassboard
  - Exploit miniaturized electronics, improved packaging techniques, and reduced power requirements of miniaturized electronics
  - Replaceable batteries (fast test turnaround)
  - Replaceable accelerometers (primary failure mode)
  - Functional and physical models have been developed, and physical model has been validated against system technical requirements



Fuzing and Instrumentation Technology Vision

- Develop and demonstrate innovative **survivable** fuze and instrumentation technologies to support the defeat of **hard** WMD related facilities

- Develop and demonstrate innovative fuze technologies to support the defeat of WMD related facilities using **non-penetrating** munitions.

Fuzing for Non-penetrating Munitions

- Wide spectrum of possible WMD targets requires a wide variety of fuzing technologies and capabilities beyond classic penetrating fuze mounted in the fuzewell:
  - Distributed sensing
  - Non-traditional sensors
  - Modular and distributed fuzing
  - Scalable effects based fuzing

Summary

- Hard target **survivable** fuzing is critical to Counter-WMD mission
  - Hardened or deeply buried facilities have become:
    - More important to potential adversarial nations and non-national organizations
    - Harder to defeat
  - Smart post-impact fuzing essential to defeating HDBTs
    - Provides optimum burst point control
  - Fuze harsh environment characterization is essential
    - Predictive test and modeling capabilities for fuze/fuze component survivability
    - Requires reliable, survivable, multi-purpose instrumentation
- Need for non-traditional fuze technologies and capabilities to defeat wide variety of WMD targets
  - DTRA pursuing a more balanced fuzing portfolio

WMD defeat requires more than just hard target fuzing

FIPS 140-2 Tamper Detection to protect Fuze Technology

Douglas Cox,Trong Huynh,

John Ambrose

Presented at the 55th Annual Fuze Conference in Salt Lake City, Utah on May 25, 2011

by Douglas Cox

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msi Mixed Signal Integration

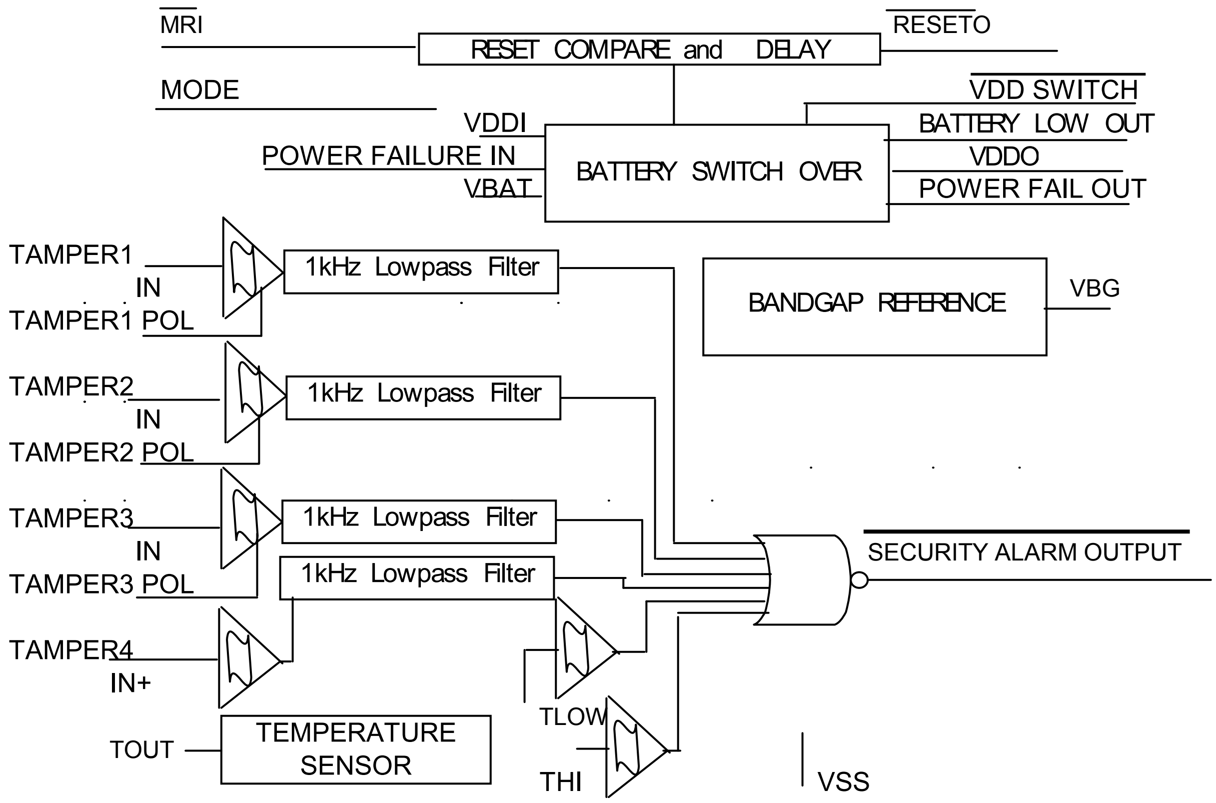
What is F.I.P.S.

- Federal Information Processing Standard
  - 5 Levels of Protection
  - Level 1 is Cryptography
  - Level 2 is Physical protection
  - Level 3 is Voltage and Reset protection
  - Level 4 is Temperature monitoring +Level 3
  - Level 5 is Current monitoring protection +Level 4

The Problem

- Fuze Technology needs protection
  - Sophisticated Analog and Digital Signal Processing techniques
  - Danger of reverse engineering
  - No battery drain
  - Tampering with Fuze ignition sequence
  - Tampering with Safe and Arm

MSI's MSFIPS provides Monitoring Functions



System Design

Life of Lithium Battery with no drain is ~10 years.

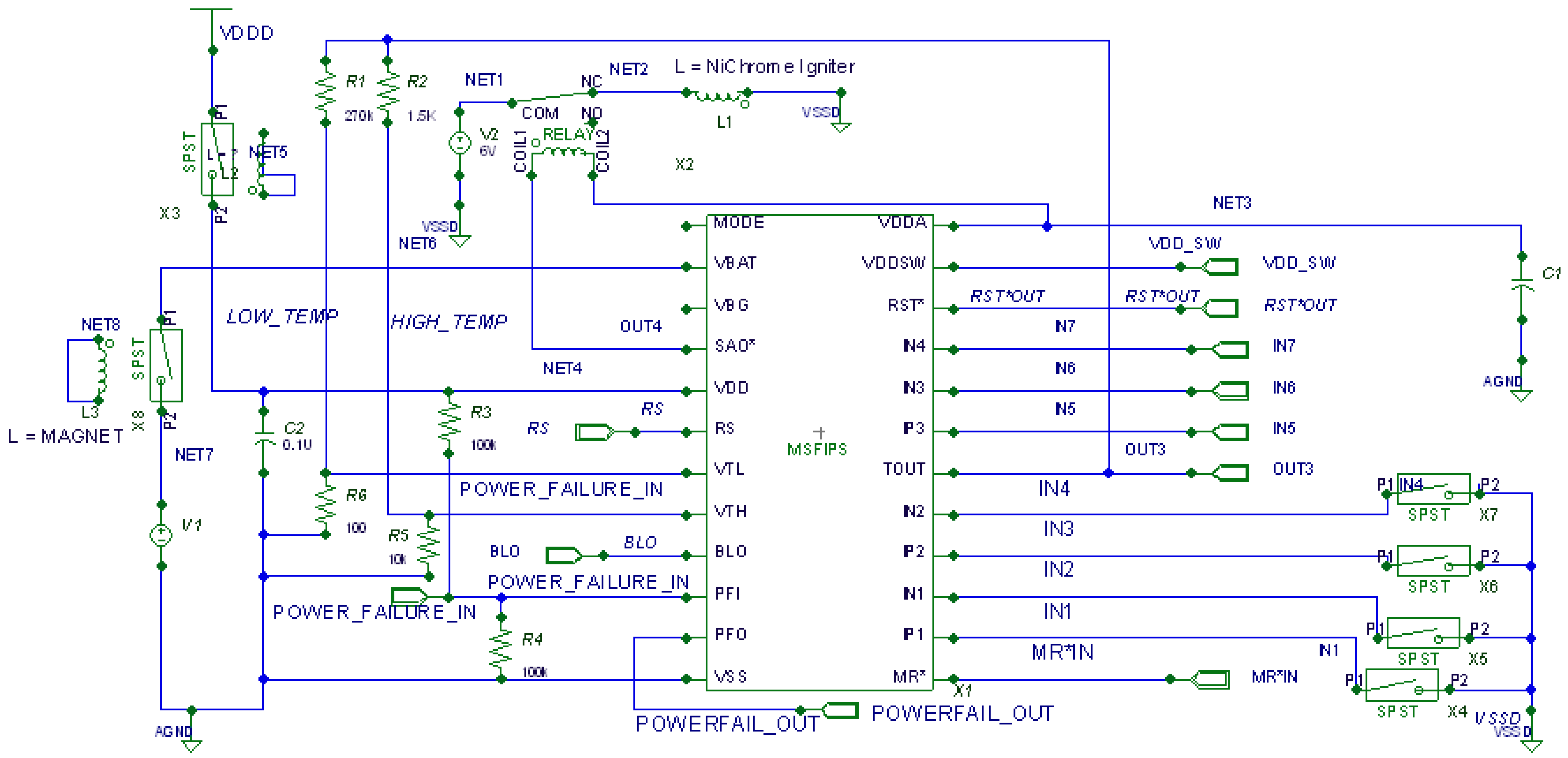
- To increase life, switches for access power the MSFIPS.
- Once case is opened, MSFIPS would monitor status.

MSFIPS Evaluation Board

What if Triggered?

- SAO* goes low closing relay to igniter.
- 50 gauge NiChrome© wire requires only 500 mA current.
- Able to burn and damage components to prevent reverse engineering.

Simplified Schematic



Technical Issues

- Position of the tamper switches
  - Ensure they cannot be bypassed
- Selection of temperature range
  - Need to be set for range found in outdoors
- Ensuring destruction of fuze technology is complete.

Summary

MSFIPS provides monitor and protection to Fuzing technology

- Monitors tampering.
- Monitors typical hacking techniques
- Triggers destruction of fuze technology.

Presented to:

55th Annual Fuze Conference

National Defense Industrial Association

Salt Lake City, Utah

Simple Optical Sensors for Firing Tests

AMRDEC

DISTRIBUTION STATEMENT A. Approved for public release; distribution unlimited. Review completed by AMRDEC Public Affairs Office 24 May 2011; FN5292.

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

May 25, 2011

Presented by:

Michael P. Connolly

Electronics Engineer

Aviation and Missile Research, Development and Engineering Center

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Presentation Outline

- Background & Requirements
- Potential Solutions
- Approach
- Apparatus
- Findings
- Future Work

Acknowledgement

- John Dunbar, Ecosse Design LLC
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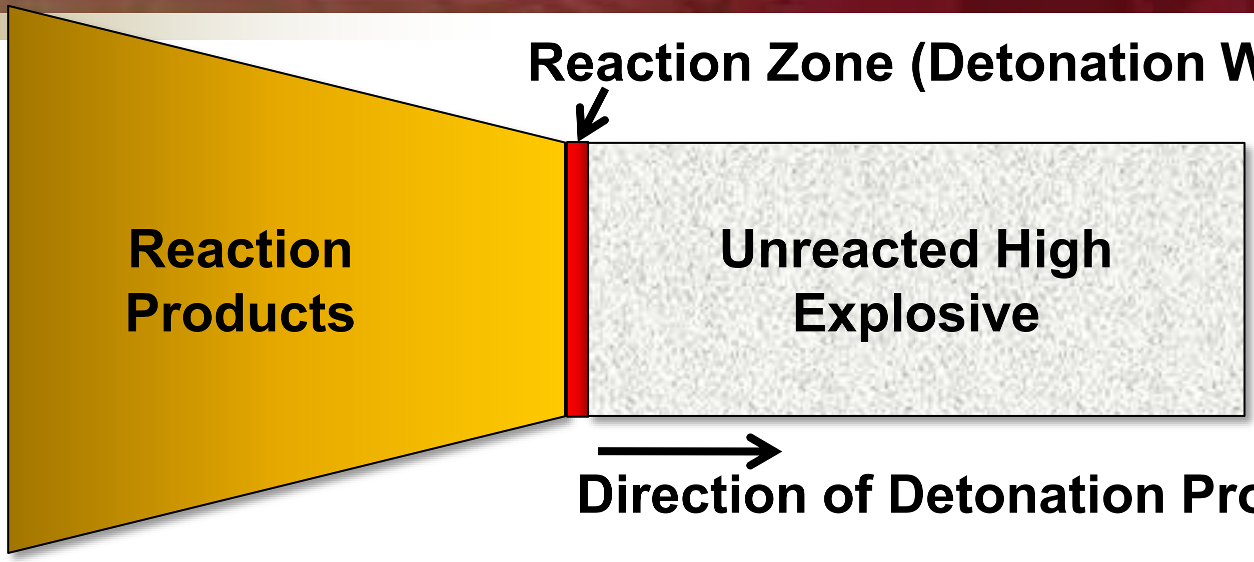
  - Allen Stults
  - Justin Sweitzer (CGI Federal)
  - Ben Sweitzer (CGI Federal)
  - Ben Thomason
- Brad Hanna, Naval Surface Warfare Center-Dahlgren Division
- Ken Jensen and Chuck Treu, Kansas City Plant

Explosives Firing Tests

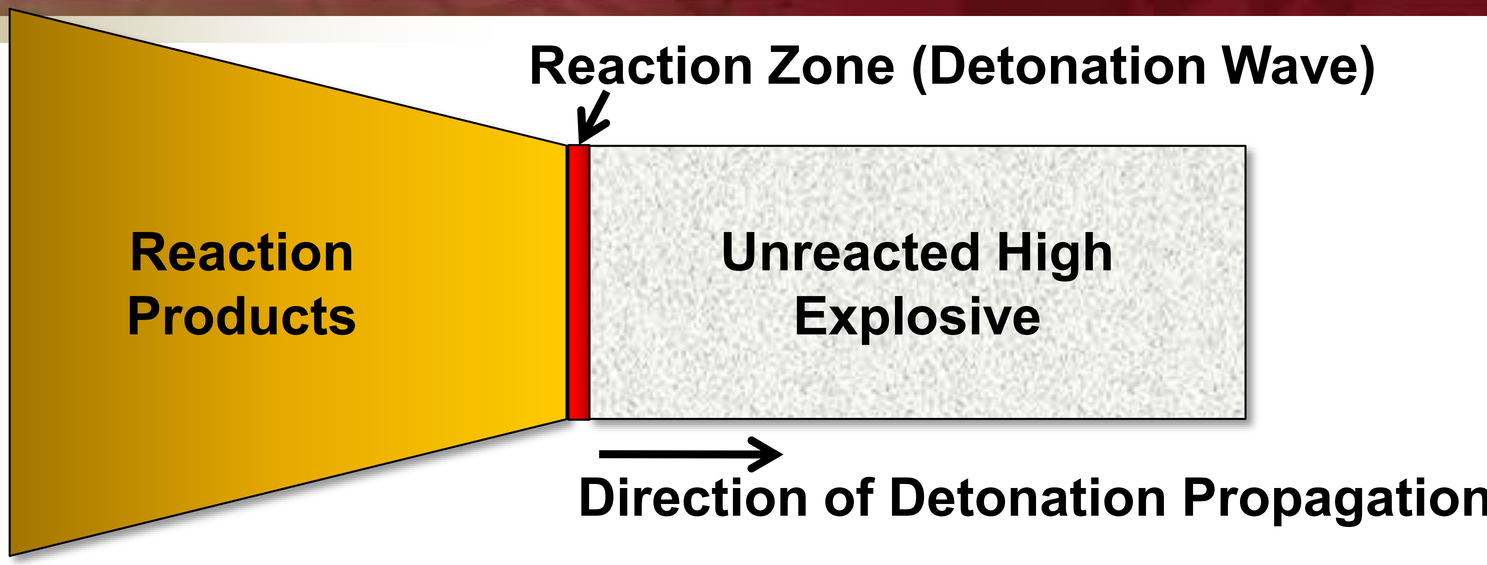


What can we measure?

- **Sensitivity**
- **Combustion**
- **Working Capacity**
- **Detonation**

Refs: Test Methods for Explosives [Suceska1995]
Tactical Missile Warheads [Carleone1993]

Explosives Firing Tests



What can we measure?

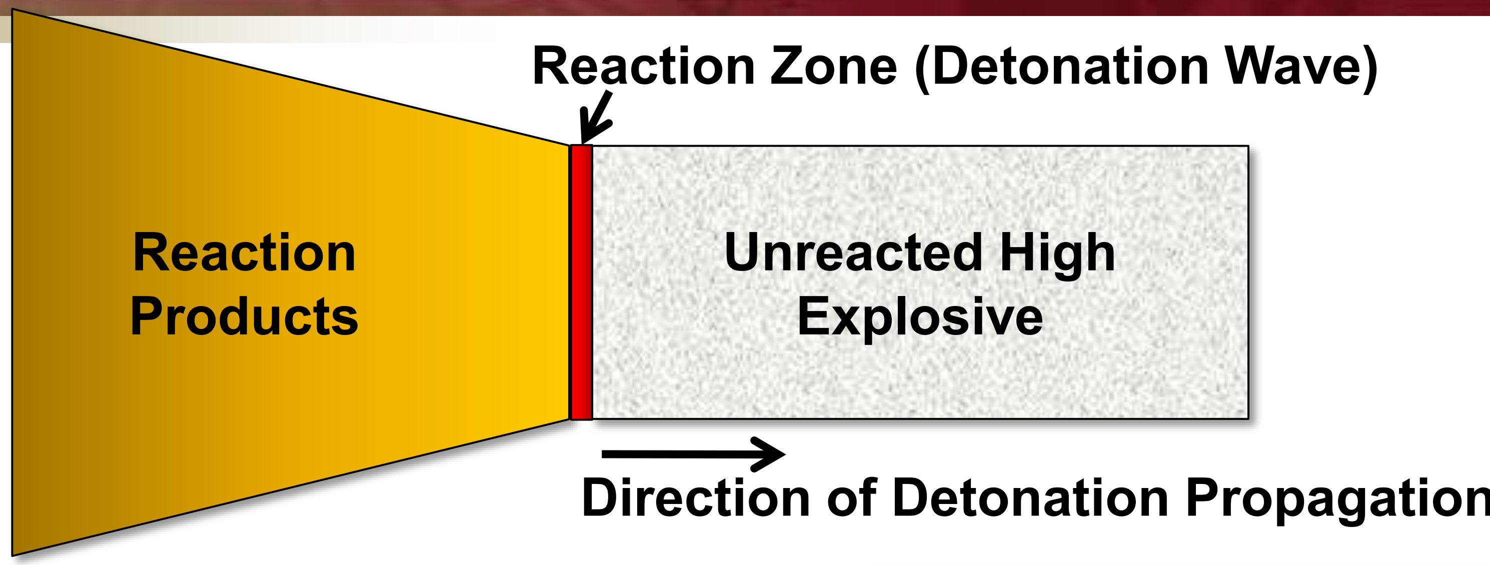
- **Sensitivity**
- **Combustion**
- **Working Capacity**
- **Detonation**

Parameters

- **Reaction or no reaction.**
- **Velocity**
- **Pressure**
- **Temperature**
- **Products‟Composition**

Refs: **Test Methods for Explosives [Suceska1995]**
Tactical Missile Warheads [Carleone1993]

Explosives Firing Tests



What can we measure?

- **Sensitivity**
- **Combustion**
- **Working Capacity**
- **Detonation**

<u>Some Techniques</u>

- **Streak / Framing Camera**
- **Schlieren / Shadowgraph**
- **Flash X-Ray Radiography**
- **VISAR**
- **PDV**
- **Fabry-Perot**
- **Conductive Probes**
- **Piezoelectric Probes**
- **Optical Fiber Probes**

Refs: <u>Test Methods for Explosives</u> [Suceska1995]
<u>Tactical Missile Warheads</u> [Carleone1993]

Tradeoffs

Want to measure:
- Reaction or no reaction.
- Velocity

- Streak / Framing Camera
- Schlieren / Shadowgraph
- Flash X-Ray Radiography

- VISAR
- PDV
- Fabry-Perot

- Conductive Probes
- Piezoelectric Probes
- Optical Fiber Probes

"Intrinsic" Requirements
- Accuracy
- Precision
- Sensitivity & Dynamic Range
- Calibration
- Channel Independence
- Intrusiveness
- Data Requirements

"Extrinsic" Requirements
- Cost (initial & recurring)
- Compatibility w/ existing equip.
- Skills required to use & maintain.
- Experimental Environment(s)

Refs: Test Methods for Explosives [Suceska1995]
Tactical Missile Warheads [Carleone1993]

Tradeoffs

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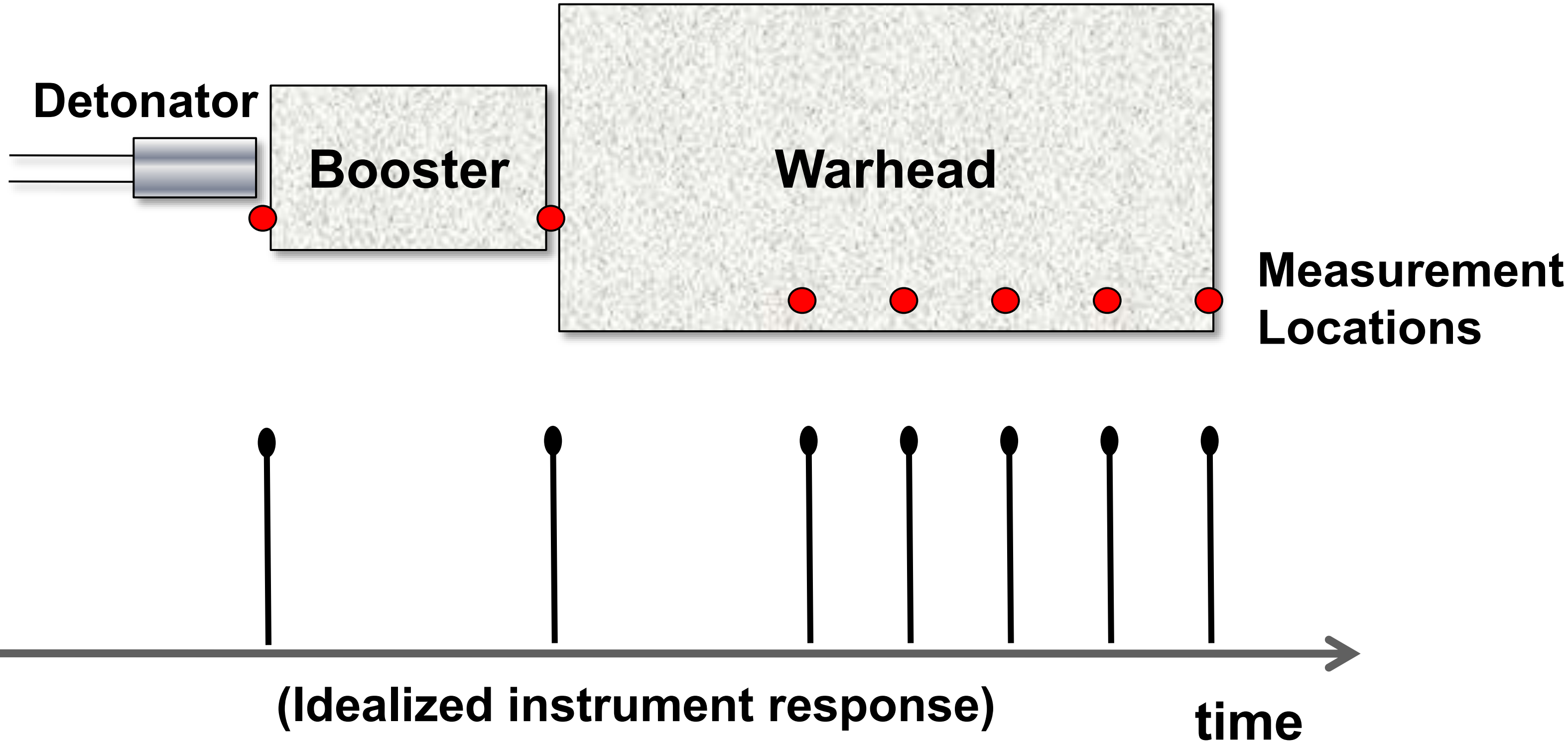
Refs: Test Methods for Explosives [Suceska1995]
Tactical Missile Warheads [Carleone1993]

Probes

Measure the timing of the detonation wave as it propagates through the experimental specimen.



Possible Solutions

Conductive Probes
- Make / Break Switches
- Nichrome Wire
- Ion Pins

Piezoelectric Probes
- PVDF
- PZT

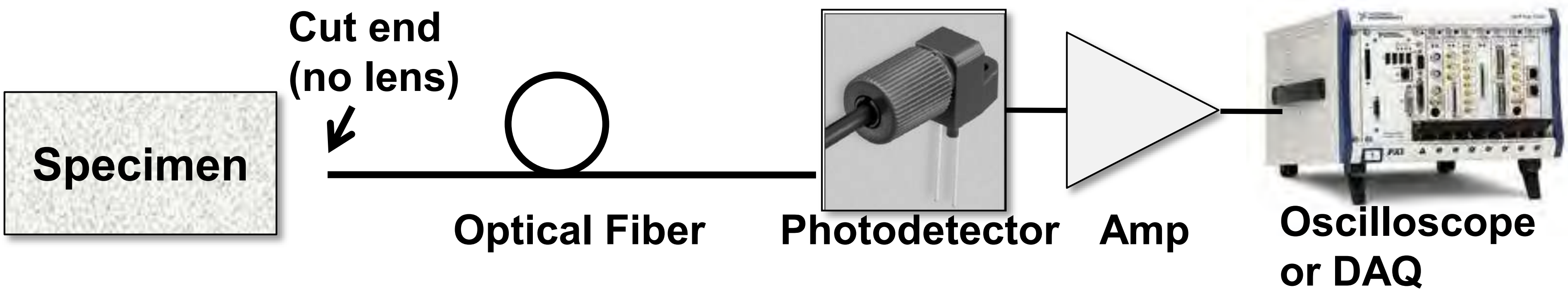
Optical Fiber Probes
- Optical Fiber
- Optical Fiber with Lens
- Modified Fiber

Potentially offers:
- Accurate, fast response.
- Channel independence.
- Scalability.
- Favorable Electromagnetics.

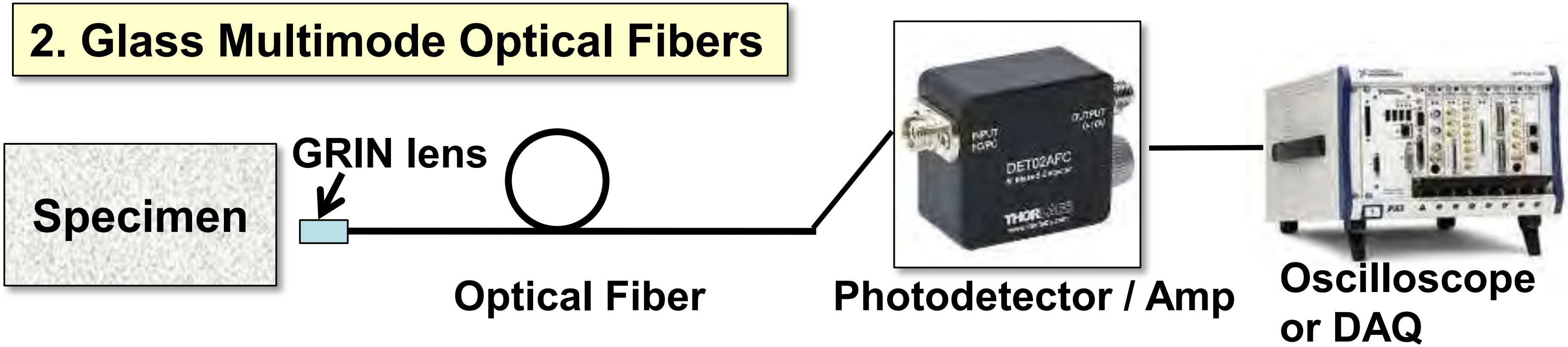
Refs: Test Methods for Explosives [Suceska1995]
High speed velocity measurements on an EFI-system [Prinse2007]
Dynasen, Inc., http://www.dynasen.com
Measurement Specialties, Inc., http://www.meas-spec.com/

Approach

1. Plastic Multimode Optical Fiber Probe

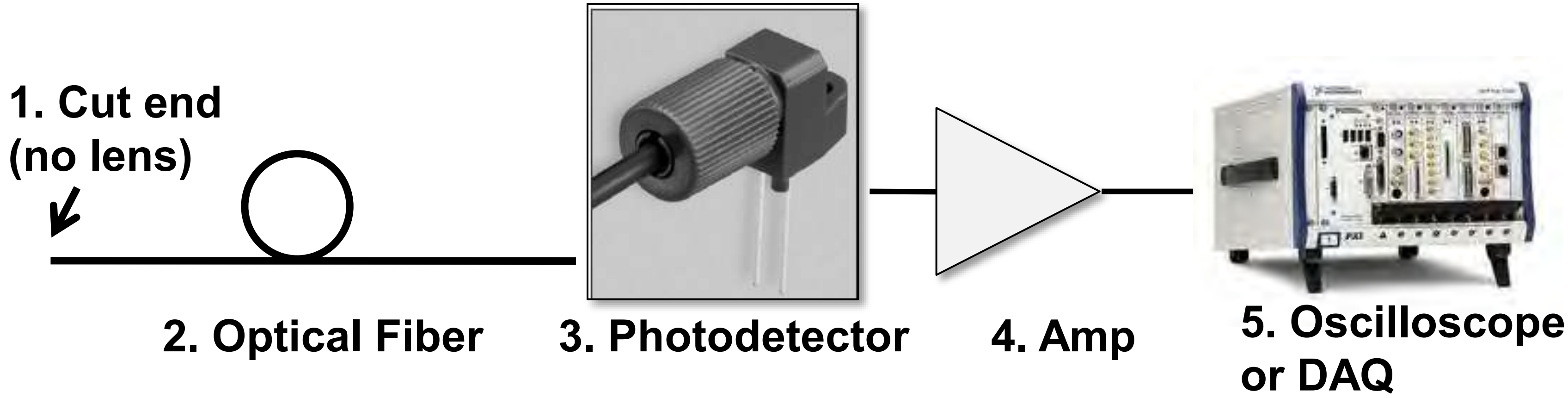


2. Glass Multimode Optical Fibers



Refs: Laser Light Scattering: Principles and Practice, Second Edition [Chu2007]
High speed velocity measurements on an EFI-system [Prinse2007]
Fiber Optic Sensors: An Introduction for Engineers and Scientists [Udd1991]
Electro-Optics Handbook, Second Edition [Waynant2000]

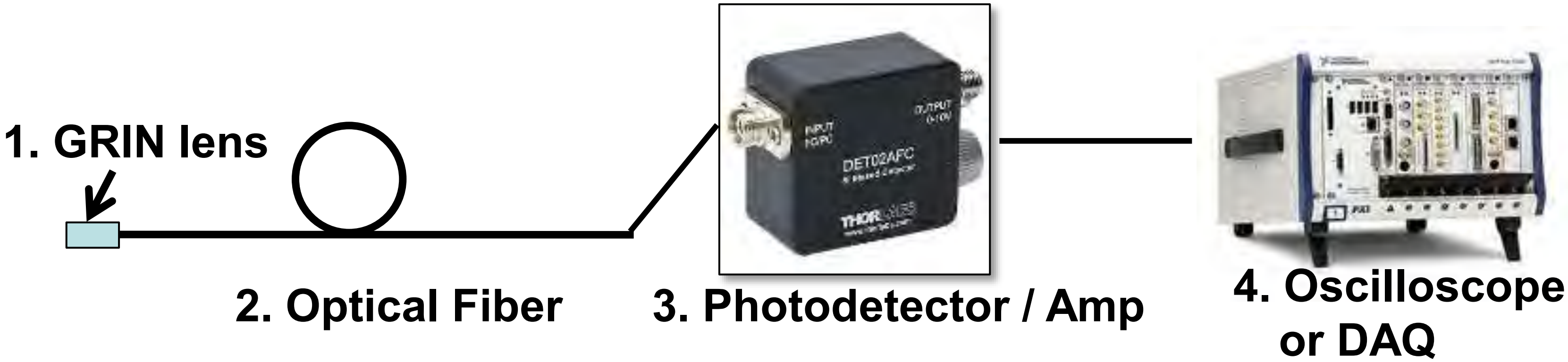
Apparatus – Plastic Fiber



1. Use a razor or craft knife to make a clean cut perpendicular to jacket.
2. Tyco Electronics, p/n 501232-4, step index multimode fiber, polyethylene jacket, PMMA fiber: n.core=1.49, n.clad=1.42, NA=0.46, Max atten 150db/km.
3. Industrial Fiber Optics IF-D91, tr=5 ns.
4. Amplifier as needed for signal conditioning.
5. Oscilloscope or Data Acquisition System (DAQ) as needed for data requirements.

Refs: Tyco Electronics, http://www.tycoelectronics.com
Industrial Fiber Optics, http://www.i-fiberoptics.com/

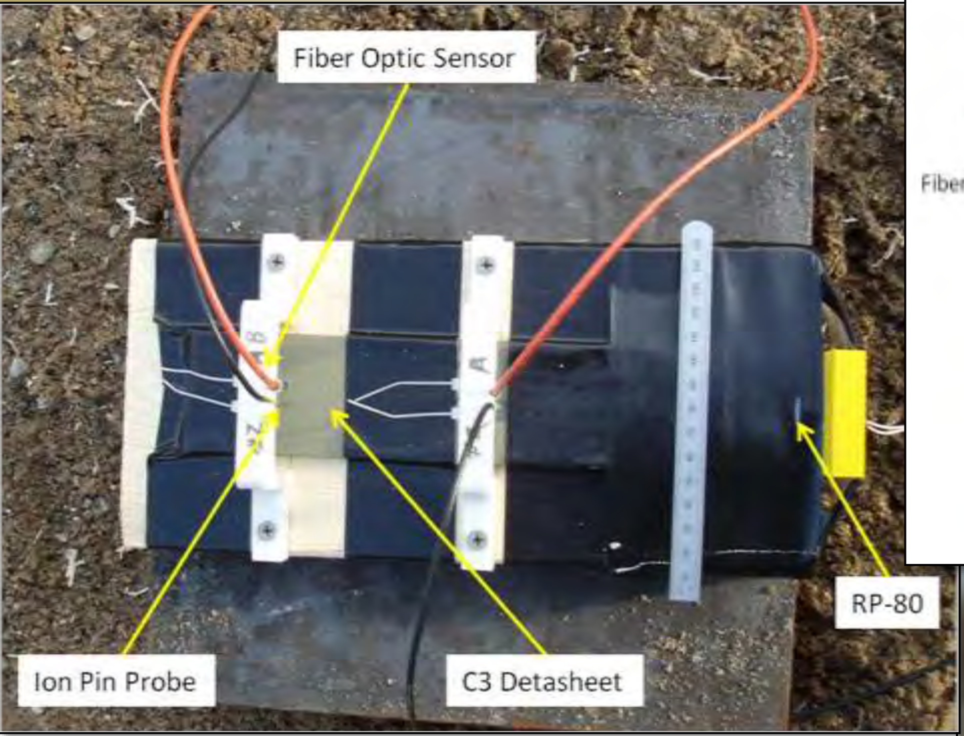
Apparatus – Glass Fiber

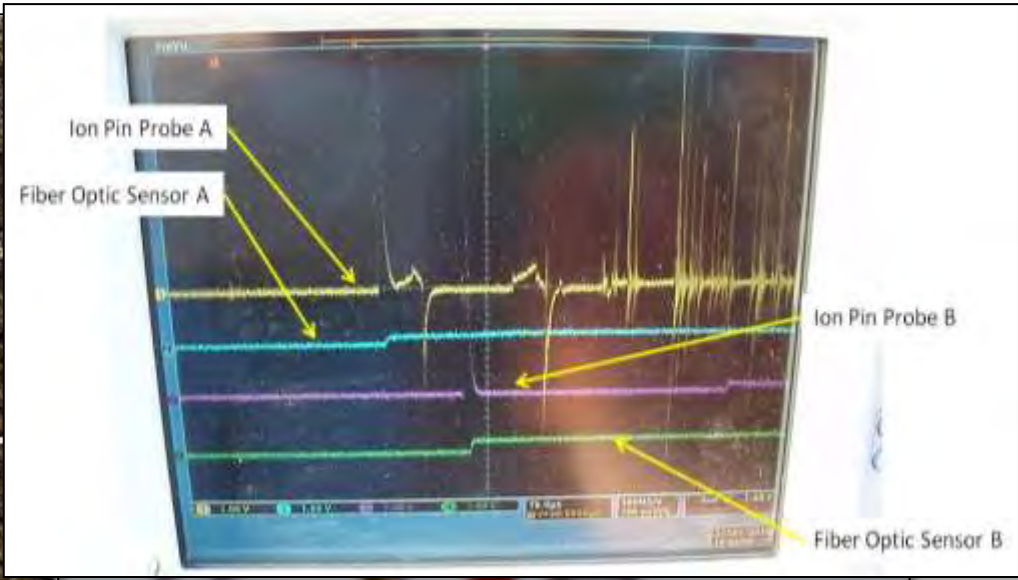


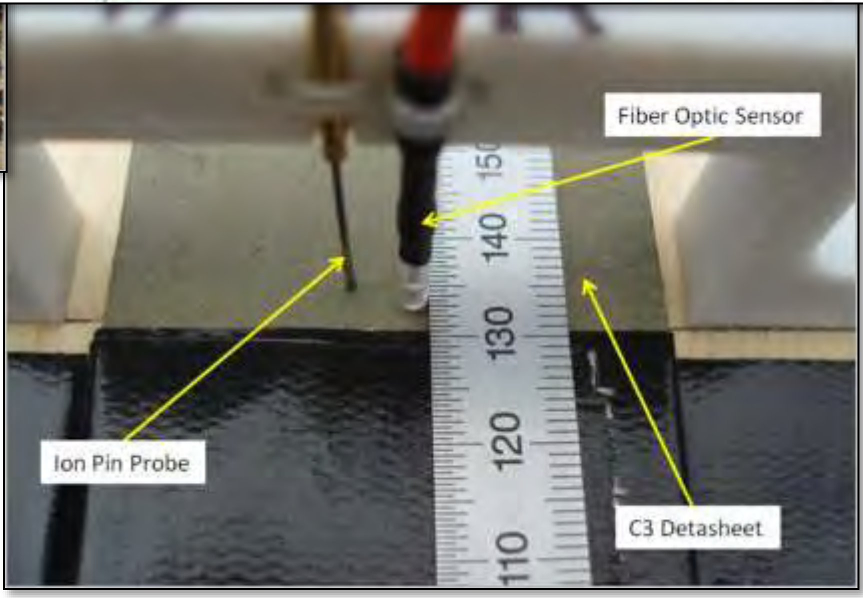
1. GoFoton (formerly NSG America) SELFOC(tm) Gradient Index Lens, p/n SLW-180-023-SBC. Oxide glass, 0.23 pitch, gradiant constant 0.332, N0=1.5986.
2. Fiber Pigtail and Patch Cable. Optequip p/n A10006 and A20182. The fiber itself is Corning Infinicore 300 62.5/125 micron glass multimode fiber. Fiber end is first cleaved, inserted in ferrule (Thorlabs p/n 50-1800-126), and polished, and then the lens is attached using Norland optical adhesive number 61 (NOA-61), which is cured using a UV light source. Polished fiber NA=0.27. FC connectors used.
3. Thorlabs DET02AFC photodetector/amplifier. Si photodetector, tr < 1ns.
4. Oscilloscope or Data Acquisition System (DAQ) as needed for data requirements.

Refs: Corning, http://www.corning.com/index.aspx
GoFoton / NSG America http://www.nsgamerica.com/
Norland Products, Inc. http://www.norlandprod.com/
Optequip, http://www.optequip.com/
Thorlabs, Inc., http://thorlabs.com/

Findings





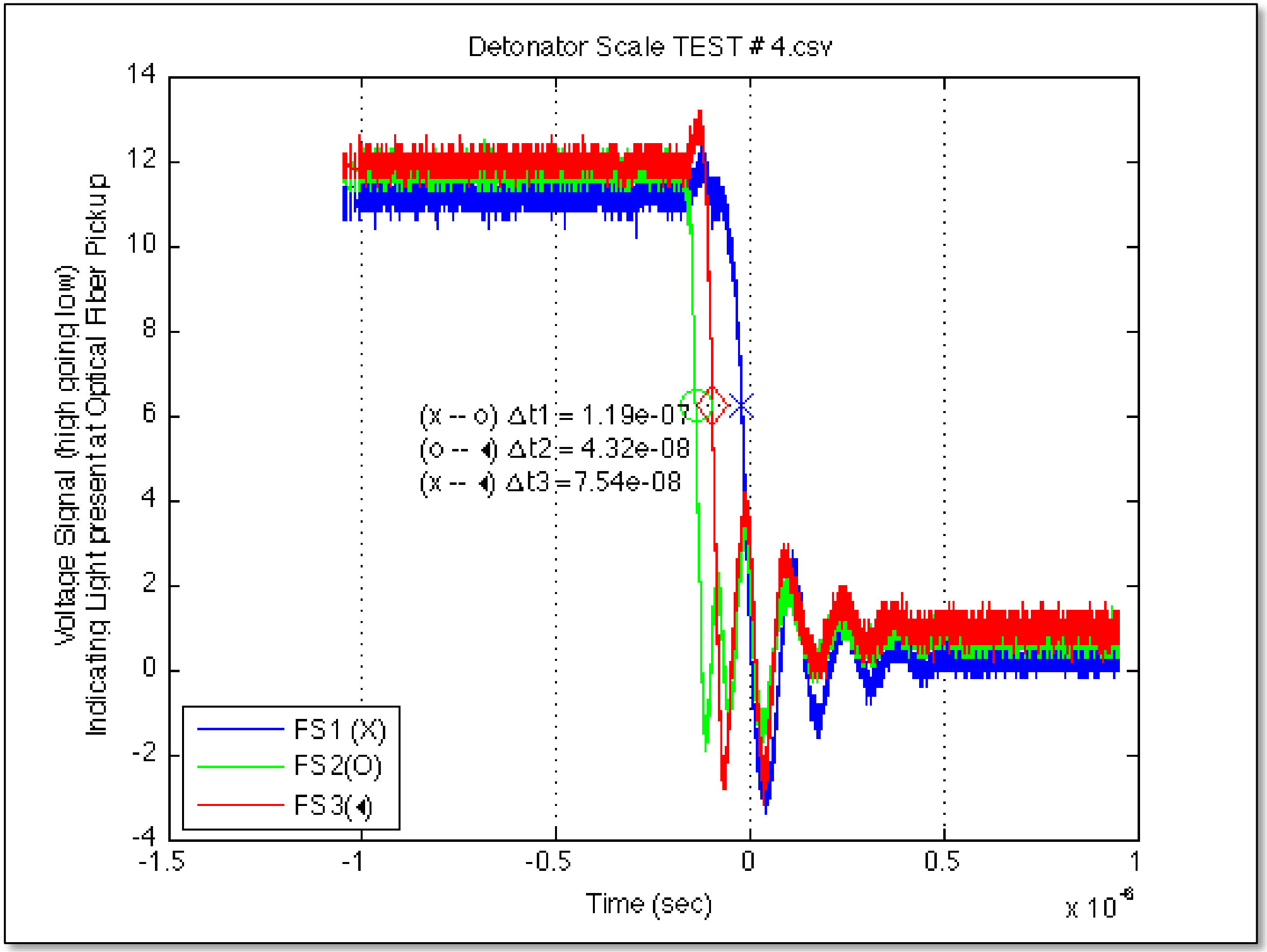


Test equipment included Tektronix DPO4101 Oscilloscope, a Dynasen model CS2-50-300 Pin Mixer to power the Ion Pin Probes, Two (2) Dynasen CA-1041 Ionization Pins, a laptop computer to record the data from the oscilloscope, two (2) Thorlabs DET02AFC Photodetectors, two (2) Fiber Optic Flash Sensors, and one (1) 100 meter multi-mode patch cable.

Courtesy of John Dunbar and Devin Chamness

Findings (cont'd)

Need to optimize system for fast, clean pulse response.



Total Delay T_D

$$T_D = \sum_{i=1}^{n} T_{Di}$$

Total Rise Time T_R

$$T_R = \sqrt{\sum_{i=1}^{n} {T_{Ri}}^2}$$

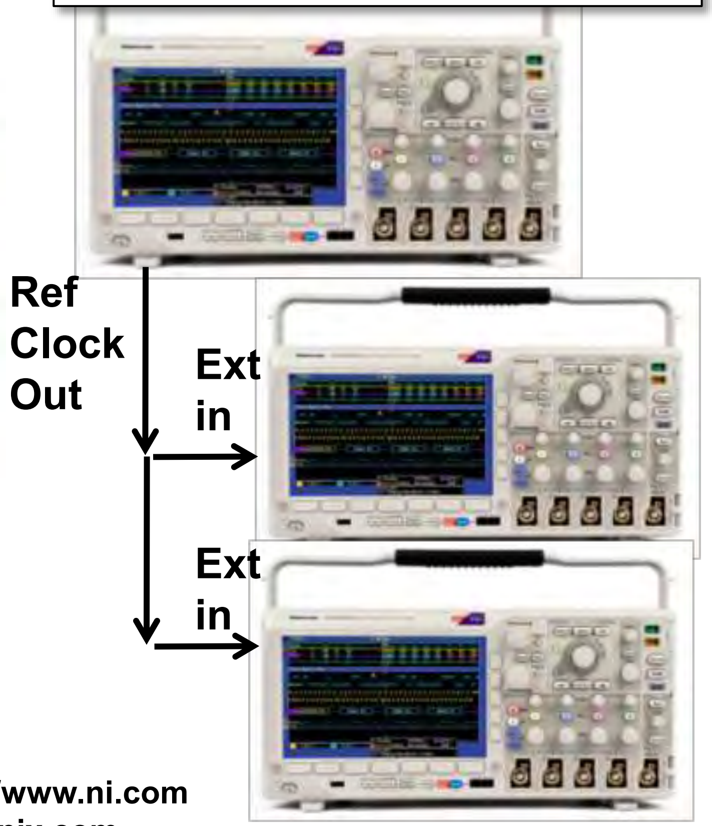
Refs: Elmore1948, Kennedy1988

Findings (cont'd)

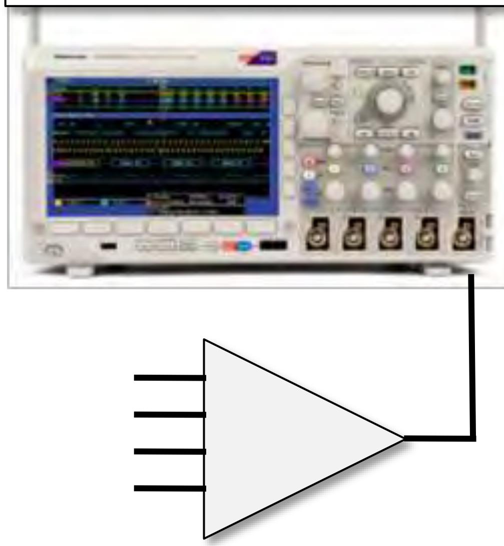
Scalability depends on common time reference across data record.

DAQ with many channels sync"d across bus.

Distribute common timing/trigger reference



Sum multiple inputs per channel



Refs: National Instruments, http://www.ni.com
Tektronix, http://www.tektronix.com
Operational Amplifier Circuits: Theory and Applications [Kennedy1988]

Future Work

- More firing experiments (Summer 2011).
- Develop calibration / channel equalization technique.
  - Suitable for field as well as lab.
- Obtain or design high-speed amplifier with compensation for high-speed pulses.
  - Lowpass filter with Thomson/Bessel linear phase
- Survey alternative parts/suppliers.

Questions?

Thank you!

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Scalable Software Evaluation Methodology and Tools

A JFTP Proposal for FY12 Under FATG IV

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Purpose

- Fuzing designs are utilizing software in part or in whole in the implementation of one or more safety features in networked environments
- Safety critical software needs to be analyzed and tested to assure proper design and function
- No documentation exists to help identify all issues related to networked safety critical software in munitions.
- AOP-52 provides guidance in the requirements of design and implementation of safety critical software throughout the entire life-cycle, but not enough network guidance exists

Background

- Implementation of Safety Features has evolved significantly
  - Mechanical (springs, setback weights, rotors, sheer pins)
  - Electronic (analog and/or simple digital circuits)
  - Software (microprocessor and/or programmable logic devices)
- The use of software has allowed designers the ability to design fuze safety features that are influenced partially or completely outside the fuze itself. The resulting "fuze chain" blurs the line between the fuze and the rest of the munition
- Recent standards and guidelines were developed to address software safety in fuzes, fuzing systems, and munitions - AOP-52 was developed under NATO AC326 Sub-group III with members of the US (DoD), UK, Germany, and France

Case History

- Distributed fuze functions first encountered by the AFSRB with Spider hand-emplaced anti-personnel landmine
  - Arming completely controlled by a Remote Controlled Unit (RCU) (laptop PC) communicating with the Munitions Control Unit (MCU)
  - On-Off-On requirements made the software on the RCU safety critical (in addition to the software on the MCU)
  - Due to lack of suitable documentation at the time, software safety guidance was developed concurrent with the system design
- Lessons learned helped produce a better safety design with Scorpion
  - FESWG Guidelines on the use of Programmable Logic Devices
  - AFSRB Guidelines Appendix C
  - AOP-52

Current Challenges

- Networked (remote controlled) munitions are becoming the "norm" given technology available today
- System of Systems allow remote arming/firing of weapons half-way around the world
- How does safety get designed into these advanced systems?
- What design parameters need to be addressed?
- What metrics can be identified to verify and test safety critical features?
- Bring to bear any existing software analysis techniques and/or tools – develop them if they don't exist

Proposed Work

- Identify safety critical parameters in a networked environment
  - Protocols (important for guaranteed communication)
  - Latency (important for real-time operations)
  - Quality of Service (QoS) (important for reliability & safety)
  - Data Integrity within networked communications and software
  - Information Assurance (IA) as it relates to safety
- Identify System of System integration issues affecting safety
- Create/augment guidance documents (i.e. update AOP-52)

Proposed Work (continued)

- Perform research consulting with academia to identify safety critical parameters that need to be addressed in networked system designs
- Create a straw-man documentation that can be used to update AOP-52
  - Create a working group of SMEs from all the services
  - Work with NATO AC326 Sub-group III to update AOP-52
- Identify analysis techniques and/or tools that can be utilized to verify safety critical functions are properly designed and implemented

Summary

- Research and identify networking parameters that affect software safety with the help of academia
- Update AOP-52 with respect to networking issues and provide additional guidance topics on System of Systems
- Identify software metrics affecting safety in network systems
- Identify and/or develop software analysis tools that can be used to test and verify safety critical metrics in network systems
- Identify scaling techniques and safety critical parameters when interfacing software in System of Systems

Questions?

Backup Slides

AOP-52 Contents

- Executive Overview
- Introduction to the AOP
- Generic Guidelines and Requirements
- Software Safety Engineering
- COTS and NDI Software
- Testing and Assessment Guidelines
- References
  - Software Development Models
  - Lessons Learned
  - Process Charts

Executive Overview

- Explains the need and importance of software safety elements in requirements and design of the program to managers and executives
- Software safety begins with program requirements and continues throughout the life-cycle of the program
- Even though software is only a part of the overall safety of a program, there are unique issues with software safety that need to be addressed

Introduction to the AOP

- Explains the major purpose for the AOP
- Presents the scope of the subject matter incorporated in the document
- How the AOP is organized for maximum benefit of use
- Also includes:
    - Historical background
    - Problem identification
    - Introduction to the "Systems" approach

Generic Guidelines and Requirements

- Introduction
- Determination of Safety-related Computing System Function
- Design and Development Process Requirements and Guidelines
- Software Design Verification and Validation
- System Design Requirements and Guidelines
- Computing System Environment Requirements and Guidelines
- Self-check Design Requirements and Guidelines
- Safety-related Computing System Functions Protection Requirements and Guidelines
- Interface Design Requirements
- Human Interface
- Critical Timing and Interrupt Functions
- Software Design and Development Requirements and Guidelines
- Software Maintenance Requirements and Guidelines
- Software Analysis and Testing

Software Safety Engineering

- Introduction
- Software Safety Planning Management
- Software Safety Task Implementation
- Software Safety Testing and Risk Assessment
- Safety Assessment Report/Safety Case

COTS and NDI Software

- Introduction
- Related Issues
- Applications of Non-Developmental Items
- Reducing Risks
- Testing
- Summary

Raytheon
Customer Success Is Our Mission

Enhanced Weapon Arming Safety

By Controlled Accumulation of Arming Energy

Thomas Harward
Tim Bonbrake

Problem Background

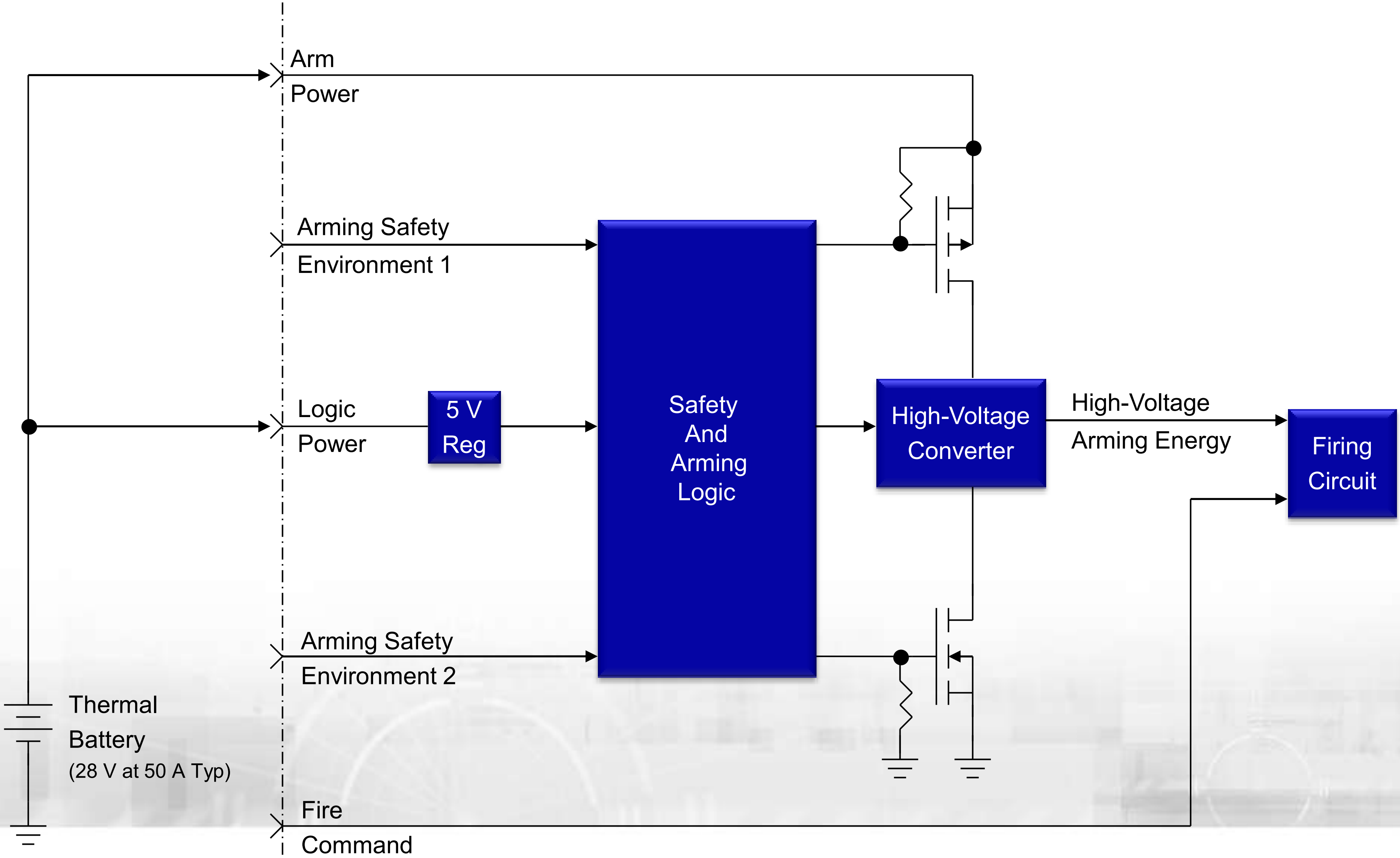
Statement Of Technical Deficiency

Raytheon

- Weapon system electronic safety devices define arming as charging of a high voltage firing capacitor to the all-fire voltage of the initiator (approximately 1.5 kV).
- Inadvertent or early arming is defined as a safety failure in MIL-STD-1316 and MIL-STD-1901.
- Most weapon systems use medium-voltage/high-power thermal batteries to power all subsystems.
- Thermal batteries have the power capability to immediately arm a safety device in the event of a sneak circuit or failed safety feature.
- The desired approach is to slowly accumulate arming energy from the environment, for example an FZU.

Current Weapon Arming Safety Architecture

High-Energy Source Applied at Start of Arming Sequence



Current Weapon Arming Safety Architecture
Summary of Issues

- Requires a high-power energy source to properly operate the safety device.
- The high-power energy source may be available to the safety device prior to safe separation.
- A sneak circuit from the high energy source to the arming circuit can cause an inadvertent or early arming condition.
- In a sneak circuit condition, the arming delay would be only a few milliseconds.

Enhanced Weapon Arming Safety Architecture
Potential Solution

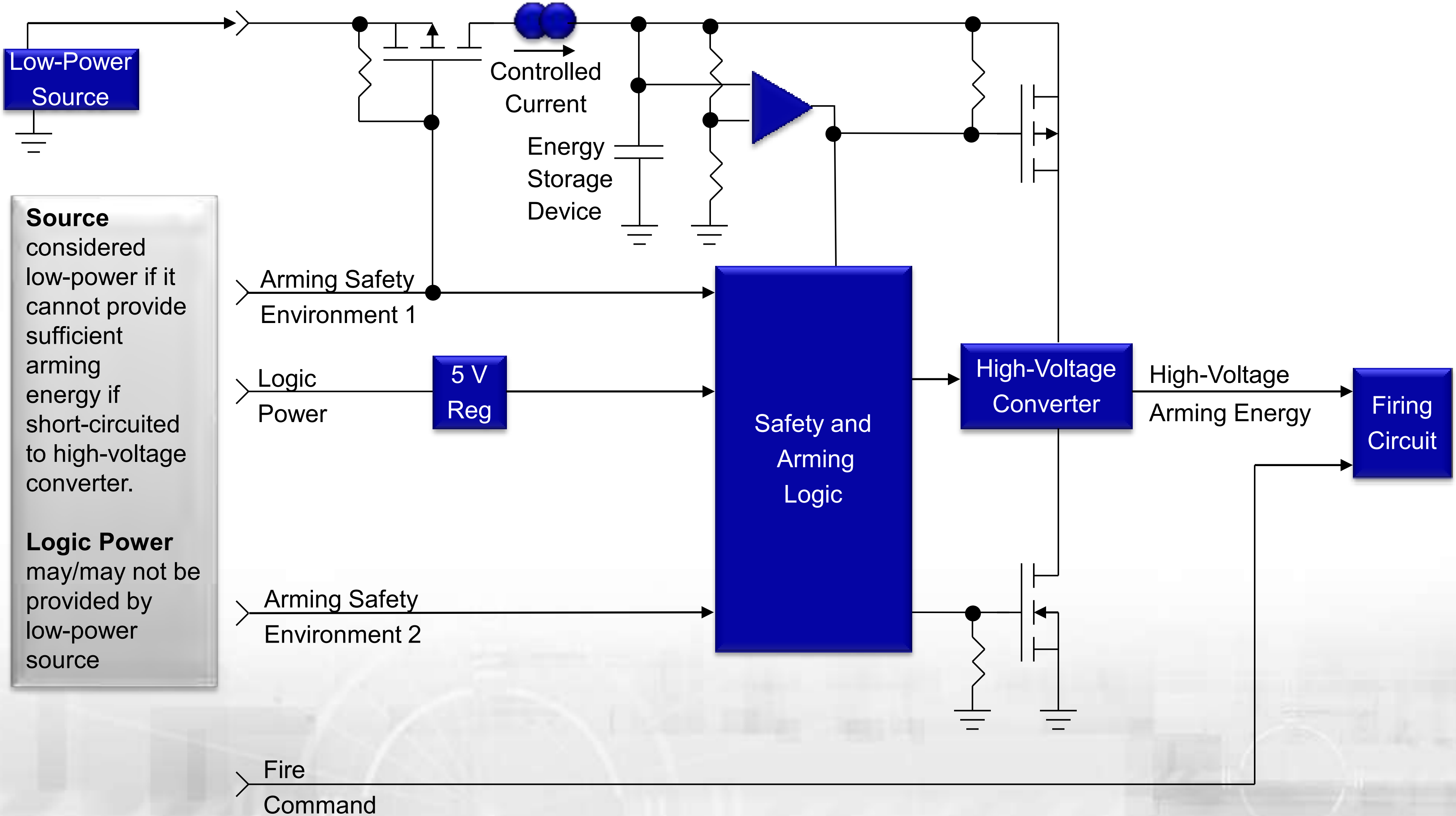
Raytheon

- Provide power to safety devices from low-voltage/low-energy power sources.
- Accumulate the required arming energy over the safe separation time based on the application.
- Store the controlled accumulation of arming energy electronically to obtain the all-fire energy at the required rate.
- Utilize this stored energy to arm the safety device when all safety conditions have been achieved and arming is commanded.

Enhanced Weapon Arming Safety Architecture

Controlled Accumulation Of Arming Energy

Raytheon



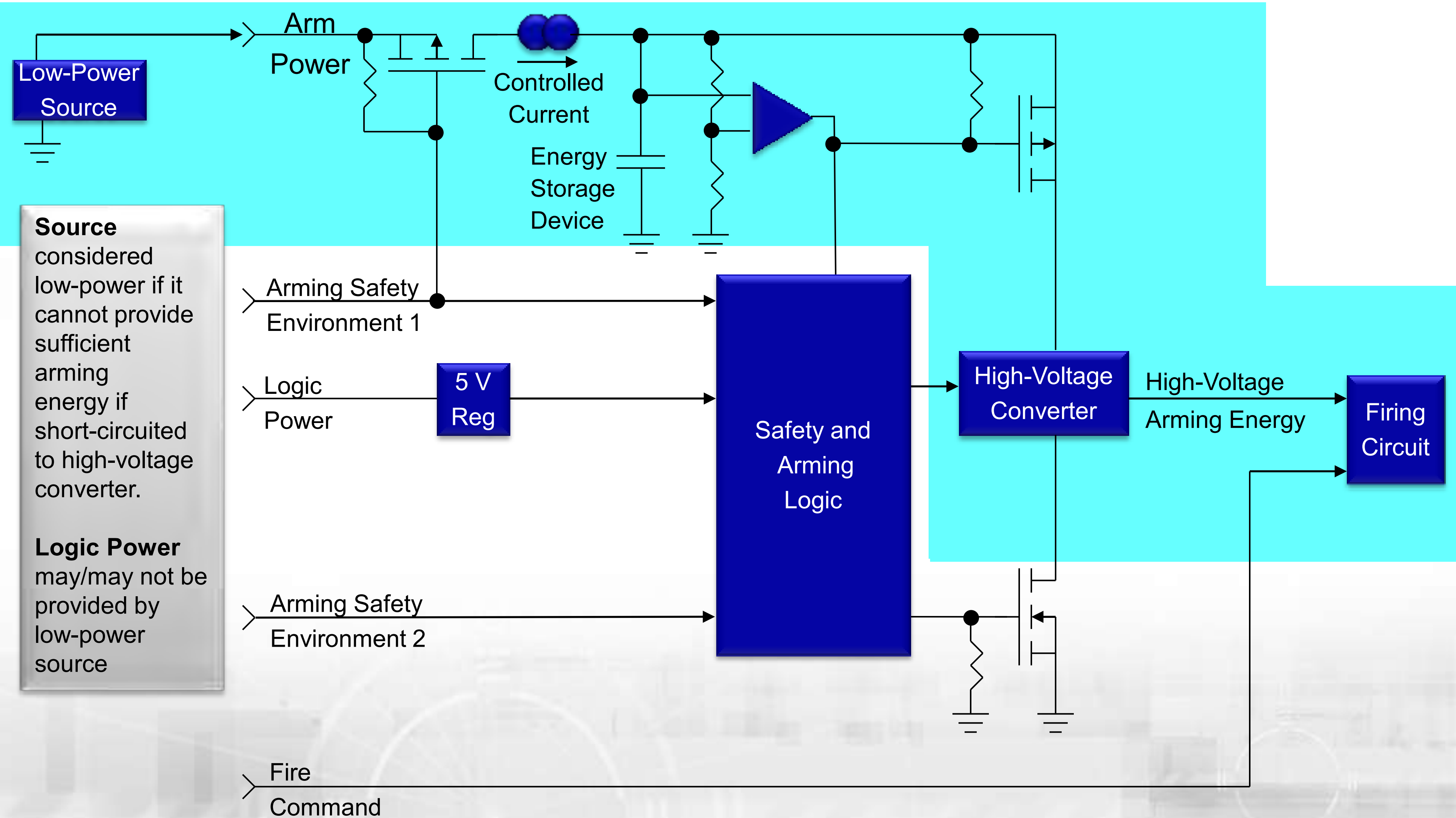
Source considered low-power if it cannot provide sufficient arming energy if short-circuited to high-voltage converter.

Logic Power may/may not be provided by low-power source

Approved for public release. DoD OSR 11-S-2023. 5/52011.

Enhanced Weapon Arming Safety Architecture
Controlled Accumulation Of Arming Energy

Raytheon



Source considered low-power if it cannot provide sufficient arming energy if short-circuited to high-voltage converter.

Logic Power may/may not be provided by low-power source

Enhanced Weapon Arming Safety Architecture
Controlled Accumulation of Arming Energy

Raytheon

Advantages

- Enhanced safety with operation from a low-voltage/low-energy source.
- Sneak circuit fault tolerant due to low-voltage/low-energy source.
- Accurate control of accumulation of energy via constant current source.
- Arming energy accumulated over time precluding unintended immediate or early arming.
- Removes requirement for high-power source for weapon arming.
- Circuit cannot be armed until accumulated energy is sufficient for proper arming.

RDECOM

NDIA 55th Annual Fuze Conference

Malcolm Baldrige National Quality Award 2007 Award Recipient

Use of PLD's in Fuze Safety Critical Circuits

ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER PICATINNY ARSENAL, NJ

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Bob Hubal
Fuze Division, FPAT
METC, ARDEC

Background

•This paper will present my views and recent experience working with the FESWG to study the use of Programmable Logic Devices in fuzes.

•Present data gathered by the FESWG and other sources will be presented.

❖ *Being a fuze designer and also a member of the Army Fuze Safety Board gives me a unique viewpoint on this issue.*

Background

- Programmable Logic Devices (PLD) are essential tools to the fuze designer

- PLD’s enable advanced fuzes to perform complex and precisely timed functions, measure environments , communicate with other subsystems, etc
- PLD’s are used in large percentage of electronic fuzes

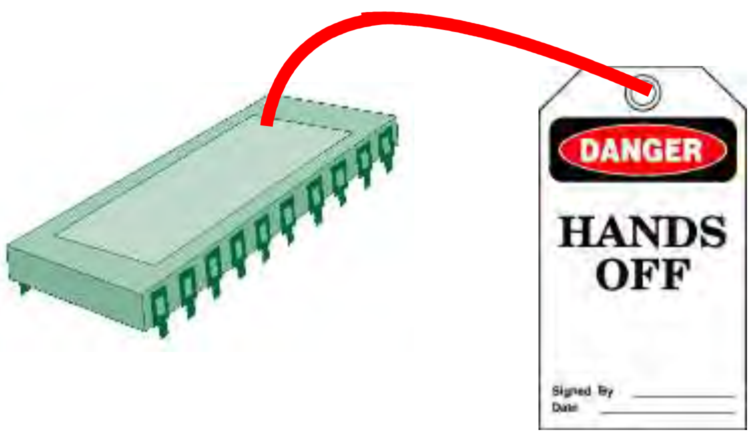
Issue

- PLD's that use charge based memory cell technology are rapidly replacing PLD's that use fixed "fusible type " memory cells
- In particular newer model PLD's which have improved performance such as reduced power consumption are only available in the charged based memory cell technology
- PLD vendors claim long memory retention time for charged based memory cells (ex: 40 years)
- Basic question for the fuze safety community – Can we rely on these devices in safety critical fuze circuits and if so what are the guidelines for their use?

FESWG PLD Subcommittee

- To date only fusible type FPGA's or OTP type microcontrollers have been approved by Fuze Safety Boards
- The FESWG created a subcommittee in 2009 to study the use of PLD's in fuze circuits.
  - Main question to be answered :

    " Is there an acceptable way to use PLD's that use charge based memory technology in safety critical fuze circuits?"



Fuze Life and PLD Memory Loss

← Must be safe →

Mfg

Fuze

Ship, Store and Transport

(up to 20 Years + extreme environments)

Field Mission

Operation

Memory Good (In circuit tests)

Is memory still good???

Memory Loss and System Safety

- Any fuze part can fail for a number of reasons and in general fuzes are designed to stay safe if a single point failure occurs.
- However if there is an inherent memory loss failure mechanism in a PLD, a significant number of fuzes could experience failures during long term storage.
- The software code would fail randomly and the PLD's performance could become unpredictable.
- *Overall system safety would be degraded.*

FESWG Subcommittee Initiatives

- Tasked Sandia NL under the DOD/DOE TCG program to assess the validity of vendors memory retention claims
- Studied potential circuit techniques and guidelines that could mitigate the effects of PLD memory loss on safety
- Initiated an update of the FESWG Logic devices guidelines

Data Retention Testing

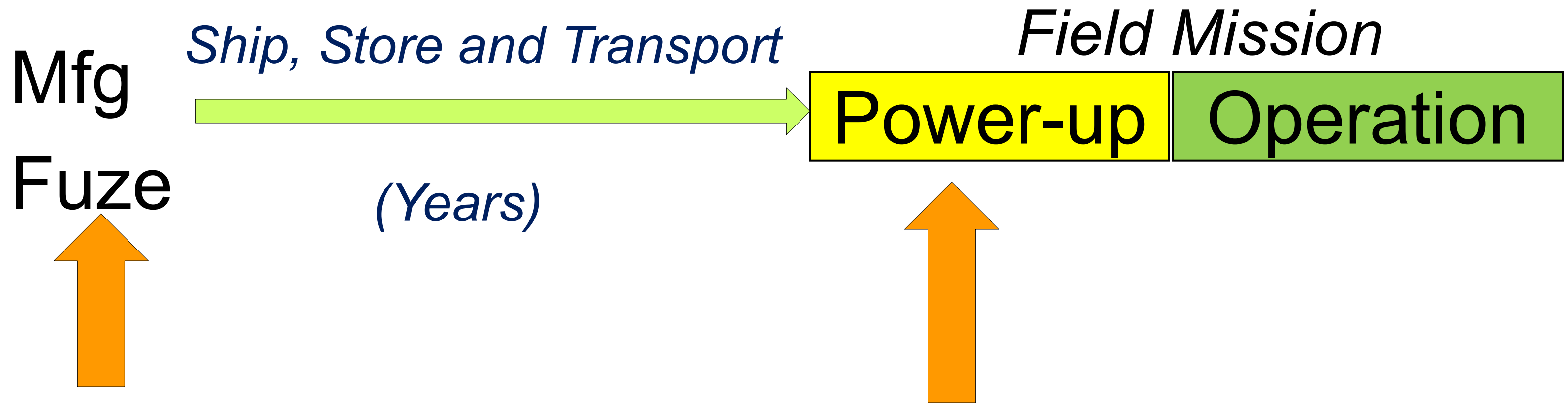
- Sample PLD's were tested by Sandia NL's in an attempt to verify vendors memory retention claims
- Two flash microcontrollers and an FPGA's were selected for test
- The following tests were conducted:
  - Unpowered HAST/130C
  - Temperature Cycling@-55 to +150C
  - High Temp Storage @ 150C

Summary of Data Retention Test Results

	HAST unpowered	Temp Cycling -55/+150C	Data Retention
FPGA	2 wire bond failures in 300-400 hrs	0 Failures 1500/2000 cycles	0 failures 3000 hrs@150C
Micro 1	0 failures in 350 hrs	0 failures 1000/1500 cycles	0 failures 3000 hrs@150C
Micro 2	N/A	N/A	0 failures 8000 hrs@150C

No memory cell failures!

Memory Checking



Memory
Good
(In circuit tests)

Is memory still good???

If we can determine this here we can failsafe the system if the memory is corrupted.

Memory Check Concept
(Hubal Key)


Fuze Safety Critical Functions Locked in here.

Now what was that combination again??

Mr PLD

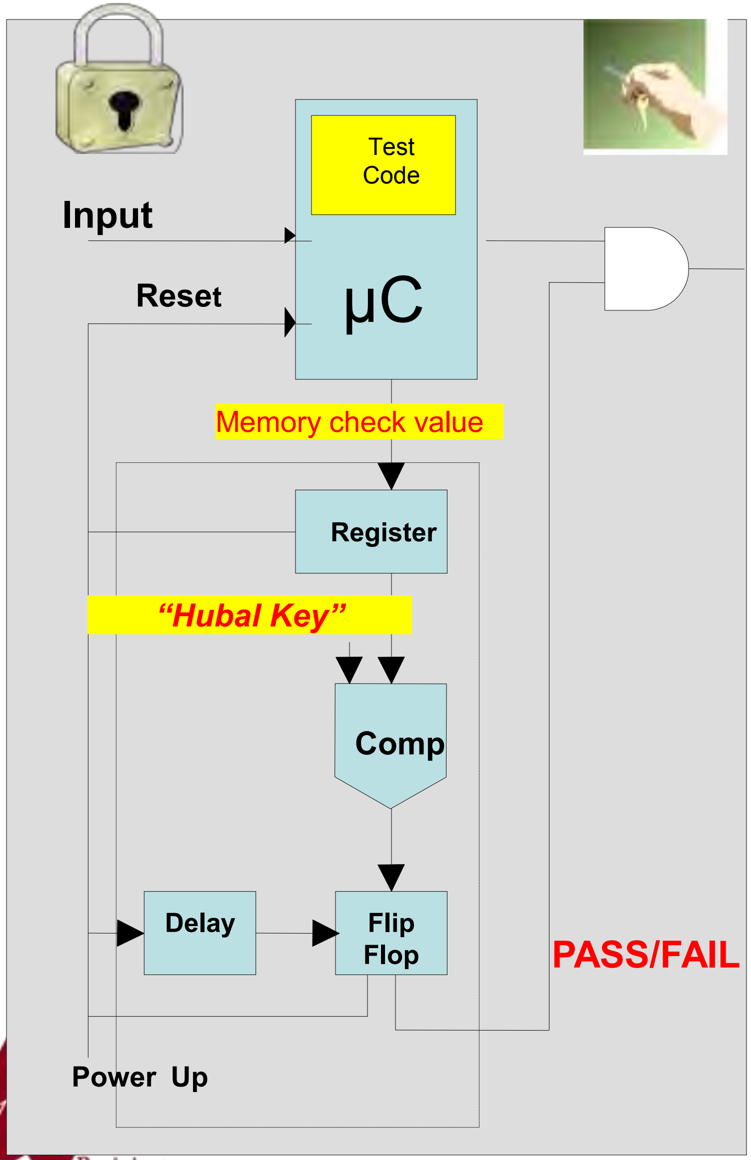
1	1	0	0	1	0	1	1	0	0	1	1	0	0	1

PLD has to derive the right combination based on checking it's memory.

This value is not resident in memory

The memory check is robust and the value is unlikely to be generated by mistake.

Hubal Key Diagram



Purpose:

Checks program memory against an external "coded word" (a.k.a. key).

Re-programmability feature shall be defeated robustly (Service-review required).

Hubal Key acts only as a check for the integrity of EPROM/EEPROM/Flash memory.

Hubal Key does not check hardware or processing functions.

Lines between µC and Hubal Key are dedicated and shall not be used for any other purposes, including monitoring.

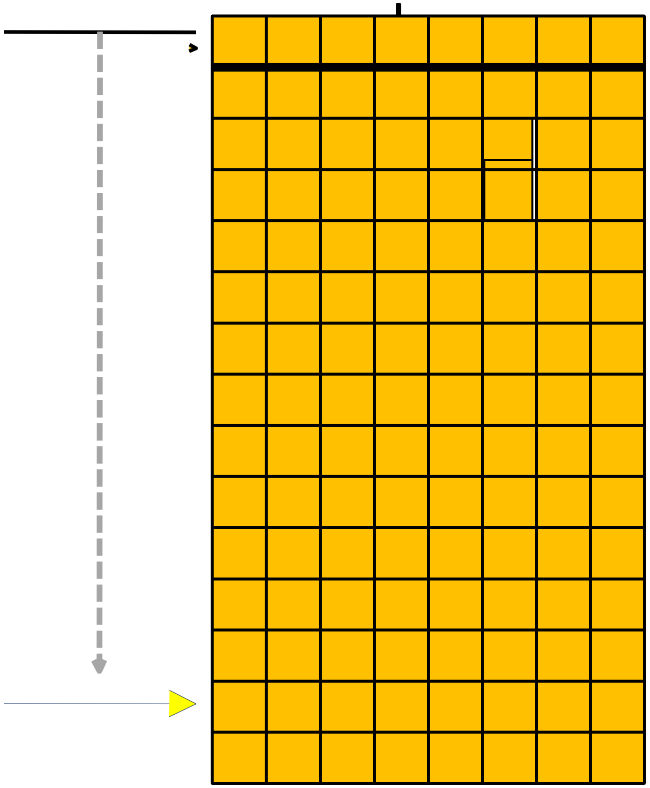
Memory integrity check shall be run upon the application of power and at the start of all arming processes.

Concept for In-Circuit Check of PLD Memory

Tactical

Test code

Read program memory



Perform 16 Bit CRC check

Add in offset value

Send 16 bits to I/O port

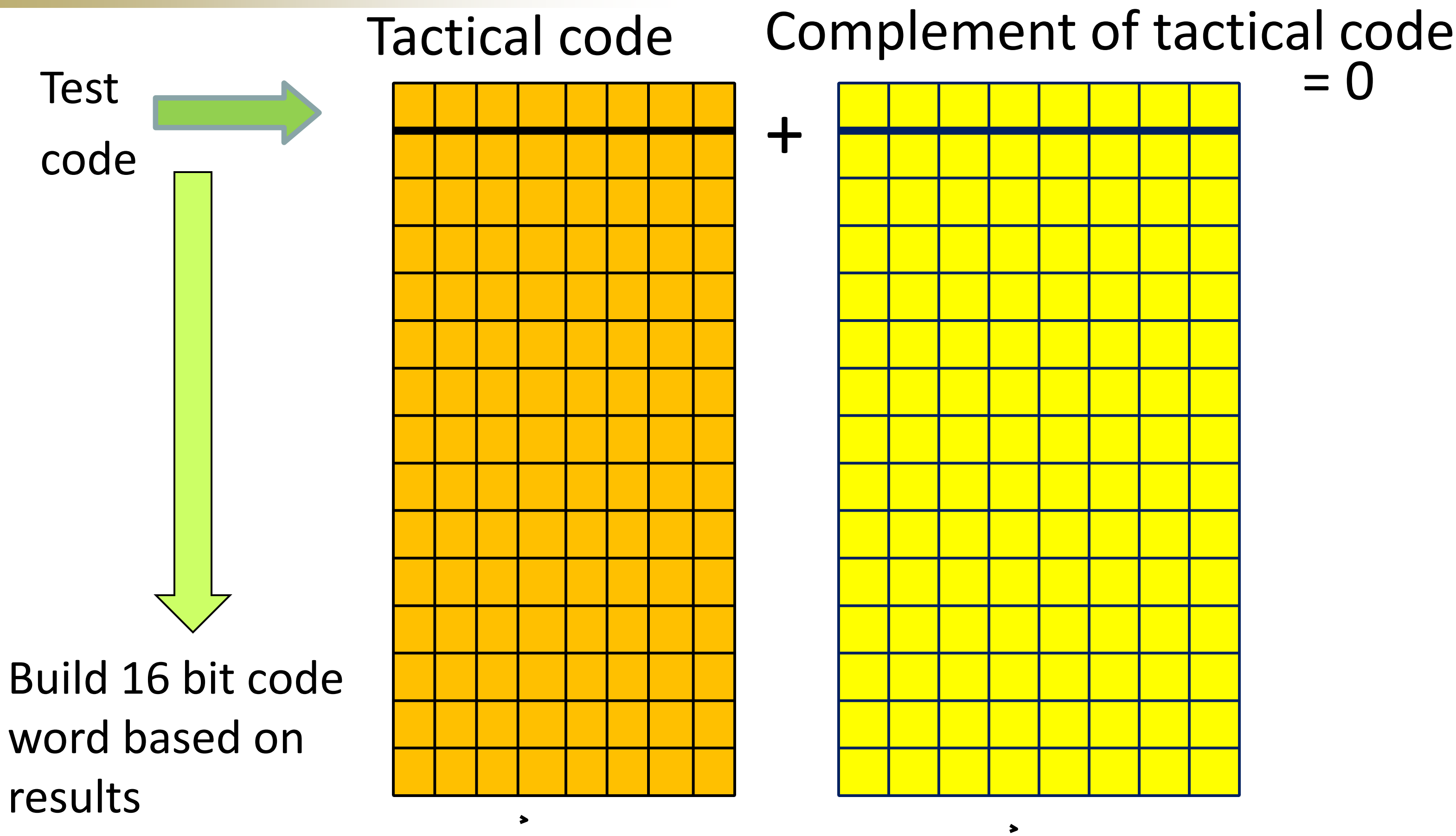
Shift out 16 bits to

Memory Checker Ckt

Memory checker Ckt

Compares micro's 16 bits to stored Hubal "key" code (65k possible combos)

Alternate memory checking scheme – Mirror tactical code and check against itself



Advantage : Fast – simple processing

Disadvantage : doubles memory size

Drawbacks and Limitations of Memory checking scheme

- Takes extra electronic parts to implement.
- More applicable to micro's, fpga's not as straightforward.
  - Can be implemented in a custom IC or by a small discrete SMD ckt
- It takes time to conduct the memory check - this may cause a problem for some systems that have to arm quickly (ex: APS & high velocity close engagement rounds).
- Memory loss still results in a fuze dud

RDECOM

Sample Time to Conduct a CRC check

Example 5. Assembly Language for CRC-16 Using a Lookup Table

```
crc_lo data 40h ; any direct address is okay
crc_hi data 41h
tmp data 42h
;------------------------------------------------------------------------
; CRC16 subroutine.
; - accumulator is assumed to have byte to be crc'ed
; - three direct variables are used, tmp, crc_hi and crc_lo
; - crc_hi and crc_lo contain the CRC16 result
; - this CRC16 algorithm uses a table lookup
;------------------------------------------------------------------------
crc16:
xrl a, crc_lo ; create index into tables
mov tmp, a ; save index
push dph ; save dptr
push dpl ;
mov dptr, #crc16_tablo ; low part of table address
movc a, @a+dptr ; get low byte
xrl a, crc_hi ;
mov crc_lo, a ; save of low result
mov dptr, #crc16_tabhi ; high part of table address
mov a, tmp ; index
movc a, @a+dptr ;
mov crc_hi, a ; save high result
pop dpl ; restore pointer
pop dph ;
ret ; all done with calculation
```

MAXIM APPLICATION NOTES

Sample computation time calc. for 16 bit crc check:

Assumptions

4 Mhz clock (typ internal clock freq.)

4 clock cycles /instruction – typ for Microchip parts

4k of tactical code

15 instructions for 2 bytes of memory check

1 usec per intruction x 15 instructions x 4k/2 =

30 msec +

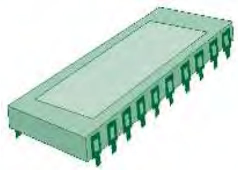
Note: A lookup table with crc values must be stored in memory for this program

Application of Memory Check in AMRDEC Small Organic Precision Munition ESA

- SOPM ESAD Safety Architectures makes use of a charged based device due to size constraints.
- Implementing CRC 16 verification of stored memory
  - Charged based device interfaces with dedicated discrete circuitry via two pins.
  - Compares expected hardwired known CRC bit-by-bit against device's memory.
  - Check occurs first, at power up.
  - Power shut down of the device occurs if:
    - Mis-match occurs
    - More than 16 bits are clocked out
    - Less than 16 bits are clocked in fixed time frame
- Active components includes a combination of shift registers, counters, and timers.
- Minimal board real estate impact.
  - Projected to be not more than 260 mm^2 or 0.4 in^2 of layout space.

Summary

- The FESWG Logic Devices tech manual has been updated to address use of charged based PLD's and include memory checking
  - Looking for feedback from the fuze industry
- More study of PLD's needed
  - Additional memory retention tests to increase confidence level
  - Develop an understanding of failure mechanisms and possible screening techniques
- Almost certainly new technologies will emerge that the fuze safety community will have to deal with



Today

PLD's

Tomorrow

???

Malcolm Baldrige National Quality Award 2007 Award Recipient

55th Annual NDIA Fuze Conference
May 25th, 2011

Evolving Requirements for the Use of Logic Devices in the Implementation of Safety Features
or
An Update to the DoD Fuze Engineering Standardization Working Group's (FESWG) Technical Manual for the use of Logic Devices in Safety Features

John D. Hughes
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Safe-Arm Development Branch, Code 478300D
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Disclaimer

- While some logic devices may be viewed as better suited for safety applications, it is important to note:
  - All logic devices can be implemented in an unsafe manner.
  - There are safety issues associated with the use of any type of logic device in safety critical applications.
  - Individual technologies may require additional measures not specifically addressed here.
- This presentation does not contain all the information found within the FESWG Tech Manual
- Presenter does not speak for the Safety Boards. Consult your Safety Authority for current requirements.

08 March 2011 Supersedes 16 July 2007

NEW

FESWG Document 2007-1

DoD FUZE ENGINEERING STANDARDIZATION WORKING GROUP

TECHNICAL MANUAL FOR THE USE OF LOGIC DEVICES IN SAFETY FEATURES

08 March 2011

DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited.

OLD

16-July-2007

DoD FUZE ENGINEERING STANDARDIZATION WORKING GROUP

TECHNICAL MANUAL FOR THE USE OF LOGIC DEVICES IN THE IMPLEMENTATION OF SAFETY FEATURES

16 July 2007

Page 1 of 8

Scope

- Increased use of logic devices in safety features has highlighted the need to address safety requirements in more detail.
- Document is intended to clarify the requirements of the current standards (MIL-STD-1316, MIL-STD-1911, MIL-STD-1901 and STANAG-4187, STANAG-4497, STANAG-4368) as applied to Safety Features implemented with logic devices.
- Logic Devices include programmable logic devices (PLDs), complex programmable logic devices (CPLDs), field programmable gate arrays (FPGAs), application specific integrated circuits (ASICs), microcontrollers, discrete logic, etc.
- Defines Appendix A (guidelines) and B (definitions)

Updated Requirements

2. OLD -> All logic devices used in the safety feature shall be non-reconfigurable.

2. NEW -> While fixed-in-structure devices are acceptable and preferred, to avoid degradation of a safety feature, any logic device used in the implementation of that feature:

   a. Shall not be re-programmable.

   b. Shall not be alterable by credible environments.

   c. Shall not have the SF logic configuration reside on volatile memory.

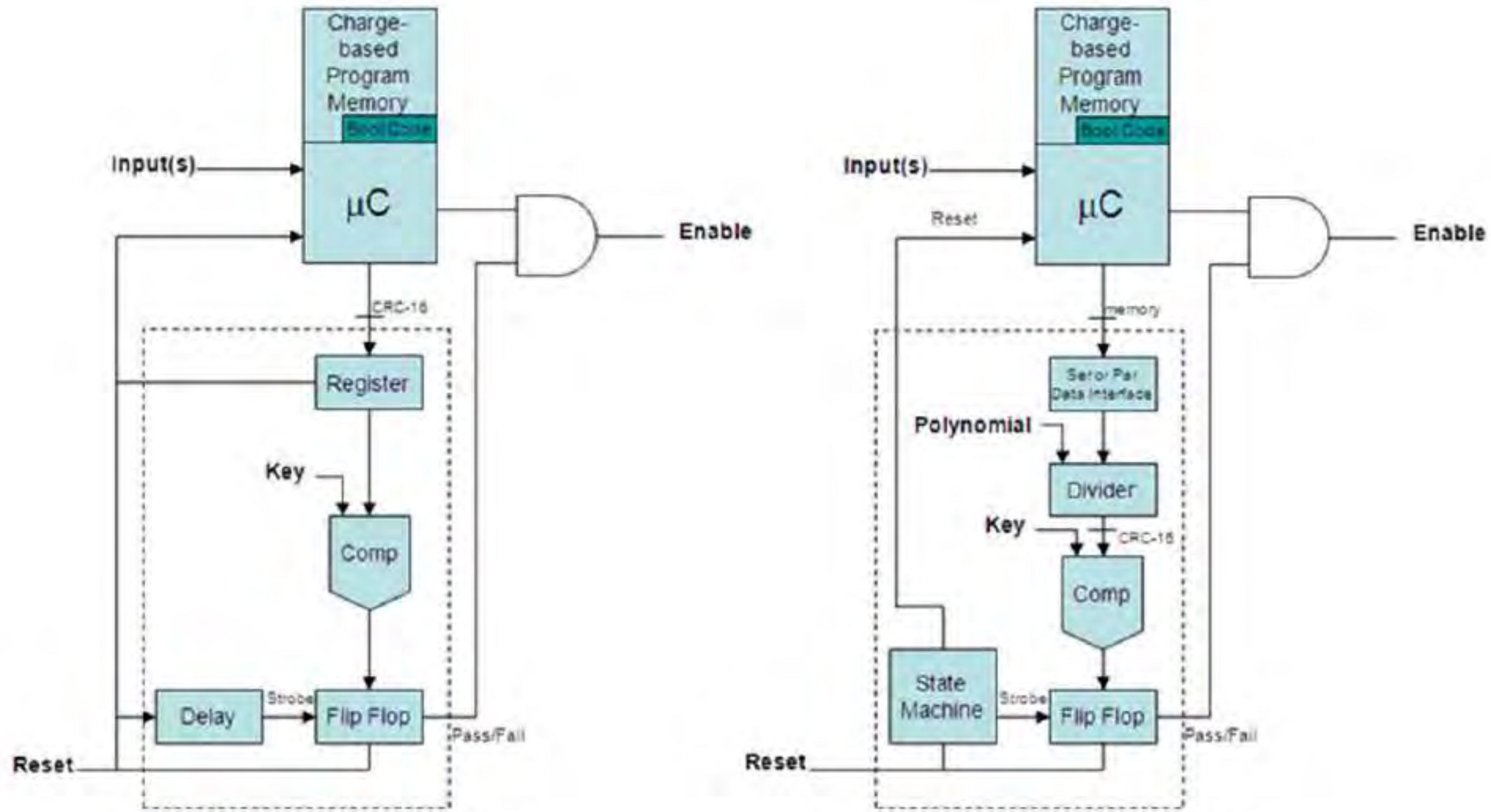
   d. Should be rated to meet or exceed the lifecycle environments of the system. Shall have engineering rationale provided and associated risk(s) for logic devices not rated to meet or exceed the lifecycle of the system.

Updated Requirements

2. Cont'd

- If charged based memory is used then following shall apply:
  - Memory validation shall be performed prior to safety function
  - Validation shall have minimum rigor of CRC16
  - Computed result shall be compared externally
  - External devices shall be dedicated, fixed-in-structure, and not contain and be exclusive from any other functions.
- Consult with the appropriate Service Safety Authority for guidance.

2. Cont'd - Notional example of memory validation:



Internal Memory Validation

External Memory Validation

Updated Requirements

5. During and after exposure to power transfers, transitions, and/or transients, logic devices shall not operate in a manner that results in degradation of SF.
   - Credible power environments (brown out, surge, spikes, etc) should not cause the loss of a safety feature.
   - Logic device power supplies need to be robust.
   - Includes reset functions [deleted reset function requirement #13 since it's covered here]

Updated Requirements

Separated arming delay (new #7) from timing functions

6. **Timing functions, excluding arming delay, within logic shall not be susceptible to single point or common cause failures resulting in early arming.**
   - Requires independent timing with dissimilar technology or verification of the clocks with a known timed event.

7. **Arming Delay single point and common cause failures shall be reduced to a minimum**
   - Failures shall exist only at or near the expiration of the intended arming delay
   - Independent timers preferred
   - Shortest arm delay set in hardware should be set to the maximum practical value
   - Transmissions and validations of arm times should be robust (checksum, parity, CRC)

Deleted Requirement

Covered by requirement #5 so verbiage added to A.5

13. Reset functions shall not be susceptible to single point or common cause failures that result in unsafe states.
   - Redundant resets with different implementations.
   - Logic device reset circuitry must be extremely robust.

Moved

Requirements

1. **Each Safety Feature (SF) implemented with logic shall use the least complex logic device that can practically perform the required functionality.**
   - Minimizes the subversion of SF(s) due to unintentional and/or unrecognized modes of operation, including failure modes.
   - KISS method.
   - Complex devices require more analysis, documentation, testing and more scrutiny by the safety authority.

No Change

Requirements

3. **Where all SFs are implemented with logic devices, at least two SFs shall be implemented with dissimilar logic devices.**
   - Minimizes the potential for common cause failures.
   - Where practical, at least one SF shall be implemented with discrete component(s).
   - Dissimilar logic refers to distinct methods and/or materials used to develop a particular device that result in devices with minimal common cause failures. Some examples include:
     - Full Custom ASIC
     - Discrete components
     - M2M FPGA
     - OnO FPGA
     - Microcontroller

No Change

Requirements

4. SF logic shall be implemented in accordance with the device manufacturer's latest specifications and notes.
   - Safety critical details could be buried within data sheets and/or footnotes.
   - Conflicts between manufacturer's specifications and other requirements shall be reviewed and approved by the safety authority.
   - All programming functionality, testing functionality, used pins, and any other non-operational functionality shall be appropriately disabled and terminated.

No Change

Requirements

8. (OLD #7) Logic implementation shall replicate the documented design.
   – Ensures the intended design is actually implemented.
   – No optimizations or changes to an approved design.
   – Know your design tools.

No Change

9. (OLD #8) Where all SFs are implemented with logic devices, the SF logic shall be physically and functionally partitioned from each other.
   – Minimizes the potential for inadvertent subversion such as sneak paths or Single Event Upsets.

Requirements

10. (OLD #9) All logic and/or functionality available within a device shall be disclosed, documented, and assessed in safety analyses and evaluations.
    - Undocumented functions within a SF can compromise the safety of the design and is unacceptable.
11. (OLD #10) SF documentation shall include the complete logic flow with all inputs and output defined, along with timing and interdependence of events.
    - Assists with design understanding and verification.

No Change

Requirements

12. (OLD #11) Manufacturing documentation and processes shall ensure that logic devices within an approved design are produced with an identical configuration.
    - Assures logic devices are reproduced consistently throughout production.

No Change

13. (OLD #12) Development tools shall be documented and controlled via configuration management procedures.
    - Assures logic devices configuration matches the intended design.
    - Know your tools and document them.

Requirements

14. Power for SF logic should be partitioned from other power such as communication or platform power.
    – Minimizes subversion of a safety feature

15. Power for SF logic should be applied as late in the launch sequence or operational deployment as practical.
    – ESAD without power = SAFE

No Change

- A copy of the technical manual may be obtained via mail from the following:

Chairman

DOD Fuze Engineering Standardization Working Group

U.S. Army Armament Research, Development and Engineering Center

ATTN: RDAR-MEF-F

Picatinny Arsenal, NJ 07806-5000

Questions???

Comments??

Universal Fuze Monitoring Test System (UFMTS)

55th Annual NDIA Fuze Conference

Jason Koonts
NSWCDD, Computer Engineer
(540) 284-0179
jason.koonts@navy.mil

Agenda

- Background
- System Upgrade
- Increased Functionality/Benefits
- Summary

What is the UFMTS?

- Universal Fuze Monitoring Test System (UFMTS)
- Hardware and software suite
  - Agilent VEE Graphical Programming Language
  - Various instruments
    - Oscilloscope, Spectrum Analyzer, Power Supplies, etc.
  - Custom hardware
    - Interface to various fuzes
    - Junction Box
- Allows for testing Navy NATO standard fuzes in one comprehensive system
- Main application is ordnance assessment

Project History

- Initial purpose of hardware was to serve as MK419 Multi-Function Fuze (MFF) tester at NSWC Crane
- Crane utilized hardware to turn system into MK432 fuze tester
- Dahlgren was provided funding independently to develop test set for MK437 Multi-Option Fuze for Navy (MOFN) in FY05
  - Decided to leverage Crane's MK432 tester to have one hardware suite capable of testing both fuzes
- Hardware shipped to Dahlgren for full integration of MOFN into software suite
  - MK432 testing not perfected
- New MFF production lot being built and no current testing capability at Dahlgren
  - Funding provided to incorporate MFF capability into MK437 and MK432 test set in FY09 (creates UFMTS)
- Design from an Ordnance Assessment (OA) perspective
  - Speed and efficiency
  - Minimal operator interference

Legacy System

- Fuze setting station and testing station
  – Very slow to set and then test each fuze
  – Separate desktop PCs for setting the fuze and running the tests
  – Two computers used increases complexity
- Code not designed for Ordnance Assessment
  – Poor operator interaction and data reporting
- Very buggy code!

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Upgraded System

- Design and code the system for an OA application
  - Minimal operator interaction
  - Fast testing algorithms
  - Efficient, clean data reporting
- Hardware modifications
  - Remove or replace obsolete components
  - Evaluate all devices in the system
  - RF range simulator upgrade

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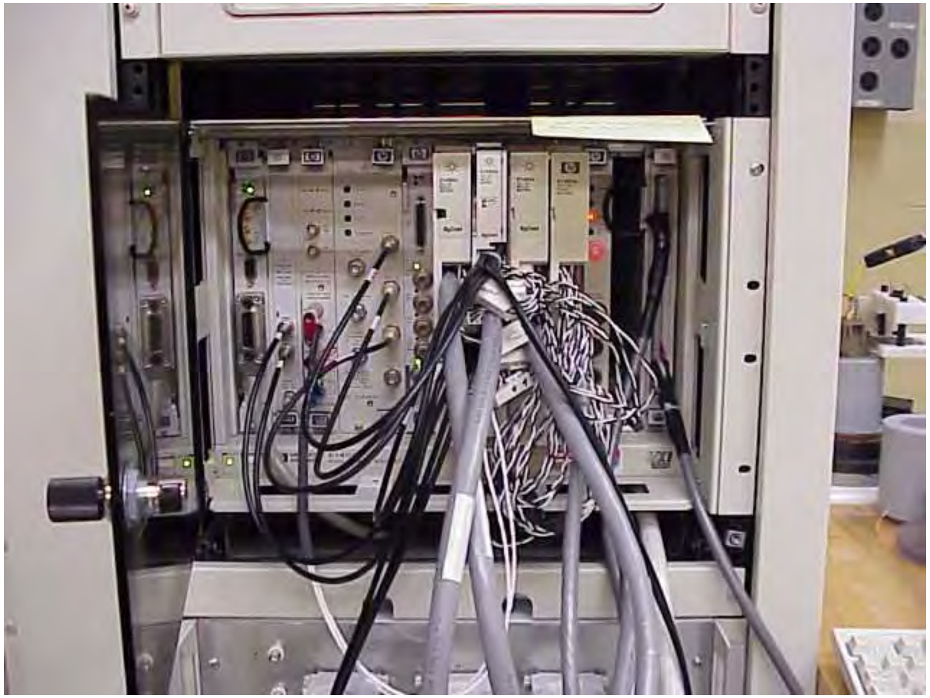
RF Range Simulator Upgrade

- RF Range Simulator (RFRS) incorporated into test system
  - Built by Electronic Development Corporation
  - Allows for proximity mode and RF testing
  - Simulates surface and air encounters
- EDC offered significant hardware and software changes to increase functionality of the instrument

Hardware Changes



Original Wiring

Neat and Tidy

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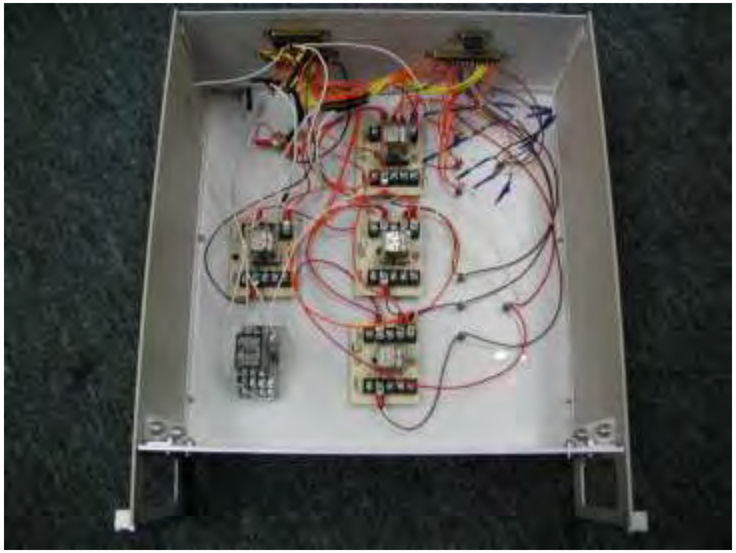
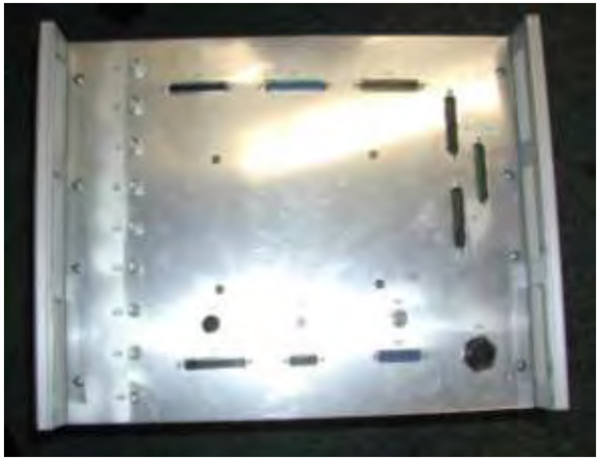
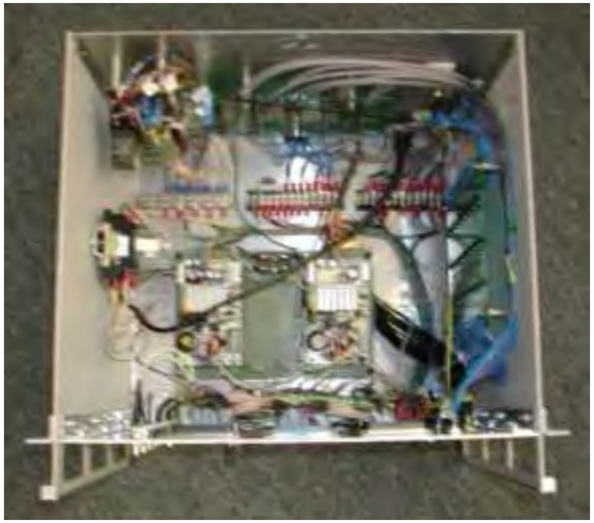
Original Custom Boxes







Interface Box

Junction Box

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Junction Box

- J-Box
  - 2U unit (could easily have been 1U)
    - Could take up much less room, smallest box we could find
  - Performs all necessary switching to connect test points from all three fuzes to all of the instrumentation
  - Provides spin switch closure for time zero of MK432, level shifting for MK419, crush switch emulation for PD functionality of MK419 and MK437, and multiple det resistances for minimum and maximum spec values across all three fuzes

Instrumentation

- Using one computer for fuze setting and the test program
- Shrank system from two full side by side racks to one rack with room to spare
- Added a counter to increase functionality
  - Necessary for MOFN testing
- Removed and replaced obsolete components
  - i.e. VXI Oscilloscope card was broken
- Only need two Relay Matrix Switches and one Relay Driver Module
  - Down from 4 relay matrix switches and two relay drivers
- Large instrumentation set to allow for future capability
  - Relay matrix switch has open channels
  - Fuze interface cable is not utilizing all pins

Fuze Connection and Interface

- One shared cable using military connectors for reliability and ruggedness
- Interfaces designed in house
  - Minimal time required for swapping fuzes
  - Cores easily interchanged to switch among the three fuzes
- Modular interface design is vast improvement over original approach

Increased Functionality/Benefits

MK432 MK437 MK419

- One comprehensive instrumentation and software set capable of setting and testing all Navy NATO standard Electronically settable fuzes
- MFF Test time decreased from ~6 minutes to 90 seconds
  - Working with contractor to realize part of this time savings on their tester

In Summary

- Original system only capable of testing MK432
  - Outdated hardware and software requiring work
- Requirements analysis to trim system and remove unnecessary, broken, or obsolete hardware
- Custom PCB designed to allow switching among and testing three Navy electronically settable fuzes
  - MK432, MK437, MK419
- RFRS upgrade increased functionality for proximity and RF testing
- Ability to expand for addition of new hardware and fuzes to be tested

Questions?

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

Pyro-MEMS ®
Technological breakthrough in fuze domain

Fuze Conference 2011

Renaud Lafont

Salt Lake City, UT

24th of May 2011

Approuved for public release

Content

1. NEXTER Munitions Fuze activities
2. Design & Demonstration of 25mm Airburst ammunition Mk I
3. Design & Demonstration of 40mm Airburst Fuze Mk I
4. Pyro-MEMS ® for ammunition Mk II

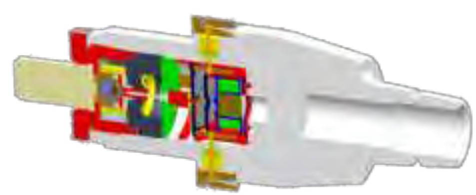
1. NEXTER Munitions Fuze activities

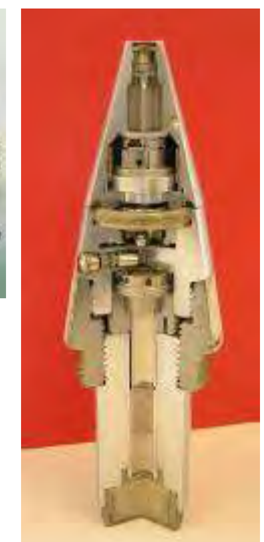
NMu: Fuzing System manufacturer

Products: Fuzing system & SAU for missile, tank ammunition (120, 100, 90 mm caliber), naval artillery (100mm caliber) and medium caliber (40, 30 and 25 mm caliber).

Strengthes:

- Pyrotechnical components manufacturer (primary & secondary explosive)
- Own proving ground, recovery system and data recorder
- Designer of the complete munition





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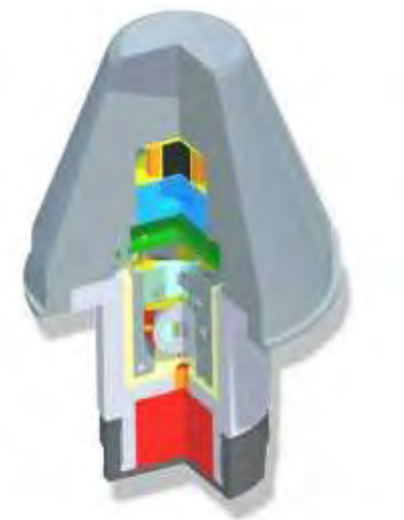
NMu: Fuzing System designer



Applications:

- ▶ Airbursting ammunition
- ▶ Opto-Pyro
- ▶ Low Energy EFI
- ▶ Pyro-MEMS
- ▶ Course Correction fuze **(cooperation with JUNGHANS Microtec)**

Strengthes:

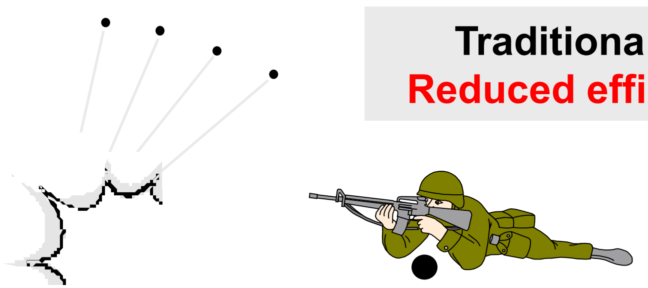
- ▶ Modelisation
- ▶ Data recorder
- ▶ Own proving ground (static, pyrotechnics, dynamic)
- ▶ Same group than weapon system designer (NEXTER Systems)

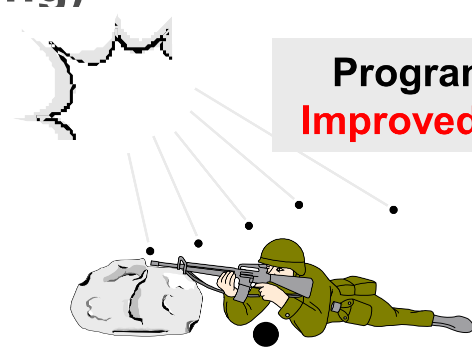
1. **Design & Demonstration of 25mm Airburst ammunition-Mk I**

Contract n°05.50.208 – Improvements of medium calibre ammunition

Aims of the study

- Airburst has to be initiated above the target with an accuracy of 1 m at 1000 m
- Airburst mode shall be compliant with the maximal range of the 25, 30 and 40 mm weapons
- Impact mode available
- Compliance with STANAG 4187
- Airburst Fuze Programming Unit shall be able to equip existing weapons systems (upgrading)





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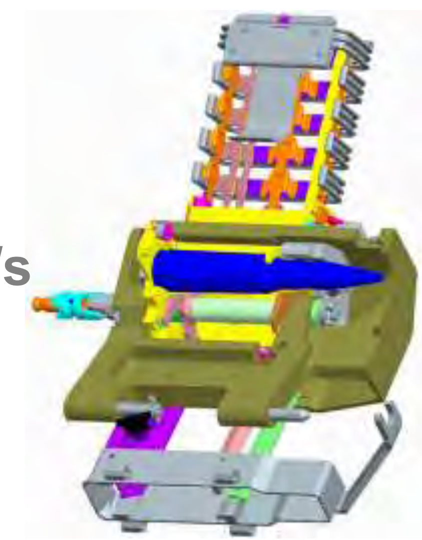
25 HEI AB Mk I

- **Programming Unit**
  - Inductive coil (Mode + Chronometry)
  - Impact mode remains available without programming unit
- **Operational modes**
  - Airburst +PD +Self-destruct
- **Airburst performances**
  - Chronometry : **+/- 0.5ms**
- **Environment conditions :**
  - Medium calibre 25x137 : 100 000 g 1000rd/s



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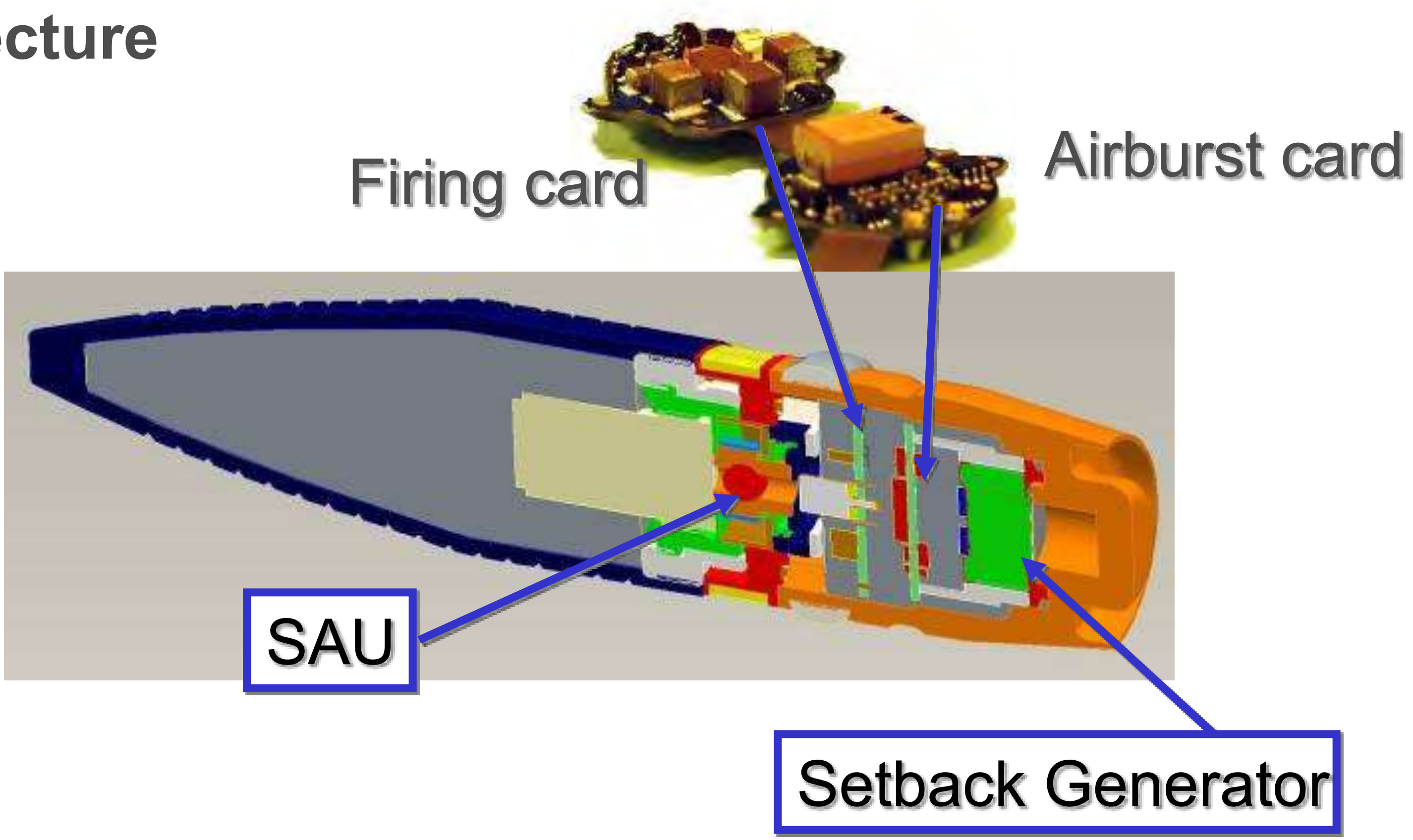
25 HEI AB Mk I

▶ Architecture



Electronics and SAU designs are deeply fitted into each other during engineering process.

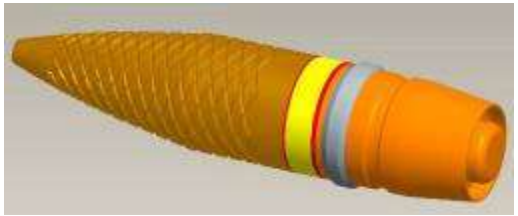
25 HEI AB Mk I

▶Architecture

HEIT

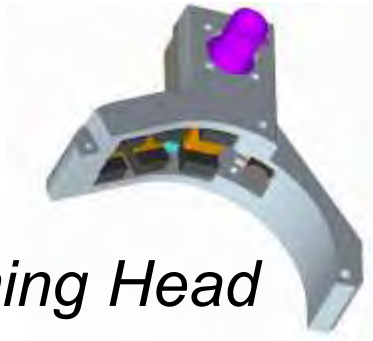
HEI-AB

Same shape + Same mass
=Equivalent ballistics



Programming coil

- Induction programming
- The ammunition are programmed before entering in gun chamber
- Programming time about 65ms
- Weapon cycle: 150ms (firing rate 400 rds/mn)



Programming Head

Approuved for public release

25 HEI AB Mk I

▶ Firing evaluation

Airburst mode

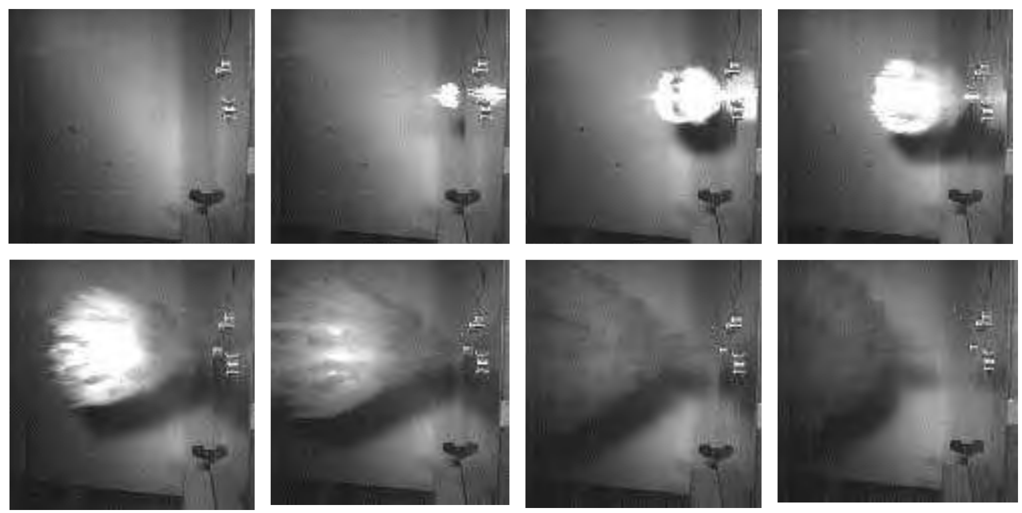
-single shot

-Burst

Functioning @ 100m

Impact mode (spotting charge)

Functioning @ 100m



1. Demonstration and development of Nexter 40CTA Airburst sub-system -Mk I

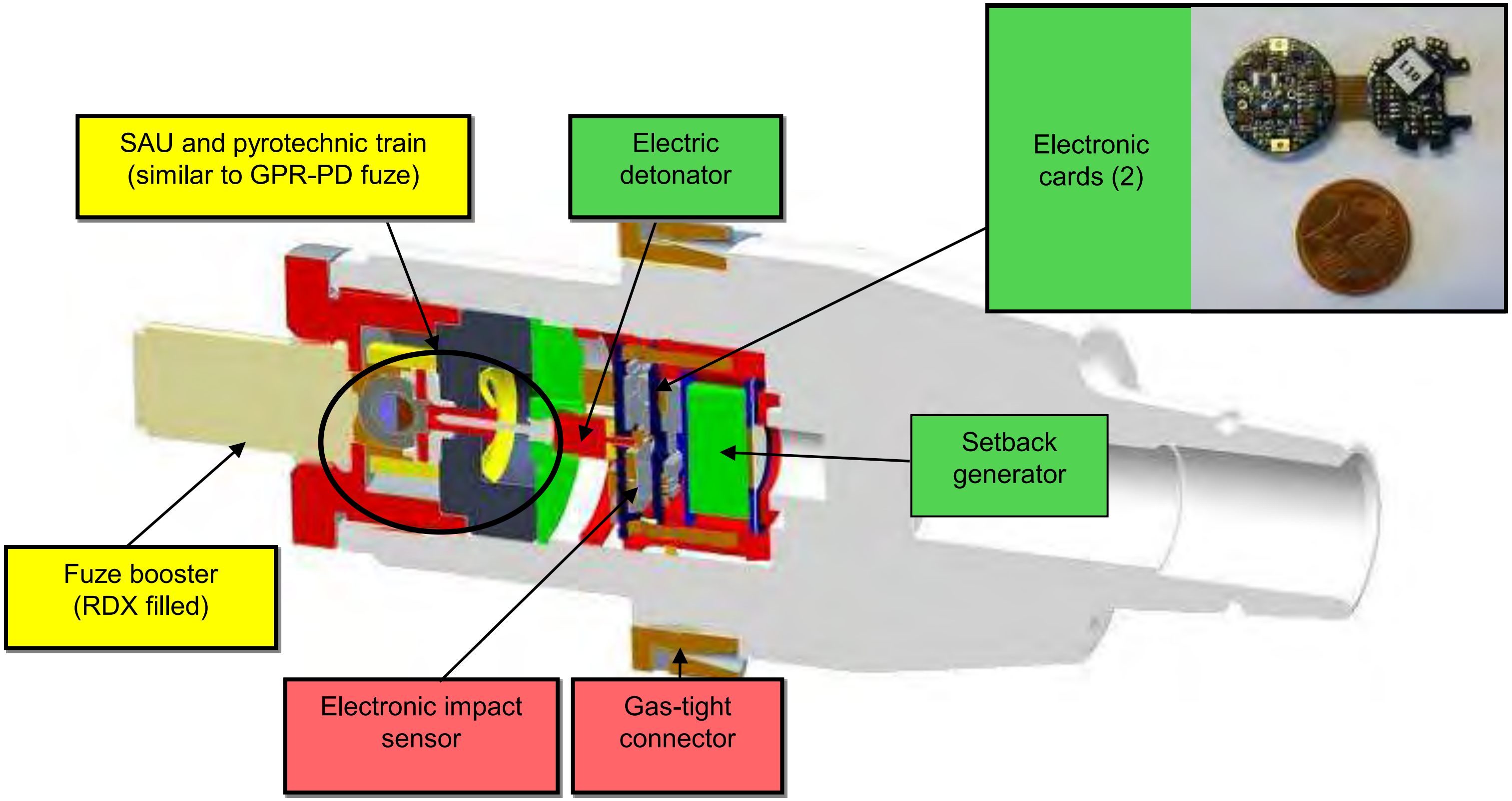
NEXTER MUNITIONS

Nexter 40CTA Airburst sub-system

Nexter Munitions proposal

- A two stages fuze :
  - Mechanical SAU : low risk design validated with 30x150 Rafale and GPR-PD ammunition fuze for safety and STANAG 4187 compliance,
  - Electronic unit with :
    - Two electronic boards including Airburst, Point Detonating, Self Destruction functions,
    - A setback generator integrated in the fuze : electrical energy on-board generation for the pyrotechnic train electric initiator
- A fuze setter :
  - Compact and tunable design compliant with the weapon mechanical interfaces and current cartridge programming coil

Nexter Munitions 40CTA Airburst Fuze



Nexter 40CTA Airburst Fuze (1)

Main features :

- **Three modes fuze, electronically driven**
  - **Impact mode delay,**
  - **Impact mode quick**
  - **Airburst mode**
- **Safety (mechanically driven, compliant with Stanag)**
  - **Storage**
  - **Handling**
  - **Firing phase**
  - **Muzzle safety**
- **Self-destruction time, two options**

Nexter 40CTA Airburst Fuze (2)

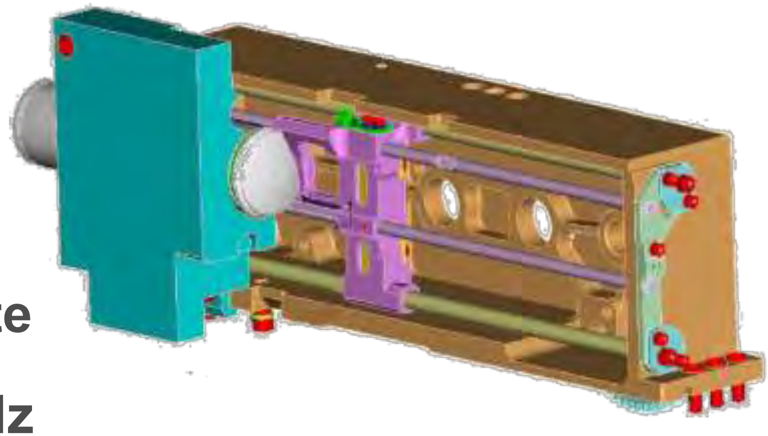
Main features :

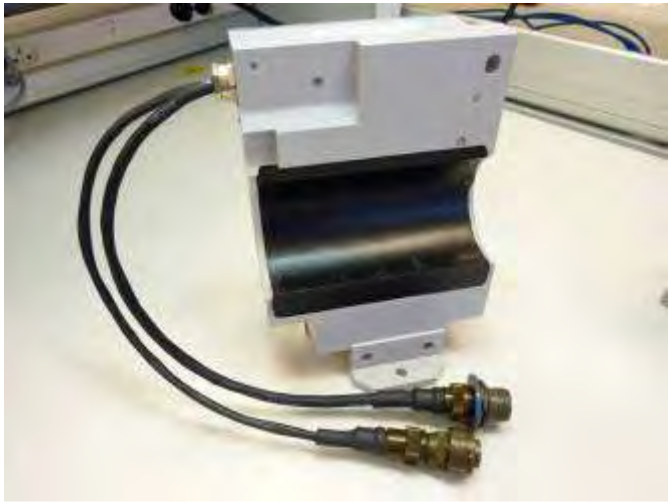
- **Safety**
  - **If fizzle occurs, there is no on-board energy after 10 s : ammunition is then totally safe for handling ,**
  - **Self-destruction is independent of programmation,**
  - **The energy for pyrotechnic train is given by setback generator : the low level of energy transmitted by Fuze Setter is not compliant with electric detonator initiation,**
  - **Default mode : point detonating (if no signal transferred or false programming message),**
  - **No functioning of the fuze against thin aluminium plate**

Nexter 40CTA Airburst Fuze setter

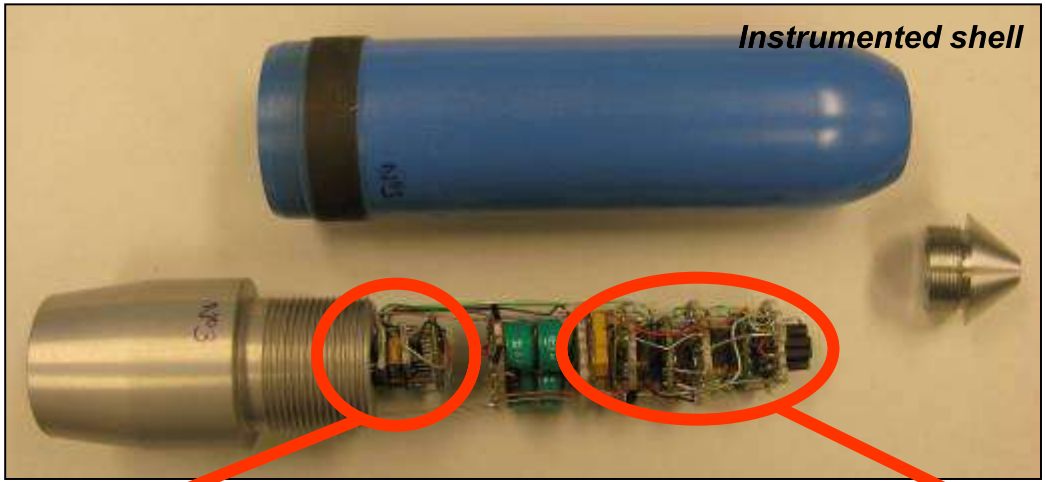
Main features :

- Magnetic head
- Programming phase duration compliant with maximal firing rate
- Programming frequency : 100 kHz
- Firing in CTA Weapon with FS : more than 400 firings





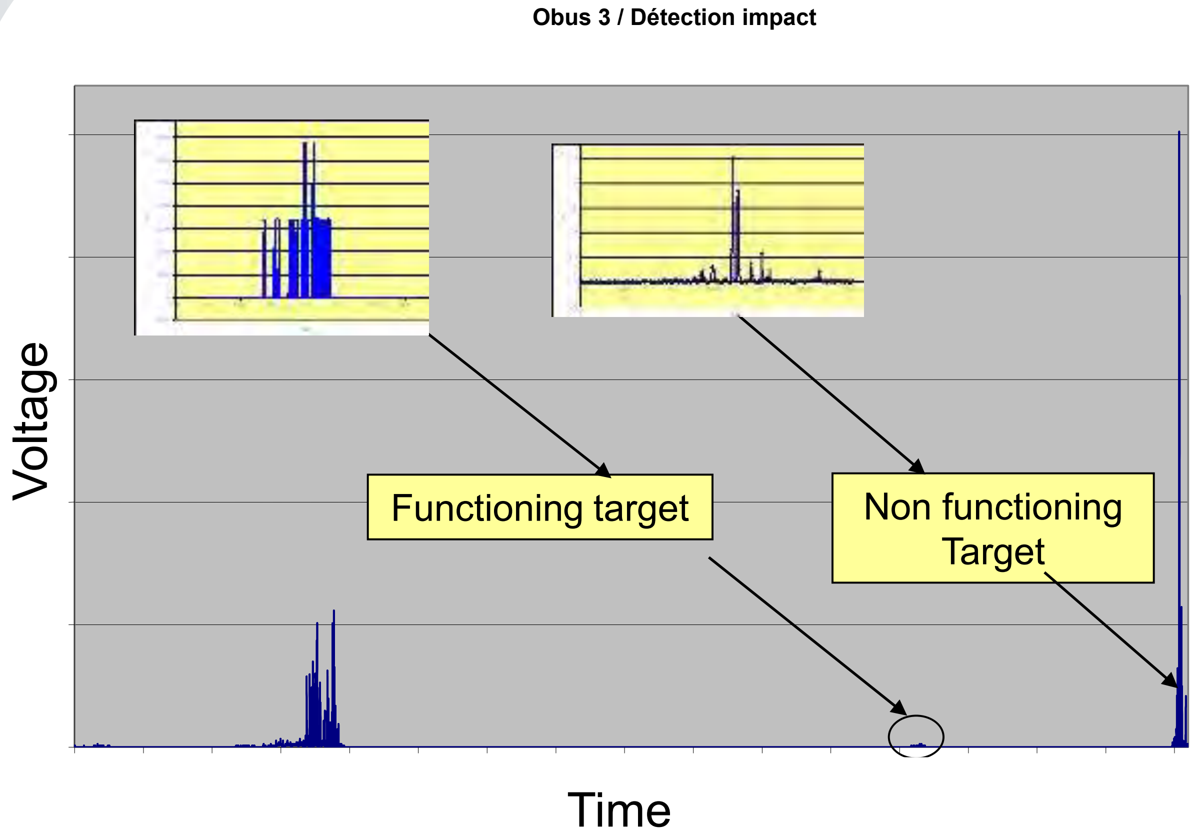
Embedded Instrumentation



Instrumented functions
(Impact detection + setback generator)

Instrumentation
(Battery / recorder / Interfaces)

Impact Detection



Analysis :

- Very high sensibility of the detector
- Détecteur
- Detection of a target with thin aluminium plate
- Detection of the specified target
- Tested successfully on others targets types

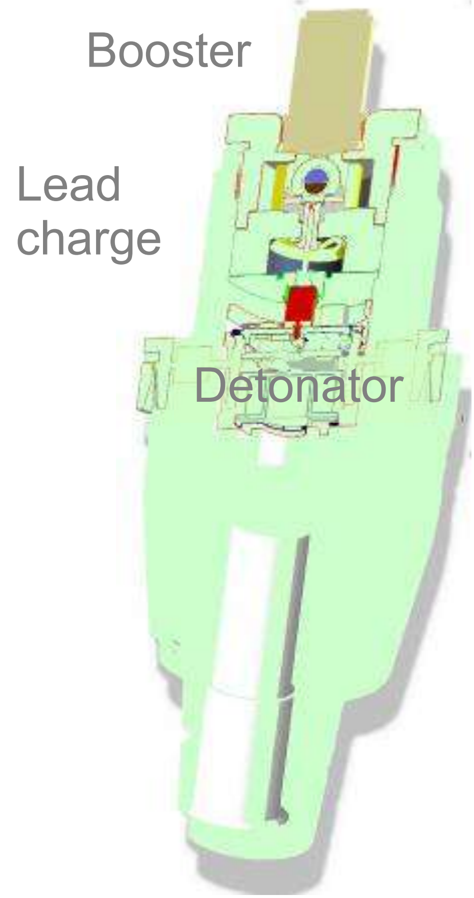
Pyrotechnic fire train

Normal functionning :

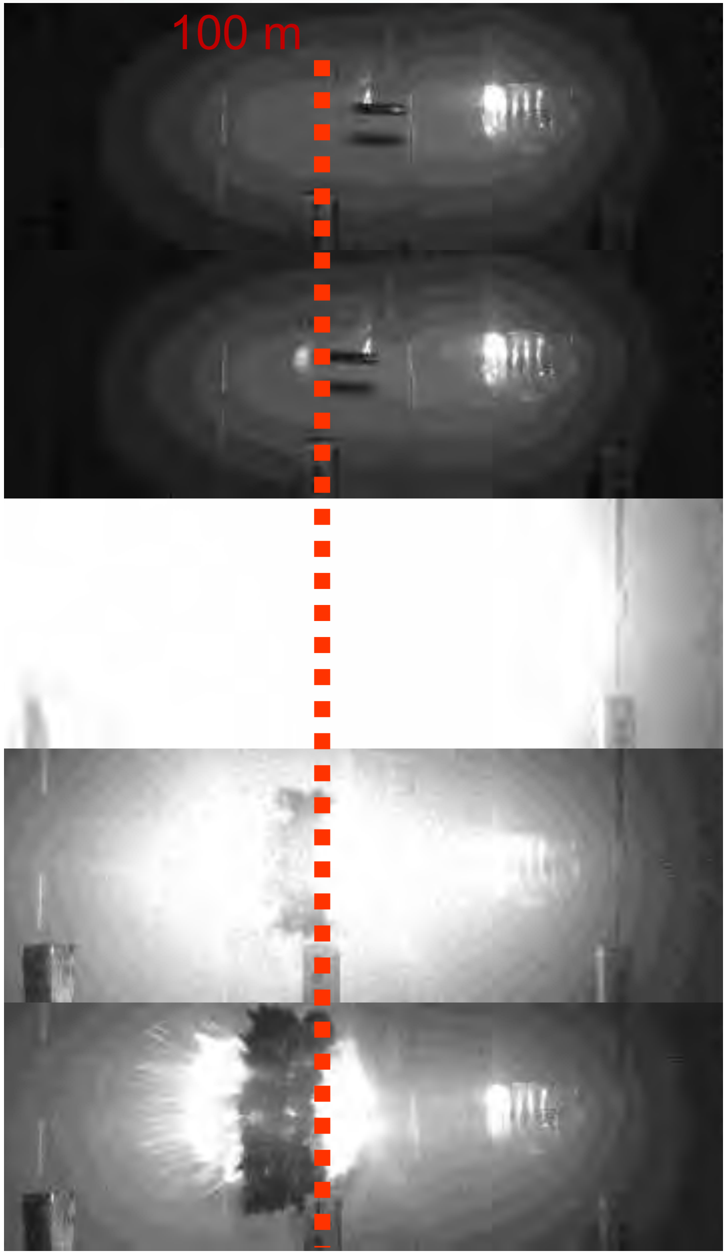
- **Transmission : 16 functioning on 16 trials**

Hardened tests:

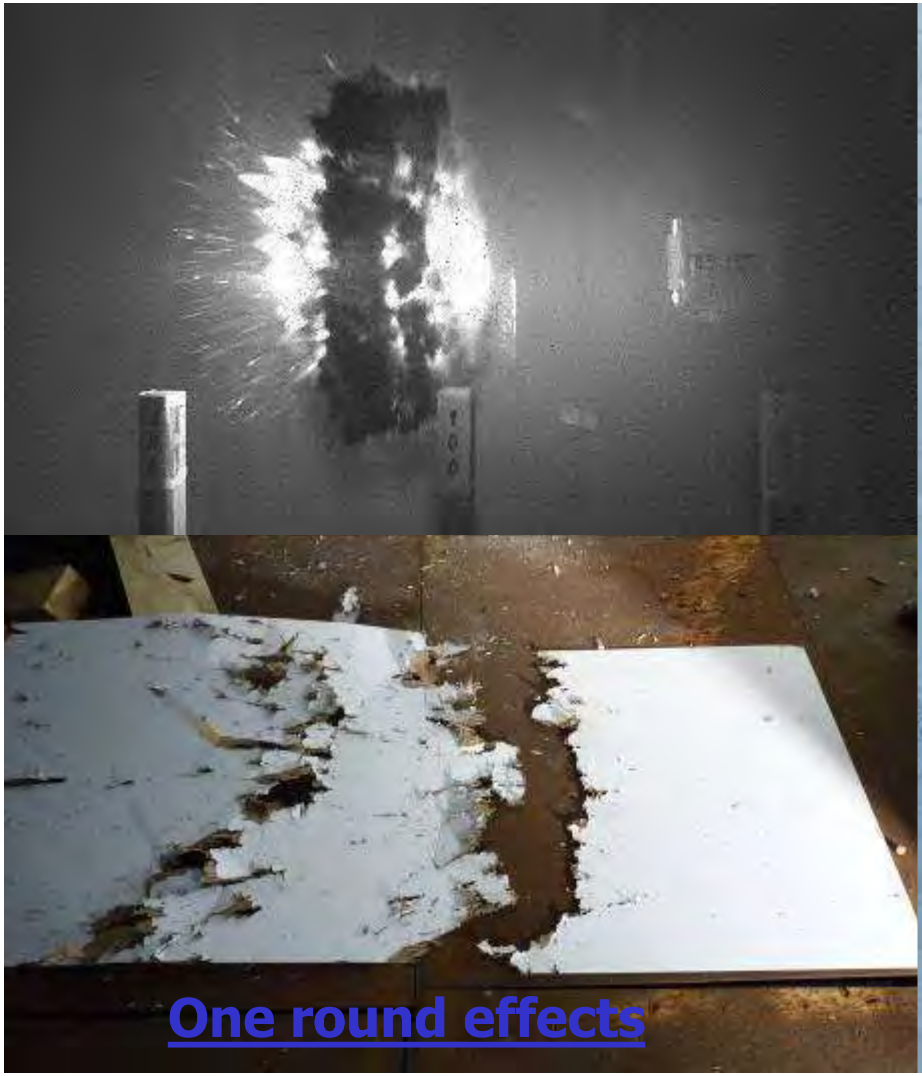
- **Transmission :**
  - Temperature tests (-46°C et +63°C)
  - Hardened factor : filling of the detonator.
- **No-transmission:**
  - Temperature tests(-46°C et +71°C),
  - Hardened factor : increase of booster sensibility.

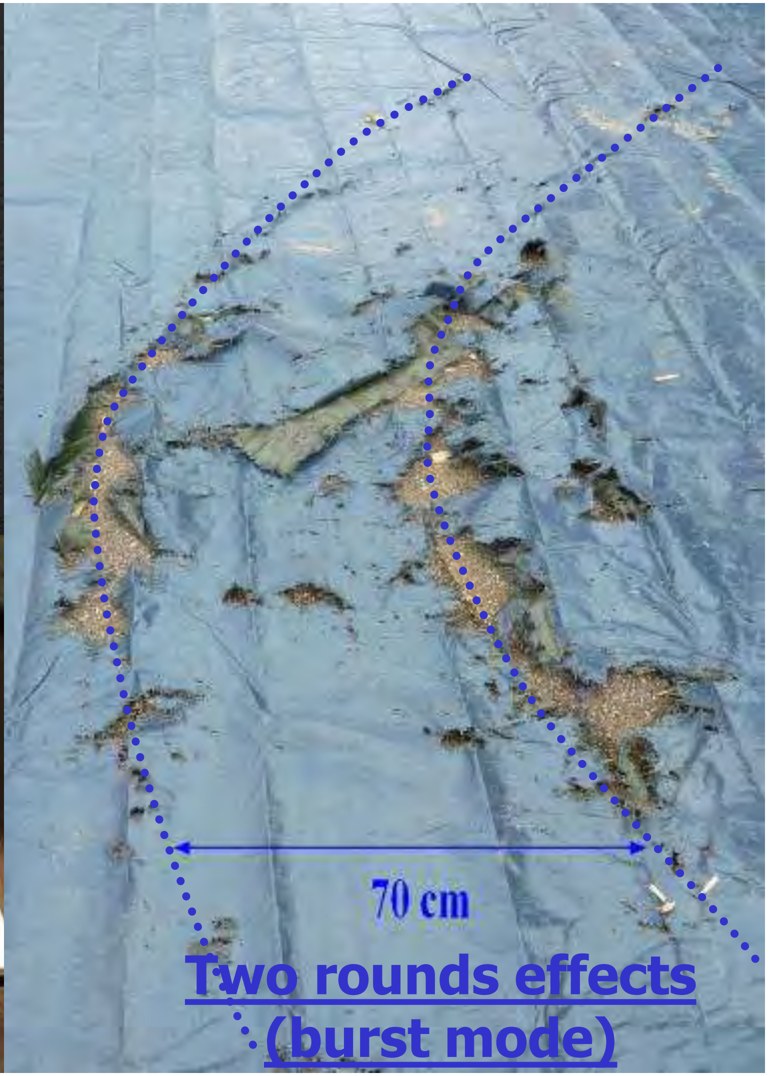


Airburst accuracy

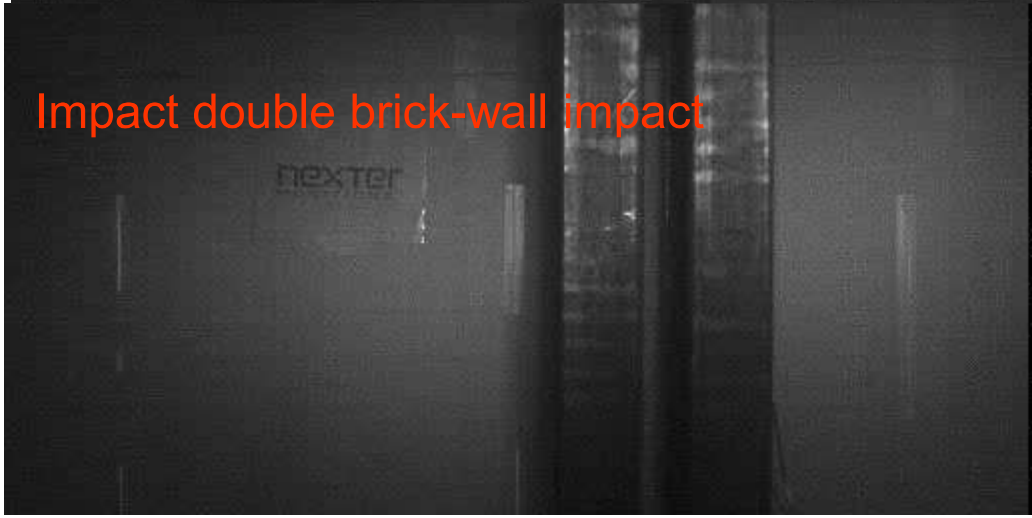


Airburst accuracy





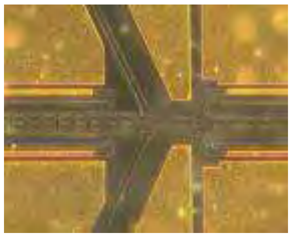
Warhead effects



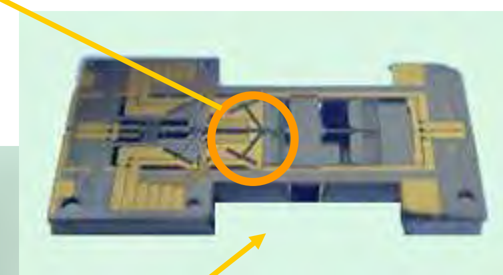
1. Pyro-MEMS®

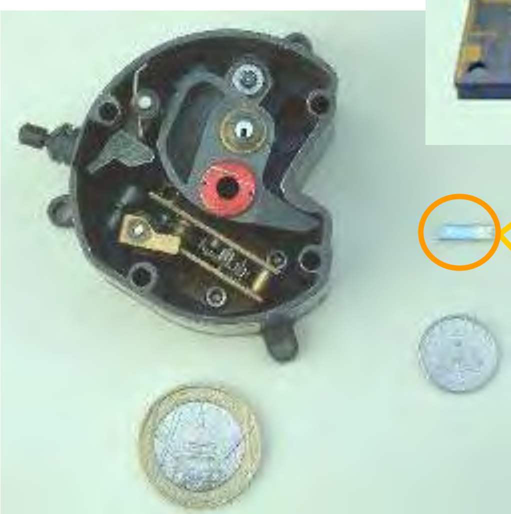
- **Preliminary study of µSAU**
- **System level test: Warhead functioning demonstration**
- **Preliminary study of medium caliber MEMS based SAU**

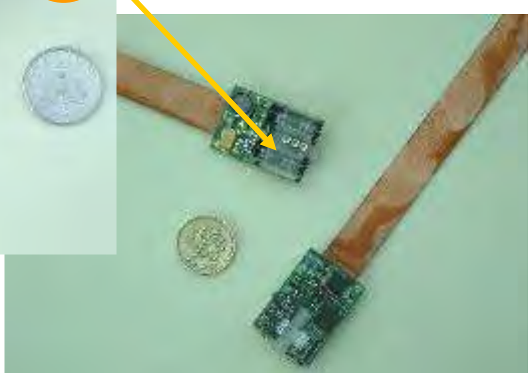
Contract 03.04.078 – Demonstration of miniaturized SAU



Pyro-MEMS: Merging of mechanics, electronics & pyrotechnics







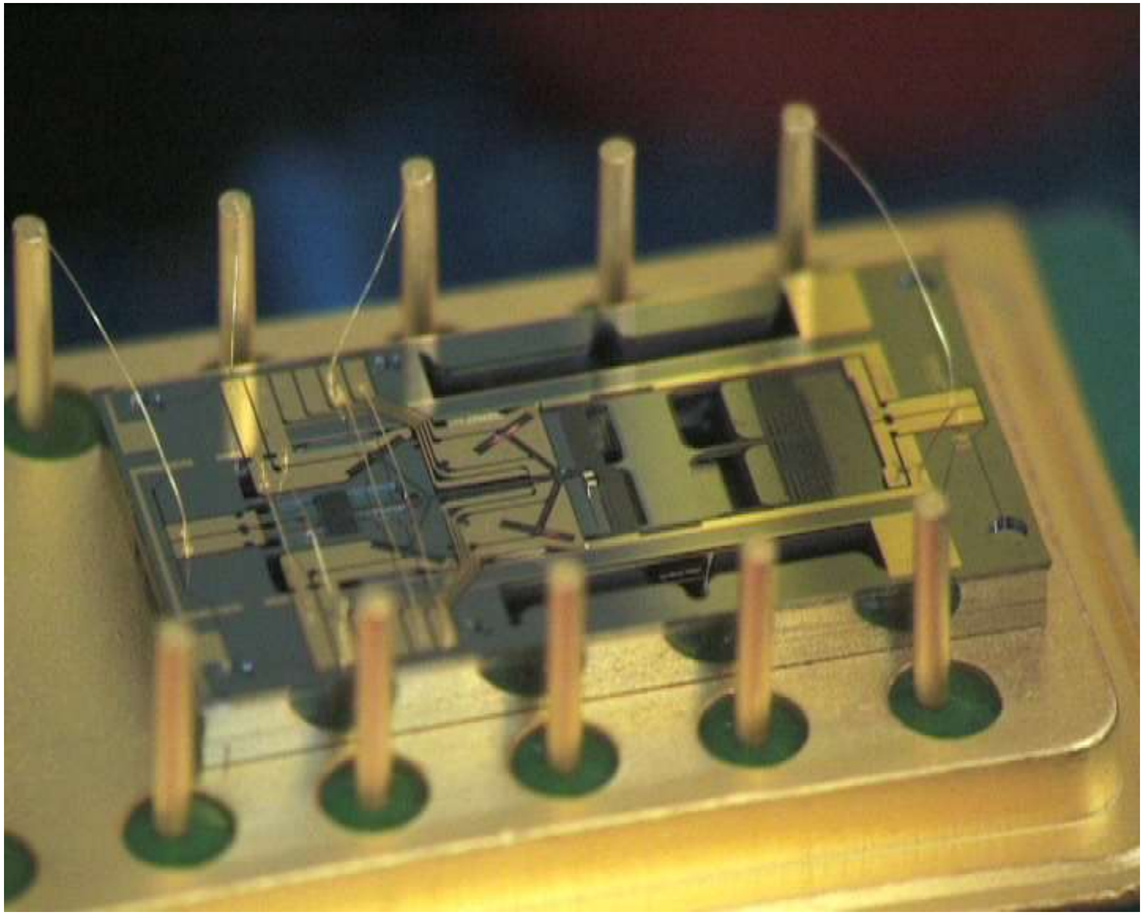
The Step Forward

03/2007 – delivery of 10 µ-SAU

Requirement

- Pyrotechnical safety managed by electronically controlled MEMS
- Volume less than 2 cm^3
- In accordance with STANAG 4187 (last edition)
- Ignition of EIDS
- Low cost
- Generic SAU

Arming ability and reversibility

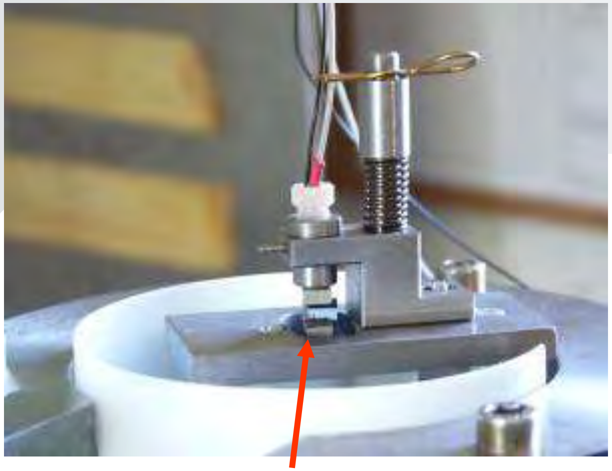


Approuved for public release

1. Pyro-MEMS®

- Preliminary study of µSAU
- System level test: Warhead functioning demonstration
- Preliminary study of medium caliber MEMS based SAU

Demonstration µSAU PyroMEMS® and in service missile warhead



MEMS

Missile warhead

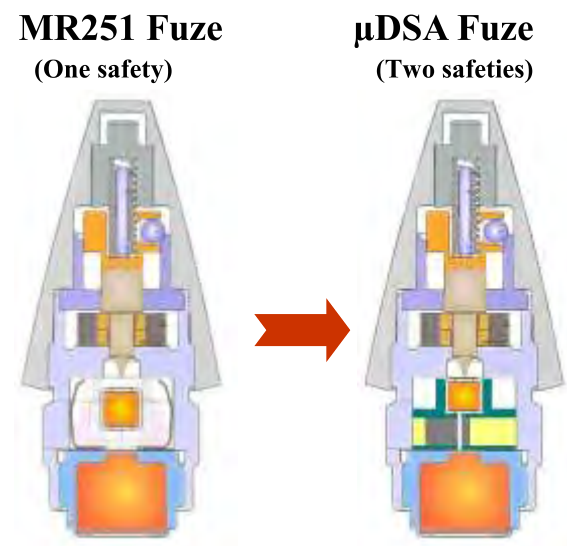
Two succesful firings of warhead (transmission and interruption)

Firing train for missile warhead OK

Approuved for public release

1. Pyro-MEMS®

- Preliminary study of µSAU
- System level test: Warhead functioning demonstration
- **Preliminary study of medium caliber MEMS based SAU**

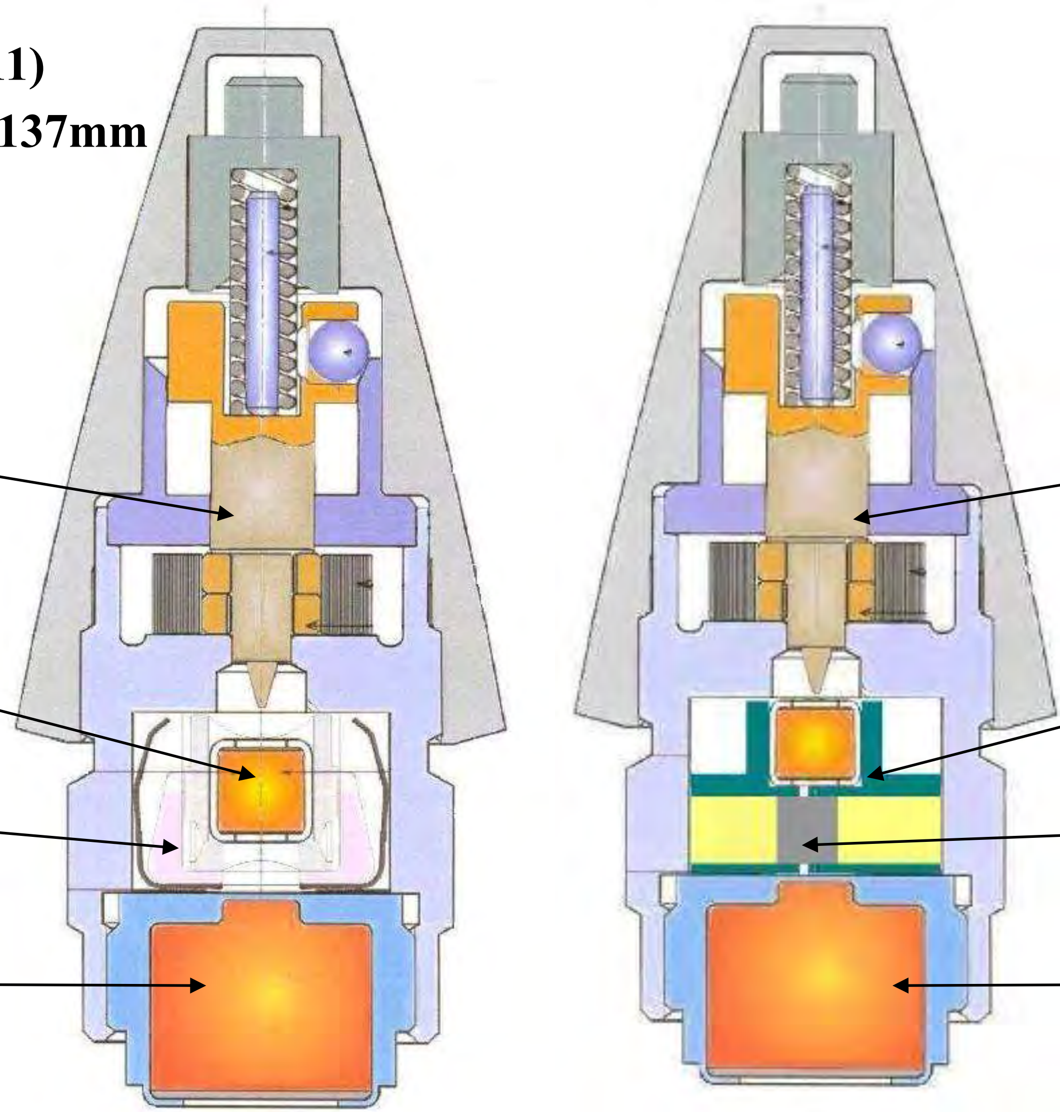


Two safeties fuzing system

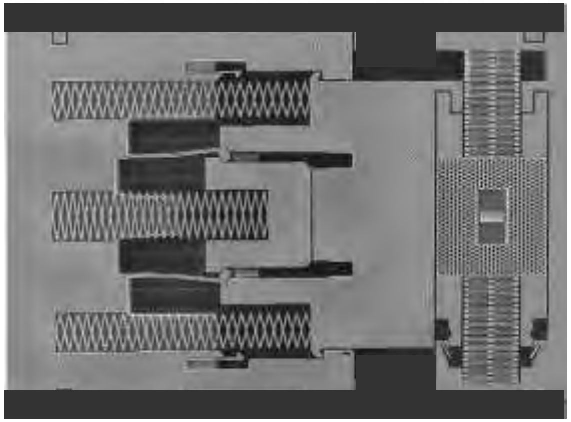
VBCI (25M811)
Munition 25x137mm

MR251 Fuze
(one safety)

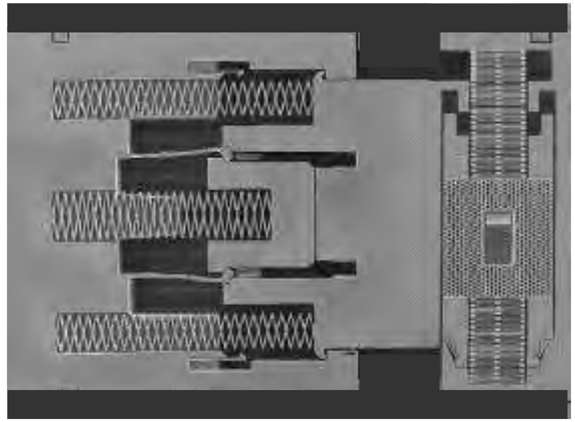
µSAU Fuze
(two safeties)



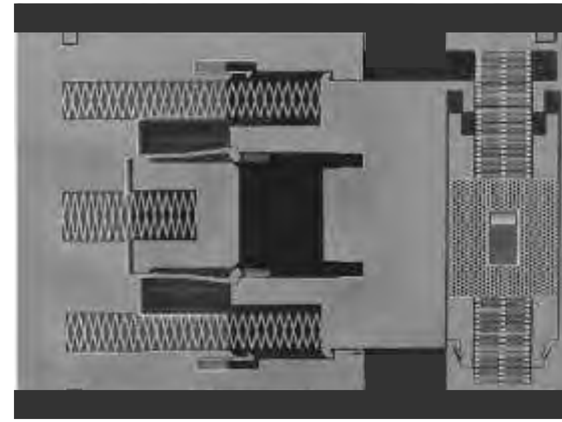
Focus on MEMS elements



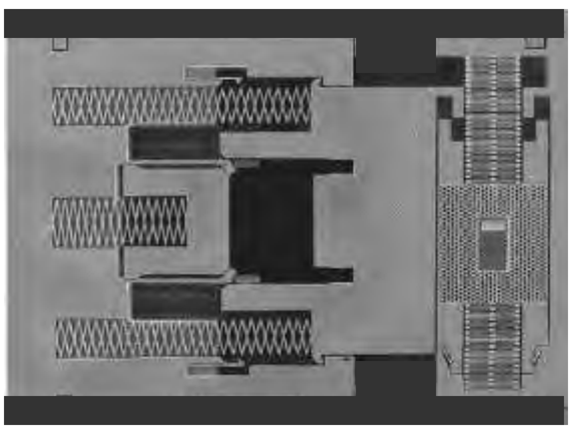
MEMS in safe position



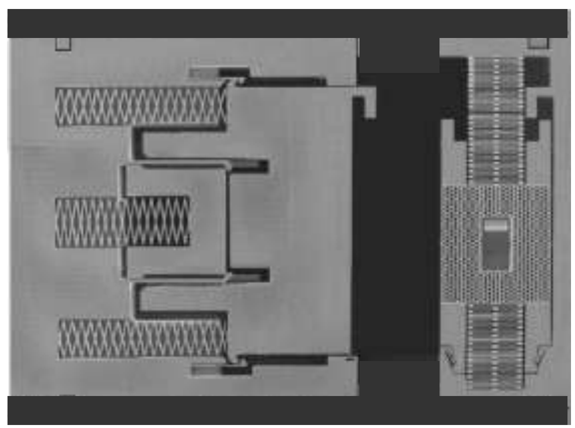
Axial satety unlocked



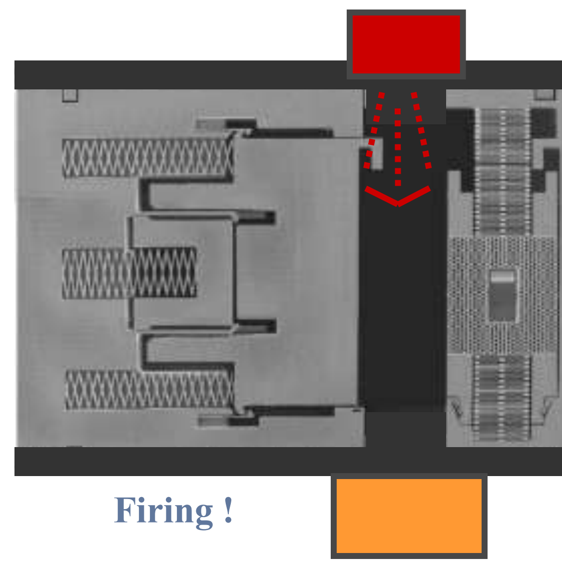
Progressive motion of the centrifugal safety



Unlocking of the shutter



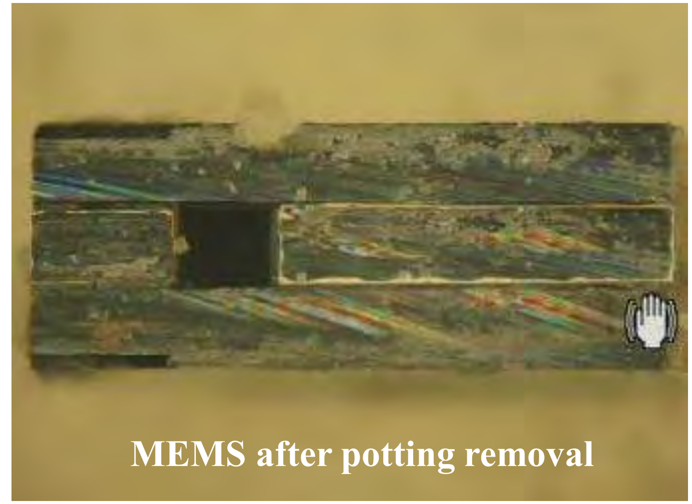
MEMS in in-line position



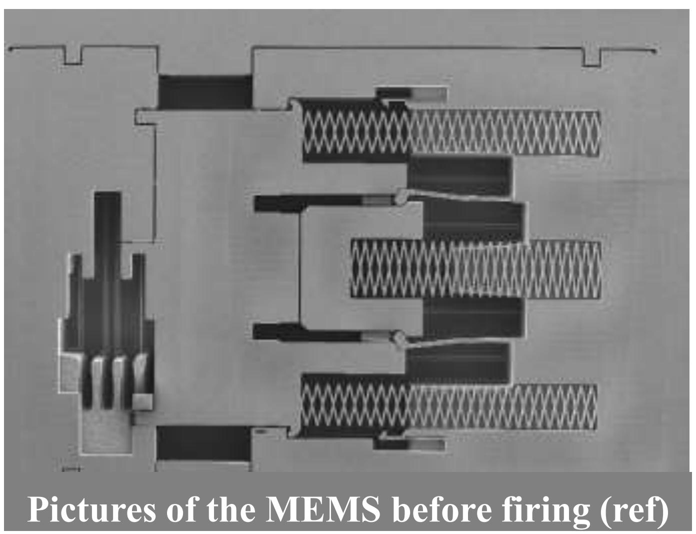
Firing !

High-G levels assessment

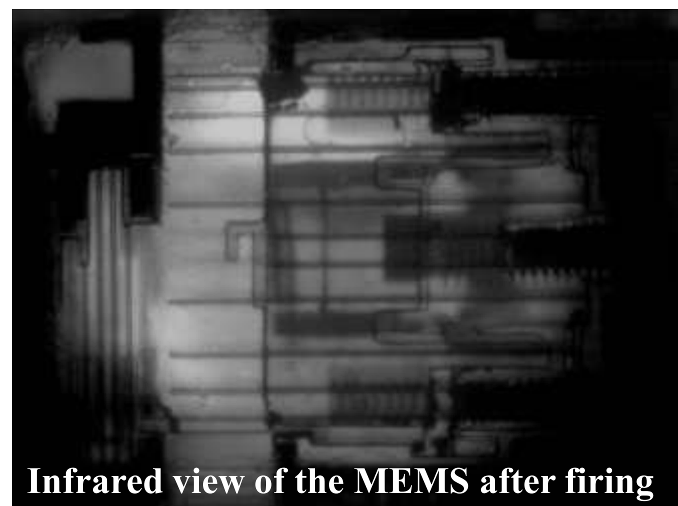
Carrier shell after firing



MEMS after potting removal



Pictures of the MEMS before firing (ref)



Infrared view of the MEMS after firing

PyroMEMS® advantages for MK II

- Replacement of obsolete mechanical timer
- Innovation able to reduce the product price
- New step in the SAU miniaturization
- Better ammunition performances: 2nd safety
- Better safety performances
- MEMS technology is now mature and largely diffused (products and processes)
- A lot of application in ammunition domain (medium and large caliber, missiles, adjustable warheads) and in spatial domain (pyromechanisms) based on a generic component.

Thank you for your attention

SAND2011-3603C

Ceramic Capacitor Failures and Lessons Learned

Presented to the 55th Annual NDIA Fuze Conference
Salt Lake City, UT

Patrick O'Malley and Darren Wang
Dept. 2627

Henry Duong, Anh Lai and Zachary Zelle
Dept. 0416

May 25, 2011

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
for the United States Department of Energy's National Nuclear Security Administration
under contract DE-AC04-94AL85000.

Unclassified Unlimited Release

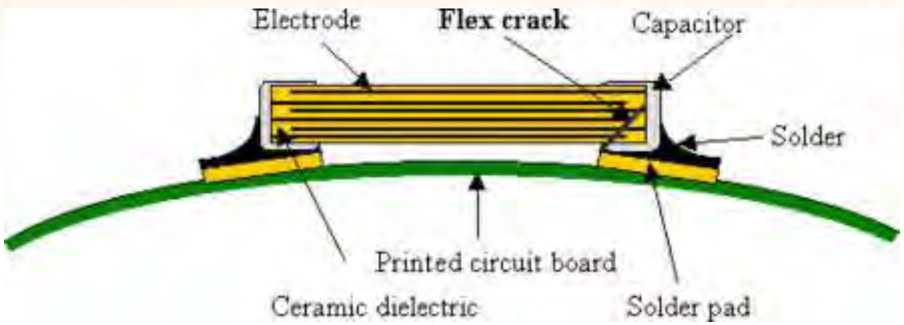
Sandia National Laboratories

Sandia's Capacitor Experiences in FY10

- Sandia had two projects in FY10 that involved damage to ceramic capacitors
  - One where a commonly-available ceramic capacitor was a dominant failure mode
  - One where we deliberately damaged ceramic capacitors in order to understand their electro-mechanical response

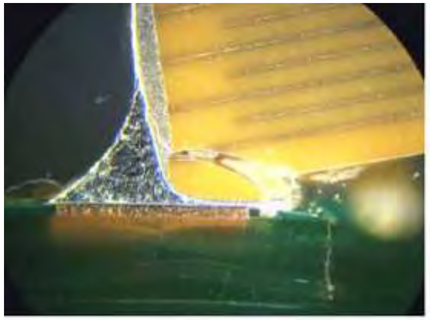
Sandia National Laboratories

Background: Capacitor Mechanical Failure



M. Keimasi, et al., Flex Cracking of Mulilayer Ceramic Capacitors Assembled with Pb-Free and Tin-Lead Solders, IEEE Trans. Device and Materials Reliability, Vol. 8, No. 1, March 2008

Failure of ceramic capacitors due to PCB flexure is a common problem.



Example MLCC flex crack

http://www.johansondielectrics.com/technical-notes/general/capacitor-cracks-still-with-us-after-all-these-years.html

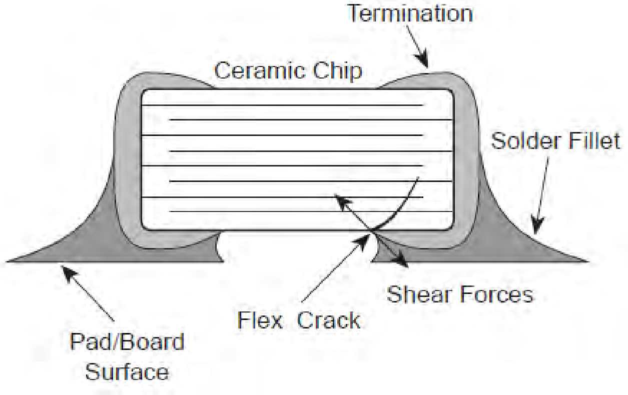


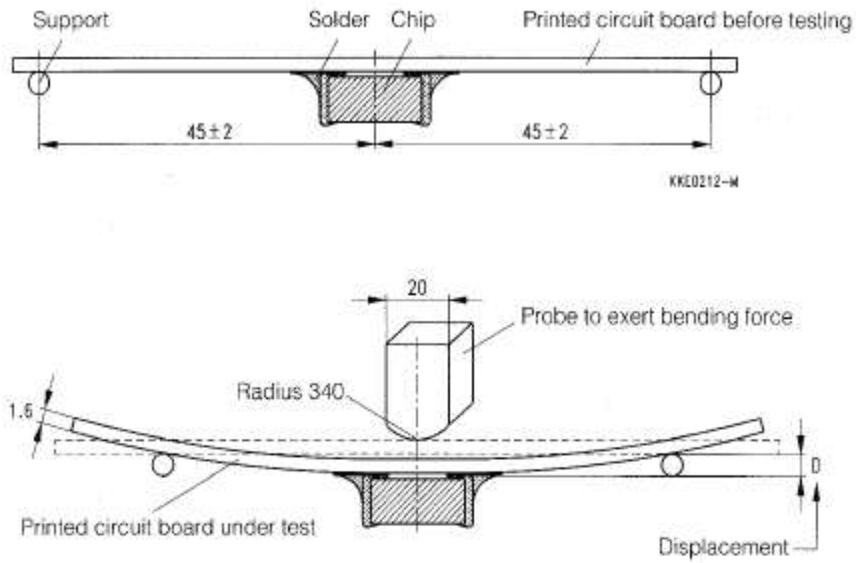
Diagram of an MLCC flex crack

Capacitance Monitoring While Flex Testing, J. Bergenthal and J. Prymak, Kemet F-2110, reprinted 8/98, http://www.kemet.com/kemet/web/homepage/kechome.nsf/file/f2110/$file/f2110.pdf

Sandia National Laboratories

Bend Testing

Bend testing is a common way to evaluate the strength of the capacitors – because it causes failures.



AEC-Q200-REV C, *Stress Test Qualification for Passive Components*, Method 005, Passive Component Board Flex / Terminal Bond Strength Test

See also:

- *Bend Testing, Methods and International Specifications*, AN0002 – Bend Testing, Issue 3, Syfer Technology Limited
- L. Mercado, B. Phillips, et al., *Handheld Use Condition-Based Bend Test Development*, IEEE Trans. Advanced Packaging, Vol. 29, No. 2, May 2006

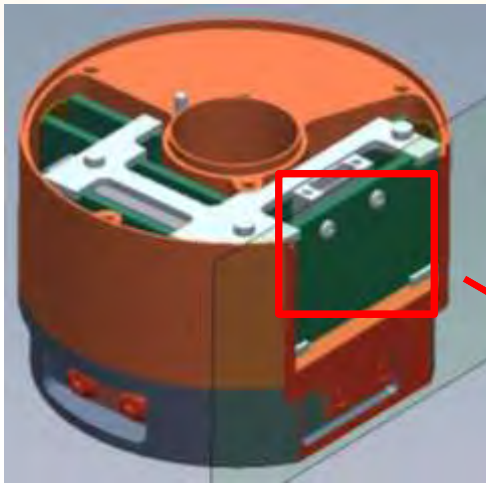
3DDR: Small Ceramic Capacitor Failures

- 3DDR is an instrumentation data recorder
- Seven units were tested to failure in order to understand dominant failure modes
  - Root cause of failure was determined for all
- The failure mode for 4 out of the 7 was a small ceramic capacitor failure

Unit	Cause of Failure
F1540	Capacitors C84/C85 (open)
F1541	Capacitor C91 (shorted)
090804	Connector failure (caused by test)
F1538	Unit failure (caused by test)
090805	Capacitor C91 (shorted)
090806	No failure (yet)
090807	Capacitor C91 (shorted)

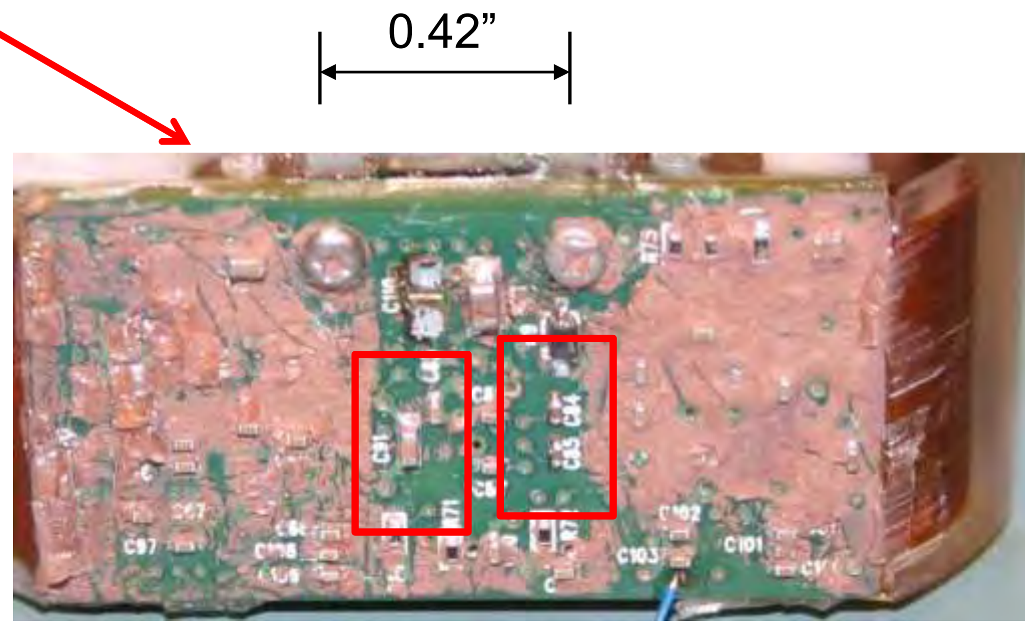
Each 3DDR unit failed after a number of mechanical tests.

Locations of Failed Capacitors



The dominant failure mode was capacitor failure in a very specific region of the back side of one rigid section of PCB.

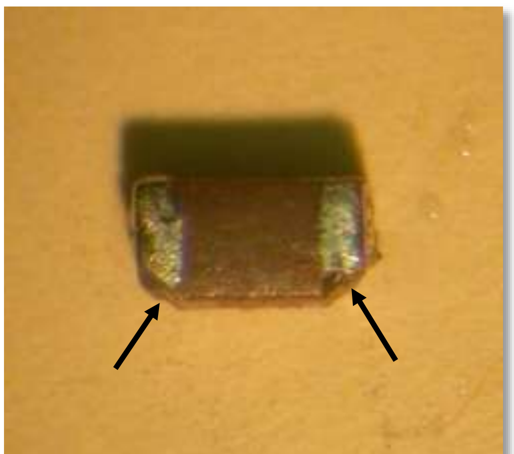
Capacitor C91 failed shorted 3 times while capacitors C84 (or C85) failed open once.



Locations of failed capacitors

Example of Capacitor Failure

Damage to the capacitor is at the corners where the capacitor is soldered to the PCB



Side View

Bottom View

Top View

The capacitor is a COTS, 0603-package, X7R dielectric component

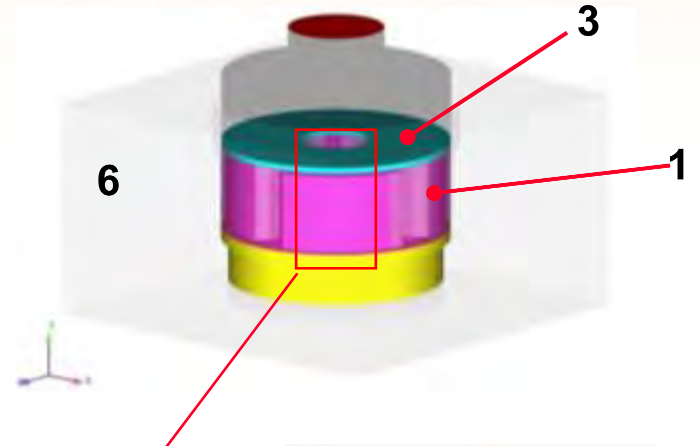
Simplified Finite Element Model

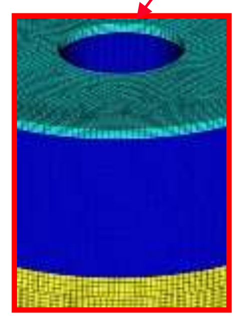
A finite element model was developed to test the hypothesis that PCB deformation was causing the capacitors to break.

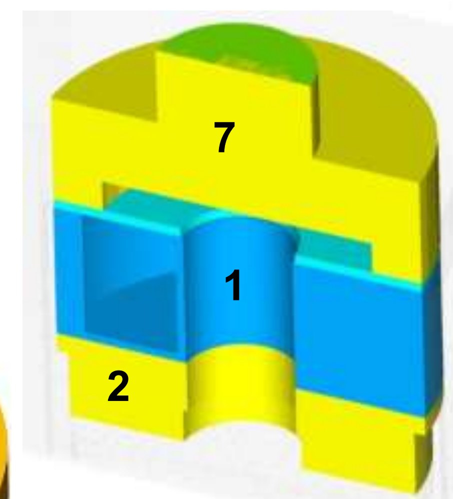
A simplified model with no PCB was developed to look at stresses in the potting material

- Full 3D Hex Element model
- 7 Material Blocks
- Nodes = 480K
- Elements = 400K
- Element Length < 0.020-inch

Component	Block ID	Material Model
Upper Housing	1	4340 Steel Elastic-Plastic
Lower Housing	2	4340 Steel Elastic-Plastic
Housing Lid	3	4340 Steel Elastic-Plastic
Potting	4	Hysol Elastic (Ref. Adolph)
Battery Pack	5	Aluminum Elastic
Fixture	6	Aluminum Elastic
Pressure-Bar/Retaining ring	7	Aluminum Elastic



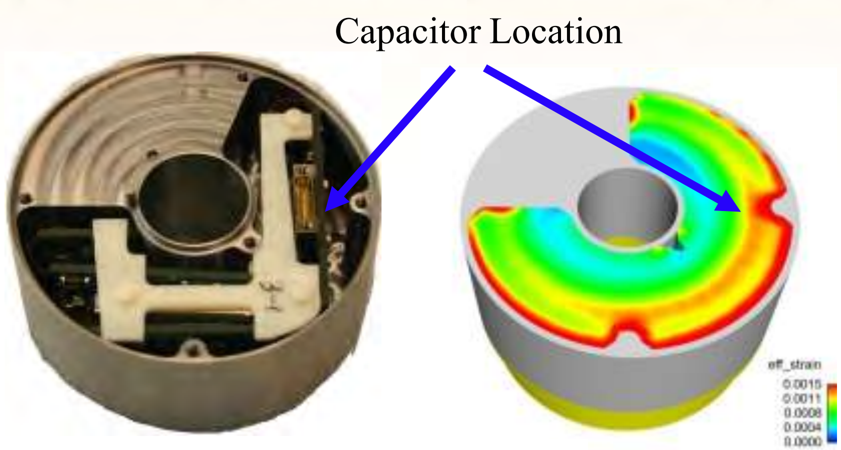


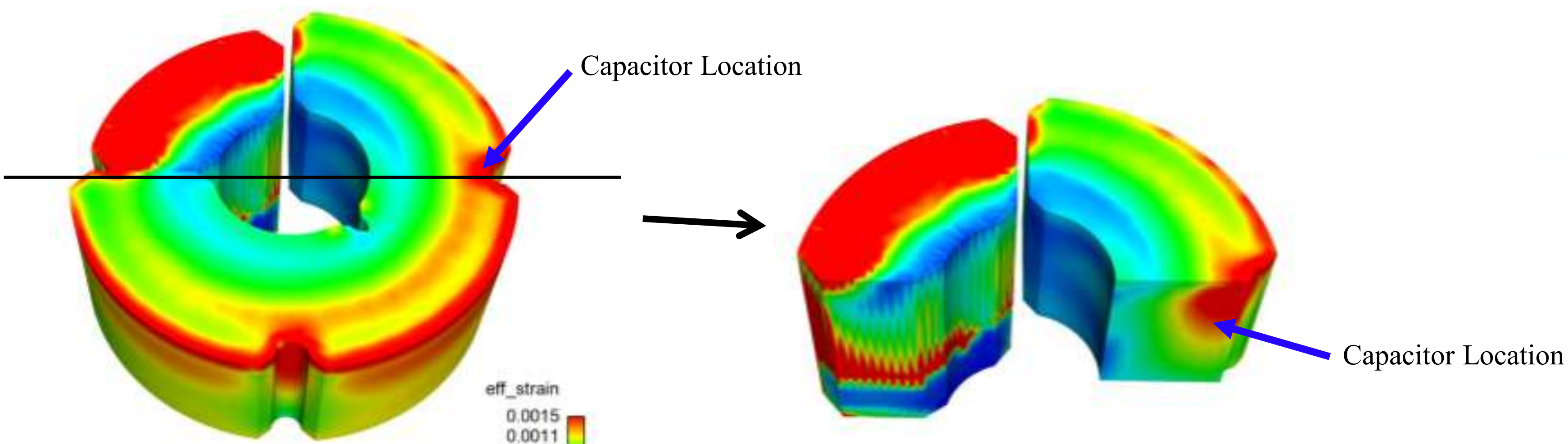


Unclassified Unlimited Release

Static Loading Results

- No yielding in potted 3DDR housing
- High stress in potting near lid
- Main potting maximum effective strain = 1500$\mu\varepsilon$
- ***High strain at capacitor location***





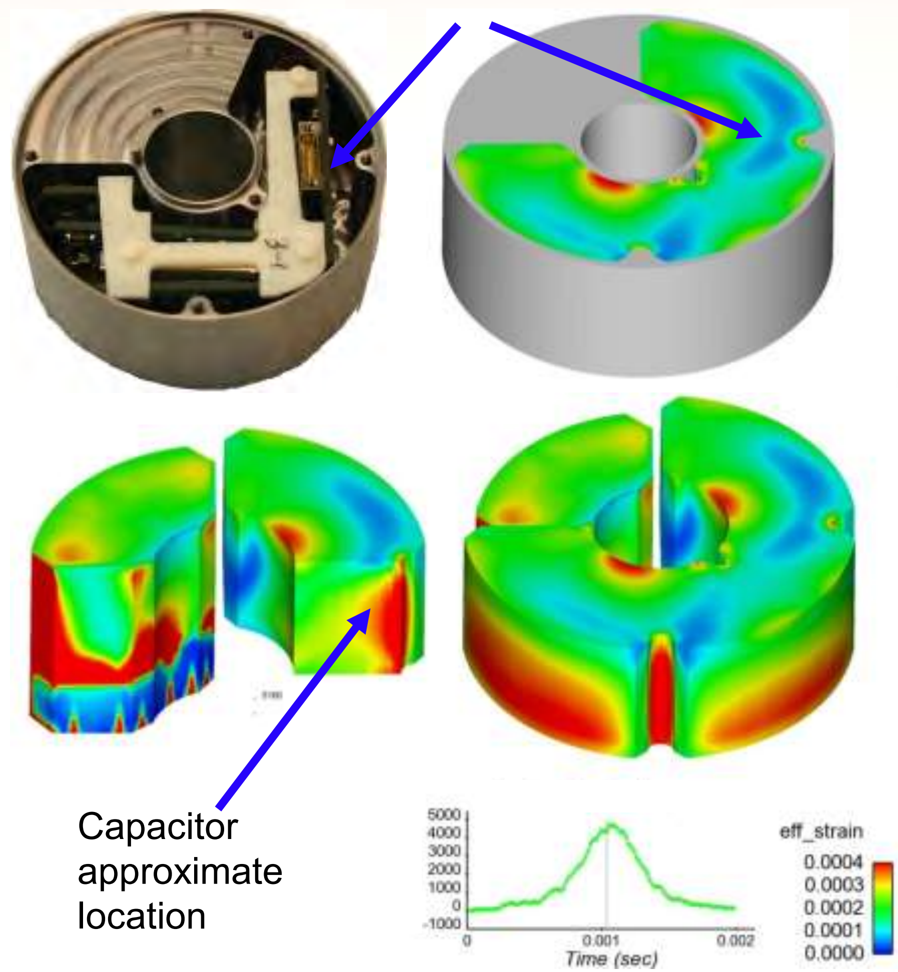
Potting Only

Cross-section of potting

Dynamic Loading Results

- Acceleration loading applied at bottom of fixture
- No yielding in potted 3DDR housing
- High stress in potting propagate from bottom up
- Main Potting Maximum effective strain = 400με
- ***Noticeable strain at capacitor location***

Capacitor approximate location



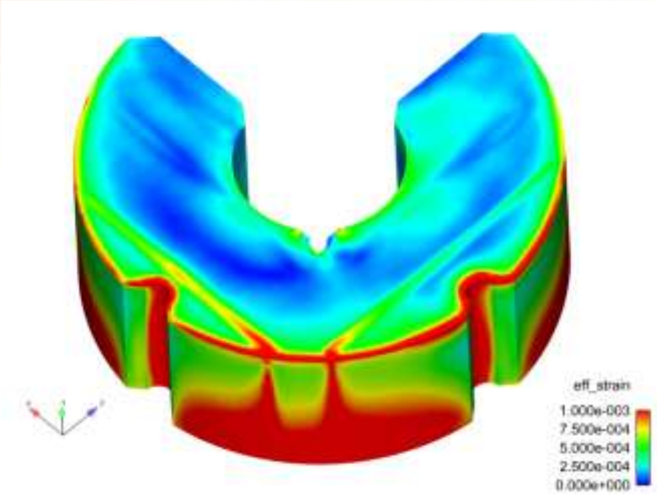
Unclassified Unlimited Release

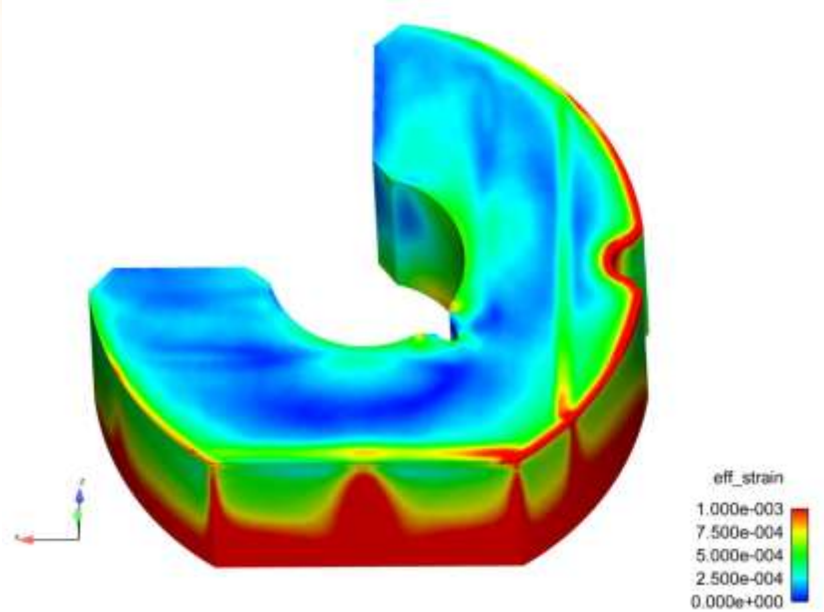
Higher Fidelity Model

A higher fidelity model was developed that included the PCB in order to understand its strain.

- 1.3M elements, 1.4M nodes
- Approximately 750K elements for the potting material
- Linear elastic PCB material model

High Fidelity Model Results



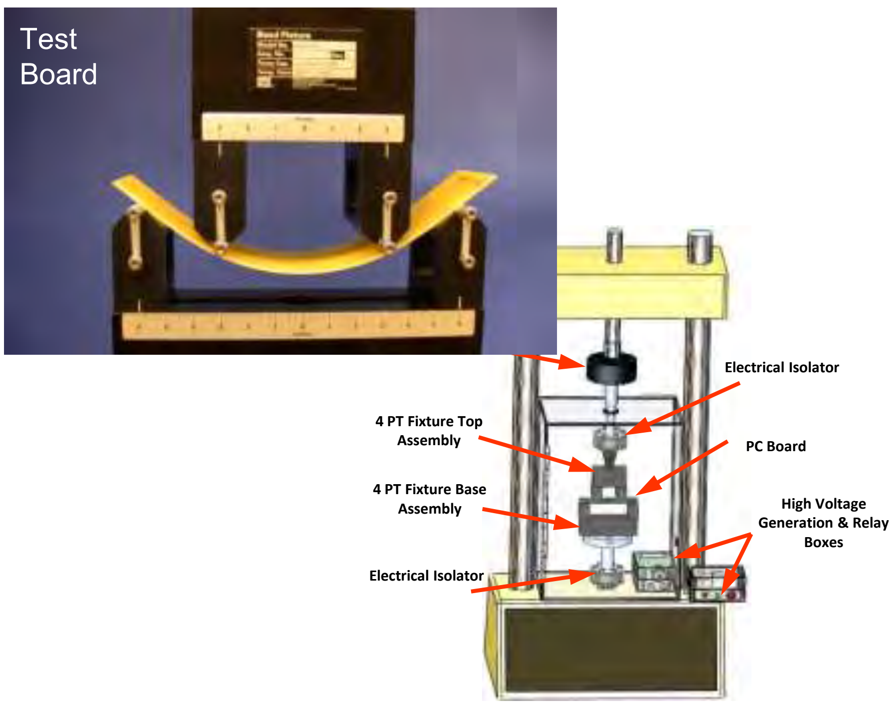


- Results based on a measured acceleration input
- Model results show that there is a strain of approximately 500με at the surface of the PCB near where the capacitors failed
- Strain is not enough* to break the capacitor off the PCB in one test – modeling matches experiment

* - Using Keimasi (2008) as the reference for necessary strain to induce flex cracking in small ceramic capacitors

Breaking Capacitors – On Purpose

- **We took ceramic capacitors with three dielectrics and subjected them to mechanical, electrical and combined tests**



Electrical Tests (columns) / *Mechanical Tests* (rows)

	Nominal	**Breakdown Voltage**	**Pulse Discharge**
Nominal		Benchtop Breakdown Voltage Characterization	Benchtop Pulse Discharge Characterization
Static Compression	Isolated Mechanical Compression	Breakdown Voltage under Compression	Pulse Discharge under Compression
Static Bending	Isolated Mechanical Bending	Breakdown Voltage under Bending	Pulse Discharge under Bending

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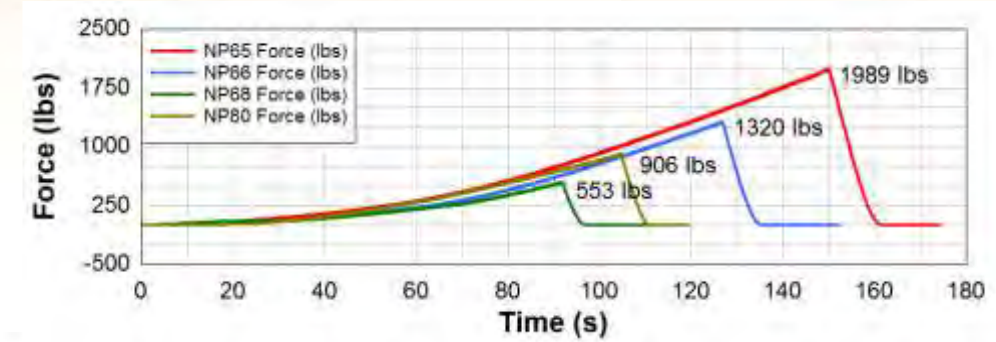
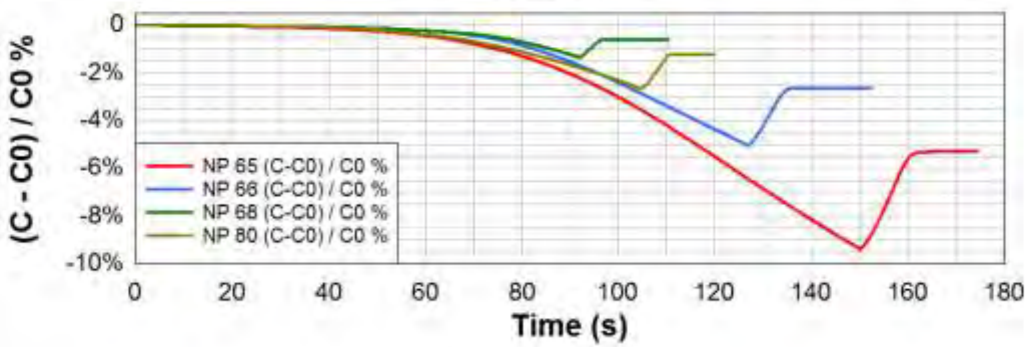
Three Results

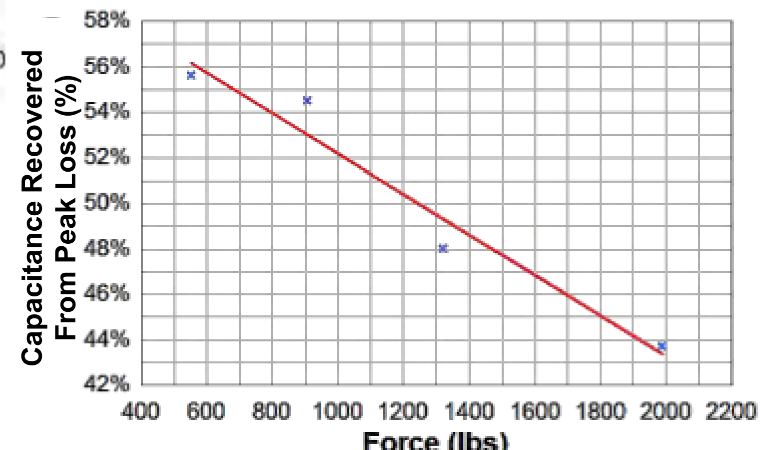
1. Capacitance recovery after mechanical compression
2. Effect of reflow soldering on mechanical failure
3. Capacitance change caused by mechanical compression

Capacitance Recovery





One dielectric showed reduced capacitance after mechanical compression



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Effect of Reflow Soldering on Mechanical Strength

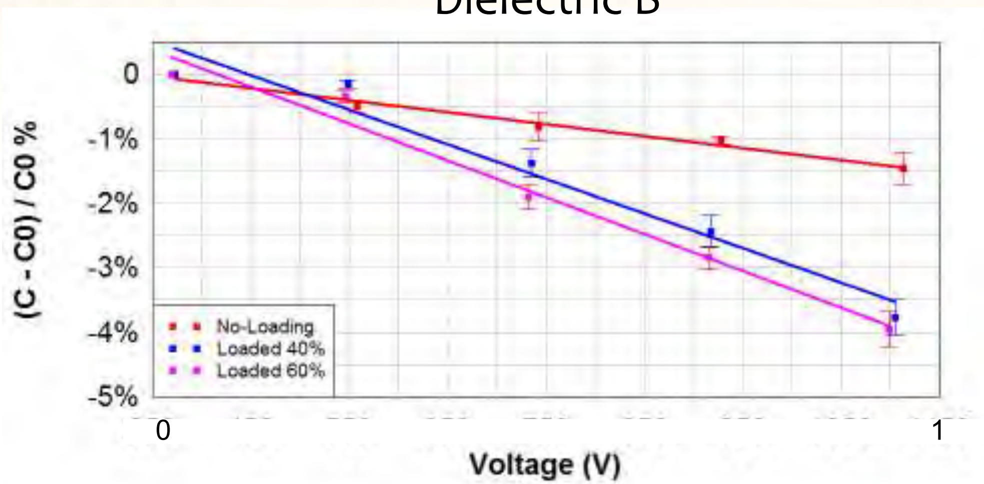
- We found that reflow soldering these capacitors causes them to fail at lower mechanical stresses than using a non-solder attachment technique
- Manufacturer soldering guidelines were followed

Average compressive displacement at failure (mils)

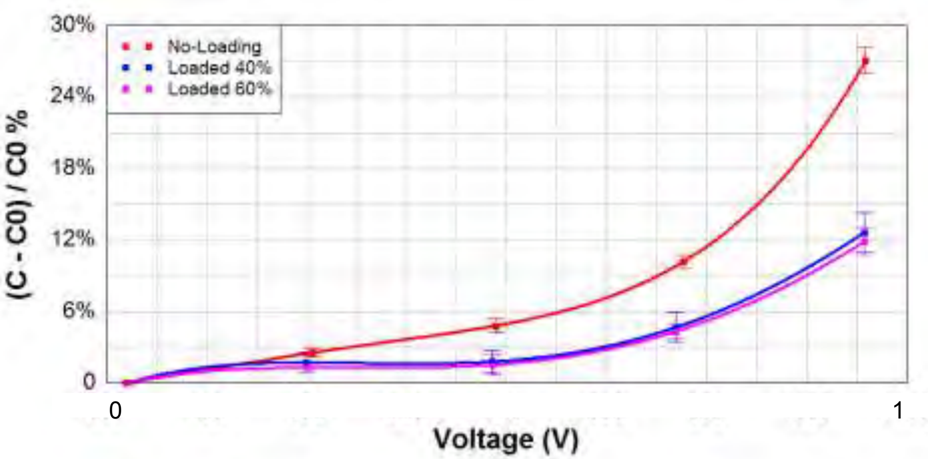
Type	Solder	Conductive Epoxy
A	5.60	8.77
B	6.71	16.0
C	9.65	18.5

Capacitance Change During Mechanical Compression

Dielectric B



Dielectric C



- Dielectric B showed a diminished capacitance when compressed
- Dielectric C showed a diminished increase in capacitance when compressed

Summary

- PCB flexure is one sure way to damage even tiny capacitors
  - But modeling and simulation, combined with existing experimental data, can help predict this
  - Even relatively low fidelity modeling can help qualitatively
- Ceramic capacitors can change characteristics during and after mechanical stresses

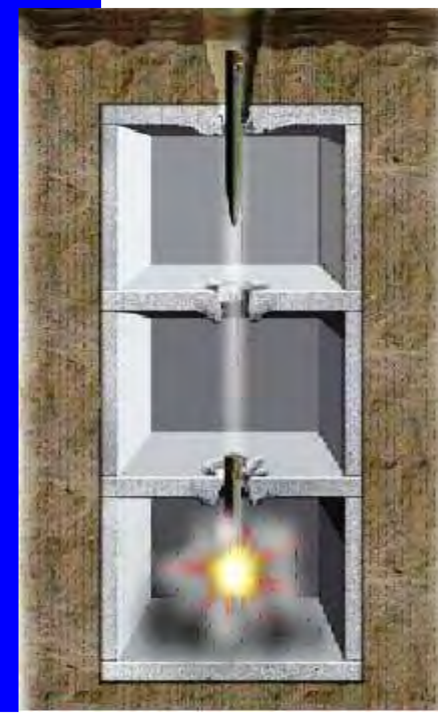
Acknowledgements

Many thanks to the sponsor and
collaborators who helped with this work.

Sandia National Laboratories

Void Sensing Fuze (VSF)
Product Improvement Program (PIP)
Transition of German Technology to Meet American Warfighter Needs

55th Annual NDIA Fuze Conference
24-26 May 2011



<u>Co-presenters:</u>
Dr. Helmut Muthig, TDW
Dale Spencer, Kaman Precision Products

Foreword

- **This joint presentation by the Defense Threat Reduction Agency (DTRA), Kaman Precision Products, and MBDA/TDW highlights significant respective management and technology success in integrating across countries, companies and cultures for a DoD Product Improvement Program (PIP). The VSF PIP of the TDW Programmable Intelligent Multi-Purpose Fuze (PIMPF) into a US produced three inch fuzewell is an impressive story involving the cooperation of USAF, Navy, and DTRA. This effort puts to rest many concerns and reservations often held for programs requiring international cooperation.**

- **This presentation is dedicated to the memory of the late *Lt. Col. Herbert J. Smith III* who was a driving force in the inception of this program and who believed so strongly in the benefit to the American Warfighter that this technology and cooperation offers.**

Agenda

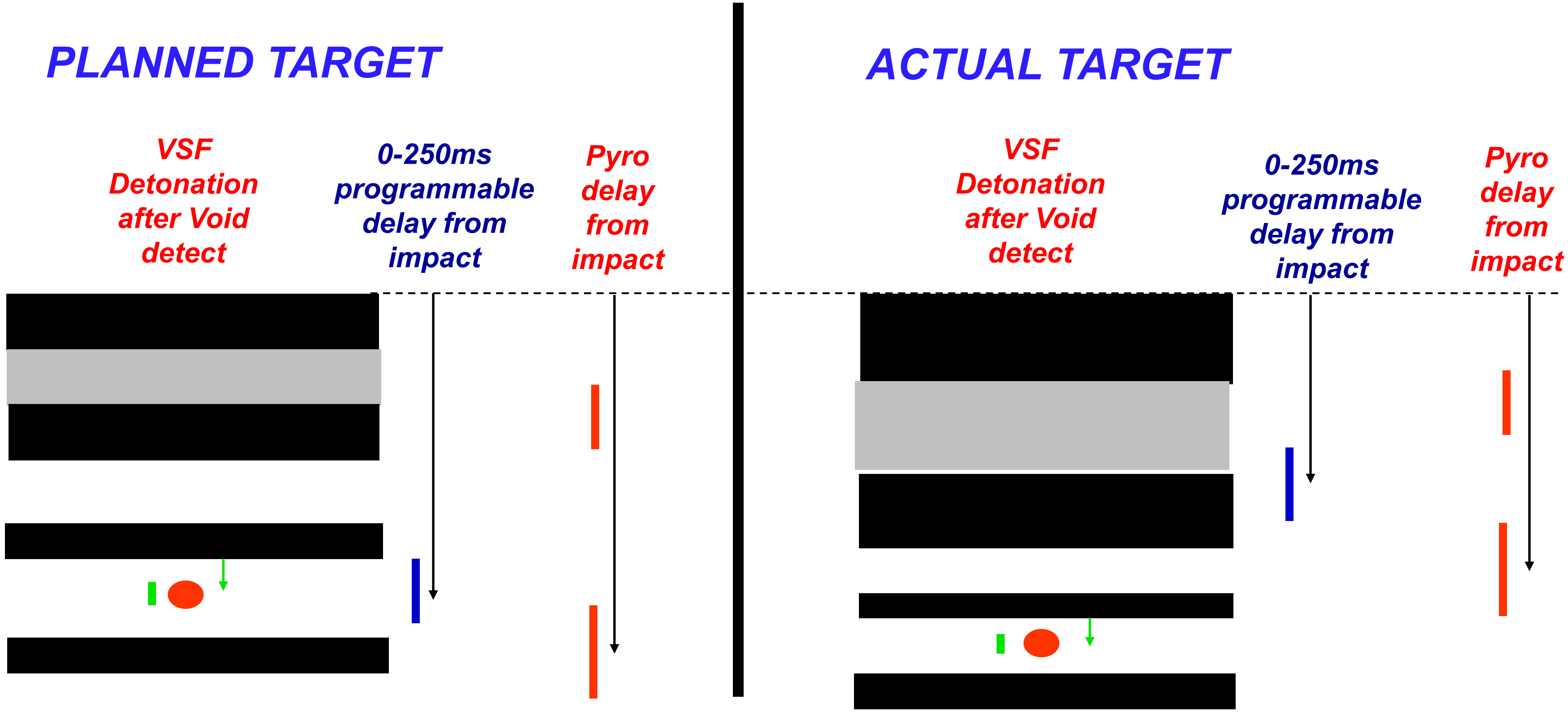
- An overview of the DTRA Void Sensing Fuze Product Improvement Program
- Overview of the functionality of the Fuze
- VSF Cannon Testing at Meppen, Germany
- VSF Cannon Testing with USAF
- VSF Sled Testing with Navy
- Environmental Validation Testing Efforts
- Transition of VSF under a JCTD to US Weapons

Historical Background

- **OSD Comparative Test Office and Defense Threat Reduction Agency (DTRA) sponsored Foreign Comparative Test (FCT) Program to evaluate the German's Programmable Intelligent Multi Purpose Fuze (PIMPF)**
  - PIMPF is a qualified fuze, currently in service in the Taurus KEPD 350 and has been selected for the Norwegian Naval Strike Missile
  - FCT program evaluated the ability of the PIMPF to penetrate hard, deeply buried targets, sense and count layers and voids as it penetrates, and then detonate in a specific void as programmed
- **Recommendation accepted to conduct a Void Sensing Fuze (VSF) Product Improvement Program (PIP) to repackage current PIMPF into a form factor compatible with US Weapon Fuzewells**

Benefits of Smart Fuzing

A Void Sensing Fuze Finds & Fires in Programmed Void

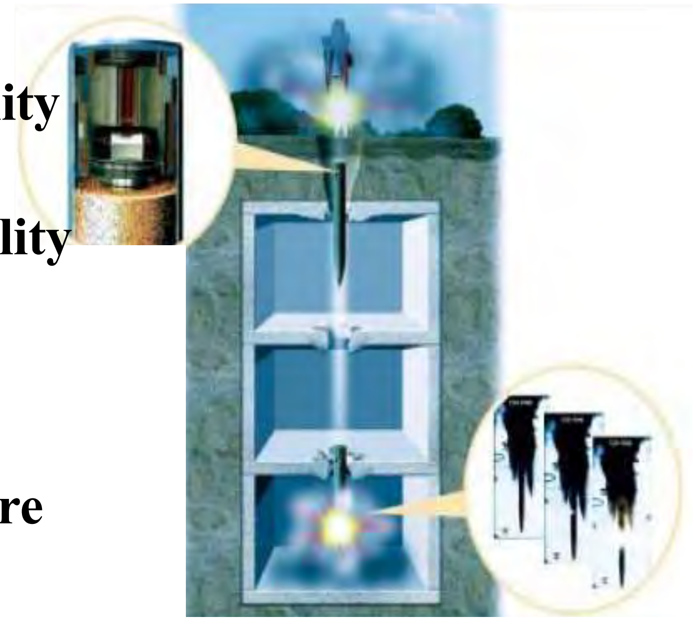


Void Sensing Fuze Provides Intelligence to Fire at Precision Location to Maximize Weapon Effectiveness

Void Sensing Fuze Objectives

Repackage the Programmable Intelligent Multi-Purpose Fuze (PIMPF) into a form factor compatible with US weapon fuzewells

- **Conduct trade studies to investigate compatibility with US weapon systems**
- **Demonstrate original void/layer sensing capability**
- **Conduct limited environmental/qualification testing**
- **Conduct USG Cannon/Sled testing to confirm functionality and serve as a risk reduction before USG integration**
- **Provide residual VSF for JMEWS development and make available for other transitional US partners**



VSF Program Requirements

- VSF must meet NATO Standard Agreement 4187 and MIL- STD-1316E
- VSF must be sized to enable incorporation into standard US weapon fuzewell
- VSF must function within the operating environments of the host weapon system
- VSF must sense/count layers and voids as it penetrates a hard target and detonate at a planned point within the target
- VSF must be field-level and cockpit programmable

VSF PIP Phases

- *Phase 1 - VSF Modification and Demonstration ~ Completed*
  - Trade Studies (capacitors vs batteries, connectors, modifications for gravity bomb applications)
  - Initial repackaging design
  - Component level environmental / shock testing
  - Engineering Evaluation Unit (EEU) design
  - Contractor led cannon testing (TDW at Meppen, Germany)
- *Phase 2 – US Pilot Assembly and Verification Testing ~ Working*
  - Pilot production of multiple fuzes - *Completed*
  - Production acceptance testing - *Completed*
  - Environmental testing - *Pending*
  - USG Production Verification Testing - *Completed*
    - Cannon Testing with USAF at Eglin AFB – Risk Reduction to Sled Testing
    - Sled Testing with US Navy at China Lake

VSF PIP Participants

- ***DTRA***
- ***TDW / MBDA Missile Systems (Germany)***
- ***KAMAN Precision Products***
- ***AFRL ~ Eglin AFB***
- ***NAVAIR ~ China Lake (SNORT)***
- ***PMA-280 Joint Multi-Effects Warhead System***

Roadmap to Success

VSF Program Milestones

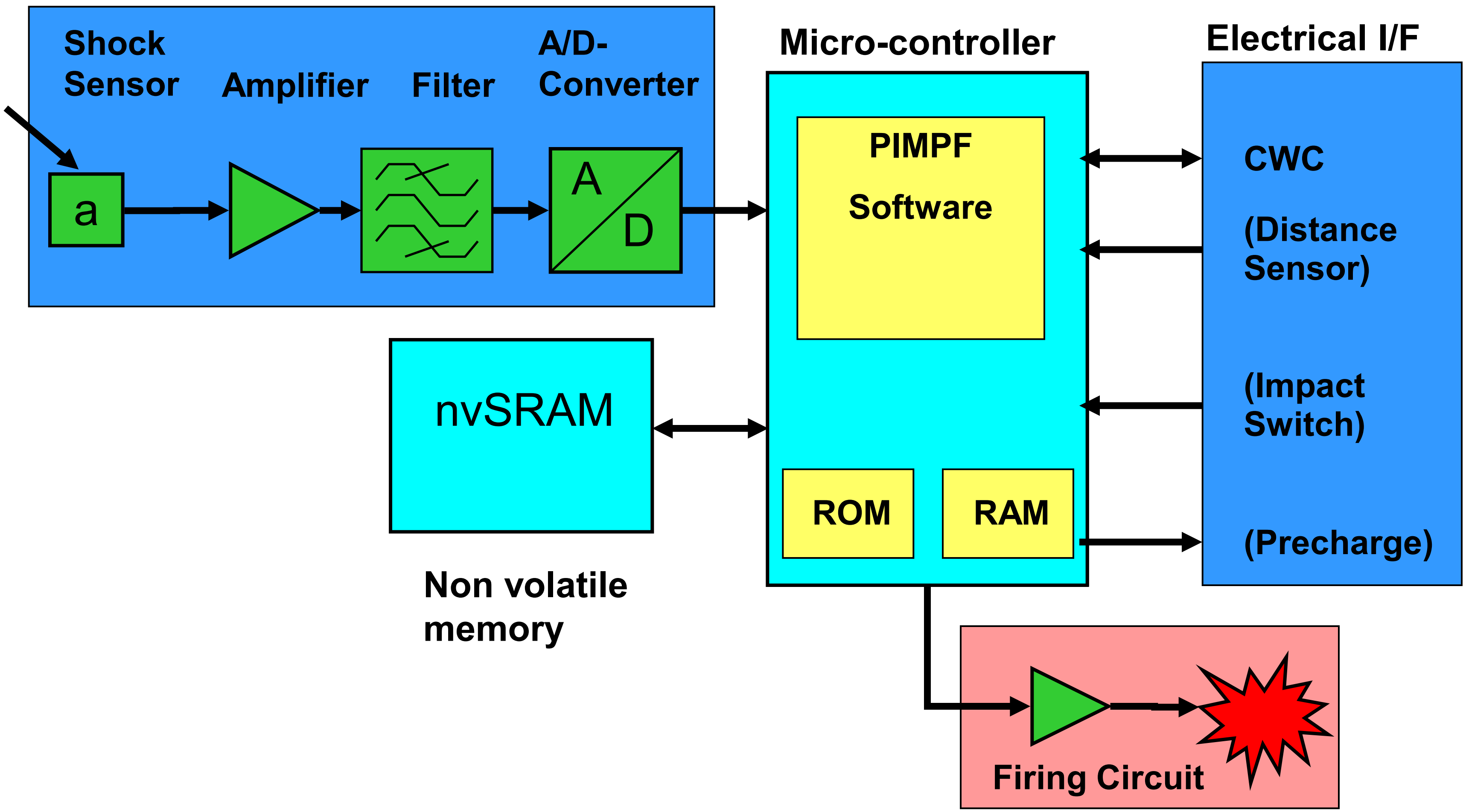
- DTRA funds FCT of PIMPF
- NNMSB Safety Review of PIMPF
- FCT Test of PIMPF
- DTRA awards Contract for VSF Product Improvement Program (PIP)
- VSF PIP SRR
- VSF PIP Preliminary Design Review (PDR)
- FISTRP Tech Assist Safety Review
- VSF Critical Design Review (CDR)
- VSF / TDW Validation Cannon Tests ~ Germany
- VSF Risk Reduction Cannon Tests ~ Eglin
- VSF Validation Sled Testing ~ Navy SNORT
- VSF Final Environmental Testing ~ Pending

Technology to Detect Voids with Penetrating Weapons

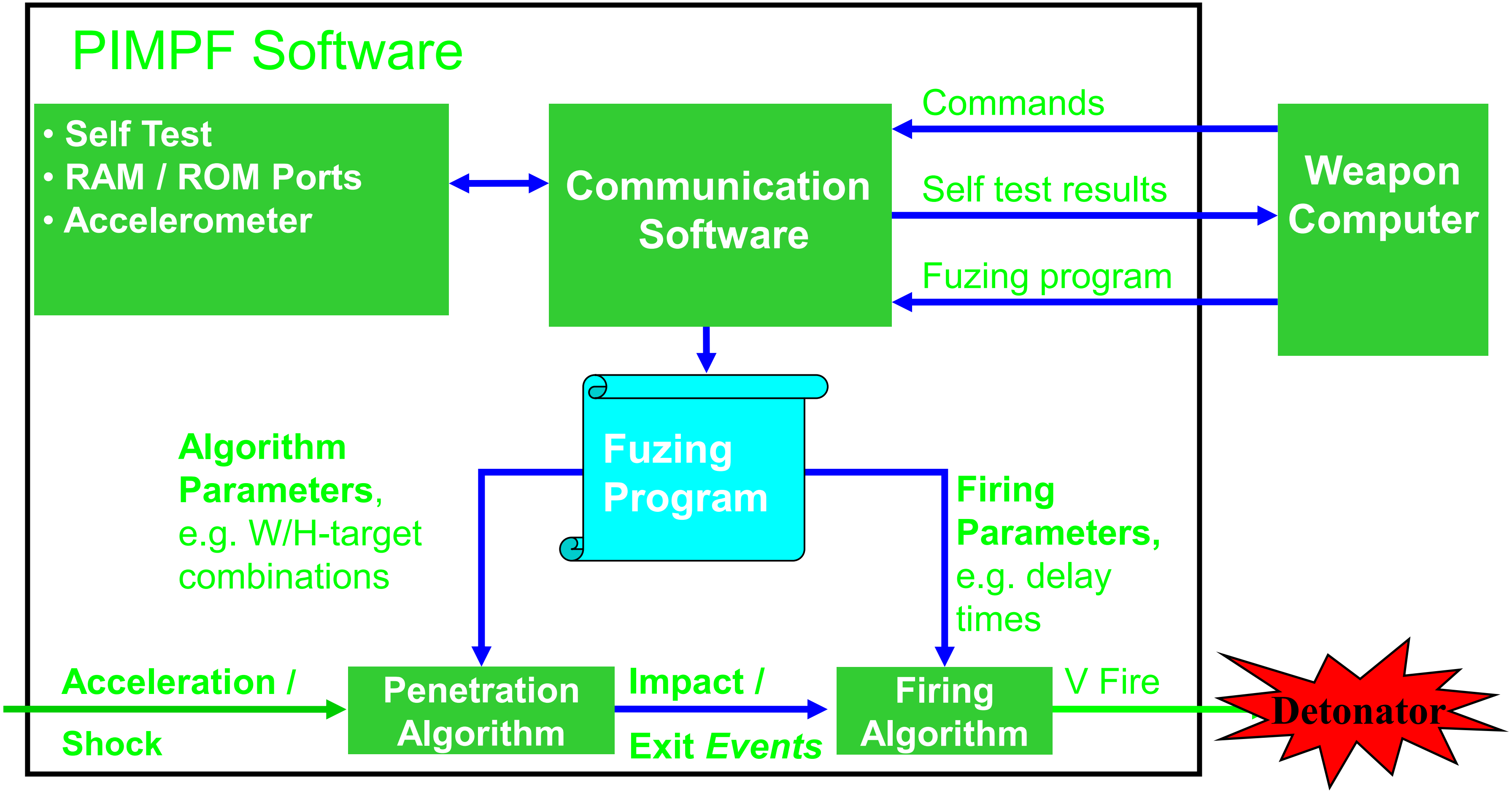
Dr. Helmut Muthig,

Managing Director, TDW / MBDA

PIMPF TDD
Functional Block Diagram

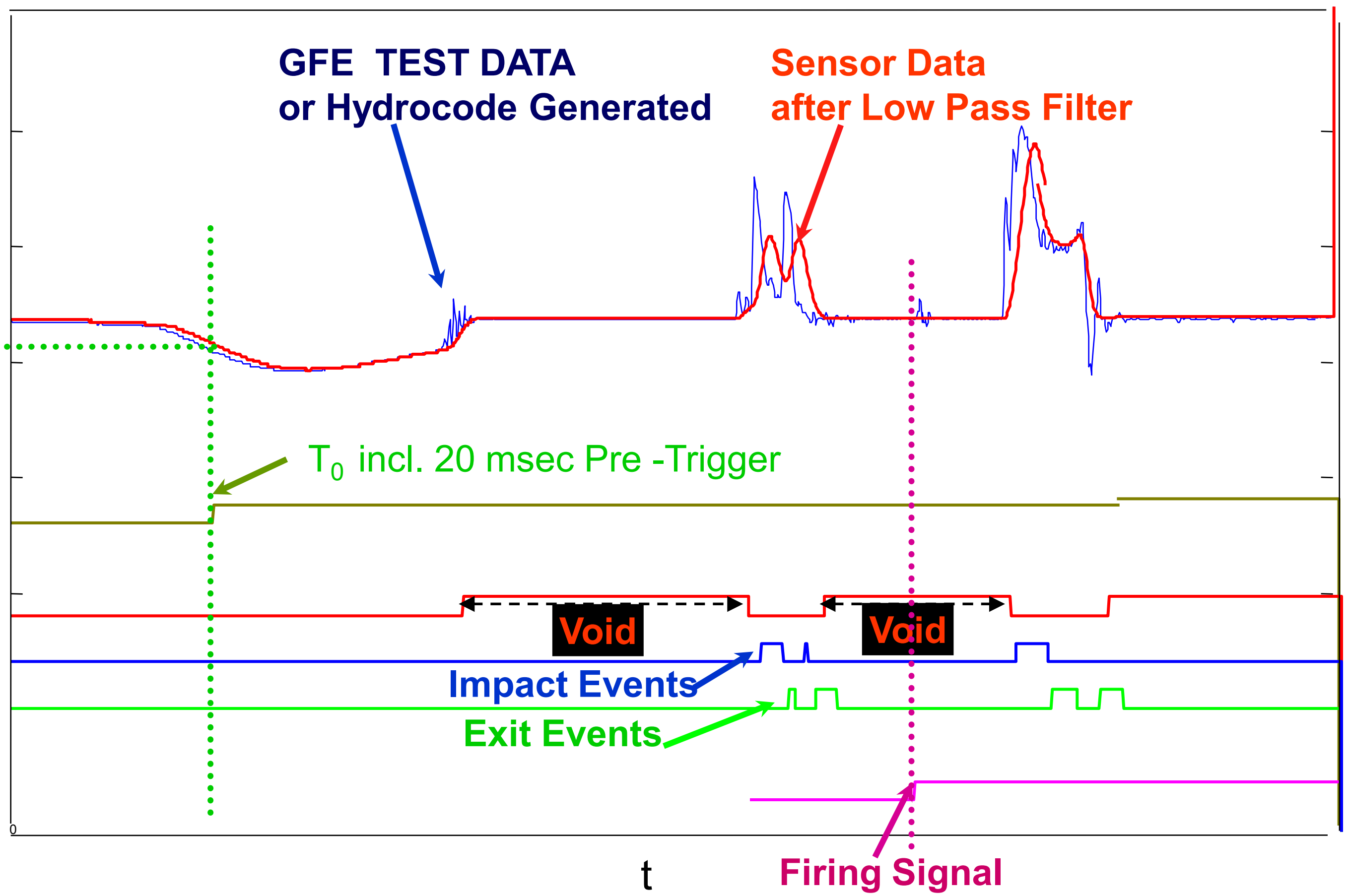


Functional Description ~ TDD



TDD Performance Prediction

VSM internal data logging capabilities



Contractor Testing Overview

- ✓ Hardware in the loop testing
- ✓ Extended Temperature testing
- ✓ Booster Initiation Testing
- ✓ Detonator / Hand Safe Testing
- ✓ Acceleration (High Shock) testing
- ✓ Basic Environment /Robustness Testing
- ✓ Shock/Impact Testing at Meppen
- ❑ U.S. Environmental Testing

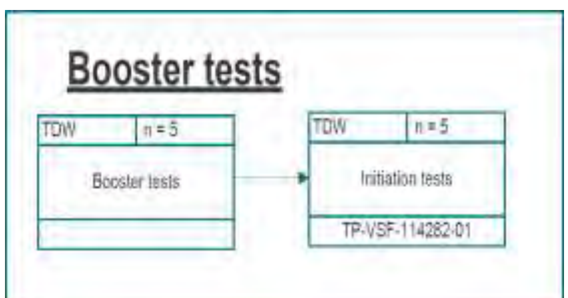
VSF Validation

VOID SENSING FUZE VSF

- Detonator Safety Test
- Pyrotechnical I/F Test
- Basic Environmental and Robustness
- Test – Ulm Germany
- Explosive Compatibility Test
- CV / Penetrations Tests at WTD 91
- CV / Environmental Test

VSF
Detonator Safety
Report

VSF
Pyrotechnical I/F
Report



MBDA MISSILE SYSTEMS

KAMAN PRECISION PRODUCTS

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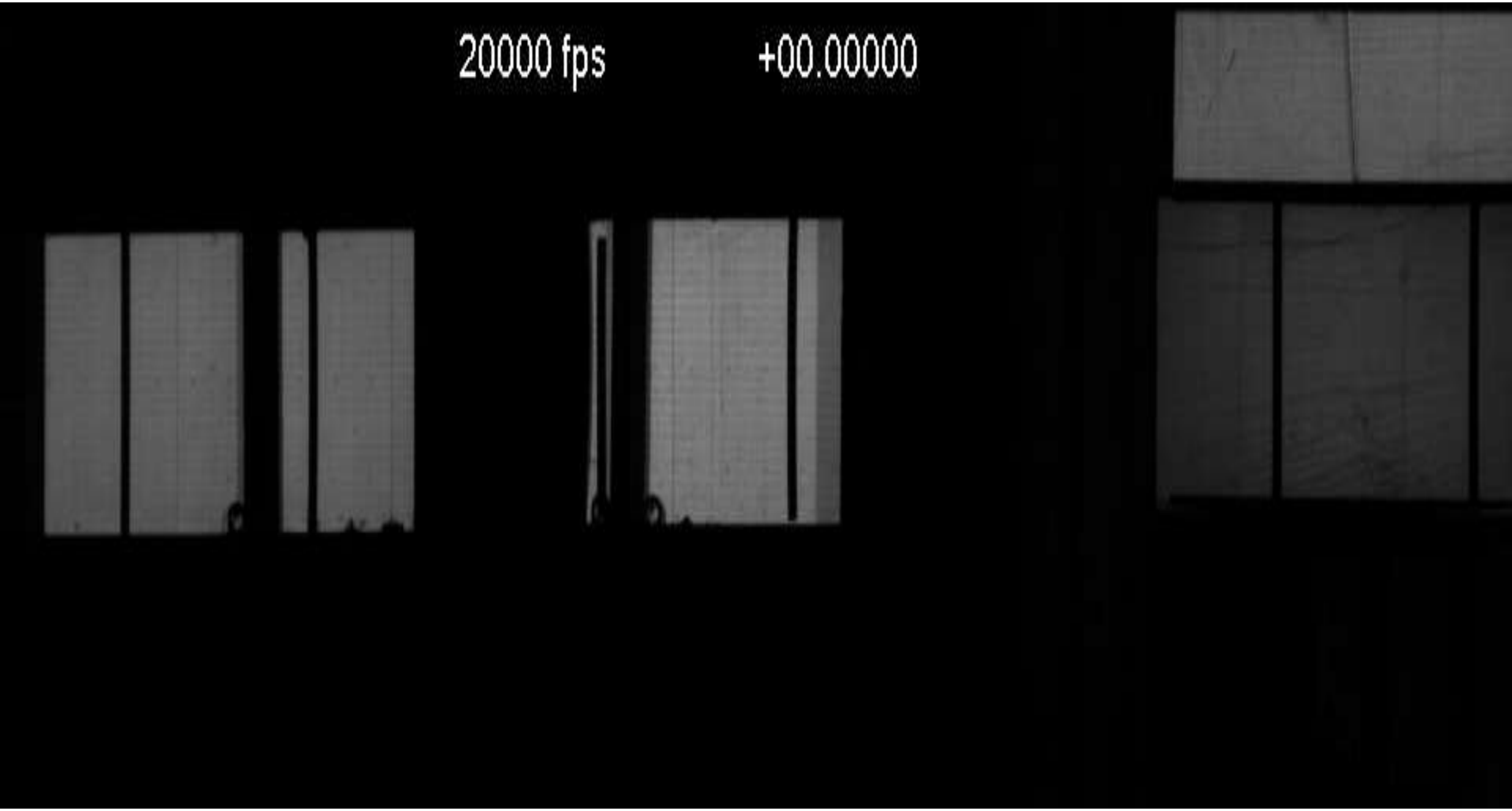
VSF - TDW Validation Field Tests

Test #	Date	Target	Lessons Learned
1	6 June 2009	1 -- 2' 9.5" Reinforced concrete	Thread Design on Booster Cup to Fuze Housing Redesigned -- Threaded Booster Facilitates Testing
2	15 June 2009	2 – 15.5" Reinforced concrete plates	Rotor Flange angle relieved Booster Cup Teflon Damping Ring redesigned for greater robustness
3	28 Oct 2009	1 – 5'5"	Enhancements to flex interconnect cable and addition of flex retaining bracket
4	23 Feb 2010	2 – 15.5" Reinforced concrete	TDW Contractor Led Cannon Tests verified CIPPS: APP Functionality; Entry/Exit Detection @ critical impact velocities and angles

VSF Contractor Penetration Testing
Cannon Test ~ Double Concrete Plate



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VSF ~ USG Testing
Dale Spencer
Kaman Precision Products

VSF ~ USG Cannon Risk Reduction Testing

- **Total of 4 Cannon Test Events**
- **Cannon Test #1 - Eglin Air Force Base**
  - **Objective:** Survivability and Functionality
    - Repeat of the TDW Contractor Validation Test conducted previously to confirm the integrity of the design high G load, and verify TDD ability to detect void layer
  - **Confirmation:** No Test
    - Pusher Plate Failed due to material failure
    - Fuze Burned, TDD Recorded and Functioned Post Test

"The fact that the TDD survived the extreme gun gas pressure and extremely high gas temperature is remarkable."

VSF ~ USG Cannon Test #2

- **Cannon Test #2 - Eglin Air Force Base**
  - **Objective:** Survivability and Functionality
    - Repeat of the TDW Contractor Validation Test conducted to confirm void/layer detection, survivability, and functionality of the VSF at distance from gun barrel to front of first target layer
    - Verify VSF integrity and exposure to **High Lateral G loading**
  - **Confirmation:** VSF Complete Success Despite Warhead Breakup
    - Fuzewell separates from the penetrator and travelled about 30 ft from the final concrete target slab
    - Fuzewell sustained severe deformation with fuze retaining ring lock-up
    - TDD functioned as programmed despite violent separation from penetrator that was exposed to severe tail slap
    - Void Sensing Fuze remains intact and undamaged in damaged Fuzewell
    - Final exit & fire signal generated successfully as programmed despite violent separation from penetrator

VSF ~ USG Cannon Test 3 & 4

- **Cannon Test 3 & 4 ~ Eglin Air Force Base**
  - **Objective:** <u>Survivability and Functionality</u>
    - Test #3 is to confirm multiple void/layer detection, survivability, and functionality of the VSF through double concrete plate
    - Test #4 is to confirm multiple void/layer detection, survivability, and functionality of the VSF through multiple concrete plate and compact soil
  - **Confirmation:** <u>Complete Success both tests</u>
    - The TDD functioned as programmed; traces show entry and exit from each concrete target and difference in deceleration levels between concrete and soil configuration
    - The final exit & fire signals were generated as planned
    - No damage to VSF Fuzewell or VSF
    - Inert VSF with Kaman HIDR in Booster Cup ~ reused multiple times

VSF ~ USG Sled Testing

VSF ~ USG Sled Testing

- **Total of 3 USG Sled Test Executed Successfully ~ China Lake**
- **Objective: Verify Survivability, Functionality, and ability for VSF to command fire signal at appropriate Pre-Programmed Void Layer Tests**
- **VSF Sled Test Parameters included:**
  - Void Sensing Fuze's conf/w Live Detonator/Inert Lead to enhance data collect & verify 'Fire' Command ~ (HIDR)
  - Pre/Post Test modeling for Risk Reduction, Comparison, and Model Update
  - Penetrator configuration designed to mitigate lessons-learned from PIMPF (FCT)
  - Penetrator engineering designs minimal for VSF

VSF ~ USG Sled Testing Snapshot

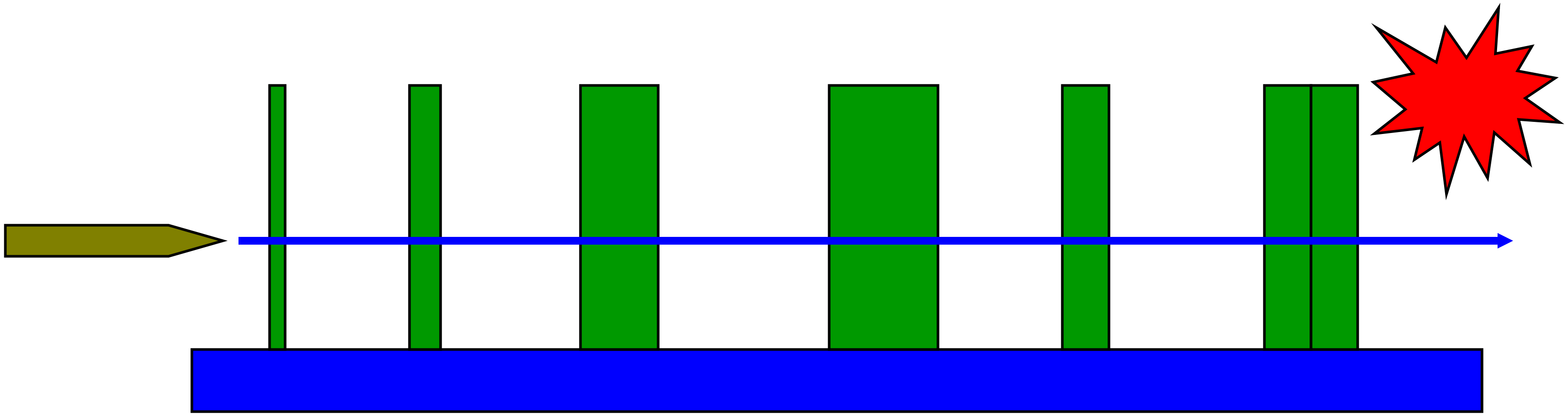
Primary Objective: Functionality & Survivability

- **VSF Sled Test #1**
  - Repeat of the PIMPF FCT test to confirm no capabilities were lost between PIMPF and VSF during the PIP program
  - Verify VSF integrity and exposure to high lateral G loading
- **VSF Sled Test #2**
  - Demonstrate VSF ability to detect the void space behind known target and issue a fire signal after exiting that target
- **VSF Sled Test #3**
  - Demonstrate the ability of the fire signal to initiate the detonator ~ HIDR
  - Determine the ability of the VSF to detect various target thickness and issue appropriate entrance and exit signals
- **Confirmation on all 3 USG Sled Tests: Complete Success**
  - The TDD functioned as programmed in all test scenarios
  - The final exit & fire signals were generated as planned
  - The TDD traces clearly showed the entry and exit from each target set
  - HIDR used during Test #3 showing useful x,y,z axial data

VSF ~ USG Sled Testing Snapshot

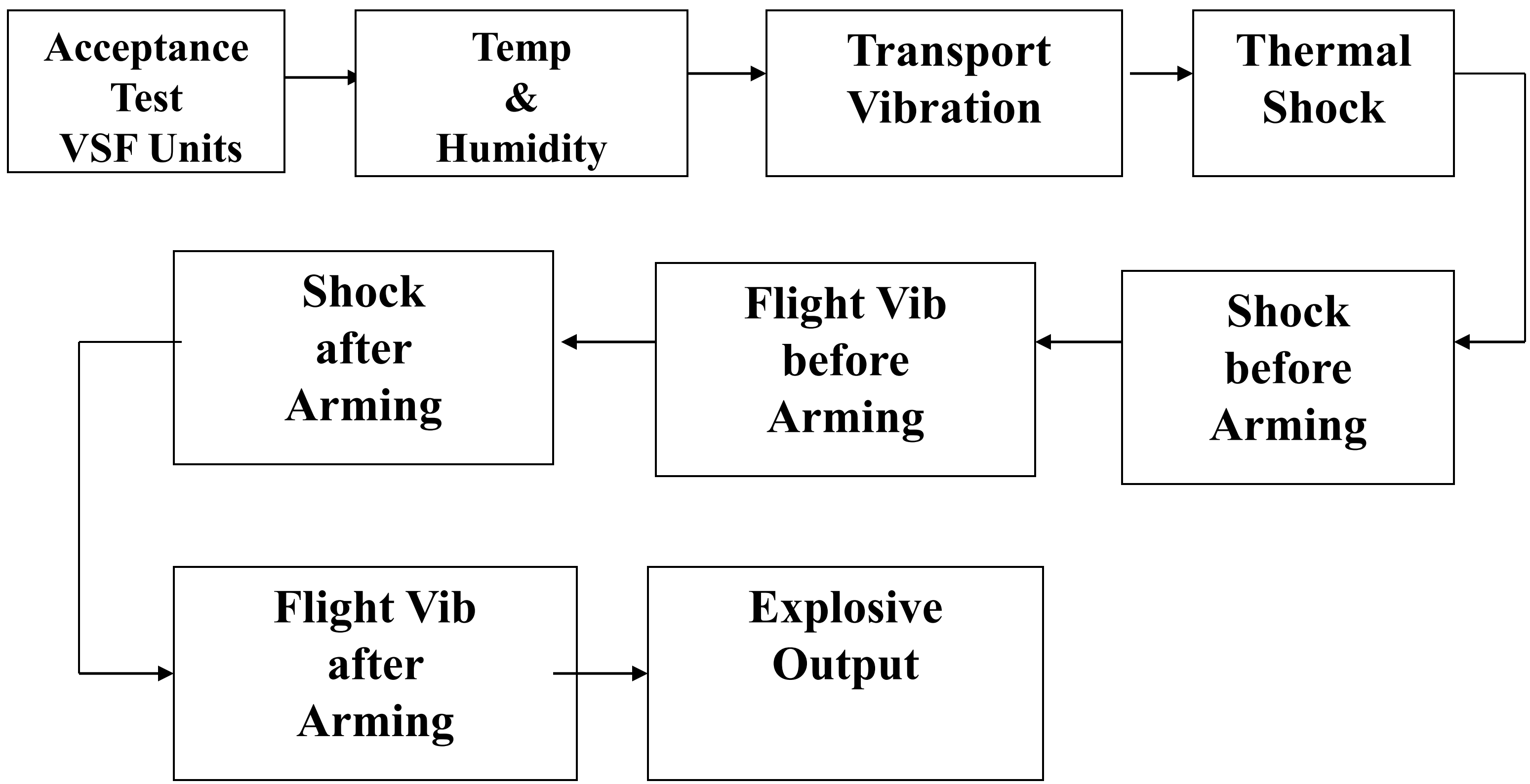
Primary Objective: Functionality & Survivability

Example of VSF Sled Testing
Multiple Target Penetration



Environmental Verification Testing

- **Objective: verify the capability of the VSF to perform within the required specifications prior to, during and following exposures to various environments – Pending**



VSF ~ Transforming Future Warfighter Capability & Integration

OSD Perspective

Chuck Kelly

OUSD (Acquisition, Technology & Logistics)

Land Warfare and Munitions

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DSN 225-1772
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Agenda

- OSD/AT&L Organization & Leadership Perspective

- Budget Perspective

- Department-level Fuze Initiatives

Secretary of Defense
Hon. Robert Gates

Deputy Secretary of Defense
Hon. William Lynn

Under Secretary of Defense for Acquisition, Technology & Logistics
Hon. Ashton Carter

Principal Deputy :
Hon. Frank Kendall

Secretary of the Army
Hon. John McHugh

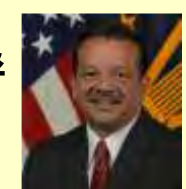
Secretary of the Navy
Hon. Ray Mabus

Secretary of the Air Force
Hon. Michael Donley

Asst. Sec. of Defense (Acquisition)
Vacant

DASD, Portfolio Systems Acquisition
Mr. Dave Ahern

Director, Land Warfare & Munitions
Mr. Jose Gonzalez



Excerpts from Secretary Gates January 6, 2011 Speech

- America is at war and confronts a range of future security threats, it's important not to repeat the mistakes of the past by making drastic and ill-conceived cuts to the overall defense budget.

- At the same time, it is imperative for this department to eliminate wasteful, excessive and unneeded spending, to do everything we can to make every defense dollar count.

- The goal was, and is, to sustain the U.S. military's size and strength over the long term by reinvesting those efficiency savings in force structure and other key combat capabilities.

- What is important is to have a budget baseline with a steady, sustainable and predictable rate of growth that avoids extreme peaks and valleys in defense spending that can be enormously harmful to readiness, planning and financial management.

Mandate for Restoring Affordability and Productivity in Defense Spending (USD(AT&L) June 28, 2010 Memo)

- Deliver the warfighting capability we need for the dollars we have
- Get better buying power for warfighter and taxpayer
- Restore affordability to defense goods and services
- Improve defense industry productivity
- Remove government impediments to leanness
- Avoid program turbulence
- Maintain a vibrant and financially healthy defense industry

Obtain 2-3% net annual growth in warfighting capabilities without commensurate budget increase by identifying and eliminating unproductive or low-value-added overhead and transfer savings to warfighting capabilities. ***Do more without more.***

Acquisition Efficiency Guidance Roadmaps

Target Affordability and Control Cost Growth

- Mandate affordability as a requirement
- Implement "should cost" based management
- Eliminate redundancy within warfighter portfolios
- Achieve Stable and economical production rates
- Manage program timelines

Incentivize Productivity & Innovation in Industry

- Reward contractors for successful supply chain and indirect expense management
- Increase Use of FPIF contract type
- Capitalize on progress payment structures
- Institute a superior supplier incentive program
- Reinvigorate industry's independent research and development

Promote Real Competition

- Emphasize competitive strategy at each program milestone
- Remove obstacles to competition
  - Allow reasonable time to bid
  - Require non-certified cost and pricing data on single offers
  - Enforce open system architectures and set rules for acquisition of technical data rights
- Increase small business role and opportunities

Improve Tradecraft in Acquisition of Services

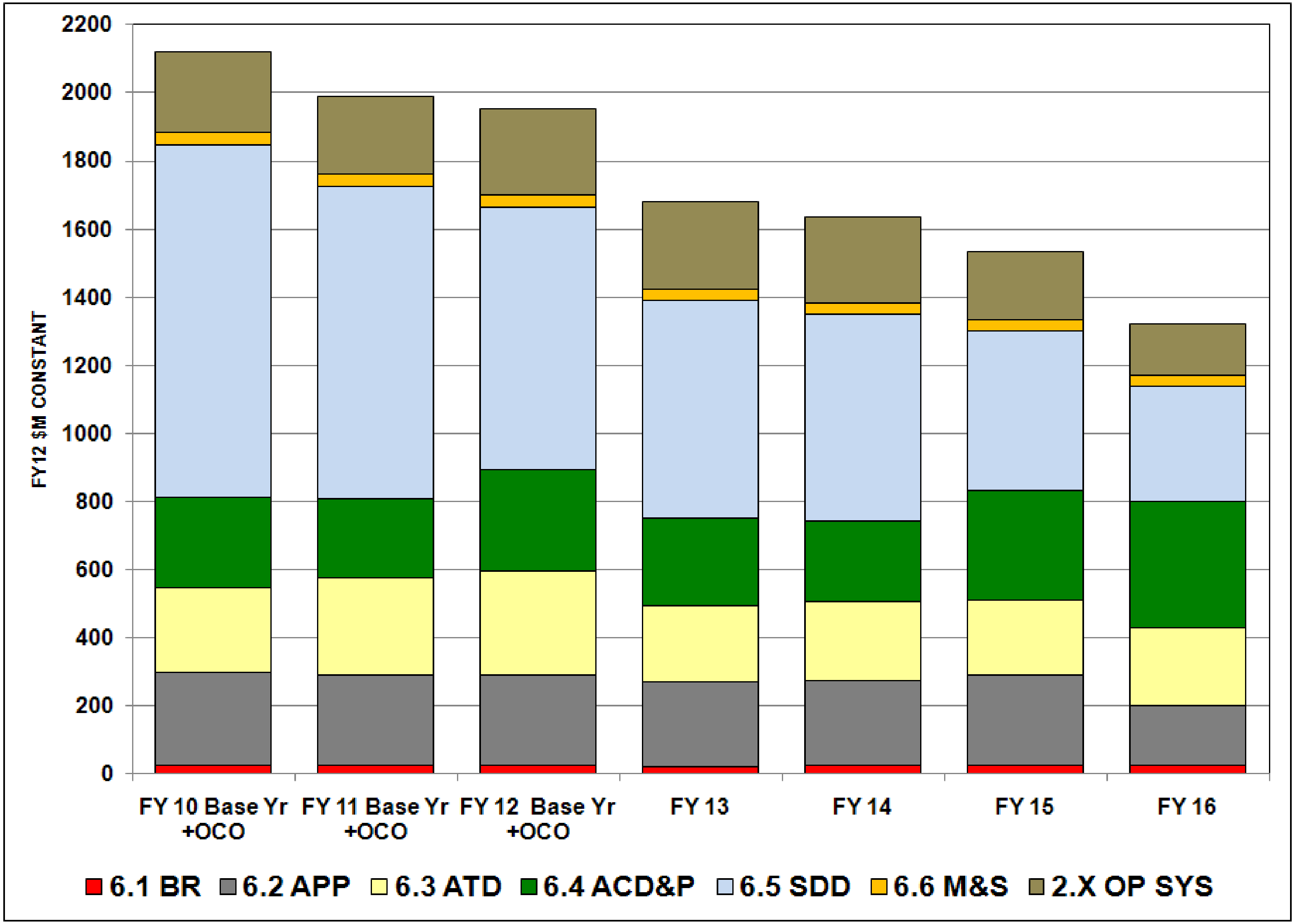
- Assign senior managers for acquisition of services
- Adopt uniform services market segmentation (taxonomy)
- Address causes of poor tradecraft
  - Define requirements and prevent creep
  - Conduct market research
- Increase small business participation

Reduce Non-Productive Processes and Bureaucracy

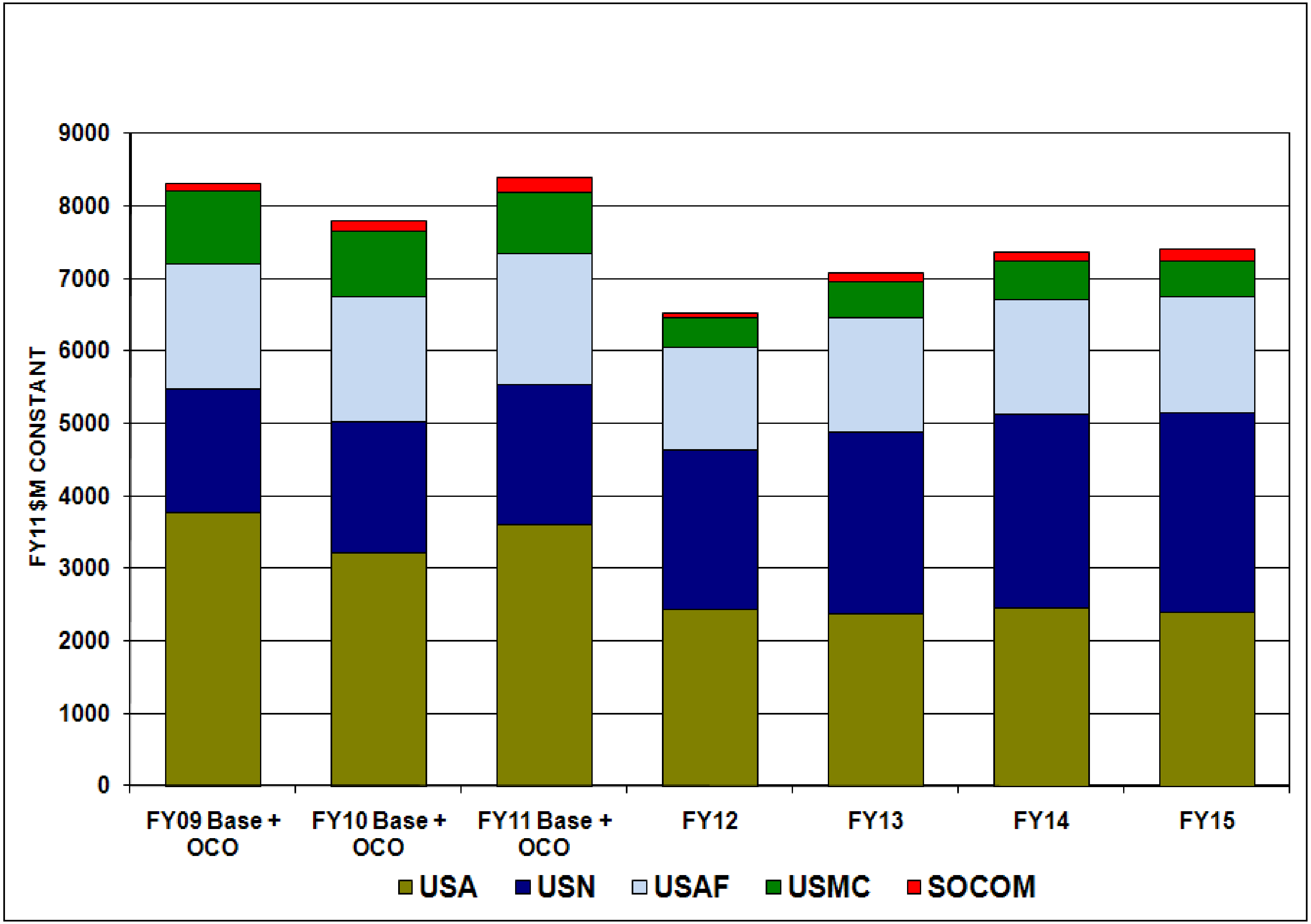
- Reduce frequency of OSD level reviews
- Work with Congress to eliminate low value added statutory requirements
- Reduce the volume and cost of Congressional Reports
- Reduce non-value added requirements imposed on industry
- Align DCMA and DCAA processes to ensure work is complementary
- Increase use of Forward Pricing Rate Recommendations (FPRRs) to reduce administrative costs

Budget Overview

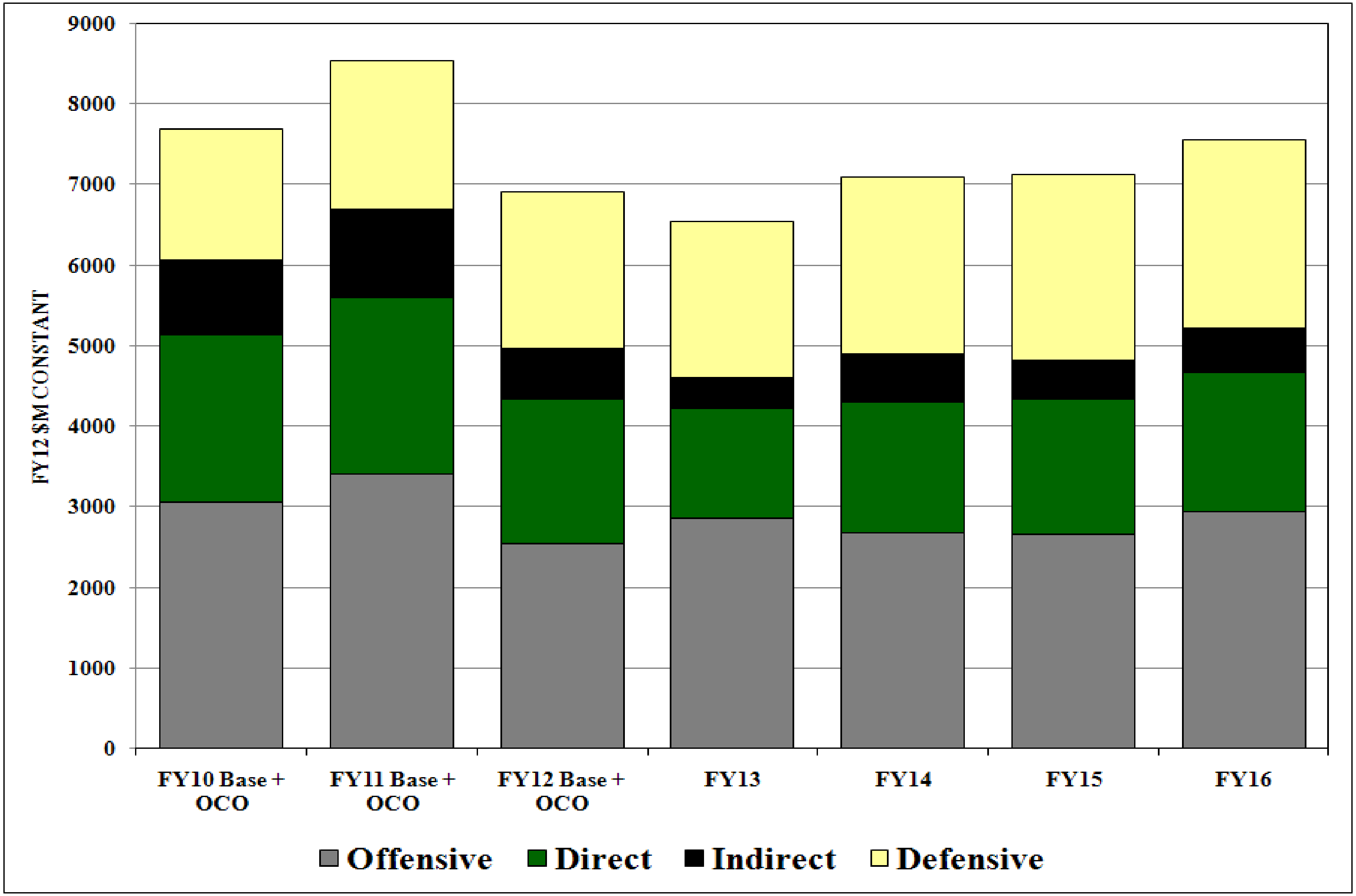
Munitions RDT&E – PB12



Munitions Procurement – PB12



Procurement by Type – PB12



Department-level Fuze Initiatives

DoD Fuze IPT Membership

- **OSD**
  - AT&L / Land Warfare & Munitions
  - AT&L / Defense Threat Reduction Agency
  - AT&L / Director of Defense Research & Engineering
  - AT&L / DCMA
  - Policy
- **Military Services**
  - Air Force
  - Army
  - Marines Corps
  - Navy
- **Department of Energy**
  - Lawrence Livermore National Laboratory
  - Los Alamos National Laboratory
  - Sandia National Laboratories

Fuze IPT Strategic Plan

- **Fuze Industrial Base Strategic Plan**
  - **Goal #1:** Advance and maintain a healthy U.S. contractor base
  - **Goal #2:** Ensure that the Government develops and maintains the capability to execute its responsibility to assure the safety and suitability for service of fuze systems
- **Fuze Technology Base Strategic Plan**
  - **Goal #1:** Advance and maintain a healthy U.S. fuze technology base
  - **Goal #2:** Establish early and continued Government involvement in the development, application, and transition of fuze technology to munitions development

Fuze IPT Issues/Focus

- **Current**
  - Monitor fuze acquisition programs
  - Identify and monitor fuze technology needs (JFTP)
  - Identify and monitor Industrial Base issues to include Single Point Failures

- **Revisit the Strategic Plan**
  - Hard look at Objectives needed to support existing Goals
  - Identify and prioritize actionable items that support Objectives
  - Coordinate with key Stakeholders in government and industry

JFTP Overview

- Established program in FY 2010
  - High Reliability and Survivability were drivers
- 4 Fuze Area Technology Groups formed:
  - Hard Target Survivable Fuzing
  - Tailorable Effects Weapon Fuzing
  - High Reliability Fuzing
  - Enabling Technologies and Common Architecture
- Participants
  - DoD communities: S&T / Requirements / Acquisition
  - Dept. of Energy
  - **Industry via DOTC**

DoD Ordnance Technology Consortium (DOTC)

Government Laboratories

- OUSD (AT&L) LW&M
- Department of The Army
- Department of the Navy
- Department of the Air Force
- Department of Energy
- Special Operations Command
- Other Agencies and Departments

Rapid & Agile Acquisitions

Section 845
Other Transaction

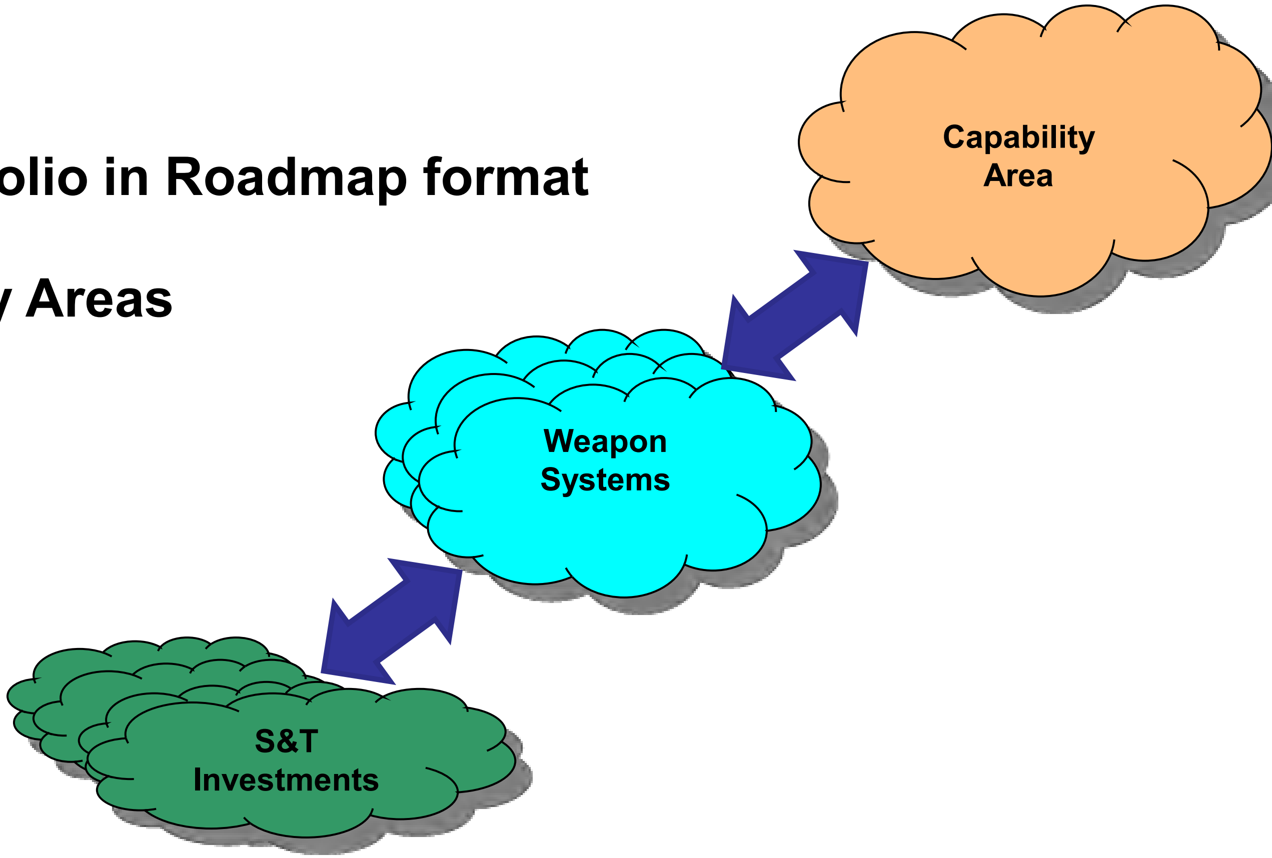
National Warheads & Energetics Consortium

- Defense Contractors
- Traditional & Non-Traditional
- Academic Institutions
- Not-for-Profits Organizations

DoD and NWEC… Partnering to Leverage Capabilities and Investment

Weapon Portfolio Assessment

- Layout Weapon Portfolio in Roadmap format
  - Identify Capability Areas



  - Identify current and future weapon systems
  - Identify S&T investments that support upgraded and new weapon systems.
- Assess the portfolio (Effectiveness and Affordability)

Questions?

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FUZE AND INITIATION SYSTEMS TECHNICAL REVIEW PANEL

THE NDIA'S 55TH ANNUAL FUZE CONFERENCE
SALT LAKE CITY, UT
24 - 26 MAY 2011

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Outline

- Background
- Purpose
- Membership
- Interface
- Design Safety Criteria
- Review Process
- Presentation/Data Package
- Recent Focus Areas
- Observations

HISTORY

USS Oriskany

- October 26, 1966
  - Magnesium parachute flare exploded in the flare locker of Hanger Bay 1, beneath the carrier's flight deck
  - A seaman threw the ignited flare back into the weapons locker where the flares were kept for storage instead of throwing it over the side into the water
  - Fire raced through five decks
  - Crewmen jettisoned heavy bombs which lay within reach of the flames, wheeled planes out of danger, and rescued pilots
- 44 killed
- 6 aircraft destroyed

USS Forrestal

- July 29, 1967
  - A ZUNI rocket was fired accidentally from an aircraft
  - 2 different teams bypassed a safety thinking the other safety would still provide the safety
  - The rocket screamed across the deck, struck the future Sen. John McCain's plane and ignited a fuel fire (3 months later he was shot down over Hanoi was a POW for 6 yrs)
  - 90 seconds after the fire started, a 1,000 lb bomb detonated
  - The detonation ruptured the flight deck, and burning fuel spilled into the lower levels of the ship
  - Bombs, warheads, and rocket motors exploded from the intensity of the fire
- 134 killed
- 161 wounded
- 21 aircraft destroyed

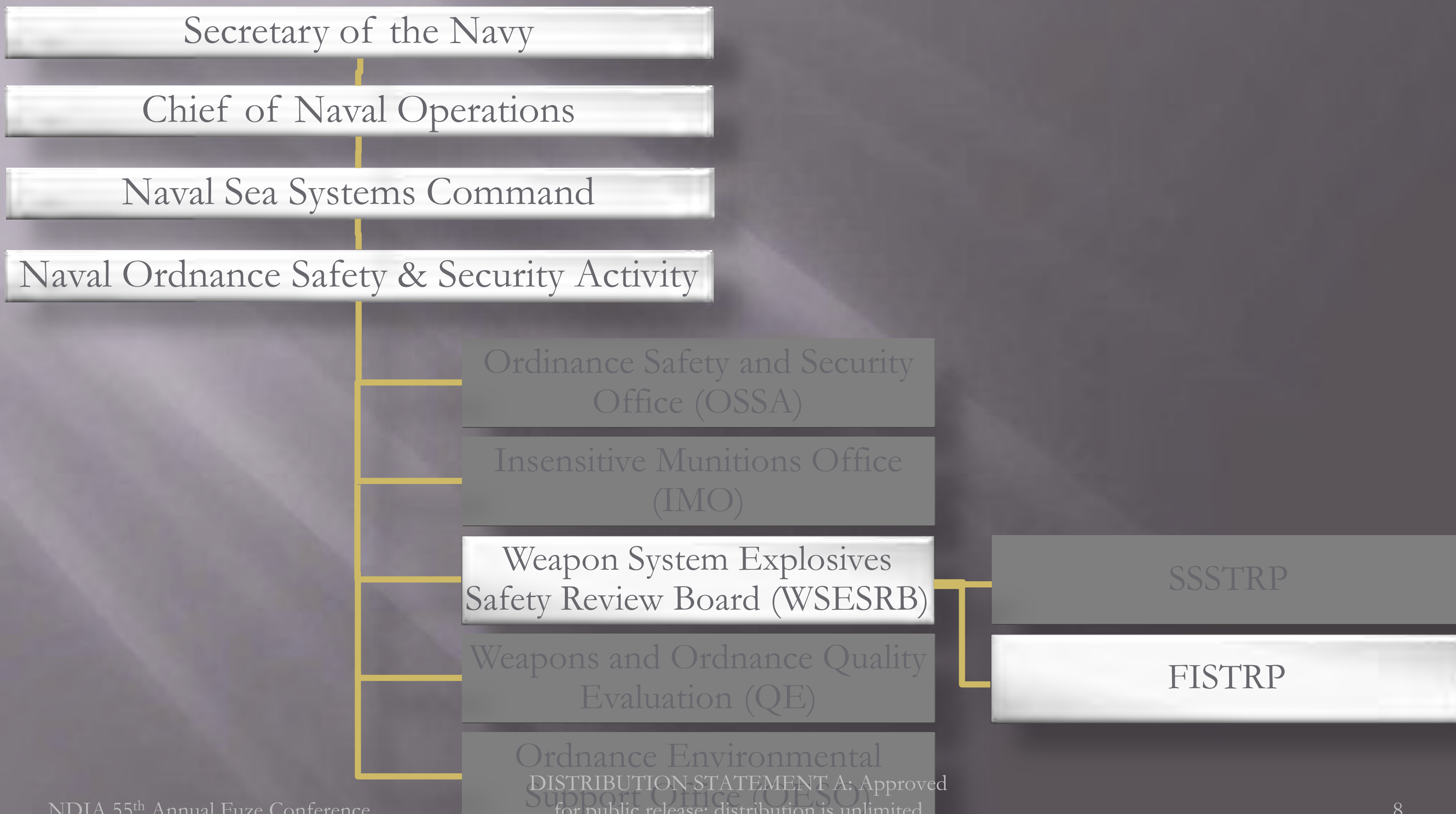
USS Enterprise

- January 14, 1969
  - Exhaust from an aircraft engine starter was directed at a pod containing 4 ZUNI rockets. Heat caused a warhead to detonate. Fragments ruptured the aircraft's fuel tank and ignited a fire.
  - Three more ZUNI warheads detonated less than a minute after the first explosion. The shaped charges blew holes through the flight deck allowing burning fuel to invade the lower decks.
- 28 killed
- 344 wounded
- 15 aircraft destroyed

Safety Program

- As a result of these accidents, a comprehensive ordnance safety program was initiated
  - Insensitive Munitions (IM)
    - Fast cook-off
    - Slow cook-off
    - Bullet impact
  - HERO
  - Environmental Testing
    - MIL-STD-331
  - Design Safety
    - MIL-STD-1316, MIL-STD-1901

Navy Safety Board Organization Chart



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Technical Review Panels

- Weapon Systems Explosive Safety Review Board (WSESRB) established Technical Review Panels (TRPs) in late 1980's
  - WSESRB chairperson may establish TRPs to review specific safety aspects requiring special expertise
  - Regularly meeting TRPs currently consist of:
    - Software System Safety Technical Review Panel (SSSTRP)
      - SSSTRP reviews specific safety aspects requiring special expertise in the area of analysis and testing of safety-critical software, firmware, and software-like devices contained in weapons and weapon systems
    - Fuze and Initiation Systems Technical Review Panel (FISTRP)
      - FISTRP reviews specific safety aspects requiring expertise in the area of design, analysis, and testing of fuzes, safety and arming (S&A) devices, initiation safety devices, and initiators

Purpose

- Provide expert technical review of the safety programs for fuze designs, ignition safety devices, and related S&A devices used in Navy weapon systems (Ref. NAVSEAINST 8020.6)
  - Allows more in-depth review
  - Affords focused review by technical experts in specialized fields
  - Reduces time required at WSESRB review

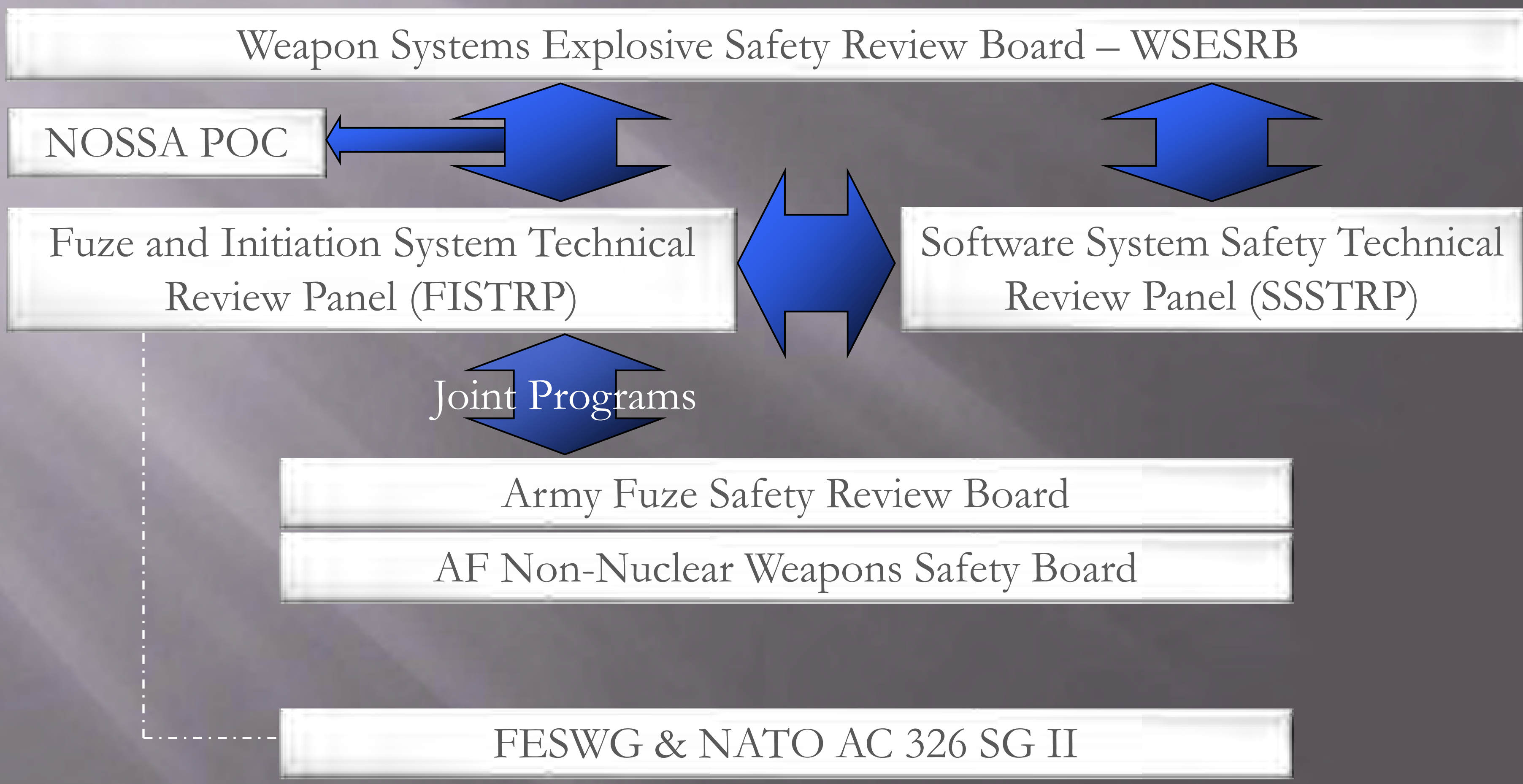
FISTRP Membership

- Chairperson appointed by the WSESRB chairperson
- Members and technical advisors appointed by TRP chairperson
  - Members are typically government employees from Navy Labs
  - Individuals must have experience and expertise in their respective areas
    - Specific areas of expertise include the following:
      - Fuze design, ignition system and ignition safety device design, explosive safety, initiators, logic devices, system safety, fuze development, and individual weapon systems design and development
  - Members are approved by WSESRB
- Individuals from the Air Force and Army safety boards may participate

2011 FISTRP MEMBERS

- Raymond Ash - Naval Air Warfare Center Weapons Division China Lake
- Ralph Balestrieri - Naval Surface Warfare Center Indian Head Division
- Tinya Coles-Cieply - Naval Surface Warfare Center Indian Head Division
- Randall Cope - Naval Air Warfare Center Weapons Division China Lake
- Michael Demmick - Naval Ordnance Safety and Security Activity
- Bradley Hanna - Naval Surface Warfare Center Dahlgren Division
- John Hendershot - Naval Surface Warfare Center Indian Head Division
- George Hennings - Naval Air Warfare Center Weapons Division China Lake
- John Hughes - Naval Air Warfare Center Weapons Division China Lake
- John Kandell - Naval Air Warfare Center Weapons Division China Lake
- David Libbon - Naval Surface Warfare Center Dahlgren Division
- Melissa Milani – EODTECHDIV Indian Head Division
- Scott Pomeroy - Naval Surface Warfare Center Dahlgren Division
- Gabriel Soto - Naval Air Warfare Center Weapons Division China Lake

FISTRP Interfaces



Review Criteria

- Design Safety Criteria
  - Fuzes/S&As — STANAG 4187/MIL-STD-1316
  - Initiation Systems — STANAG 4368/MIL-STD-1901
  - Hand Emplaced Ord. — STANAG 4497/MIL-STD-1911
  - Initiators — STANAG 4560/MIL-DTL-23659
  - Explosive Materials — STANAG 4170/AOP-7
  - Safety & Suitability — STANAG 4157/AOP-20/MIL-STD-331
  - WSESRB Technical Manual on Electronic Safety and Arming Devices with Non-interrupted Explosive Trains

Review Criteria (continued)

- Design Safety Criteria (continued)
  - FESWG Technical Manuals on Logic Devices
  - FESWG Guideline for Qualification of Fuzes, S&As and ISDs (Draft)
  - Proposed Methodology for Electrical Stress Testing (EST) of Electronic Safe Arm Devices (Draft)
- Designs will be assessed against most current version

Review Process

- Program coordinates with NOSSA POC and FISTRP chairperson to determine appropriate type of review
  - Formal Review
    - Data package is required 21 days prior to review
    - Typical review will consist of no more than four to six hours of review/discussions and two or more hours for panel members to caucus
    - Draft findings will be briefed to the program at the conclusion of review
      - Findings are not final until presented to and accepted by the WSESRB
      - Findings are formally briefed to WSESRB at Executive Session
    - The agenda will be left to the discretion of the program office; however, it should take into consideration the above and should address the items listed in the Technical Data Package section below.
  - Letter Data Package
    - Requires limited review of data
    - Involves narrowly focused issue
  - Technical Assistance Meeting
    - Can be a specific device or concept
    - No findings or minutes generated

Data Package and Presentation Material

- Brief program and/or weapon system overview
- Identification of the specific application, platform, and/or weapon for which approval is being requested
- Design description including:
  - Detailed description of arming environment/user interactions
  - Detailed description of safety feature implementations to include mechanical drawings and/or electrical schematics
  - Identification of all energy sources, including stored energy devices, in the system
  - Identification of all energetic materials in the design and the qualification status of each
  - Identification of application unique hazards
- Design validation and qualification test program
  - Detailed description of the life cycle and life cycle environments to which the device is exposed throughout its service life
  - MIL-STD-331 qualification plan/report including number of units, sequence of tests, test parameters, pass-fail criteria, and justification of test selection
  - Comparison of qualification testing to "DoD Fuze Engineering Standardization Working Group Guideline for Qualification of Fuzes, Safe and Arm Devices and Ignition Safety Devices"
  - Justification of 'by similarity' claims

Data Package and Presentation Material

- Initiator Qualification Test Program, where appropriate
  - MIL-DTL-23659 Qualification plan/report
  - Justification of ‘by similarity’ claims
- Fault Tree Analysis including:
  - Failure modes, effects, and criticality analysis
  - Description of fault tree analysis process and underline assumptions
  - Description of minimum cut sets and causal factors
  - Independent assessment of fault tree analysis
- Assessment of the design to applicable safety standards such as MIL-STD-1316D, MIL-STD-1901, MIL-STD-1911, WSESRB Technical Manual, and other safety criteria to include:
  - Compliance matrices
  - Supporting documentation
  - For any areas of non compliance, quantification and acceptance of risk at the appropriate level
- Safe Separation/Arming Delay Analysis, where applicable
  - Joint Munitions Effectiveness Manual, or equivalent, safe separation analysis which includes effects of warhead blast, heat and fragmentation. Analysis should also include the effect of weapon parasitic and any unspent energetic
  - Identify any operational requirements which mandate early arming – arming where the probability of hit is less than one in 10,000 or probability of hazardous fragment (for human body damage) is less than one in 10,000 - and quantify the hazard to the user
- Draft presentation

Compliance with Requirements

- Compliant
  - Meet the requirement
  - Meet the intent of the requirement (as interpreted by the FISTRP)
- Non-Compliant
  - Seek risk acceptance in accordance with MIL-STD-882
    - The hazard associated with a non-compliance must be determined
    - The risk associate with this hazard must be quantified
    - Mitigations should be considered
    - The residual risk must be accepted at the appropriate level

Closing Findings

- Submit a Letter Data Package (LDP) through your NOSSA POC
  - Provide justification
- Request closure during a formal review
  - Present justification
- Finding are not closed at informal reviews

RECENT TECHNICAL TOPICS

Logic Devices

- Important updates concerning charge-based memory device usage
  - Evolving Requirements for the Use of Logic Devices in the Implementation of Safety Features
    - Mr. John Hughes
- Use of microprocessors/microcontrollers

Acceptable In-Line Energetics

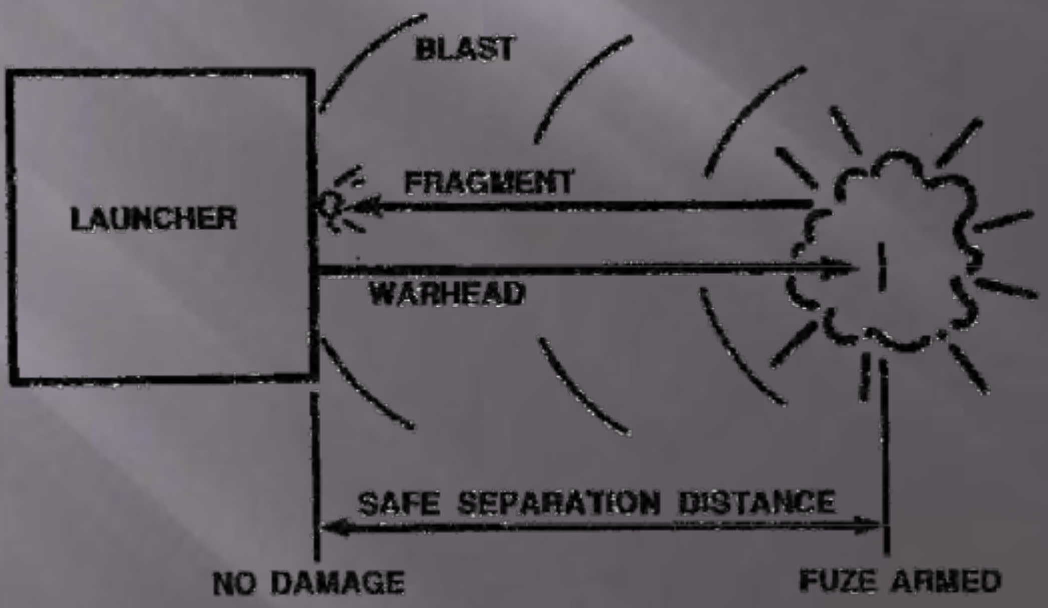
- Only those energetics listed in the appropriate standard are approved for use in a position leading to the initiation of the main energetic without interruption
- Other materials must be tested in accordance with AOP-7 and shown to be no more sensitive than RDX type I or II, class 5 conforming to MIL-DTL-398 (RDX or BKNO3 for pyrotechnic energetics)
  - Requires testing reference material contemporaneously with the candidate material
  - Must pass all mandatory AOP-7 requirements

Use of In-Line Initiators

- New or Modified Initiator
  - MIL-DTL-23659 qualification test series
    - ILIs not fully tested to MIL-DTL-23659 may be acceptable for a particular application, but will not be MIL-DTL-23659 qualified and will need to show a non-compliance in the applicable MIL-STD
  - Safety fireset testing
  - Must use energetics qualified and approved for in-line use
- Previously Qualified Initiator
  - Consider environments not covered in previous qualification
    - Electrical cook-off testing
    - Environmental exposure
  - Firing properties with intended use fireset
    - Transient electrical characteristics 25% rule
  - High fire testing

Safe Separation Distance

- The minimum distance between the launcher and the munition beyond which the hazards to the delivery system and personnel resulting from the functioning of the munition are reduced to an acceptable level



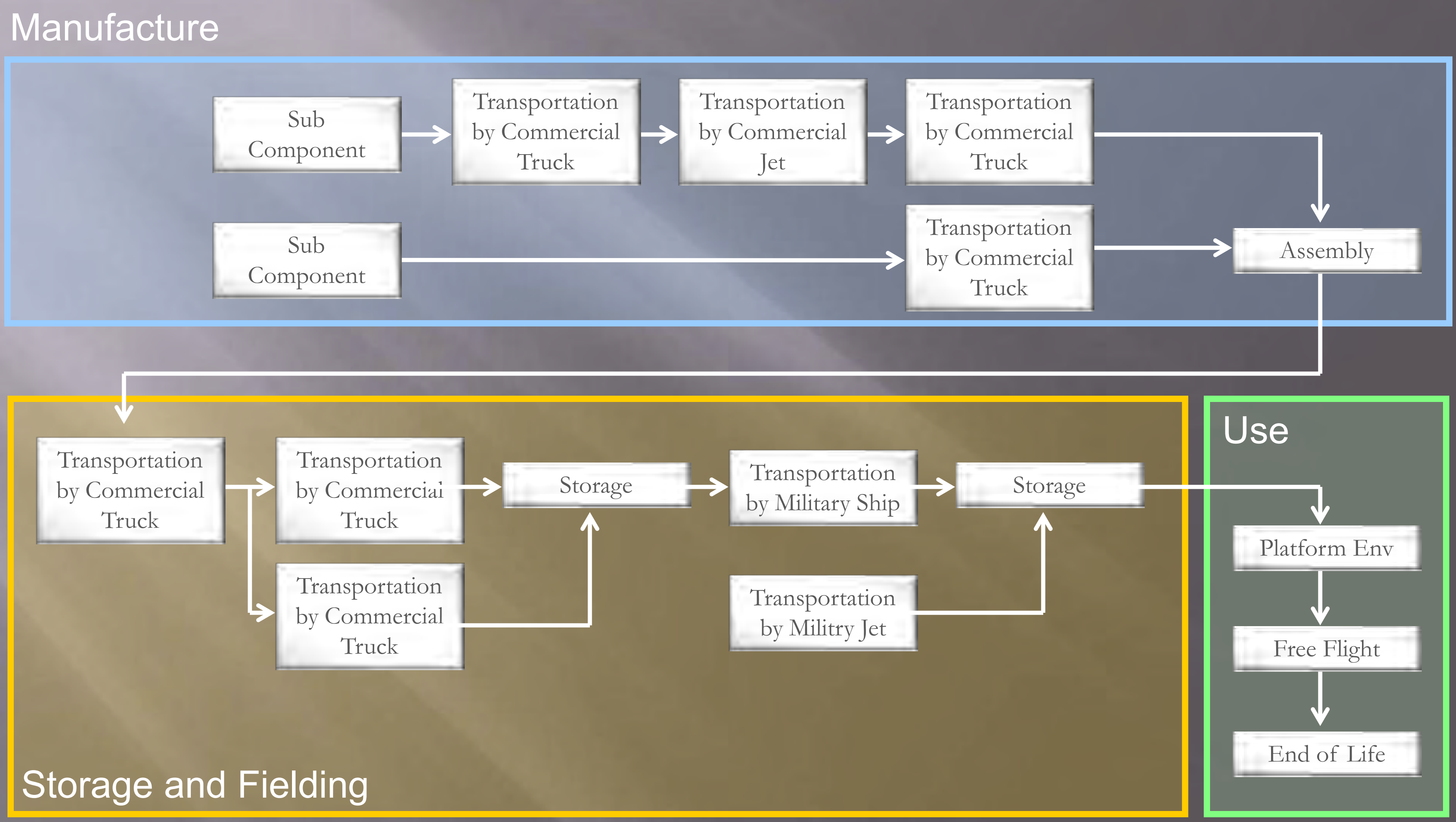
Safe Separation Analysis

- MIL-HDBK-504
  - Assumes function/detonation at minimum arming distance
  - < 1 in 10,000
    - Probability of Hit for launch platform (MIL-HDBK-504, appendix B)
    - Probability of hazardous fragment for personnel (MIL-HDBK-504, appendix A)
  - > 1 in 10,000 must seek risk acceptance
    - Residual risk < 1 in 1,000,000 for a 1E Hazard
      - Probability of function limited to 1 in 100
      - Probability of kill
      - Probability of lethal fragment

Fuze Qualification Testing

- MIL-STD-331C Environmental and Performance Tests for Fuze and Fuze Components Mechanical Shock Tests
  - Jolt - safe for use
  - Jumble - safe for use
  - 40 ft (12 m) drop - safe for disposal
  - 5 ft (1.5 m) drop - safe for use
  - Transportation Vibration
- Vibration/Climatic Tests – Operable
  - Thermal Shock
  - Long Term Storage @ -65°F / +160°F
  - Rough Handling
  - Salt Fog
  - Rain
  - Dust
- Safety, Arming and Functioning Tests
- Fuze Exposure to Physical Conditions During Complete Life Cycle

Example of Life Cycle Environments



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Review Tips

- Refresh our memory
  - Formal, informal, LDP
- Fuze/initiation system safety requirements can impact design; early start is essential to minimize this potential
- Advancement in technology often stresses safety assessment ability
- General requirements continuously being clarified for specific technology
- Keeping safety architecture and implementation simple is generally a good thing
- Misinterpretation of safety requirements
- Comprehensive testing is essential part of safety assessment

MK419 Mod 1
Multi-Function Fuze
Product Improvement Program

BY

Richard Chapman
Naval Surface Warfare Center
Dahlgren Division

OUTLINE

- **PERFORMANCE:**

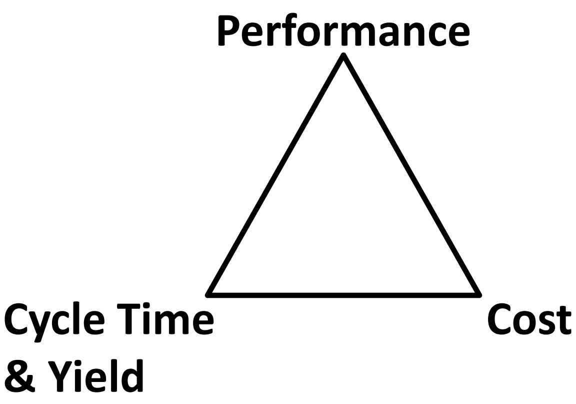
Multi-Function Fuze (MFF) Operational Modes

- **CYCLE TIME & YIELD:**

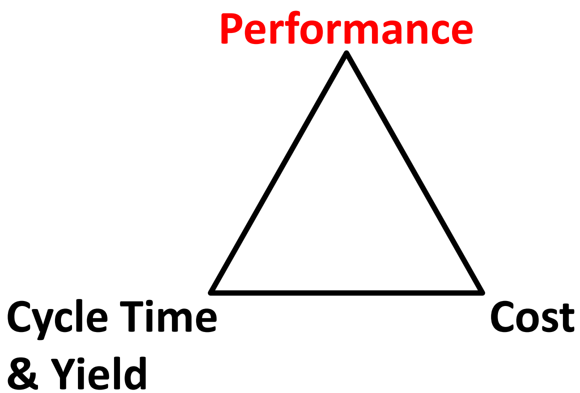
Statistical Process Control Handshake for Cycle Time and Yield

- **MOD 1 COMPONENT SUMMARY:**

Performance, Cycle Time, Yield, and Cost with Full Module Assembly

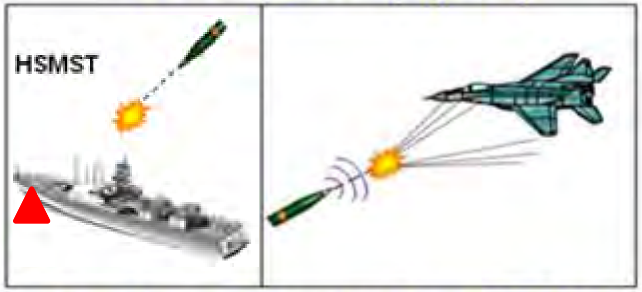


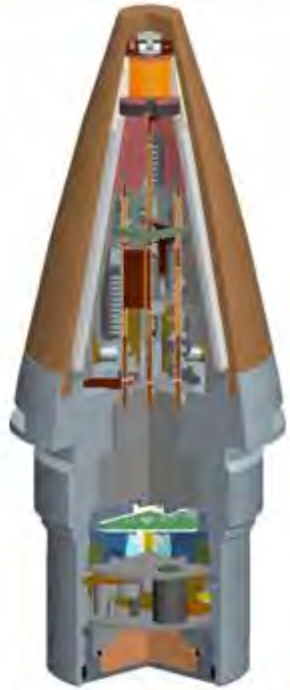
PERFORMANCE:
Multi-Function Fuze (MFF) Operational Modes



Multi-Function Fuze (MFF) Operational Modes

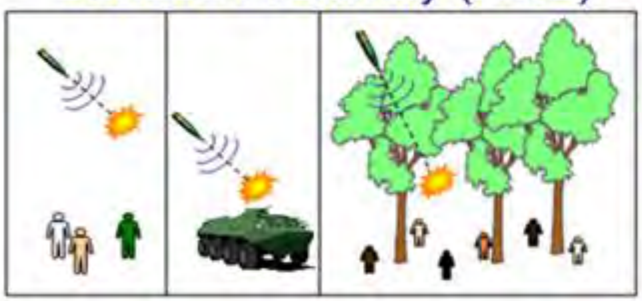
Air Proximity (AIR)





Point Detonating (PD)

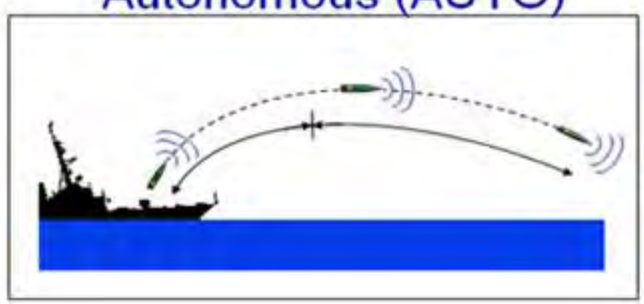
Surface Proximity (HOB)



Electronic Time (ET)

Replaces VT, CVT, MT and PD fuzes on HE rounds. Simplifies logistics. Uses IM Explosives.

Autonomous (AUTO)

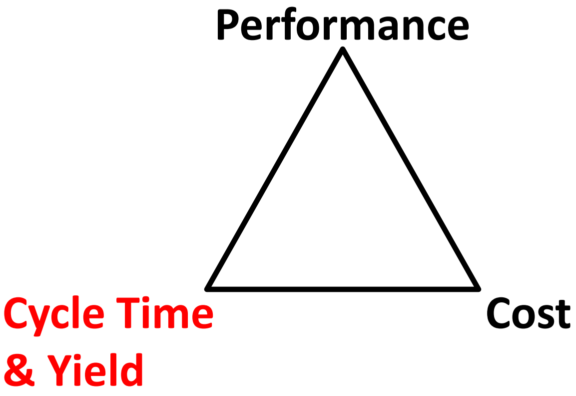


Multiplies effectiveness of ship's magazine. Improves fuze performance, accuracy and versatility.

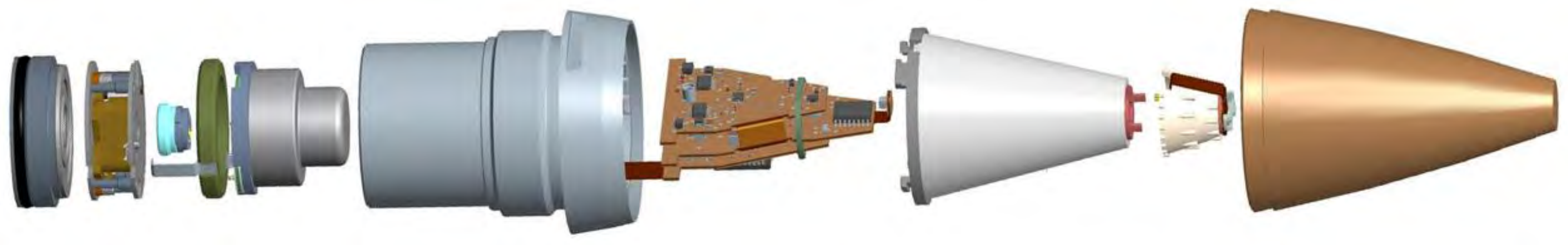
The MFF can fit 76mm and 5 inch rounds.

CYCLE TIME & YIELD:

Statistical Process Control Handshake for Cycle Time and Yield



Statistical Process Control For Cycle Time Reduction



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

+

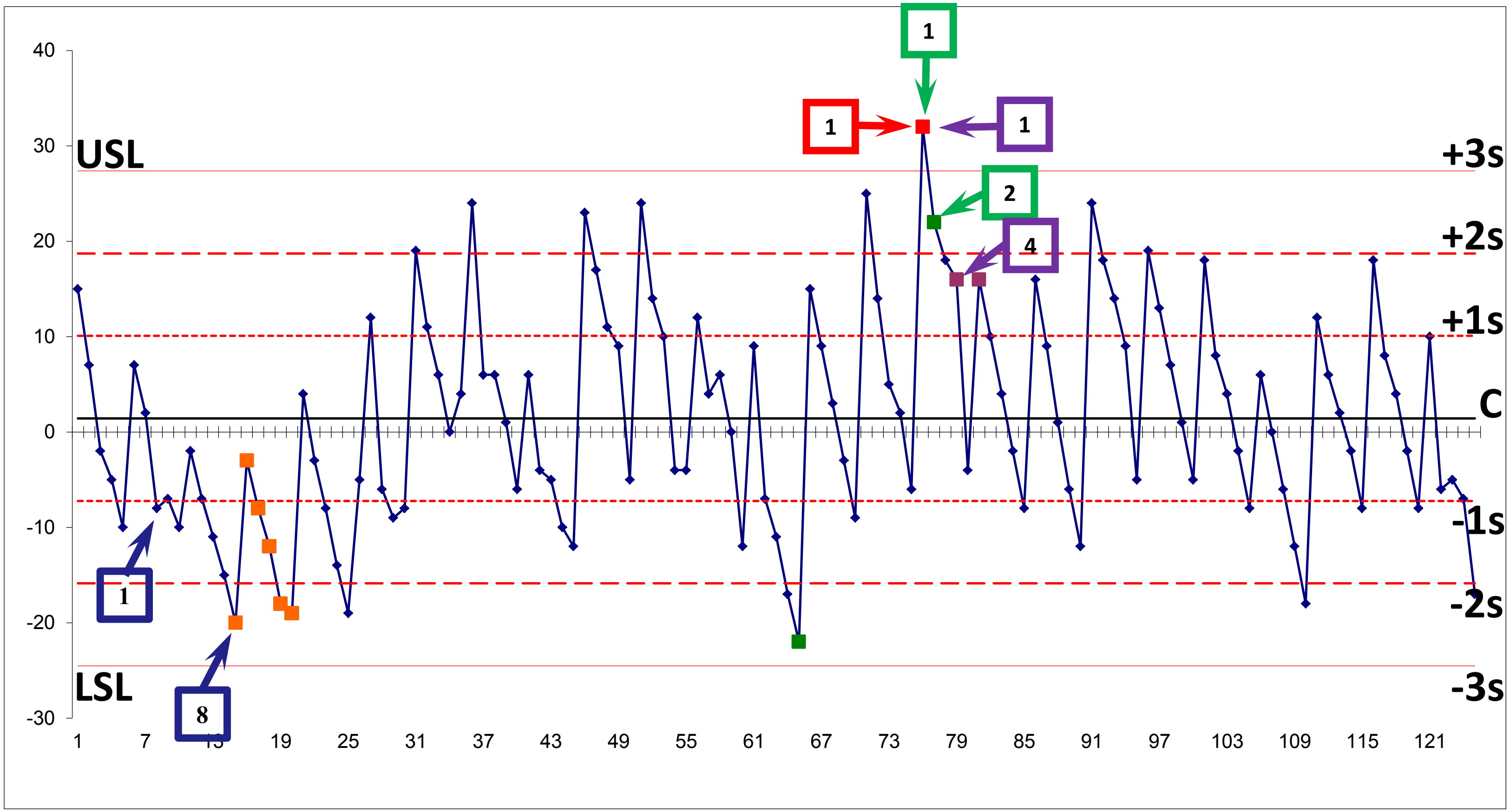
WIDE USL – LSL

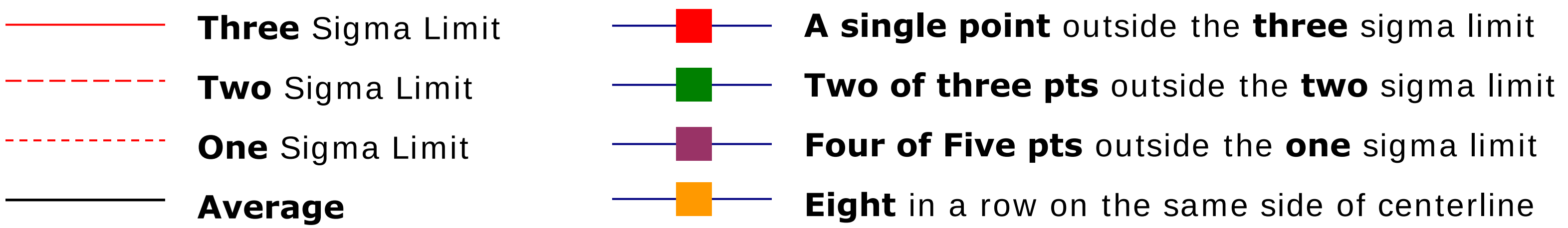
=

GOOD CAPABILITY

EXCELLENT YIELD

X Bar & S Statistical Process Control Shewhart Rules (Yield Consequence)





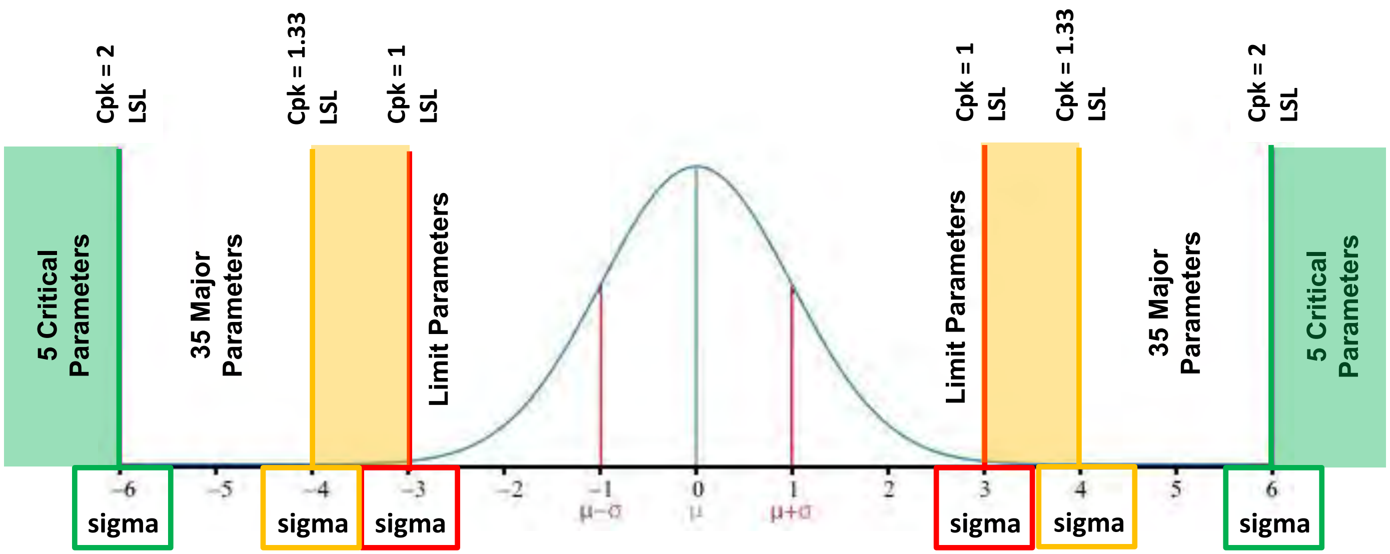
http://asq.org/learn-about-quality/statistical-process-control/overview/overview.html

Statistical Process Control
Cycle Time and Yield Handshake

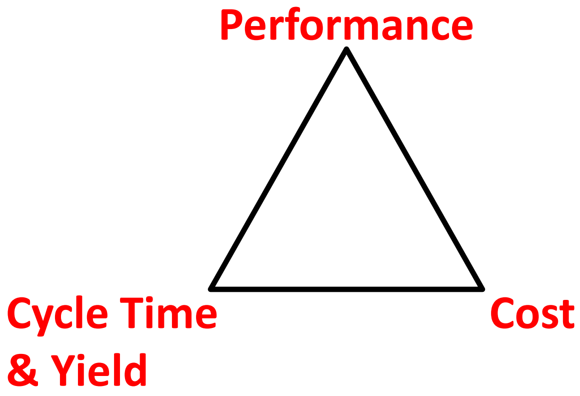
Fewer steps not only reduce Cycle Time, but increases Yield due to reduced manipulative errors.

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%

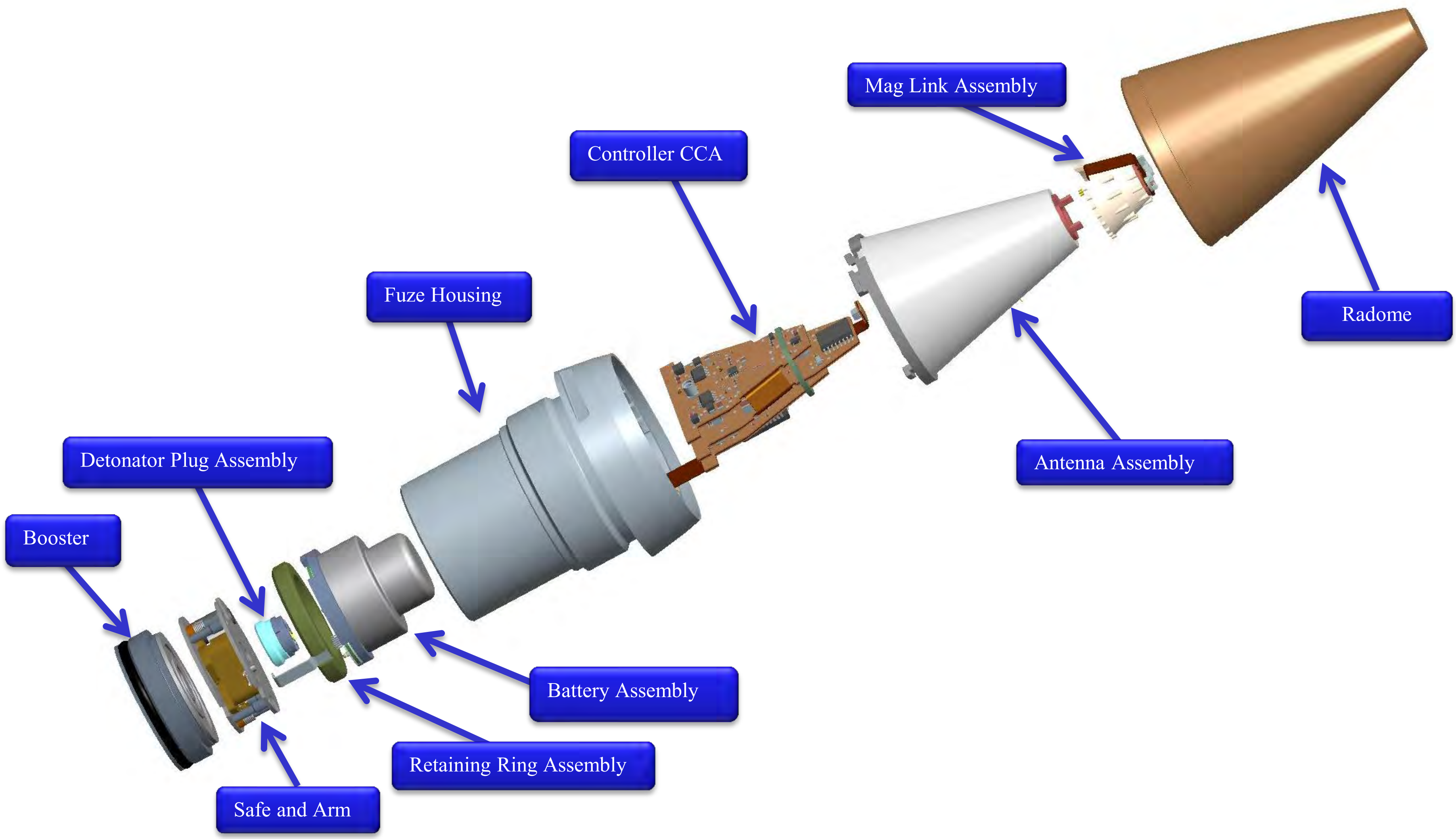
95% Fuze Yield



MOD 1 COMPONENT SUMMARY: Performance, Cycle Time, Yield, and Cost with Full Module Assembly



Major Subassemblies And Components



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Radome And Mag Link Assembly

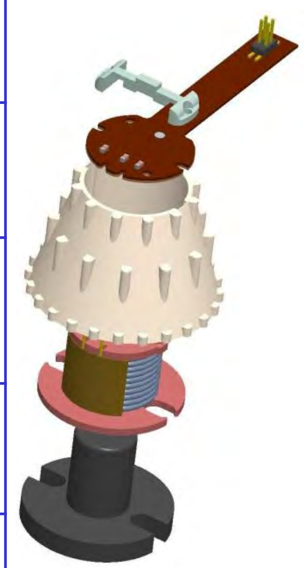
IMPROVEMENTS FOR MOD 1

- **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

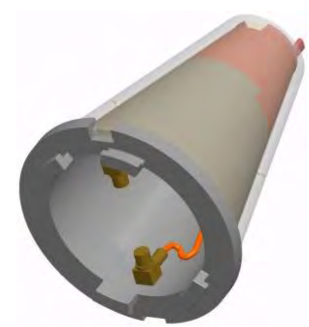
- **Performance:**
Dielectric improvement
ESD protection improvement

- **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

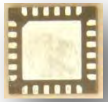
- ✓ MOD1 Receiver successfully designed, repackaged, built, and tested
- ✓ Increased LO drive range helps eliminate expensive unit tuning
- ✓ Successfully integrated and tested Receiver MMIC

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



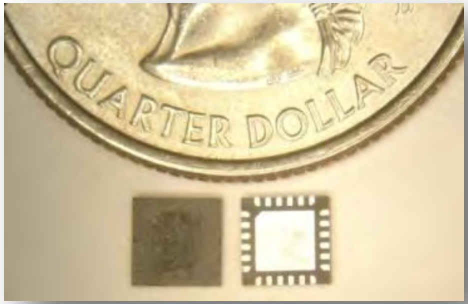
- ✓ Added ESD protection to improve reliability

- ✓ 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



<u>1st Design Iteration</u>

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

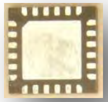
<u>2nd Design Iteration</u>

- ✓ 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

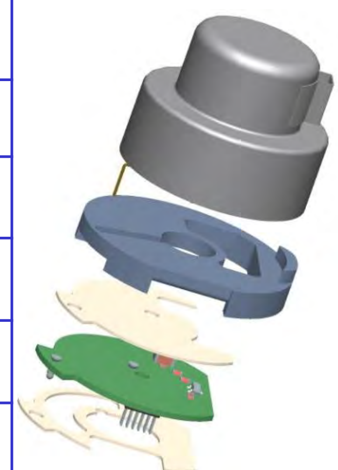
MOD-1
✓ Integrated into one PWB ✓ Panel fits twice as many PWBs 
✓ Obsolete parts resolved ✓ Miniaturized components
✓ New potting eliminates component staking ✓ Improved component clearances for potting flow
✓ Improved component clearances ✓ No taping required
✓ Improved clearance and fitment
✓ Standard 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

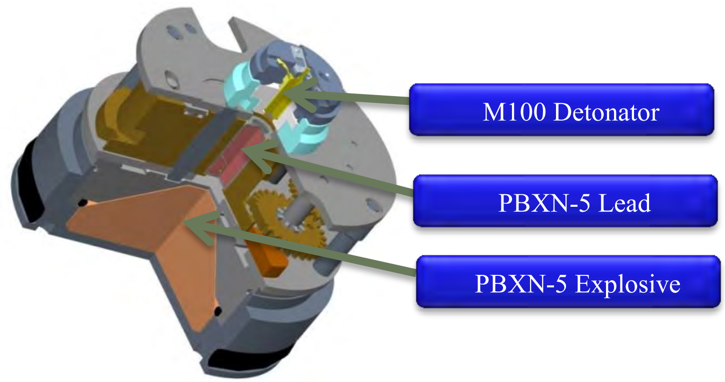
IMPROVEMENTS FOR MOD 1

- **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



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

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

✓ PERFORMANCE:

- Going forward for HSMSTs
- New hardware has improved tolerance

✓ CYCLE TIME:

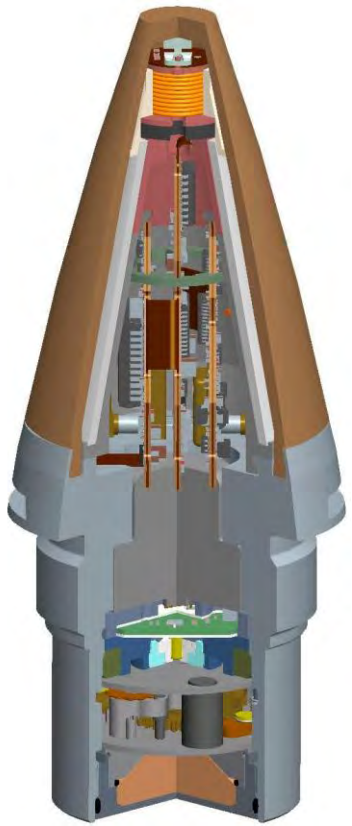
- 72 parts for Mod 0 compared to 40 parts for Mod 1
- Mod 1 Cycle Time is reduced by 65%

✓ 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

55th Annual Fuze Conference
Fuzing„s Evolving Role in Smart Weapons

Development of a new MEMS High-g Accelerometer

R. Külls,
S. Nau, S. Heß, N. Pilous
Fraunhofer Ernst-Mach-Institut EMI

Salt Lake City, May 26th 2011

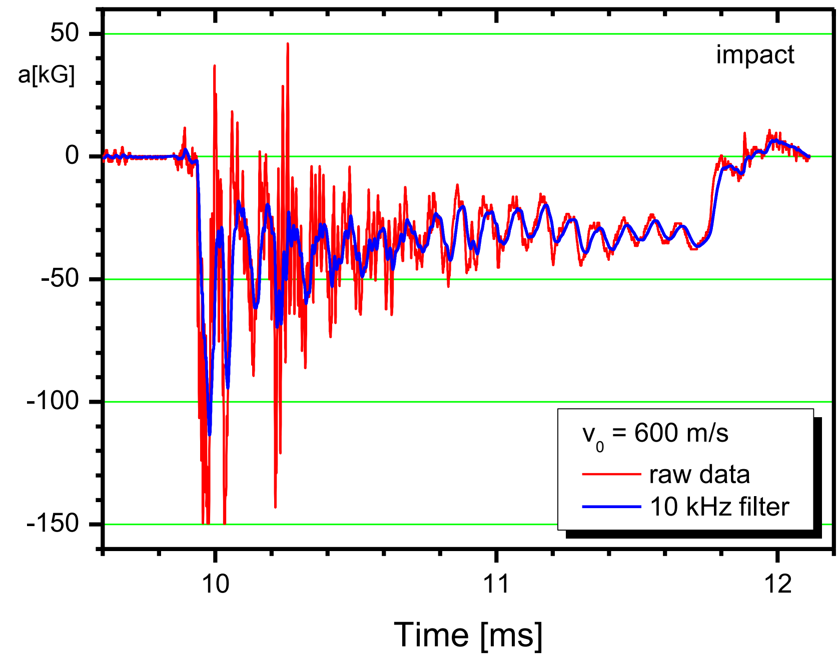
Fraunhofer EMI

OUTLINE

- Introduction
  - High-g Applications
- Theory
  - Transient Excitations
- Design
- First Experimental Data
  - Hopkinson Bar
  - 200,000 g Measurement
- Summary and Outlook

High-g Applications: Research

- Analysis of highly dynamic processes
  - Shock-testing of electronics
    Measurement range needed: 50,000 g
  - Material characterization
    g-Range > 80,000 g
  - Penetration processes
    g-Range > 100,000 g
  - Near field blast
    g-Range > 100,000 g



High-g Applications: Military

Pictures: Wikipedia

- High-g hardened fuzing in smart weapons
  - Large warheads
  - Artillery shells
  - Upcoming:
    Smaller calibers
    > 100,000 g
- The smaller the ammunition, the bigger the acceleration

High-g Applications: Military

Pictures: Wikipedia

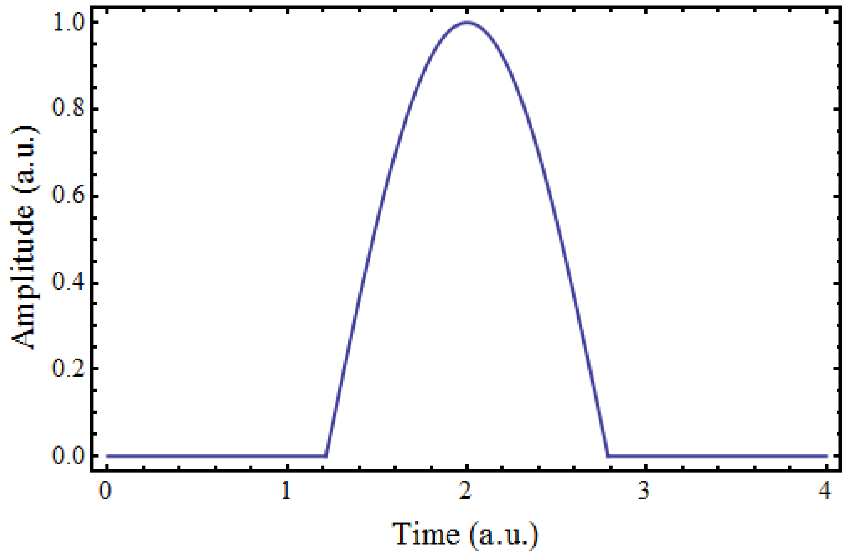
- High-g hardened fuzing in smart weapons
  - Large warheads
  - Artillery shells
  - Upcoming: Smaller calibers > 100,000 g

Requirements:
g-Range
Survivability
Size

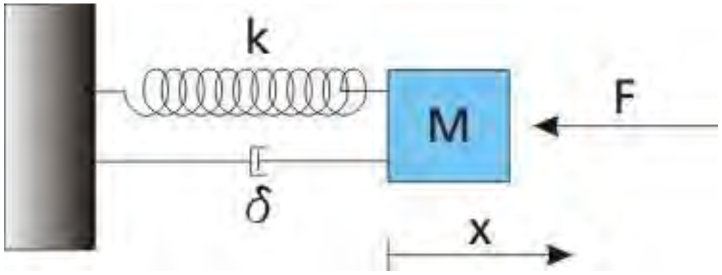
- The smaller the ammunition, the bigger the acceleration
- ➢ Need for small, affordable (very-)high-g accelerometer

Basics of High-g Accelerometry

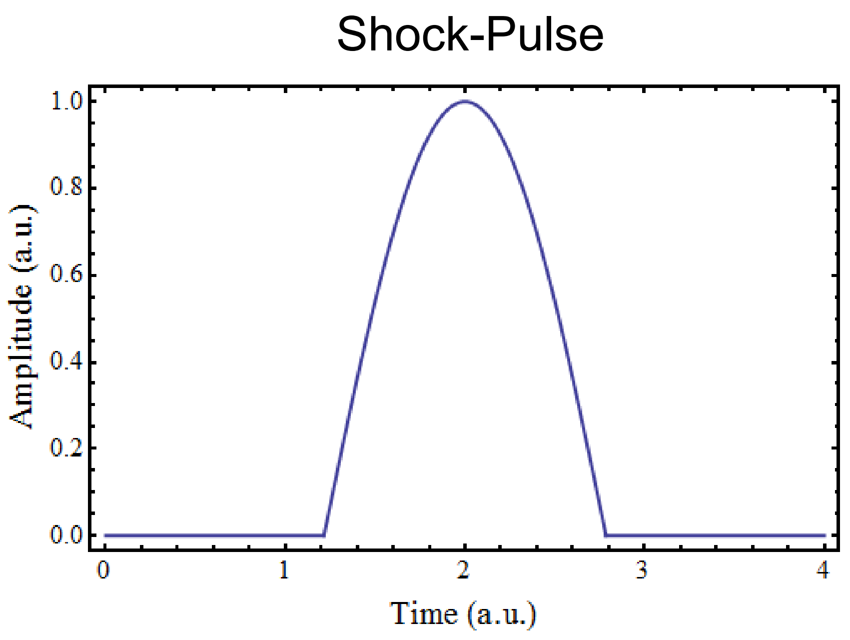
- Shock pulse:
  - “short“, “discontinuous“, “rapidly varying“

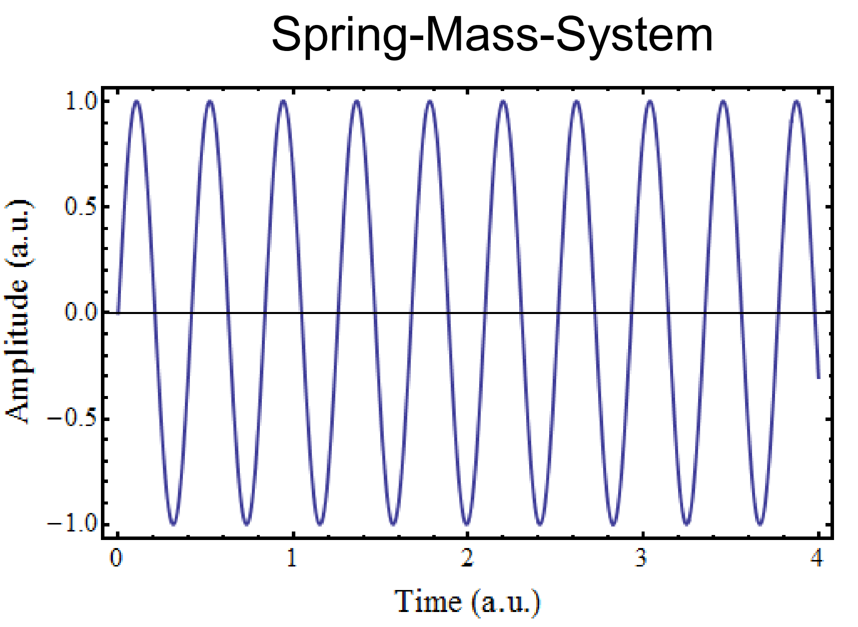


- Accelerometer:
  - Spring-mass-system with resonant frequency
  - Displacement results in signal

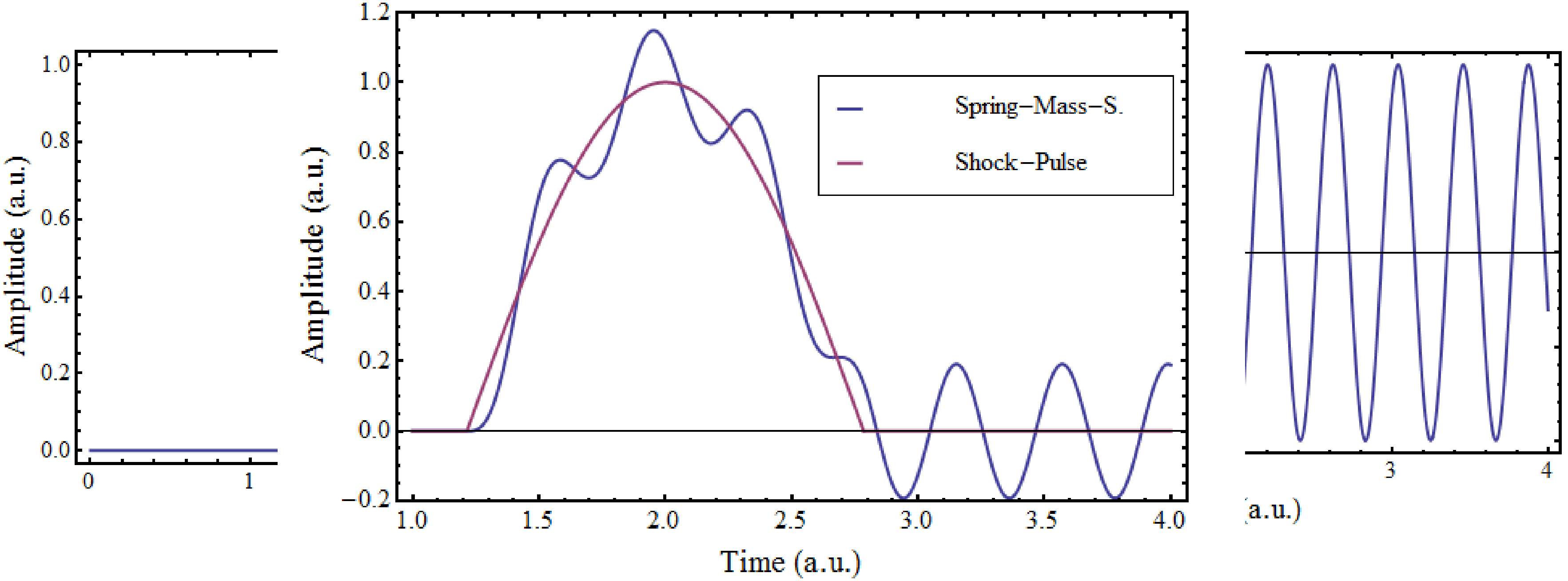


Excitation of a Spring-Mass-System: Sample Pulse





Excitation of a Spring-Mass-System: Analytical Solution



- How to avoid oscillations and over-excitation?
  1. Damping (+ stops)
  2. Higher resonant frequency

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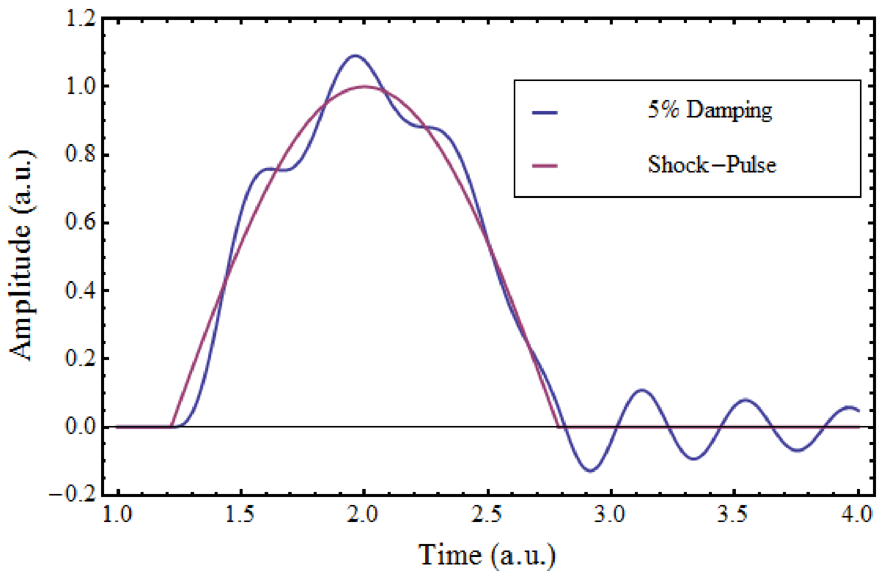
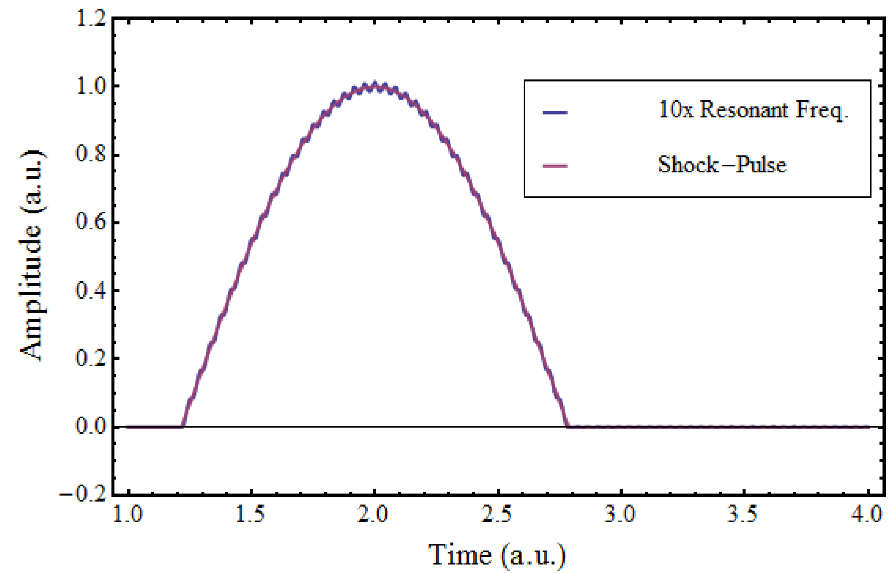
Reducing Oscillations





- 5% Damping:
  - Over-excitation 15% -> 10%
  - Oscillations 20% -> 10% -> 0%
- 10x Resonant Frequency:
  - Over-excitation 15% -> 2%
  - Oscillations 20% -> 2%

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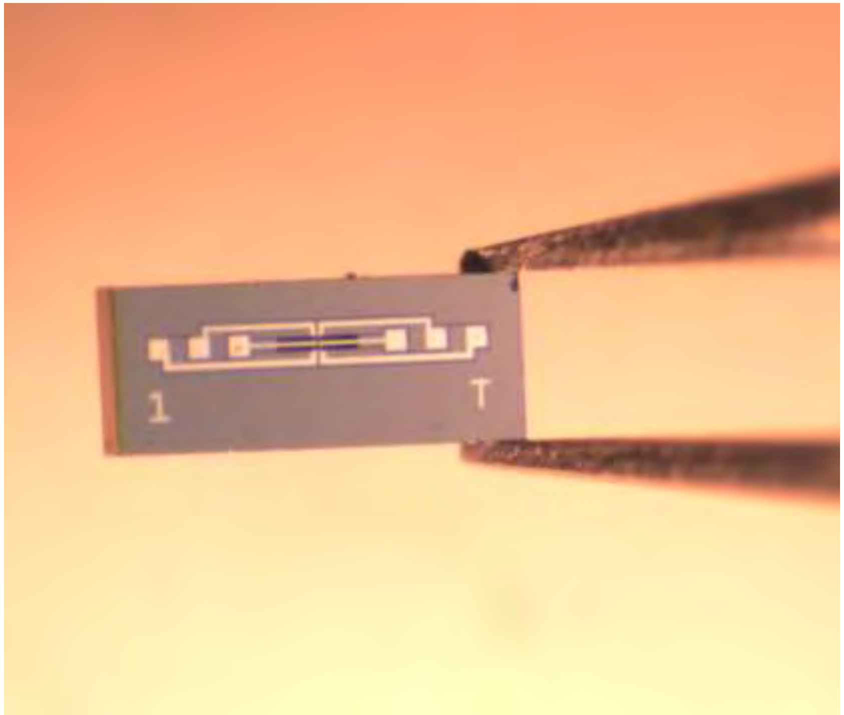
EMI Accelerometer

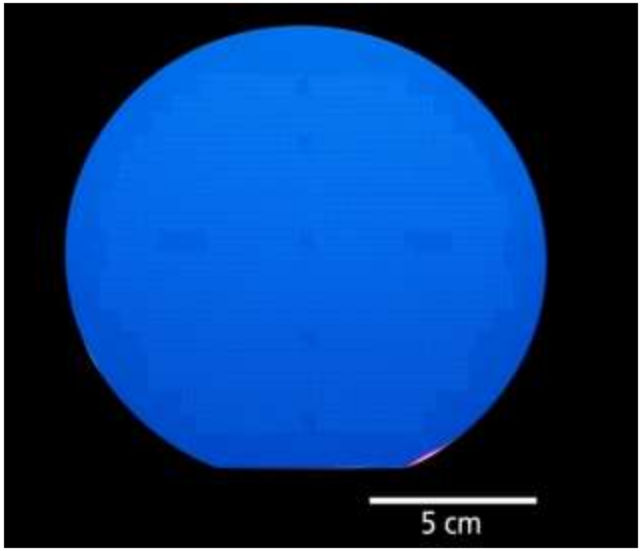
- Undamped, piezoresistive, MEMS accelerometer

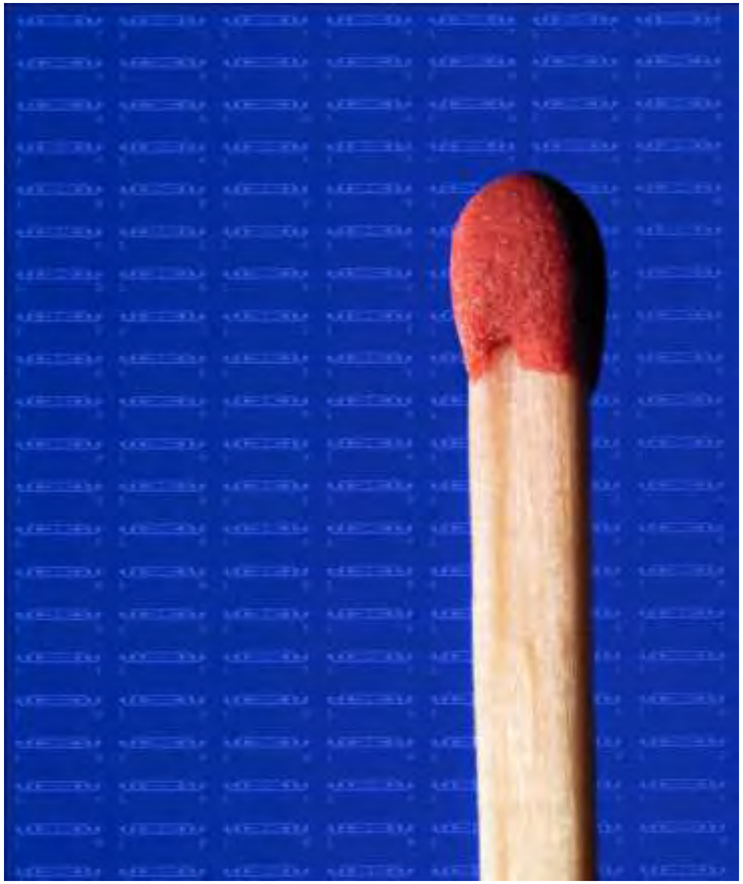
- Status of development
  - Design is patent pending
  - First specimens were successfully manufactured and tested
- Different variants exist:
  - Measurement range > 100,000 g
  - Resonant frequency 1 – 3 MHz
  - Sensitivity 0.1 – 1 µV/V_{exc}/g



EMI Accelerometer

- Manufactured with standard silicon processes, single sided
- Sensor-chip about 2 x 1 mm^2
- Straightforward integration of 2D and 3D measurement capabilities





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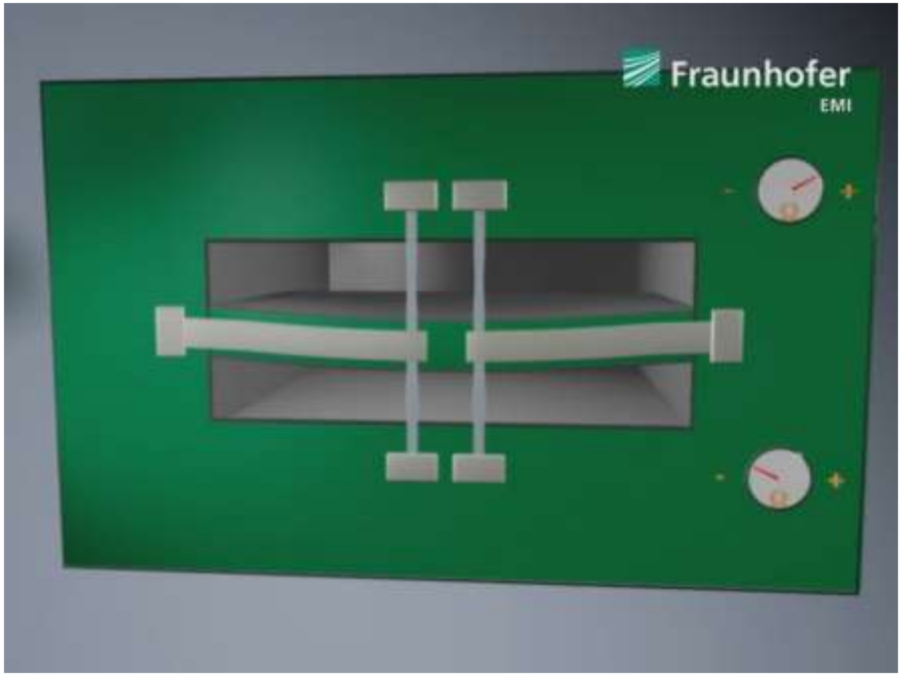
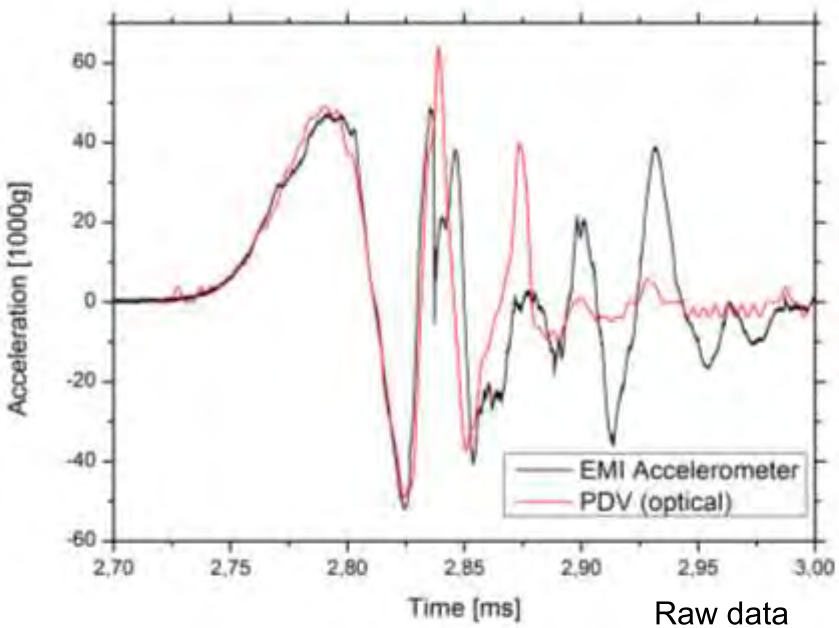
EMI Accelerometer: Functional Principle

- Main components:
  - Flexural plate
  - Self-supporting piezoresistive elements
  - Full Wheatstone-bridge
- Functional principle:
  - Inertial forces cause deflection of plate
  - Straining of piezoresistive elements
  - Change in resistance is measurement signal

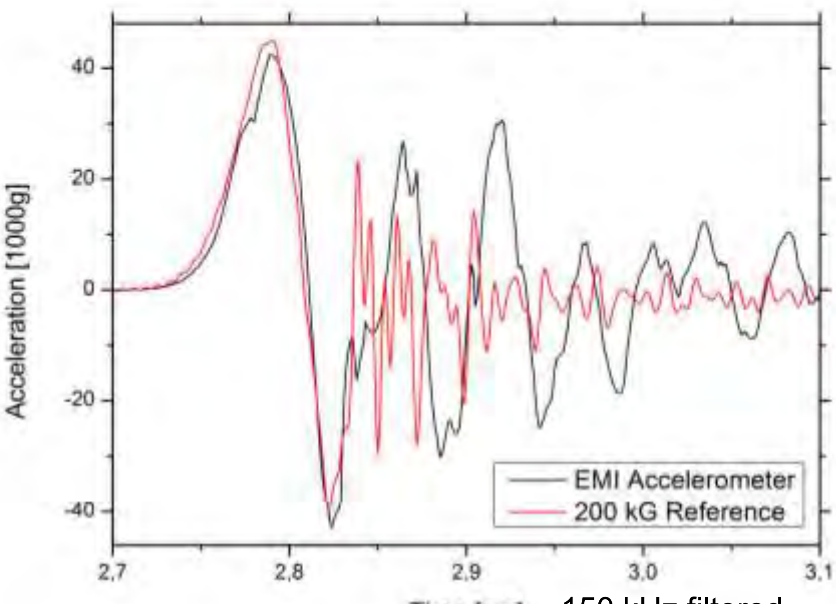


Hopkinson Bar Measurements

- Assessment of accelerometer performance on Hopkinson bar
- Comparison:
  - First peak well reproduced
  - Differences after breakaway

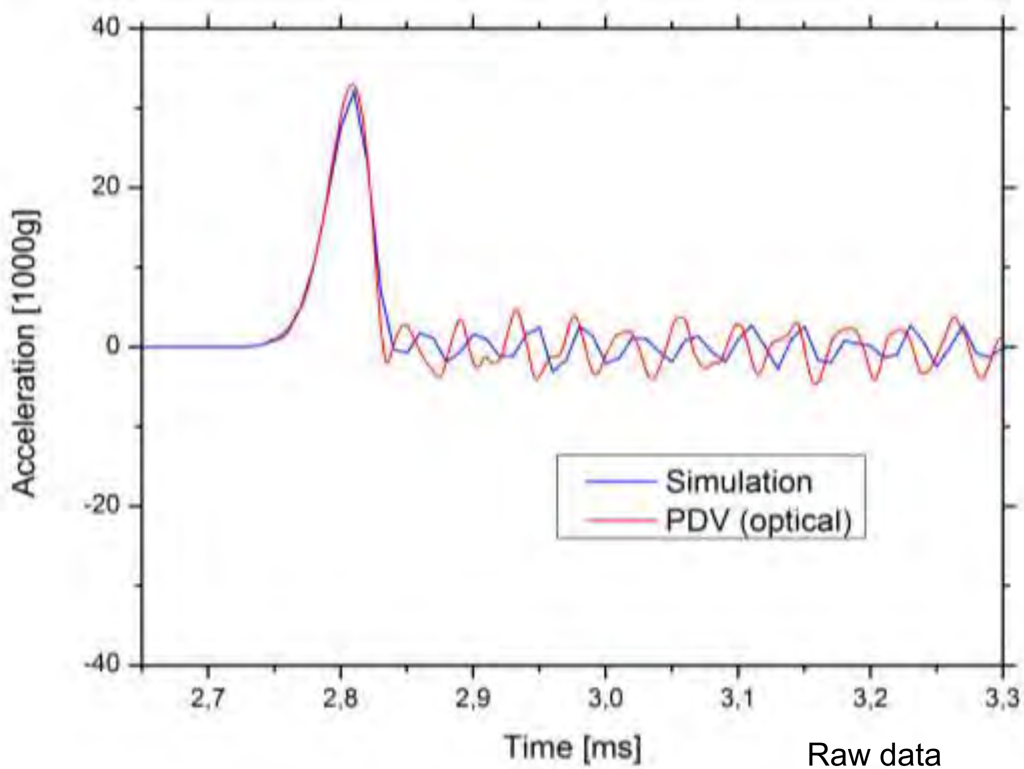


Raw data



150 kHz filtered

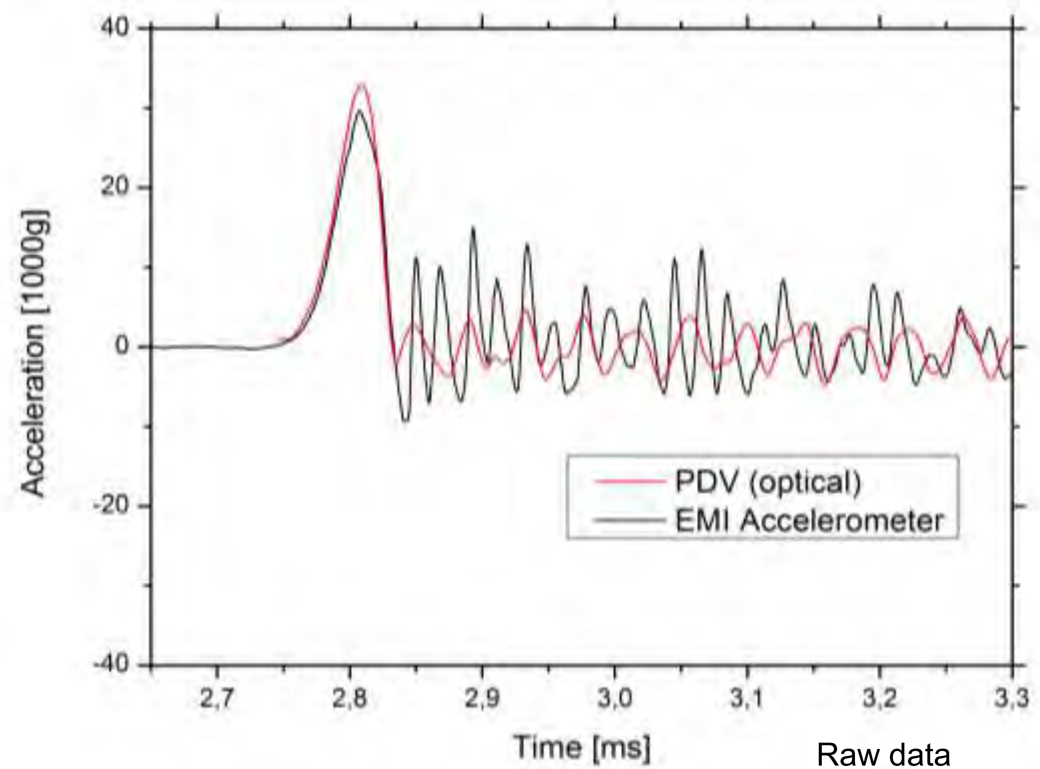
Shock Plate Test: Reference



Raw data

- Test of accelerometers on shock plate
- Simulation and reference measurement with PDV
  - 30,000 g pulse
  - Plate shows oscillations with 23 and 46 kHz (1st and 2nd harmonic)

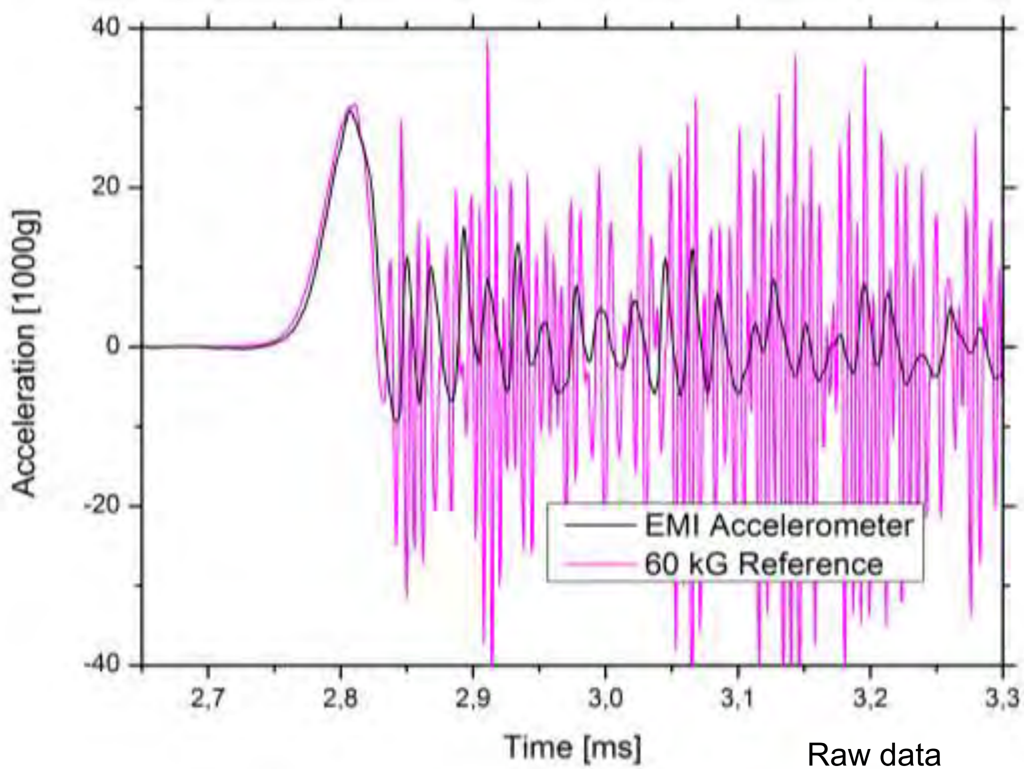
Shock Plate Test: Comparison



Raw data

- Second flyer plate experiment with EMI accelerometer and 60 kG lightly damped sensor
- 2nd harmonic more distinct in this test

Flyer Plate Test: Comparison



Raw data

- Second flyer plate experiment with EMI accelerometer and 60 kG lightly damped MEMS
- 2nd harmonic more distinct in this test
- Both sensors reproduce first peak
- EMI: Plate oscillations with 23 and 46 kHz are well visible
- 60 kG: 165 kHz resonant frequency overlays plate dynamics

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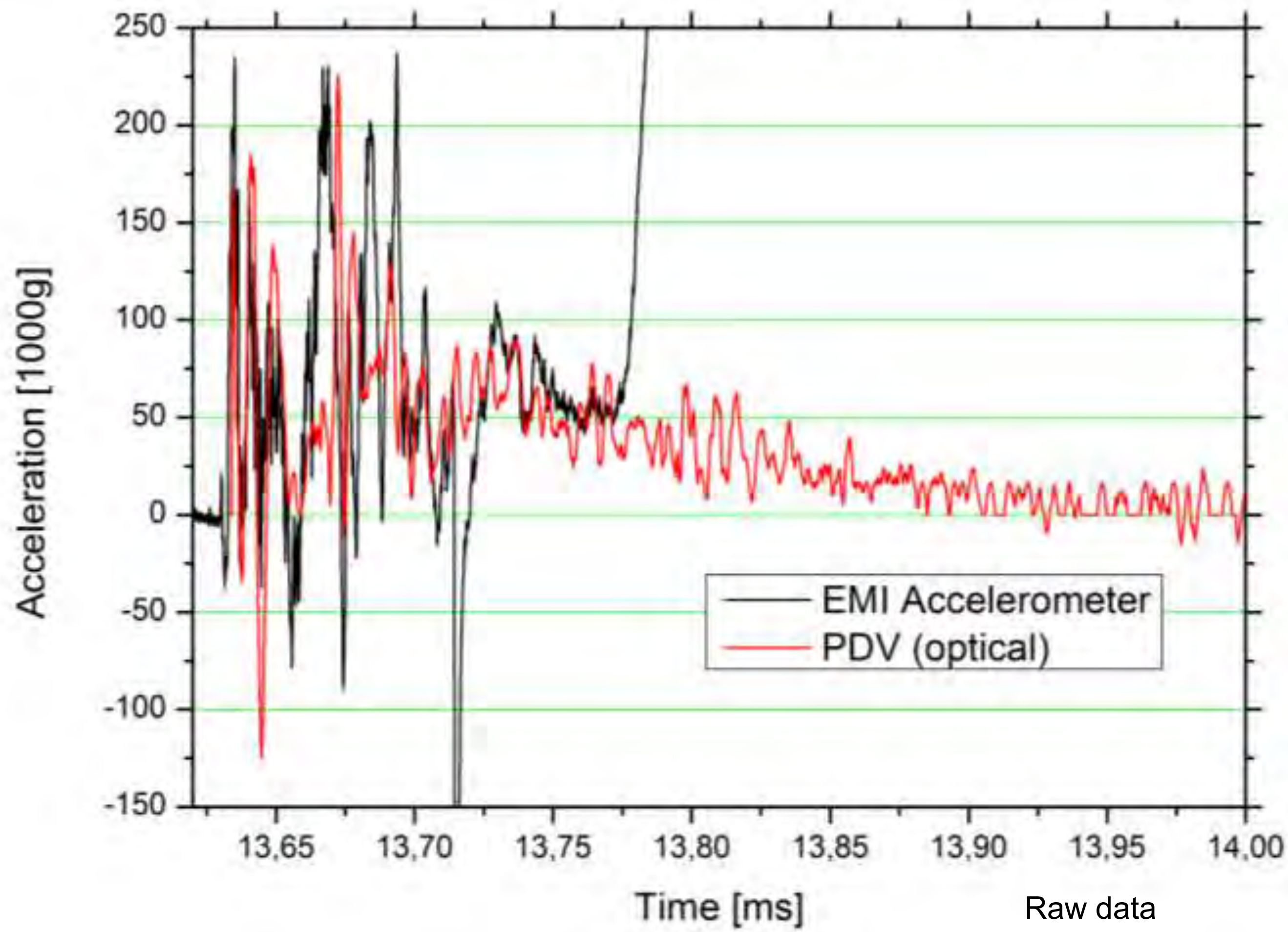
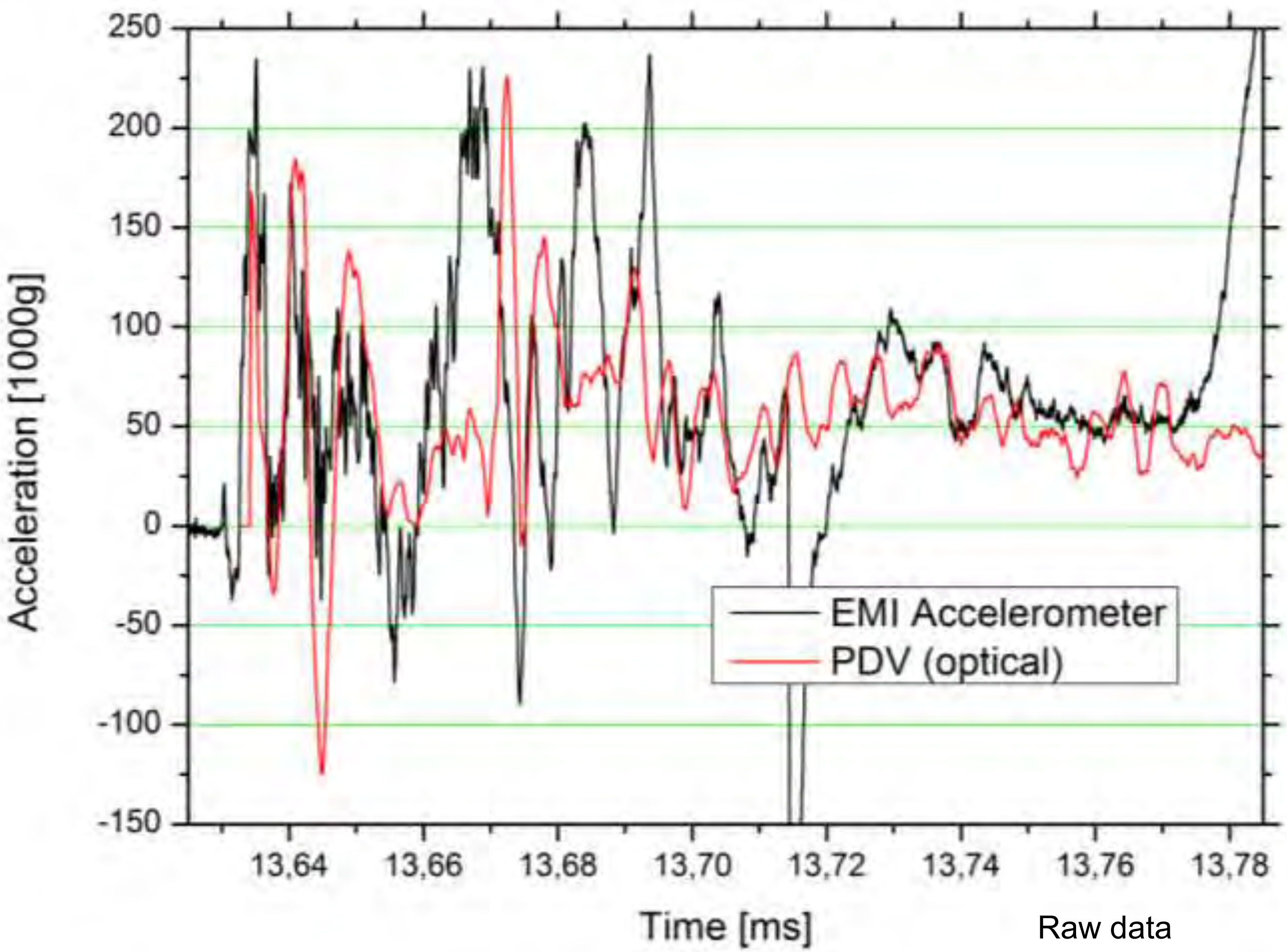
200,000 g Measurement



Raw data

- Impact experiment with PDV measurement
- Overall agreement is good
- Failure of cable connection

200,000 g Measurement



Raw data

- Confirmed acceleration over 200,000 g
- Defective contact at 13.72 ms and failure of cable at 13.78 ms
- No resonant oscillation
- Sensor-chip is completely intact!

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Summary

- EMI accelerometer has been designed and manufactured
  - Design patent pending
  - Standard silicon processes
  - Successful proof of concept

- The EMI design combines:

  … the sensitivity of medium g-range sensors (> 0.2 µV/V_{exc}/g) (proven)

  … with the survivability of high g-range sensors (> 200.000 g) (proven)

  … while having a uniquely high bandwidth (> 2 MHz) (not meas. yet)

Outlook

- Determination of accelerometer performance is to be completed

- Further development will focus on:
  1. Realization of an "easy to use" and robust package
  2. Monolithical integration of bi- or tri-axial accelerometers

Thank you for your Attention!

This work was funded by the
Federal Office for Defence Technology and Procurement BWB
(Bundesamt für Wehrtechnik und Beschaffung)

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Fraunhofer EMI

55th Annual Fuze Conference

Fuzing„s Evolving Role in Smart Weapons

Generation and Measurement of Long Duration High-g Acceleration Profiles

S. Nau,
V. Aust, N. Pilous
Fraunhofer Ernst-Mach-Institut

Salt Lake City, May 26th 2011

Fraunhofer EMI

OUTLINE

- Introduction
  - Need for Test Methods
- Generation of Long Duration Transients
  - EMI Defined-Long-Duration Shock Test
- Application
  - Choice and Test of Electronic Components
- Measurement of Long Duration High g-Acceleration Profiles → “g-rec”
  - Penetration of Concrete
- Summary

Motivation
Smart Weapons with Penetration Capability

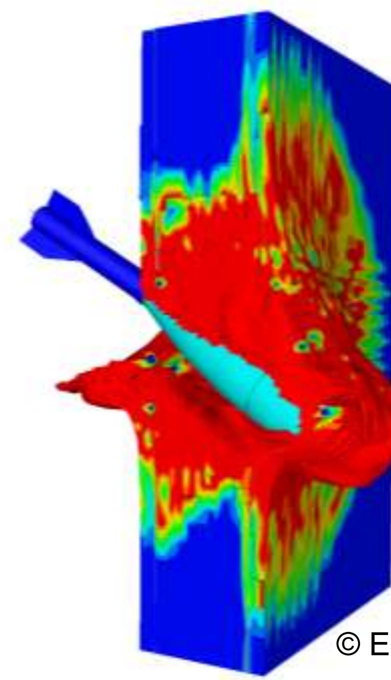
image: wikipedia

- High-g hardened fuzing
  - Large warheads
  - Upcoming: Smaller calibers
    as for precision guided munitions
    with moderate effect
    $a_{max} > 100{,}000$ g

  ⇒ the smaller the ammunition,
  the bigger the acceleration

- No manufacturers specifications available for electronic parts for high-g-regime
- Inexplicable system failures in the field

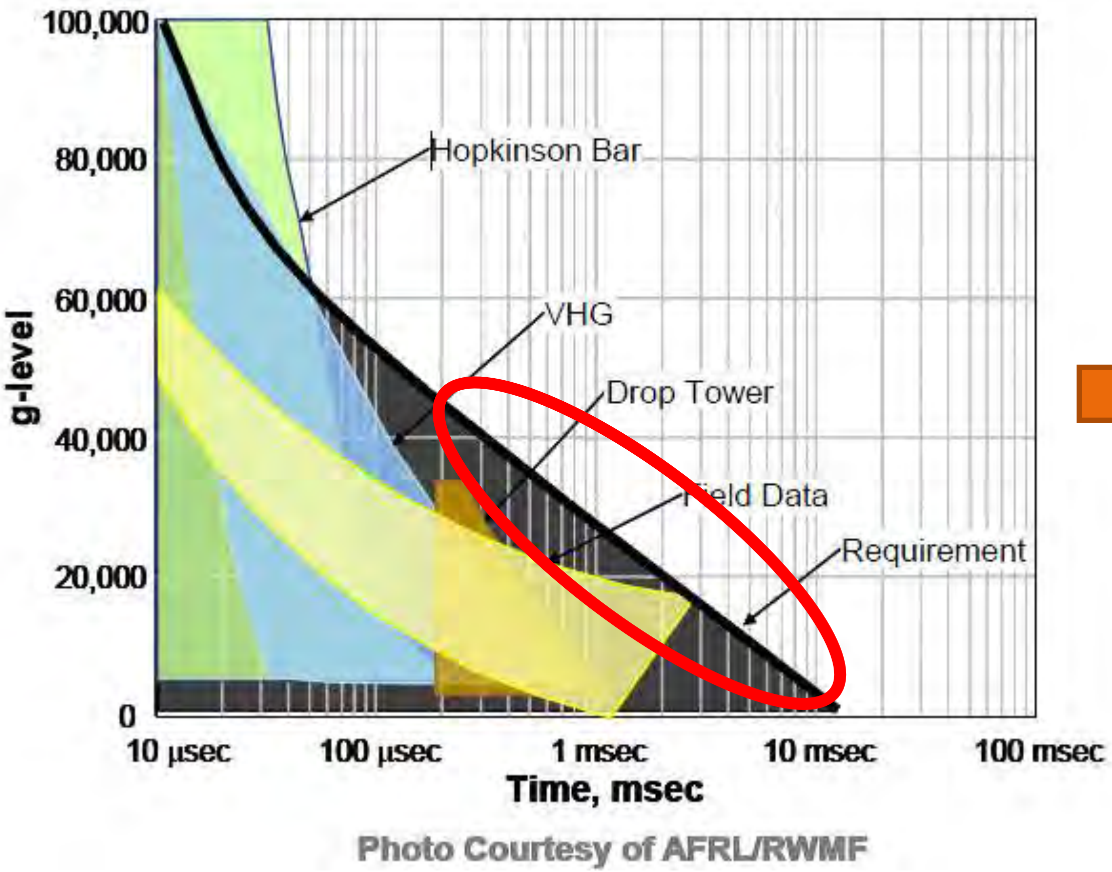
⇒ need for reliable, cheap high-g-test methodology



© EMI

Required Test Methodologies for Sub-Scale Survivability Test

Fuze-Conference 2010:
D. Hayles, DTRA : Notional Shock Spectrum



technical requirement:
$v_{0,\ DUT} > 100$ m/s

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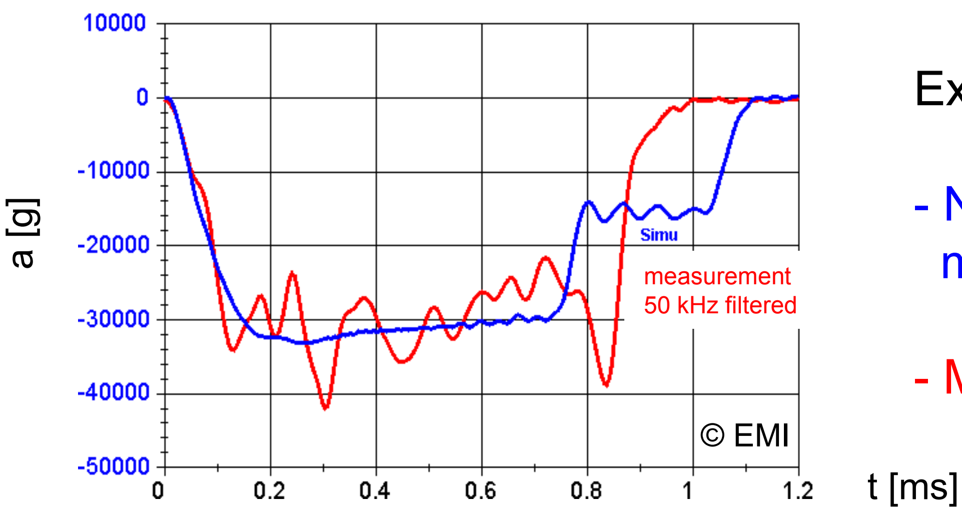
EMI Defined-Long-Duration (DLD) Shock Test

- High initial velocity of actuator
  - ⇒ long duration *and* high amplitude load profiles
- Numerically tailored compression body
  - ⇒ quantitative load profile estimation
  - ⇒ new load regimes reproducible accessible
- Experimental validation by g-rec or PDV* measurements



Example: 30.000 g, 800 µs

- Numerical prediction:
  movement of center of gravity

- Measurement inside sample holder

* PDV: Photonic Doppler Velocimetry

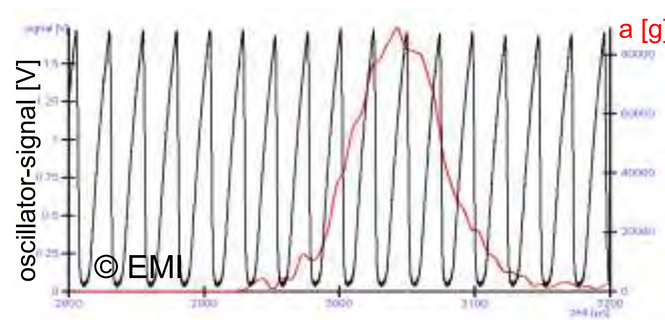
Fraunhofer EMI

EMI Defined-Long-Duration (DLD) Shock Test

- Current R&D-setup:
  - $m_{(Device\ Under\ Test)}$ up to 200 g
  - ø < 34 mm,
  - l = 100 mm

  } scalable to higher values
- If needed: Device under Test electrically connected
- Low temperature experiments (-46 °C) possible
- Modest cost
- Extension to spinning systems is under way

Exemplary sample holder



Example: 80.000 g oscillator-Test

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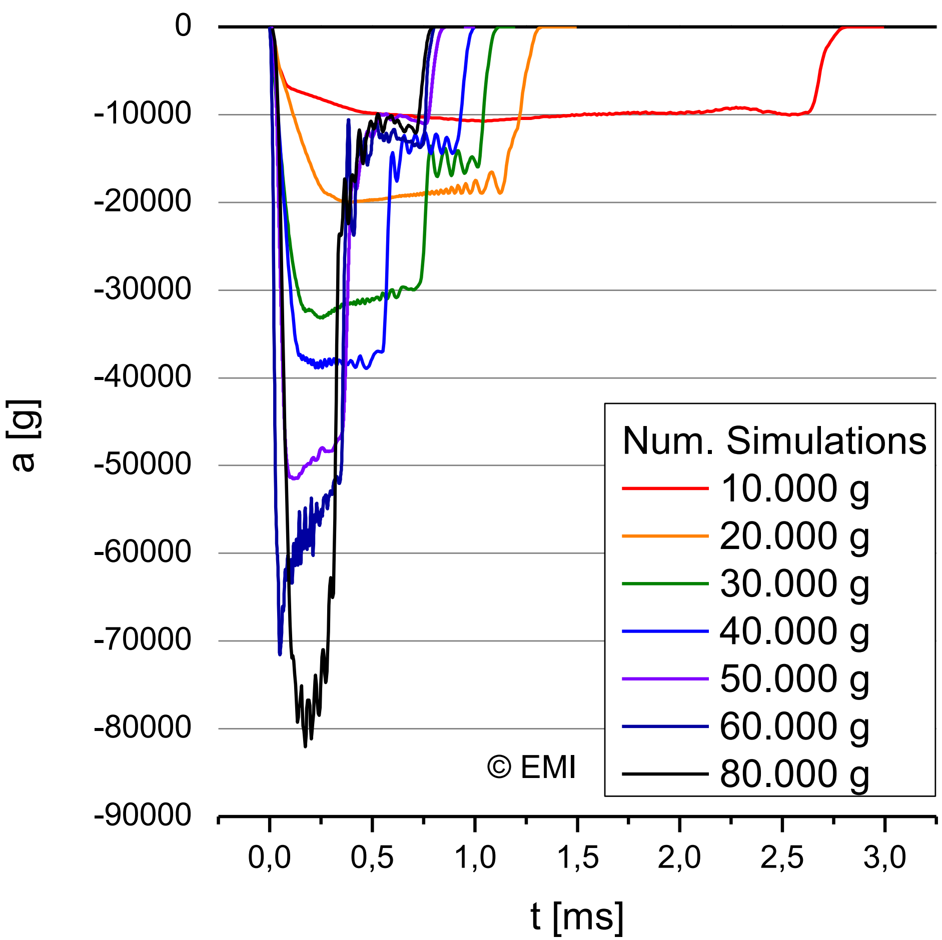
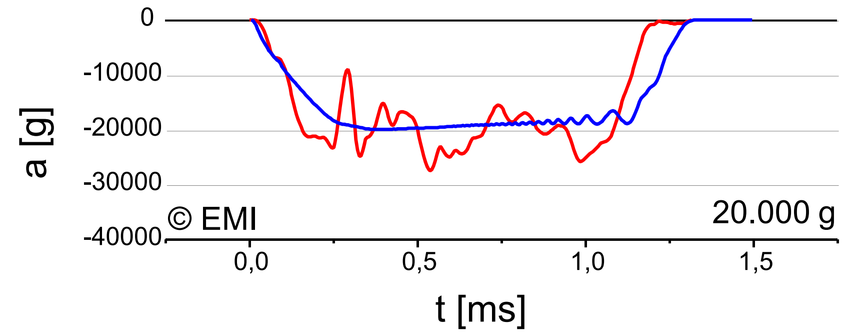
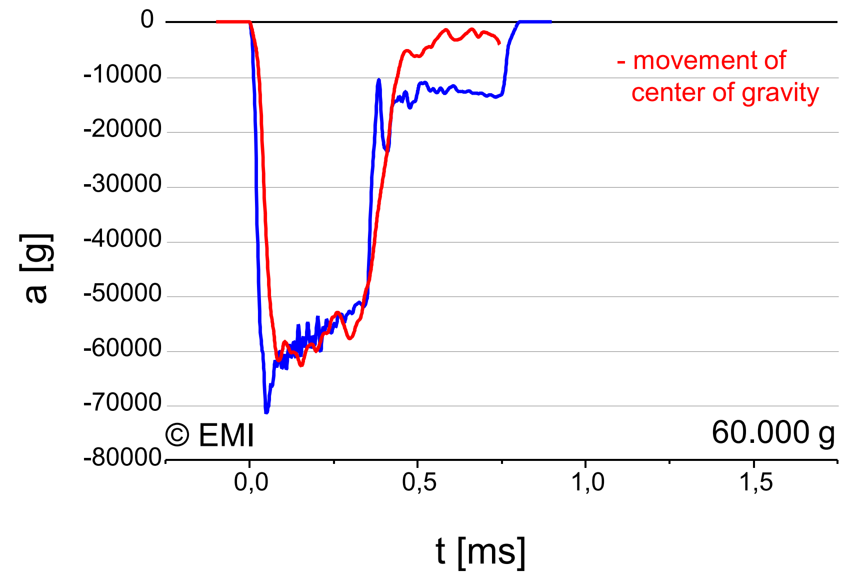
EMI - DLD - Shock Test



Comparison
- Experimental Data (50 kHz filtered)
- Numerical Simulation





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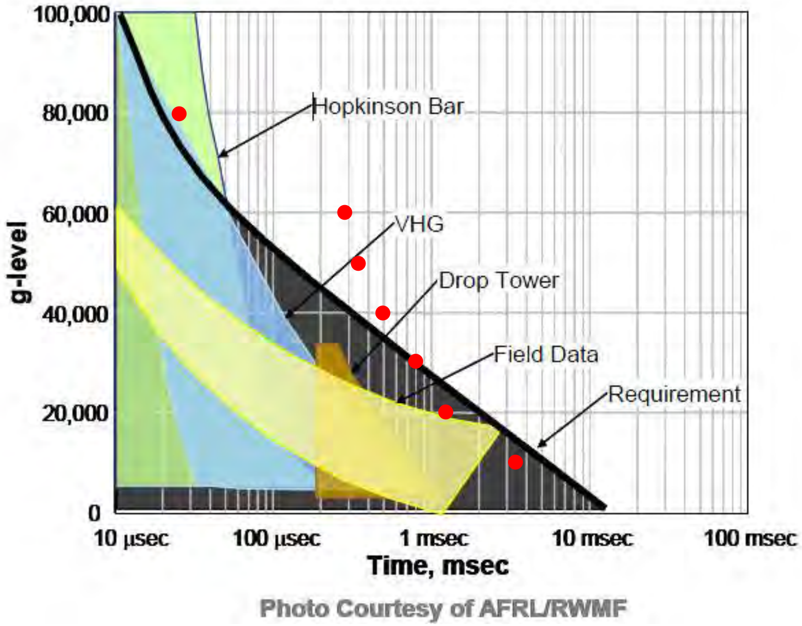
EMI - DLD - Shock Test

Experimental Results

D. Hayles, DTRA, Fuze Conference 2010



EMI-DLD-Experiments

10.000 g	3.300 ms	(exp)
20.000 g	1.250 ms	(exp)
30.000 g	0.800 ms	(exp)
40.000 g	0.520 ms	(exp)
50.000 g	0.350 ms	(sim)
60.000 g	0.310 ms	(exp)
80.000 g	0.025 ms	(exp)
	0.300 ms	(sim)

Experiments were conducted in cooperation with industry partners and used for product development.

Experiments validated by

- exp — acceleration measurement or Photonic Doppler Velocimetry
- sim — numerical Simulation *and* high-speed Video

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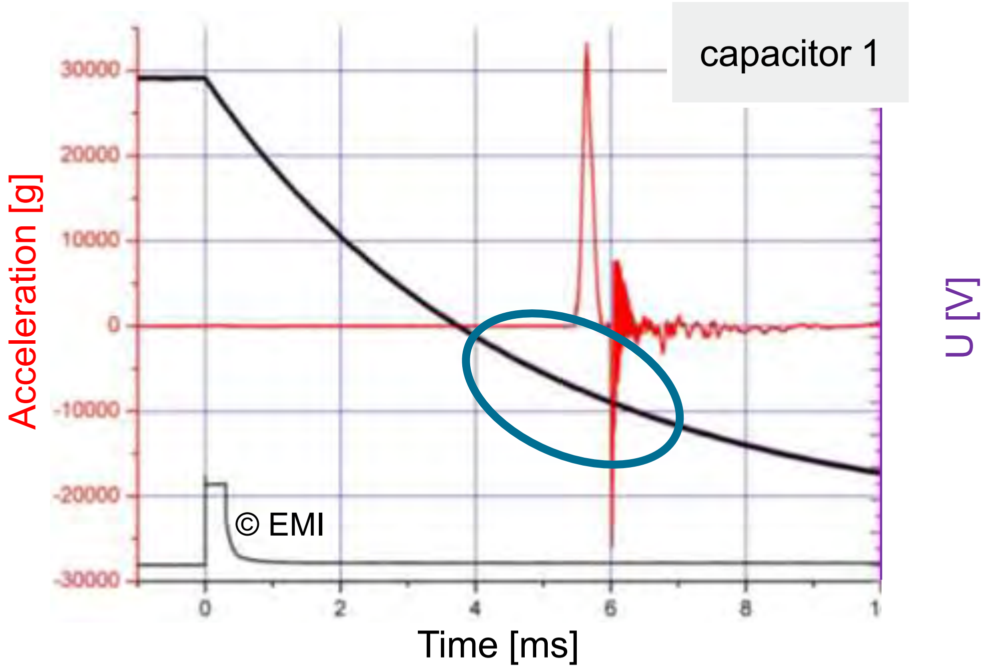
Application
Choice and Test of Electronic Devices

Device behavior upon high-g-loads:

- Intended function
- Disintegration of the device
- Malfunction only during load

⇒ DLD-Shock-Test with electrical access to relevant device properties during load



Example: Capacitor 1

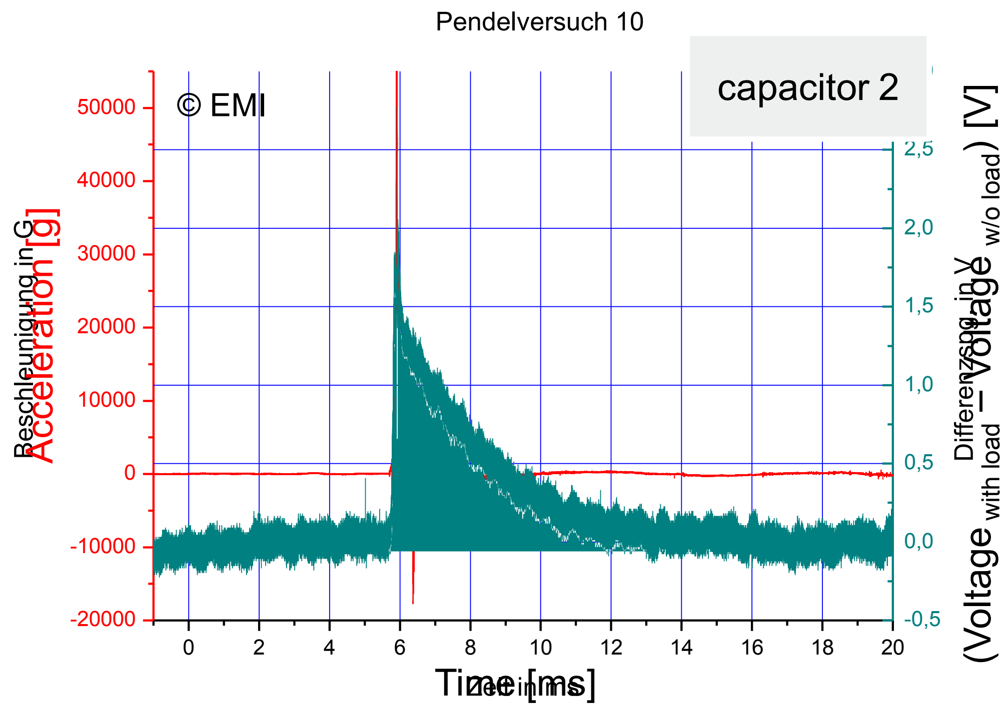
⇒ intended function

Application
Choice and Test of Electronic Devices

Device behavior upon high-g-loads:

- Intended function
- Disintegration of the device
- Malfunction only during load

⇒ DLD-Shock-Test with electrical access to relevant device properties during load



Example: Capacitor 2

- (Reversible) effect only during load !
- Pre- and post-mortem results could be misleading

Approach / solution :

- Usage of different devices, or device technologies
- Improved engineering concepts

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Application g-rec

Measurement of Long Duration High-g Acceleration Profiles

Concept

- Autonomous digital data recorder with shock accelerometer
- Resistant to high accelerations and decelerations (> 100,000 g, Ver. a)
- PC based data retrieval after projectile recovery

modular assembly:

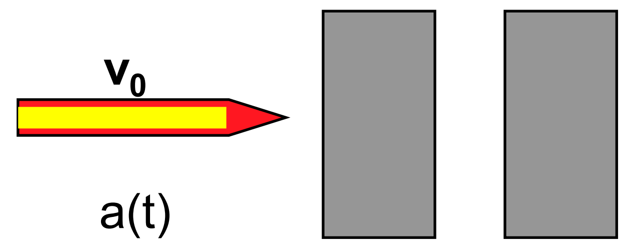
2 versions: a) hard-wired version ø = 26 mm, l = 155 mm

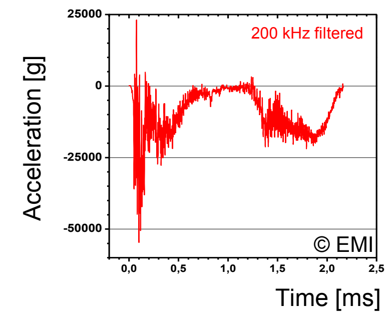
b) programmable, based on microcontroller ø = 23 mm, l = 80 mm

Application g-rec

Measurement of Long Duration High-g Acceleration Profiles

- Investigation of penetration processes
  - Movement of the center of gravity
  - Characterization of mechanical properties of HE during impact conditions
- Stand alone data recorder for harsh environments
- Measurement tool for fuze systems during impact
- Investigation of interior dynamic of penetrators
  - Study of mechanical wave propagation and resonances
  - Damage mechanisms, …





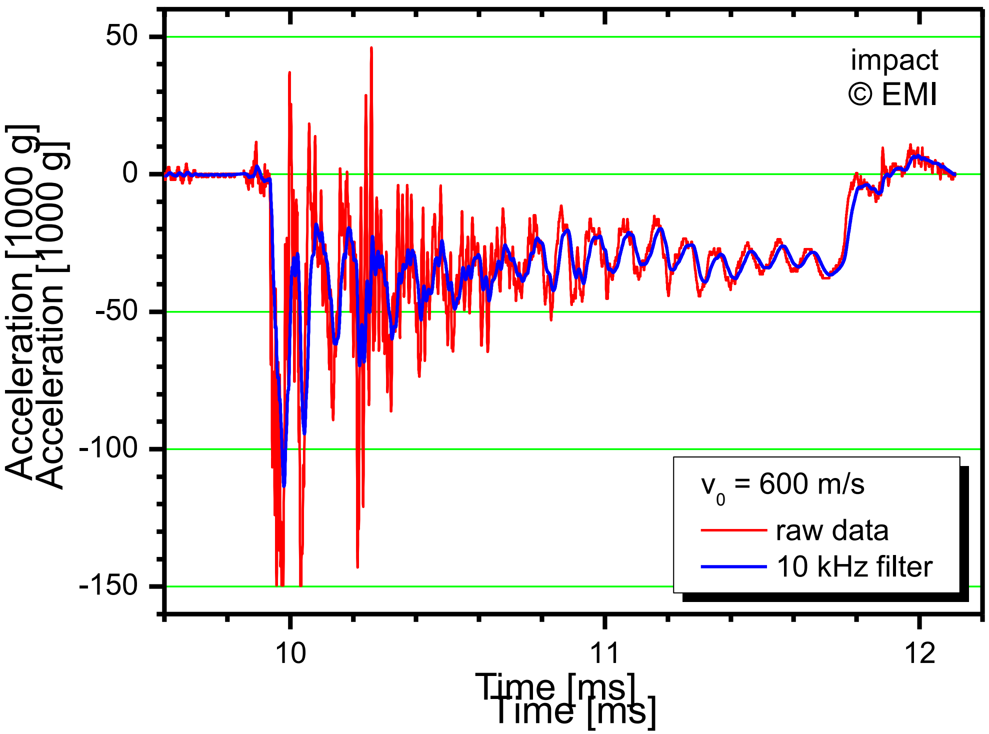
Application Concrete Penetration

Measurement of Long Duration High-g Acceleration Profiles

36 mm - penetrator equipped with g-rec:
Gun launch (powder cannon) v_0 = 600 m/s

Application Concrete Penetration

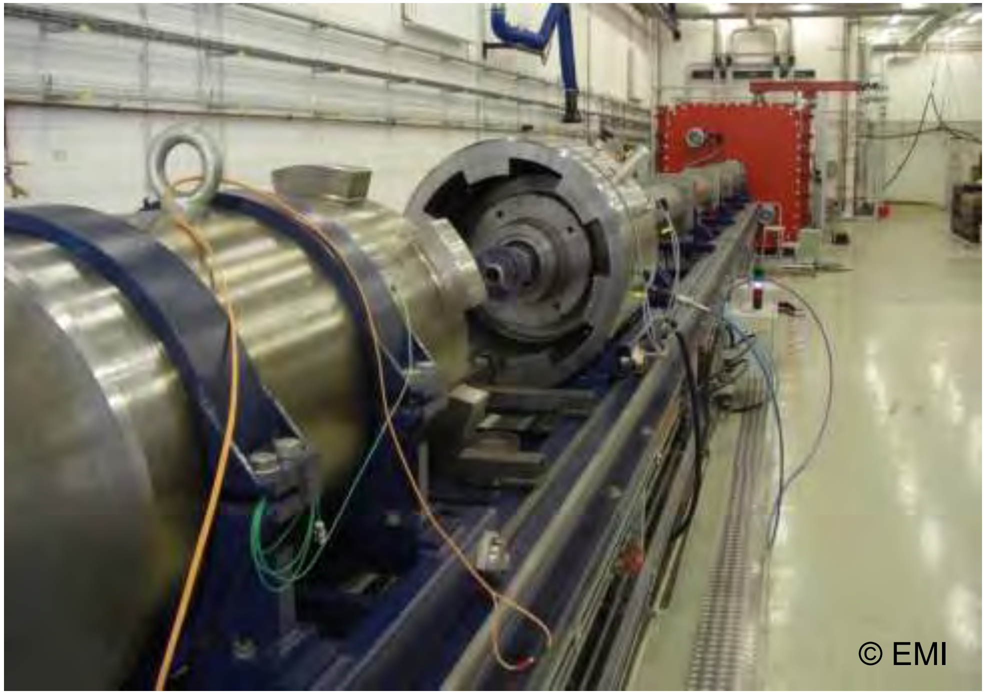
Measurement of Long Duration High-g Acceleration Profiles



Application Concrete Penetration
Measurement of Long Duration High-g Acceleration Profiles

Experiments with 60 mm projectiles

Projectile and sabot,
projectile: cal. 60 mm



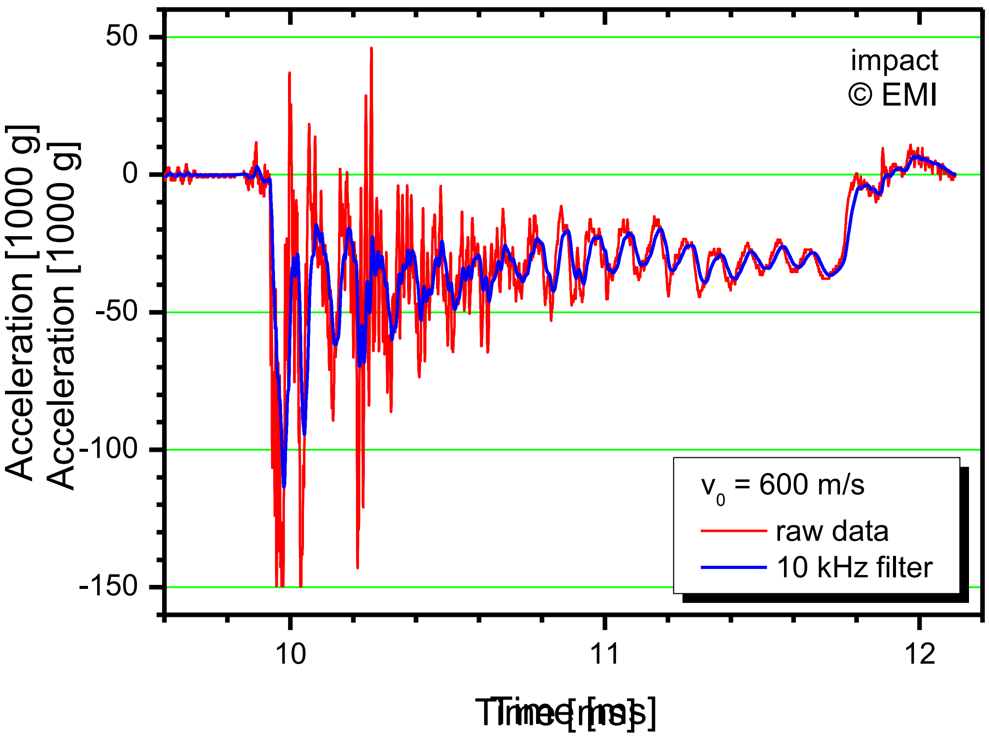
150 mm-Facility,
Ernst-Mach-Institute, Germany

Application — Concrete Penetration

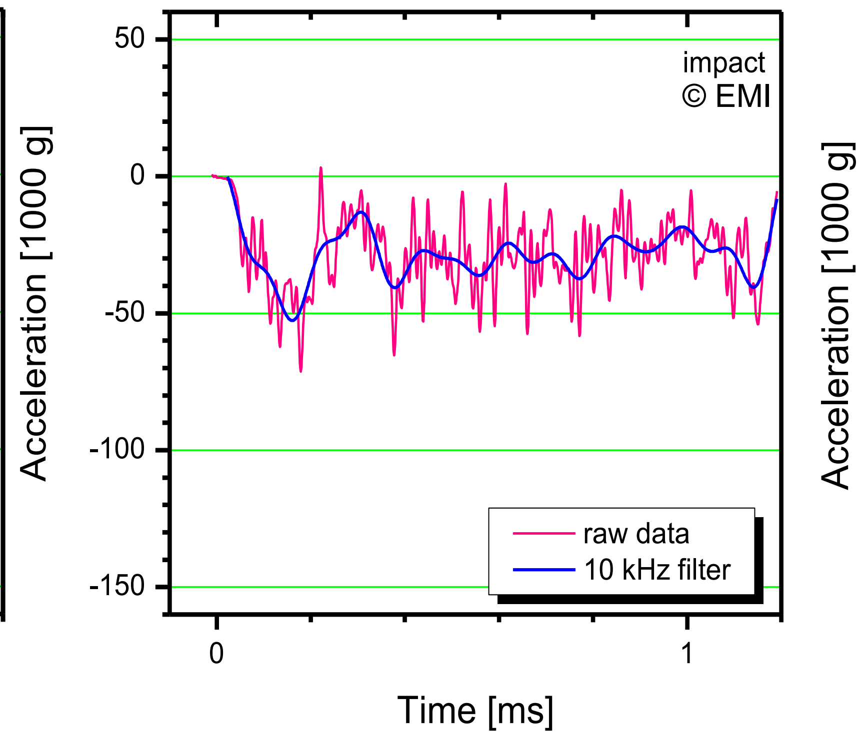
Measurement of Long Duration High-g Acceleration Profiles

Interpretation after experiment, no real time processing.

caliber: 36 mm



caliber: 60 mm



⇒ $a_{max,\ 36\ mm}$ more than two times higher than $a_{max,\ 60\ mm}$

Summary

- EMI-DLD-Shock Test
  - Powerful test-method that covers interesting high-g-load and long duration pulse regime
  - Reproducible lab-test at moderate costs
- Application of DLD-Shock Test: behavior of capacitors during high-g-load
- Measurement of long duration shock pulses with autonomous data recorder
  - g-rec: versatile and robust measurement-tool
  - Medium caliber concrete penetration at high velocities

    $\Rightarrow$ the smaller the ammunition, the bigger the acceleration

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Thank you for your Attention!

Questions?

This work was funded by the
Federal Office for Defence Technology and Procurement BWB
(Bundesamt für Wehrtechnik und Beschaffung)

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Fraunhofer EMI

Smart Materials for Fuzing

55th ANNUAL FUZE CONFERENCE

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Outline

- Presentation Objective: Review several smart materials and potential applications to fuzing and ordnance
- Smart material overview
- Piezoelectrics
  - *Damage sensing, power harvesting*
- Shape Memory/Superelastic Alloys
  - *IM, self-healing, safe & arm applications*
- Magneto/Electro-rheological Fluid
  - *Suspension, safe & arm*
- Conclusions

Smart Material Classification

- Materials converting energy/fields into other (especially mechanical)
- Many definitions, other names and related areas
  - *Intelligent materials, multifunctional materials*

	Electric Field	Magnetic Field	Thermal Energy	Light	Chemical Energy
Actuation	**Piezoceramics Piezopolymers Electrostrictors Electrorheological fluids**	**Magnetostrictors Magnetorheological fluids**	**Shape memory alloys, ceramics, polymers**	**Light activated gel (Becker and Glad 2000) Laser driven flyer plates**	**Ionic polymers**
		Force Displacement		Force Displacement	
Sensing	**Piezoceramics Piezopolymers Electrostrictors Electrorheological fluids**	**Magnetostrictors Magnetorheological fluids**	**Shape memory alloys, ceramics, polymers**	**Fiber optics**	**Ionic polymers**
	Charge, capacitance resistance	Resistance, inductance	resistance	Light intensity, frequency	Concentration, pH

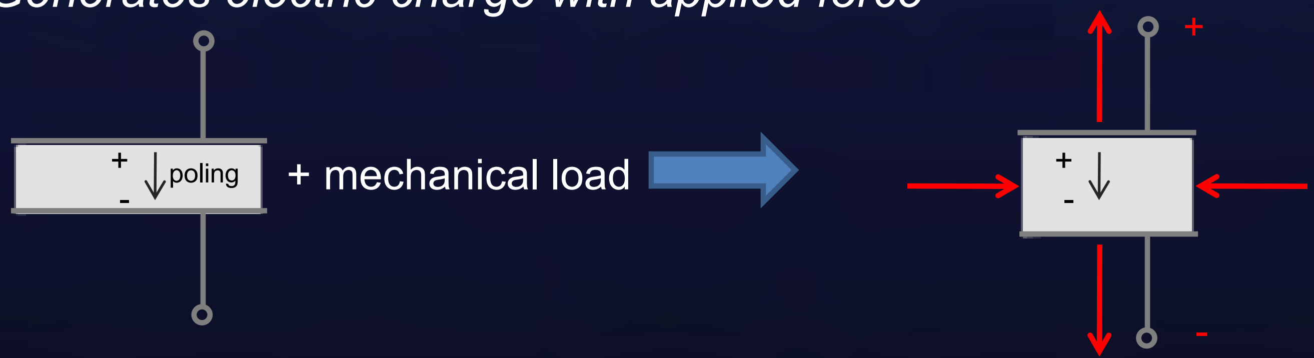
- Smart structures use these materials to provide integrated sensing, actuation or control and structural integrity

Why Consider Smart Materials?

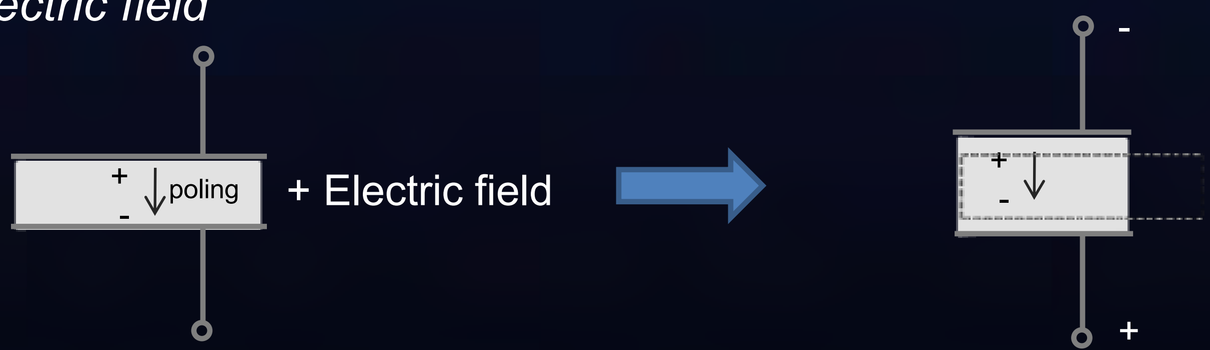
- Increased functionality
  - *Monitoring functions*
    - As munitions age, increased likelihood of malfunctions.
    - Sensing solutions can help predict individual or subpopulation reliability
  - *Environment sensing*
    - Both during storage and at use
  - *Adaptivity*
    - Shape morphing and control
    - Self repair
- Reduced size
  - *Higher energy density*
  - *Smaller munitions*
  - *Smarter munitions*
    - Fit more into the provided space
      - Integrated fuzing guidance and targeting

Piezoelectric Background

- Generally high force/ low stroke
- Direct effect
  - *Generates electric charge with applied force*



- Converse effect
  - *Generates mechanical force/ displacement from electric field*



Piezoelectric Material Background

- Piezoelectric effect found in crystals, ceramics polymers and biological materials
- Common piezoceramics lead zirconate titanate (PZT), Barium titanate, lead metaniobate (PMN)
- PZT – high piezoelectric and dielectric constants
    - Many formulations of PZT exist – Hard, soft
- DOD-STD-1376 - Originally defined standard material types for Hydrophones
    - *DOD or Navy Type I- VI*
    - *Hard or soft, Curie point, Self heating susceptibility (high electric drive potential)*
- Manufacturers generally report material properties

Material Modeling

- 3D constitutive equations

$$\begin{bmatrix} S_1 \\ S_2 \\ S_3 \\ S_4 \\ S_5 \\ S_6 \end{bmatrix} = \begin{bmatrix} s_{11}^E & s_{12}^E & s_{13}^E & 0 & 0 & 0 \\ s_{21}^E & s_{22}^E & s_{23}^E & 0 & 0 & 0 \\ s_{31}^E & s_{32}^E & s_{33}^E & 0 & 0 & 0 \\ 0 & 0 & 0 & s_{44}^E & 0 & 0 \\ 0 & 0 & 0 & 0 & s_{55}^E & 0 \\ 0 & 0 & 0 & 0 & 0 & s_{66}^E = 2\left(s_{11}^E - s_{12}^E\right) \end{bmatrix} \begin{bmatrix} T_1 \\ T_2 \\ T_3 \\ T_4 \\ T_5 \\ T_6 \end{bmatrix} + \begin{bmatrix} 0 & 0 & d_{31} \\ 0 & 0 & d_{32} \\ 0 & 0 & d_{33} \\ 0 & d_{24} & 0 \\ d_{15} & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} E_1 \\ E_2 \\ E_3 \end{bmatrix}$$

$$\begin{bmatrix} D_1 \\ D_2 \\ D_3 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 & d_{15} & 0 \\ 0 & 0 & 0 & d_{24} & 0 & 0 \\ d_{31} & d_{32} & d_{33} & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} T_1 \\ T_2 \\ T_3 \\ T_4 \\ T_5 \\ T_6 \end{bmatrix} + \begin{bmatrix} \epsilon_{11} & 0 & 0 \\ 0 & \epsilon_{22} & 0 \\ 0 & 0 & \epsilon_{33} \end{bmatrix} \begin{bmatrix} E_1 \\ E_2 \\ E_3 \end{bmatrix}$$

- Simplified to one dimension

$$S_1 = s_{11}^E T_1 + d_{31} E_3$$

$$D_3 = d_{31} T_1 + \varepsilon_{33}^T E_3$$

Typical Material Constants

PZT 5H (Navy Type VI)					
d_{31} (m/V)	d_{33} (m/V)	Elastic modulus (N/m^2)	Density (kg/m^3)	ε^T_{33} (F/m)	Curie temp (°C)
$-320\text{x}10^{-12}$	$650\text{x}10^{-12}$	$6\text{x}10^{10}$	7800	$3.36\text{x}10^{-8}$	230

$$+\begin{bmatrix} 0 & 0 & d_{31} \\ 0 & 0 & d_{32} \\ 0 & 0 & d_{33} \\ 0 & d_{24} & 0 \\ d_{15} & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} E_1 \\ E_2 \\ E_3 \end{bmatrix}$$

$d_{33} \sim 2\text{x } d_{31}$

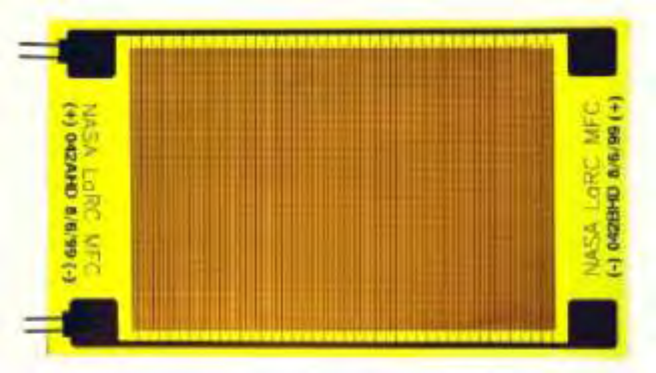
Since E is scaled by distance (V/m) field applied across thin dimension

Common Configurations

- Patch
  - *Generates /responds to plate and beam bending and tensile/compressive waves*
  - *Unimorph and bimorph configurations*
- Stack
  - *Takes advantage of d_{33} coefficient*
- MFC
  - *Uses d_{33} coefficient for in-plane motion*

Stack actuators from APC International www.americanpiezo.com

Patch actuator



MFC actuator

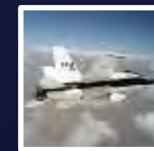
Piezo Sensing/Actuation Examples

Sensing

- *Accelerometer*
- *Power harvesting*
- *Passive damping – shunting (skis)*

Actuation

- *Atomic force microscope position control*
- *Speakers*
- *Buzzers*
- *Anything "ultrasonic" (humidifiers, cleaners)*
- *Depth finders/SONAR*



Sensing/ actuation

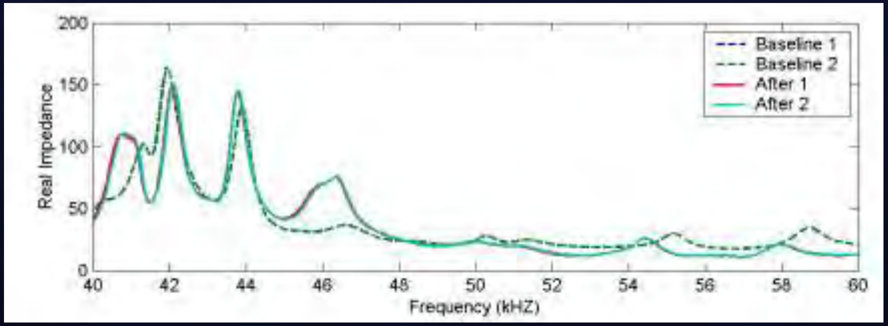
- *Structural monitoring*
- *Vibration control*

Current Fuzing Applications

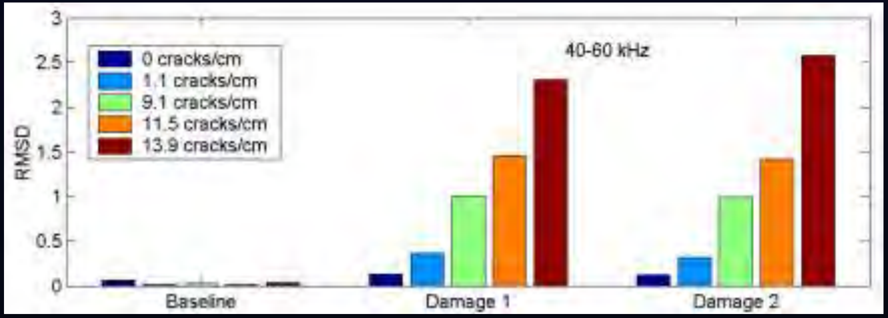
- Dozens of piezoelectric fuze patents
- Rocket Propelled Grenade
  - *Acceleration at launch strains **piezoelectric fuze** that ignites primer.*

Piezo-Based SHM

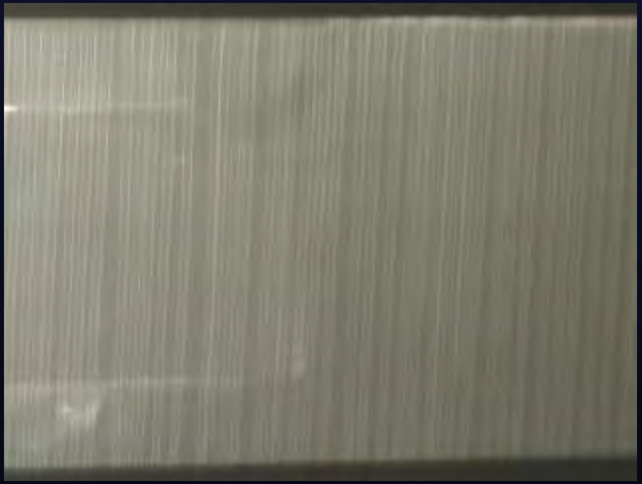
- Utilizes high frequency vibrations to detect local changes in materials
  - *Stiffness changes due to cracking*
  - *Increases in damping*
  - *Interface changes such as loosening of a joint.*
- Electrical impedance is directly related to mechanical impedance
- Wave propagation approach can also be utilized
  - *Measure reflections, attenuation, delay due to damage*



Impedance response



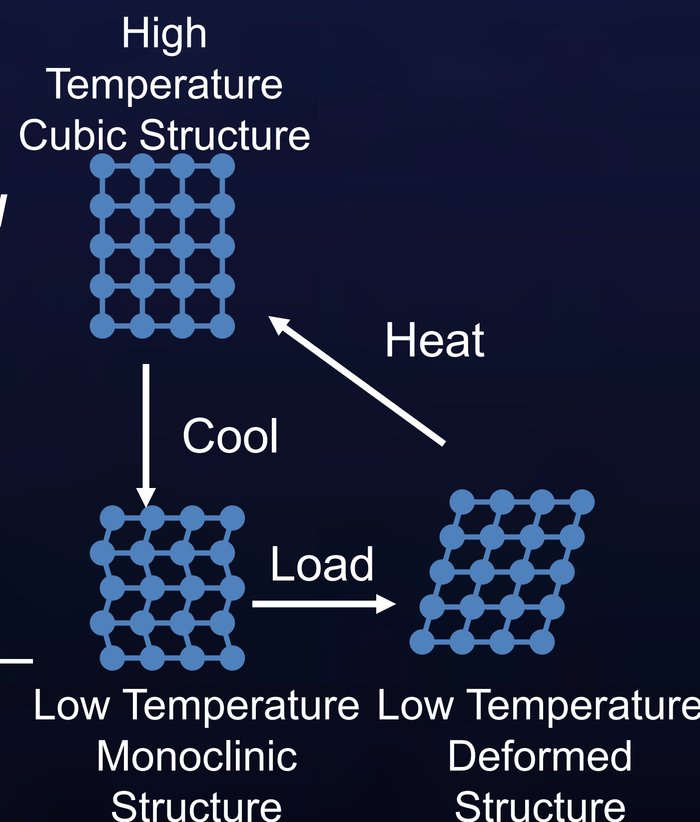
Damage Metric



Matrix cracking in carbon fiber composite

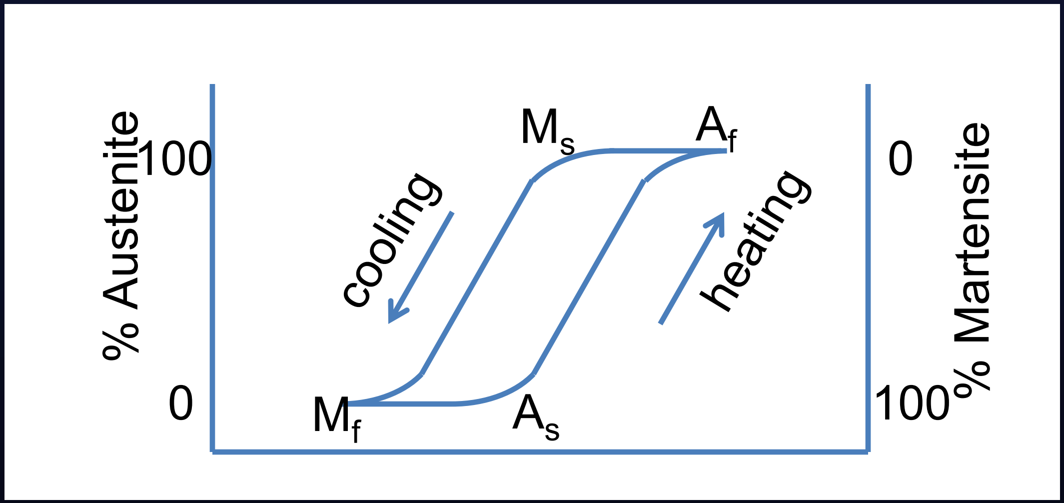
Shape Memory Alloy

- NiTiNOL developed at Naval Ordnance laboratory
- Shape memory effect : result of change in crystal structure
  - *Martensite at low temperature- **twinned** crystal structure*
  - *Austenite at high temperature- body centered cubic*
  - *Reverts to original undeformed shape when heated beyond transition temperature*
  - *One-way and two-way effects*
- Stress can also cause transition – Superelastic effect
- 6-8% strain
- Relatively slow response time
  - *Speed increased for low volume (faster temperature change)*



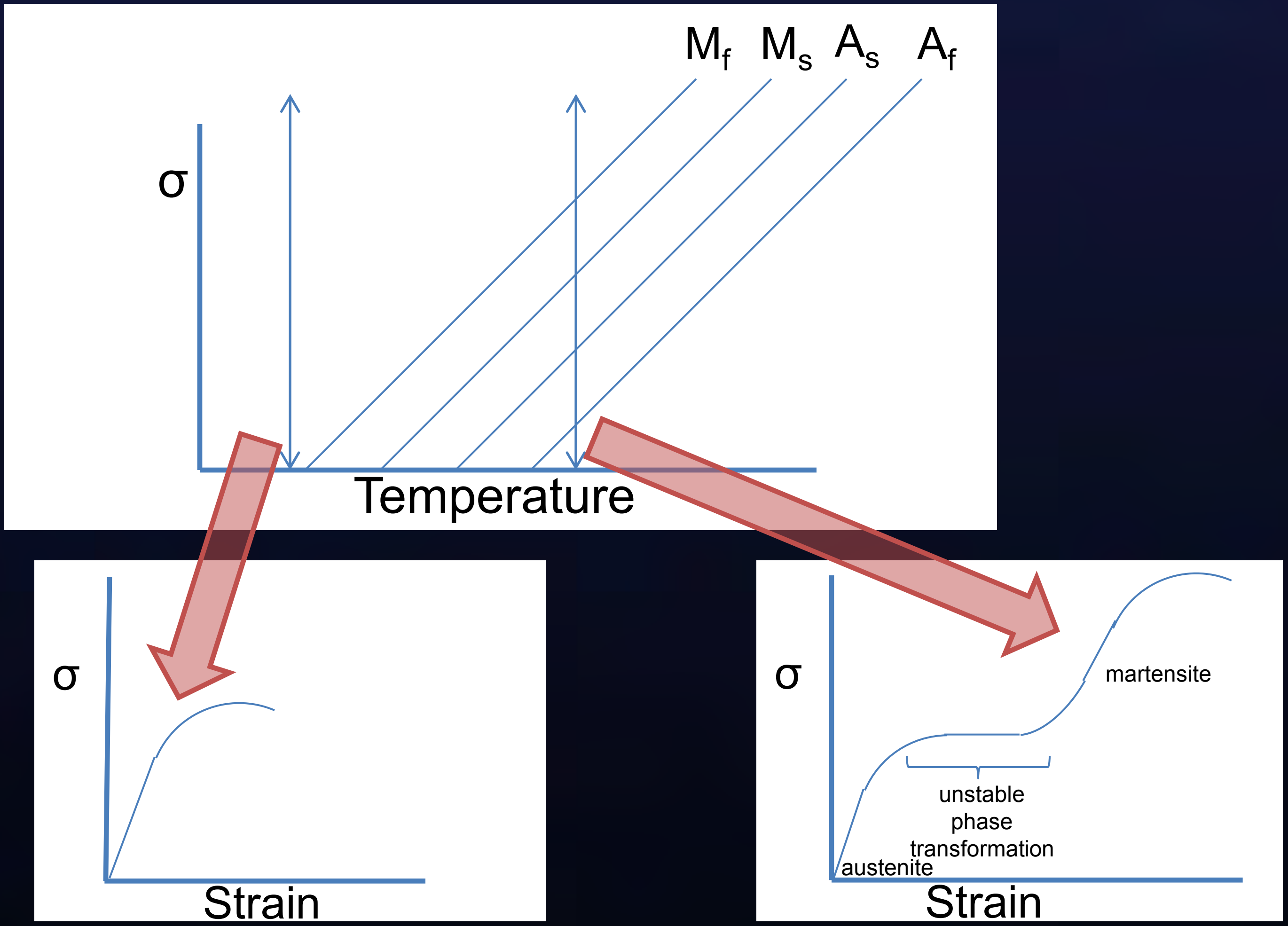
Temperature Transition

- Width and temperature of hysteresis can be controlled
- State dependent on path to current temperature



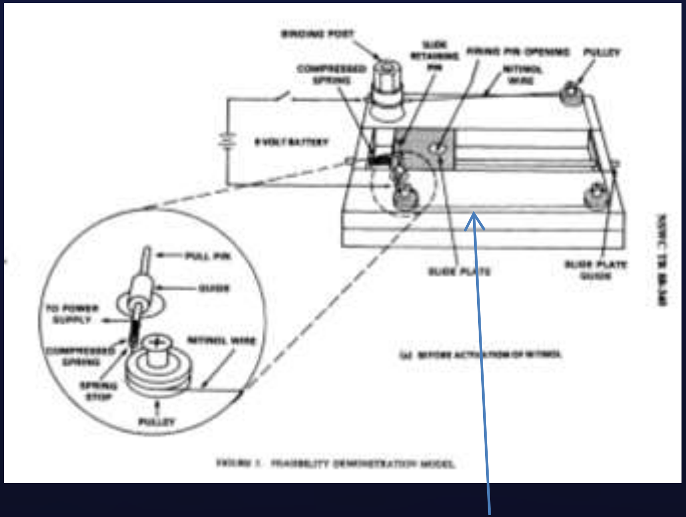
Superelastic Behavior

- Stress-strain curve depends on material temperature relative to transition temperature



SMA Fuzing Examples

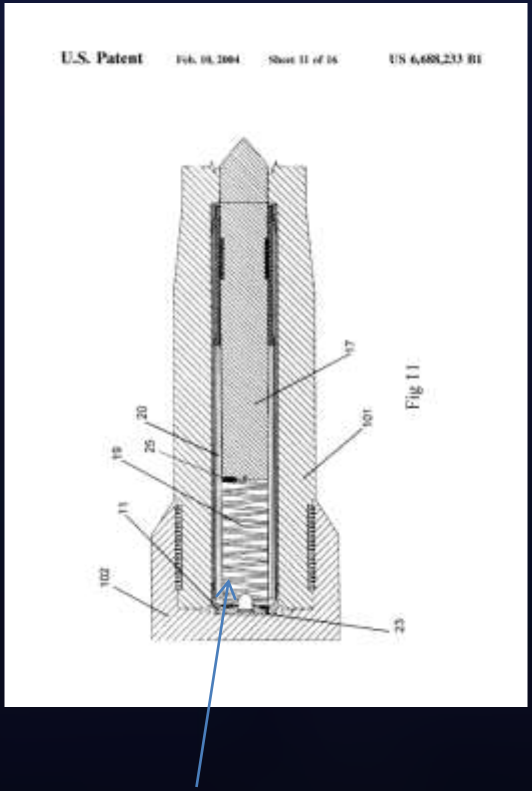
- Damping
- S&A actuation
  - *Goldstein and Weiner*
  - *Investigated effects of prestrain on transition temperature*
    - Activation temperature up to 150 C
- Non-pyrotechnic separation systems
- IM compliance
  - *Marchand et al. - Mine Clearance System rocket-towed linear demolition charge makeover*
  - *SMA proposed for release rocket motor case at both ends and actuate thermal igniter for Slow-Cook mitigation*
- Manufacturing
  - *Removable fixturing*



SMA wire

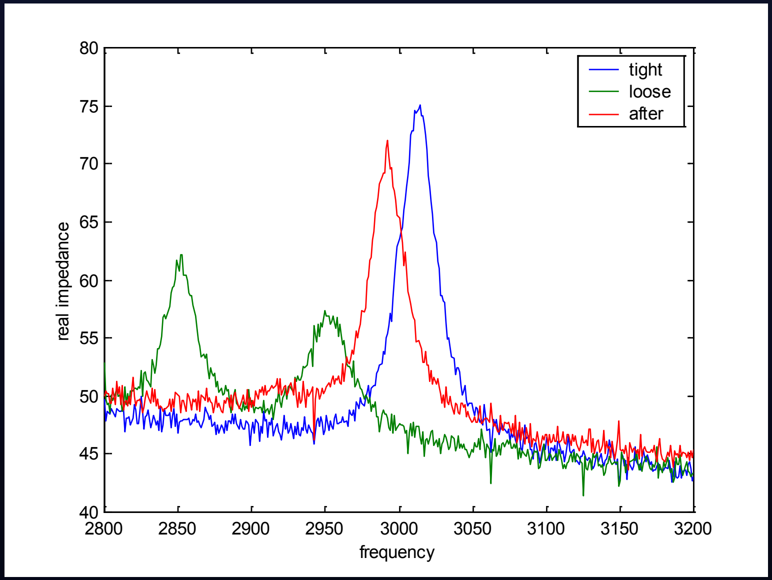
Reusable SMA Projectile Translation

- Recoil, launch stress can be reduced by translating projectile a small distance forward prior to launch
- Typically accomplished by secondary charge
  - *Not reusable if launch is aborted*
- SMA spring suggested for Cased Telescoped Ammunition
- Manole et al. 2004 US patent 6,688233B1

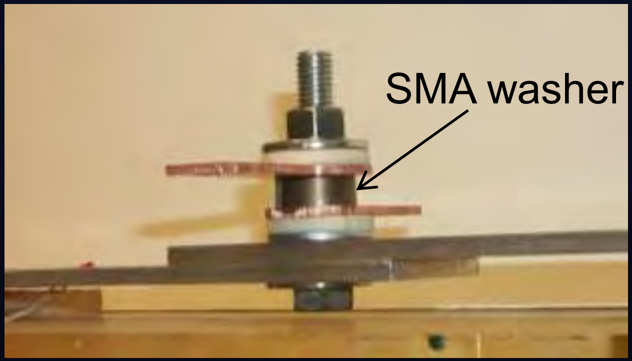


Self-Healing Bolted Joint

- Proof-of-concept testing
- Heated with external heater or resistively
  - *Competing for electrical and thermal isolation and high stiffness*
- Joint tightness monitored with PZT
- SMA ring sized to provide tension to compensate for reduced torque tightening

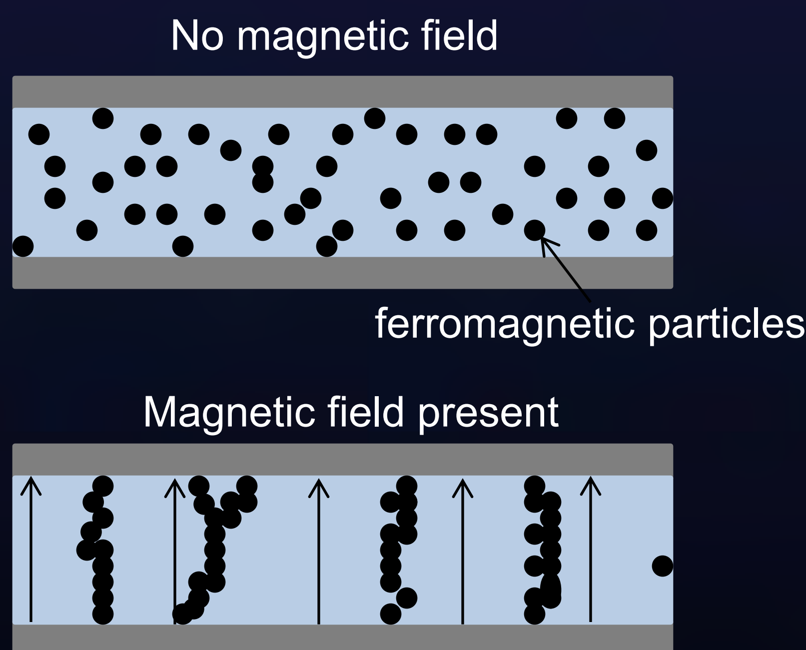


Impedance response of joint



Magnetorheological (MR) Fluids

- Change viscosity with magnetic field
- Response times on order of 10 ms
- Viscoelastic solid below yield stress when field applied
  - *Field dependent modulus*
- Newtonian fluid when field is off

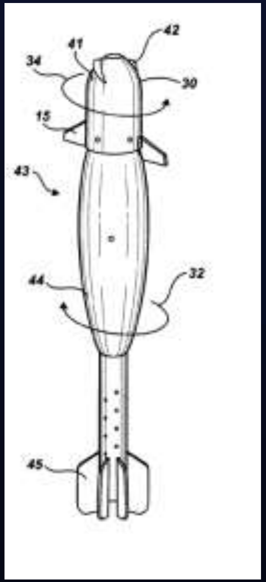


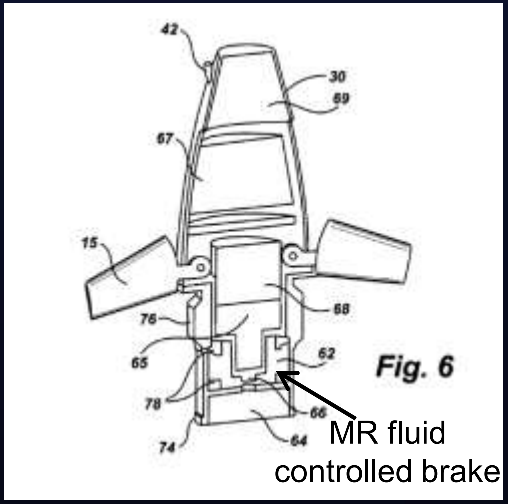
Possible Fuze Application

- Research on self-regulation of delay arming time of MR fluid fuze (Hu et al. 2010, Jiaxing University and Nanjing University of Science and Technology)
  - *Permanent magnet used to keep MR fluid as a solid during storage*
  - *Setback causes magnet to separate and rod impacts a piezo energy harvester*
  - *Energy harvester charges capacitor*
  - *Capacitor discharges into coil to regulate MR fluid viscosity*
  - *MR fluid viscosity controls flow through an orifice to control arm time*

MR Fluid Braking

- Morris et al., US Patent 7354017, 2008, Projectile trajectory control system
- Used to control de-spin of a projectile with braked rotating fins.





Summary and Conclusions

- Smart Materials offer alternative sensing and actuation systems
  - *Piezoelectric materials provide both sensing and actuation at high speed and forces, but low displacement*
  - *SMA provides high displacement and forces, but low speed*
  - *MR fluid provides fast response time and relatively high forces*
- Numerous unexplored applications for these materials exist including in the fuzing and ordnance environment

Course Correction Fuzes Integration Technologies

55th Annual Fuze Conference

"Fuzing's Evolving Role in Smart Weapons"

Salt Lake City, UT - May 24-26, 2011

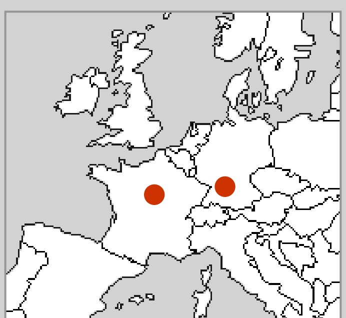
Max Perrin
JUNGHANS Microtec

Outline

- Course Correction Fuze – Main technology issues
- Main functions
- Technology evolutions and technical challenges
- Example of current Course Correction Fuze programmes
- Integration solutions for 1D-CCF
- Future trends
- Conclusion

Company Presentation

- **A leader in the field of ammunition fuzes and S&A devices**
- **Full range of products**
- **Key competences in**
  - Fuzing technologies
  - Micro-technologies
  - Ammunition electronics



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Course Correction Fuzes
Main Technology Issues

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- Standard fuze size
  - Fitted on conventional munitions




- Additional functionalities and performances, in a fuze enveloppe
  - Fuzing functions (MOFA type)
  - + Course correction functions
    - Electronics and guidance device


- Gun environment
  - Ramming / Firing
  - Standard interfaces with weapon systems
  - Data link with weapon system
    - Before flight / during flight





CCF – Main Functions

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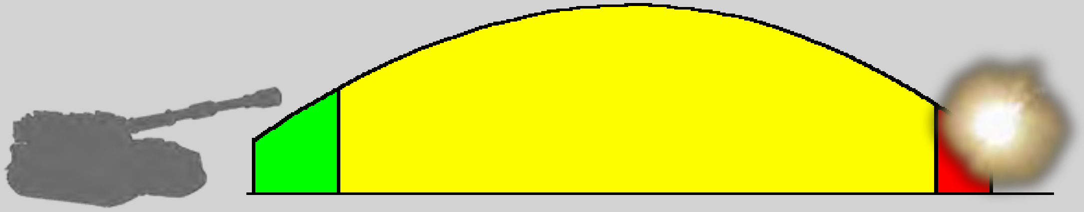
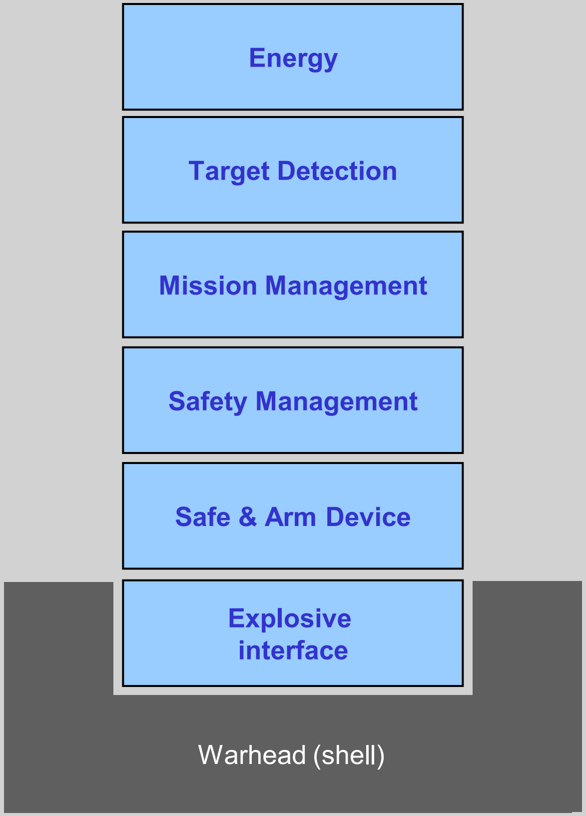
- Fuzing functions and modules
  - Safety
    - Safety environment sensors + safety management + firing train interruption
  - Mission management
    - Data-Link with weapon, before and/or in-flight (mission parameter programming)
  - Target detection :
    - Sensors + processing + triggering decision
  - Warhead initiation
    - Firing train + interfaces





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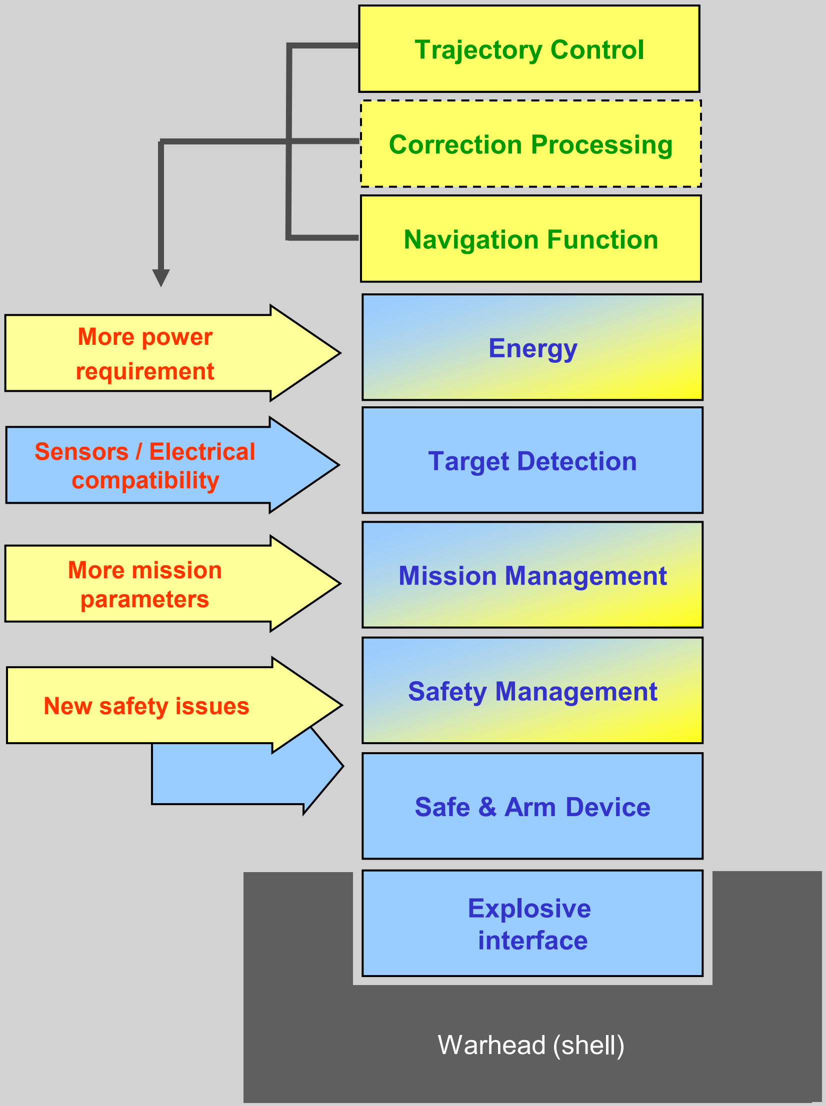
CCF – Main Functions

- Fuzing functions

  \+

- Course Correction Functions
  - Navigation Function: trajectory estimation
  - Correction Computing: algorithm + processor
    - Fuze embedded processing
    - or Weapon system processing
  - Trajectory Control: air control device + actuators

- The implementation of these functions has an impact on the requirement and the design of the fuze's other functions



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Technology Evolutions
Fuzing Functions

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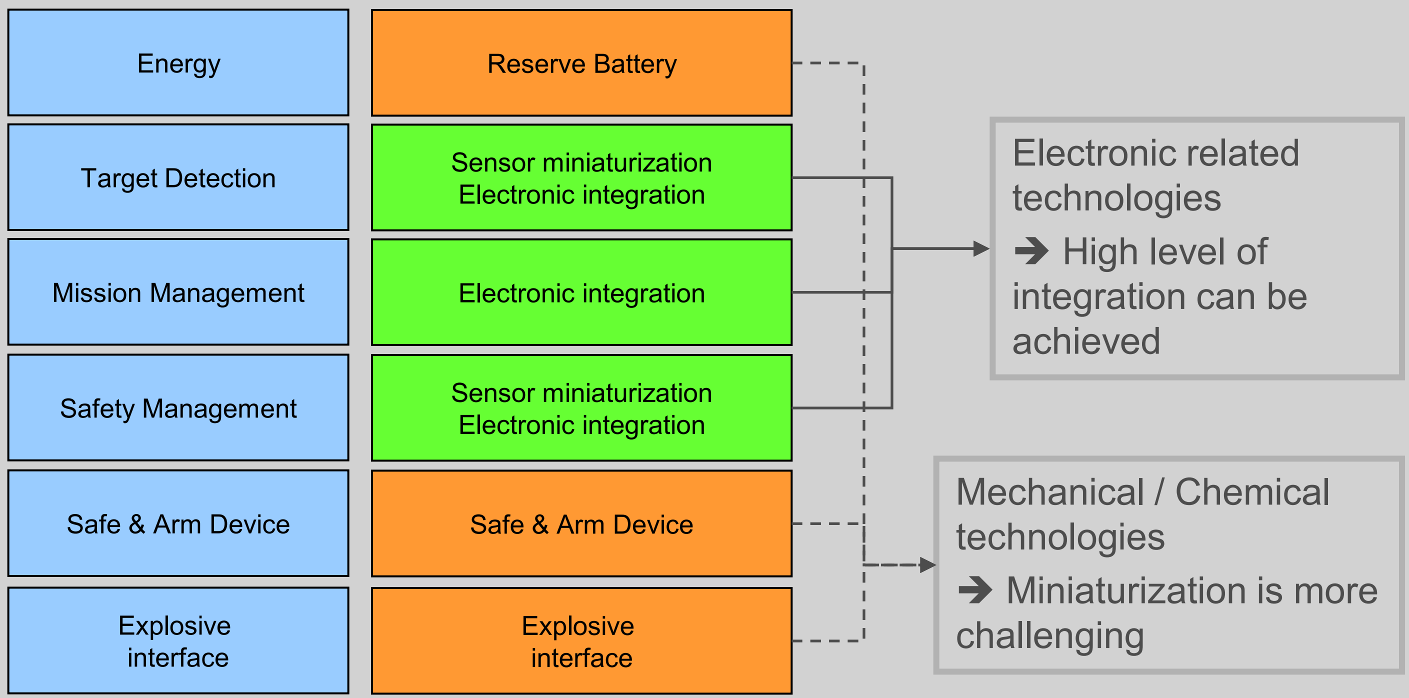
- Fuzing functionalities and capabilities have been significantly improved due to the electronic and sensor technology evolution (dual use components)
  - More versatility, operational flexibility, target detection performance
    ➔ Multifunction fuzes
- Difficult to get the same technology progress with non-electronic and specific fuze modules



Technology Evolutions
Course Correction Functions

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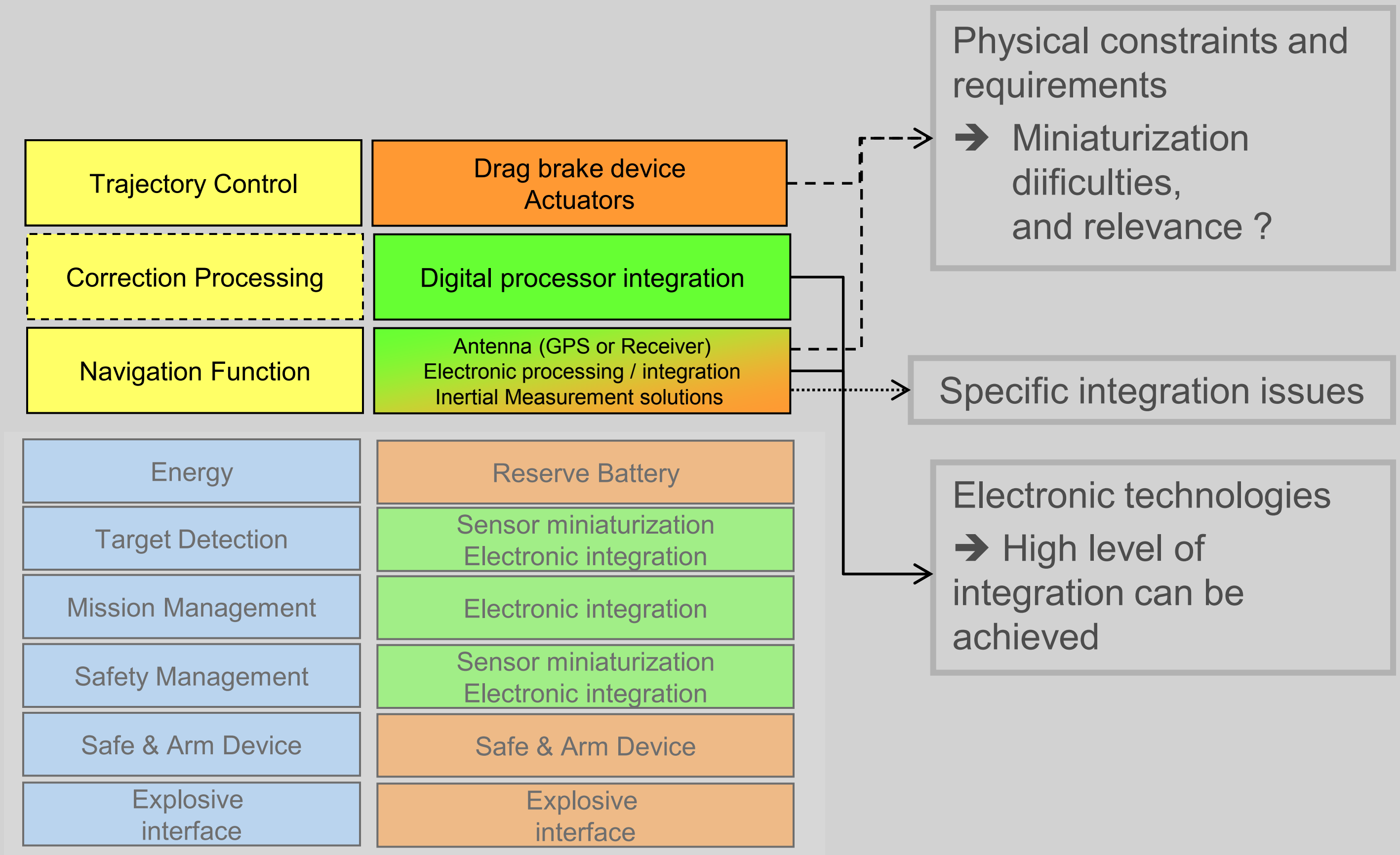
- Implementation of Course correction functions
  - Require significant space in the standard fuze architecture
  - Use various technologies which cannot be highly integrated



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CC Fuze Development
Main Technology Challenges

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- Main objective: Low-risk – low-cost design approach
  - Leverage in-service modern fuze design
  - Use existing qualified components
- Main challenges
  - Comply with the standard fuze size: STANAG 2916 contour / short intrusion
  - Re-use available sub-assemblies, in their current design
  - Optimise the integration for some of the fuze functions to provide space for the additional course correction functions
  - Cope with available (autonomous) power supply
  - Deal with compatibility issues between the different technologies living together in a small space, in particular:
    - Electromagnetic compatibility and interference issues within the various electronic circuits
    - Various antenna type integration, for different purposes, inside the fuze enveloppe

CC Fuze Development
Example of current CCF programmes

- JUNGHANS is today implementing integration solutions in major course correction fuze programmes carried out in Europe
  - Relying on modern multifunction fuze architecture and proven modules and components
- Two concepts based on different navigation and localization solutions:
  - ➔ very different concept and design
  - ➔ different integration problems and solutions

  - ***SPACIDO* Fuze**: in co-operation with NEXTER, France
    - "Non-GPS" trajectory navigational system solution Trajectory estimation based on the projectile initial velocity measurement by the muzzle velocity radar (MVR)
    - Range correction order sent to the fuze by the MVR

  - ***ECF* (European Correcting Fuze):** in co-operation with BAE Systems, UK, (GCSM) and Sweden (GCSW)
    - GPS based solution
    - Trajectory estimation based on the use of GPS C/A receiver

SPACIDO System

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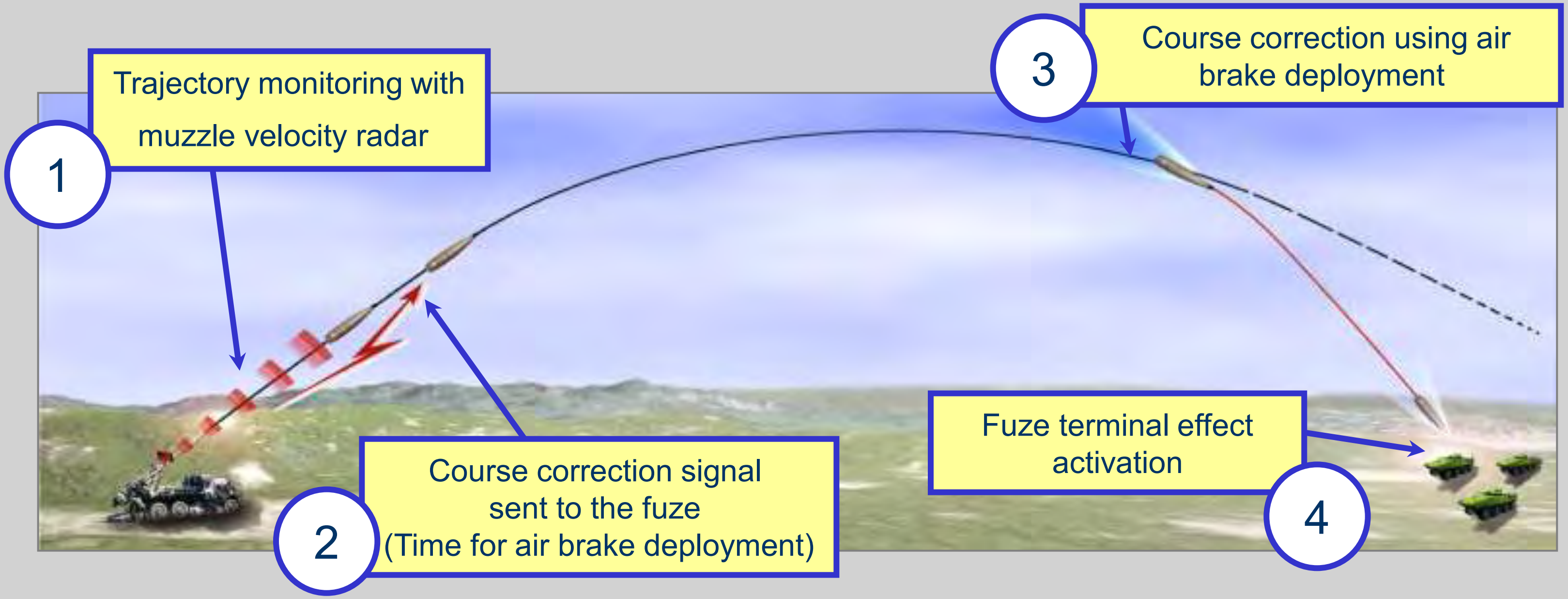

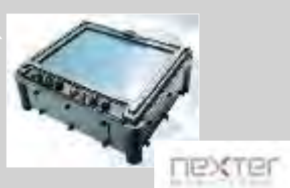

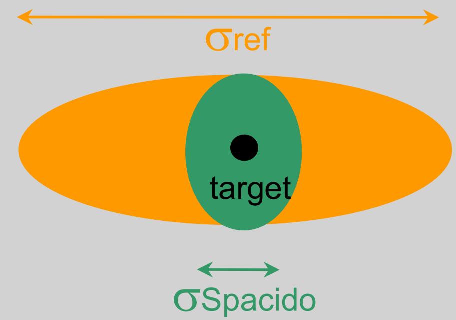

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SPACIDO

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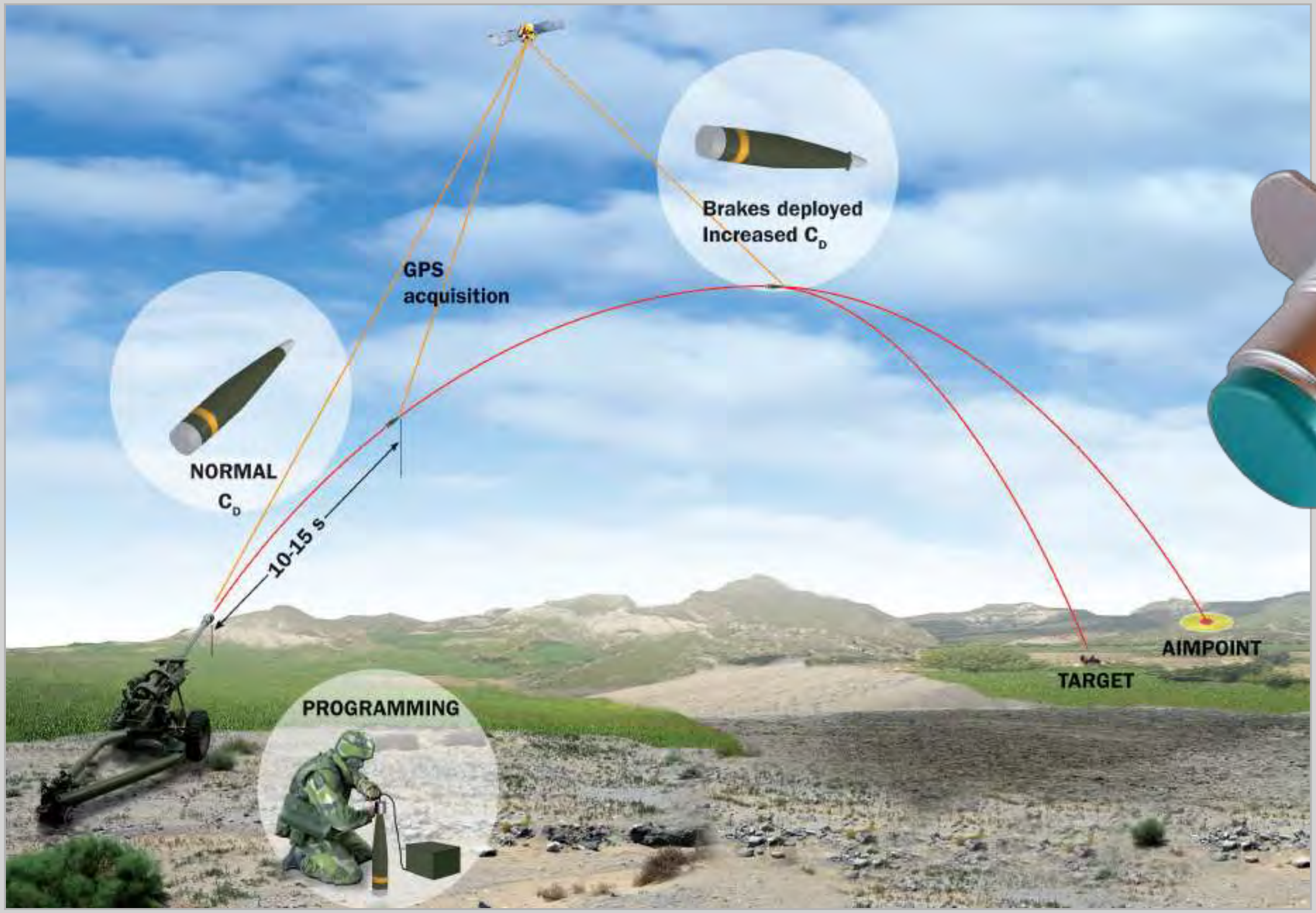
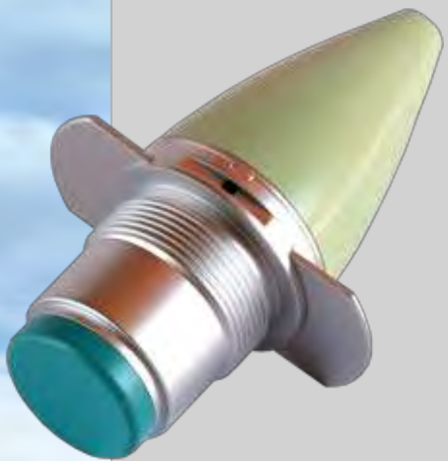
Fuze Integration Technologies

Course Correction Fuze

ECF (European Correcting Fuze)





- **In cooperation with** BAE SYSTEMS

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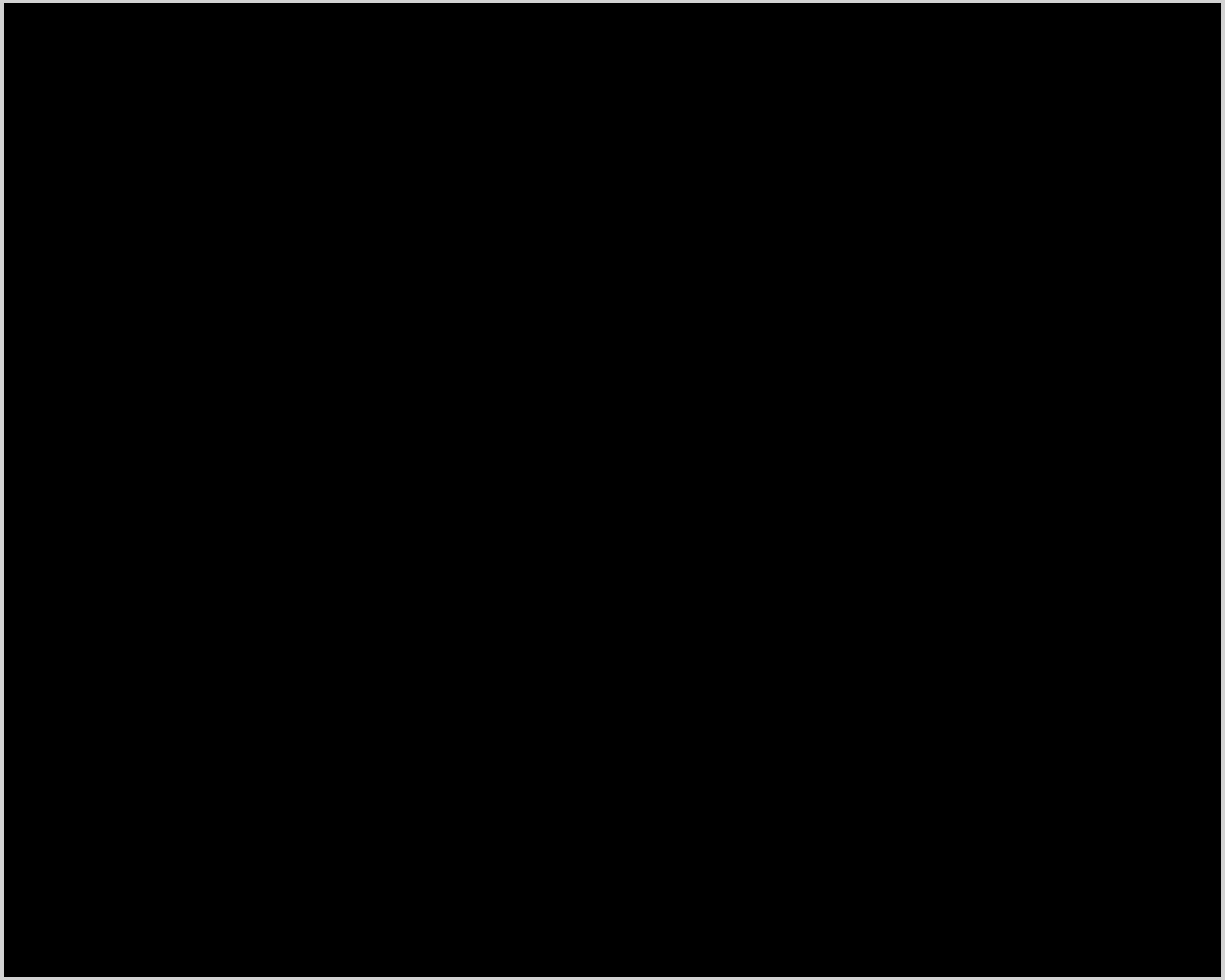
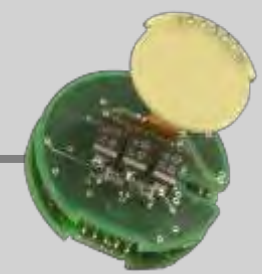
ECF



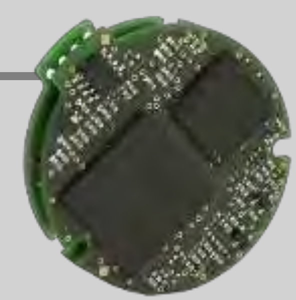
Integration Solutions for 1D-CCF
Basic Options

- Re-use proven sub-assemblies, as they are
  - Reserve battery - Lithium
  - Mechanical Safe & Arm Unit
  - Even if they are bulky items,
  - ➔ More cost effective and less risky

- Re-use target detection device (HoB sensor)
  - ➔ Slight adaptation to cope with space compatibility with other electronic boards, but same design



- Share the processing unit between target detection signal processing and correction processing
  - ➔ Select suitable component to cope with computation power requirement



Integration Solutions for 1D-CCF

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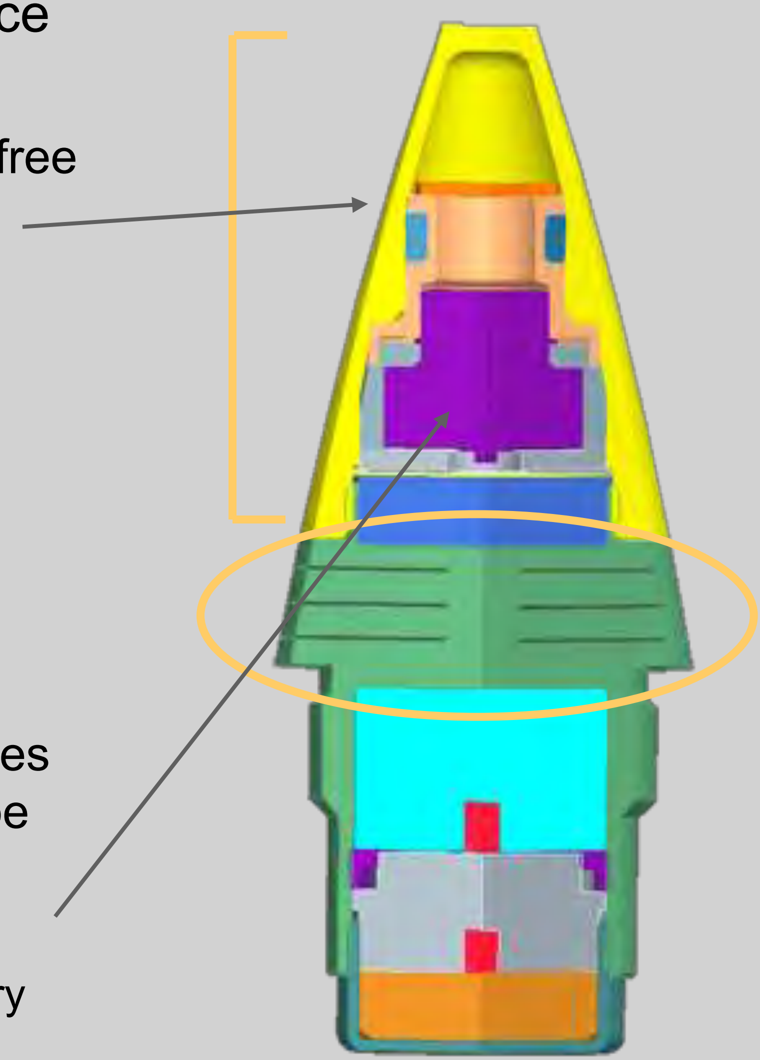
- 1D-CCF are fitted with drag brake device located in the central part of the fuze
  - Benefit: The nose cone of the fuze is free for antenna and radome integration
    - SPACIDO: Data-link receiver with antenna
    - ECF: GPS receiver and antenna
- Power requirements for 1D-CC
  - Aerodynamical control devices do not need high power actuators
  - Functioning of the various fuze modules and related power consumption can be managed all along the flight
    - Benefit: The power requirement is compatible with current reserve battery features



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Integration Solutions for 1D-CCF

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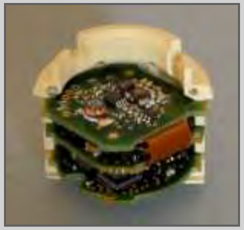
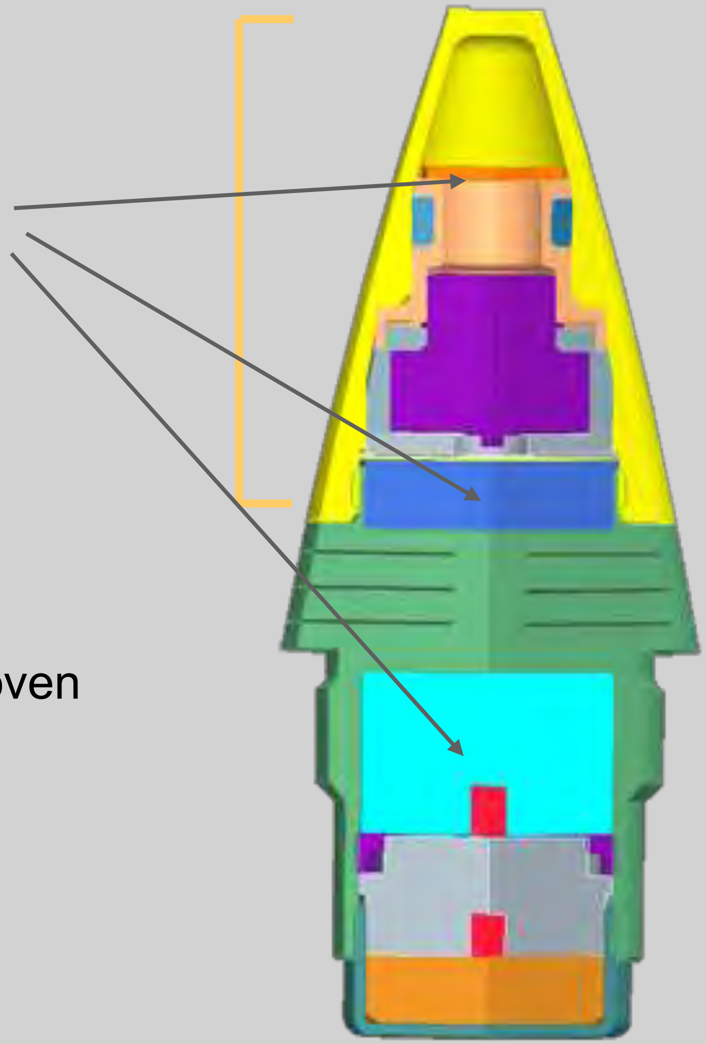
- Board interconnection techniques
  - More constraints: numerous boards, more data, no space available for connections, testing requirements
  - Optimized architecture to reduce interconnections
  - Flexprint circuits



- G-hardening
  - Possibility to keep and implement proven techniques from modern electronic artillery fuzes
    - Fuze frame design
    - Electronic board design
    - Potting material and techniques



Integration Solutions for CCF
Antenna Integration

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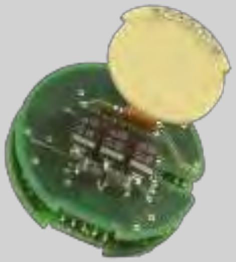
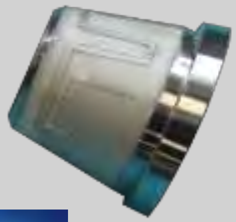
- SPACIDO
  - Integration of an embedded data-link receiver
    - receiver / decoder board
    - with "looking backward" antenna
  - Compatible with other modules requiring external access
    - STANAG 4369 programming coil
    - HOB sensor antenna and signal processing board



- ECF
  - Integration of an embedded GPS receiver
    - GPS receiver board
    - with antenna (revolution symetric radiation pattern)
  - Compatible with other modules requiring external access
    - Programming interface for high-rate data transmisison
    - HOB sensor antenna and signal processing board



Other integration issues and technology solutions

JUNGHANS microtec

- Interference problems between the different electronic modules operating in a very close vicinity
  - Converters, processors, oscillators, etc

→ No room for physical shielding: Therefore the design requires very fine optimization (PCB layout, circuit frequency selection)

- Data-link for fuze programming before flight
  - Low rate or high-rate depending on the required mission parameters (Fuzing parameters, GPS ephemeris, etc..)

→ Optimization of the communication protocol to lower hardware and software constraints

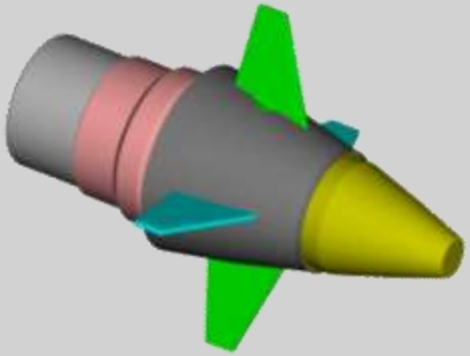
- … and always
  - Keep good reliability
  - Keep high level of survivability to harsh conditions created by gun firing
    - High-G hardening on new technologies

Trends for guidance integrated fuzes

JUNGHANS microtec

- Integration of future CCF concept or guidance integrated fuzes:
  - Much more tricky issue to keep all functions fitted into a standard short intrusion fuze enveloppe
  - Difficult to re-use conventional fuze components

- Some new challenges:
  - Guidance solutions
  - Navigation, incl. Inertial Measurement
  - New safety issues for the artillery systems
  - High-G hardening of new technology devices



- Some technological breakthrough will be required to meet the requirements in terms of:
  - Miniaturization, cost, reliability, safety for such products

Conclusion

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- Course Correction Fuze development has created significant technical challenges to the fuze designer who has now to integrate new functionalities in the same fuze enveloppe
- Thanks to the progress achieved in electronic technologies but also in the fuze integration techniques, it is now possible to design smart fuzes featuring significant functionalities, including course correction capability
- JUNGHANS has taken on the technological challenges and has implemented solutions
  - To provide the user with smart fuzes, but still affordable and reliable
  - To prepare the technological breakthrough required for future fuze generation

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Thank You

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JUNGHANS microtec

Fuze for Tiger Helicopter Rocket Inductive Setting and Motor Ignition

55th Annual Fuze Conference

"Fuzing's Evolving Role in Smart Weapons"

Salt Lake City, UT - May 24-26, 2011

Max Perrin
JUNGHANS Microtec

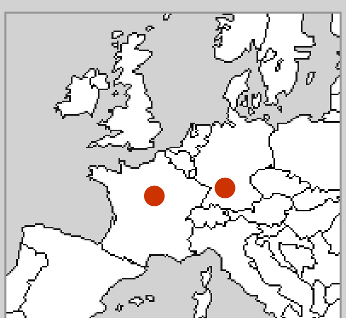
Outline

JUNGHANS microtec

- Tiger Rocket system
- Operational Issues
- Fuzing Solutions
- *METAE* Fuze – Inductive setting
- *METAE-AI* Fuze – Inductive setting + motor ignition
- Future developments

Company Presentation

- **A leader in the field of ammunition fuzes and S&A devices**
- **Full range of products**
- **Key competences in**
  - Fuzing technologies
  - Micro-technologies
  - Ammunition electronics



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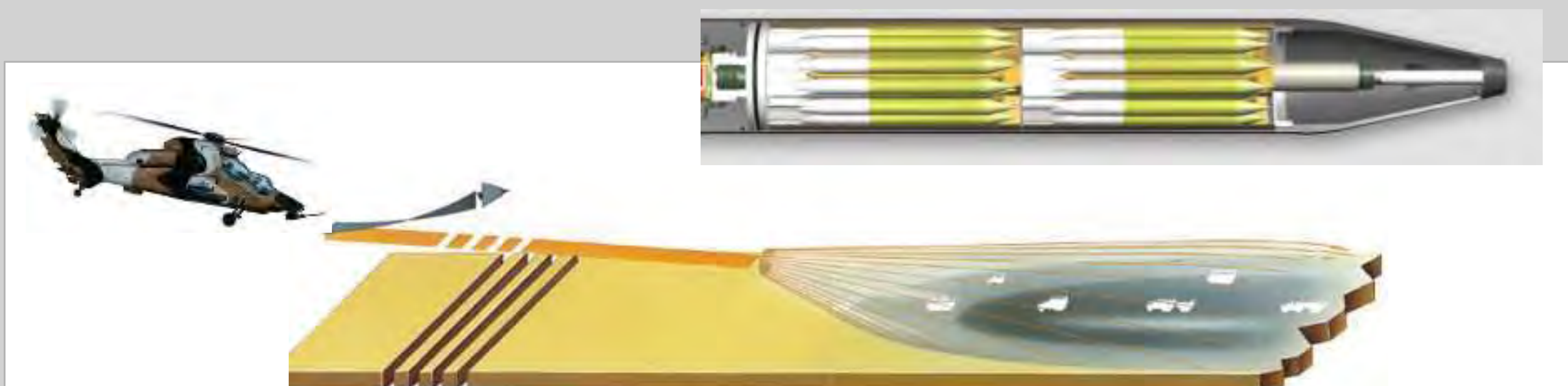
Rocket System for Attack Helicopter
Anti-vehicle Flechette Warhead Concept

JUNGHANS microtec

- The efficiency of air-to-ground rockets fitted with a flechette warhead has been proven in the past as well as in todays conflicts
- Basic features
  - Used against light armored targets
  - Contains a large number of small arrow-shaped projectiles (darts)
  - Target damage caused by the kinetic energy of the flechette
  - Flechette dispensing controlled by a programmable time fuze
  - Various dart size available for different target / terminal effect
- The projectile dispersal concept compensates
  - the target's movements
  - the inaccuracy around the point of impact



French Tiger Helicopter Rocket System

JUNGHANS microtec

- Today the French Tiger Helicopter is fitted with the most modern rocket system. This system relies on 68mm caliber rockets
- It is currently in service in operational theaters
- The 68mm Rocket System is designed and produced by TDA Armements, France

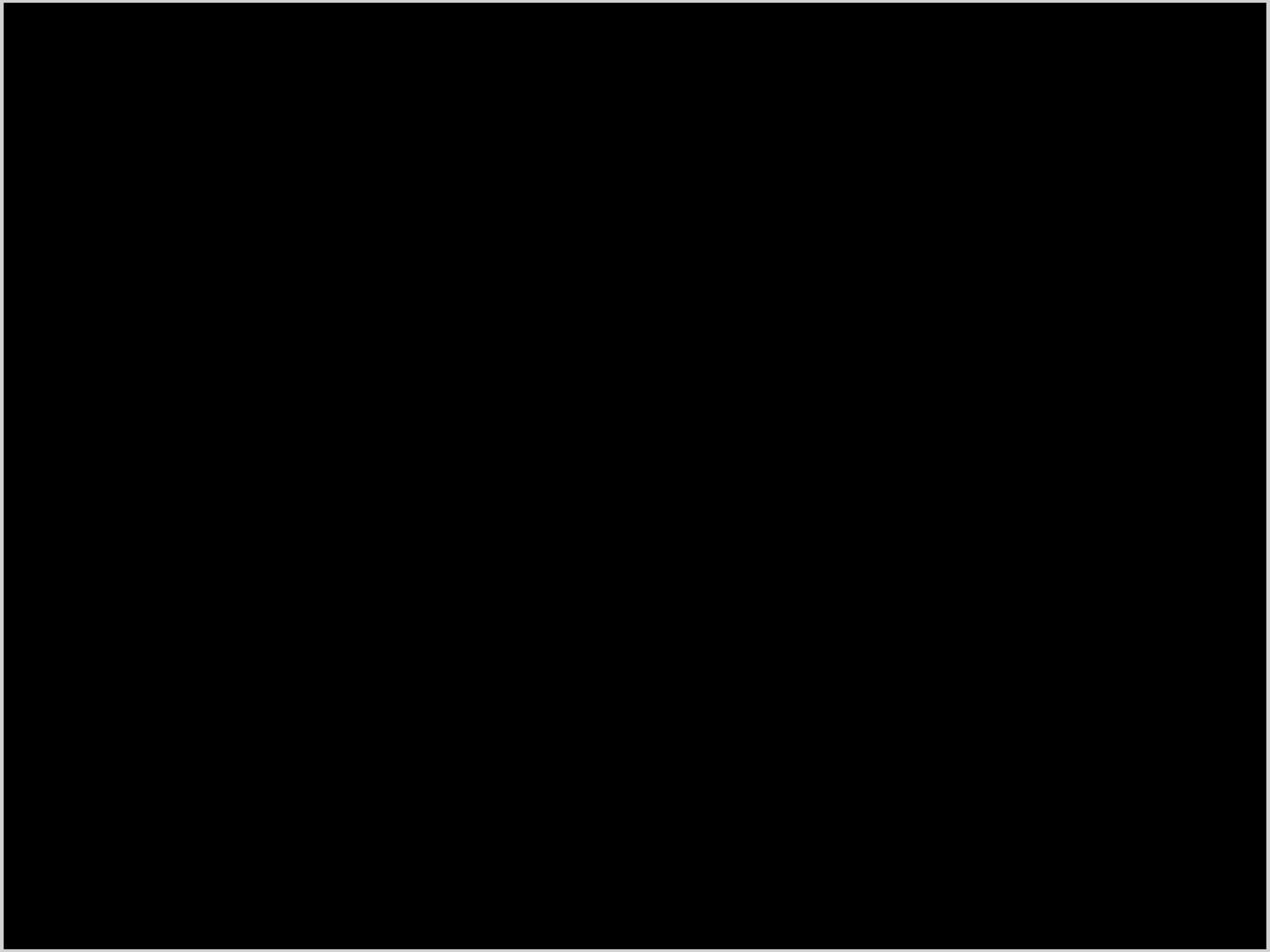
TDA

A Diehl and Thales Company

68mm Rocket System on Tiger

A Diehl and Thales Company

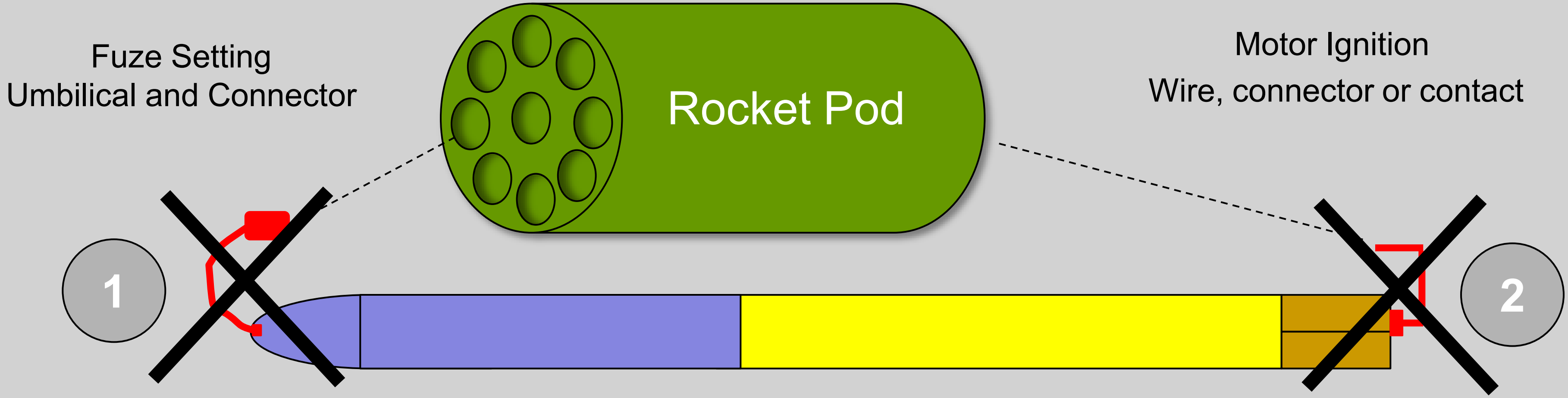
Video – Rocket System



68mm Rocket System - Main Objectives

JUNGHANS microtec

- Provide benefits to the user in terms of
  - Logistics – Maintenance – Reliability – Safety
- By removing any wire or contact connection between the launcher and the rocket
- Solution: Achieve fuze setting and motor ignition with wireless techniques
  - The 68mm Rocket System features this technique with a new generation electronic fuzing system



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Operational Issues related to wire connecting

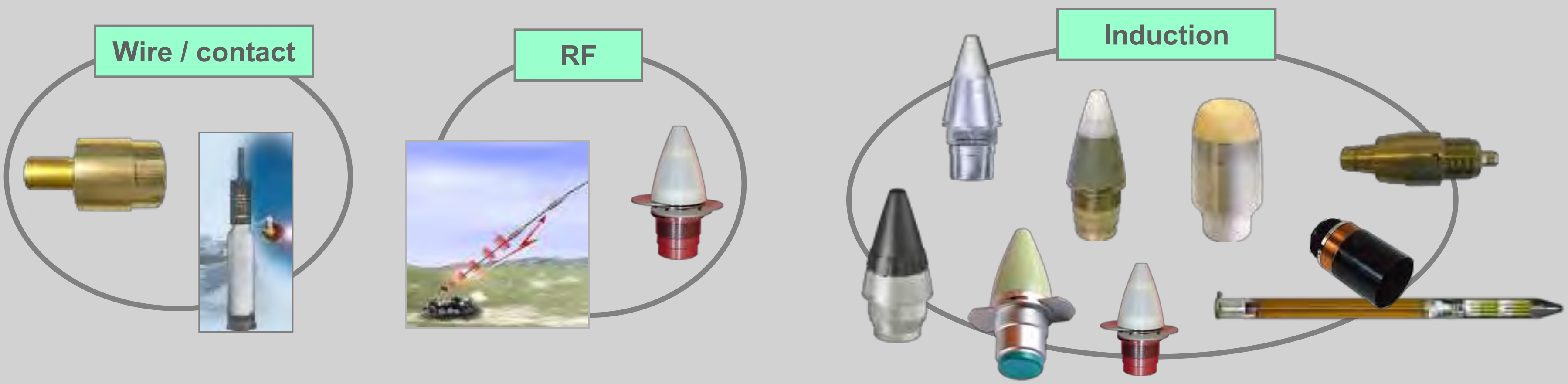
JUNGHANS microtec

- Fuze setting and motor ignition with conventional solutions, based on wire or contact link, lead to significant operational constraints and problems:
  - Scattered scraps generated when firing the rockets (cables, connectors)
    - Safety issue if debris damage the helicopter body or controls
  - Long loading time of rocket in pods
    - Connection to be carried out for each rocket
  - Wire and connectors weaknesses
    - Possible clogging up of connectors and contacts
    - Loose connections
  - Watertightness issues
  - EMC issues

METAE and *METAE-AI* new generation fuzes

- Wireless fuze setting solutions developped by JUNGHANS have provided new generation rocket system with unmatched operational flexibility, safety and reliability
  - METAE fuze: Inductive setting.
    - Qualified and produced from early 90’s onwards
    - Qualified on Tiger helicopter in 2000
  - METAE-AI fuze: Inductive setting + inductive motor ignition
    - Qualified in 2010, Serial production started early 2011

- JUNGHANS background in fuze setting / communication techniques



METAE Fuze – Inductive Fuze Programming

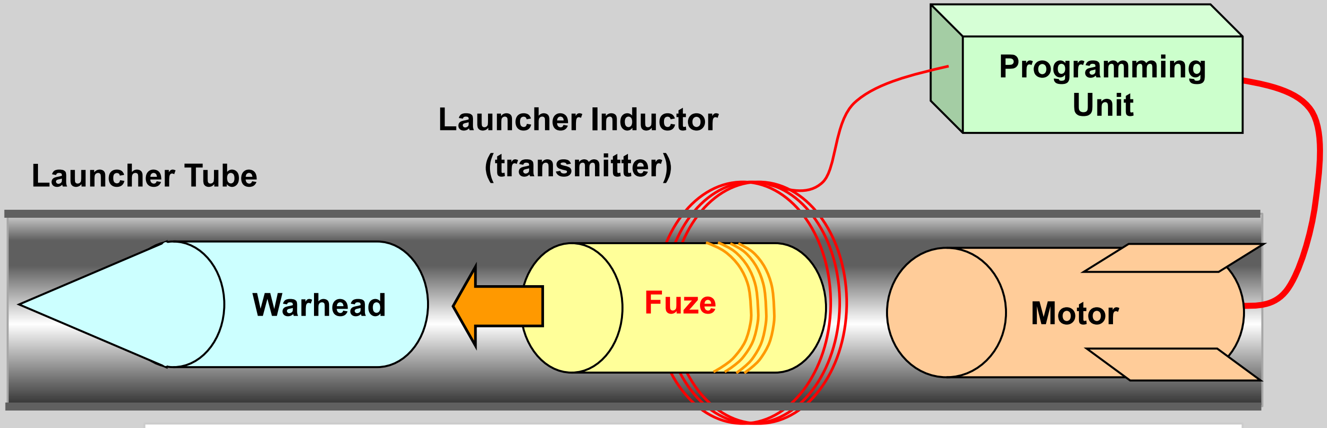
JUNGHANS microtec

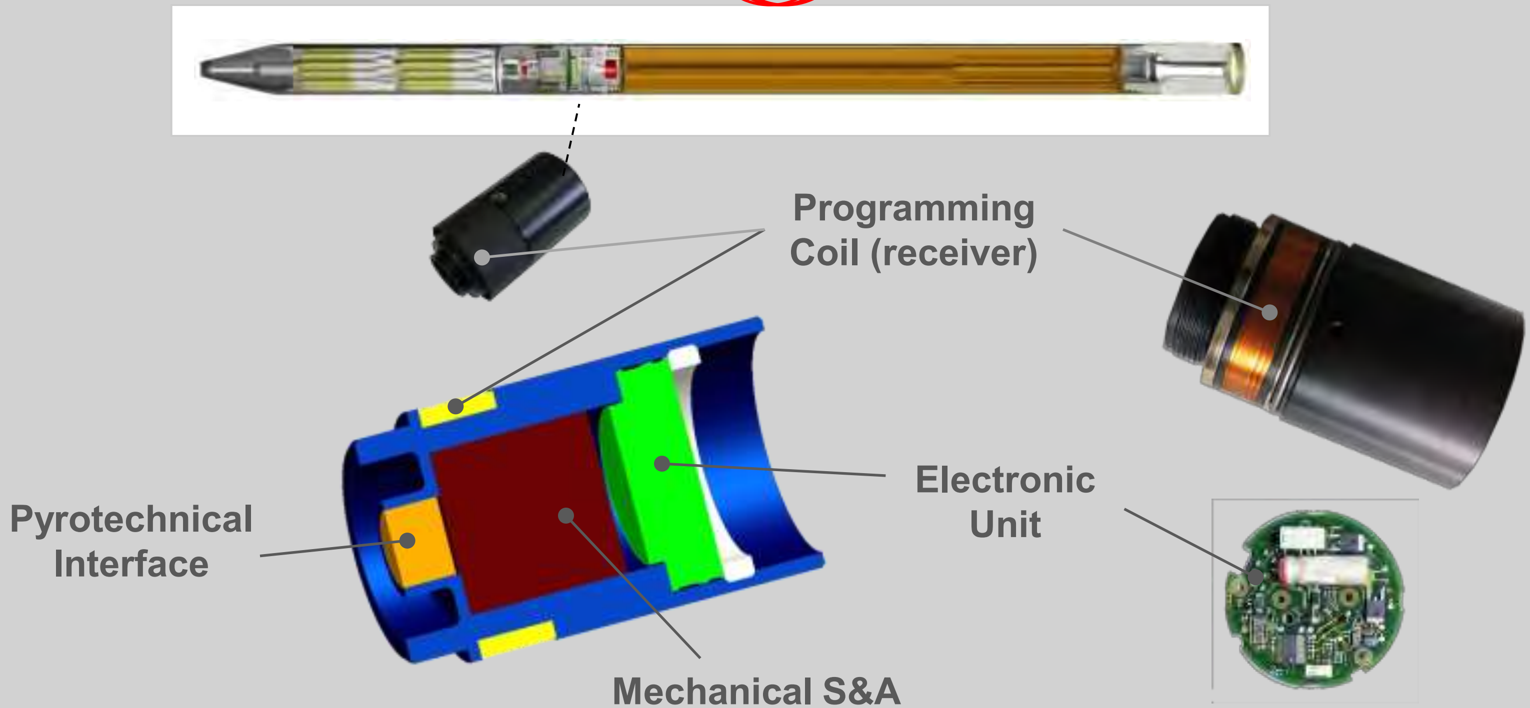
- Main technical challenges
  - Inductive link through metallic launcher tube ☑
  - Multiple tube launcher ☑
  - Fuze power supply ☑
  - Fuze electronics power consumption ☑
  - Data transmission safety ☑
- *METAE* Fuze solutions
  - Selection of the good compromise for
    - suitable metal material for the tube
    - thickness of the tube
    - frequency of the carrier signal for data link

    to deal with inductive transmission issues
  - No internal battery
    - Energy provided by the fuze setting unit and transferred at setting phase, prior to firing
  - Use of safe communication protocol

METAE Fuze – Inductive Programming

JUNGHANS microtec





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METAE and *METAE-AI* Fuzes
Launcher integration

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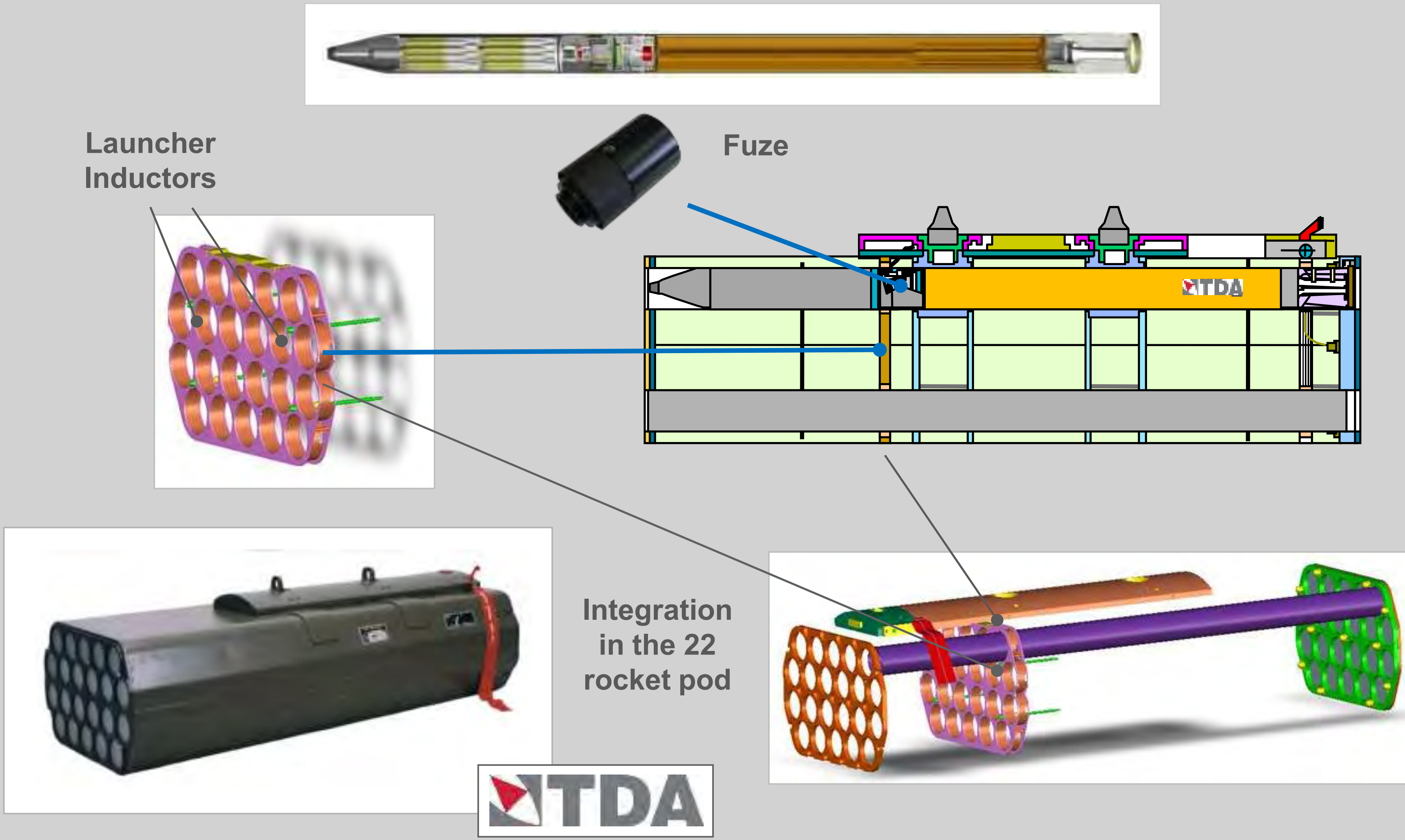


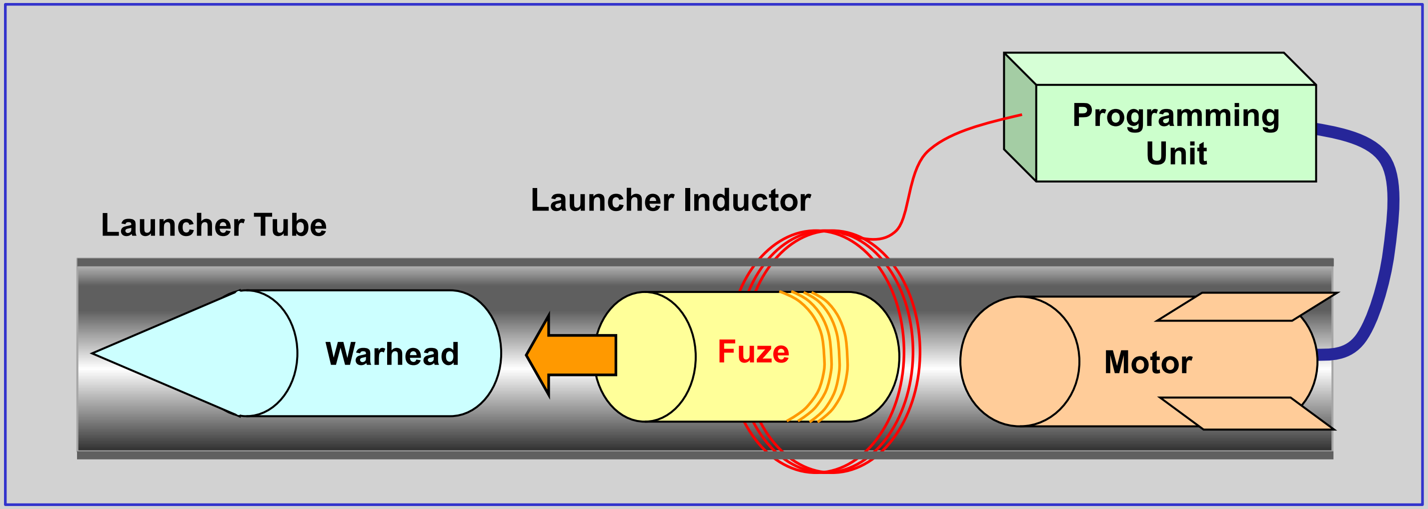
METAE Fuze – Main Features

JUNGHANS microtec

- Inductive fuze setting
  - Data transmission, electronic energizing and energy transfer
  - Fuze setting carried out just before firing
  - Message duration: 35ms
  - Manchester encoding
- Programmable flight time
  - From 1.28s to 30s
- Power supply
  - Energy transfer at inductive programming
  - Energy storage by capacitor
- Digital electronics
- Safety distance
  - Mechanical S&A unit: 0.7s arming delay

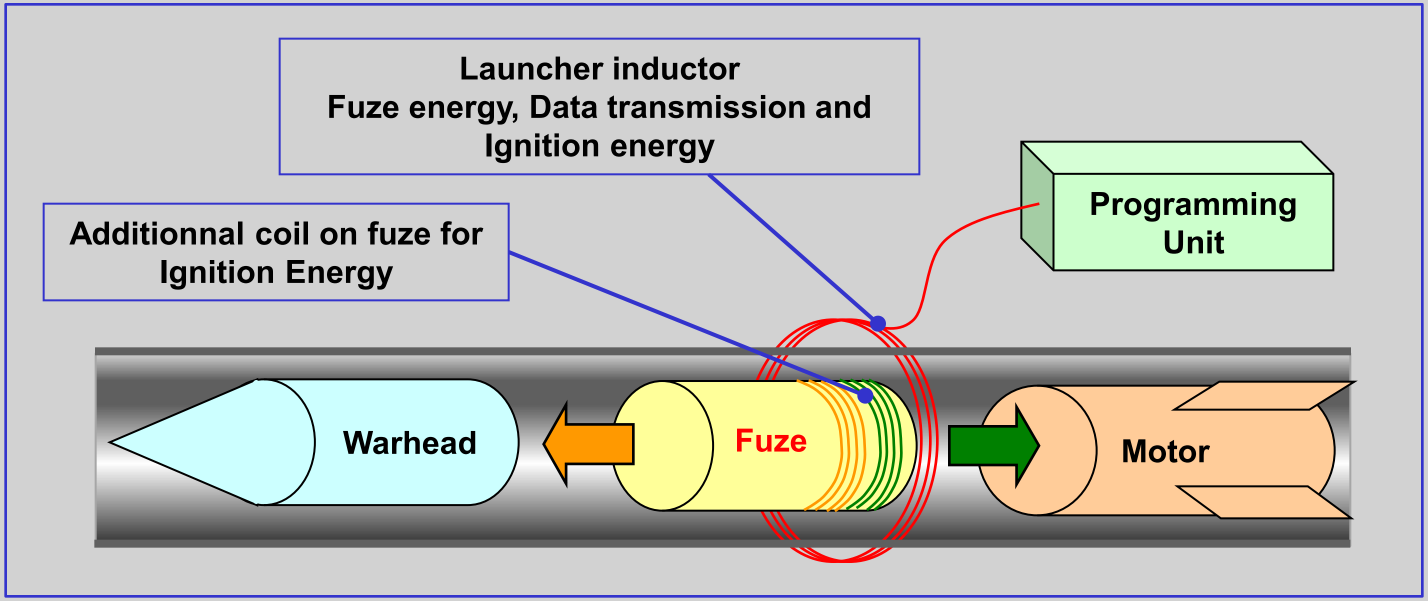
METAE-AI Fuze – Programming + motor ignition

JUNGHANS microtec



METAE **Fuze**

Inductive Programming
+
Contact / connection for motor ignition



METAE-AI **Fuze**

Inductive Programming
+
Inductive Motor Ignition

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METAE-AI Fuze – Main Features

JUNGHANS microtec

- Fuze setting:
  - Same as the METAE fuze
- Fuze features
  - Same as the METAE fuze
- Motor ignition
  - No contact nor connection with the launcher
  - Fully controlled by the fuze
  - Dual coil to transmit suitable iginition energy
  - Motor ignition carried out just after message transmission
  - Ignition signal generated when two conditions are met
    - Decoding of the correct message and flight time
    - Checking that the required ignition energy is available

METAE-AI Fuze
Summary of Operational Benefits

JUNGHANS microtec

Feature	Benefits
• No wire - no connector	- Reduced time for maintenance - Reduced time for loading operation - Enhanced reliability
• No scattered scrap and debris when firing	- No damage to helicopter - Enhanced safety
• Qualified in severe EMC environment	- Enhanced safety - Enhanced reliability
• Digital electronics	- Enhanced precision - Enhanced operational flexibility - Growth potential for new weapons
• No external access / induction protocol needed to activate motor or fuze	- Prevent enemy to reuse the rocket as improvised weapon or IED

Future developments
Rocket System and Fuze

- Digital electronics and inductive setting features provide growth potential and capabilities to deal with further rocket system developments, e.g
  - Advanced Guided Rocket development (TDA programme)
    - Capability to transmit additional data and mission parameters, eg. Laser code, etc..
  - New generation of warhead for rockets
  - Transposition of Tiger helicopter launcher to fixed-wing aircraft integration
  - Advanced Rocket Launcher for rotary-wing or fixed-wing aircraft

Conclusion

JUNGHANS microtec

- Due to its inductive fuze setting and communication techniques, the 68mm Rocket System provides the Tiger attack helicopter with unmatched operational benefits:
  - Enhanced terminal effect on target
  - Better operational flexibility
  - More reliability and safety
- New trends in modern warfare highlight new operational needs. This concerns air-to-ground rockets as well as all other weapons and ammunition
- The fuze is the main contributor to the munition’s performance. New weapon evolutions relies on progress in fuze capabilities and technologies as well as in fuze integration in the weapon systems
- The fuze designer/producer has a key role in the development of smart weapons

JUNGHANS
microtec

Thank You

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New Data Recorder for Gun Launch and Impact Test with Options for Built-in High G Accelerometers and Angular Rate Sensors

www.dtsweb.com

Stephen Pruitt

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May, 2011

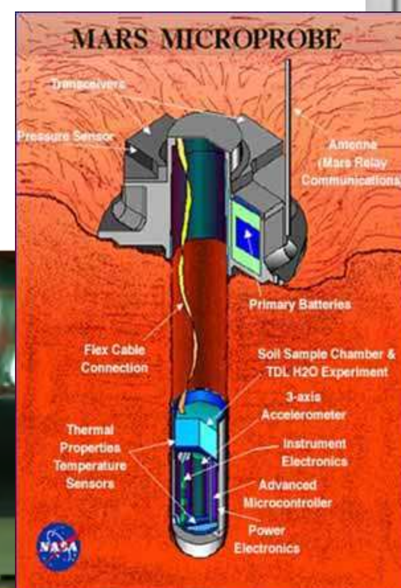
DTS Introduction

- Data recorders and sensors for high shock testing
- Founded in 1990 by three test Engineers
- Small US private corporation with 55 staff members in 6 offices worldwide
- 90+% of customers do "must collect data" testing
- Key DTS staff have over 100 years of combined high shock test experience

DTS Introduction – Customers

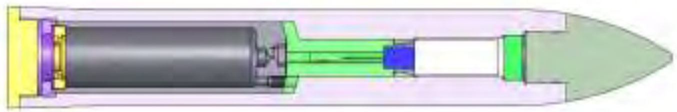
Applications for DTS Products

- Data recorders for Manikin and cadaver test
- Vehicle and soldier blast event
- Ejection seat drop tower and rocket sled
- Aircraft/spacecraft flight and crash test
- Hard target recorders



Applications and Shock

- Hard Target Recorder



- Gun Launch

- Military Blast

- Vehicle Crash Safety
- Motorsports

Shock		Sample Rate
100,000 g	↑	1 Msps
20,000 g		100 Ksps
5,000 g		
500 g		20 Ksps
100 g		5 Ksps

Data Acquisition History

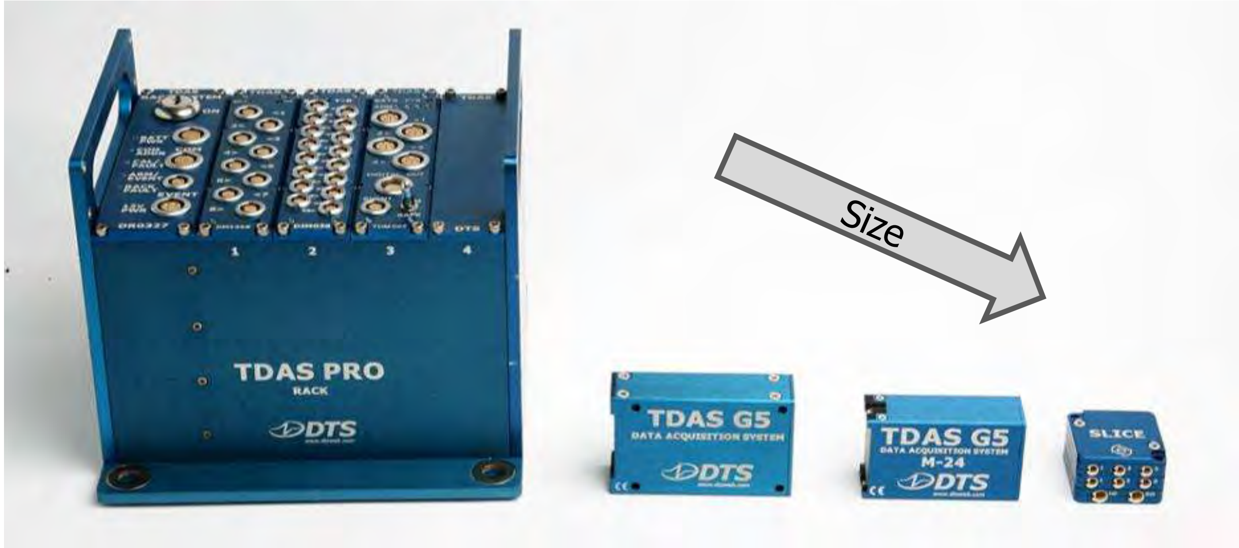
1980s

Amplifiers

Tape Recorders and Oscillographs

1990s to Present

Self-contained Data Recorders



Technical Terms

- **DAS**: Data Acquisition System, includes analog electronics for sensor inputs, digital conversion and non-volatile memory
- **Sensor or Transducer:** converts physical world to analog or digital voltages
- **ADC**: converts analog signals to digital data, usually 12 or 16 bit resolution
- **Sampling Rate**: how fast ADC samples each channel (sps)
- **Bandwidth**: analog frequency content of data (Hz, usually expressed as -3dB point filter roll-off)
- **AA Filter**: anti-alias filter, determines bandwidth

SLICE HG

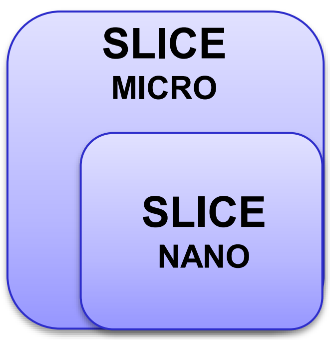
- Based on DTS SLICE data recorder technology
- Eglin Air Force Research Lab ASPIRE Program
  - Phase I and Phase II SBIR, ~Jan 2009 to March 2011
  - Develop 50+ Kg recorder
- DTRA Hard Target Recorder
  - Phase I SBIR, ~Mar 2010 to Dec 2010
  - Develop 100+ Kg recorder
- Also have worked with Sandia Labs and China Lake
- Current contract with Army to up sample rate to 1 Msps/chan, production in 2012

SLICE Overview

- Two package options, same electronics:
- **SLICE NANO**
  - 26 x 31 mm footprint
  - Circular connector inputs
  - For tight space or embedded applications

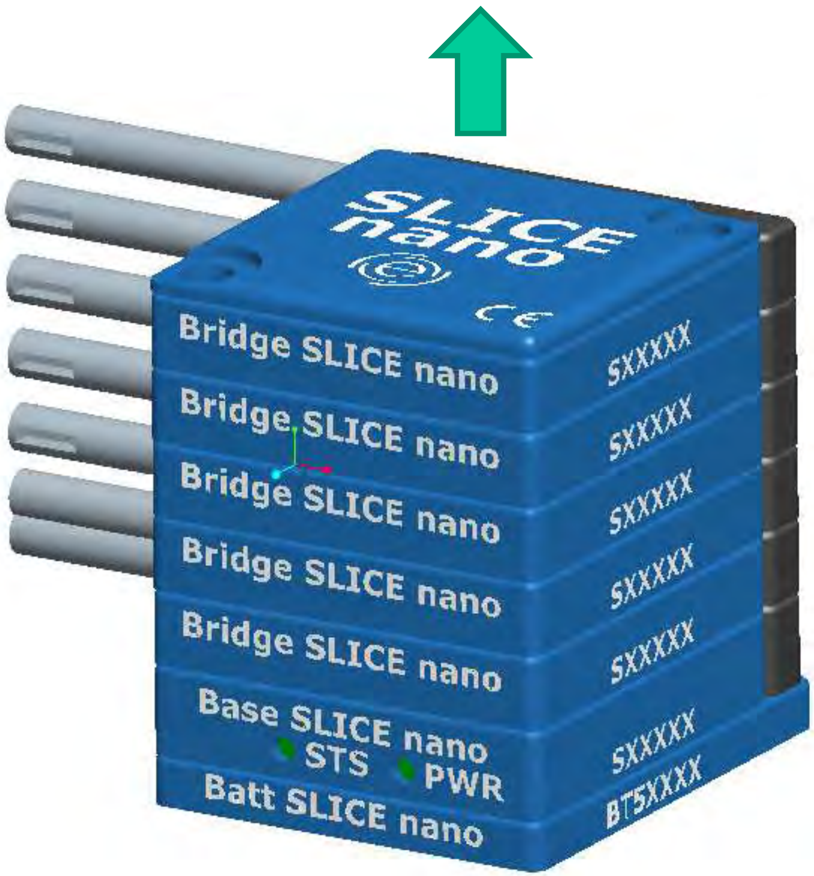
SLICE MICRO
- 42 x 42 mm footprint
- Circular connector inputs

Relative Size



SLICE Modularity

Up to 8 sensor SLICEs per STACK (24 channels)



Emergency Backup Power, up to 3 minutes

Bridge SLICE

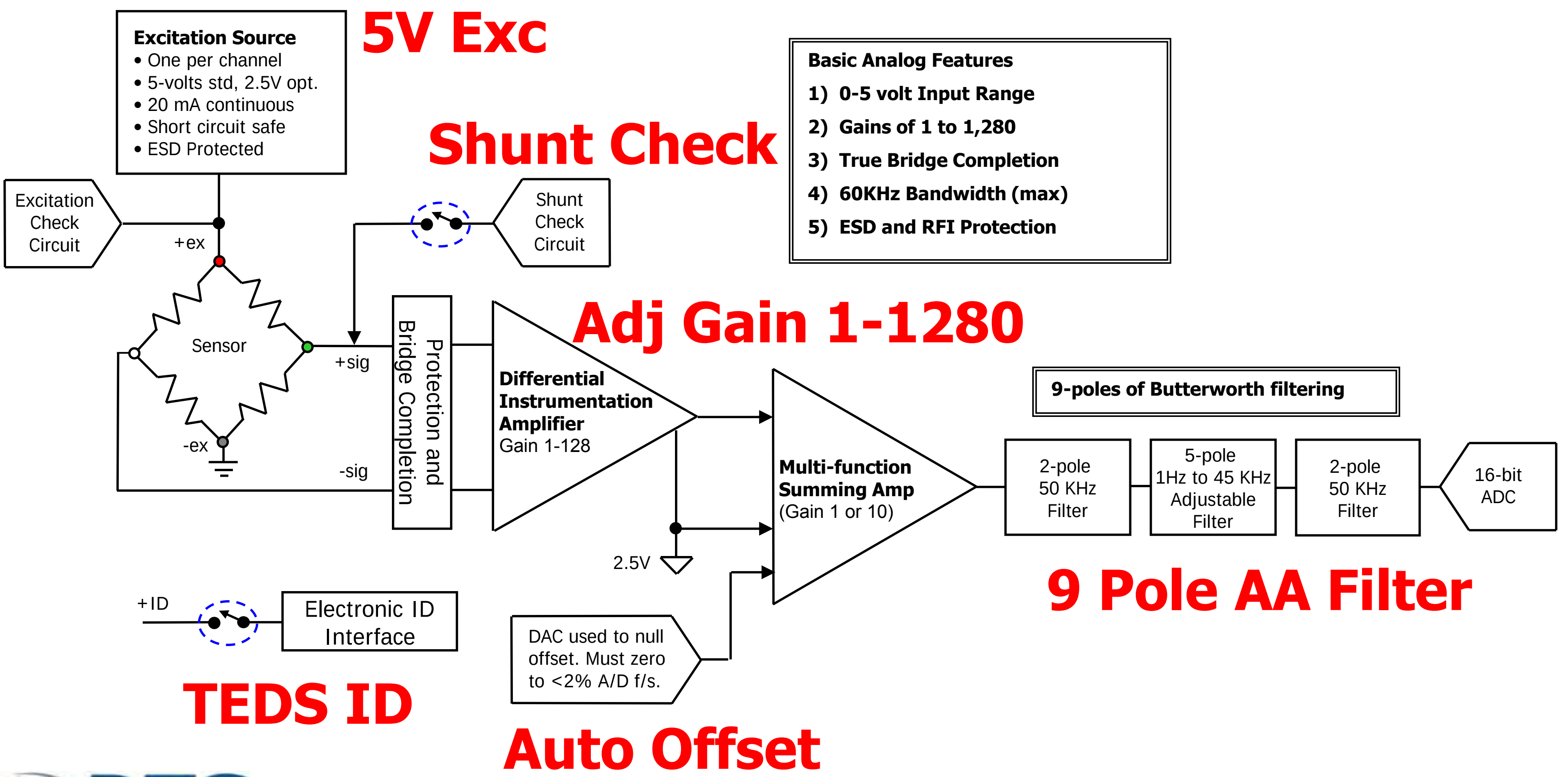
- 26 x 31 x 5.5 mm
- 3 channels, 16 bit/chan
- 9-poles of Butterworth filter, adjustable 1 to 40 KHz
- 5V sensor excitation
- Auto offset and shunt

Base SLICE

- 26 x 31 x 6.5 mm
- USB 2.0 plus USB hub
- 7 GB Flash memory
- Up to 120 Ksps/chan
- 1 Msps coming in 2012
- Standard 5 Kg shock
- HG packaging to ~50 Kg

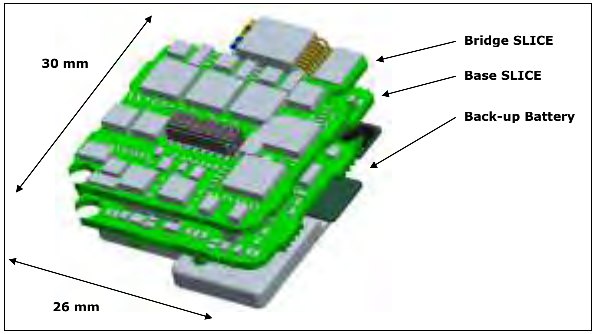
SLICE Bridge – Sensor Interface

Piezo-resistive, strain gauge or voltage inputs



SLICE HG – General Specs

- Uses standard SLICE PCBAs (1 Base SLICE, 1 Bridge SLICE, 1 Battery SLICE), packaged in two stage potting process



- 3 channels, 120 Ksps/chan
- 40 KHz bandwidth, 9 pole hardware AA filters
- 7 Gbyte non-volatile flash memory = > 2 hours
- Backup power source for ≥ 3 minutes
- Every unit tested at DTS to > 20 Kg, 0.1 msec

SLICE HG – Arming and Triggering

Arming Options

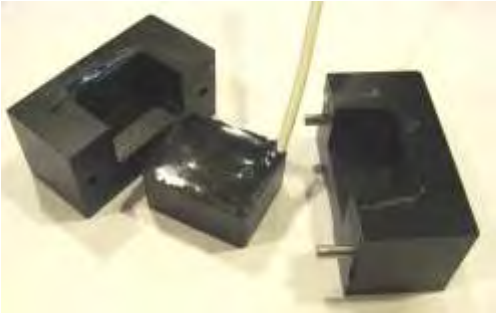
- Arm on Power up – wait for Start signal
- Start Recording on Power up

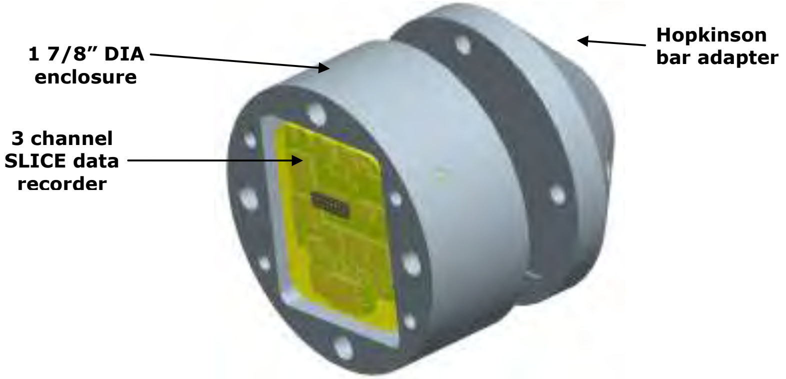
Triggering Options

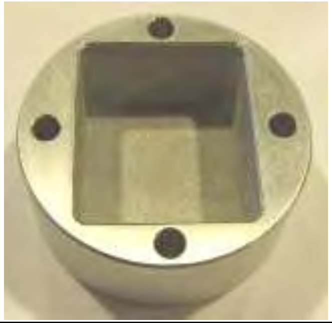
- Start signal on separate 0-5V input
- Event (T=0) on Contact Closure or Level Trigger
- Over 2 hours of data collection
- Non-volatile flash memory

SLICE HG - Packaging

Two stage, hard then software potting

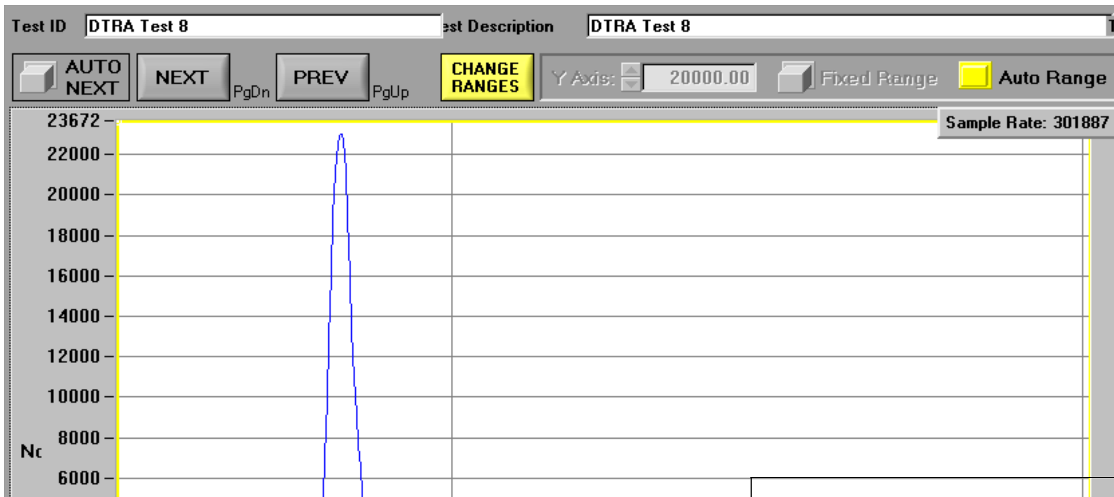






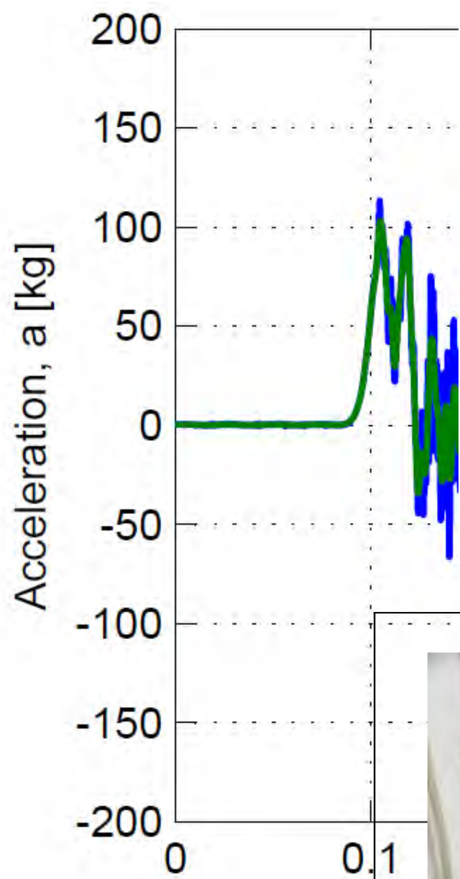
SLICE HG – Shock Testing

Tested at DTS to ~23,000 g's, 0.1 msec

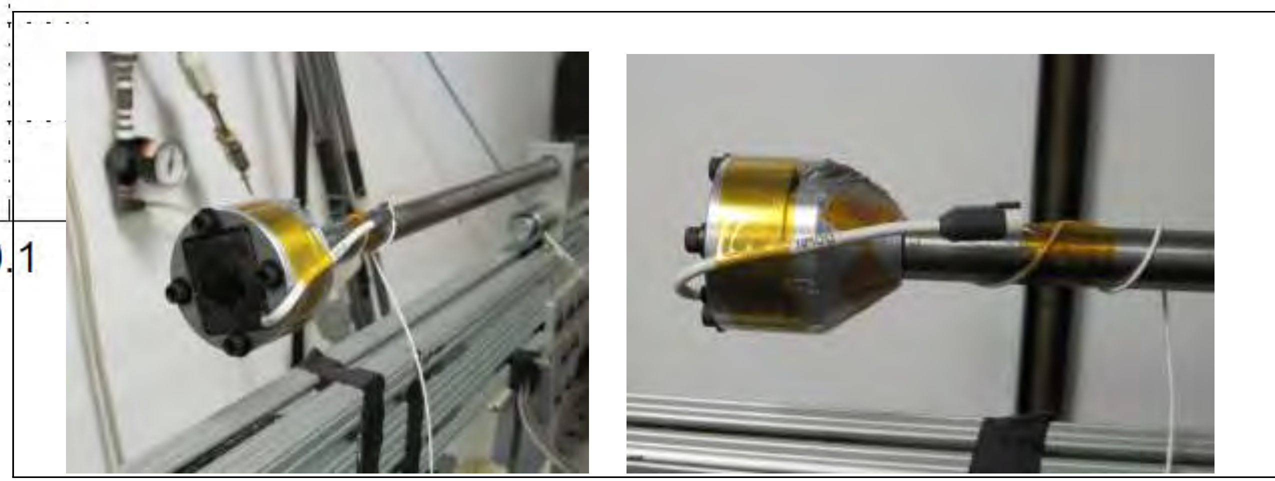


www.dtsweb.com

SLICE HG – Shock Testing



Tested at Endevco on Hopkinson Bar, ~80,000 g's, 0.04 msec



SLICE HG – Shock Testing

- China Lake has run sled tests for missile impact with success
- 6 SLICE HG units delivered to Eglin AFB for test
- SLICE HG at Sandia for test

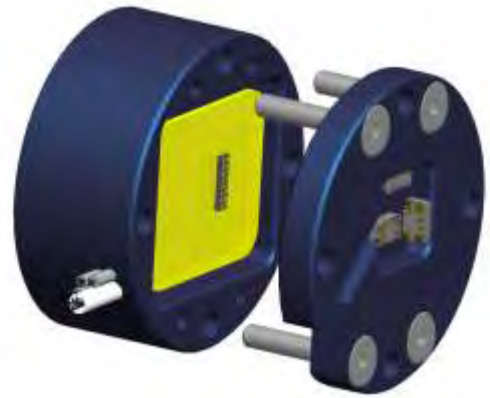
Shock Hardening Considerations

For 20 Kg+ g environments, DTS products incorporate these features:

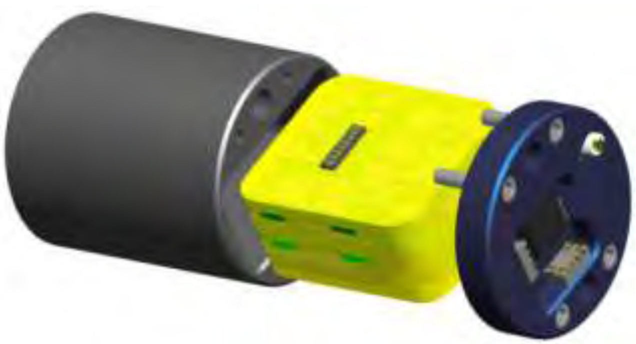
- Large IC's on PCB epoxied down before soldering
- Other larger components have adhesive applied
- Crystal time base oscillators used, up to 100K g rating
- Other high shock rated components used as required
- Visual and X-Ray inspection used on PCB assemblies and solder joints
- PCB assemblies are potted in a two-stage potting process
- All final products are 100% shock tested to 20+ Kg to verify robust operation before delivery to customer

SLICE HG – Package Sizes

- 1.875″ DIA x 1.05″ (47.6 x 26.5 mm)

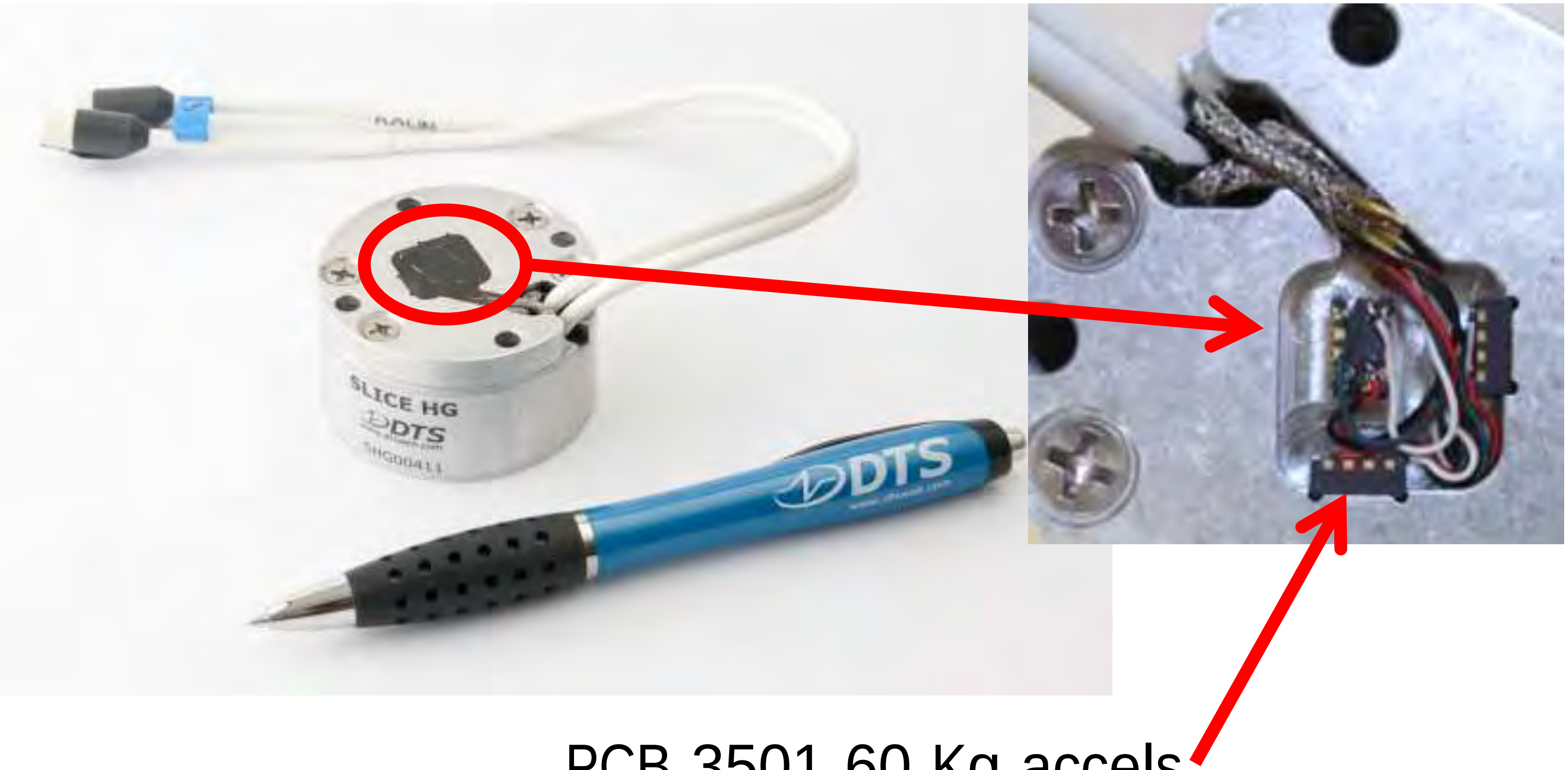


- 1.25″ DIA x 1.67″ (31.8 x 42.5 mm)



SLICE HG – Configurations

Option for embedded 3 axis accelerometers from various manufacturers or an angular rate spin sensor



SLICE HG – Configurations

- Up to four 3 chan. units can be chained (12 chan.)
- External power: ~12V at 250 mA per 3 channel unit
- Units are independent, standalone. The failure of one does not cause failure of another
- Various options for triggering and monitoring

SLICE HG – Availability

- In production
- Price is ~$15,000 per 3 channel unit
- Additional cost of built-in accelerometer or ARS options depend on sensor manufacturer/model
- Typical lead time is 8 weeks
- Export status is pending revue
- DTS offers 24/7 technical support and on-site training

New Data Recorder for Gun Launch and Impact Test with Options for Built-in High G Accelerometers and Angular Rate Sensors

www.dtsweb.com

Stephen Pruitt

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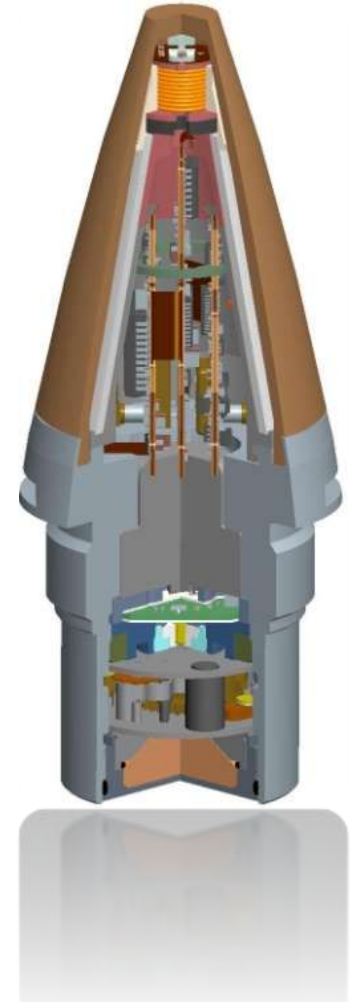
May, 2011

Public Releasable – Distribution Unlimited

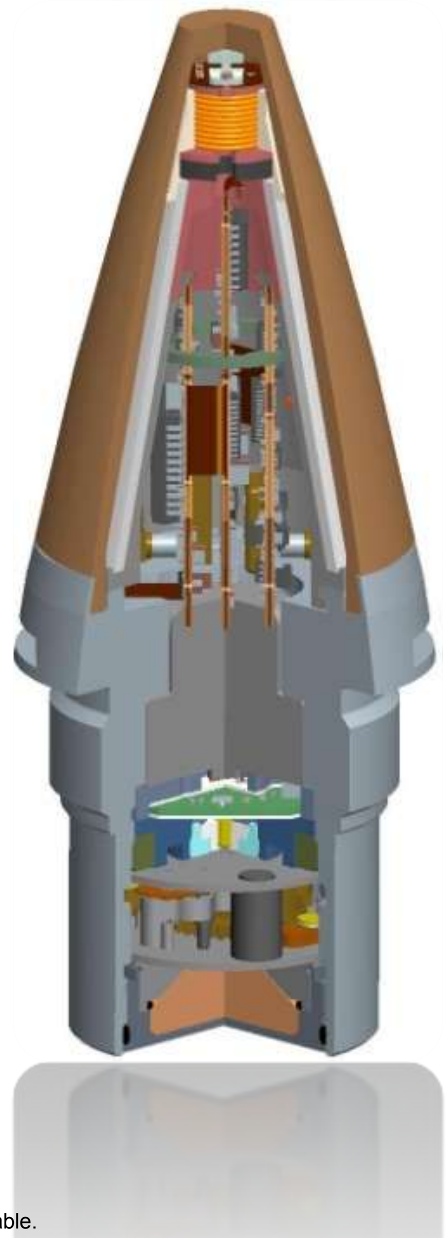
Multi-Function Fuze Capability Against High Speed Mobile Water Attack Craft



55th Annual NDIA Fuze Conference
Presenter: James Ring
ATK Propulsion & Controls

Presentation Agenda

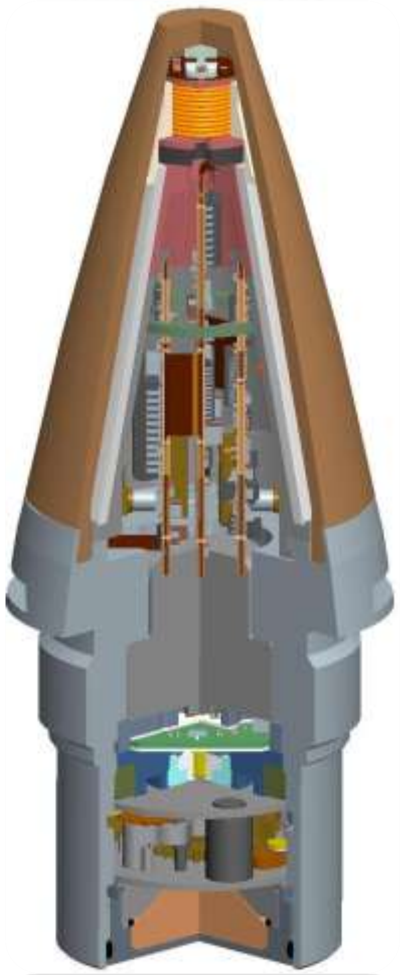
- **Functional Overview**
- **Design And Production Background**
- **Major Components & Subassemblies**
- **Fuzing Concept**
- **Benefits vs. Today's 5" Gun Solution**
- **Performance Results**
- **What's Next**
- **Summary**
- **Acknowledgements**



Functional Overview

ATK

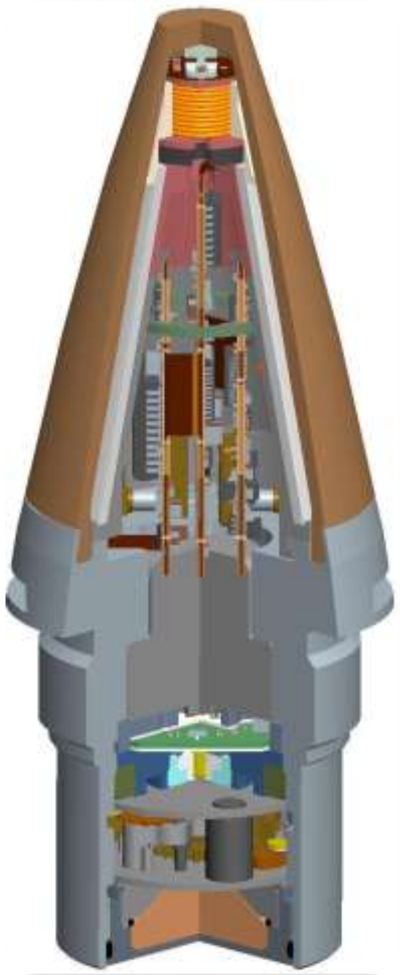
- MK419 is a Multi-Function Fuze (MFF) for the Navy 5” Gun
- Inductively Set by the Navy’s MK 34 electronic fuze setter
- Selectable Operational Modes
  - Air Proximity (AIR)
  - Height of Burst (HOB)
  - Autonomous (AUTO)
  - Electronic Time (ET)
  - Point Detonate (PD)
- Primary safety mechanism is the MK 60 Safe and Arm
- Flight power is provided by Lithium Reserve Battery
  - Activated by setback and spin
  - Provides electronics power for >105 seconds



MFF Is A Single Fuze Solution That Supports All Required Modes Of Operation

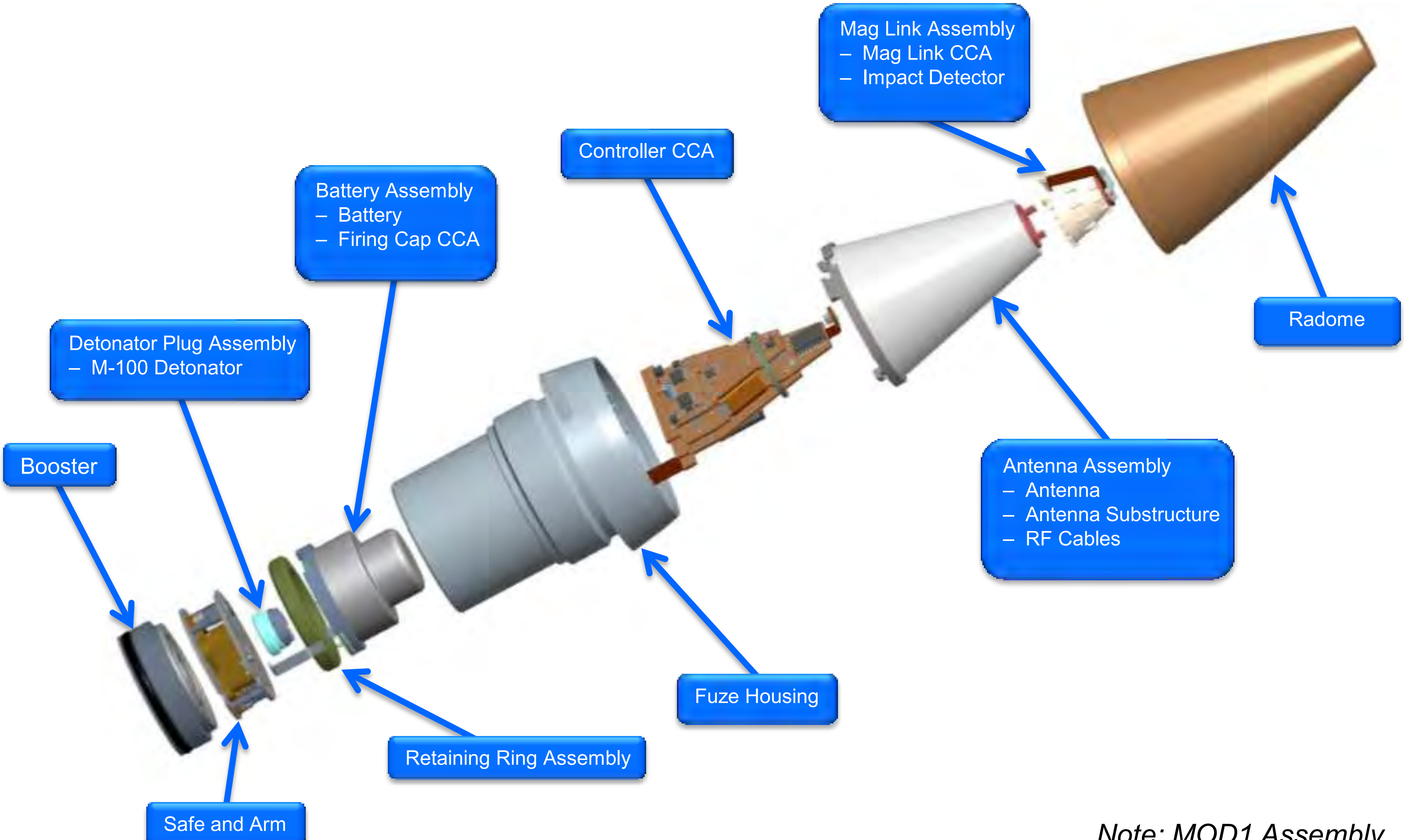
Design And Production Background

- MOD0 Design (~1980s to 2001)
  - Early design efforts began in the late 1980’s by Motorola
  - Transitioned to ATK in 1998
  - Qualification in 2000
- MOD0 FAAT And Production (2001 to 2004)
  - First Article Acceptance Testing (FAAT) in 2001
  - Produced at ATK production facility
- MOD1 Production Improvement Program (PIP) (2009 to 2011)
  - Reduced AUPC
  - Exceeded functional capability
- MOD1 Production Planned for 2011
  - Planned to be manufactured at ATK’s production facility



MOD1 Simplified Design and Assembly
Increases Reliability, Lowers Cost, and Improves Performance

Major Components & Subassemblies

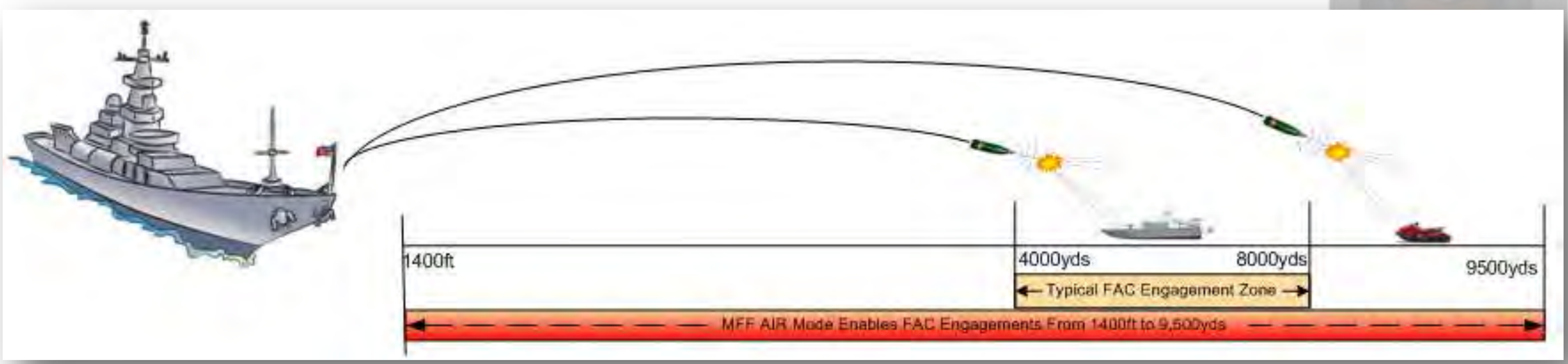


Note: MOD1 Assembly

MOD1 Updated Subassemblies Greatly Simplify Assembly Operations

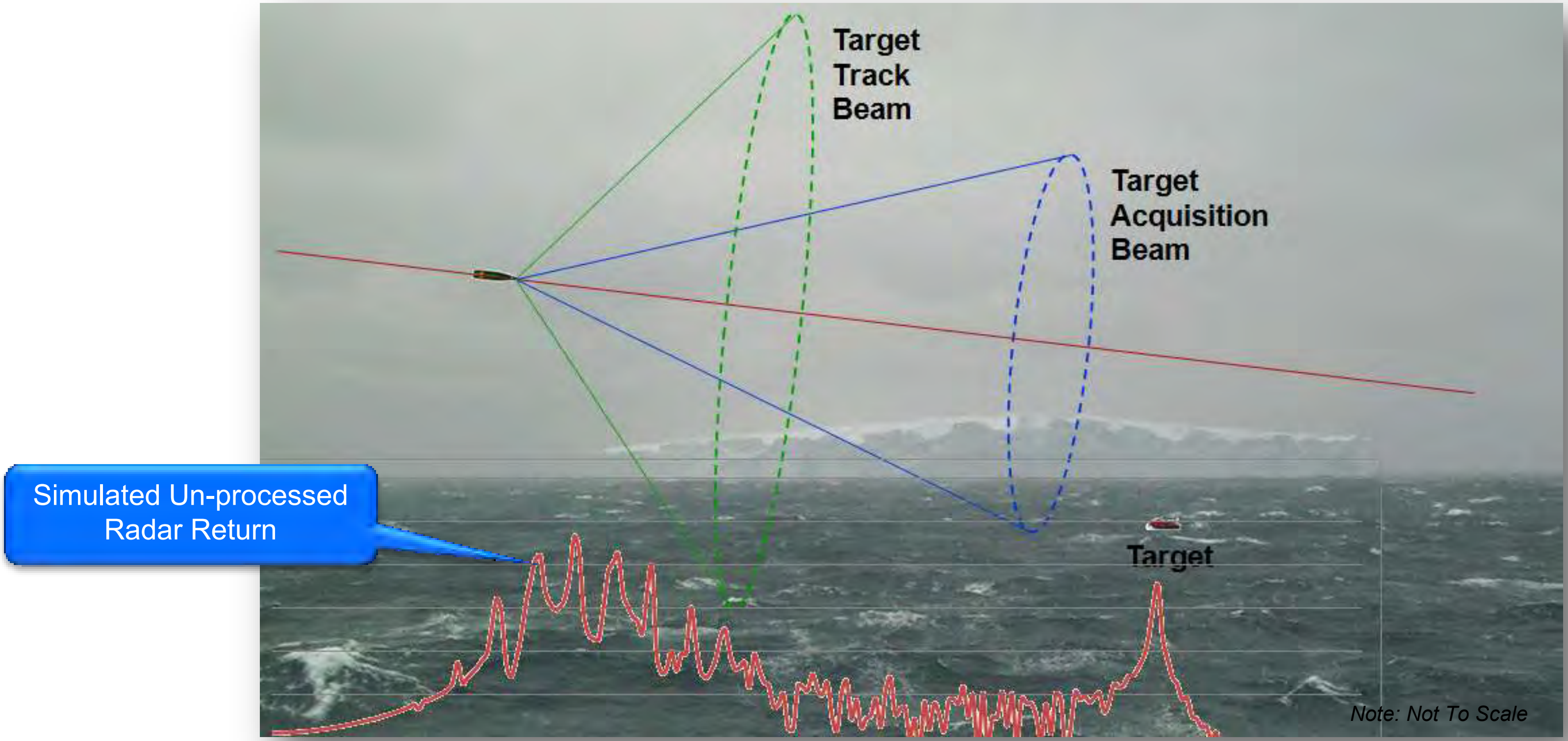
Fuzing Concept

- Fast Attack Craft (FAC) provide serious threats to Navy ships
- Navy 5” Gun with ***currently deployed*** MOD0 and new MOD1 MFF fuzes
- **“Use-As-Is”** existing MFF AIR Mode fuzing capabilities
- Engagement range from 1400ft to 9500 yards
- Engagement of very small Radar Cross Section (RCS) targets
- Ability to engage targets in various sea states



MFF Provides Navy With Immediate Solution To FAC Threats

Fuzing Concept

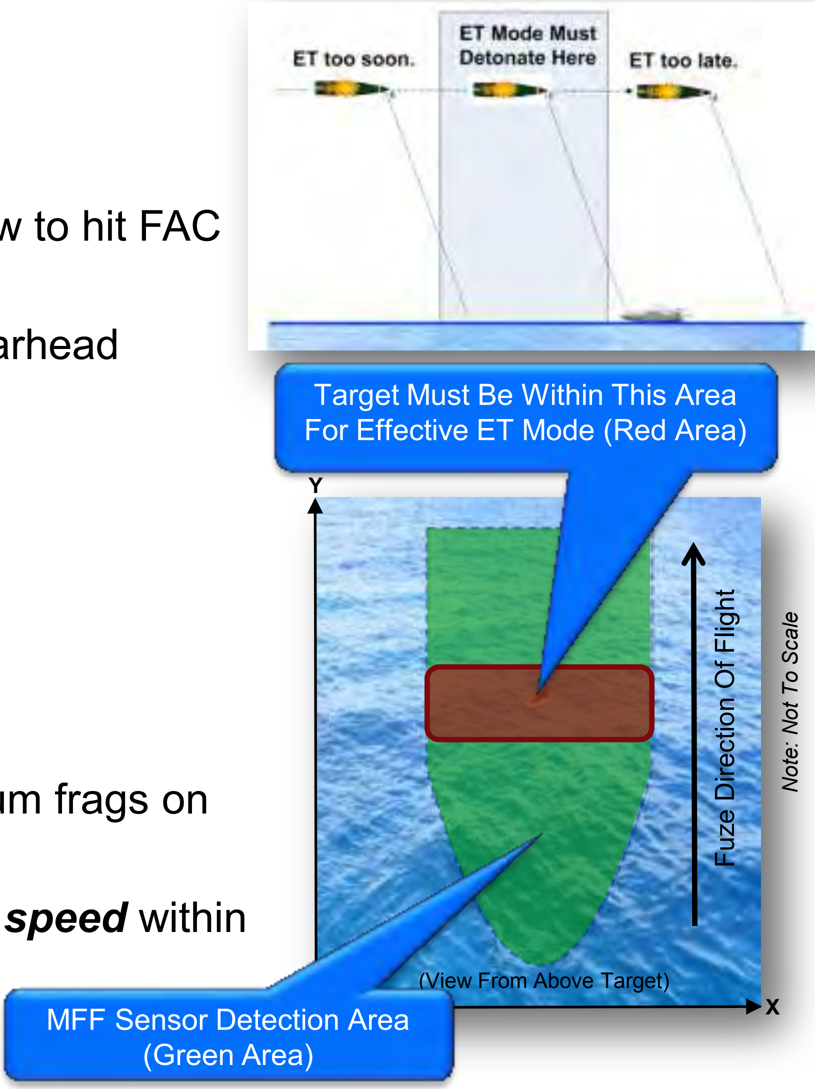


- MFF scans water for targets without detonating on sea clutter in various sea states
- Target Acquisition Beam (search mode)
  - Signal processing dynamically focuses radar toward expected target area
  - Filters out sea clutter to enable fuze to operate very close to water
- Target Track Beam (locked and tracking mode) tracks target to optimum burst angle

MFF Dynamic Signal Processing Filters Sea Clutter And Detects Valid FAC Target

Benefits vs. Today's 5" Gun Solution

- Electronic Time (ET) Mode Against FAC Targets
  - High Explosive with high velocity fragments
  - Current 5" artillery FAC counter measure
  - Fuze must detonate within a small time window to hit FAC target.
  - Small errors will result in a miss or reduced warhead fragments on target:
    - Electronics timing error
    - Gun Weapon System error
    - Change in target direction or speed
- MFF AIR Mode Against FAC Targets
  - High Explosive with high velocity fragments
  - Detonates at ***optimal fuzing angle*** to maximum frags on target
  - Adapts when FAC ***changes direction and/or speed*** within sensor detection area



MFF Detonates At Optimal Fuzing Angle To Maximize Warhead Effectiveness

Performance Results

- Dahlgren, Potomac River, in November 2004 (MOD0)
  - Objective: Detect and fuze on small boat targets
  - Functioned and localized fragment pattern on target
  - Initial assessment of sensor detection distance threshold
- Dahlgren, Potomac River, in June 2007 (MOD0)
  - Objective: Further evaluation of MFF against boat targets
  - Functioned and localized fragment pattern on target
  - Boat targets were destroyed on first shot
- Dahlgren, Potomac River, in Dec 2010 (MOD1)
  - Objective: Verify MOD1 Sea Clutter Rejection feature
  - Sea Clutter Rejection performance exceeded expectations

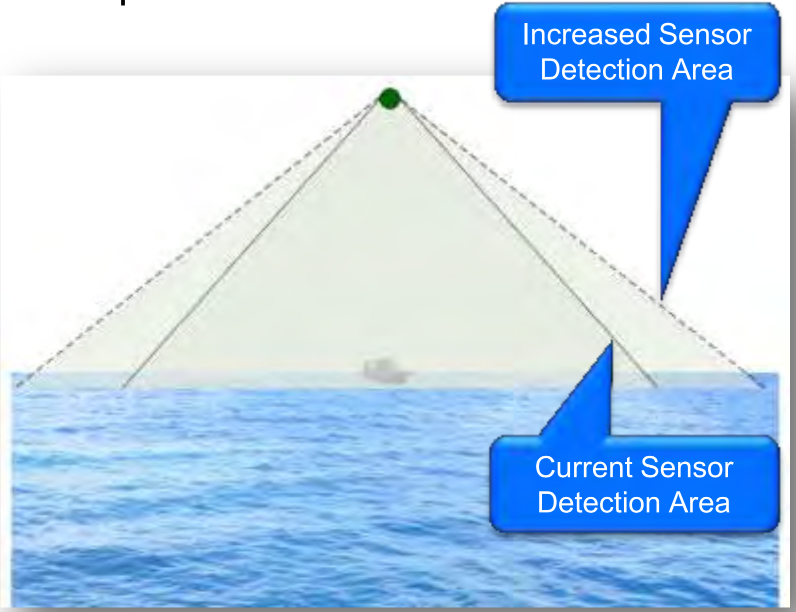
MOD0 Fuzing on RCS of $1.3m^2$

MOD0 Fuzing on RCS of $0.37m^2$

MFF Successfully Detected And Fuzed On Small Boat Targets

What's Next

- Further characterization in various RCS targets in various sea states
- Navy system operational analysis of 5" gun using MFF AIR mode
- Define requirements (ie: RCS, sea states, ect..)
- Qualification testing
- Develop enhancements to optimize and enhance current capabilities
  - Increase maximum sensor detection area
  - Optimize target validation algorithm
  - Optimize performance in various sea states
  - Optimize for maximum range of 5" gun
  - Implement ET Mode as the backup mode

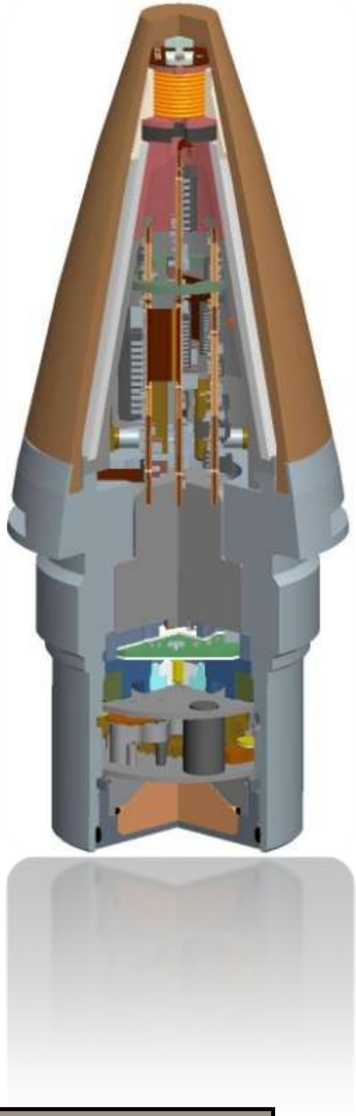


Note: View From Aft

Future Enhancements Will Optimize Effectiveness For Tomorrow's FAC Threat

Summary

- MFF has ***immediate*** defeat capability against FAC targets
- Ballistic testing has ***verified performance***
- MOD1 has ***improved*** performance and capability
- Need to qualify and characterize MOD1 against FAC targets
- Quick-turn enhancements can ***optimize*** current capability
- MOD1 production line is ready ***today*** to build additional fuzes for this effort



MFF Provides An ***Immediate And Effective*** Solution To FAC Threats

Acknowledgements

Thanks to:

Mr. Richard Chapman – NSWC-DD Project Manager

Mr. Marty Davis – ATK Program Manager

Fuze Power Quo Vadis?

55th Fuze Conference
May 26th, 2011, Salt Lake City, UT

Harald Wich

DIEHL & EAGLE PICHER
Batterie-Systeme

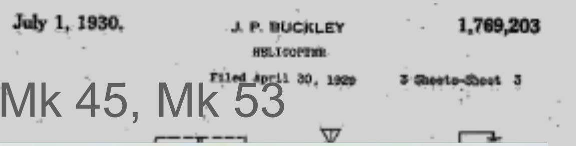
Outline

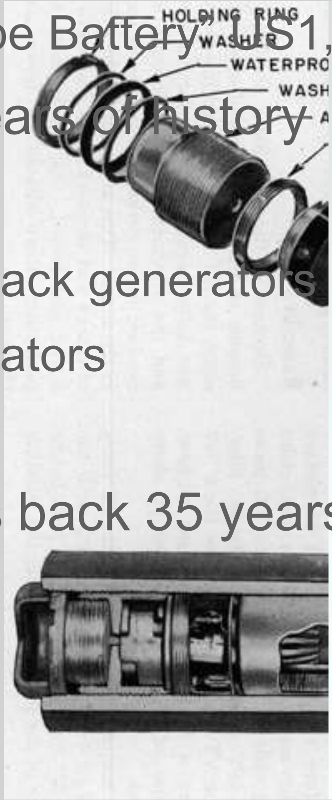
DIEHL & EAGLE PICHER
Batterie-Systeme

- History
- Requirements
- Alternative Power Sources
- Liquid Reserve Batteries
- Quo Vadis – Fuze Power ?

Some History

- First time Electric Power required for Proximity Fuzing in the early 1940´s
  - some earlier Patents e.g. US1,769,203 in the 30´s
  - Pye Ltd in GB and USNAVY in US – Mk 32 later on Mk 45, Mk 53
  - first “Reserve Type Battery” US1,658,142
    - ⇨ 70 years of history
- My own experience
  - piezoelectric setback generators
  - air – driven alternators
  - thermal battery
    - ⇨ dates back 35 years





Requirements general

DIEHL & EAGLE PICHER
Batterie-Systeme

- Volume (size) and Weight
- Power = Voltage x Current
  - ⇩ ⇩ ⇘ µA to 100´s of mA
  - ⇩ ⇘ a mere 2 V up to 10´s of V
  - ⇘ µW to W
- Lifetime < 10 s to > 600 s
- Energy = $\int_{t=0}^{t_{lt}} V(t) * I(t)\, dt$ µJ up to J
- Rise time ms up to 100´s of ms
- Reliability 99.xxxx%
- Storage Life 10 years +
- Cost nil

Requirements

DIEHL & EAGLE PICHER Batterie-Systeme

- Fuze Categories PD Detonator
  classical artillery
  - 100 µJ M100
  - 5 mJ Silicon Bridge Initiator
  - 50 mJ 1 W/1A
  - 100 mJ LEEFI

⇨ usually a Factor of 3 – 5 (10) in the firing circuit !

Requirements

DIEHL & EAGLE PICHER
Batterie-Systeme

- Fuze Categories
  classical artillery

PD	Det	
SD	Det + Timer	
		↳ 2 µW e.g. digital watch

Requirements

DIEHL & EAGLE PICHER
Batterie-Systeme

◆ Fuze Categories classical artillery	PD	Det
	SD	Det + Timer
	ET	Det + programmable Timer
		↳ 600 µW e.g. RFID-Circuit

Requirements

DIEHL & EAGLE PICHER
Batterie-Systeme

- Fuze Categories
  classical artillery

PD	Det
SD	Det + Timer
ET	Det + programmable Timer
PX	Det + prog. Timer + TX/RX

↳ some 100 mW´s

Requirements

DIEHL & EAGLE PICHER
Batterie-Systeme

- Fuze Categories
  classical artillery

PD	Det
SD	Det + Timer
ET	Det + programmable Timer
PX	Det + prog. Timer + TX/RX
CCF	Det + prog. Timer + TX/RX + Control Power

↳ some W´s

Requirements

DIEHL & EAGLE PICHER
Batterie-Systeme

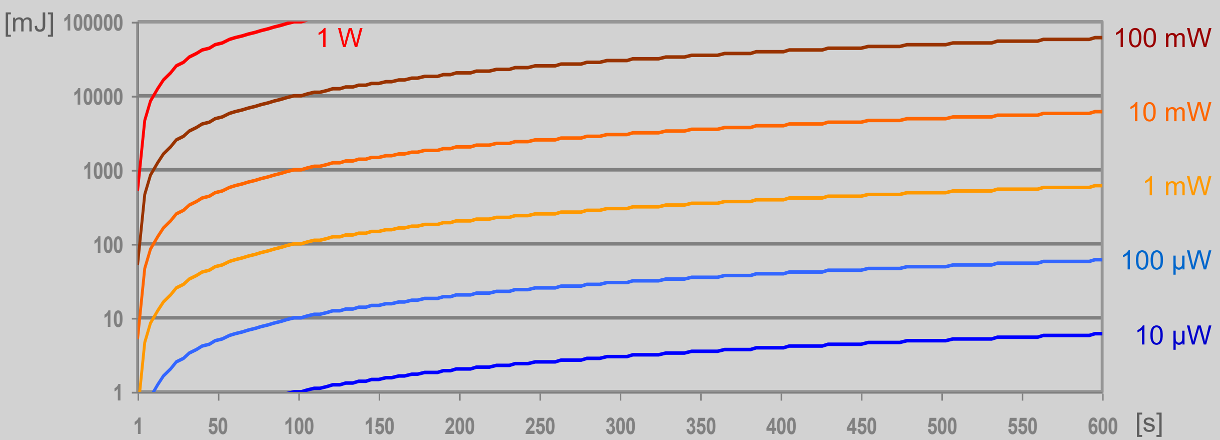
- Fuze Categories
  classical artillery

PD	Det
SD	Det + Timer
ET	Det + programmable Timer
PX	Det + prog. Timer + TX/RX
CCF	Det + prog. Timer + TX/RX + Control Power

- Operating Times

short	≤ 10 – 20 s	direct fire
medium	< 100 s	indirect fire Mortars
long	< 200 s	indirect fire Arty 105/155 mm
x-long	up to 600 s	gliding and/or powered

- Energy



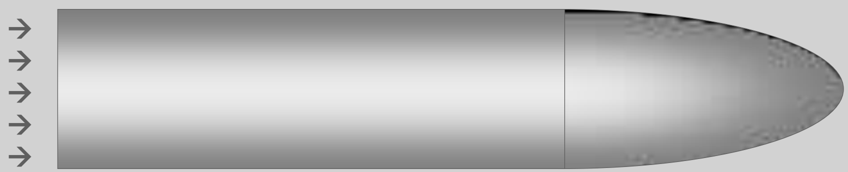
Alternative Energy Sources

DIEHL & EAGLE PICHER
Batterie-Systeme

- Where could the energy come from

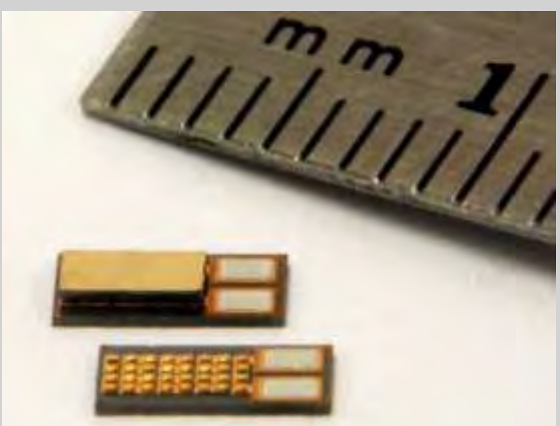
source requires storage device

pressure
temperature



thermoelectric

- access



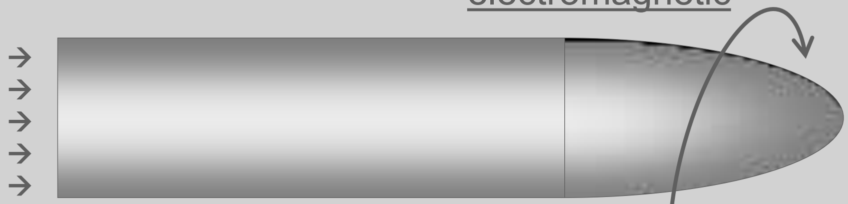
Alternative Energy Sources

DIEHL & EAGLE PICHER
Batterie-Systeme

- Where could the energy come from

setback force ← — — — source requires storage device

↳ piezoelectric
electromagnetic



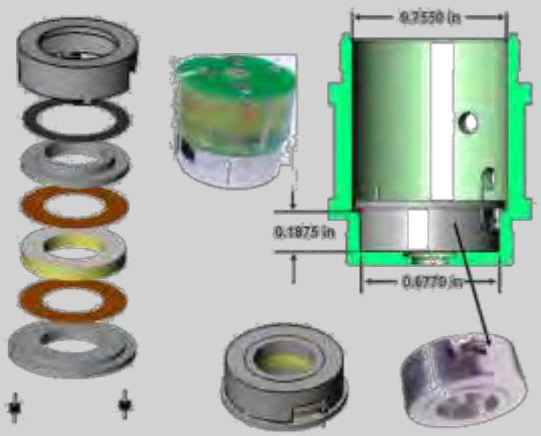
pressure
temperature

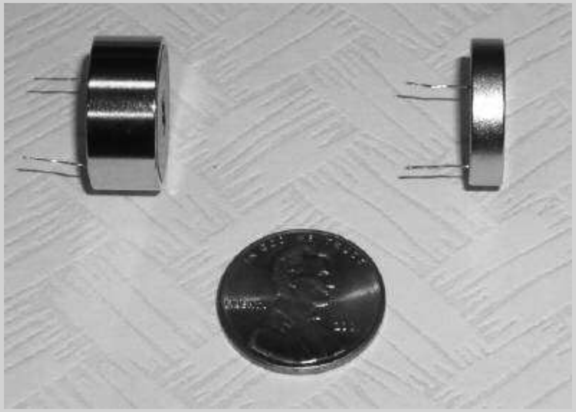
↳ thermoelectric

- access

angular acceleration

↳ electromagnetic





Alternative Energy Sources

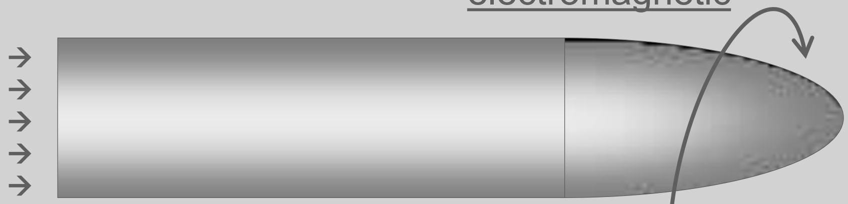
DIEHL & EAGLE PICHER
Batterie-Systeme

- Where could the energy come from

— — — source requires storage device

setback force

↳ piezoelectric
electromagnetic



pressure
temperature

↳ thermoelectric

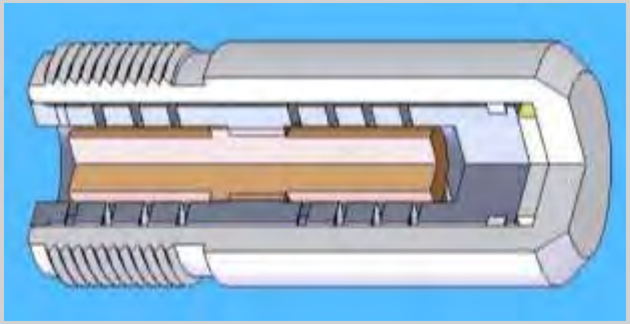
- access

in-flight vibration

↳ piezoelectric
electromagnetic

angular acceleration

↳ electromagnetic



Alternative Energy Sources

DIEHL & EAGLE PICHER
Batterie-Systeme

- Where could the energy come from

setback force

piezoelectric
electromagnetic

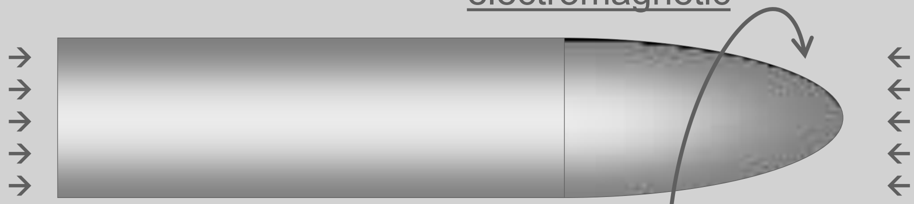
source requires storage device

- range of velocity
- air intake

EM air turbine

airstream

aerodynamic heat



pressure
temperature

thermoelectric

- access

in-flight vibration

piezoelectric
electromagnetic

angular acceleration

electromagnetic

thermoelectric
thermo photovoltaic

- rise time
- high speed only

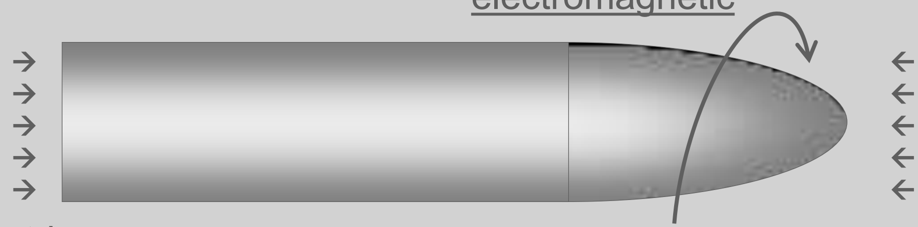
Alternative Energy Sources

DIEHL & EAGLE PICHER
Batterie-Systeme

- Where could the energy come from

source requires storage device

setback force
piezoelectric
electromagnetic



pressure
temperature
thermoelectric
- access

in-flight vibration
piezoelectric
electromagnetic

angular acceleration
electromagnetic

- range of velocity
- air intake

EM air turbine
air stream
aerodynamic heat
thermoelectric
thermo photovoltaic
- rise time
- high speed only

- Capacitive energy storage

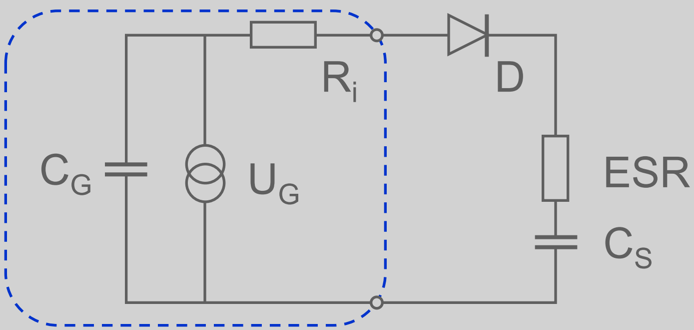
storage of	1 mJ	@ 10 V	⇨	20 µF	$0.22\ mm^3$	
		@ 30 V	⇨	2.2 µF		
	100 mJ	@ 10 V	⇨	2000 µF	$22\ mm^3$ ⇨	2.8 mm
		@ 30 V	⇨	220 µF		
	10,000 mJ	@ 10 V	⇨	0.2 F	$2,222\ mm^3$ ⇨	13 mm
		@ 30 V	⇨	0.022 F		

Alternative Energy Sources

DIEHL & EAGLE PICHER
Batterie-Systeme

- Charging and discharging the capacitor

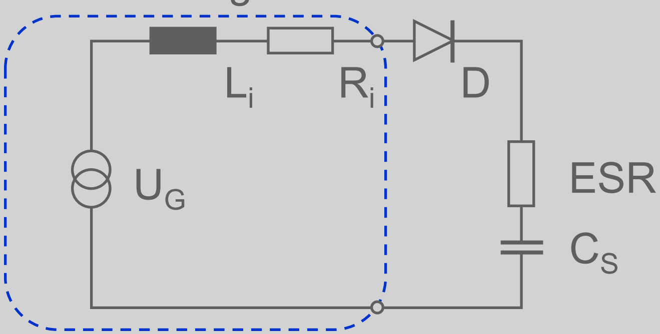
Piezo **G**enerator



PG-Voltage proportional to pressure (= acceleration)
↳ peak voltage @ peak pressure
ms only ⇨ high currents, matching losses

e.g. storage of 10 mJ	@ 10 V ⇨	200 µF	⇨	1.1 A (2 ms)
	@ 30 V ⇨	22 µF	⇨	0.33 A (2 ms)

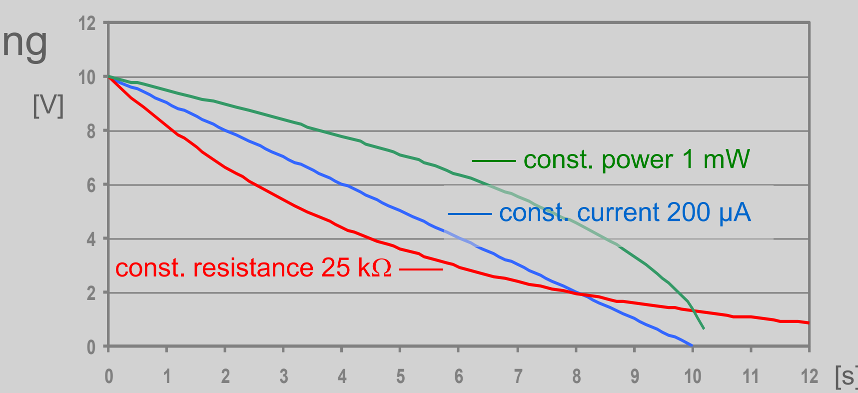
Electro**M**agnetic **G**enerator



EMG-Voltage proportional to # of turns/inductance
↳ natural frequency $f_r = (2 * \pi * \sqrt{L_i} * C_s)^{-1}$

e.g. storage of 10 mJ	@ 10 V ⇨	200 µF	⇨	112 Hz (10 mH)
	@ 30 V ⇨	22 µF	⇨	339 Hz (10 mH)

Discharging

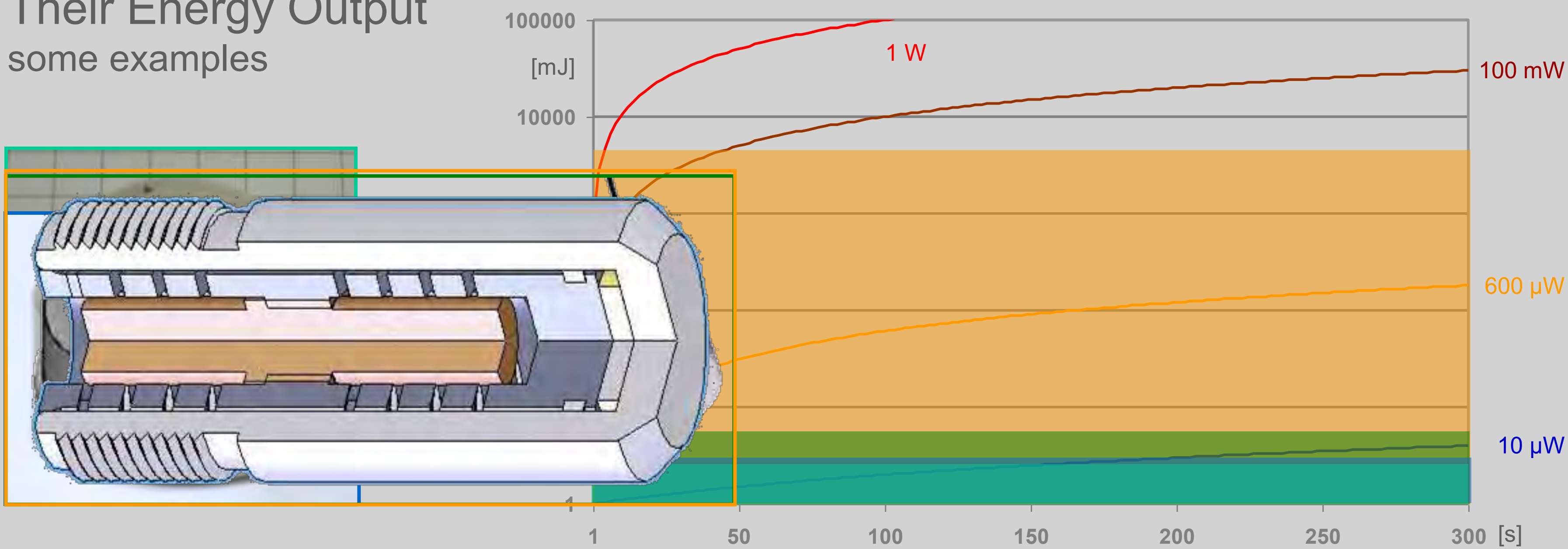


No constant Voltage during discharge!

Alternative Energy Sources

DIEHL & EAGLE PICHER
Batterie-Systeme

- Their Energy Output
  some examples



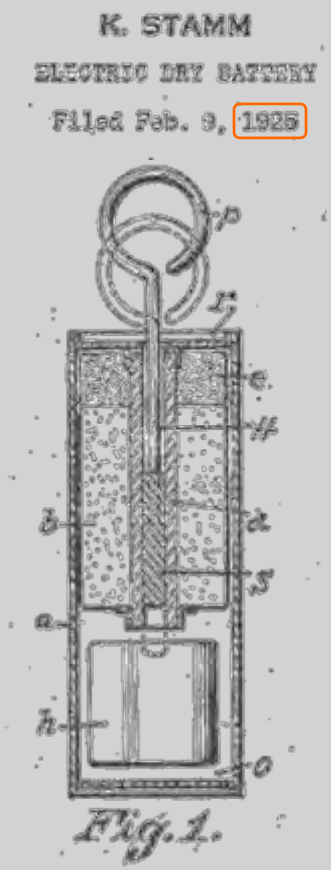
- My Conclusion
  - no significant improvement of energy generated since 35 years

  limited to
  - low energy pyrotechnics
  - short time of flight
  - simple functions

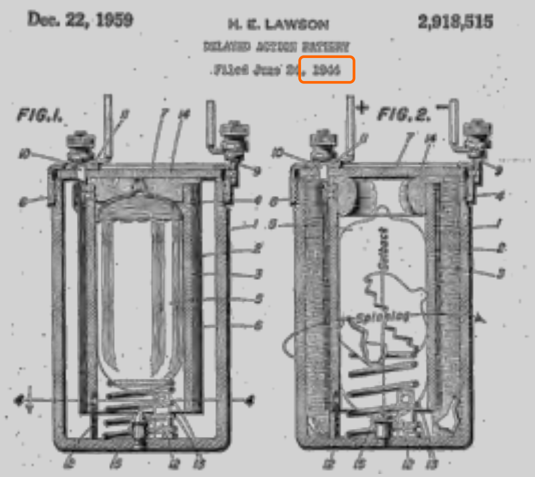
Liquid Reserve Batteries

DIEHL & EAGLE PICHER
Batterie-Systeme

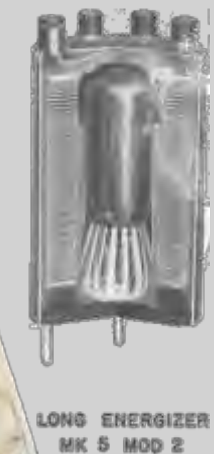
- Legacy

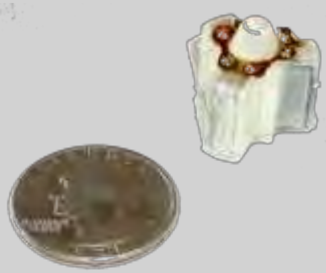


First Reserve Battery



Fuze Battery





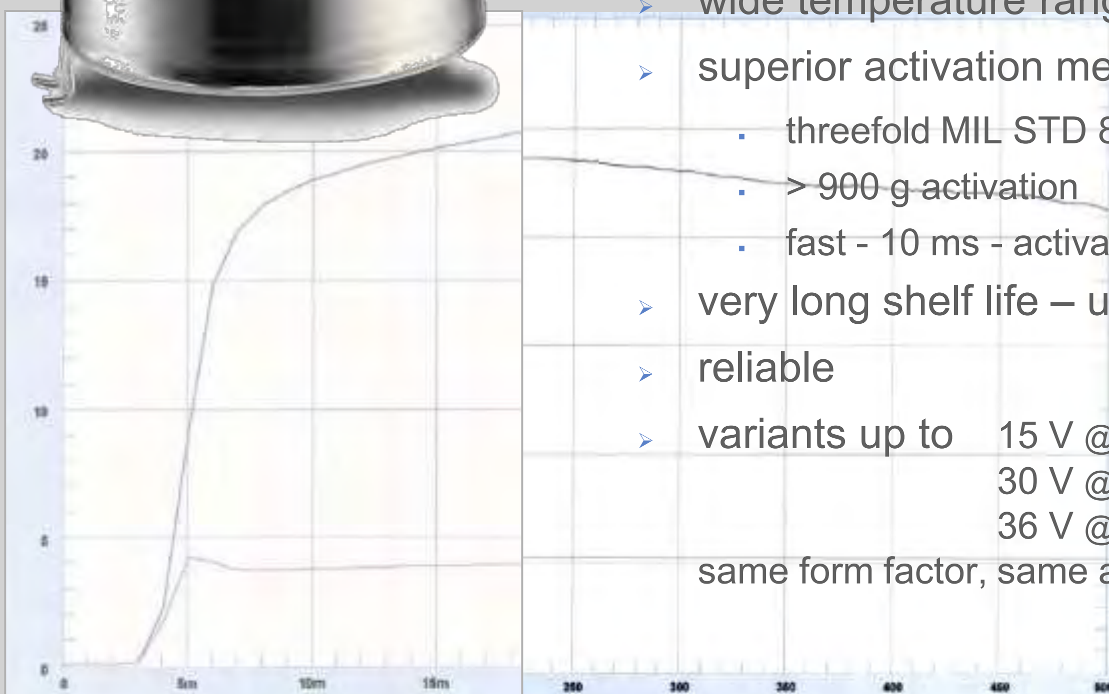
Fuze Battery

MOFA Fuze Battery

Mk53 Fuze

Liquid Reserve Battery current

DIEHL & EAGLE PICHER
Batterie-Systeme



The workhorse (type 597) Lithium Thionyl Chloride

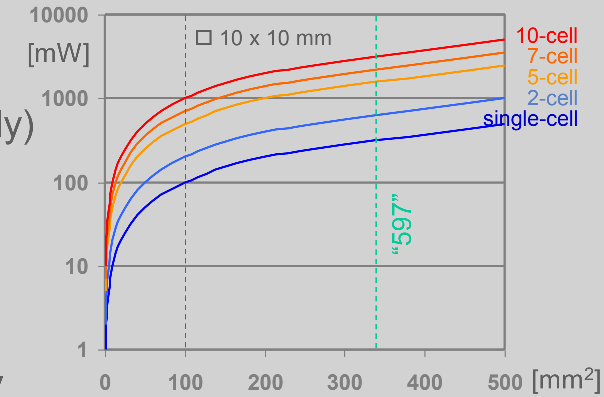
- most common fuze battery in Europe
  (European complement to MOFA-Battery)
- produced in 100 thousand´s
- powerful (0.25 W/cm^2 active cell area)
- wide temperature range -46°C to +63°C
- superior activation mechanism
  - threefold MIL STD 883 1.5 m drop safety
  - > 900 g activation
  - fast - 10 ms - activation under spin environment
- very long shelf life – up to 20 years
- reliable
- variants up to 15 V @ 600 mA
  30 V @ 300 mA
  36 V @ < 100 mA

same form factor, same activation

Liquid Reserve Battery future

- How big is their Energy-/Power-Density

this volume equals **3,000** mJ (Electrochemistry only)



  - what's needed for a complete LRB
    - Electrochemistry
    - Electrolyte separated from Cell Stack

“597”

“762”

    - Activation System

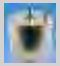
“AM”

“AH/AD”

For low and medium Power a single Cell will be the preferred Solution

Small Liquid Reserve Batteries

DIEHL & EAGLE PICHER
Batterie-Systeme

- Can be very small whilst maintaining their excellent properties
  - superior Power-/Energy-Density
  - long shelf life
  - wide temperature range
  - excellent reliability
  - low cost
- Some recent examples
  - M235 
  - M80 
  - MRB 
  - 40 mm AB 

single cell Lithium

multi cell Pb PbO2

Yet a new small Liquid Reserve Battery

DIEHL & EAGLE PICHER
Batterie-Systeme

- For small and medium calibre applications

- 12 mm diameter
- 12 mm high
- single cell Lithium Battery
- 3.0 ÷ 3.6 V closed circuit voltage
- up to 50 mA load current
- setback/spin activation mechanism
  - > 7000 g activation
  - fast - < 5 ms - activation under spin environment
- lifetime > 50 s
- wide temperature range -46°C to +63°C
- very long shelf life – up to 20 years
- reliable
- low cost

Lithium Liquid Reserve Batteries provide superior Energy Density

Thank you for your Attention!

Any Questions, Comments, Objections, …

Diehl & Eagle Picher in a Nutshell

DIEHL & EAGLE PICHER
Batterie-Systeme

- About the company
  - US/German Joint Venture;
    Shareholders are Eagle Picher Technology, Joplin MO and Diehl BGT Defence, Ueberlingen GE
  - Located in Roethenbach Germany
  - Thermal- and Fuze-Batteries and Battery Packs
  - R&D and Production of the above Batteries
  - Annual Turn Over > 10 mEur

Diehl & Eagle Picher Contact

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