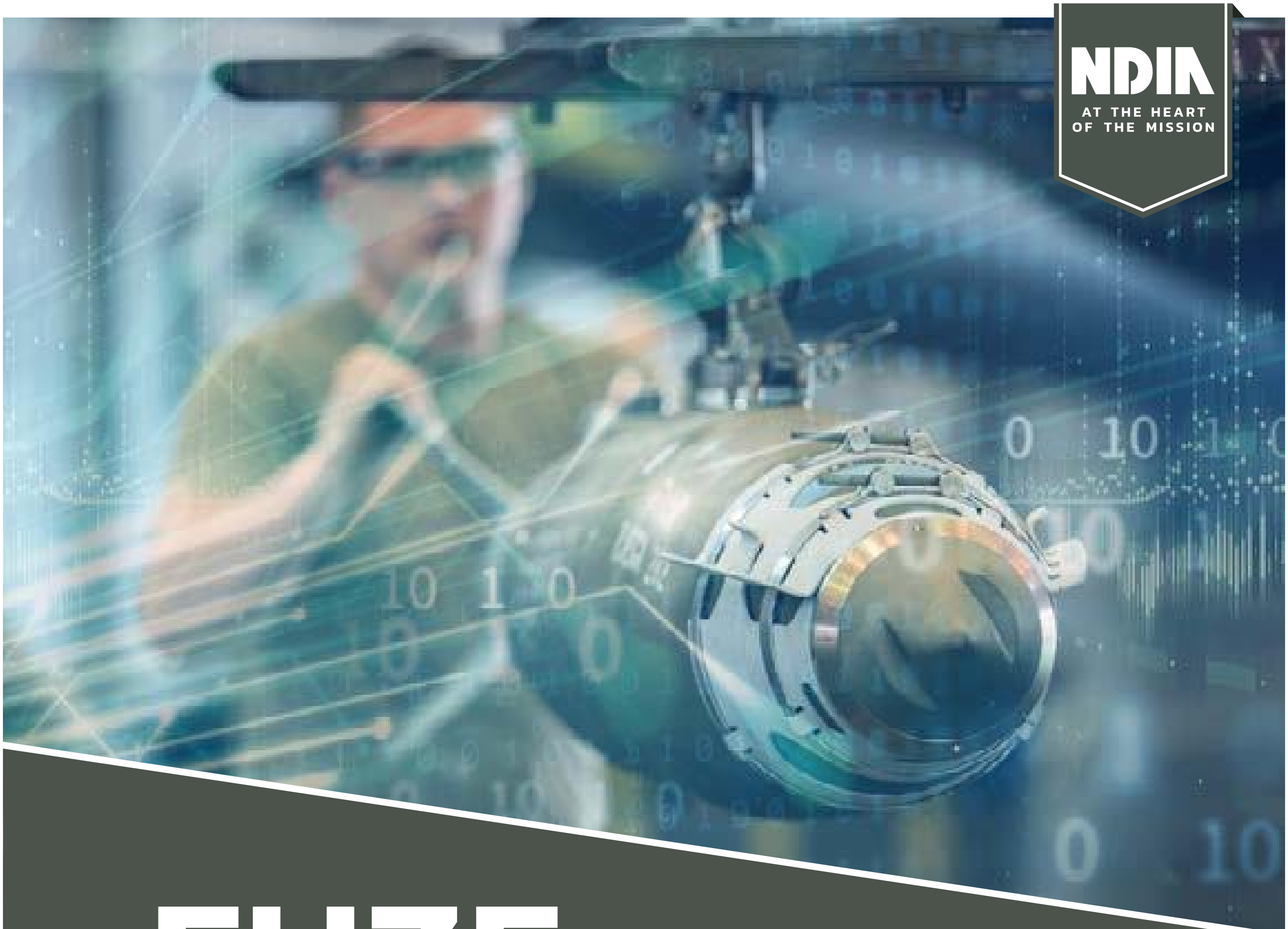


# vFUZE

## Next-Generation Fuzing for Next-Generation Weapons Systems

August 4 – 5, 2020 | NDIA.org/vFuze

NDIA

## WHO WE ARE

The National Defense Industrial Association is the trusted leader in defense and national security associations. As a 501(c)(3) corporate and individual membership association, NDIA engages thoughtful and innovative leaders to exchange ideas, information, and capabilities that lead to the development of the best policies, practices, products, and technologies to ensure the safety and security of our nation. NDIA's membership embodies the full spectrum of corporate, government, academic, and individual stakeholders who form a vigorous, responsive, and collaborative community in support of defense and national security. For more than 100 years, NDIA and its predecessor organizations have been at the heart of the mission by dedicating their time, expertise, and energy to ensuring our warfighters have the best training, equipment, and support. For more information, visit **NDIA.org**

# SCHEDULE AT A GLANCE

### TUESDAY, AUGUST 4

**General Session**
10:00 – 11:55 am

**Networking Chat Lobby**
11:55 am – 12:10 pm

**General Session**
12:10 – 2:15 pm

**Networking Chat Lobby**
2:15 – 2:45 pm

### WEDNESDAY, AUGUST 5

**General Session**
10:00 am – 12:15 pm

**Networking Chat Lobby**
12:15 – 12:30 pm

**General Session**
12:30 – 2:00 pm

**Networking Chat Lobby**
2:00 – 2:30 pm

# WELCOME TO vFUZE

On behalf of NDIA and the Fuze Conference Steering Committee, I would like to welcome you to NDIA's first-ever virtual fuze conference, called vFuze.

This international conference not only convenes the top fuzing professionals from government, industry, and academia but also enables the exchange of the latest fuzing research and development—all with the common goal of improving safety, capability, and reliability for our warfighters.

We have a thrilling keynote scheduled in addition to the conference's signature science and technology sessions. There will also be an opportunity to virtually network with your peers.

Through the ongoing passionate work of the presenters, sponsors, and attendees at this conference and across our worldwide defense industry, new challenges will be overcome, resulting in safer and more reliable fuzes being fielded to our warfighters.

**Thomas Harward**
Chair, Fuze Section, Munitions Technology Division, NDIA
Lead Technologist, Fuzing & Safety Devices, Advanced Systems, Raytheon Missiles & Defense


### LEADERSHIP

**Thomas Harward**
Committee Chair

**Nassir Alaboud**
Committee Vice Chair

**Perry Slayers**
Committee Secretary

# MUNITIONS TECHNOLOGY
## FUZE SECTION

### WHO WE ARE

The Munitions Technology Division works to maintain the open exchange of technical information among government and industry programs and technical managers. In addition, the Division identifies changes and trends in policy, guidance, and organizational functions that affect the development, production, maintenance, and demilitarization of munitions.

The Fuze Section aims to promote an open exchange of technical information among government and industry personnel, and to identify and address changes in standards, guidance, policy, and organizational functions that impact the development, production, and performance of fuzes.

# AGENDA

## TUESDAY, AUGUST 4

10:00 – 10:05 am

### INTRODUCTION & ADMIN REMARKS
**Thomas Harward**
Lead Technologist, Fuzing & Safety Devices, Advanced Systems, Raytheon Missiles & Defense
Chair, Fuze Section, Munitions Technology Division, National Defense Industrial Association (NDIA)

10:05 – 10:15 am

### NDIA OPENING REMARKS
**MG James Boozer, USA (Ret)**
Executive Vice President, NDIA

10:15 – 10:45 am

### KEYNOTE SPEAKER
**Lt Col Brian A. "Hanzo" Stiles, USAF**
Commander, 72d Test and Evaluation Squadron, Whiteman Air Force Base, U.S. Air Force

11:00 – 11:20 am

### ARMY S&T STRATEGY
**Mike Connolly**
Electronics Engineer, U.S. Army Combat Capabilities Development Command (CCDC), Aviation and Missile Center

11:35 – 11:55 am

## NAVY S&T STRATEGY

**Kevin Cochran**
Technical Project Manager, Indian Head Explosive Ordnance Disposal Technology Division, Naval Surface Warfare Center

11:55 am – 12:10 pm

## NETWORKING CHAT LOBBY BREAK

12:10 – 12:30 pm

## AIR FORCE S&T STRATEGY

**George Jolly**
Technical Advisor, Air Force Research Laboratory

12:45 – 1:05 pm

## MEMS SHOCK ACCELEROMETER CHARACTERIZATION FOR HIGH G APPLICATIONS

**Dr. Adriane Moura, PhD**
Staff Mechanical Engineer 2, Applied Research Associates, Inc.

1:20 – 1:40 pm

## MODULAR APPROACH TO THE MUNITION FUZE DEVELOPMENT FOR CASE TELESCOPED WEAPON SYSTEMS

**Dr. Isabelle Delagrange, PhD**
Lead Engineer, Ammunition, CTA International

1:55 – 2:15 pm

## DEVELOPMENT IN METAL MEMS LATCHING SETBACK SENSING MECHANISM

**Kevin O'Connor, Jr.**
Mechanical Engineer, Fuze Division, Armaments Center, U.S. Army CCDC

2:15 – 2:45 pm

## NETWORKING CHAT LOBBY

## WEDNESDAY, AUGUST 5

10:00 – 10:05 am

### INTRODUCTION & ADMIN REMARKS

**Thomas Harward**
Lead Technologist, Fuzing & Safety Devices, Advanced Systems, Raytheon Missiles & Defense
Chair, Fuze Section, Munitions Technology Division, NDIA

10:05 – 10:25 am

### FUZE INCIDENT, SHOALWATER BAY, AUSTRALIA, 2014

**Bernard Smith-Roberts**
Manager, Engineering Systems, Explosive Materiel Branch, Joint Systems Division,
Capacity Acquisition and Sustainment Group, Australian Department of Defence

10:45 – 11:05 am

### ARMY S&T STRATEGY

**Nick Malinoski**
Supervisory Engineer, Fuze Division, Armaments Center, U.S. Army CCDC

11:20 – 11:40 am

### SANDIA NATIONAL LABORATORIES CAPABILITIES AND MISSION

**Shane Curtis**
Senior Staff Member, Advanced Fuzing Technology, Sandia National Laboratories

11:55 am – 12:15 pm **DOD JOINT FUZE TECHNOLOGY PROGRAM (JFTP)**
Lawrence Fan
Program Manager, Fuzing Technology & Development, Energetic Technologies,
Indian Head Explosive Ordnance Disposal Technology Division, Naval Surface Warfare Center

12:15 – 12:30 pm **NETWORKING CHAT LOBBY**

12:30 – 12:50 pm **FUZE TECHNOLOGY REFRESH**
Vincent Matrisciano
Program Manager, Research & Development, Joint Program Executive Office Armaments & Ammunition

1:05 – 1:25 pm **FULLY RESETTABLE MEMS SAFE/ARM WITH LOCK AND SLIDER POSITION FEEDBACK**
Dr. Daniel Jean
Senior Microsystems Engineer, Army Research Laboratory, U.S. Army CCDC

1:40 – 2:00 pm **NEXT-GENERATION LARGE CALIBER SETTER**
Maxim Keyler
Electronic Engineer, Fuze Division, Armaments Center, U.S. Army CCDC

2:00 – 2:30 pm **NETWORKING CHAT LOBBY**

# BIOGRAPHIES

## MG JAMES BOOZER, USA (RET)

*Executive Vice President*
National Defense Industrial Association

Major General James “Jim” Boozer became executive vice president of the National Defense Industrial Association (NDIA) December 4, 2017.

Boozer came to NDIA after a 35-year career in the U.S. Army, from which he retired as a two-star general in October 2015. His last assignment was as Commander, U.S. Army Japan at Camp Zama in Japan.

Prior to serving in Japan, Boozer was the Deputy Commanding General of U.S. Army in Europe, the Army component for U.S. European Command in Weisbaden, Germany. Prior to that assignment, Boozer was the Operations Director for the Assistant Chief of Staff for Army Installations at the Pentagon in Washington, DC.

Boozer has served in various operational and staff assignments throughout the Army and commanded at the Brigade and 2 Star level. He served as chief of plans at U.S. Central Command Forward in Baghdad and Qatar.

Boozer has also participated in multiple deployments in support of Operation Iraqi Freedom and Operation Enduring Freedom.

Boozer was a field artilleryman and commanded a brigade in Operation Iraqi Freedom 1 as a part of the Task Force that secured Baghdad.

Boozer graduated from The Citadel in 1980 with a bachelor of arts degree in history. He received a master’s degree in strategic studies in 2001 from the U.S. Army War College.

## KEVIN COCHRAN

*Technical Project Manager*
Indian Head Explosive Ordnance Disposal Technology Division, Naval Surface Warfare Center

Kevin Cochran is a Technical Project Manager in the Fuze and Initiation Systems Branch at the Naval Surface Warfare Center, Indian Head Explosive Ordnance Disposal Technology Division. Since 1998, he has focused on developing miniaturized fuze/S&A systems and has worked on a variety of applications including underwater weapons, mine clearing systems, and guided mortars. He is currently the Project Manager for the High Reliability DPICM Replacement project that is tasked with developing a Cannon-Delivered Area Effect Munition that meets the requirements of the 2017 DoD Policy on Cluster Munitions. Mr. Cochran received a B.S. and M.S. in Mechanical Engineering from the University of Maryland, College Park, in 1998 and 2003, respectively.

## MIKE CONNOLLY

*Electronics Engineer*
U.S. Army Combat Capabilities Development Command, Aviation and Missile Center

Michael Connolly is an electronics engineer at the U.S. Army Combat Capabilities Development Command, Aviation and Missile Center (CCDC AvMC) at Redstone Arsenal, Alabama. He earned a B.S. in Electrical Engineering with honors from the University of Tennessee, Knoxville, in 1995. Since then, he has worked for the Army in various duties as an engineer specializing in radar systems, missile test sets, air and missile defense systems, and—since 2001—conventional missile fuzing and rocket motor ignition safety systems. Mr. Connolly is a member of the Technical Steering Committee for the DoD/DOE Joint Munitions Program, the Institute of Electrical and Electronics Engineers (IEEE), the International Council on Systems Engineering (INCOSE), the Tau Beta Pi National Engineering Honor Society, and the Eta Kappa Nu Electrical Engineering Honor Society.

## SHANE CURTIS

*Senior Staff Member, Advanced Fuzing Technology*

Sandia National Laboratories

Shane Curtis is a senior staff member of the Advanced Fuzing Technology (AFT) department at Sandia National Laboratories, which specializes in the research and development of advanced concepts for the DoD and DOE fuzing communities. Shane has a B.S. and M.S. in Mechanical Engineering, and has spent eight years in the department as the primary mechanical designer and researcher for hard target fuzing and data recorder applications.

## DR. ISABELLE DELAGRANGE, PHD

*Lead Engineer, Ammunition*

CTA International

Dr. Isabelle Delagrange, PhD, is a research and development engineer with over 20 years experience in the armament industry.

After graduating in engineering in 1995, Isabelle joined Giat Industries as a PhD student in gun barrels dynamics. This work was the subject of several publications and a presentation on the 10th U.S. Army gun dynamics in 2001.

After being awarded her PhD in 1998, Isabelle continued working in R&D at Nexter as Lead Engineer on several cannons and turrets in medium and large caliber followed by Head of Engineering for weapon systems at Nexter Systems.

Isabelle joined CTAI in 2009 as CT-Cannon Lead Engineer for the end of development and as 40CTA Qualification Technical Lead in charge of the specification, witnessing, analyzing, and reporting of qualification trials for both cannon and ammunition. Since 2014, she worked as Lead Engineer for ammunition development and has been Head of Ammunition Engineering since 2017.

## LAWRENCE FAN

*Program Manager, Fuzing Technology & Development*

Energetic Technologies Department, Indian Head Explosive Ordnance Disposal Technology Division, Naval Surface Warfare Center

Lawrence Fan is a project manager for fuzing technology and development programs in the Energetics Technology Department at the Naval Surface Warfare Center's Indian Head Explosive Ordnance Technology Division. Since entering government service in 1990, he has supported fuzing development for Navy gun projectile, mine clearance and torpedo applications. He has headed several fuze R&D projects, including the development of the S&A Device for the Navy's Countermeasure Anti-Torpedo Torpedo. Since 2010, Mr. Fan has served as the program manager for the OSD Joint Fuze Technology Program (JFTP). The JFTP selects, coordinates, and funds the execution of 6.2 and 6.3 fuzing technology projects with a portfolio of $13M annually. Mr. Fan is also the Navy lead in the DoD Fuze IPT.

## THOMAS HARWARD

*Lead Technologist, Fuzing & Safety Devices, Advanced Systems*

Raytheon Missiles & Defense

Thomas Harward, an Engineering Fellow with 23 years of experience at Raytheon Missiles & Defense, is the Lead Technologist for Fuzing and Safety Devices. As Lead Technologist, Mr. Harward is the top reviewer for fuze designs, central point of contact for the fuze safety boards, and approver of estimates and solutions. He guides sourcing selection. Mr. Harward is also very active in the fuze industry as chair of the NDIA Fuze Conference Committee and panel member of the DoD Fuze IPT Advisory Panel. Mr. Harward is also the fuze tech council engineering representative, former Section Head for fuzing, and has held sever leadership roles, including several payload IPT lead roles. He presented a paper at the 2011 NDIA Fuze Conference in Salt Lake City, "Enhanced Weapon Arming Safety by Controlled Accumulation of Arming Energy." Mr. Harward has a B.S. in Electrical Engineering from the University of Arizona and an M.S. in Systems Engineering from Johns Hopkins University.

## DR. DANIEL JEAN

*Senior Microsystems Engineer*

Army Research Laboratory, U.S. Army Combat Capabilities Development Command

Dr. Daniel Jean has worked for the past 20+ years in MEMS and fuzing for the Naval Surface Warfare Center in Indian Head, Maryland. Areas of research included MEMS design for miniature fuzes and packaging for high-G survivability. Recently, Dr. Jean moved to the Army Research Lab in Adelphi, Maryland, where he performs research in MEMS and additive manufacturing.

## GEORGE JOLLY

*Technical Advisor*

Air Force Research Laboratory

George Jolly serves as the Technical Advisor for the Fuzes Branch, Ordinance Division, Munitions Directorate, Air Force Research Laboratory, Eglin Air Force Base, FL. He acts as the subject matter expert for fuzing within the directorate to assist in all weapons development activities. As the Technical Advisor for the Fuzes Branch, he works with the branch personnel to assure the quality of research activities and its products and to set strategic goals. He also assists both the Ordinance Division Chief and the Directorate Chief Scientist in setting internal and external strategic research goals. Such goals include research in fuze system architecture, extreme environment survivability, end game sensing, initiation sciences, and the characterization and phenomenology of fuzes. In this role, he is responsible for solving the technical gaps for fuzing in the U.S. Air Force for future weapon requirements.

Mr. Jolly has had a broad career for more than 36 years as a technologist having begun as an Air Force officer at the Weapons Laboratory, Kirtland AFB, where he researched radiation hardened microelectronics for space vehicle application. After leaving the Air Force in 1988, Mr. Jolly worked as a support contractor at Eglin AFB focused on fuze technology for various weapon systems that includes JDAM, PAVWAY, CALCM, and the Sensor Fuzed Weapon. In 2003, he took the position of Director of Engineering for a company that designed and manufactured various avionic systems for both Air Force and Navy aircraft. In this position, he managed personnel in three locations around the country and was responsible for development programs for avionics on the F-15, FA-18, F-22, AC-130, and ACH-130 aircraft. In 2009, Mr. Jolly returned to Eglin AFB and technology development for weapon systems. Mr. Jolly became a Civil Servant and joined AFRL in 2010.

## MAXIM KEYLER

*Electronic Engineer*

Fuze Division, Armaments Center, U.S. Army Combat Capabilities Development Command

Maxim Keyler is an Electronic Engineer in the U.S. Army CCDC-Armaments Center Fuze Division, Picatinny Arsenal, NJ, where he has worked since 2004. He obtained a Bachelor of Engineering / Computer Engineering and Master of Engineering / Electrical Engineering from Stevens Institute of Technology. He has experience in both designing and troubleshooting electronic hardware as well as in software and firmware development. He is part of a team that develops fuze setting technologies ranging from designing custom single board computers, developing applications for embedded systems, and researching ways to efficiently transfer information to increasingly more complex fuzes.

## NICK MALINOSKI

*Supervisory Engineer*

Fuze Division, Armaments Center, U.S. Army Combat Capabilities Development Command

Nick Malinoski graduated in 2003 from Rutgers University with a B.S. in Mechanical Engineering and then worked for a couple years for the U.S. Navy at the Naval Surface Warfare Center, Carderock Division (NSWCCD), providing modeling and simulation work for ship structures and propulsors. Then, he spent a couple of years working for General Dynamics AIS on undersea hardware design, analysis and thermal testing, and the analysis of electronic components and systems. Mr. Malinoski began employment with the U.S. Army at the Armaments Center in 2008 in the Fuze Division, beginning with hand grenade fuzing before transition to support mortar fuzing and then medium caliber fuzing. He became a Team Lead in 2013, overseeing hand grenade, medium-caliber, shoulder-launched, and artillery fuzing. In 2017, Mr. Malinoski became branch chief and has since been serving in that capacity.

## VINCENT MATRISCIANO

*Program Manager, Research & Development*

Joint Program Executive Office Armaments & Ammunition

During his 30-year career, Vincent Matrisciano has worked many different weapon system programs from tanks, howitzers, mortars, and small arms to advanced systems like remotely operated weapons and advanced energy systems. Early in his career, he was the U.S. Army's Technical Lead for the M95 Mortar Fire Control System development program, a very successful program providing never-before-seen position and navigation, weapon pointing, and ballistic calculation capability to the mounted mortar battalion. That system was also used as the baseline for the subsequently developed digital fire control system for towed artillery (M777 and M119). Mr. Matrisciano has spent the past 10 years in JPEO Armaments and Ammunition (formerly PEO Ammo), overseeing portfolios of technology and development projects. In this role, he is responsible for facilitating the transitions of technology into programs to be fielded to our warfighters. He is also an active representative of the DoD Fuze IPT, where he leads and supports multiple improvement efforts.

## DR. ADRIANE MOURA, PHD

*Staff Mechanical Engineer 2*

Applied Research Associates, Inc.

Dr. Adriane Moura, PhD, is currently a mechanical engineer at Applied Research Associates, Inc., supporting the Air Force Research Laboratory at Eglin Air Force Base in Florida. Dr. Moura received her PhD from the Georgia Institute of Technology and her B.S. from Florida State University, both in Mechanical Engineering. Dr. Moura's technical interests include theoretical and experimental structural dynamics, linear/nonlinear vibration and modal analysis, smart structures, mechanics of materials, and microelectromechanical systems.

## KEVIN O'CONNOR, JR.

*Mechanical Engineer*

Fuze Division, Armaments Center, U.S. Army Combat Capabilities Development Command

Kevin O'Connor, Jr., graduated in 2018 from the New Jersey Institute of Technology with a Bachelor in Mechanical Engineering. He has been working as a Mechanical Engineer in the U.S. Army CCDC-Armaments Center's Fuze Division for the past two years. Kevin works on the research and development of mechanical Fuze S&A Technology, using specialized skills in Computer-Aided Design and Finite Element Analysis.

## BERNARD SMITH-ROBERTS

*Manager, Engineering Systems*

Explosive Materiel Branch, Joint Systems Division, Capacity Acquisition and Sustainment Group, Australian Department of Defence

Bernard Smith-Roberts is the Engineering Systems Manager for the Explosive Materiel Branch within the Capability Acquisition and Sustainment Group of the Australian Department of Defence. In this role, he is responsible for the engineering system under which the safe, environmentally compliant, and effective performance of explosive ordnance is delivered to the Australian Defence Force.

Mr. Smith-Roberts' career over the last 10 years within the Australian Public Service has spanned a number of roles within explosive ordnance and high-risk platform integration, systems safety, and regulatory organizations. He graduated from the Australian National University with a BEng in Systems Engineering with honors in 2010 and from the University of New South Wales (Australian Defence Force Academy) with an MEng in Systems Engineering in 2013.

## LT COL BRIAN A. "HANZO" STILES, USAF

*Commander*

72d Test and Evaluation Squadron, Whiteman Air Force Base, U.S. Air Force

Lieutenant Colonel Brian A. "Hanzo" Stiles, USAF, is the Commander, 72d Test and Evaluation Squadron, Whiteman AFB in Missouri. The 72d is responsible for the planning and execution of B-2 operational test and evaluation, including force development evaluations, tactics development and evaluations, and software evaluations. He is an evaluator pilot in both the B-2A and T-38A.

Lt Col Stiles is from Roseville, CA, and received his commission in 2002 from the United States Air Force Academy where he was a distinguished graduate. He has served as an instructor pilot in the T-38A and B-2A. Prior to becoming the Director of Operations of the 72d, he was the Director of Plans and Programs for the 509th Bomb Wing, planning and executing all major exercises and readiness evaluations. Lt Col Stiles is a senior pilot with more than 2,200 flight hours.

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L3Harris Technologies is an agile global aerospace and defense technology innovator, delivering end-to-end solutions that meet customers' mission-critical needs. The company provides advanced defense and commercial technologies across air, land, sea, space and cyber domains. L3Harris has approximately $18 billion in annual revenue and 48,000 employees, with customers in more than 100 countries.

Defense Electronic Systems (DES), a division of L3Harris, provides precision electronic components, subsystems, and systems for the DOD and international allies.  DES specializes in the design and manufacture of fuze solutions, ignition safety devices, proximity sensors, inertial measurement and GPS navigation systems, aerospace indicators, and intelligence management systems.  Furthermore, DES is introducing CHIEF (Configurable High-Impact Embedded Fuzing), a key enabler for tactical flexibility and survivability in extreme target environments.

Headquartered near Cincinnati, Ohio, DES' primary manufacturing facility was specifically designed and constructed for the manufacture of fuzing and ordnance systems and precision electronic components.  With additional locations in Anaheim, CA, Budd Lake, NJ, and San Diego, CA, DES has strategically positioned its resources, including program management, engineering, and quality assurance, at each site to ensure complete adherence to programmatic and technical requirements.

DES is a partner you can count on to deliver quality products and solve your toughest technical challenges.  To learn more, please connect with us at vFuze, visit www.L3Harris.com, or call 513-943-2000.

# B-2 Test Team

*Testing - Training - Tactics - Innovation - Operations*

# NDIA Keynote Speech:

# B-2 Operational Test

**Lt Col Brian 'Hazno' Stiles**
**Commander, 72 Test and Evaluation Squadron**

Last updated: 26 July 2020
POC: Lt Col Stiles

*"Perfecting Lethality"*

# OVERVIEW

- My Background
- 72 TES Mission
- B-2 Test Enterprise
- Operational Test & Operations Tempo
- FY20 Projected B-2 Operations Test Schedule
- B-2 Sustainment Roadmap
- DT at Whiteman AFB
- Challenges

# LT COL BRIAN 'HAZNO' STILES

- '02 USAFA Graduate Distinguished Grad
- MS in Mech Eng from Rice University ('04)
- 2000+ hours AF flight time (B-2 & T-38)
- AF Fellow – SNL Weapon Intern Prgm ('15B)
- '15-'17: Led B-2 Requirements at AFGSC
- '18-'20: Director of Ops of 72 TES
- Commander since May '20

Everything We Know About The B-2 Spirit Emergency Landing in Colorado Springs

Official Investigation Pending. Internet Buzzing with Speculation About Cause.

# 72 TES MISSION

**Execute OT&E of the B-2 bomber weapon system**

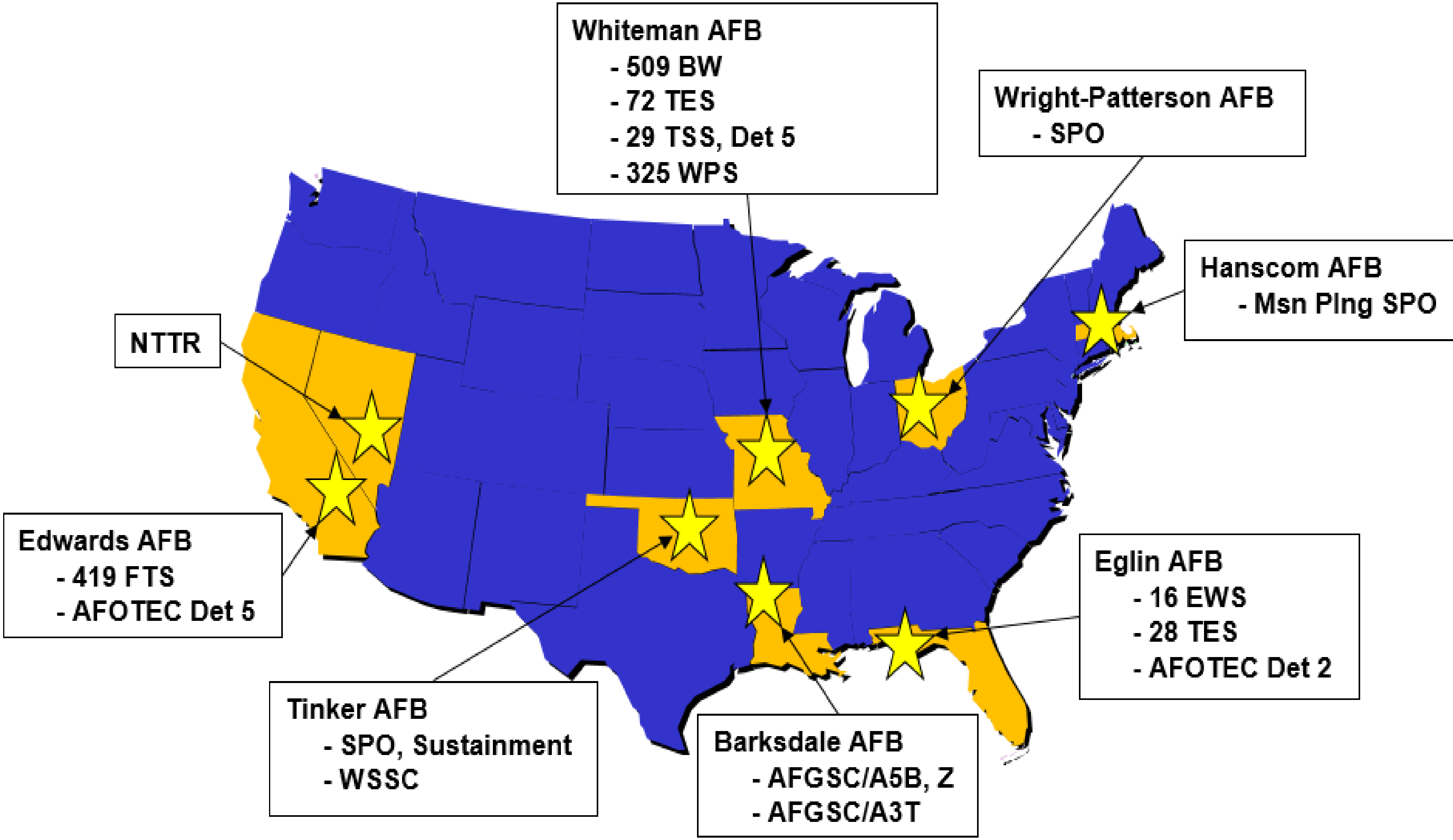
**Evaluate the effectiveness and suitability of B-2 Software, Weapons, Mission Planning, Survivability and Tactics**

**Coordinate the B-2 Nuclear Weapon System Evaluation Program**

**Provide Tactical and Technical expertise to U.S. Air Force headquarters, Department of Defense agencies and industry in development of B-2 employment techniques**

***Accomplish this through FDE, TD&E and NucWSEP***

# B-2 TEST ENTERPRISE



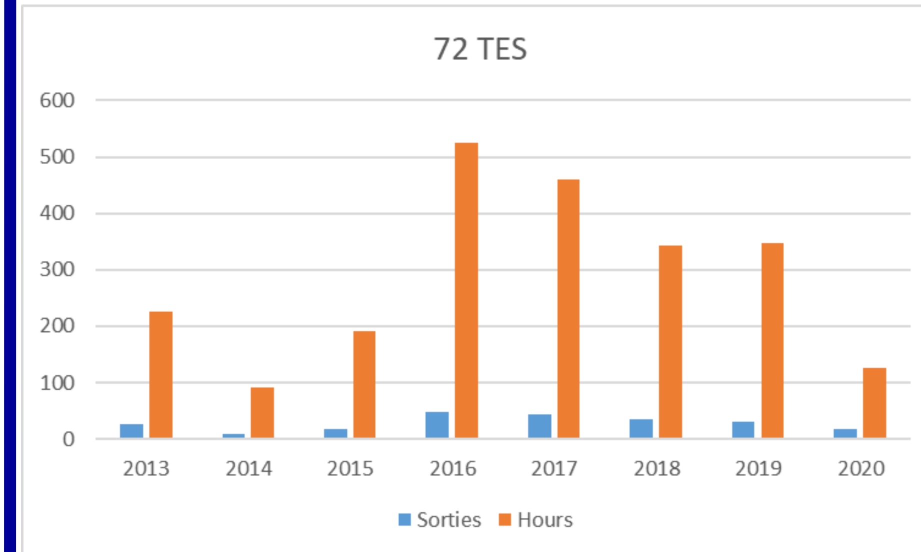
# OPERATIONAL TESTING

- **Sources of our Tests**
  - Acquisitions (e.g., IFC FDE, MPE, Weapons, etc.)
  - Operations (e.g., WEPTAC TIPs, requests from users, etc.)
  - All require ACC tasking/scope
- **Force Development Evaluation (FDE)**
  - Effectiveness and Suitability
  - Scope of test determined by the SUT
  - Analysis of range and aircraft data, operator observations
  - Fielding Recommendations
  - Common FDEs are for IFCs, Mission Planning, LO Mods
- **Tactics Development and Evaluation (TD&E)**
  - Tests generated from WEPTAC or T3WG
  - Develops and/or assesses TTPs
  - Most common TD&Es are Survivability missions
- **Operational Utility Evaluation (OUE), Operational Assessments (OA)**
  - Lower fidelity, less rigorous operational look

# 72 TES OPS TEMPO

## Previous Ops Tempo

- FY 2013- 224.8 hrs/ 27 sorties
- FY 2014- 92.3 hrs/ 10 sorties
- FY 2015- 190.1 hrs/ 17 sorties
- FY 2016- 525.2 hrs/ 48 sorties
- FY 2017- 459.2 hrs/ 43 sorties
- FY 2018- 343.8 hrs/ 34 sorties
- FY 2019- 346.9 hrs/ 30 sorties




## Current Ops Tempo

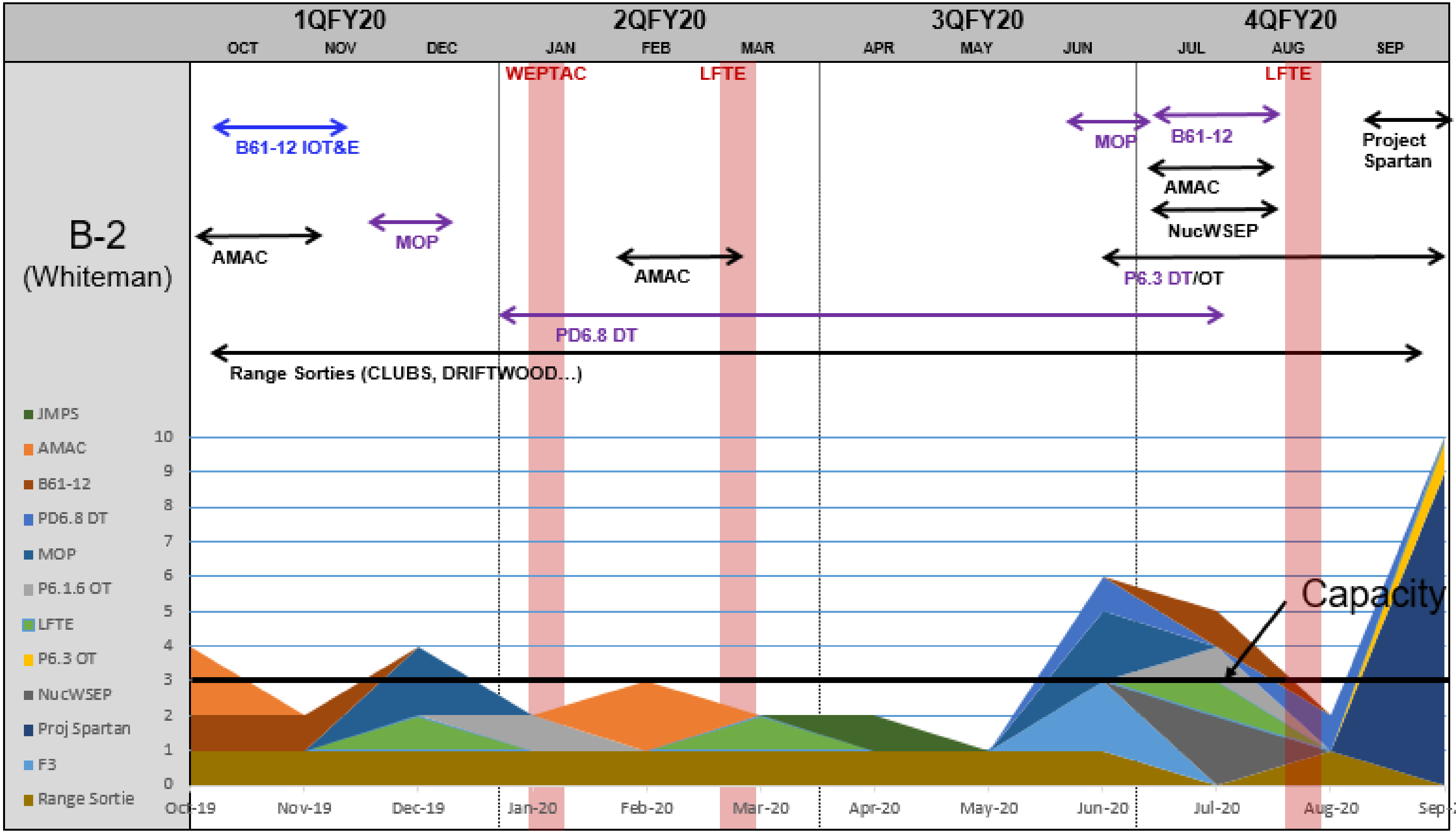
- FY 2020- 125.8 hrs/ 17 sorties (a/o June 2020)
- Projected to be 250 hrs by the end of FY20

## Programs Supported

- New IFCs (P6.3 / P6.4)
- Weapons (MOP / B61-12)
- System 2 AMAC
- LFTE
- F3s
- "Other Stuff"

*"Perfecting Lethality"*

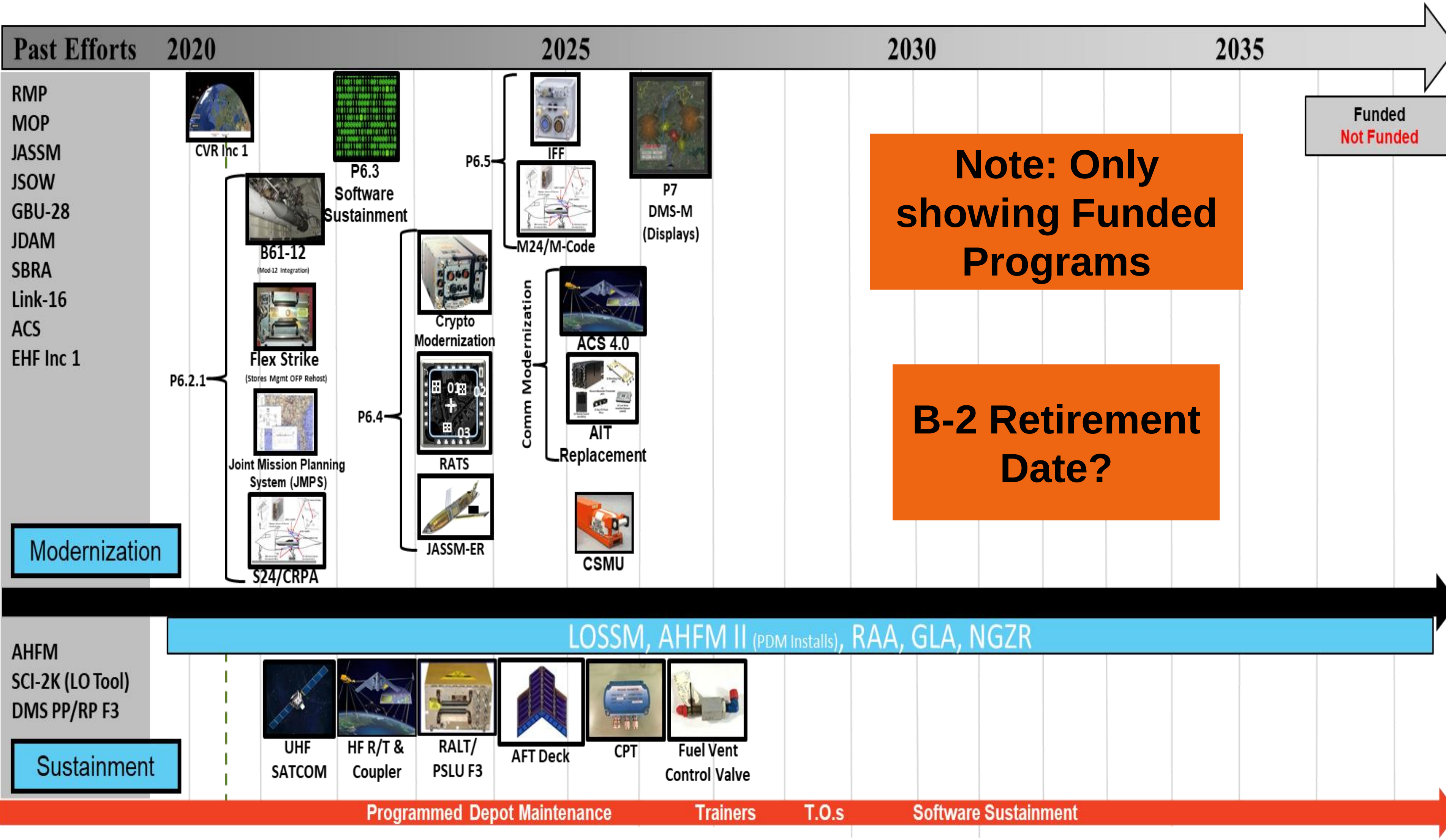
# FY 20 PROJECTED B-2 OPS TEST



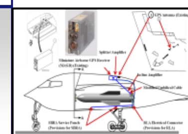
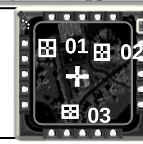
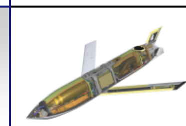

OT AFOTEC DT Supt

*"Perfecting Lethality"*

# B-2 SUSTAINMENT ROADMAP



# B-2 SUSTAINMENT ROADMAP

| | | | |
|---|---|---|---|
| Flex Strike Phase 1 |  | Needed for B61-12 integration<br>Provides multiple wpn enhancements<br>Needed for all future wpns mods<br>Fields: 2 a/c modified | P6.2.1 |
| B61-12 Integration |  | Integration Contract awarded Jan 2015<br>Defining Thermal environment for B-2<br>C/D Ring RLA configuration discussion<br>Fields: 2 a/c modified | P6.2.1 |
| GPS Antenna Upgrade |  | Counter GPS Jamming<br>Adds CRPA Antenna and SASSM Receiver<br>M-Code Receiver will field w/P6.4<br>Fields: 2 a/c modified | P6.2.1 |
| Radar Aided Targeting System (RATS) |  | Provides GPS-like quality solution w/o GPS<br>Software Only Integration for B61-12<br>Fully funded FY19-21 ($43M)<br>Fielding starts in 3QFY21 | P6.4 |
| Crypto Mod Upgrades |  | NSA-mandate cryptographic mods<br>UHF/HF/Link-16 Terminal<br>Fielding starts in 3QFY21 | P6.4 |
| JASSM-ER Integration |  | Software Only Integration<br>Funded; req's $18.5M in FY21 to complete<br>Fielding starts in 3QFY21 | P6.4 |
| IFF Mode 5/S |  | EUROCONTROL mandates Mode S by 2016<br>ADS-B Out has been deferred<br>Funded in FY18 POM<br>Fielding starts in 3QFY22 | P6.5 |
| ~~Defensive Management System Modernization (DMS-M) –~~ B-2 Displays Modernization |  | Needed for A2/AD fight<br>Provides in flight real-time auto-routing<br>Fully funded in FY20 PB<br>Schedule tripwire to Joint Staff in-progress<br>De-Scoped to displays only – COAs in work | P7 |

*"Perfecting Lethality"*

# DT AT WHITEMAN AFB

## BACKGROUND

- Developmental Test (DT) efforts have started executing out of WAFB due to aircraft availability and configuration limitations at Edwards AFB, CA
- Form, Fit, Function (F3) DT support includes contributions from 72 TES instrumentation,  MX, engineer, and pilot personnel

## F3 SCOPE

- Scheduled F3 projects:
  - Cabin Pressure Transducer (CPT), 8 hr sortie
  - UHF SATCOM, 1 ground test and 1 sortie
  - HF RX/TX, 1 ground test and 1 sortie
  - HF Coupler, 1 ground test and 1 sortie
- F3 projects often do not require dedicated sorties and can be executed concurrently with other test objectives

## DT SCOPE

- All Future P6.3+ DT Programs
  - PD6.8 (P6.3) currently in test at Whiteman AFB
  - P6.4 in test in early 2021
  - P6.5 in test in early 2022
- Require Dedicated sorties / AC configs
- Coordinate w/ 419 FTS on test
- Data analysis by EDW

# CHALLENGES

- **Test Capacity Throughput**
  - Aircraft availability and reliability, B-2 fleet management
  - Range availability and capabilities
- **Security Issues**
  - B-2 enterprise not on a common network, Operational vs. Acquisition
  - Barriers among platforms, limited TTPs
- **Enterprise Issues**
  - DT/OT transition to Whiteman
  - Modeling & Simulation

# U.S. ARMY COMBAT CAPABILITIES DEVELOPMENT COMMAND – AVIATION & MISSILE CENTER

## Overview Brief

Michael Connolly

Electronics Engineer

Technology Development Directorate



26 November 2019

# CCDC VISION AND MISSION

## VISION

To be the scientific and technological foundation of the Future Force Modernization Enterprise through world-leading research, development, engineering and analysis.

## MISSION

To provide the research, engineering, and analytical expertise to deliver capabilities that enable the Army to deter and, when necessary, decisively defeat any adversary now and in the future.

# CCDC ORGANIZATION

## Headquarters U.S. Army Combat Capabilities Development Command
Aberdeen Proving Ground, MD


COL
Terrece Harris
CoS


BG
Vincent Malone
DCG


MG
John George
CG


Mr.
John Willison
DtCG


CSM
Jon Stanley
CSM

## CCDC Army Research Laboratory and Centers

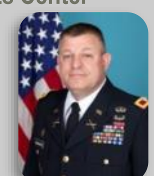
### Army Research Laboratory


Dr.
Patrick Baker


COL
Thomas Ryan

### Armaments Center


Mr.
John Hedderich


COL
Kelly Laughlin

### Aviation & Missile Center


Dr.
Juanita Christensen


COL
Eric Rannow

### C5ISR Center


Mr.
Patrick O'Neill


COL
Mark Henderson

### Chemical Biological Center


Dr.
Eric Moore

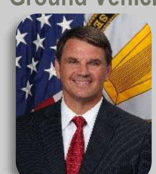

COL
Cory Berg

### Soldier Center


Mr.
Douglas Tamilio


COL
Frank Moore

### Ground Vehicle Systems Center


Mr.
Jeffrey Langhout


COL
Kevin Vanyo

### Data & Analysis Center


Mr.
James Amato


COL
Gregory Smith

## CCDC Forward Elements

### CCDC Americas


COL
Patrick Badar

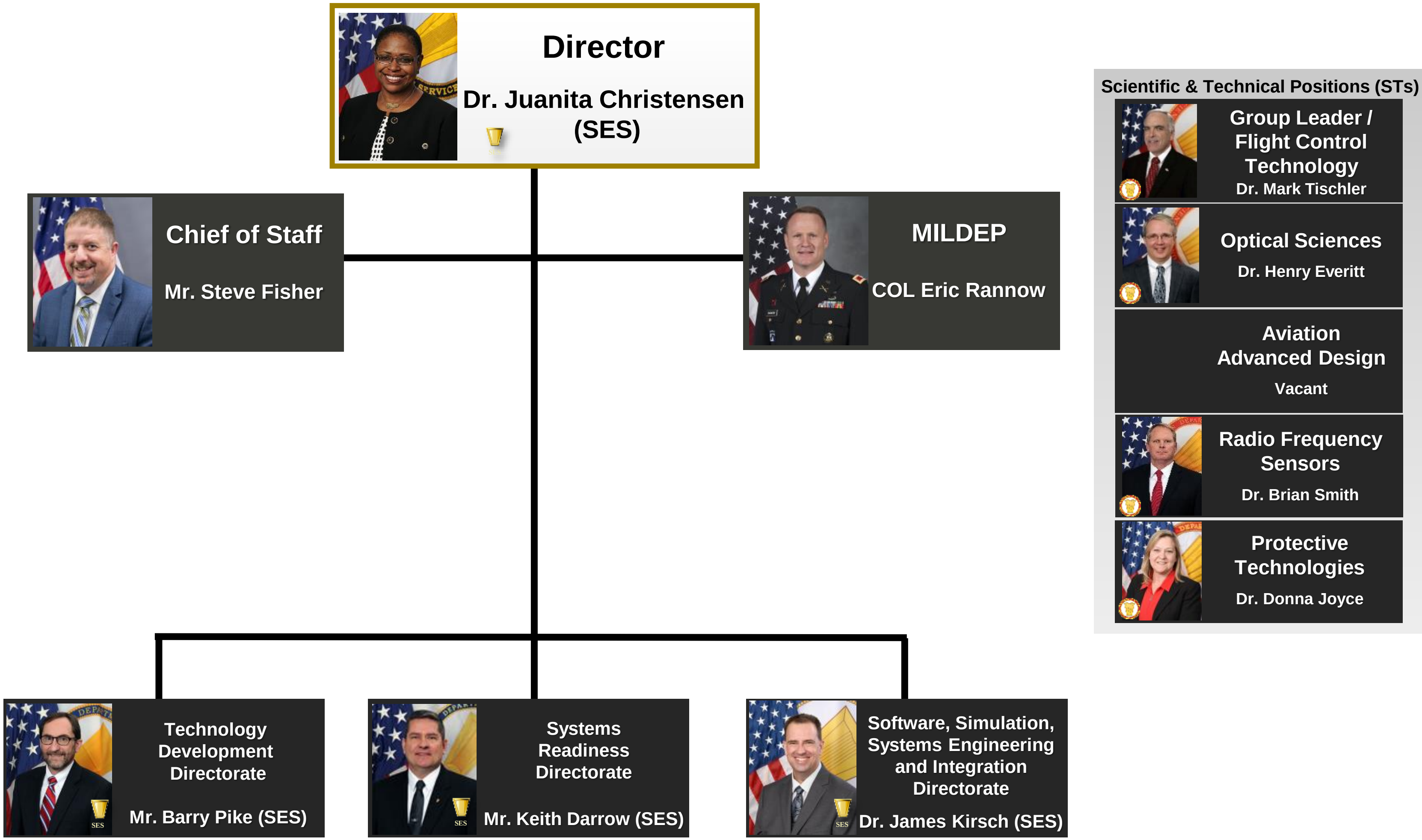
### CCDC Atlantic


COL
Steven Ansley

### CCDC Pacific


COL
Daryl Harger

# OUR LEADERSHIP



# OUR MISSION

**Deliver collaborative and innovative aviation and missile capabilities for responsive and cost-effective research, development and life cycle engineering solutions.**

# BY THE NUMBERS

**12,054** FY19 Strength

**3,036** Civilian

**23** Military

**~8,995** Contractor

## FY19 Funding

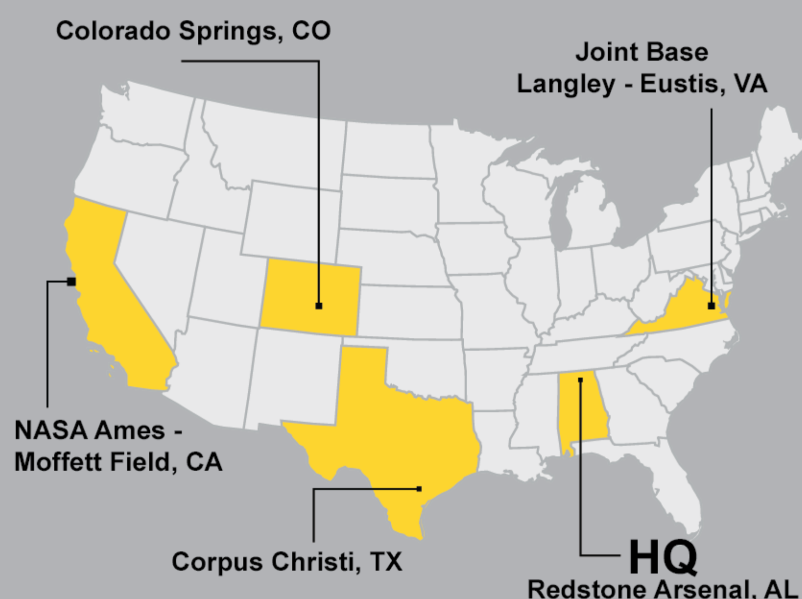
**$3.8B**

**6%** Aviation S&T

**7%** Missile S&T

**59%** Army

**28%** Other




## Core Competencies

***Technical Domain:***

- Active and Passive Air Defense Sensor Technology (S&T)
- Aerial Autonomy
- Aerospace and Aerodynamics
- Capabilities Engineering
- Materials and Structures
- Fuzing, Guidance, Controls and Seekers
- Propulsion, Explosives, Energetics, Warheads

***Capabilities Engineering:***

- Software Engineering
- Weapons Assurance
- Modeling and Sim Design, Dev, VV&A
- Configuration Management
- Engineering Prototype Design and Dev
- Maintenance, Life Cycle Cost Reduction, and Logistics Engineering
- Manufacturing Tech and Production Support
- Multidiscipline Acquisition and Project Engineering
- Quality Engineering and Management
- Reliability, Availability, and Maintainability
- Sustainment, Industrial Base, and Obsolescence
- Systems Engineering, Integration, and Interoperability
- Test and Evaluation
- Air Defense Radar (Reimbursable)
- Airworthiness

# OUR PRIORITIES

DEVCOM
AVIATION & MISSILE CENTER

## #1: People

People are the Army's greatest strength and its most important weapon system.

## #2: Readiness

The Army must be ready to defeat any adversary, anywhere, whenever called upon, under any condition.

## #3: Modernization

The Army must modernize to remain lethal and ready to fight tomorrow, against increasingly capable adversaries and near-peer competitors.

## #4: Reform

The Army will improve the way we do business, including how we implement our top priorities, to make the Army more lethal, capable, and efficient.

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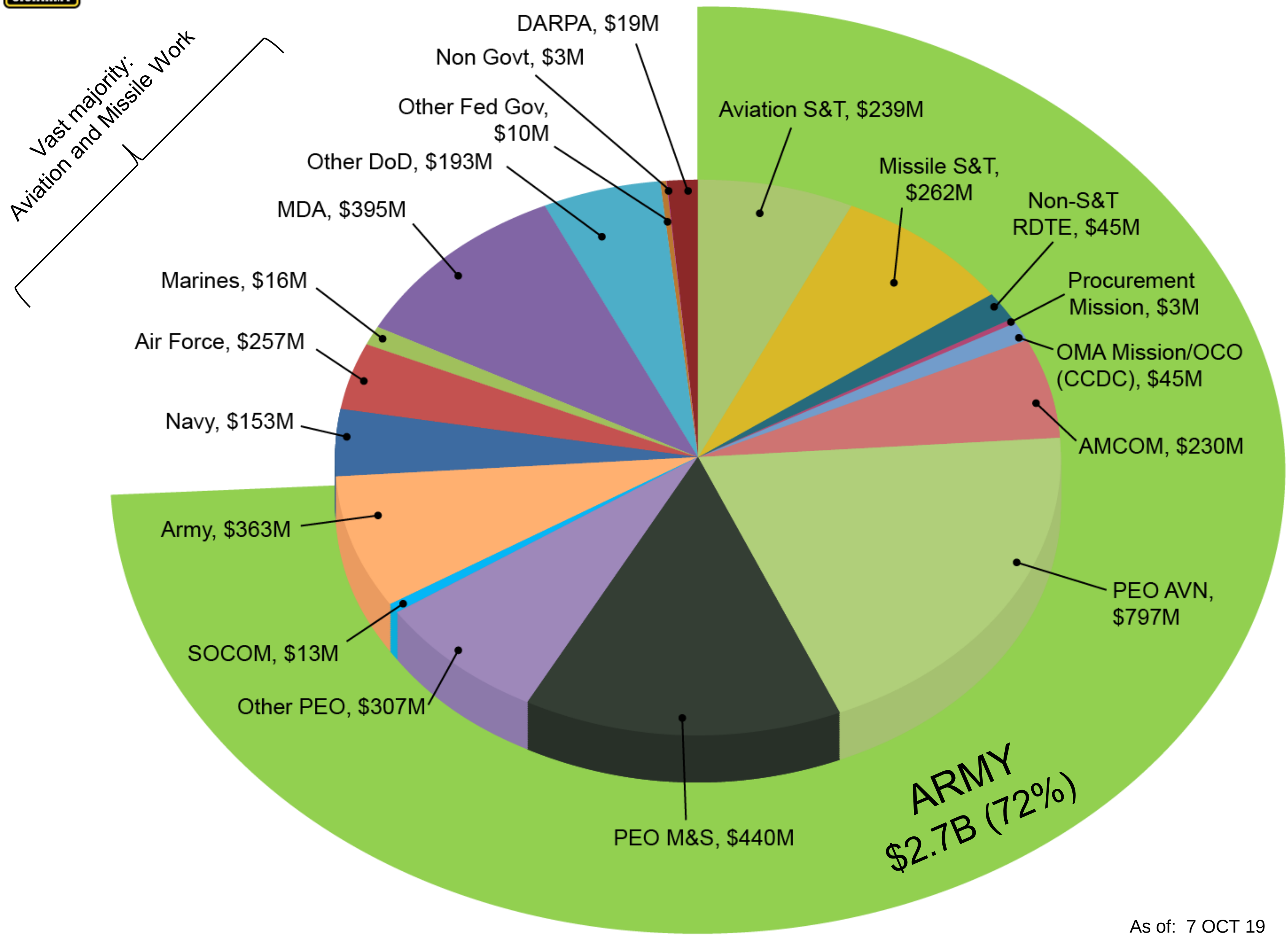
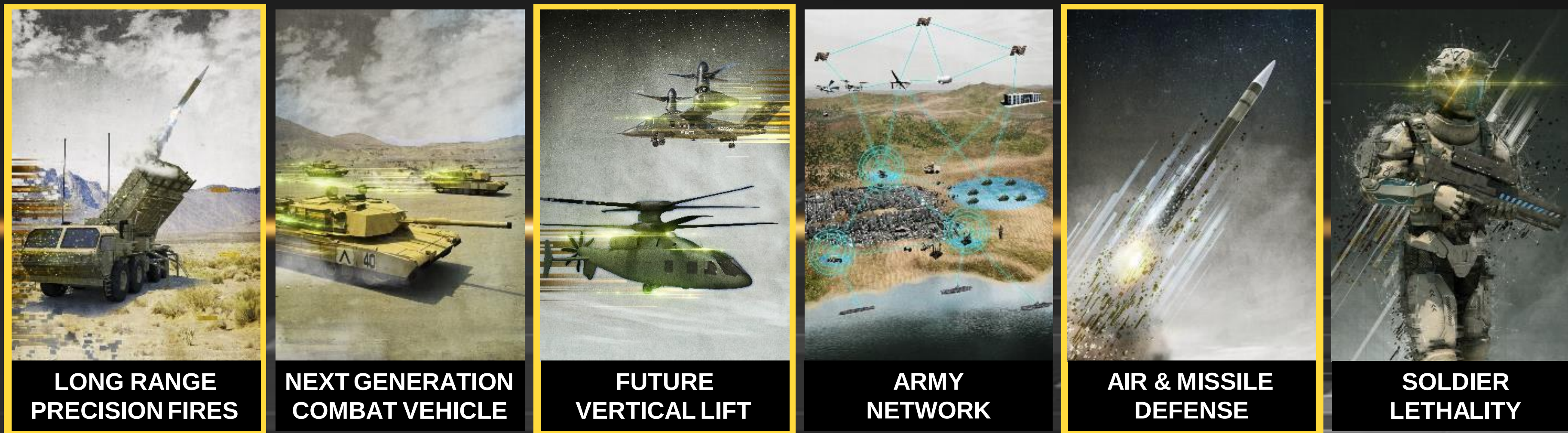
# FY19 TOTAL REVENUE ($3.8B)




As of: 7 OCT 19

# S&T PRIORITIES ALIGNED WITH THE ARMY MODERNIZATION STRATEGY




**Supporting Army and Joint Readiness now and in the Future MDO Environment**

## RESEARCH ISO FUTURE FORCE

Driving the discoveries and innovations which will be critical to realizing new capabilities for the Army of 2030 and beyond.

## ANALYSIS

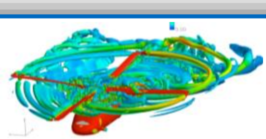
Conducting objective experimentation and systems analysis to support the equipping and sustaining of our Warfighters.

## ENGINEERING

Providing lifecycle engineering expertise to support fleet development and readiness across warfighting battlefield operating systems.

# TOP AVIATION S&T INITIATIVES

## Platforms



- Structures
- Sustainment
- Concept Design & Assessment

## Major Program Areas

- Joint Multi-Role Technology Demonstration
- Degraded Visual Environment – Mitigation
- Next Generation Tactical UAS Technology Demonstration

## Mission Systems

- Survivability
- Avionics & Networks


## Power

- Engines & Other Power Sources
- Drives

## Basic Research

- Computational Aeromechanics
- Experimental Aeromechanics

## Vehicle Management & Control and Rotors

- Rotors
- Vehicle Management & Control

## Autonomous and Unmanned Systems

# FUTURE VERTICAL LIFT LINES OF EFFORT

Army Aviation is committed to maintaining vertical lift dominance with the development of critical combat systems enabling the joint force to operate dispersed over wide areas with the ability to ***rapidly converge*** in order to ***penetrate*** the multiple layers of ***stand-off*** employed by the threat, ***dis-integrate*** A2/AD systems, and ***exploit*** this advantage with enhanced Attack/Reconnaissance, Air Assault and MEDEVAC capabilities.

## FARA Capability Set 1

**Future Attack Reconnaissance Aircraft:** Critical combat system needed to prevail in future wars by enabling Army Aviation to achieve a "leap-ahead" in lethality, survivability, and reach to find, fix, and finish our pacing threats.

## FUAS & AUAS

**Future & Advanced Unmanned Aircraft Systems:** Advanced teaming FVL with next generation UAS delivering lethal and non-lethal air launched effects enables cross-domain fires to penetrate and dis-integrate enemy A2AD systems and exploit expanded maneuver to overmatch peer adversaries.

## FLRAA Capability Set 3

**Future Long Range Assault Aircraft:** Essential to exploit the windows of opportunity created by FARA and advanced teaming with UAS/ALE with its increased speed and reach providing significantly more lethal and effective Air Assault and MEDEVAC capabilities on the future battlefield.

## MOSA


**Modular Open Systems Architecture:** The government defined Modular Open System Approach will establish the digital backbone of FVL aircraft allowing for rapid and affordable integration of innovative avionics and mission equipment technologies into our platforms.

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# MISSILE S&T ALIGNMENT TO ARMY MODERNIZATION PRIORITIES

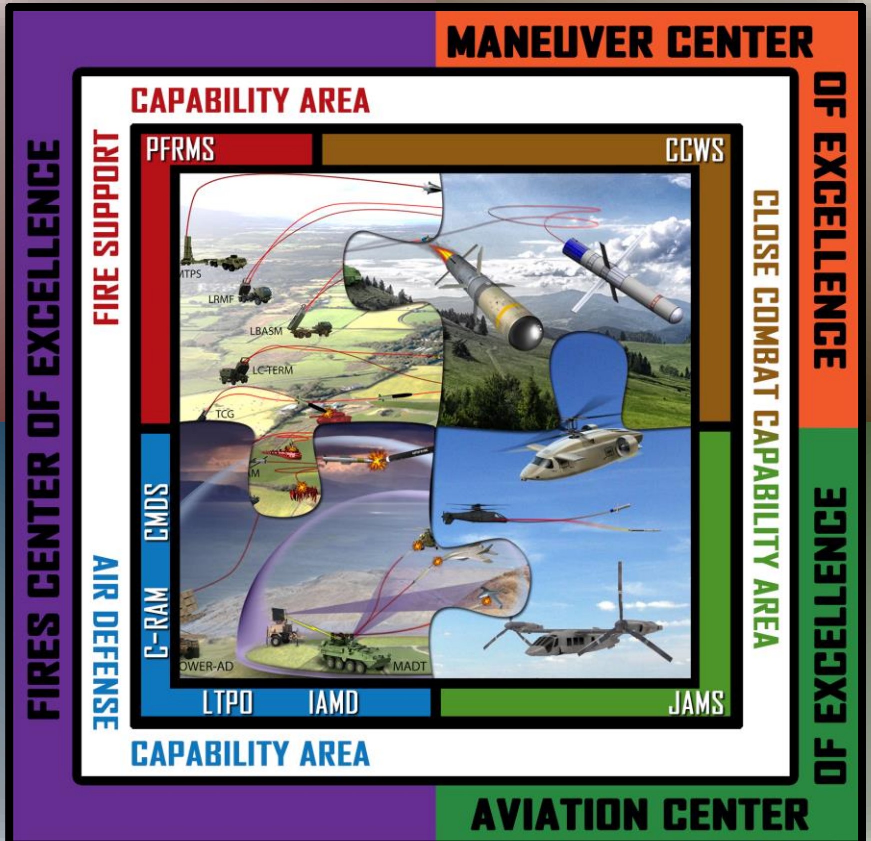
*Army Modernization Priorities*

## Long Range Precision Fires

Technologies for the development, integration and delivery of long range fires at the tactical, operational, and strategic echelons to restore overmatch, improve deterrence, and disrupt A2AD on a complex, contested and expanded battlefield.

## Next Generation Combat Vehicle

Technologies for active protection systems and enhanced lethal effects that will increase our ability to survive and win in the complex and densely urbanized terrain of an intensely lethal and distributed battlefield where all domains are continually contested.




## Air & Missile Defense

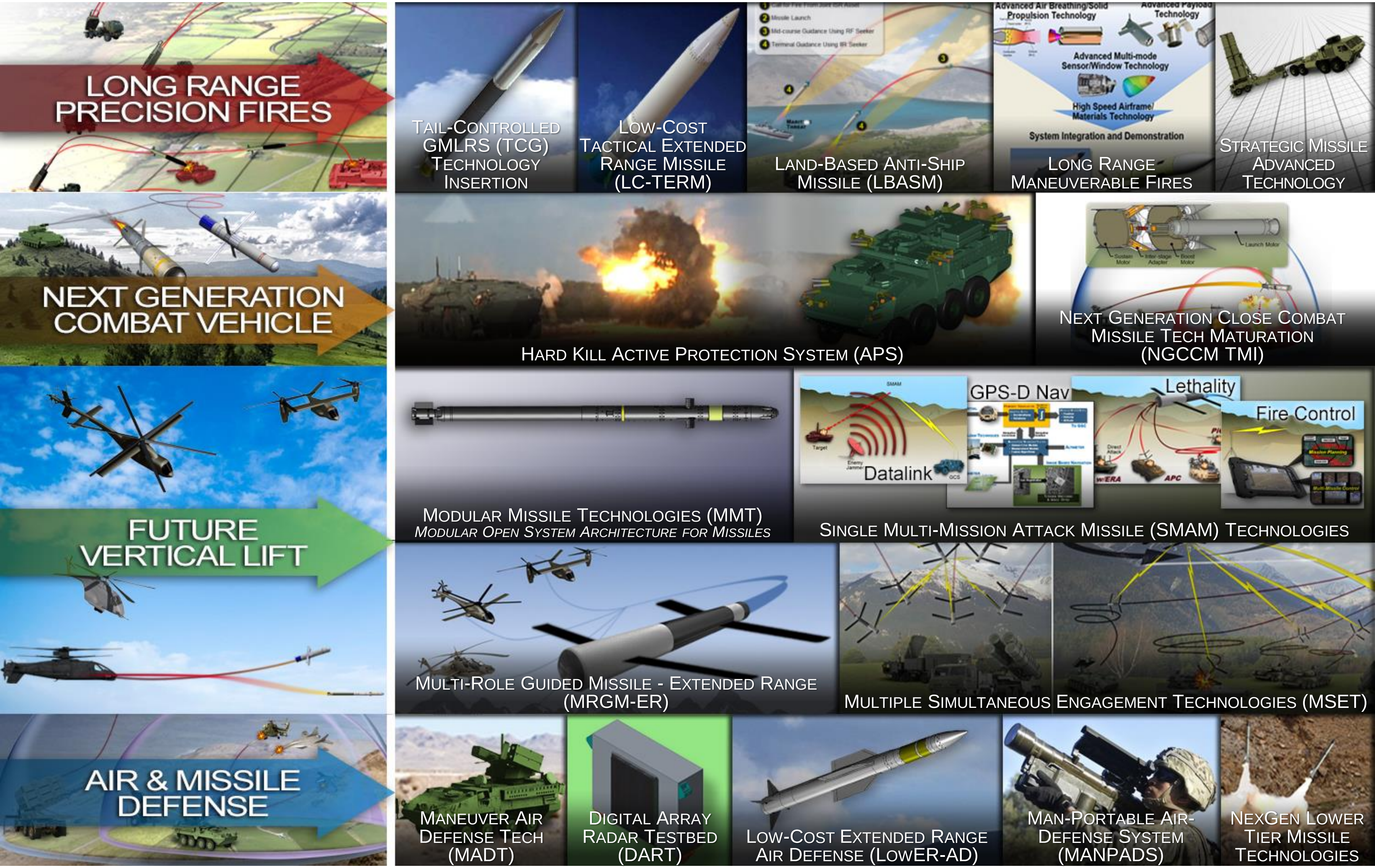
Technologies for the development of mobile air defense systems that reduce the cost curve of missile defense, restore overmatch, survive volley-fire attacks, and operate within sophisticated A2AD and contested domains.

## Future Vertical Lift

Technologies for the development, integration, and delivery of aviation launched air-to-ground and air-to-air missile systems to restore overmatch within sophisticated A2AD and contested domains.

**Engage First** **Expand the Dome** **On the Move**

# CCDC AVIATION & MISSILE CENTER MISSILE S&T ALIGNED TO ARMY PRIORITIES



# QUESTIONS?



"Through teamwork, the U.S. Army will remain the most lethal, modern fighting force in the world."

Ryan D. McCarthy, Secretary of the Army

**Web Site**
https://www.avmc.army.mil

**Facebook**
www.facebook.com/ccdc.avm

**Instagram**
www.instagram.com/CCDC_AVM

**Twitter**
@CCDC_AVM

**Public Affairs**
usarmy.redstone.ccdc-avmc.mbx.pao@mail.mil

# Navy Fuze Science & Technology

Presented to:

**National Defense Industrial Association**

**Virtual Fuze Conference (vFuze)**

Presented by:

**Naval Surface Warfare Center**

**Indian Head EOD Technology Division**

**August 4, 2020**

# Outline

- Navy Fuze Organizations Overview
  - Naval Surface Warfare Center (NSWC) Indian Head EOD Technology Division (IHEODTD)
  - NSWC Dahlgren Division (DD)
  - Naval Air Warfare Center Weapons Division (NAWCWD) China Lake (CL)
- Fuze Science and Technology (S&T) Projects and Thrust Areas
- Fuze S&T Roadmap
- Navy vFuze Presentations

NAVSEA WARFARE CENTERS
Indian Head EOD Technology Division

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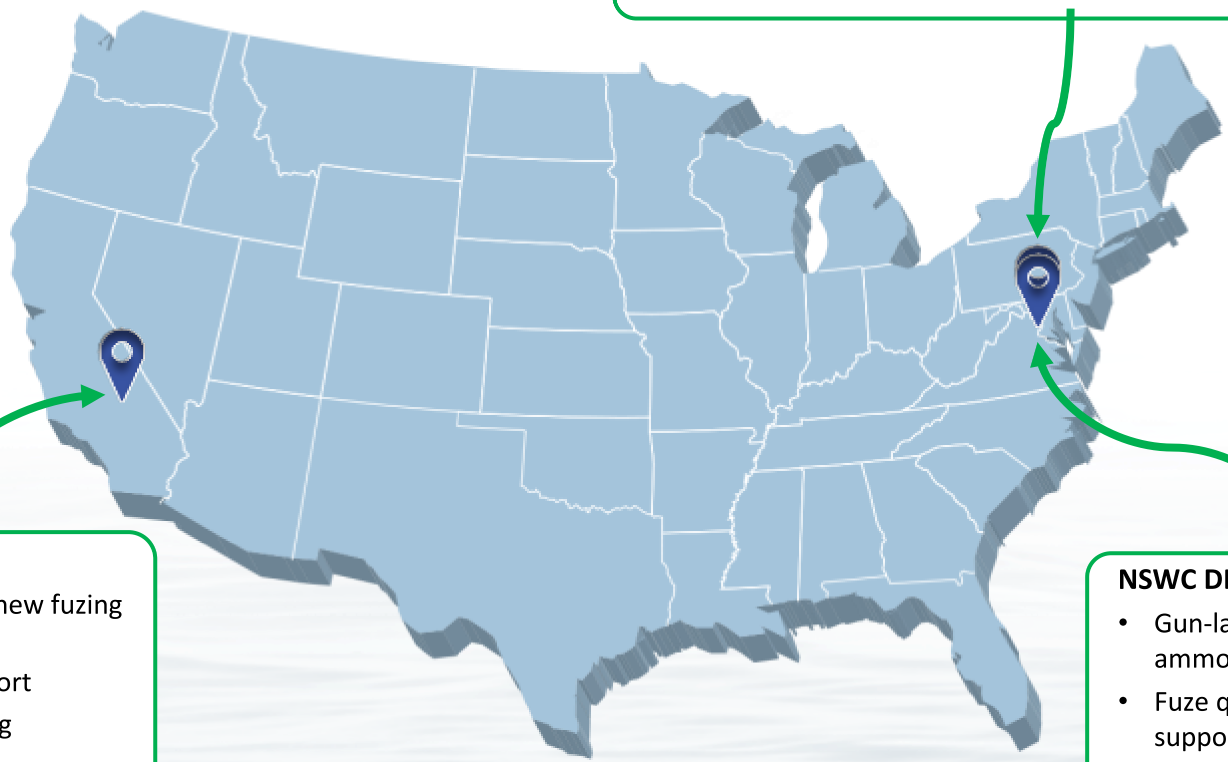
# Navy Fuze S&T Strategic Locations

**NSWC IHEODTD**

- Naval Sea Systems Command Center of Excellence for Energetics
- DoD EOD program lead
- Expeditionary Exploitation Unit ONE (EXU-1)
- Co-located with Naval Ordnance Safety and Security Activity



**NAWCWD CL**

- Design and develop new fuzing concepts
- In-Service fleet support
- Extensive fuze testing capabilities

**NSWC DD**

- Gun-launched, conventional ammo fuzing
- Fuze qualification and fleet support
- Potomac River test range



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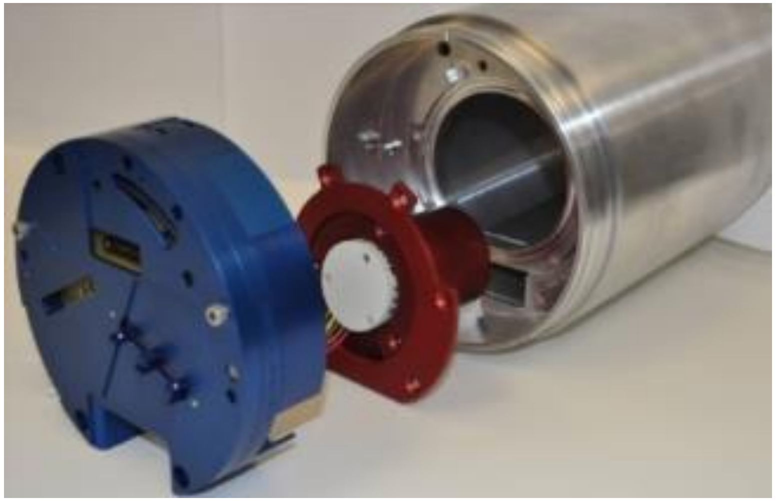
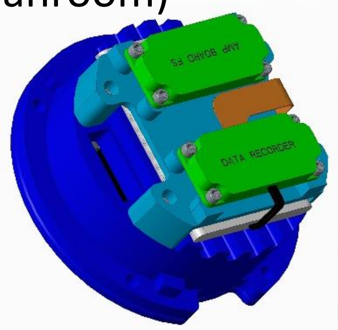
# NSWC IHEODTD Fuzing Overview

- Fuze safety architectures, safety analysis, system safety
- Distributed fuzing, multipoint and embedded
- Firing systems and firesets
- Fuzes
  - Torpedoes
  - Mine / mine neutralization
  - 40mm grenade
  - 155mm
  - Hand emplaced
- Target detection
- Microelectromechanical Systems (MEMS) and energetics integration (explosively certified cleanroom)
- Energy harvesting
- Powerless environment sensors
- Rapid and continuous prototyping
- In-house production





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# NSWC IHEODTD Core Capabilities

- Electrical design and test
  - Electronic Safe Arm Devices (ESADs) and MEMS SADs
  - Sensing technologies, imbedded systems, RF design
- Initiation systems design and test
  - Micro-energetics, micro-firesets
  - Characterization (e.g., Photonic Doppler Velocimetry)
- Mechanical design and test
  - Fuze packaging
  - Full scale launch and impact testing (reverse impact available and explosive certified)
    - Guns up to 21” diameter
    - Speeds >2000 ft/s
  - MEMS
  - High G shock testing and survivability





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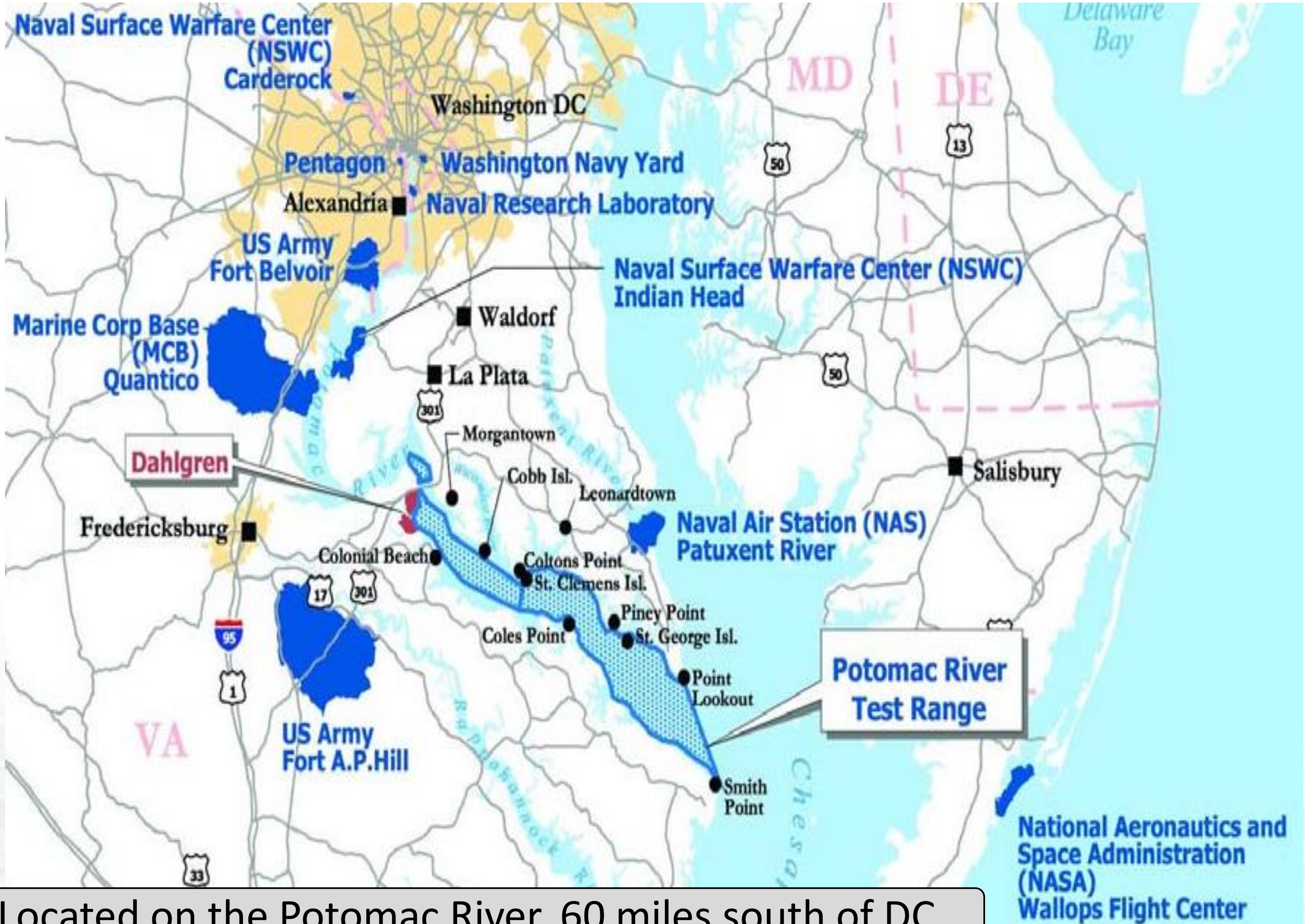
# NSWC DD Overview




Located on the Potomac River, 60 miles south of DC

# NSWC DD Core Fuzing Capabilities

## Development

- Gun-launched, conventional ammo fuzing
- S&A design
- Preparing specs and requirements
- Benchtop electronics testing
- CAD modeling and finite element analysis
- Rapid prototyping

## Qualification

- Closed and open loop HWIL testing
- Execute and approve qualification testing
- Energetics and ballistic testing
- Extensive safety support with FISTRP representation

## Fleet Support

- Direct communication with fleet
- Support various at-sea test events
- Respond to Conventional Ordnance Deficiency Reports (CODRs)
- Provide SME support/training

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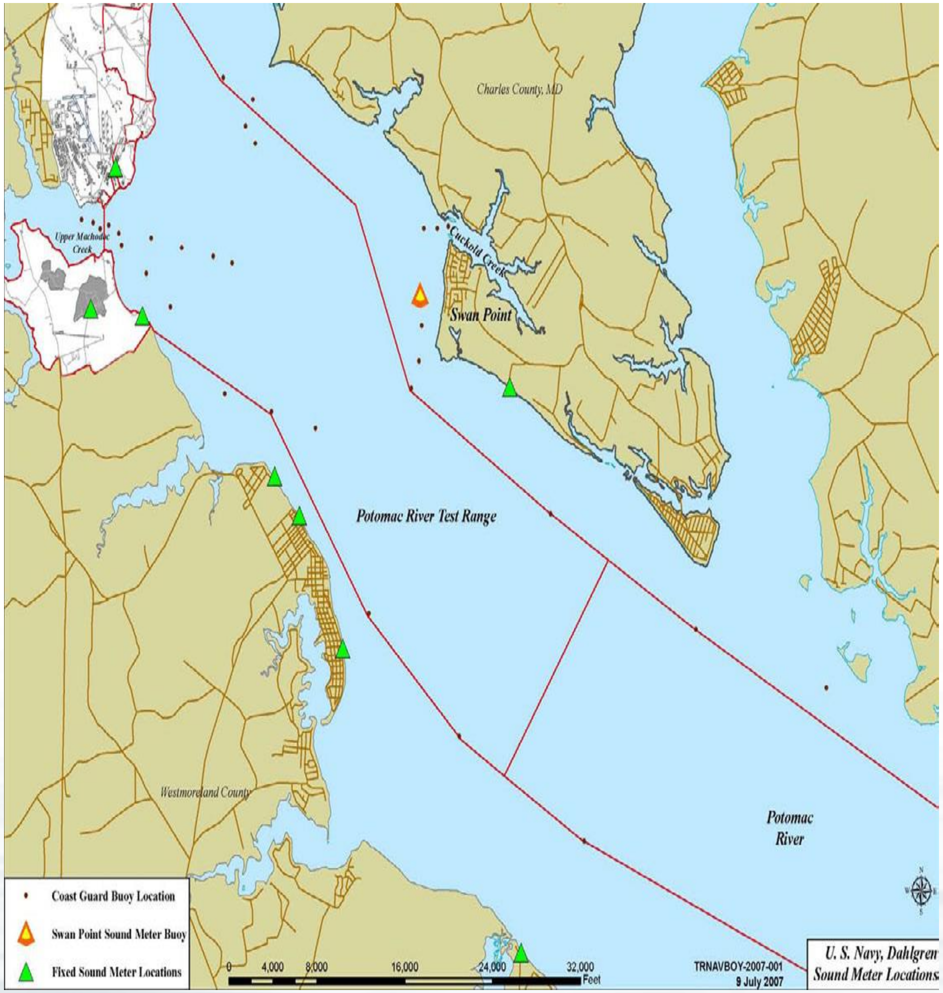
Indian Head EOD Technology Division

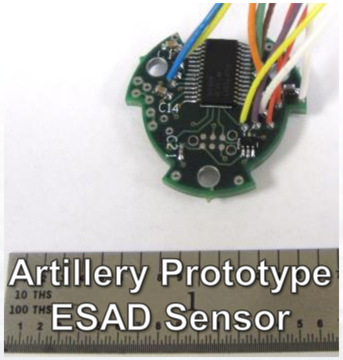
# NSWC DD Potomac River Test Range

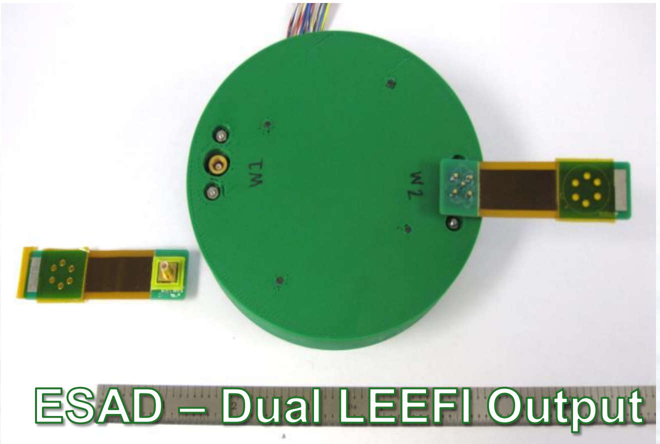
- 169 square miles of controlled water
  - Ballistic range of up to 20 nautical miles
  - Airspace clearance to 60,000 feet
- Fully instrumented network of range stations along Virginia shore of the Potomac River
- Over 2,300 acres of explosive ranges provide full spectrum of capabilities for live fire testing of energetics and directed energy systems
- Test range supports legacy, emergent, and “Navy after Next” programs
- Fuze test facility capable of:
  - S&A spin testing
  - Battery activation testing
  - Detonator time and explosive output testing
  - Fuze electronics testing
  - RF target simulation
  - Environmental testing



# NAWCWD CL Engineering Overview

- Design and develop new fuzing concepts
  - Rapid prototyping (3D print or machined)
  - FPGA development and logic analysis (up to 208 channel)
  - ESADs, ISDs, FTSAs, test range fire-sets

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# NAWCWD CL In-Service Fuze Support

- Over 50 years of combined experience
- Program support from production through sustainment and ordnance assessment
- Respond to CODR from the fleet

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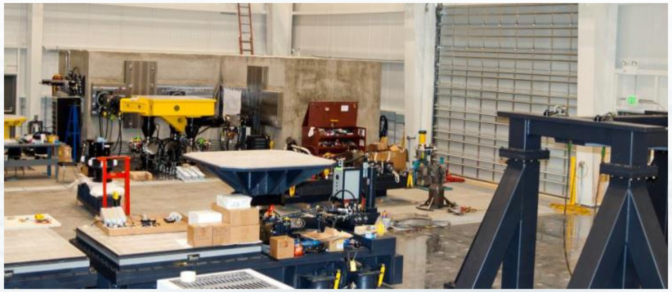
Indian Head EOD Technology Division

# NAWCWD CL Fuze Testing Capabilities

- Environmental/functional test sites to support qualification, LAT, ordnance assessment (OA), recertification and experimental testing
- Capability on-site to test AUR configurations with both multi-shaker underwing and 6DOF capabilities
- Full suite of Insensitive Munitions test facilities
- Sled test capability



# Navy Fuze S&T Thrust Areas

- Microelectronics and micro explosive trains
- 3D printed electronics and explosive components
- High-fidelity fuze testing >2000 ft/s
- Increased modeling and simulation capability
- Power sources
- Low power passive sensors
- Target detection sensors and algorithms
- Electronics packaging for extreme environment survivability

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Indian Head EOD Technology Division

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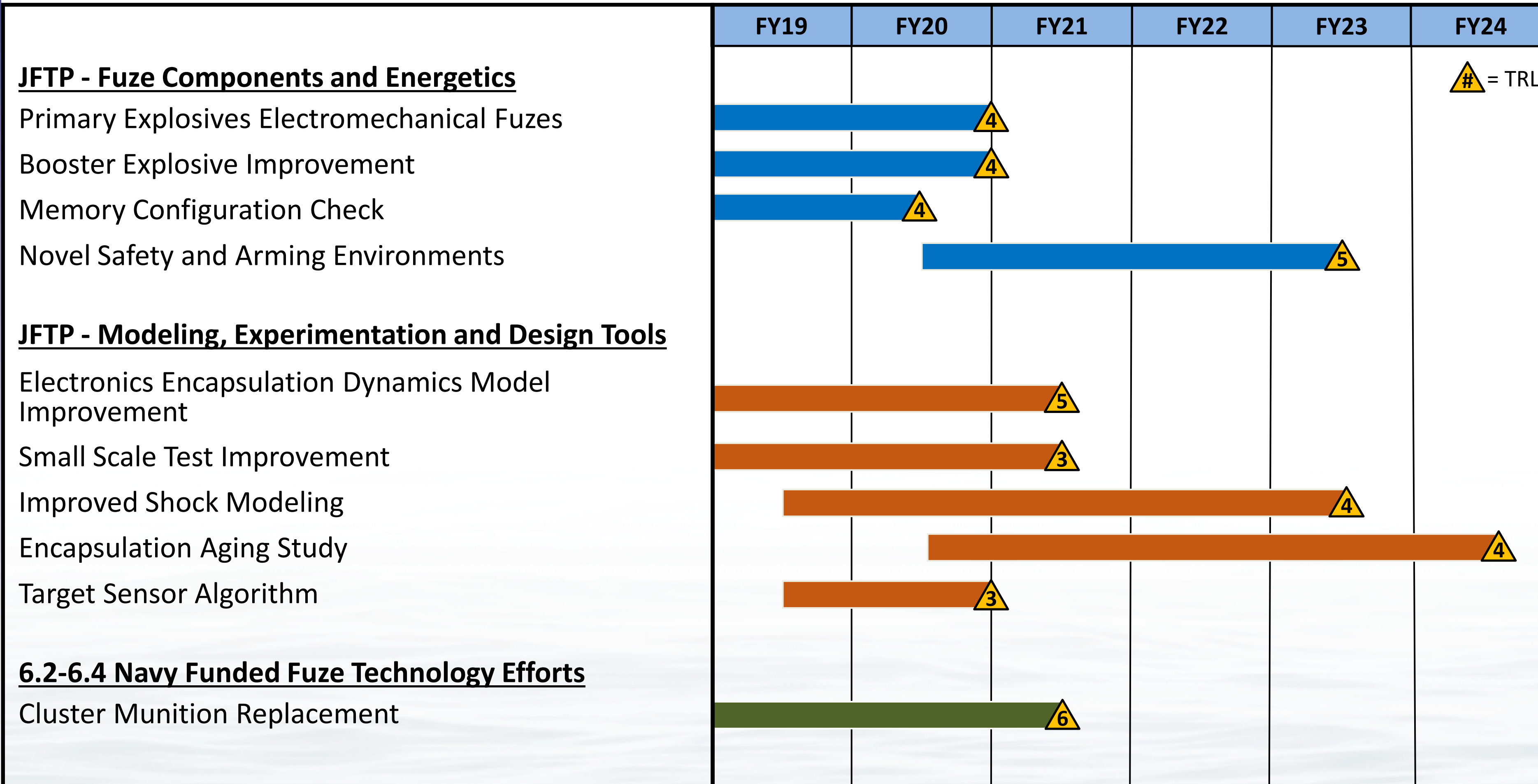
# Navy Fuze S&T Road Map

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# Navy vFuze Briefings

- Wednesday, August 5
  - 1305 to 1325: Fully Resettable MEMS Safe/Arm with Lock and Slider Position Feedback
    - Presenter: Daniel Jean, PhD

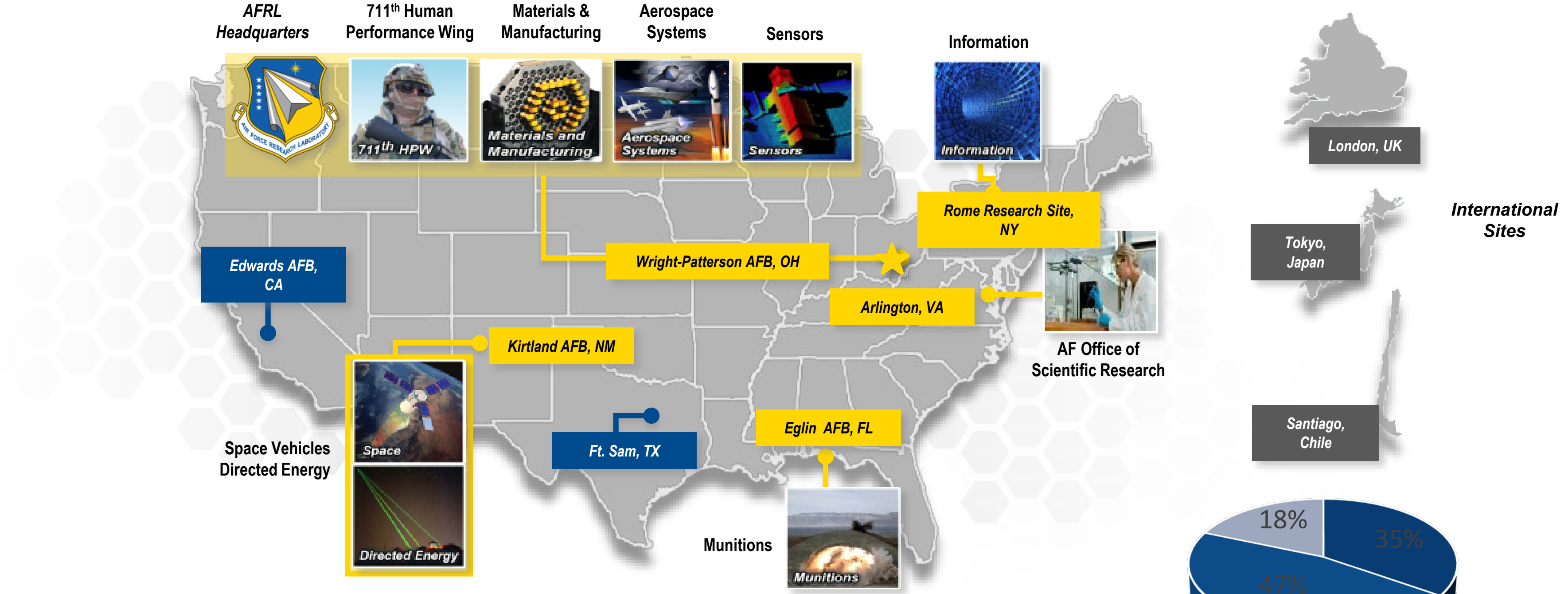
# Fuze Science and Technology Overview

63rd Annual NDIA Fuze Conference
August 4-5, 2020

George Jolly

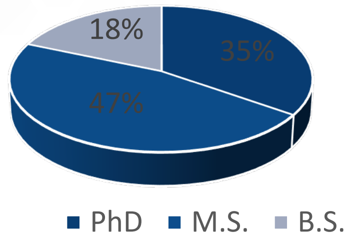
Ordnance Division, AFRL Munitions Directorate

# A World-Wide Enterprise of Researchers





| | Employees | Civilian | Military |
|---|---|---|---|
| Total | 6,254 | 5,072 | 1,182 |
| S&Es | 3,611 | 3,041 | 570 |

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# AFRL/RW
# The Munitions Directorate

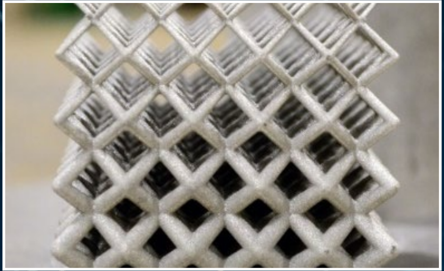
# AFRL/RW Mission

**Lead the discovery, development, integration, and transition of affordable weapons technology, enabling the warfighter to win across all domains**

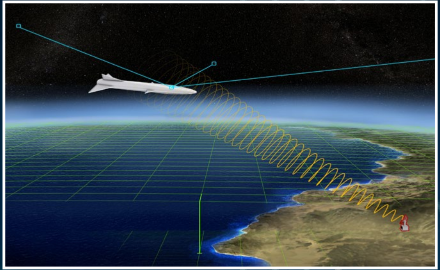
[ **Better Buying Power 3.0:**
**Achieving Dominant Capabilities through Technical Excellence and Innovation** ]

# Our Responsibility to the Warfighter

## Develop Superior Weapons Technologies That Are Effective & Affordable



3D Printed Structural Reactive Materials

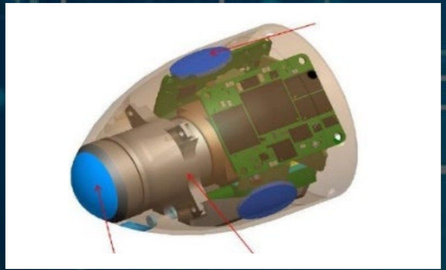


Alternative Navigation

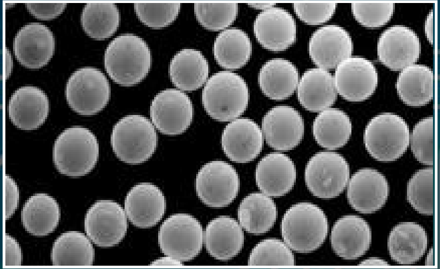
Autonomy / Networked

Selectable / Dialable Effects

Modeling & Simulation

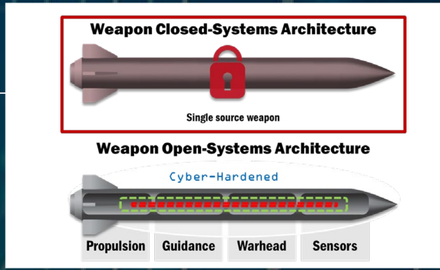


Advanced Seeker Technologies



Advanced Energetics

Stronger, Cost-Effective Metals




System Modularity

**Maturing Tech to Give Our Warfighters an Asymmetric Advantage**

# OSD(AT&L)

## Office of Land Warfare & Munitions

- Joint Munitions Program
- Joint Fuze Tech Program
- Joint Insensitive Munitions Tech Program
- Leveraging Dept. of Energy – NNSA
- Common services challenges

# International

- The Technical Cooperation Program
- Program Agreements (PA’s)
- International Cooperative Research and Development (ICR&D)
- Coalition Warfare Program (CWP)
- AFOSR Int’l Offices of Aerospace R&D

# Industry

- Open and Special BAA
- DEFENSEWERX (Doolittle)
- SBIR/STTR/STMP
- NAC – National Armaments Consortium
- IRAD - Industry Research and Development
- CRADA – Cooperative Research And Development Agreement


# Other Gov’t Entities

- DARPA
- DoD Labs
- Other
- Communities of Interest (COI)
- Joint Capability Tech Demonstration
- Quick Reaction Support
- Emerging Capability & Prototyping
- POM & Seedling Initiatives
- Joint Service MOA’s

# Academia

- AFOSR
- UARC- University Affiliated Research Center
- Centers Of Excellence
- Mathematics Modeling and Optimization Inst.
- Summer Faculty Fellowship Program
- SMART – Science, Mathematics & Research for Transformation
- AFRL Science and Technology Fellowship
- AFRL Scholars Program
- STEMM Academy

AFRL

# RWM Integrated Ordnance Integrating Concepts Fuzes

# RWM Technology Area Priorities

- **Hypersonics**
- **Selectable Effects**
- **Hard Target Defeat**
- **Air-to-Air**
- **Distributed, Collaborative, Cumulative Effects**

# Fuze S&T Decomposition - Hypersonics

- **Initiation**
  - Reliable initiation of new formulations
  - High temperature detonator and booster HE
- **Multipoint (Forward Modules)**
  - OSD funded CPS program.  SNL collaboration
  - Heavily leverages AFRL Distributed Embedded Fuze Sys (DEFS) Research
  - Focus is a single module that allows for both above and post perforation detonation.
  - Optimized location for survivability, lethality (asymmetric warhead shape), and reliability.
- **Sensors**
  - Proximity Sensor with High Temperature antenna
  - S&A Sensor
- **High Temperature Electronics**

# Fuze S&T Decomposition – Selectable Effects

- **Success and lessons learned in Dialable Effect Munition**
- **Initiation**
  - Reliable initiation of new formulations such as graded HE or Hybrid Loads
  - Dual Mode energetics
- **Multipoint (Forward Modules)**
  - DEFS
    - Selectable forward modules that perform different functions
    - Smart layer counting
- **Sensors**
  - Precision Height of Burst
  - Active Imaging
  - S&A Sensor (Replace current wind turbine generator technology)

# Fuze S&T Decomposition – Hard Target Defeat

- **Initiation**
  - Reliable initiation of advanced formulations (Cast-cure and Pressed)
  - Initiation to detonation in cellular/lattice structured warhead
  - Effective initiation of combined DE/KE mechanisms
- **Multipoint (Forward Modules)**
  - Heavily leverages AFRL DEFS Research
  - Wireless technology to accommodate internal structures and increase reliability
  - Layer/Void detection
- **Sensors**
  - S&A Sensor (same as Selectable Effects)
  - Terra sensing (non-inertial or tuned warhead)
  - Health Monitor Salvage

# Fuze S&T Decomposition – Air-to-Air

- Initiation
  - Multipoint initiation for effects
- Electronic Safe and Arm/Flight Termination and Directional Fire
- Sensors
  - Active Imaging
  - Conformal seeker/fuze antenna

# Fuze S&T Decomposition – Distributed, Collaborative, Cumulative Effects

- **Initiation**
  - Miniaturized Firesets
  - Focused Effects
- **RF Communication for Weapon Collaboration and Synchronization**
  - Data Link Radar Suite
  - Guidance Integrated Fuzing

# Questions?

# MEMS Shock Accelerometer Characterization for High-g Applications

63rd Annual NDIA Fuze Conference
August 4-5, 2020

**Presenter: Dr. Adriane G. Moura**
Applied Research Associates Inc.

**Dr. Alain Beliveau**
Applied Research Associates Inc.

**Dr. Jacob Dodson**
Air Force Research Laboratory

# Outline of Topics

- Motivation & Objective
- Background & Approach
- Experimental Setup
- Results
- Conclusions

# Motivation

- Accelerometers are essential sensors for measuring and understanding high-g environments
  - Fuze applications
    - Assess environment
    - Provide information for fuze to make decision
  - Testing/instrumentation
    - Measure shock
    - Understand environment

# Objective

- Summarize MEMS shock accelerometers high-g performance
  - Dynamic evaluation on Hopkinson bar illustrated with Kulite accelerometer

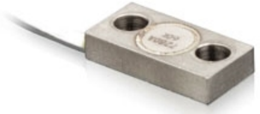
# Accelerometers of interest

**Reference Accelerometer**

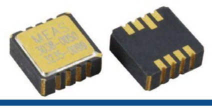
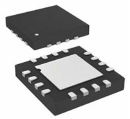
Endevco (undamped) — 7270A

**Sensors under test (SUT)**

**Traditional High-G**

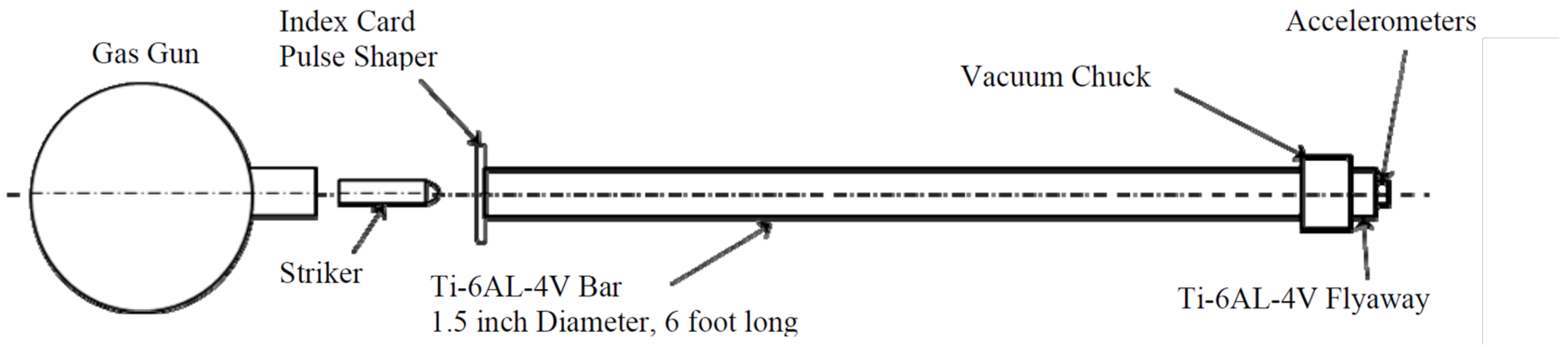
| | | |
|---|---|---|
| Endevco (damped) | *7280A*  | *7280AM4*  |
| Kulite (damped) | *GMD280*  | **60 kg$_n$** |
| PCB (damped) | *3991A10/11*  | *3501A12*  |

**Low Cost High-G**

| | | |
|---|---|---|
| TE Connectivity | *Model 3038*  | **6 kg$_n$** |
| Analog Devices | *ADXL 377*  | **200 g$_n$** |

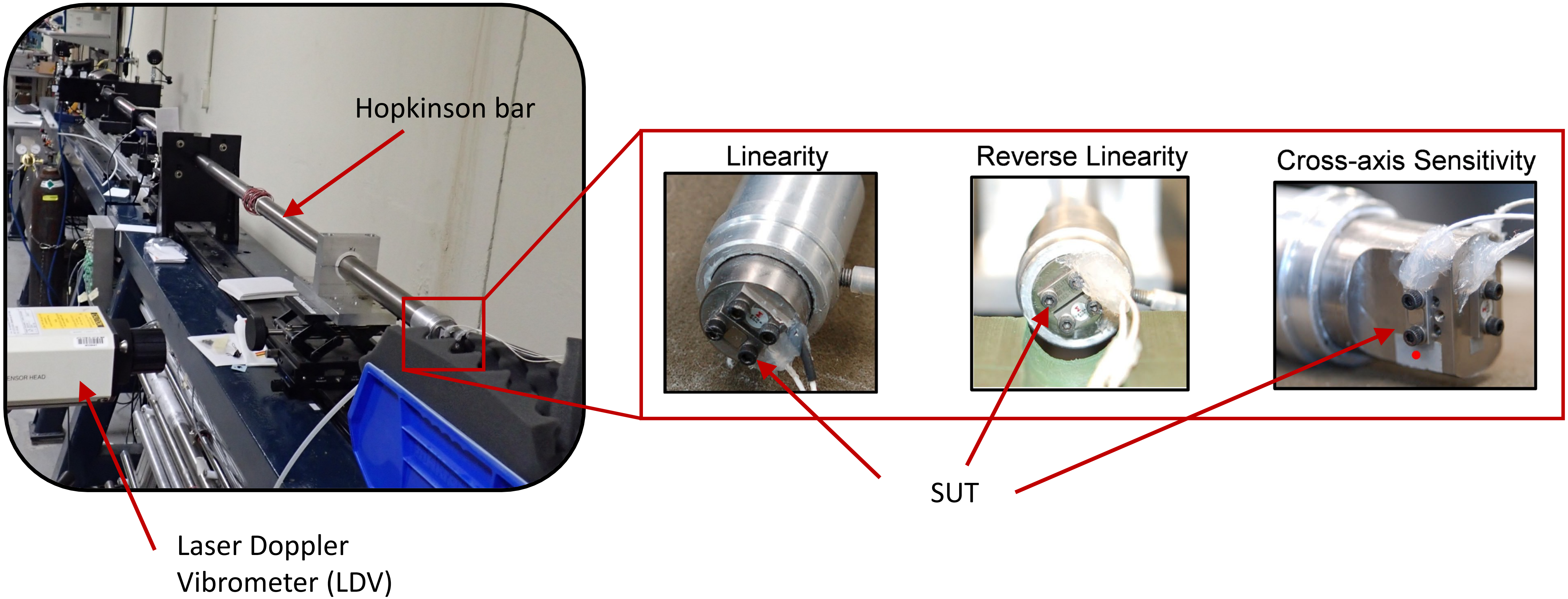
# Background and Approach

- Over the years, piezoresistive accelerometers have been preferred in the AFRL Fuzes branch
  - Surface mount
  - Two-hole screw mount
  - Stud mount
- Hopkinson Bar Approach
  - Reference acceleration was obtained from laser vibrometer (up to its limit of 20m/s) or from Endevco 7270A series
  - Accelerometers were tested in their axial and lateral orientation (when applicable)



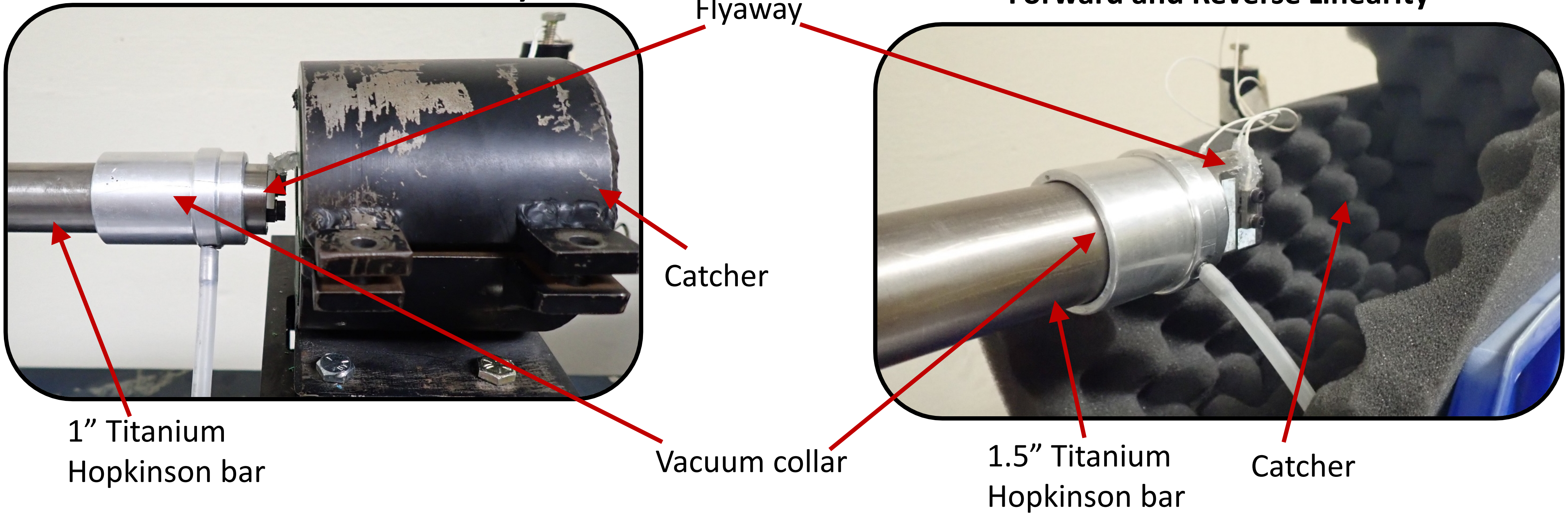
AFRL

# Experimental Setup

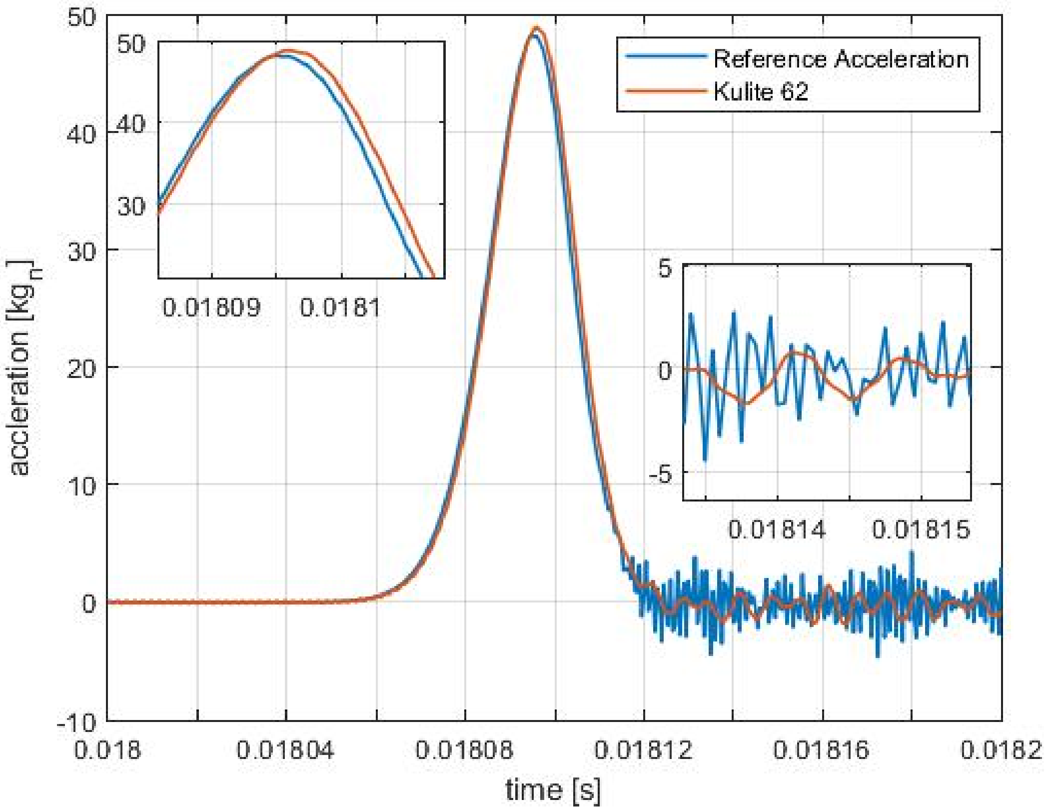


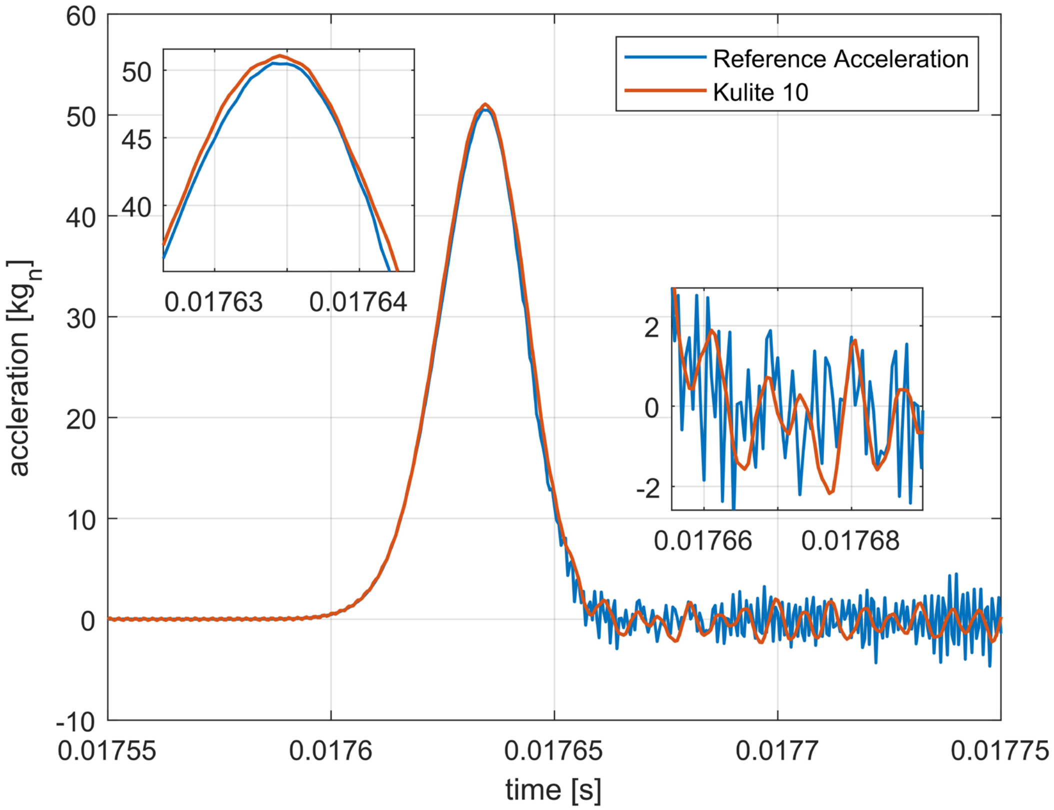
# Experimental Setup

**Forward and Reverse Linearity** **Forward and Reverse Linearity**



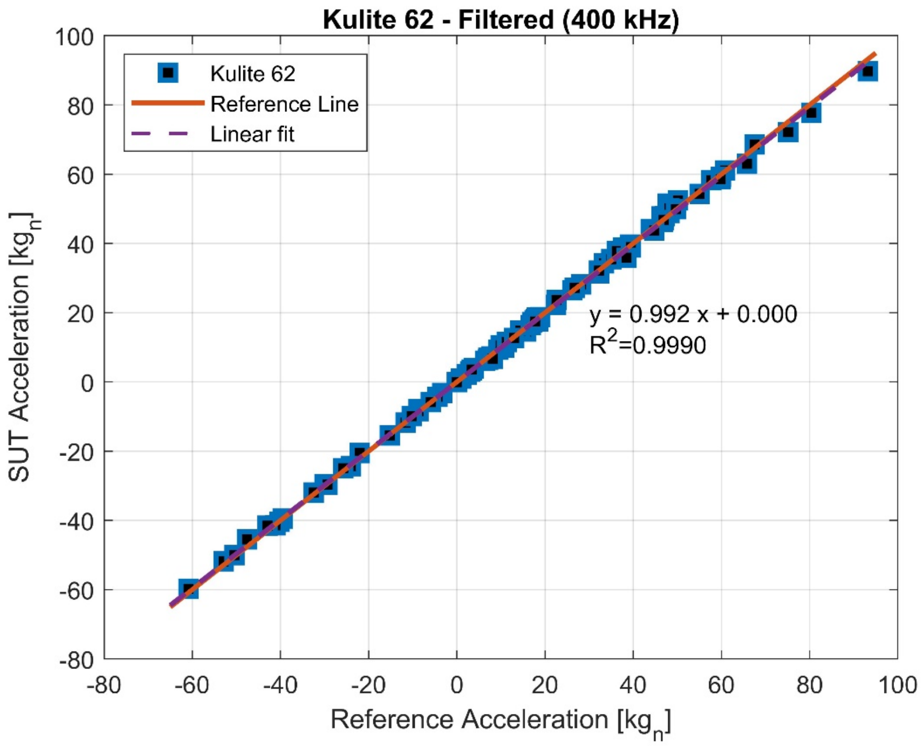
# Results – Axial Response Linearity

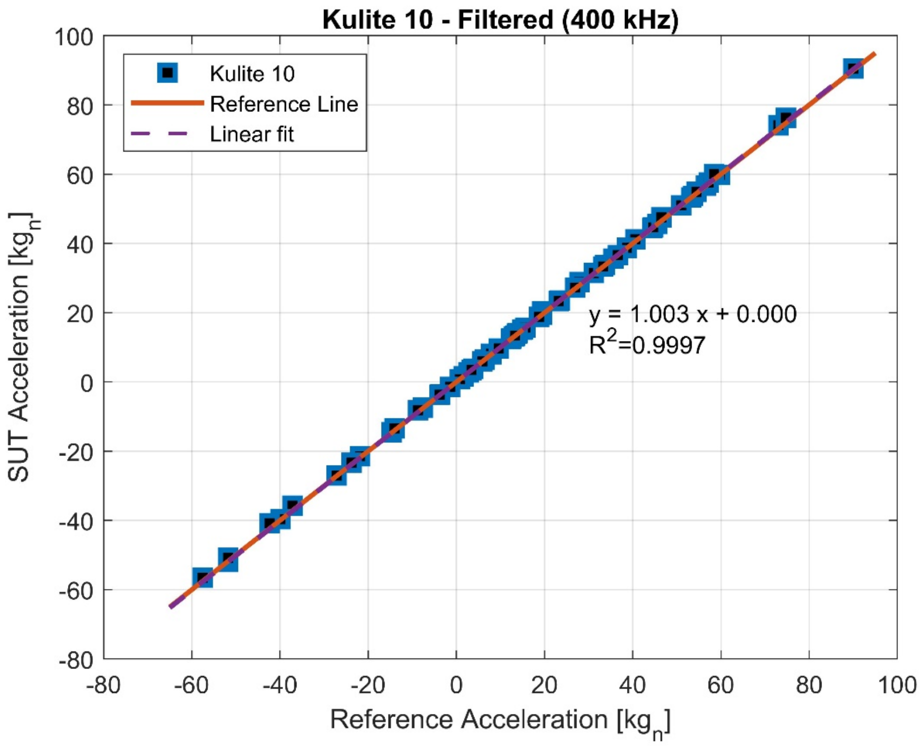



**Kulite accelerometers closely matched the reference accelerometer over the range tested**

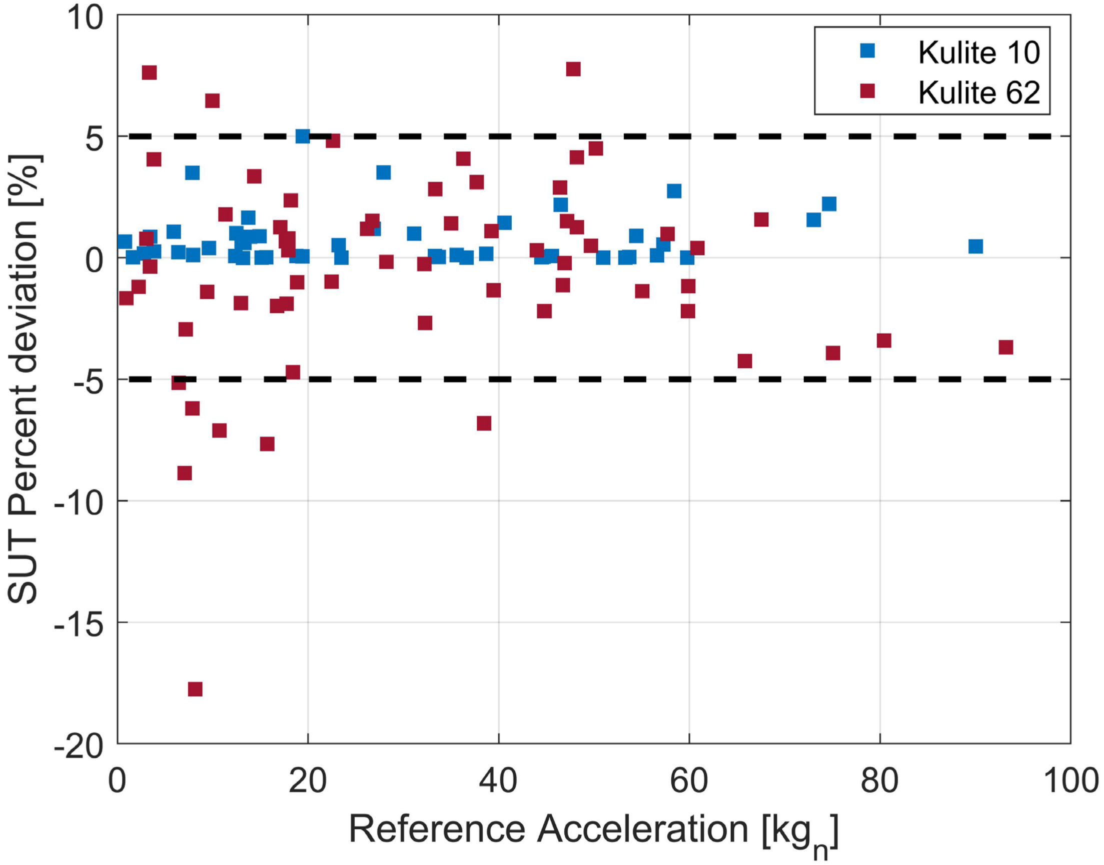
# Results – Axial Response Linearity




**Kulite sensors demonstrated linearity in forward and reverse configurations over range of use**

# Results – Axial Response Linearity




**Kulite 10 displayed a tighter bound on the linearity response over the range of tested values**

# Results – Axial Response Linearity

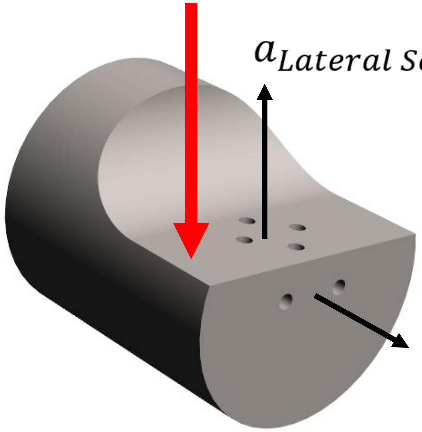
| Model | Rated acceleration | Acceleration level for >5% deviation | 5% deviation level to rated ratio |
|---|---|---|---|
| Endevco 7280A-20k [1] | 20 $kg_n$ | ~ 45 $kg_n$ | ~ 2.25 |
| Endevco 7280A-60k [1] | 60 $kg_n$ | ~ 70 $kg_n$ | ~ 1.17 |
| Endevco 7270AM4-20k | 20$kg_n$ | - | - |
| Endevco 7270AM4-60k [1] | 60 $kg_n$ | > 60 $kg_n$ | > 1 |
| PCB 3991A10-20kg [1] | 20 $kg_n$ | ~ 35 $kg_n$ | ~1.75 |
| PCB 3991A10-60kg [1] | 60 $kg_n$ | > 70 $kg_n$ | > 1.17 |
| PCB 3501A12-20kg | 20 $kg_n$ | - | - |
| PCB 3501A12-60kg [1] | 60 $kg_n$ | > 65 $kg_n$ | > 1.08 |
| Kulite GMD-280-60KG (10) | 60 $kg_n$ | >90 $kg_n$ | > 1.5 |
| Kulite GMD-280-60KG (62) | 60 $kg_n$ | >90 $kg_n$ | > 1.5 |
| Analog Devices ADXL 377 – 200g | 200 $g_n$ | - | - |
| TE Connectivity Model 3038 – 6000g | 6 $kg_n$ | >8.5 $kg_n$ | >1.4 |

[1] Beliveau, A., Hong, J., Foley, J., Coker, J., Glikin, N., "COTS Piezoresistive Shock Accelerometers Performance Evaluation," *Proc. SAVIAC 83rd Shock and Vibration Symposium*, New Orleans, LA, November, 2012.

# Results – Cross-Axis Sensitivity

$$a_{Laser} = a_{Transverse} + a_{Poisson}$$

$$a_{Lateral\ Sensor} = a_{Transverse} + a_{Poisson} + a_{Cross-axis}$$



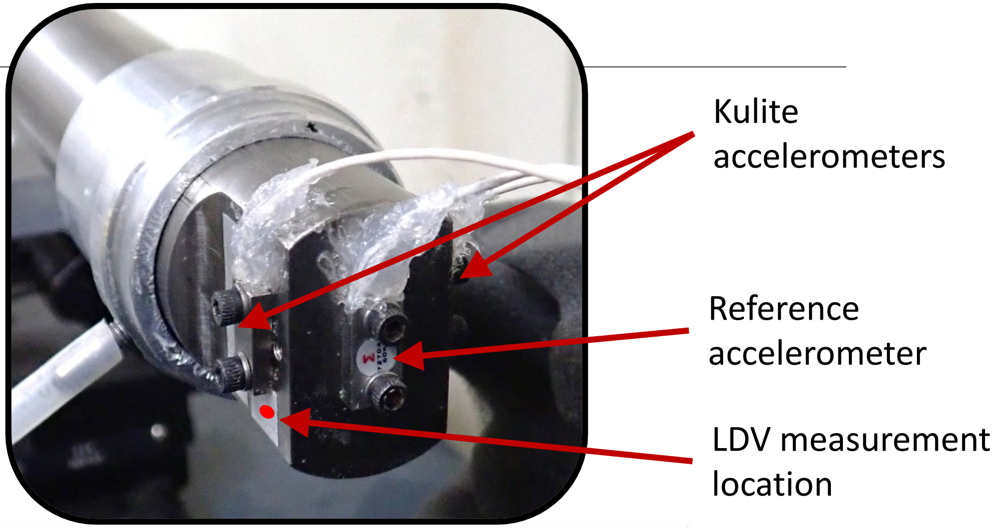
$a_{axial}$

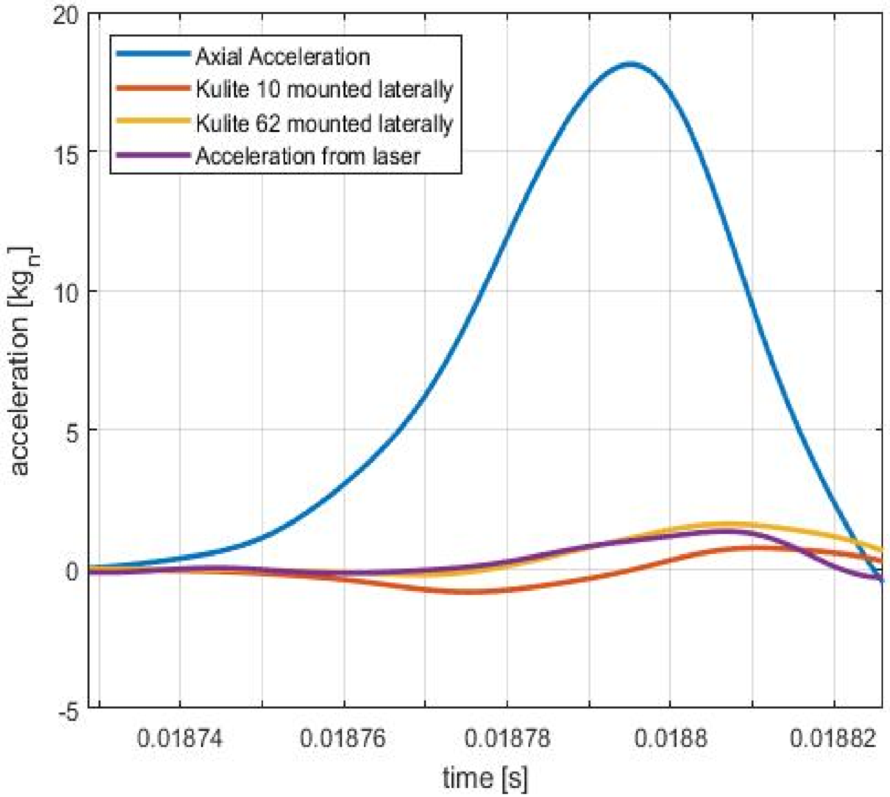
$$a_{Cross-axis} = a_{Lateral\ Sensor} - a_{Laser}$$

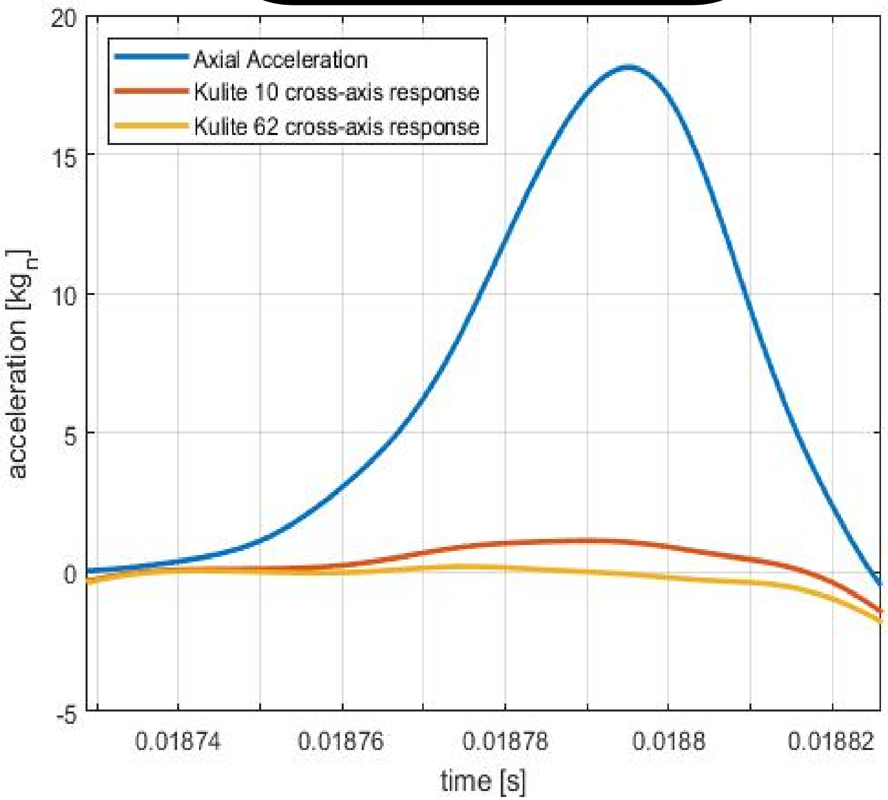
$$Cross\ axis\ Sensitivity = \frac{a_{cross-axis}}{a_{axial}} \times 100$$

# Results Cross-axis sensitivity

| | Horizontal → | Vertical → |
|---|---|---|
| Kulite 8514-9B-62 | 7.91% | 2.65% |
| Kulite 8514-9B-10 | 13.67% | 6.58% |



# Results – Cross-Axis Sensitivity

| Model | Cross-axis sensitivity (long side) | Cross-axis sensitivity (short side) |
|---|---|---|
| Endevco 7280A-20k [1] | 3% ± 1% | 5% ± 2% |
| Endevco 7280A-60k [1] | 5% ± 1% | 5% ± 2% |
| Endevco 7270AM4-20k | - | - |
| Endevco 7270AM4-60k [1] | - | - |
| PCB 3991A10-20kg [1] | 4% ± 1% | 3% ± 1% |
| PCB 3991A10-60kg [1] | 5% ± .5% | 3% ± 2% |
| PCB 3501A12-20kg | - | - |
| PCB 3501A12-60kg [1] | - | - |
| Kulite GMD-280-60KG (10) | 13.67% | 6.58% |
| Kulite GMD-280-60KG (62) | 7.91% | 2.65% |
| Analog Devices ADXL 377 – 200g | 2.2% | - |
| TE Connectivity Model 3038 – 6000g | - | - |

[1] Beliveau, A., Hong, J., Foley, J., Coker, J., Glikin, N., "COTS Piezoresistive Shock Accelerometers Performance Evaluation," *Proc. SAVIAC 83rd Shock and Vibration Symposium*, New Orleans, LA, November, 2012.

# Frequency Response

- **Power Spectral Densities**
  - Auto spectral densities

$$G_{XX}(\omega) = \sum_{i=1}^{n} X^{i}(\omega) X^{i*}(\omega)$$

$$G_{YY}(\omega) = \sum_{i=1}^{n} Y^{i}(\omega) Y^{i*}(\omega)$$

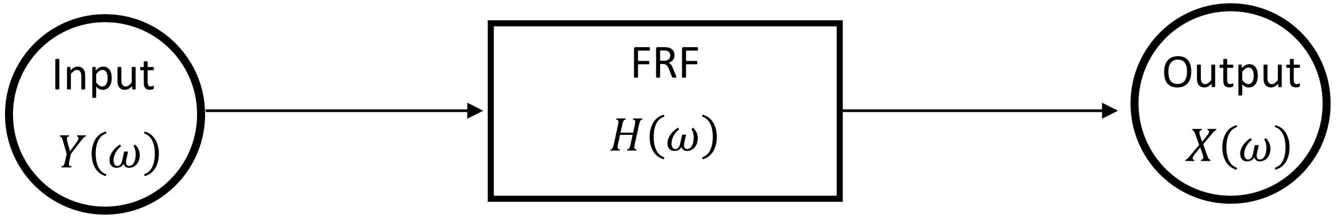
  - Cross spectral densities

$$G_{XY}(\omega) = \sum_{i=1}^{n} X^{i}(\omega) Y^{i*}(\omega)$$

$$G_{YX}(\omega) = \sum_{i=1}^{n} X^{i*}(\omega) Y^{i}(\omega)$$

# Frequency Response

- Frequency Response Function (FRF)




$$H(\omega) = \frac{X(\omega)}{Y(\omega)} \quad \text{or} \quad H(\omega) = \frac{H_1(\omega) + H_2(\omega)}{2}$$

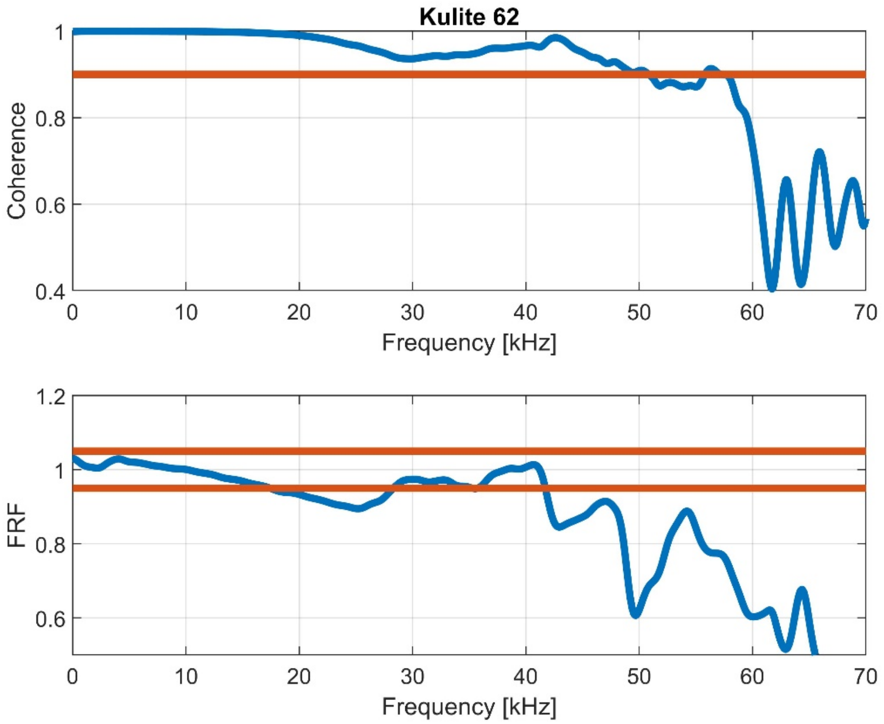
where $H_1(\omega) = \frac{G_{XY}(\omega)}{G_{YY}(\omega)}$

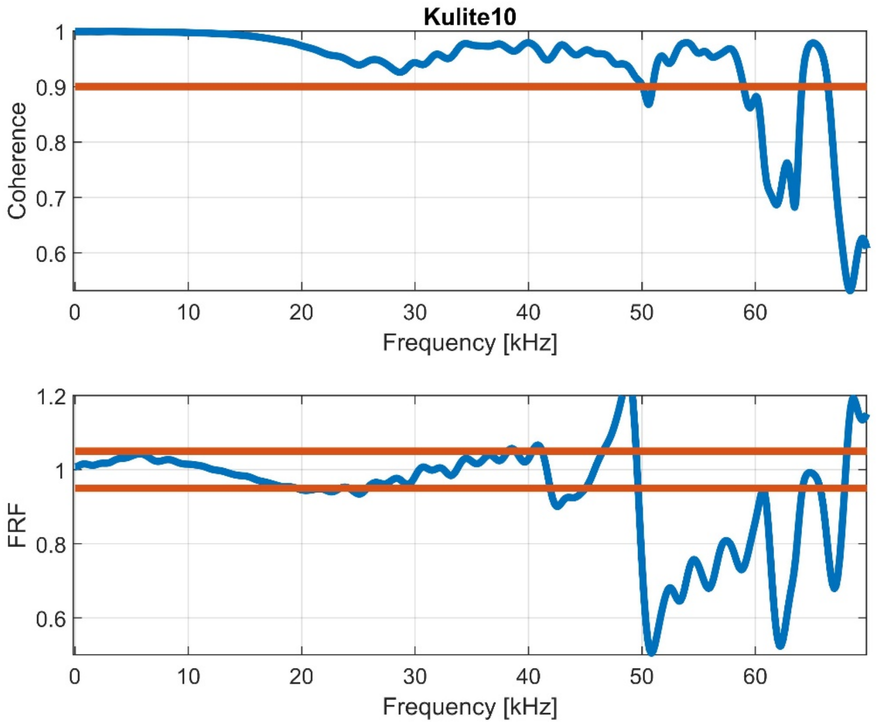
and $H_2(\omega) = \frac{G_{XX}(\omega)}{G_{YX}(\omega)}$

- Coherence

$$\gamma_{XY}^2(\omega) = \frac{G_{XY}(\omega)G_{YX}(\omega)}{G_{YY}(\omega)G_{XX}(\omega)}$$

# Kulite Frequency Response and Coherence




90% coherence: up to ~51 kHz
FRF Linearity: up to ~17.5kHz

90% coherence: up to ~50 kHz
FRF Linearity: up to ~19.5 kHz

# Results – Frequency Response Function

| Model | FRF < 1dB |
|---|---|
| Endevco 7280A-20k [1] | 20 kHz |
| Endevco 7280A-60k [1] | 15 kHz |
| Endevco 7270AM4-20k | - |
| Endevco 7270AM4-60k [1] | - |
| PCB 3991A10-20kg [1] | 20 kHz |
| PCB 3991A10-60kg [1] | 20 kHz |
| PCB 3501A12-20kg | - |
| PCB 3501A12-60kg [1] | - |
| Kulite GMD-280-60KG (10) | 19.5 kHz |
| Kulite GMD-280-60KG (62) | 17.5 kHz |
| Analog Devices ADXL 377 – 200g | - |
| TE Connectivity Model 3038 – 6000g | 2.5 kHz |

[1] Beliveau, A., Hong, J., Foley, J., Coker, J., Glikin, N., "COTS Piezoresistive Shock Accelerometers Performance Evaluation," *Proc. SAVIAC 83rd Shock and Vibration Symposium*, New Orleans, LA, November, 2012.

# Conclusions

- All evaluated accelerometers are linear to more than their rated measurement
- The cross-axis sensitivity is <5% for most traditional accelerometers
- Most traditional accelerometers have a bandwidth of ~15kHz while the low cost accelerometer has a bandwidth of ~2.5 kHz

Future work

- Study affects of mounting in surface mount accelerometers
- Cross-axis evaluation of surface mount accelerometers

# Acknowledgements and References

Acknowledgments:

Mr. John Scaduto, PI of 19-G-013  Commercial Off the Shelf (COTS) Accelerometer as Impact Switch, for sourcing of low cost accelerometers.

References:

[1] Beliveau, A., Hong, J., Foley, J., Coker, J., Glikin, N., "COTS Piezoresistive Shock Accelerometers Performance Evaluation," *Proc. SAVIAC 83rd Shock and Vibration Symposium*, New Orleans, LA, November, 2012.

# Questions?

# U.S. ARMY COMBAT CAPABILITIES DEVELOPMENT COMMAND – ARMAMENTS CENTER

## Developments in Metal MEMS Latching, Setback Sensing Mechanisms

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Mechanical Engineer

U.S. Army CCDC - Armaments Center, Fuze Division





04 AUG 2020

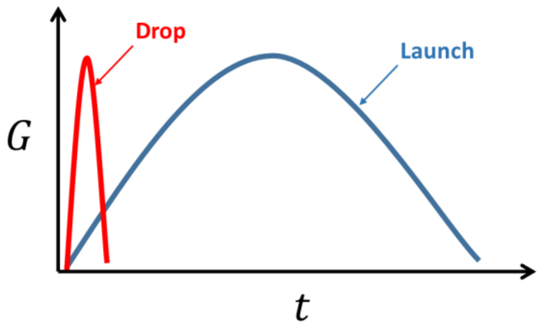
# Project Background

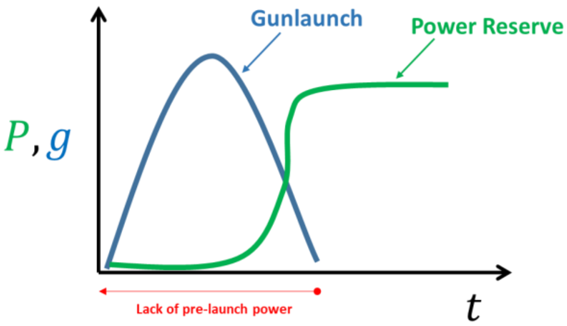
Fuze Community Need and MEMS Design Process

# HISTORY

- **The Army fuzing community has a need for a high-G, un-powered latching sensor**
  - Distinguish between valid gun launch, and the vibration and mechanical shock exposures of the tactical environment

- **Electronic Safe and Arm Devices (ESAD)**
  - Need for a mechanical sensor within the fuze electronics that can record and report whether or not a true gun launch has occurred
  - There can be no powered launch-detecting sensors because the ESAD battery takes time to power up
  - What is needed is an unpowered mechanical switch that could detect launch (and reject handling drops) by latching during the no-power phase and that could then be queried later when the fuze circuit and ESAD wants to function

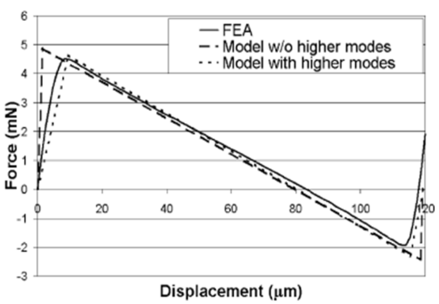


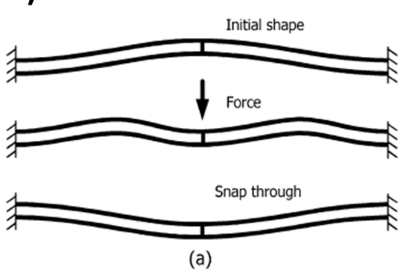
# MEMS DESIGN

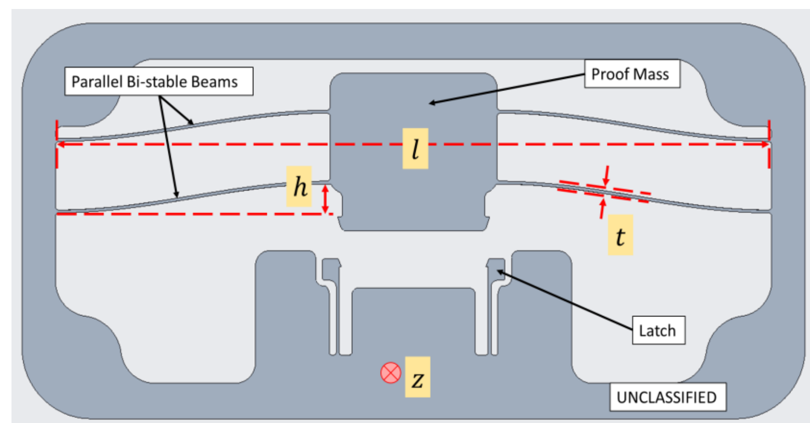
- **Bi-stable mechanism in a curved parallel beam design**
  - A minimum force threshold required to actuate a 'snap-through' effect. Forces greater than this threshold will result in an unrecoverable 'snap-though' of considerable distance
  - The force to actuate this mechanism can be estimated from: $F_{snap-thru} = \mathrm{C} * \frac{Etz^3h}{l^3}$
  - This design includes latching barbs to catch the proof mass

a)




b)

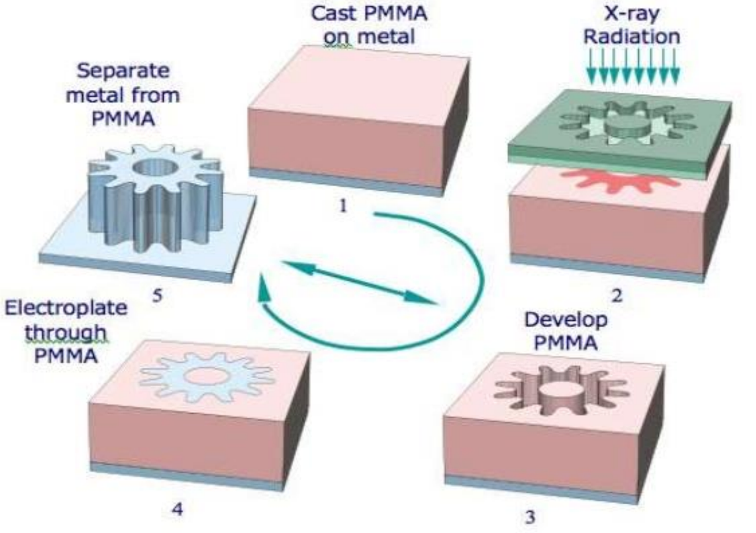


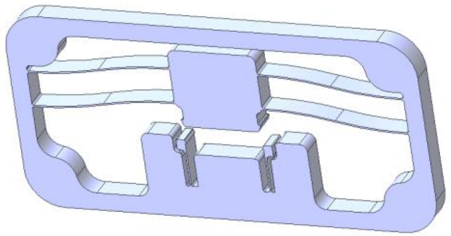

  - Design size is roughly 3mm x 6mm, with a thickness of less than 0.5mm

# LIGA FABRICATION PROCESS

- **Precise lithography**
  - A sensitive polymer is bonded to an electrically conductive substrate
  - Allows dimensional control of micro-sized geometrical features
  - Ability to fine tune the geometry to the appropriate ‘snap-through’ force
- **HT MicroAnalytical**
  - Fabricated 5 variant wafers of the MEMS switch design.
  - Used a LIGA MEMS foundry with an electroplated Nickel alloy material




LIGA Processess

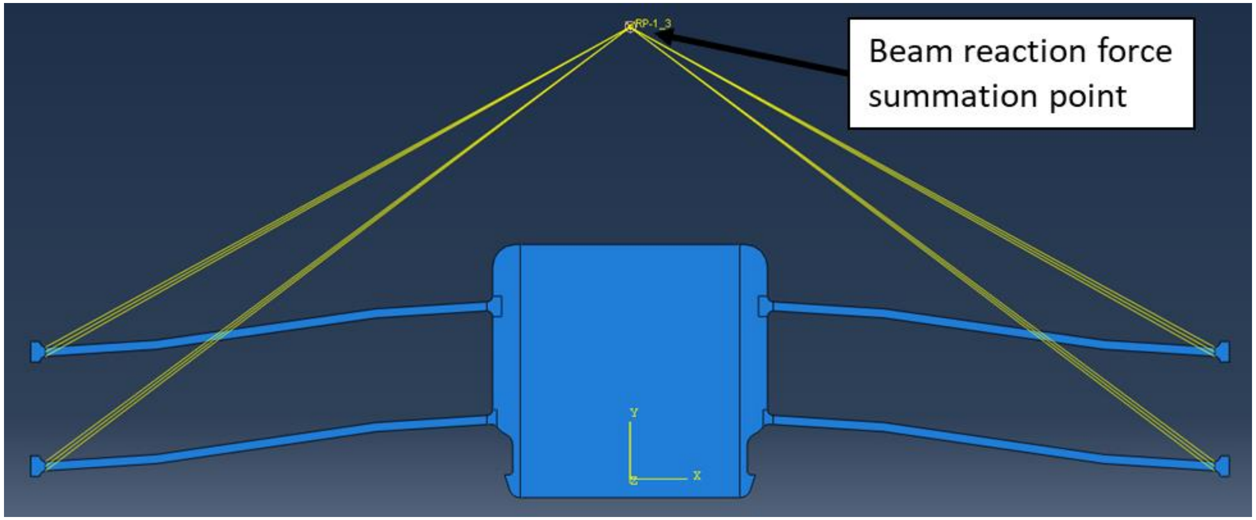


# Mechanical Characterization

Numerical, Analytical & Experimental Testing

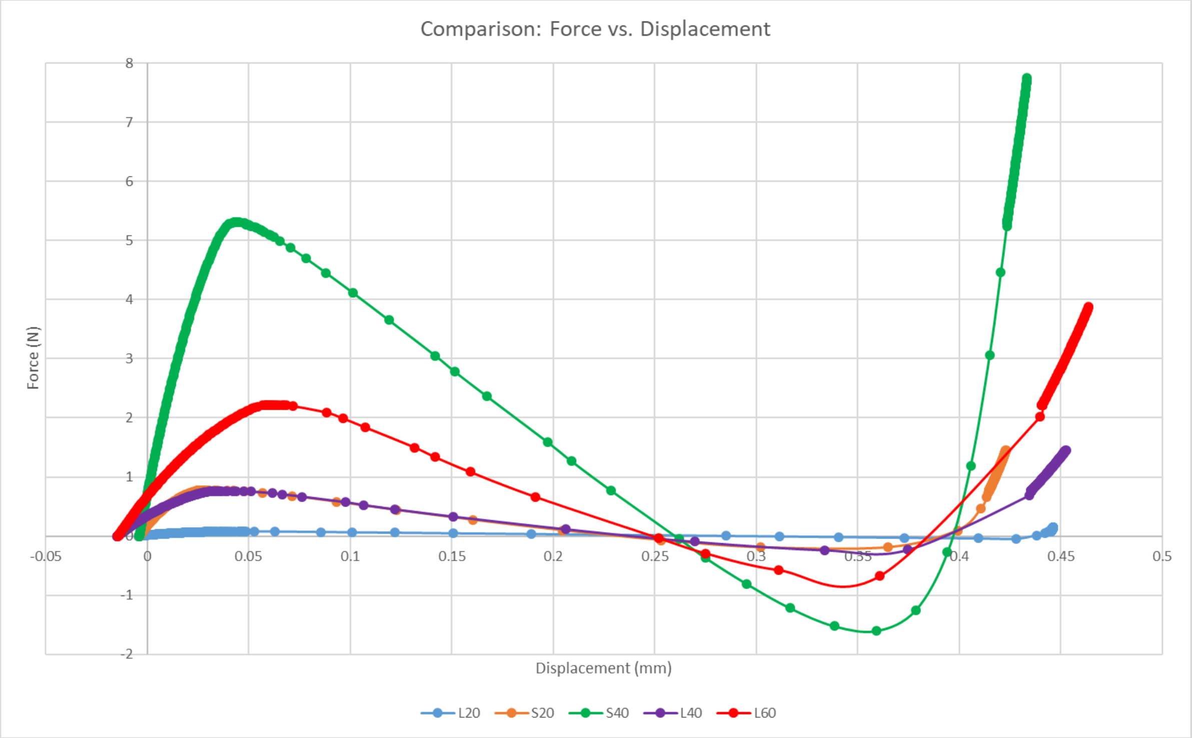
# FINITE ELEMENT ANALYSIS - SETUP

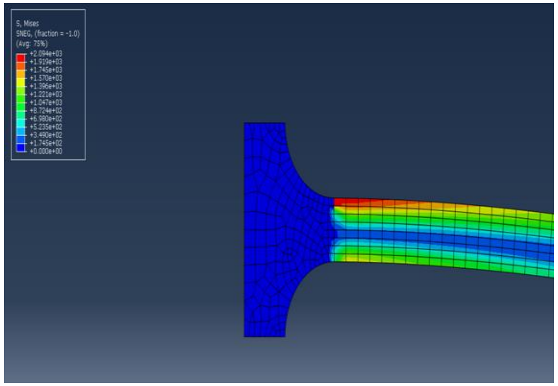
- **Abaqus 2018 was used to extract the static closure force of the five switch variants**
  - Symmetry of the switches in the z-direction, a homogeneous shell section was utilized
  - To extract the total reaction force from the system into a graph, a reference point was created above the switch and was coupled to the ends of the four beams
  - The displacement of a single node at the bottom of the switch mass was also extracted into a graph
  - The applied shell edge load varies between each design; Static, elastic analysis



# FINITE ELEMENT ANALYSIS - RESULTS

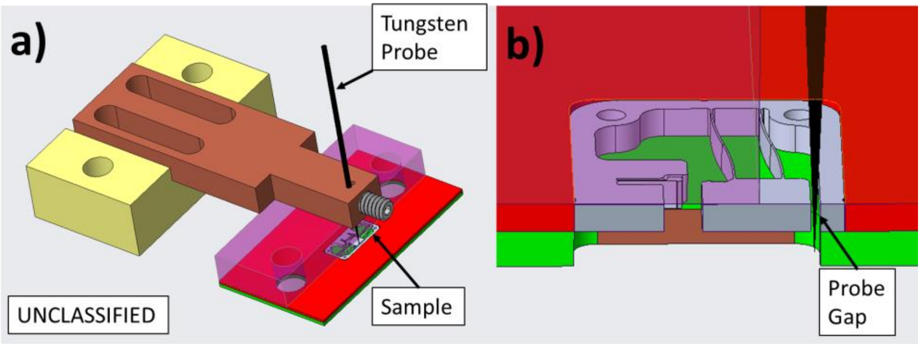
- **Switch variant comparison**
  - Combining the two curves from the history output allows the creation of the Force vs. Displacement graph for each switch design
  - The location of the max von Mises stress for each design is shown to be located at the top surface of the beam's edge furthest from the central mass

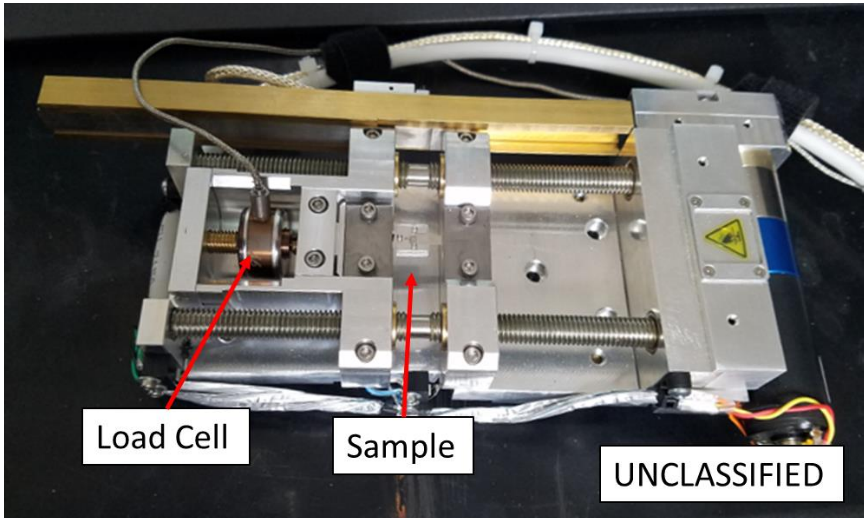


# TENSILE TEST - SETUP

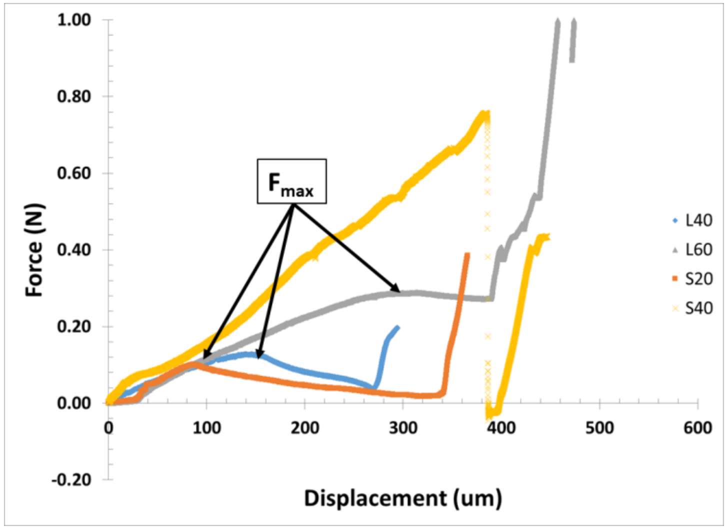
- **Displacement-controlled miniature tensile test apparatus (MTIfullam SEMtester)**
  - A sub-mm tungsten probe was used to engage and actuate the proof mass of the latching switch
  - After the probe made contact with the sample proof mass and the load was zeroed, the test apparatus was operated at 25.4 µm/s until the test was stopped. The load cell recorded the force at 1000 Hz
  - The overall system spring constant of the parallel beam structure, K, can be extracted from the linear region of the F vs displacement slope before the snap-thru actuation has occurred

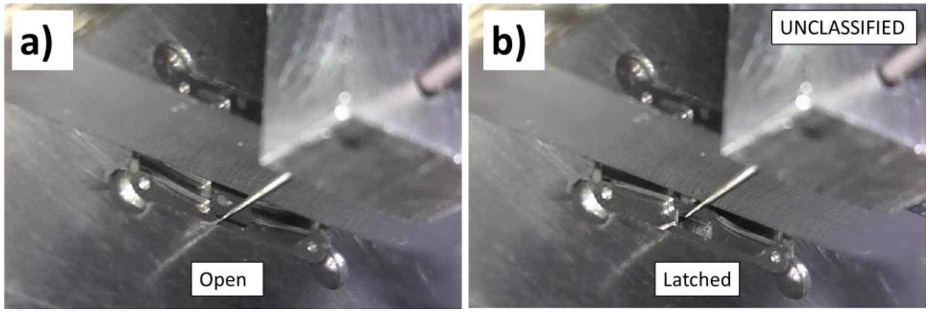


# TENSILE TEST - RESULTS

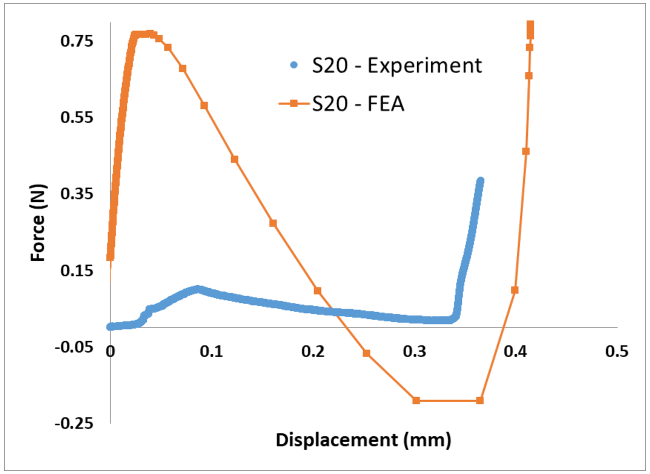
- **Four of the five designs (S20, S40, L40, and L60) were evaluated with the MTS tensile test apparatus**
  - The Force vs. Displacement plot includes key features such as the linear ramp up of force to $F_{max}$ at which point the force "snaps-thru" and decreases to a force minimum
  - The S40 switch had a larger strength than the bending stiffness of the tungsten probe and the probe was bent or curled before the snap-thru event

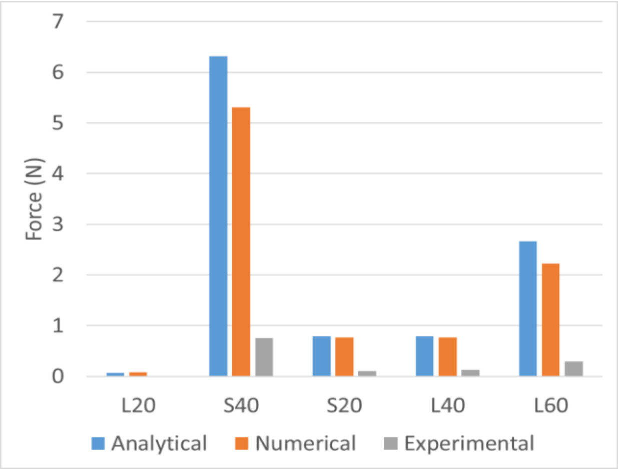


# ANALYSIS RESULTS COMPARISON

- **The bi-stable nature of the MEMS switches was observed in both experiment and simulation**
  - The numerical analysis (FEA) matches quite closely with the analytical analysis. The experimental response is systematically lower in all cases
  - There was visual evidence that during tensile tests the bi-stable latches did not rapidly snap-thru as expected but simply tracked the motion of the tungsten pin as the force was applied
  - Doubling the beam width (t) of the switch increased the force to snap-thru. Halving the beam length (l) resulted in a similar increase



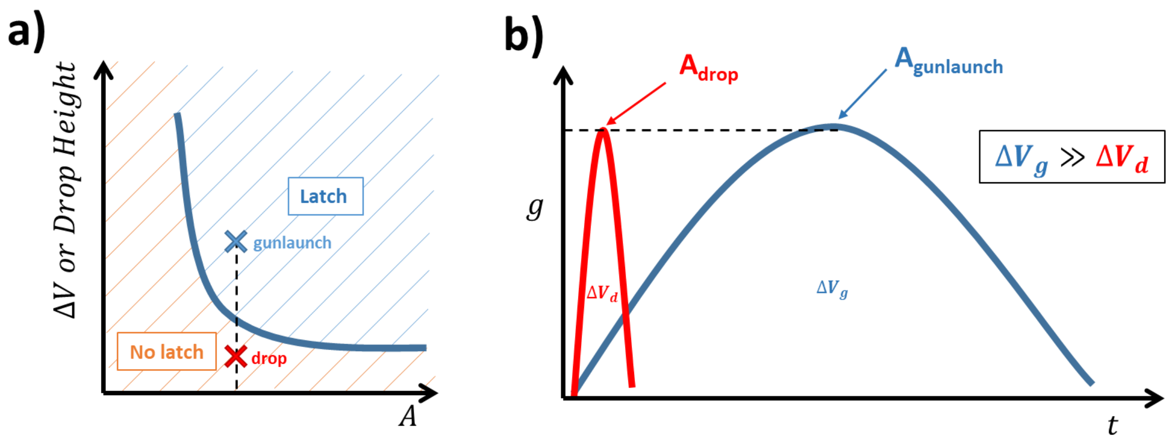



# Sensitivity Characterization

Drop Environment & Airgun Testing

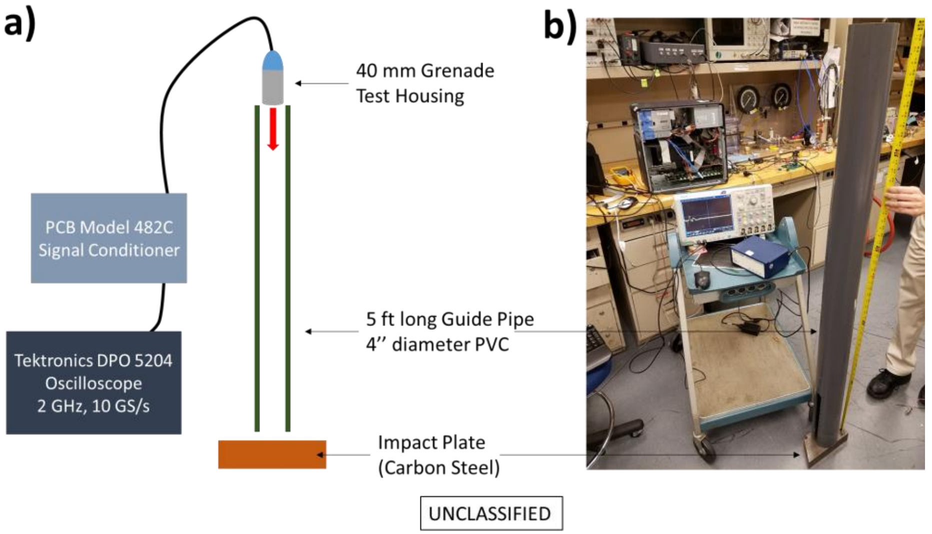
# SENSITIVITY GRAPHS

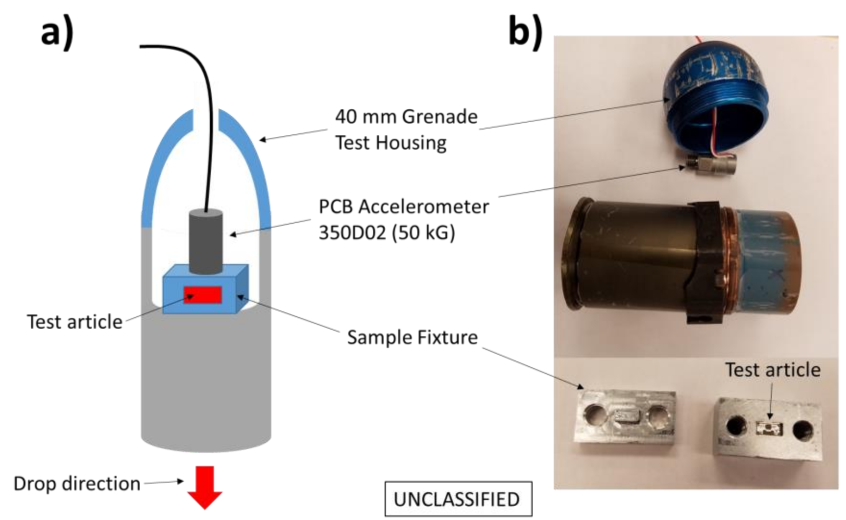
- **Show thresholds for drop height or corresponding change in velocity ($\Delta V$) for a munition that impacts a surface base down**
  - This sensitivity curve predicts whether a spring-mass system will latch or not latch for a given acceleration amplitude ($A$) of known pulse duration
  - The geometric variations in each design determine the shape and location of the sensitivity curve



# DROP TESTING - SETUP

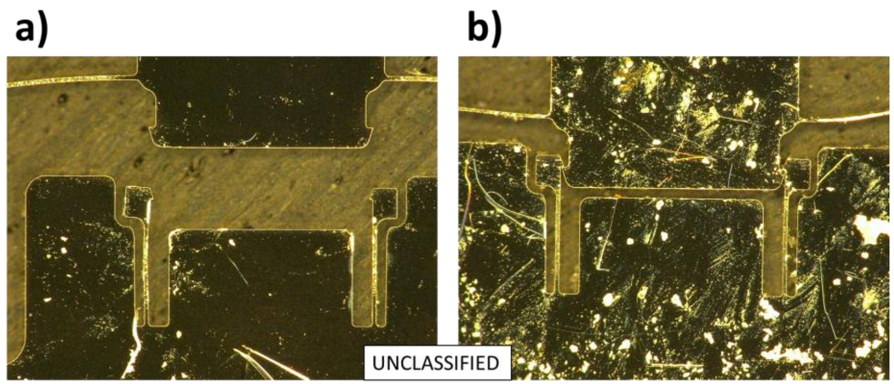
- **Design**
  - 4 inch diameter, 5 foot long PVC tube was used to guide drop fixture onto the impact surface
  - 40 mm grenade drop fixture
  - 2 inch thick steel plate was used as the impacting surface
  - a 9 foot drop was used to evaluate stiffer spring design iterations
  - oscilloscope was triggered to measure and record the first few hundred microseconds following impact



# DROP TESTING - RESULTS

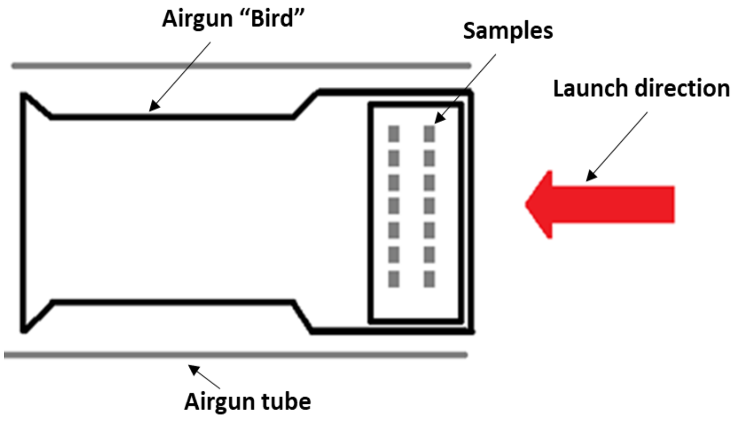
- **Component Testing**
  - The average peak acceleration experienced under 5 foot drop is calculated to be 14,720 g's for the test setup.
  - After each drop, the test fixture was carefully disassembled to inspect the latching status of the LIGA MEMS mechanism
  - L20 was found to frequently latch under a 5 foot drop
  - Other designs did not latch in a 5 foot drop and were then subjected to a more severe drop environment of 9 feet




| Drop Height (feet) | Version | Average Half Sine Peak Duration (s) | Average Max g's | Latched | % |
|---|---|---|---|---|---|
| 5 | L20 | 8.2E-05 | 16,680 | 6/9 | 66.7% |
| 9 | S40 | 7.7E-05 | 22,760 | 0/4 | 0% |
| 9 | S20 | 8.3E-05 | 21,150 | 0/4 | 0% |
| 9 | L40 | 8.6E-05 | 12,480 | 0/8 | 0% |
| 9 | L60 | 7.8E-05 | 16,980 | 0/4 | 0% |

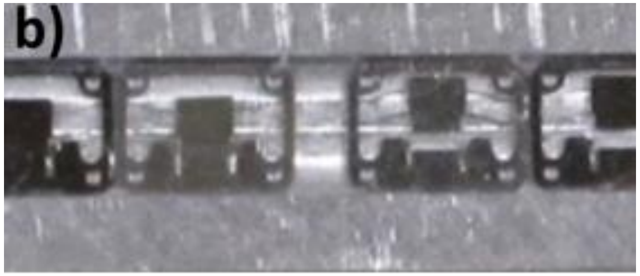
# AIRGUN TESTING - SETUP

- **155mm air cannon**
  - Switch fixture was oriented so that the setback from the airgun was the only force acting on the switches
  - Fixture housed 4 variants of the switch design
  - The bird itself with the fixture weighed a total of 24 lbs and was launched at a pressure of 18,150 psi

# AIRGUN TESTING - RESULTS

- **The bird experienced a max of 15,100 g’s**
  - All four of the L40 switches latched while three of the four S20 switches latched. The S40 and L60 switches remained unlatched
  - After the airgun test was completed, the test fixture was carefully disassembled to inspect the latching status of each switch



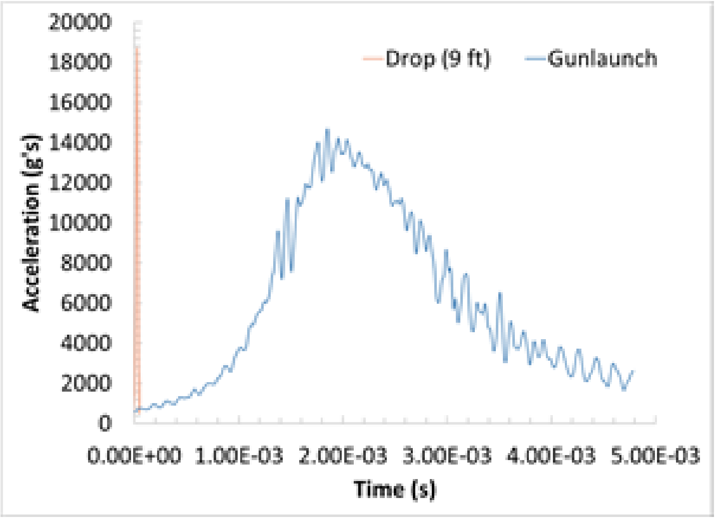

| Airgun Peak Pressure (psi) | Version | Half Sine Peak Duration (s) | Max g's | Latched | % |
|---|---|---|---|---|---|
| - | L20 | - | - | - | - |
| 18,150 | S40 | 3.7E-03 | 15,120 | 0/3 | 0% |
| 18,150 | S20 | 3.7E-03 | 15,120 | 3/4 | 75% |
| 18,150 | L40 | 3.7E-03 | 15,120 | 4/4 | 100% |
| 18,150 | L60 | 3.7E-03 | 15,120 | 0/3 | 0% |

# TESTING COMPARISON

- **Drop vs. Airgun**
  - Demonstrated that certain designs of the bi-stable latching mechanism would latch in airgun environments would not latch in 9-ft drop environments
  - The acceleration amplitude ratio (drop:gunlaunch) is typically 1:1 while the pulse duration ratio can be as much as 1:45

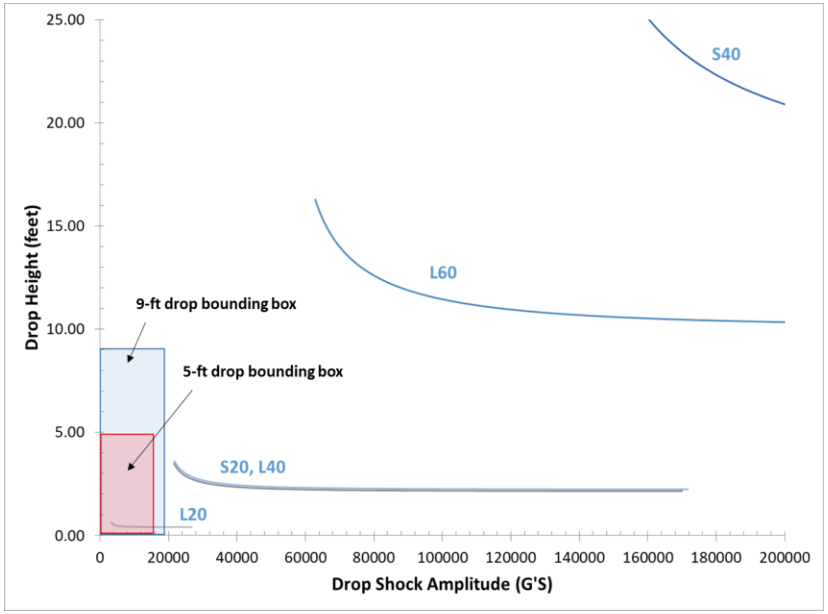
| Version | 5-ft drop | 9-ft drop | Airgun |
|---|---|---|---|
| L20 | 67% | - | - |
| S40 | - | 0% | 0% |
| S20 | - | 0% | 75% |
| L40 | - | 0% | 100% |
| L60 | - | 0% | 0% |

a)



# CONCLUSIONS

- **Resultant Sensitivity Curves**
  - The S20 and L40 sensitivity curves predict that these designs are on the marginal edge of latching in 9-ft drop environments.
  - The L60 and S40 designs are sufficiently stronger and would require a much larger amplitude shock and pulse duration to latch
  - The implications of this work are that these bi-stable mechanisms may be useful in munitions packages that have higher g-level acceleration profiles



# PATH FORWARD

- **DTIC Reports Currently in Review Process**
  - "Analysis of LIGA MEMS Parallel Beam, Bi-stable Latching Metallic Mechanisms - Part 1 - Mechanical Characterization (in preparation)," DTIC, Picatinny Arsenal, 2019. J. R. Smyth, K. M. O'Connor and A. DeSantis

  - "Analysis of LIGA MEMS Parallel Beam, Bi-stable Latching Metallic Mechanisms - Part 2 - Sensitivity Characterization (in preparation)," DTIC, Picatinny Arsenal, 2019. J. R. Smyth, A. Warne, K. M. O'Connor, A. DeSantis and S. Genberg

- **Joint Fuze Technology Program (JFTP) - Project**
  - 21-G-035 6.2 Time Integrating Miniature Setback Switch (TIMSS)
    - Time-integrating features (like a ZigZag) would enable functioning in a less high-g sensitivity range

    - Similar testing of designs using three different manufacturing methods:

      - MEMS-based planar technique
      - micro-Electric Discharge Machining (µ-EDM) planar technique
      - micro additive manufacturing (AM, 3D printer) three dimensional technique

# Questions?

# REFERENCES


- J. R. Smyth, K. M. O'Connor and A. DeSantis, "Analysis of LIGA MEMS Parallel Beam, Bi-stable Latching Metallic Mechanisms - Part 1 - Mechanical Characterization (in preparation)," DTIC, Picatinny Arsenal, 2020.

- J. R. Smyth, A. Warne, K. M. O'Connor, A. DeSantis and S. Genberg, "Analysis of LIGA MEMS Parallel Beam, Bi-stable Latching Metallic Mechanisms - Part 2 - Sensitivity Characterization (in preparation)," DTIC, Picatinny Arsenal, 2020.

Australian Government
Department of Defence
Capability Acquisition and
Sustainment Group

# Fuze Incident, Shoalwater Bay, Australia 2014

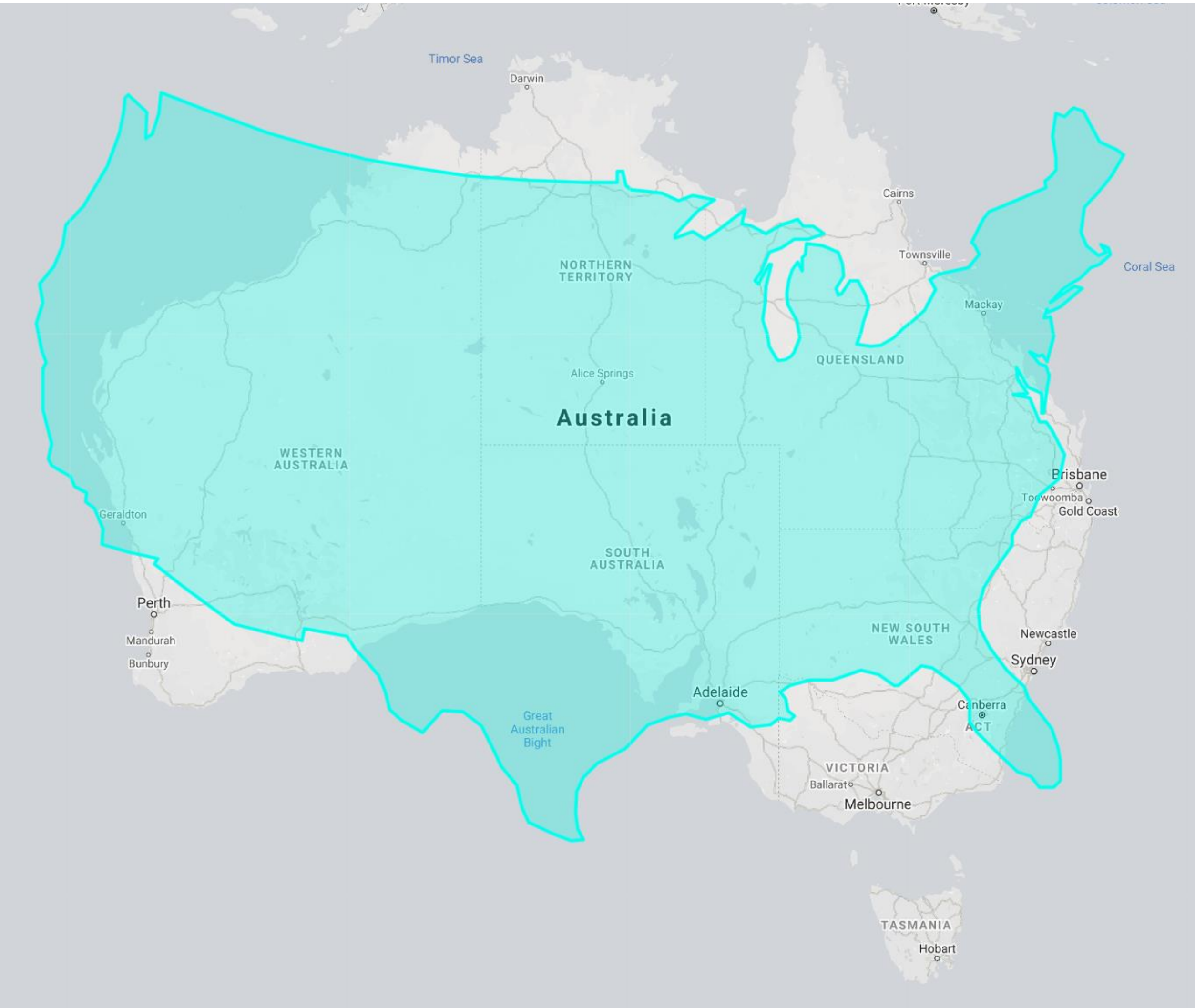
**Mr Bernard Smith-Roberts**
Engineering System Manager

# Contents

- Shoalwater Bay Incident, 18 March 2014
- Investigation and Inspector General ADF Inquiry
- Incident Context
- Incident Outcomes
- Lessons Learned
- Questions

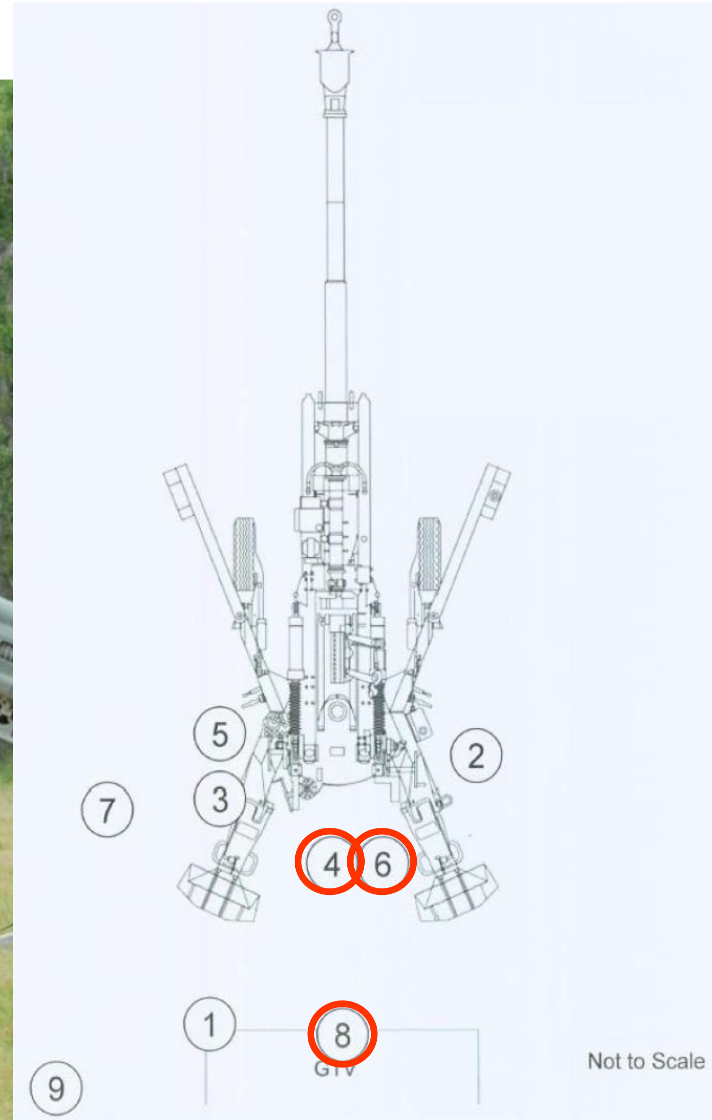
# Shoalwater Bay location

# Shoalwater Bay location



# Shoalwater Bay Incident Scene

# Shoalwater Bay Incident Scene

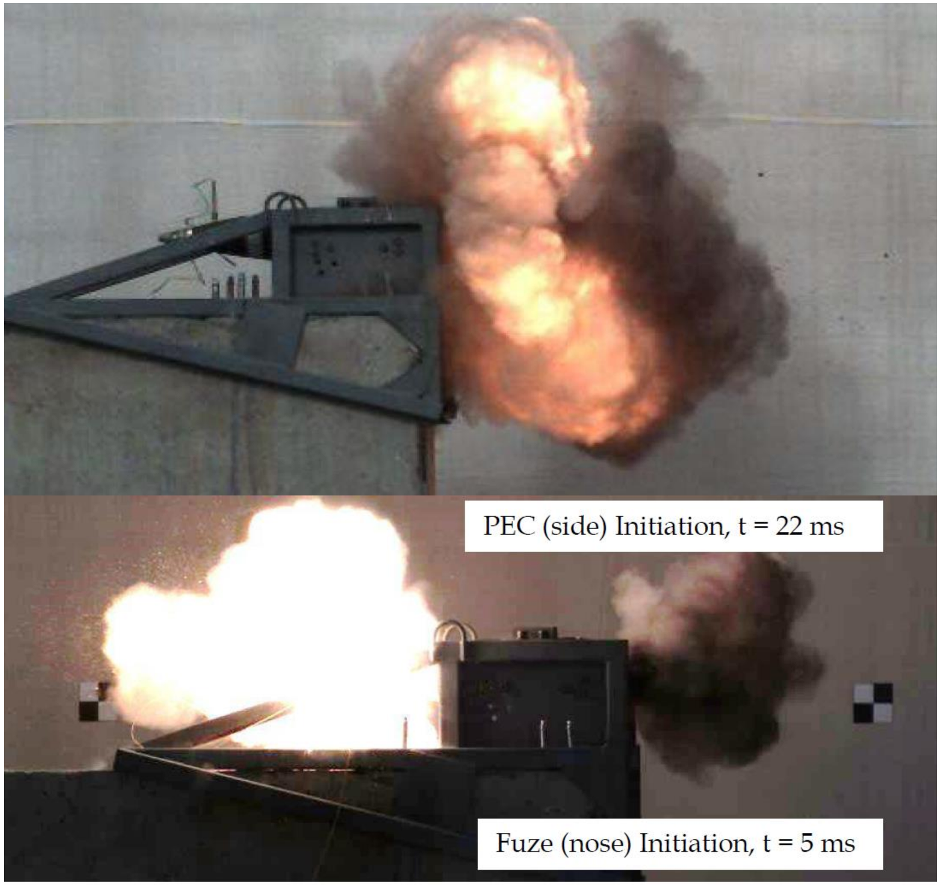


# Investigation and Inspector General ADF Inquiry

- ADF Investigative Service (ADFIS) launched investigation, and separate Chief of Defence Force directed Inquiry by Inspector General ADF (IGADF)
- ADFIS investigation focused on what had happened; Inquiry on systemic issues - how this happened
- Australian Defence Science and Technology Group (DST Group) contributed technical investigation under ADFIS investigation

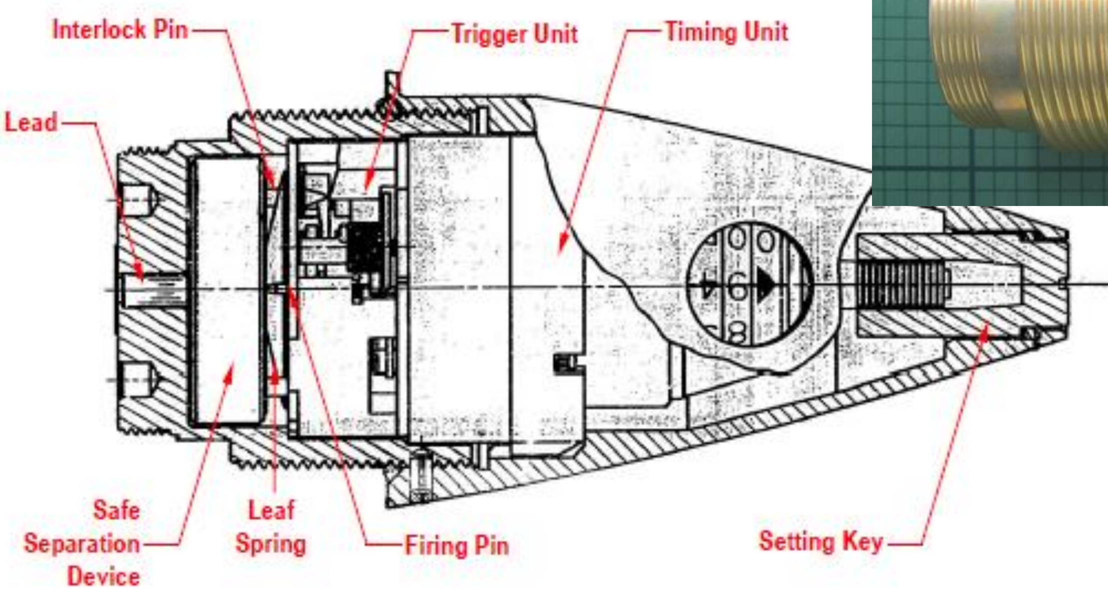
# DST Investigation Findings

- Investigated all AUR elements based on Fault Tree Analysis (FTA)
- Expelling charge and fuze became the focus through this approach
- Analysis of forensic data, compared to experimental results narrowed the cause to a failure within the fuze

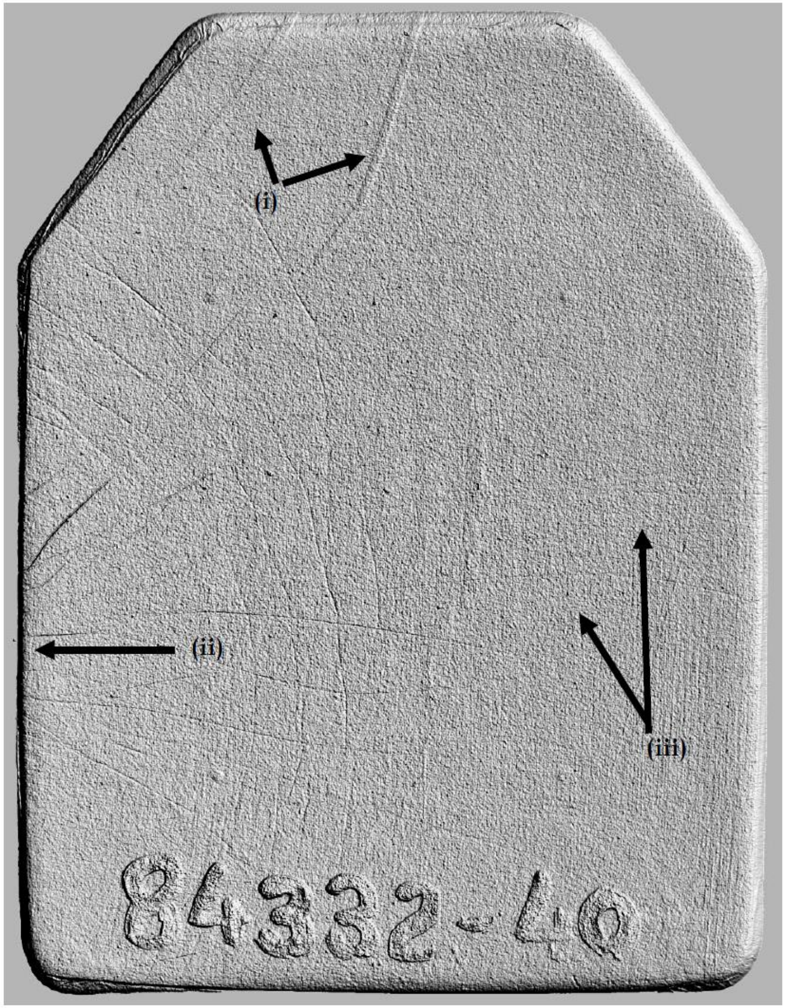


# DST Investigation Findings

- **Cause** - Fuze assembled with SSD in the armed state
- Set-forward on ramming drive SSD into fixed firing pin, initiating the projectile

# DST Investigation findings




# Inquiry Findings

- Produced 24 recommendations
  - From high-level systemic (EO Safety Program)
  - Review process of life extensions and surveillance
  - EO accident response methods
  - Wearing of PPE during training (based on DST investigation)
- Recommended implementation international accepted practice standards (MIL-STD-1316 and STANAG 4187)
- Recommended assessment of current fuze inventory against these standards
- Apportioned no blame on unit involved – failures systemic.

# Incident Context

- This system was assessed against requirements, risk associated with lack of malassembly feature identified as low likelihood but high consequence
- Many other similarly categorised risks that drowned out important message
- System for introduction into service (including fuze assessment) at the time was very compliance and template focused

# Incident Context

- Australia is a tech follower (especially for complex systems)
- Aus effort is in understanding suitability of a design for our context, not developing design
- Aus applies STANAG 4187 and MIL-STD-1316 and associated AOPs/MIL-STDs
  - As assessment standards, not design standards
- No in-depth Fuze Subject Matter Expertise

# Context - Global Supply Chain

## Outcomes

- Three fundamental outcomes
  1. Subject fuze removed from service and slated for disposal;
  2. Assessment conducted of fuze inventory;
  3. Systemic changes to manner in which we acquire and sustain explosives
     - Associated with introduction of Australian Workplace Health and Safety Act 2011
     - Movement to principles-based approach – understand important risks, and communicate them

# Outcomes – Fuze Disposal

- Large body of effort to dispose of extant stock of these fuzes fitted to obsolescent 105mm All Up Rounds (AUR)
- As they may be in the armed state (and extremely sensitive to impact stimulus) challenge to handle them safely for disposal
- large program in partnership with Australian munitions disposal industry to remotely process and interrogate the safe/arm state of the fuzes after removal from the AUR  in support of safe disposal

# Outcomes – Fuze Disposal

# Outcomes – Fuze Inventory Audit

- Aus embarked on a body of effort to understand fuze inventory, consider against international best practice standards
- Still ongoing in mortar space, but completed for artillery and maritime
- Allowed sensible decisions to be made about which natures were kept in service, which were retired, and whether certain acquisition programs needed to be accelerated.

# Outcomes – Systemic Changes

- change to the manner in which we conduct IIS and assess risk – previous approaches led to the critical concerns (e.g. lack of malassembly feature) being lost in the noise of many high consequence-low likelihood risks
- Moved to a system to communicate critical information more explicitly – what do the services care about?
- Supported by systemic changes to put focus on risk technology areas – fuzing included
- Some efforts to re-establish fuze testing capability to conduct AOP-20 and MIL-STD-331 tests.

# Outcomes – fuze test capability development

# Lessons Learned

- Have a good understanding of the systems we purchase – smart customer!
  - Effective application of international best-practice standards
- Lack of Independent fuze suitability advice – addressed by mandated Regulator Engagement
- Re-establish deep technology area expertise – bootstrap upwards

# Lessons Learned

- Acquiring necessary information during procurement – procurement methodology
- Test capability/capacity can be expensive to establish and conduct, but allows independent determination of suitability
  - Assurances of compliance from manufacturers don’t necessarily guarantee that a system is compliant
- Engagement with international fuze community
- Modernisation of Australian fuzing fleet  - expensive!

# Questions

## Contact

Mr Bernard Smith-Roberts, Engineering System Manager

bernard.smith-roberts@defence.gov.au

# U.S. ARMY COMBAT CAPABILITIES DEVELOPMENT COMMAND – ARMAMENTS CENTER

## ARMY Fuze S&T Overview at the 63rd NDIA Fuze Conference

Nicholas Malinoski

Fuze and Precision Armaments Directorate, Fuze Division





Distribution Statement A: Approved for Public Release Distribution Unlimited

# AGENDA

Organization

Facilities

Fuze S&T Overview

– Current Investment Areas

–Ongoing Projects

–Thrust Areas

Collaboration Opportunities

63rd Annual Fuze Conference Presentations

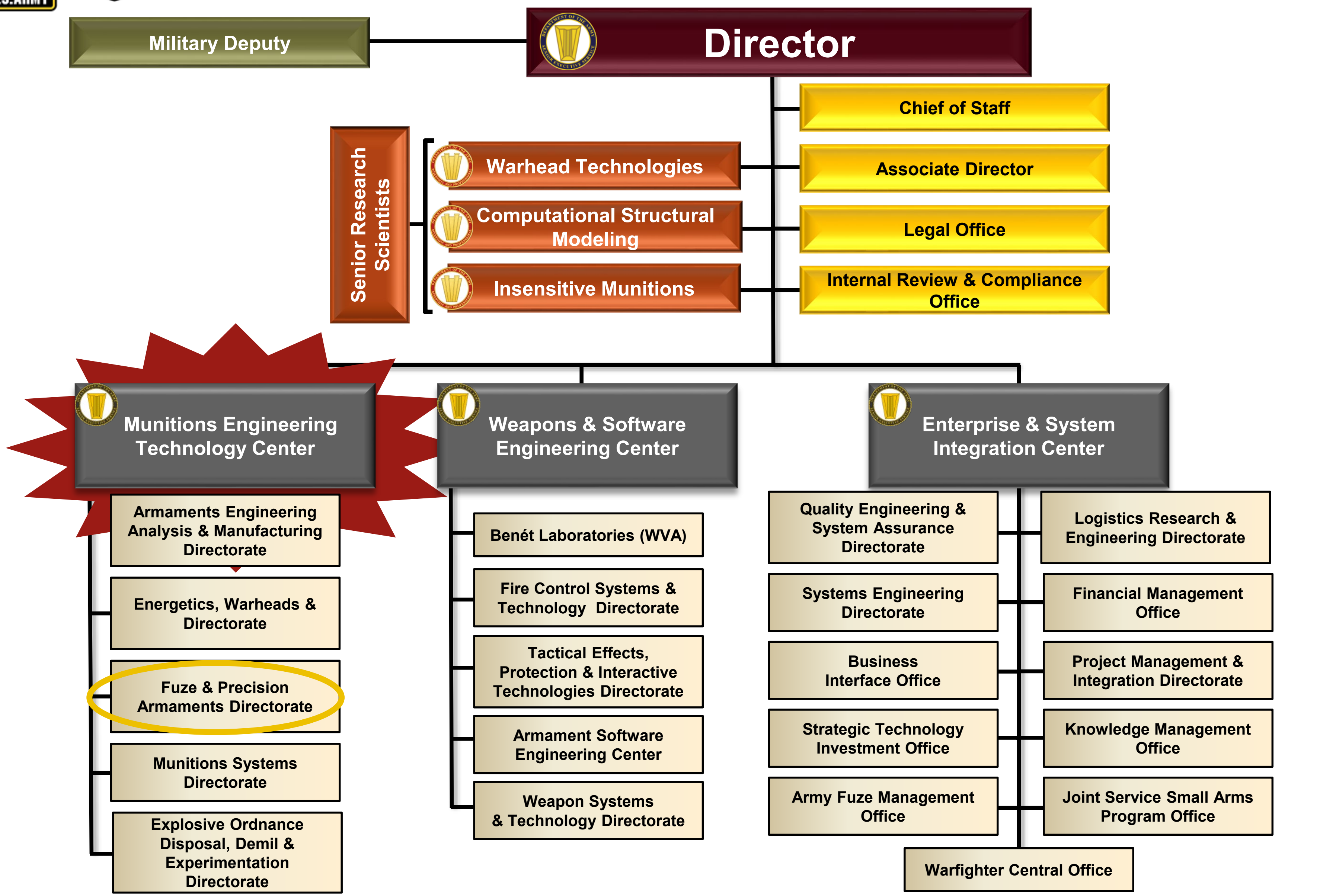
# ARMY FUTURES COMMAND ORGANIZATION

**Army Futures Command**
**AFC Commanding General**

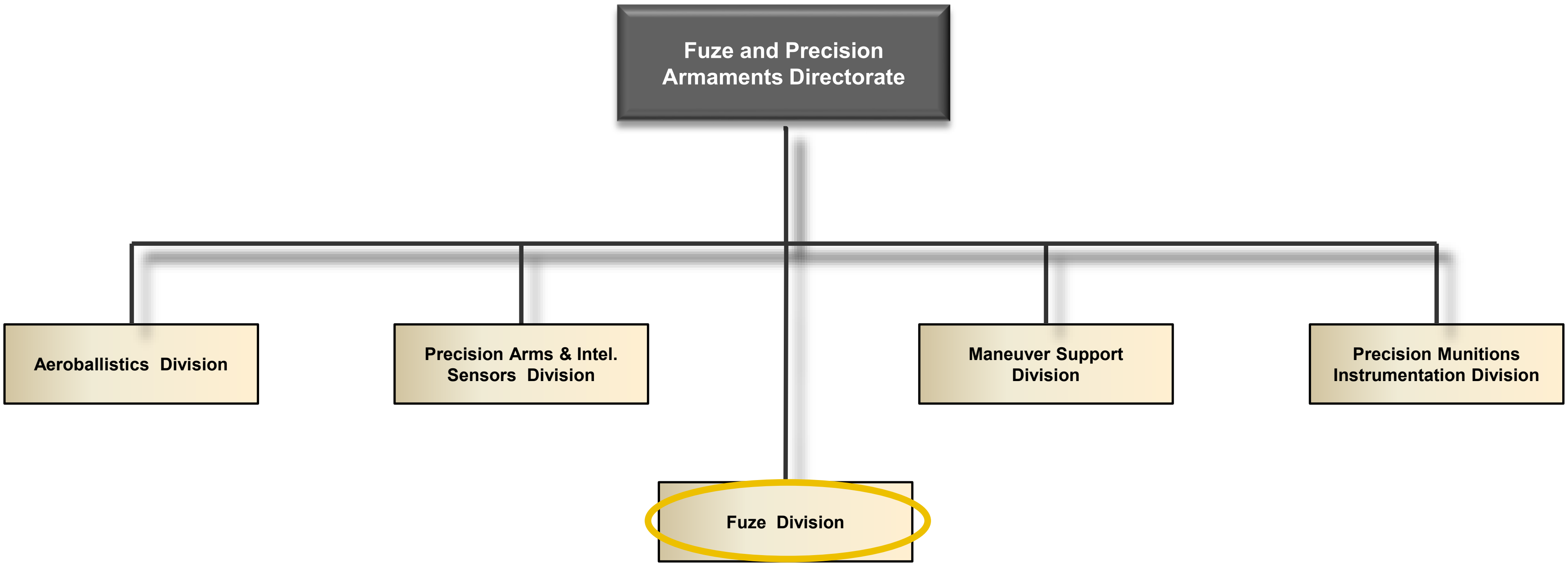
**Combat Capabilities Development Command, Commanding General**

- Aviation and Missile Center
- C5ISR Center
- Data & Analysis Center
- Army Research Laboratory
- ARMAMENTS CENTER
- Soldier Center
- Chemical Biological Center
- Ground Vehicle Systems Center

# ARMAMENTS CENTER ORGANIZATION



# FUZE AND PRECISION ARMAMENTS DIRECTORATE



# PICATINNY'S OTHER TENANTS

PEO Soldier
PM Soldier Weapons

PEO Ground Combat Systems
PM Ground Combat Vehicle

DCMA - Springfield

Civilian Human Resources Agency

Combat Capabilities Development Command – Armaments Center CCDC-AC

Garrison Commander

CG/JPEO Armaments & Ammunition

- PM CCS
- PM CAS
- PM MAS
- PM TAS
- PM JS
- PM JP

Joint Munition & Lethality LCMC

Office of the Executive Director for Conventional Ammunition O/EDCA

Naval Surface Warfare Center

Marine Corps G Co 2-25

Army Contracting Center – ACC- NJ

Recruiting Northern NJ HQ (Company)

7245th Installation Medical Support Unit

**DoD Joint Specialty Site for Guns and Ammunition**

# ARMAMENTS CENTER CAPABILITIES

RESEARCH

DEVELOPMENT

PRODUCTION

FIELD SUPPORT

DEMILITARIZATION

## *Advanced Weapons:*

- Line-of-sight (LOS), beyond line-of-sight (BLOS) and non line-of-sight (NLOS) fire
- Scalable effects; non-lethal; directed energy; autonomous weapons.

## *Ammunition:*

- Small, medium, large caliber
- Propellants; explosives; pyrotechnics; warheads; insensitive munitions
- Fuzes
- Logistics; packaging; environmental technologies and explosive ordnance disposal

## *Fire Control:*

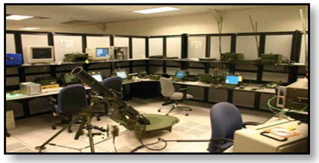
- Battlefield digitization; embedded system software; aero ballistics and telemetry

***"Center of Lethality" for Armament Systems and Munitions for Joint Services***

# ARMAMENTS CENTER FUZE DIVISION COMMODITY AREAS

# ARMAMENTS CENTER FACILITIES

Armament Software Engineering Center



Ballistic Gun Range Complex

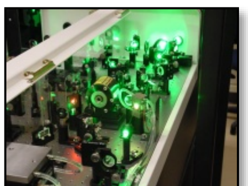
Energetics Synthesis, Formulation and Scale-up Complex

High Performance Propellants Complex

Davidson Warhead Facility

Automated Test Sets Facility

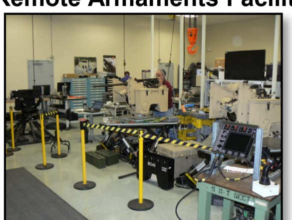
Fuze Development Center



Directed Energy Facility

Electromagnetic Effects Complex

Remote Armaments Facility



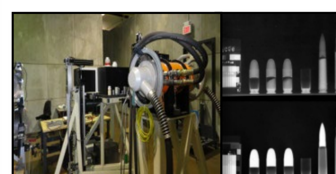
Soft Catch Gun Facility

***Our Organic Facilities Enable Integrated Armament System Solutions***

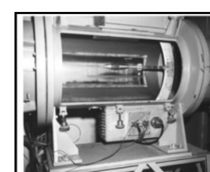
DoD Joint Packaging, Handling, Storage, and Transportation Complex

Demilitarization Facility

Drop Tower Facility



Non-Destructive Evaluation Facility



Wind Tunnel Facility

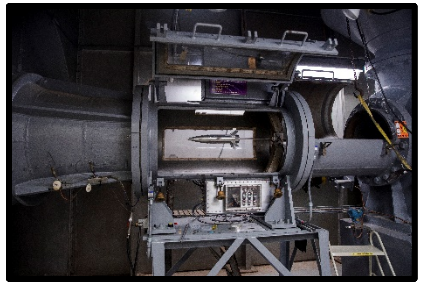
Precision Armaments Complex

Distribution Statement A: Approved for Public Release Distribution Unlimited

# FUZE AND PRECISION ARMAMENTS FACILITIES


Precision Armaments Lab

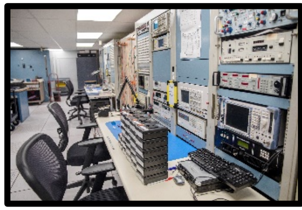

Encapsulation Lab


Wind Tunnel Facility

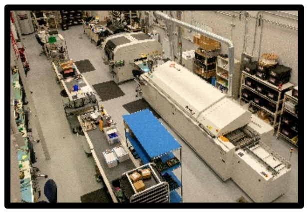

Environmental Lab


Hardware In the Loop Lab

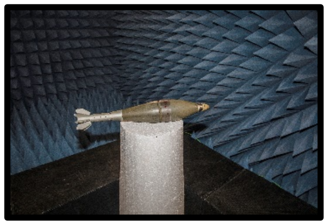
***Our Organic Facilities Enable Integrated Armament System Solutions***

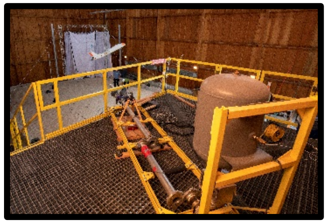

Telemetry Ground Station & Electronics Lab

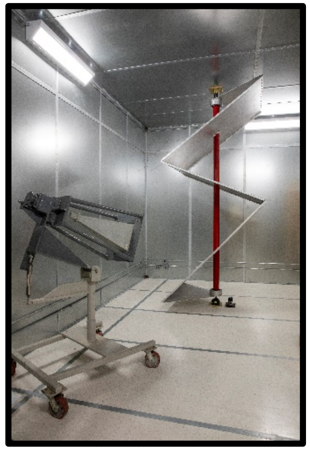

Electronics, Electro-Mechanical & Prototype Facility


Fuze Development Center


Integration Lab


RF Anechoic Chamber


Electromagnetic Sensor Test Facility


Electromagnetic Environmental Effects Lab

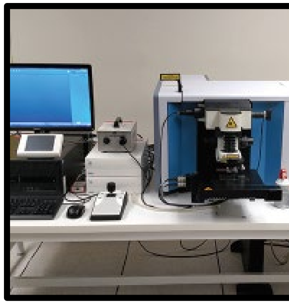

Soft Catch Gun Facility


Battery Test Lab


Sensor Calibration Lab


Fuze Division Lab


Soldering Inspection Facility


Raman Spectroscopy Lab

# FUZE S&T INVESTMENT AREAS

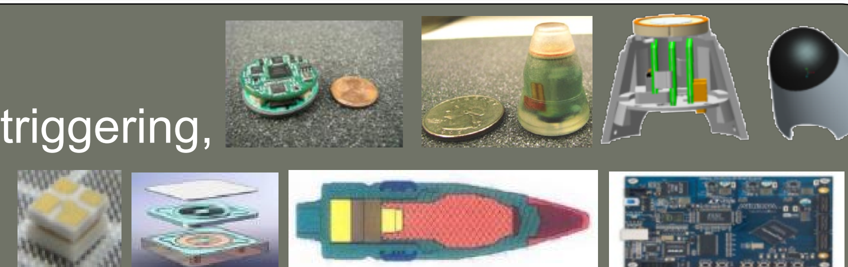
DEVCOM ARMAMENTS CENTER

## Advanced Fuze Setting
- PIAFS, ePIAFS, iPIK
- Medium caliber setters

PIAFS EPIAFS iPIK

## Advanced Warhead Initiation Schemes
- Many point ESAD, networked initiation
- Micro-Scale Firetrain (MSF)
- Embedded Fuzing

## Launch and Target Sensing
- Next-Gen Prox, tracking prox, dynamic triggering, optical prox, active imaging
- G-Switch, Target Media Sensing



Fuze Decision Logic

## Novel Power & Energy
- Thermals, liquid reserve, harvesters

Thermals


Liquid Reserves

## Advanced Safe and Arming
- MEMS S&A, Low Cost ESAD

Rotor S&A

# CURRENT FUZE PROJECTS

Gold, 17-G-
Green, 18-G-
Blue, 19-G-
Red, 20-G-

## Emerging & MaturingTechnologies

### 6.2 OSD Joint Fuze Technology Program (JFTP)

- MEMS Stab Detonator
- EPIC-ABAQUS Subroutines
- Alt. Prox Fuze Technologies for CUAS
- Low Cost Tracking Proximity Sensor
- Fracture & Damage Mechanisms of LIGA MEMS
- TPV Power Generation for HVP

### 6.3 OSD Joint Fuze Technology Program

- Target Scene Generator
- Determination Optimal Potting Hi-G Electronics & Fuzes
- High Reliability Micro-Scale Firetrain
- High-Voltage Power Generation for ESAD
- COTS Accelerometer As Impact Sensor
- Glass Ampoule Analysis Capability Transition

### CCDC-AC S&T Projects & Demonstrations

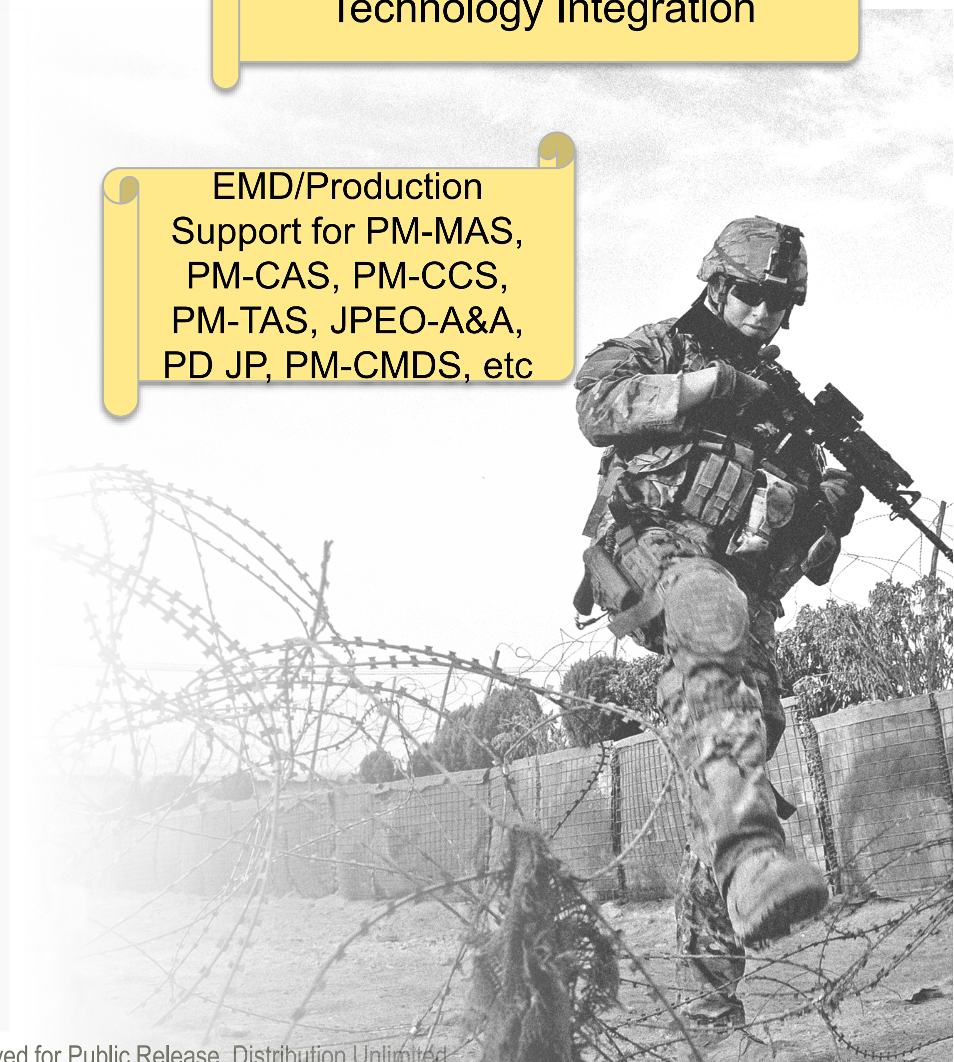
- Fuze & Power Tech Enablers: Tracking Proximity Sensors, Advanced Initiation, Wireless Setting, Novel Power
- Cluster Munitions Replacement Technology
- XM1155 Development
- XM1182, XM1204, and XM1206 Hardware Development
- XM1068 Development
- MOFA2/iMOFM Development

### 6.7 Fuze Technology Integration Efforts (FTI)

- M734A1 MEMs Impact Switch Producibility
- Replace Obsolete Prox Electronics Components (MMIC replacement)
- M550 Spinlock Replacement
- ESAD Enhancements for Indirect Fire
- Hand Grenade Fuze Improvements
- Improved Delay Assembly for M739A1

On-going 6.7 RDTE Fuze Technology Integration

EMD/Production Support for PM-MAS, PM-CAS, PM-CCS, PM-TAS, JPEO-A&A, PD JP, PM-CMDS, etc



# FUZE S&T CURRENT THRUST AREAS

- Novel Power for Long Range Applications
- MEMs Sensing and MEMs S&A
- Advanced Initiation Schemes – Many Point ESAD
- Fuze Proximity - Low Cost Tracking Proximity Sensors, Dynamic Triggering, Optical Proximity and Active Imaging
- Secure Wireless Data Transmission for In-Flight Fuze Setting
- Networked Fuzing Architectures
- Moving toward Embedded Fuzing – Fuze on a Chip (ESAD, Prox, Setting)

# COLLABORATION OPPORTUNITIES

- **Industry to CCDC-AC engagements**
  - Formal IR&D Reviews with CCDC-AC
  - Informal IR&D Reviews with Fuze Division
  - Cooperative Research and Development Agreements (CRADAs)
  - DoD Fuze IPT Opportunities
- **DOTC**
  - Industry-suggested topics
  - Annual plan feedback
  - Enhanced-whitepaper feedback
  - General Membership Meeting one-on-ones
- **Joint Fuze Technology Program**
- **DOD Fuze IPT**

# ARMAMENTS CENTER BRIEFINGS AT 63RD NDIA FUZE CONFERENCE

| Presenter/Author | Titles | Time |
|---|---|---|
| Kevin O'Connor | DEVELOPMENT IN METAL MEMS LATCHING SETBACK SENSING MECHANISM | Tues 1:55PM |
| Maxim Keyler | NEXT-GENERATION LARGE CALIBER SETTER | Wed 1:40PM |

# Thanks for your time and Attention

SAND2020-7592 C

# Advanced Fuzing Technology
# Sandia National Laboratories

ADVANCED FUZING TECHNOLOGY


*PRESENTED BY*

Shane Curtis & Adam Church

(505) 284-5493, skcurti@sandia.gov



U.S. DEPARTMENT OF ENERGY NNSA

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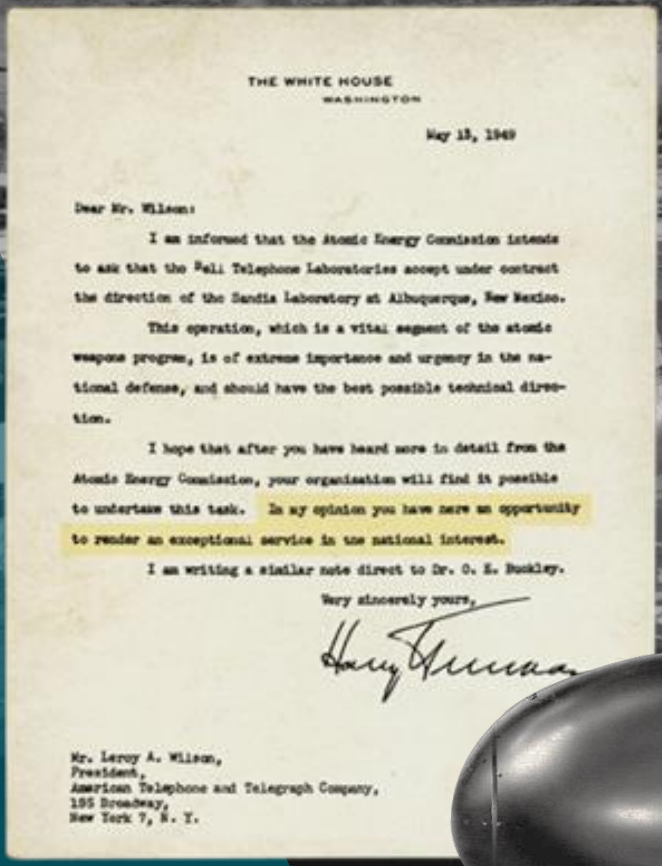
# SANDIA'S HISTORY IS TRACED TO THE MANHATTAN PROJECT

*…In my opinion you have here an opportunity to render an exceptional service in the national interest.*

- July 1945
  Los Alamos creates Z Division
- Nonnuclear component engineering
- November 1, 1949
  Sandia Laboratory established
- AT&T: 1949–1993
- Martin Marietta: 1993–1995
- Lockheed Martin: 1995–2017
- Honeywell: 2017–present



THE WHITE HOUSE
WASHINGTON

May 13, 1949

Dear Mr. Wilson:

I am informed that the Atomic Energy Commission intends to ask that the Bell Telephone Laboratories accept under contract the direction of the Sandia Laboratory at Albuquerque, New Mexico.

This operation, which is a vital segment of the atomic weapons program, is of extreme importance and urgency in the national defense, and should have the best possible technical direction.

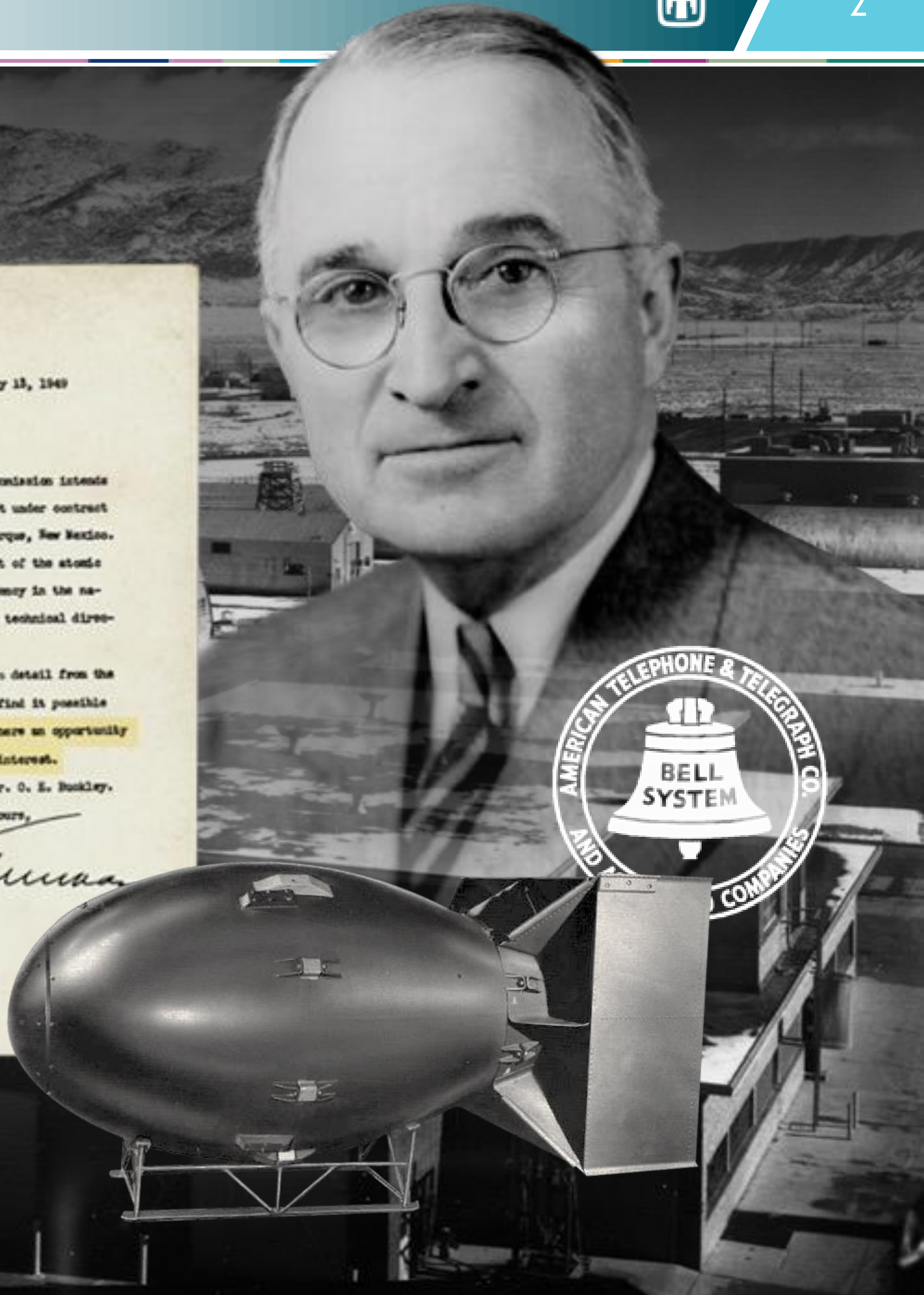
I hope that after you have heard more in detail from the Atomic Energy Commission, your organization will find it possible to undertake this task. In my opinion you have here an opportunity to render an exceptional service in the national interest.

I am writing a similar note direct to Dr. O. E. Buckley.

Very sincerely yours,

Harry Truman

Mr. Leroy A. Wilson,
President,
American Telephone and Telegraph Company,
195 Broadway,
New York 7, N. Y.



# SANDIA IS A FEDERALLY FUNDED RESEARCH AND DEVELOPMENT CENTER MANAGED AND OPERATED BY

National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc.: 2017 – present

Government owned, contractor operated

# SANDIA HAS FIVE MAJOR PROGRAM PORTFOLIOS

# NUCLEAR DETERRENCE

## Responsibilities form a critical mandate

### Warhead systems engineering & integration

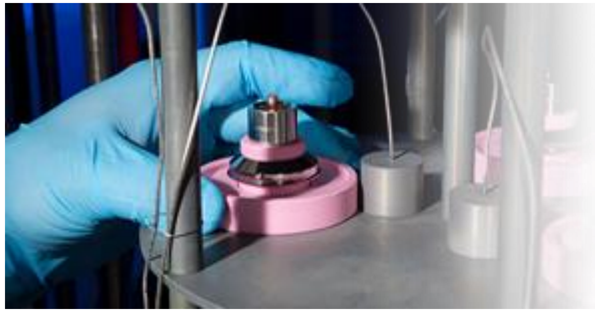
### Design agency for nonnuclear components

- Gas transfer systems
- Radar
- Safety systems
- Arming, fuzing & firing systems
- Neutron generators

### Multidisciplinary capabilities

Required for design, qualification, production, surveillance, computation/ experimentation

- Major environmental test facilities & diagnostics
- Materials sciences
- Light-initiated high explosives
- Computational analytics



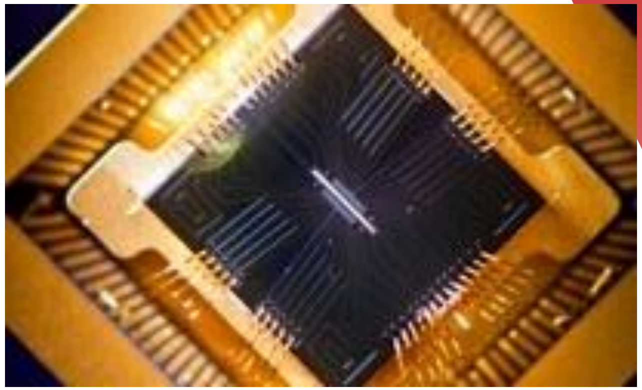
### Production agency

- Neutron generators
- Sandia external production
- Microelectronics
- Thermal battery backup

# NATIONAL SECURITY PROGRAMS

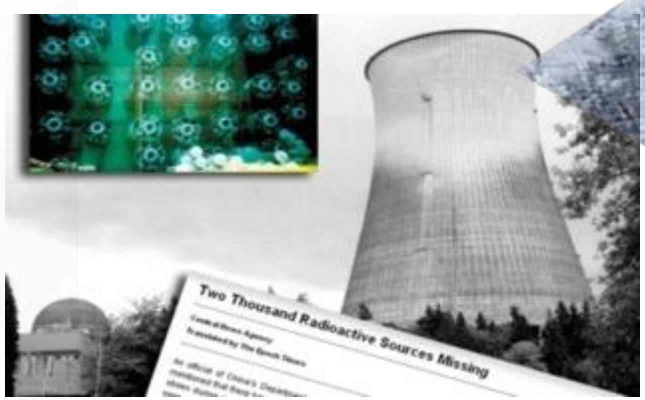
## Strengthens our nation's defenders

Information operations



Science & technology products

Integrated military systems




Proliferation assessment

Surveillance & reconnaissance

# Advanced Fuzing Technology Dept

Advanced Fuzing Technology seeks to develop fuzing and firing systems that are on the forefront of technology

- **Miniature** --- smallest in the world
- **Multipoint** --- with precise timing
- **Embedded** --- within the explosive system
- **Hardened** --- against mechanical shock
- **Understood** --- by state of the art simulation & experimentation
- **Safe** --- by military standards
- **Reliable** --- by proven demonstration & margin
- **Forward Looking** --- for emerging and future applications

Advanced Fuzing Technology is responsible for the design of fuzing devices for both the Nuclear Deterrence and National Security Programs missions at Sandia

*Unique understanding of both mission areas and customer needs*

**Customers/partnerships**

DOE/NNSA

DoD – (AFRL, DTRA, Navy SSP, NSWC IHOEDTD, ARDEC, etc.)

Joint Fuzing Technology Program (JFTP)

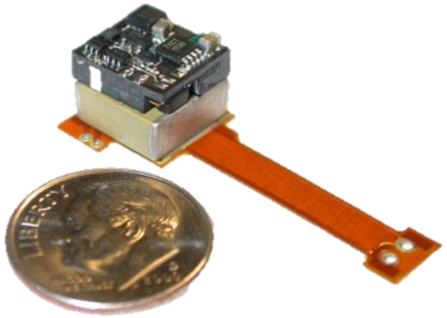
Joint Munitions Program (DOE/DoD)

Fuzing industry partners (Raytheon, etc.)

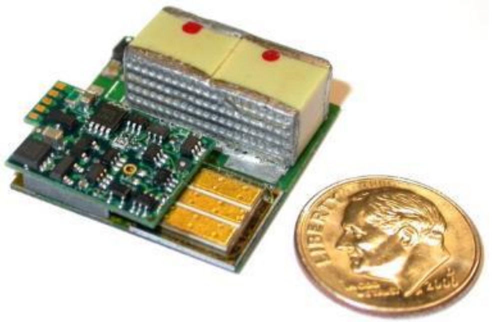
ADVANCED FUZING TECHNOLOGY

# Miniature & Multipoint

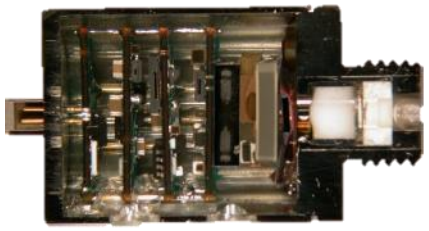
## *Small Firing Sets w/ Precise Timing*



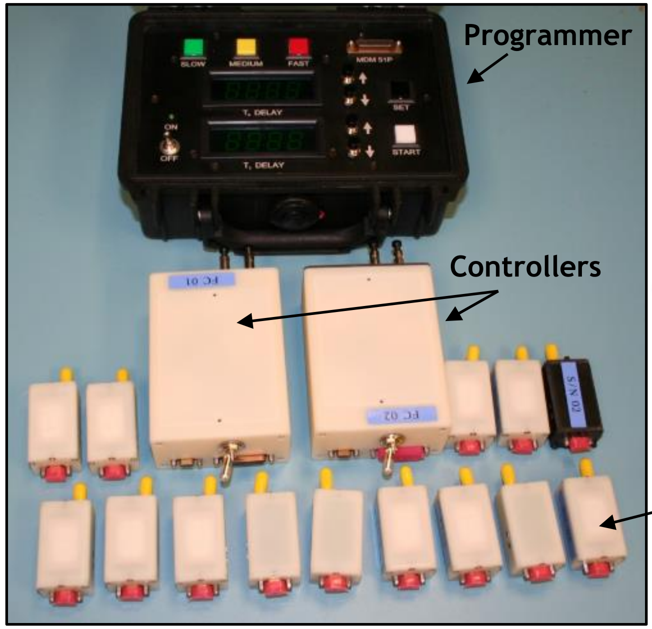
Miniature Electronic Safe-Arm Device



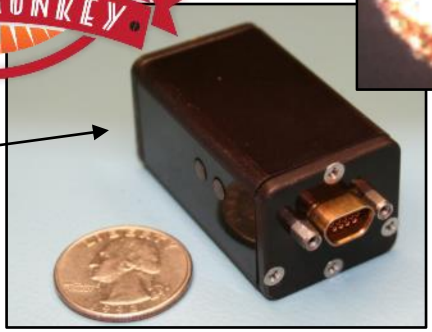
Miniature Electronic Safe-Arm Device

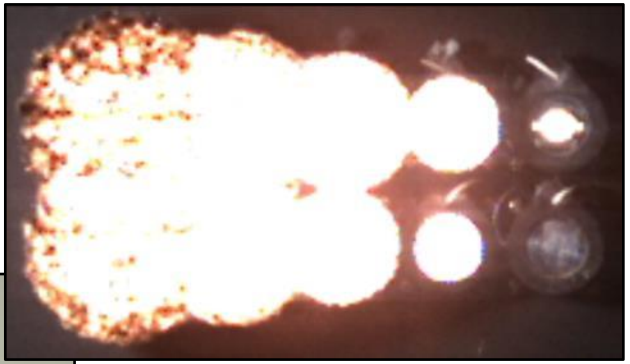


Hermetic, Miniature Firing System with Digital Logic




Firing Node





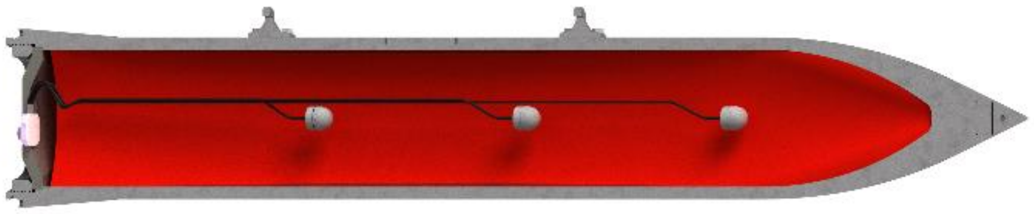
High Speed Video Capture (sub-μs timing)

# Embedded

*Fuzing systems embedded in fill material for survivability*

Traditional Fuzing Design

Distributed Fuzing Design

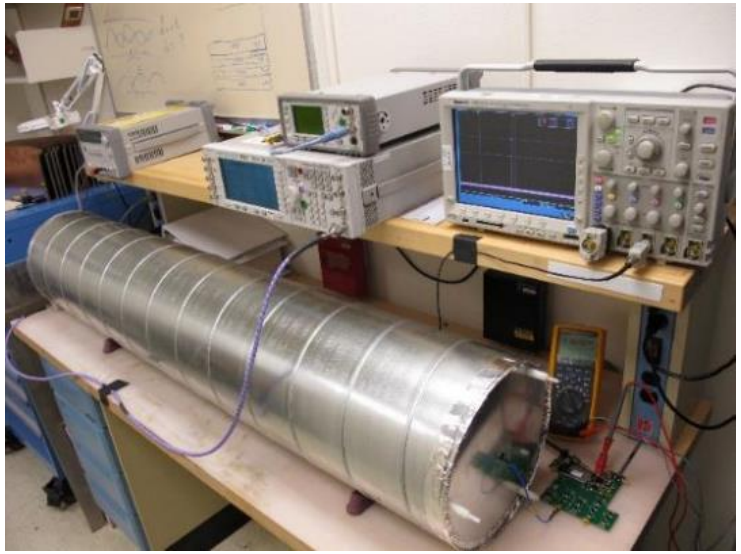


AFRL fuzing architecture design concepts

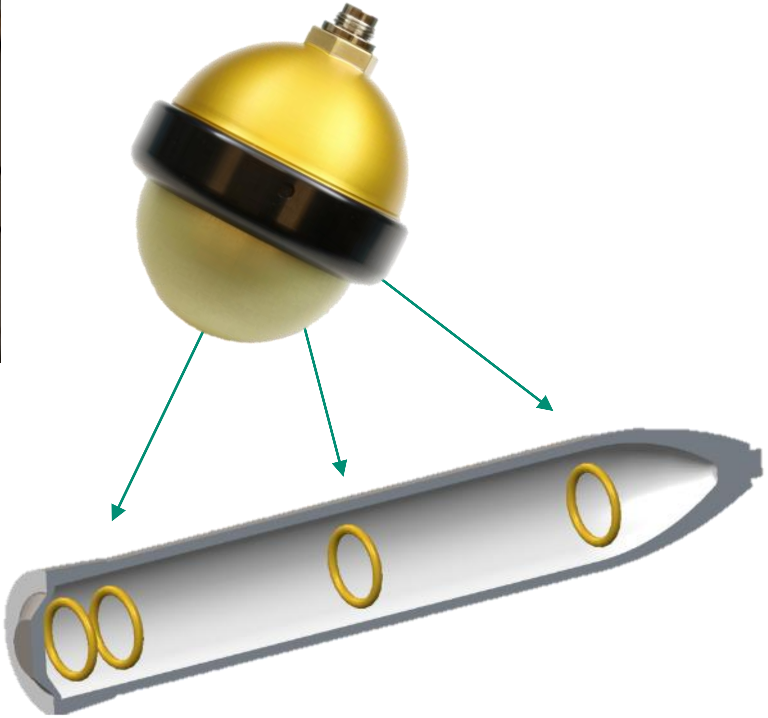

<u>Embedded fuzes can enable survival in harsh system environments</u>

# Embedded

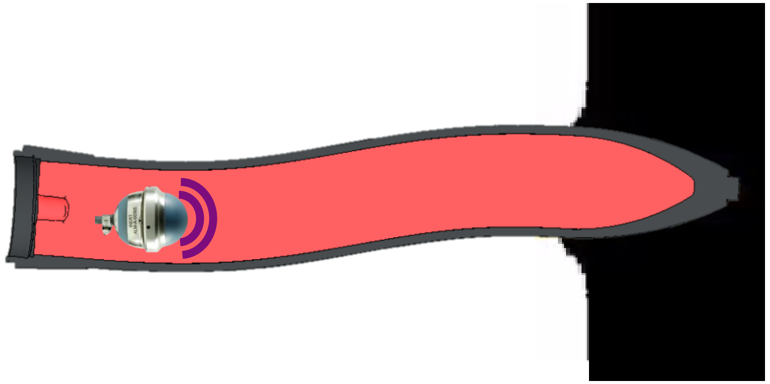
## *Fuzing systems embedded in fill material for survivability*



Benchtop test of power distribution scheme



Notional design for EM power distribution to embedded fuzing nodes



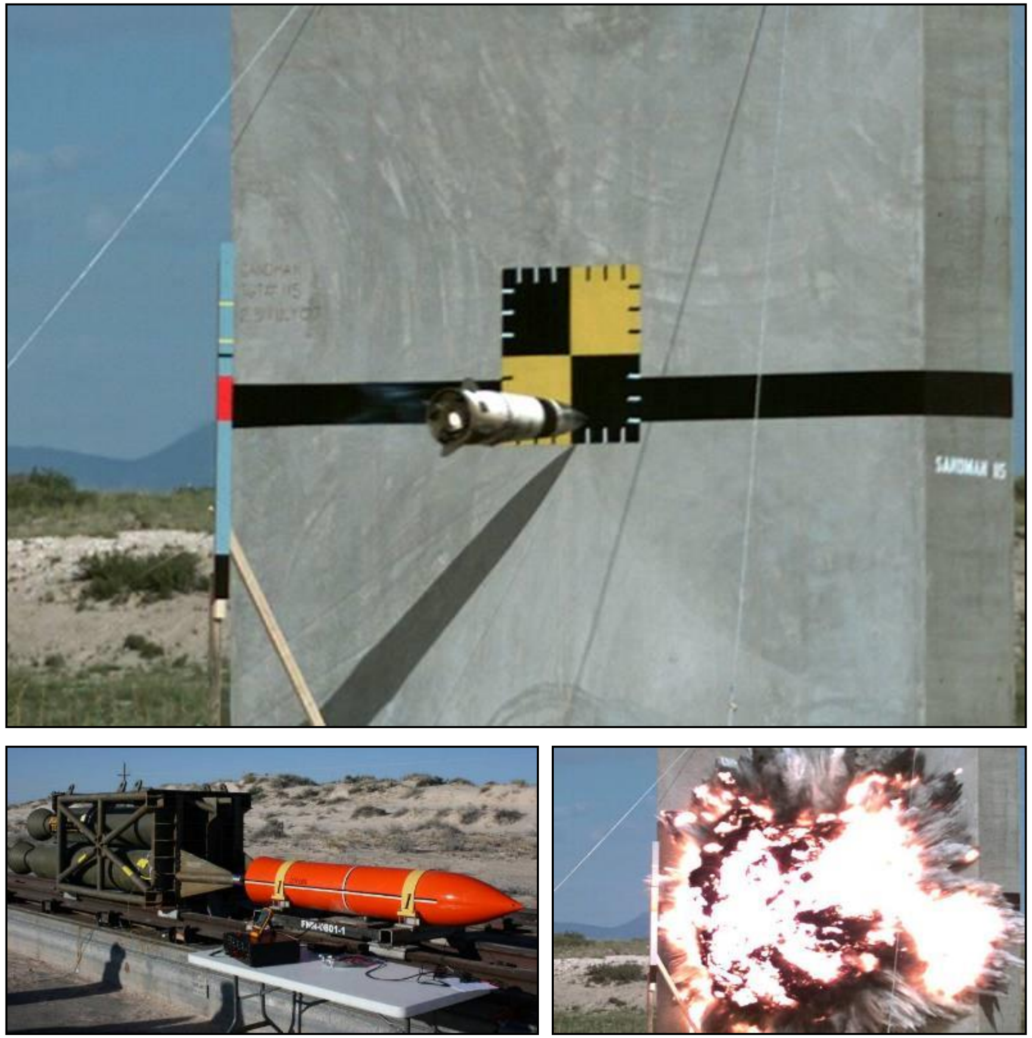
Research into enabling technologies for embedded fuzes in DoD JFTP

Working to provide solutions for embedded fuzes to operate internally without hard-wired connections, including all aspects of operation, such as:

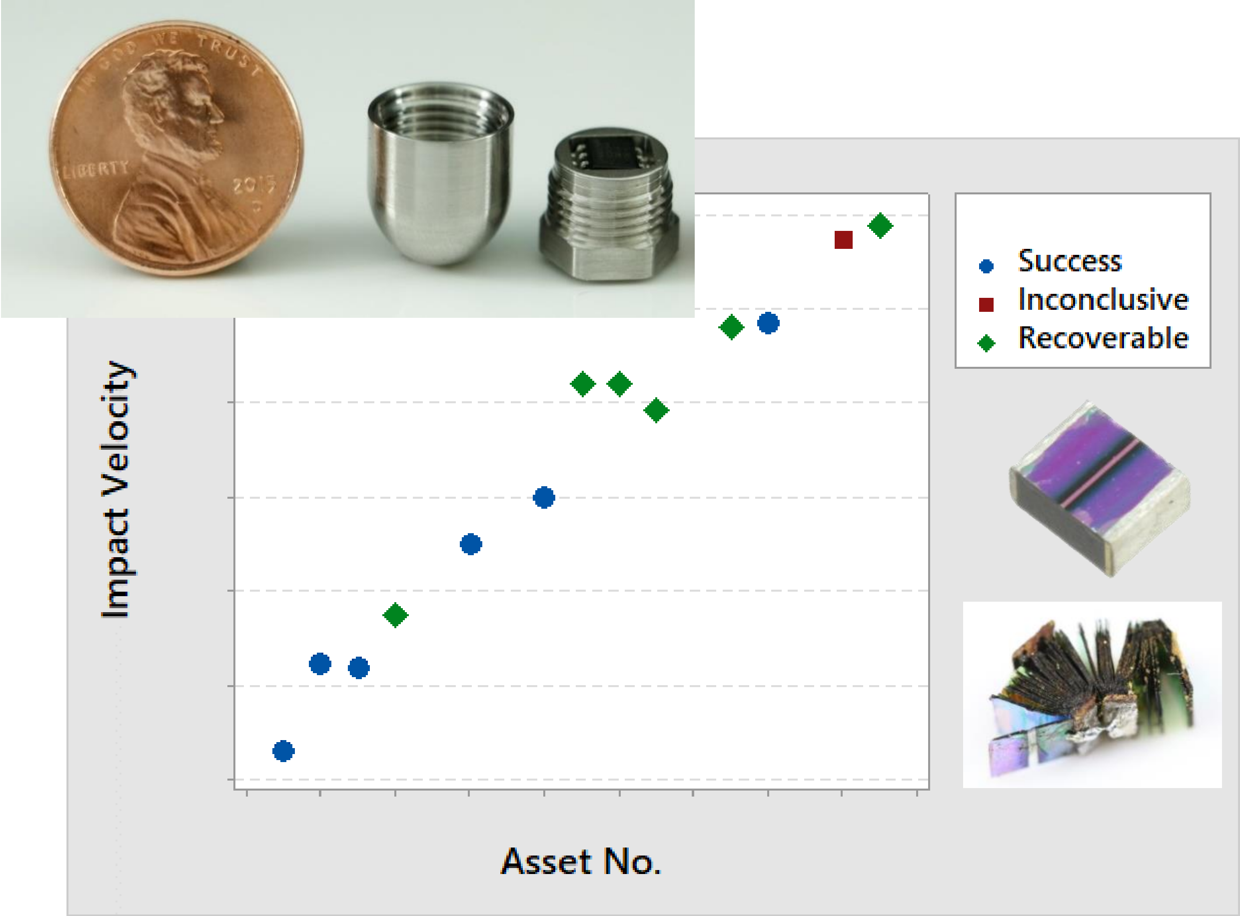
- <u>Power distribution</u>
- <u>Safe/arm communication</u>
- <u>External environment detection</u>

# Hardened

*Advancing the state of the art to ensure severe environment survivability*



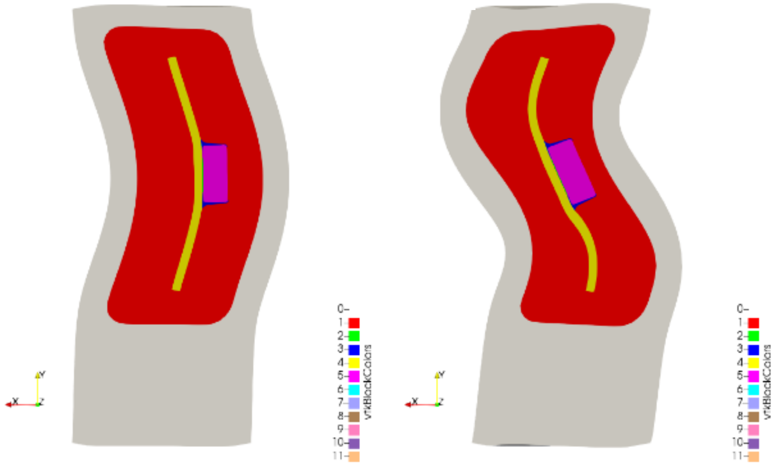
Full scale and sub-scale testing



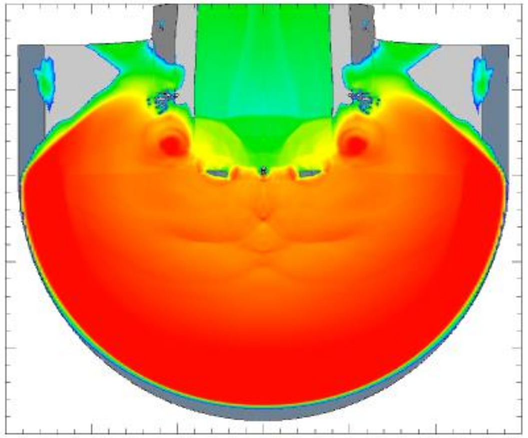

Component/technology evaluation for high velocity impact survivability

# Understood

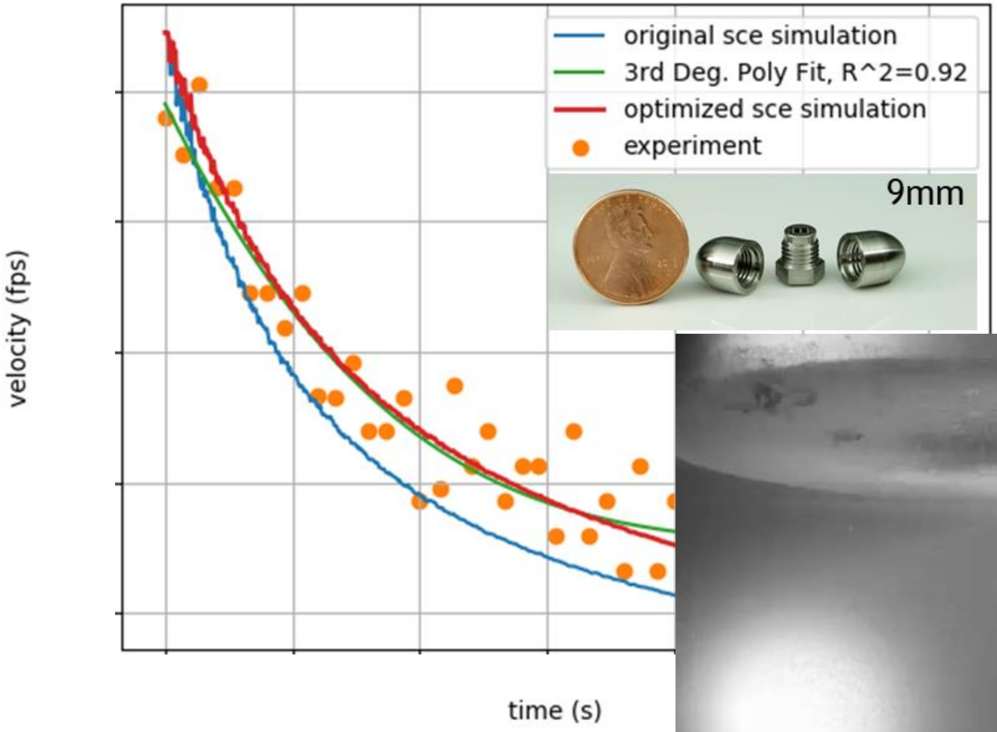
## *Leveraging capability to fully characterize fuze design space*



FEA studies of component designs



Modeling explosives interface for design basis trade studies




Modeling of relevant environments

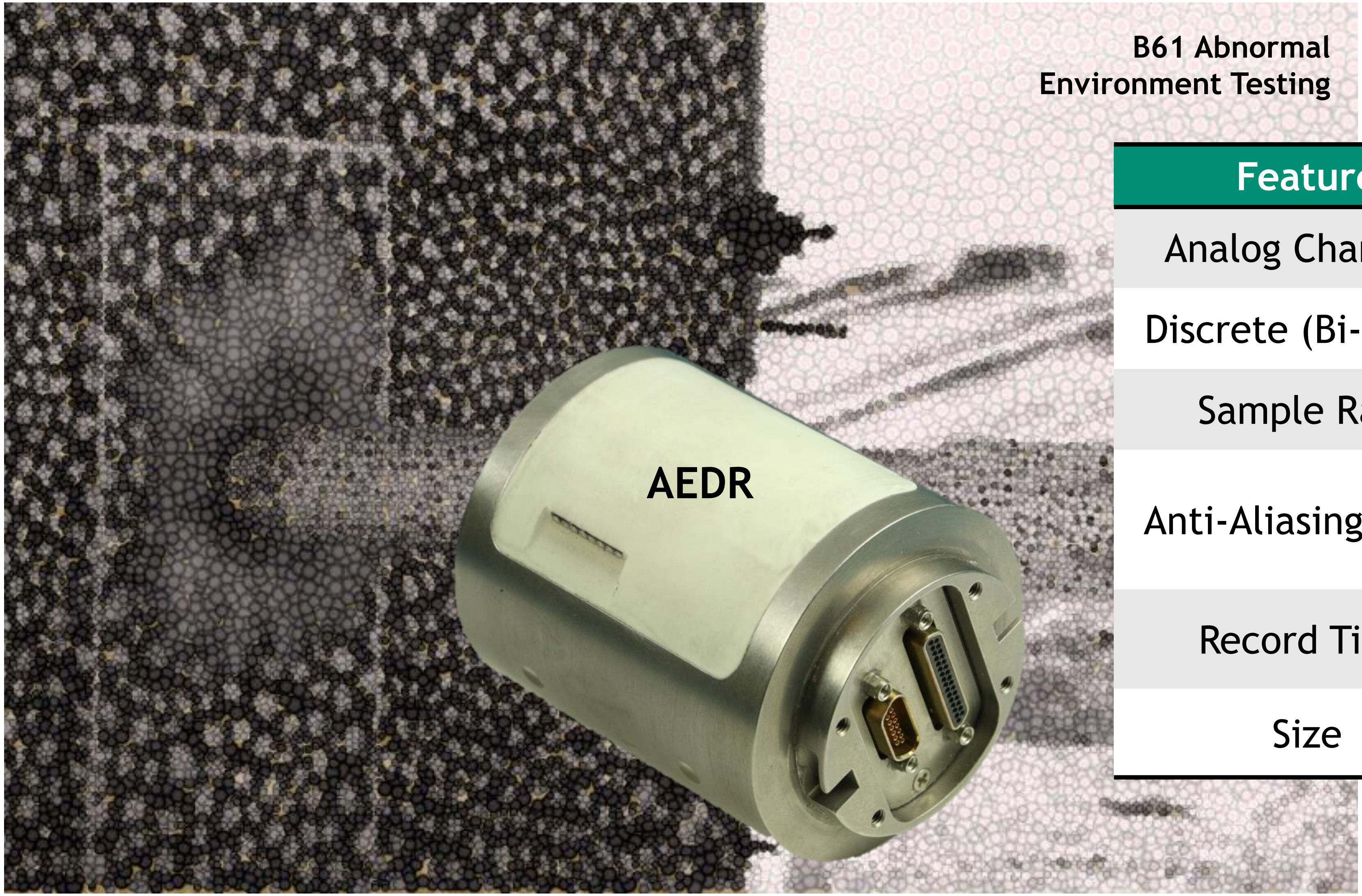
# Understood

## *Conducting novel experimentation to verify designs*

**EMRTC water impact testing**

# Understood

*Developing state-of-the-art instrumentation to record harsh environments*




| Feature | Value |
|---|---|
| Analog Channels | 4 |
| Discrete (Bi-Level) | 2 |
| Sample Rate | 250 ksps |
| Anti-Aliasing Filter | 50 kHz Bandpass,<br>7-Pole Butterworth |
| Record Time | 213 seconds,<br>with 75 ms pre-trigger |
| Size | 1.4 lbs<br>Ø2.35" x 3.0" |

# Safe & Reliable

*Designs proven through demonstration and designed to safety standards*

AFRL Design Verification SPEAR test of SNL embedded fuze.

# Leveraged Capabilities

*Working across SNL, DoD and DOE*

## Materials and Component Research

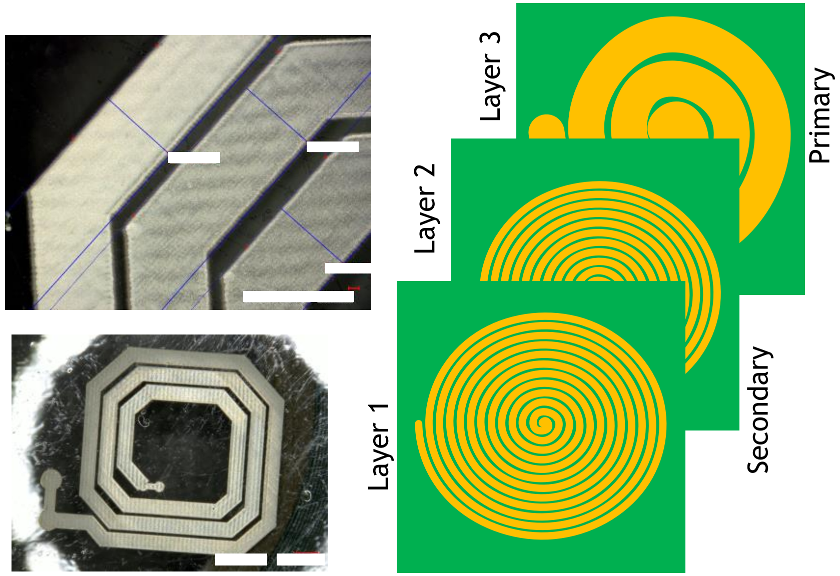
- High Voltage Capacitors
- Additive Manufactured Transformers
- High Voltage Switches

## Explosives and Initiation Devices

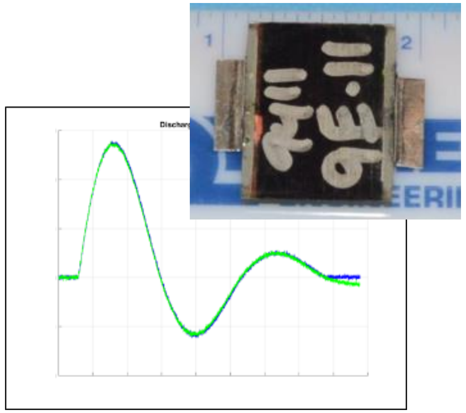
- Direct Header Deposition
- High-g survivable detonators

## Survivable Electronics Research

- Shock Isolation Systems
- Encapsulants and Potting Materials development

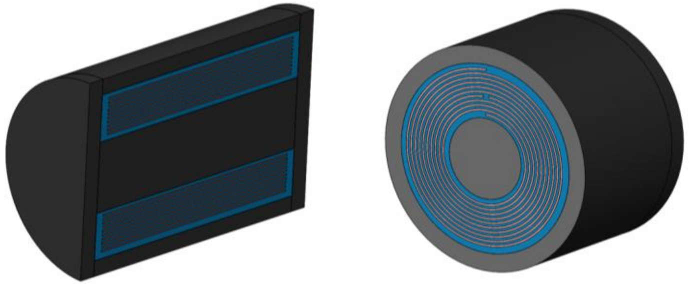



Coreless Transformer and Direct Write Printing



High Voltage Capacitor Development

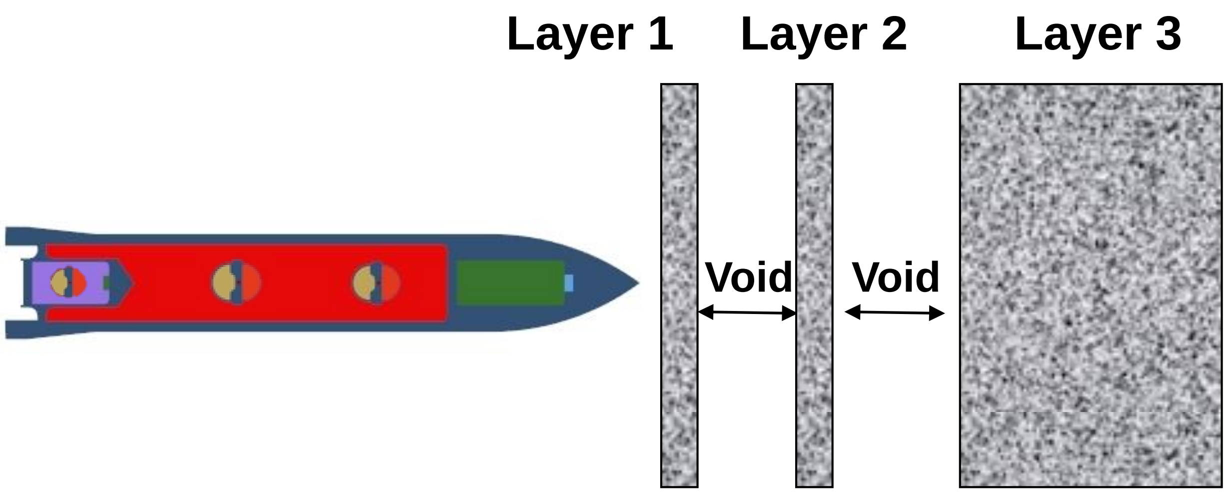
Low Complexity Sprytron



Advanced Manufactured Jellyroll Transformer

# Forward Looking

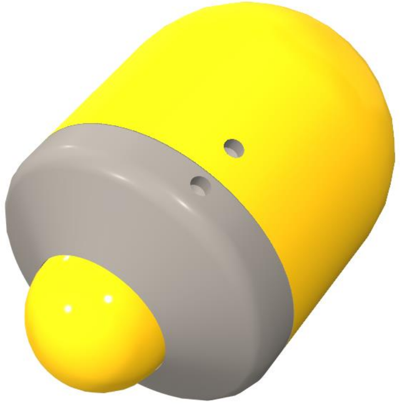
*Advancing technologies for future applications through basic research*



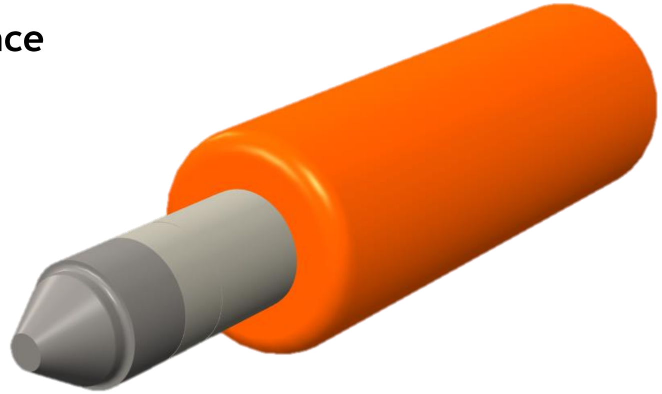

Development of algorithms to enable smart fuze intelligence

**Current R&D Efforts**

- 3D Printed Fuzing Components
- Wireless Safe, Arm & Fire Communication System
- RF Signature Detection for Smart Fuzing Applications
- Polymer Multi Layer Capattery
- Explosive Model Development



Conceptual designs to survive new environment regimes



Developing recoverable data recorder design concepts

Research into applicability of alternate component technologies for hard target applications

Exceptional Service in the National Interest

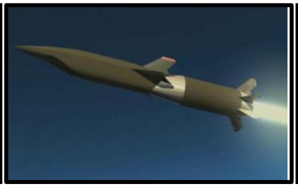
# DoD Joint Fuze Technology Program (JFTP) Overview

## NDIA vFuze Conference
### 05 August 2020

Lawrence Fan
JFTP Program Manager

# Joint Fuze Technology Program (JFTP)

- Develop enabling and common fuze technologies into DoD and Combatant Command high priority weapon capability needs
- Focal point to set technical direction for fuze solutions and technologies that enable munitions to meet current and future requirements
- Organized in four Fuze Area Technology Groups (FATG) addressing fuze technology aspect:
  - Extreme environment survivable fuzing
  - Tailorable effects and initiation
  - High-reliability safety and arming devices
  - Target detection and burst point control
- Driving DoD Fuzing Technology Capabilities:
  - High-speed weapon fuzing
  - Air defense / C-sUAS
  - Embedded, survivable fuzing technology
  - Miniature, affordable safe and arm devices





# JFTP Management and Partnerships

**OUSD Research & Engineering, Research & Technology**

**Director, Weapons and Platforms**

**Director of Munitions**

**Joint Fuze Technology Panel** | **Program Manager**

## FUZE AREA TECHNOLOGY GROUPS

| FATG I – Extreme Environment Survivable Fuzing | FATG II – Tailorable Effects & Initiation | FATG III – High Reliability Safe and Arm Technology | FATG IV – Target Detection and Burst Point Control |
|---|---|---|---|
| Army, Navy, Air Force Co-Chairs | Army, Navy, Air Force Co-Chairs | Army, Navy, Air Force Co-Chairs | Army, Navy, Air Force Co-Chairs |

## Leveraging and Collaboration

- Joint Munitions Portfolio and DOE
- Services Munitions S&T and Laboratories
- Commercial Fuze and Component R&D
- Academia and Gov't Laboratories

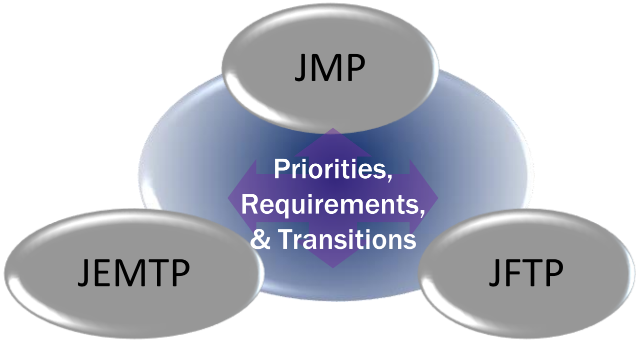
## Transitions

- Service Weapon PM/PEO
- Fuze Industrial Base

# JFTP and R&E Organization Overview

- **OUSD Research & Engineering (R&E) Leadership**
  - Dr. Douglas Blake, (Acting) Deputy Director, Research, Technology & Laboratories OUSD(R&E)
  - Mr. Michael Holthe, Director, Platform and Weapons OUSD(R&E)
  - Dr. Jason Jouet, Director of Munitions OUSD(R&E)
    - Manager Joint Munitions Portfolio (JMPo)
  - Mr. Lawrence Fan, Program Manager, Joint Fuze Technology Program
- DoD Tech Panel and FATG Support
  - Army: CCDC AC, CCDC AvMC
  - Air Force: AFRL
  - Navy: NSWC Indian Head EOD Technology Division / NAWCWD

# OUSD(R&E) Joint Munitions Portfolio




- **Joint Munitions Portfolio Synergy**
  - JFTP and JEMTP help define hard S&T problems for JMP
  - JFTP and JEMTP transition technologies developed by JMP
- **The Joint Fuze Technology Program (JFTP)**
  - Developing and transition next generation capability with enabling fuze technologies
  - Leverage other technology development programs for rapid innovation and industrial base diversification
- **The Joint Enhanced Munitions Technology Program (JEMTP)**
  - Focus and objectives aimed advancing capability with respect to performance, range, and lethality
- **The Joint DoD/DoE Munitions Program (JMP)**
  - Leverages the expansive capabilities of the DOE weapons laboratories to advance the Department's conventional weapons capabilities

**The JMP has multiservice participation, long history of transition and impact, and is aligned with NDS and supporting R&E priority areas**

# JFTP Overview

- JFTP realignment focus is on investing and driving enabling and common fuze technologies for DoD weapon capabilities (e.g. Hypersonic and high speed weapons)
- JFTP looking for "tech pull" feeder technologies (basic research pipeline) for high payoff tech insertions
    - Applying and leveraging R&E Priority Modernization Technologies
- JFTP Budget:

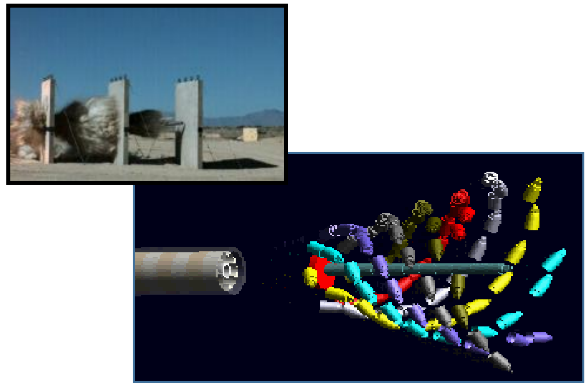
**Budget by Year ($M)**

| | **FY19** | **FY20** | FY21 | FY22 |
|---|---|---|---|---|
| 6.2 | 6.198 | 6.237 | 6.288 | 6.408 |
| 6.3 | 6.546 | 6.574 | 6.621 | 6.782 |

**Strategic Thrusts > Technology Planning > Technology Application**

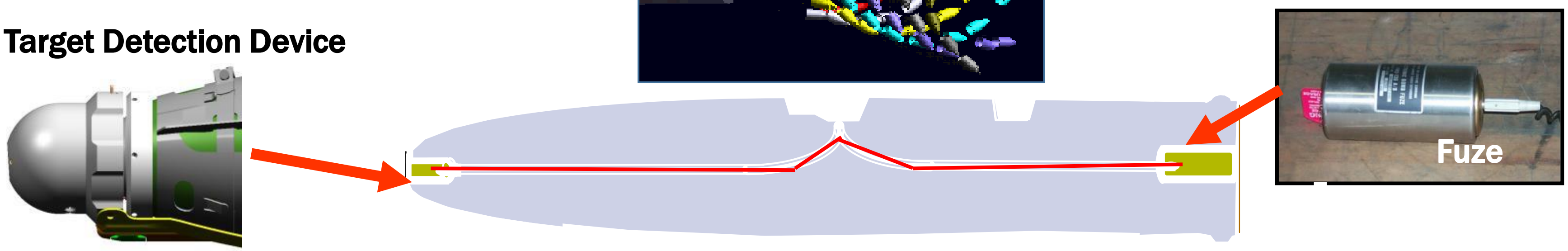
# Fuzing S&T Enables Weapon Capabilities

**Survivable Fuzing:**
- Extreme environment survivability: potting, thermal protection
- High G, precision fuzing



**Safe and Arm:**
- Common/modular safe and arm devices and sensors
- Distributed fuzing architecture

**Target Detection Device**

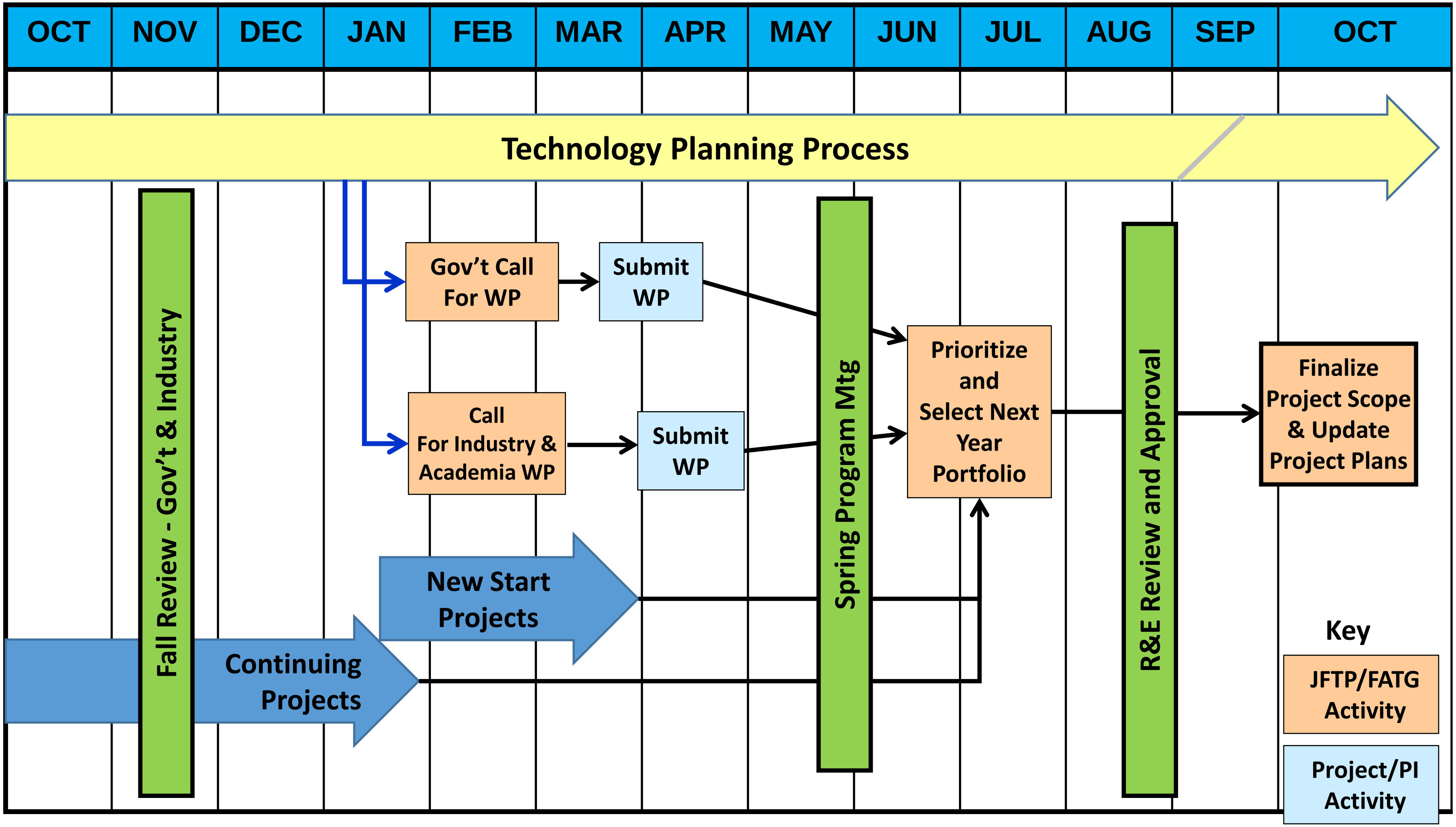



**Target Detection**

**Selectable height-of-burst (HOB), Proximity sensing:**
- Precision target detection fuzing technology to optimize lethality

**Initiation**
- Burst point control of warhead initiation
- Survivable and reliable detonators and explosive initiation trains

# JFTP Annual Cycle



# JFTP / DoD Fuze IPT Schedule

- 4-5 August 2020 – NDIA Annual Fuze Conference (virtual)
- 6 August 2020 – 54th DoD Fuze IPT
- 11-12 August 2020 – DoD Fuze IPT and industry one-on-one sessions (virtual)
- Mid-November 2020 – 55th DoD Fuze IPT / JFTP Fall Review @ Booz Allen McLean, Virginia
- December 2020 - Posting of JFTP 2020 project reports (Distro D) on DTIC
- January 2021 – JFTP call for FY22 white paper ideas

# JFTP Summary

- JFTP Aligned OUSD R&E Strategic Thrusts
- Looking for High Risk = High payoff (Constant Innovation)
- Continued Technical Planning and Collaboration (Strategic Investment)
- Providing Future Warfighter Capability

# Questions?

# Fuze Technology Refresh Process

Vince Matrisciano
R&D Program Manager
Joint PEO Armaments & Ammunition

4 August 2020

# Problem Statement

- There is currently no formal process or mechanism for all stakeholders to collectively determine technology refresh and part obsolescence priorities in fuze products.
    - Technology insertion is currently ad-hoc.
    - Producers and Program Managers do not always know what technology is in development.
    - Technology Developers do not always have insight into Program Manager and Producer’s program plans.

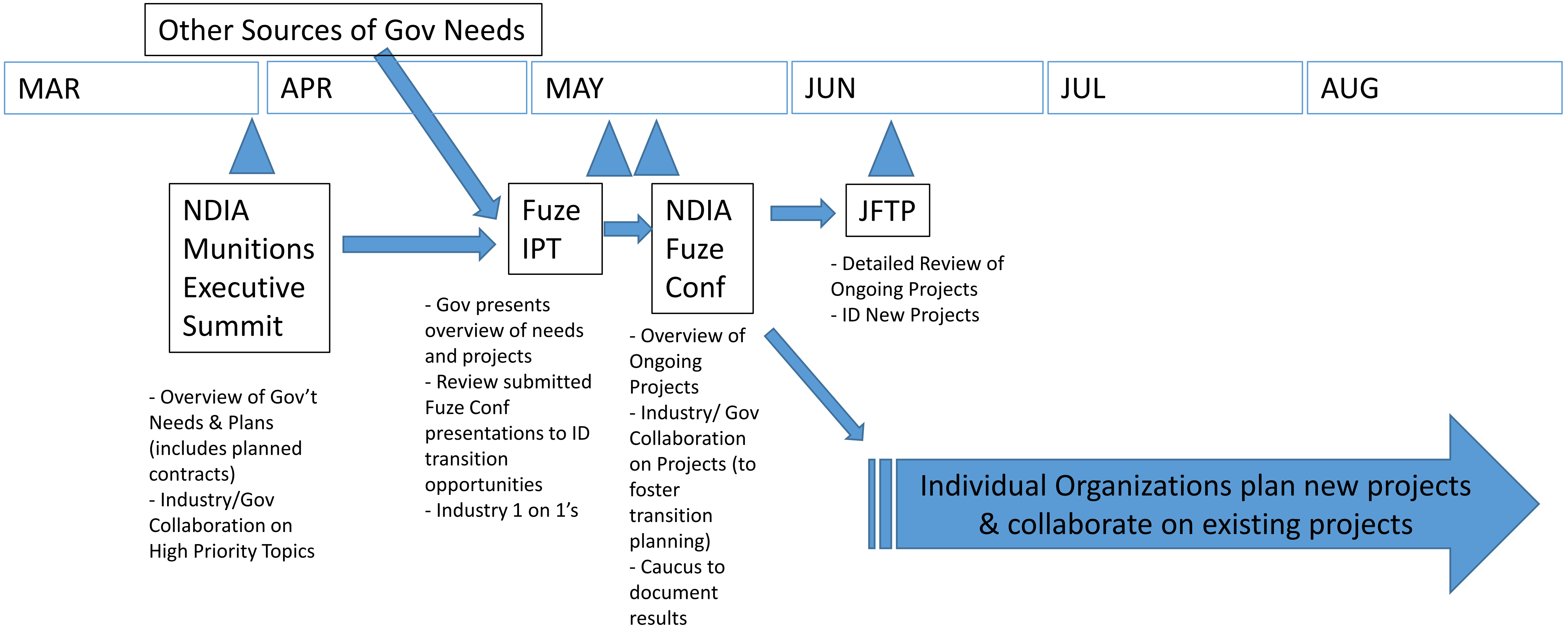
- Goal: increase stakeholder coordination to maximize technology transition.

# Approach

- A structured annual cycle to increase full stakeholder involvement in transition planning.
  - Provide insight into technology needs and changes of government items.
  - Provide a forum for government and industry stakeholders to discuss specific transition plans, both one-on-one and open forum.
  - Provide a clear understanding of what the government is working on in-house.
  - Provide a clear understanding of emerging technology that relates to fuzing.
  - Facilitate involvement of all stakeholders and minimize “speedbumps” to transition
  - Identify specific insertion points and insertion methods for new technology.
  - Leverage existing processes and forums as much as possible.
  - Support key decision points of all stakeholders.

Conceptual

# Fuze Technology Refresh Annual Cycle




DISTRIBUTION STATEMENT A; Approved for public release; distribution unlimited. (PAO Log 492-20, 22 July 2020)

# Summary/Go Forward

- Key Government & Industry Stakeholders have agreed on the basics of the new process
- Implementation will start next annual cycle - Expect some changes in format and focus in next year’s events
- Widespread involvement is encouraged via the appropriate forums

NAVSEA WARFARE CENTERS
Indian Head EOD Technology Division

# Fully Resettable MEMS Safe/Arm with Lock and Slider Position Feedback


Presented by:

**Daniel Jean, Ph.D.**
**NSWC IHEODTD**


- 5 Aug 2020 –


Coauthored by :

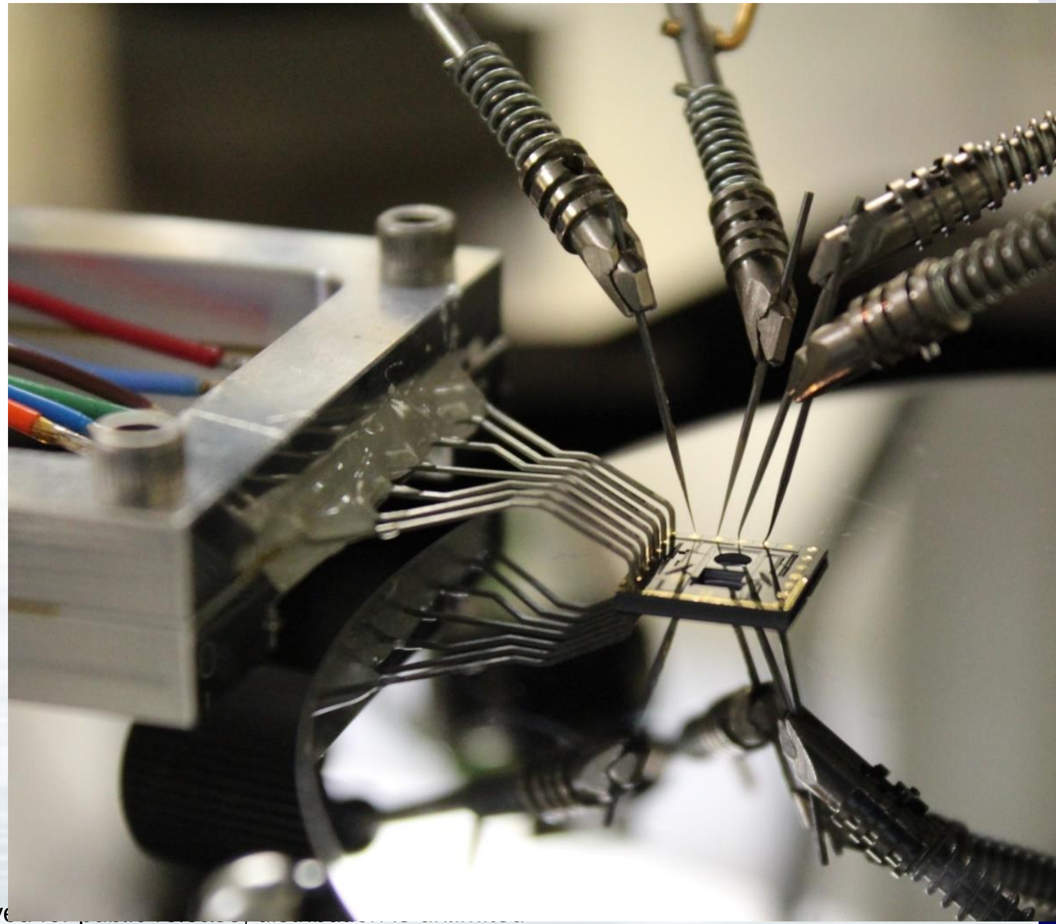
Ezra Chen
NSWC IHEODTD


**Capt. Scott H. Kraft, USN**
**Commanding Officer**

**Mr. Ashley G. Johnson, SES**
**Technical Director**

# Outline

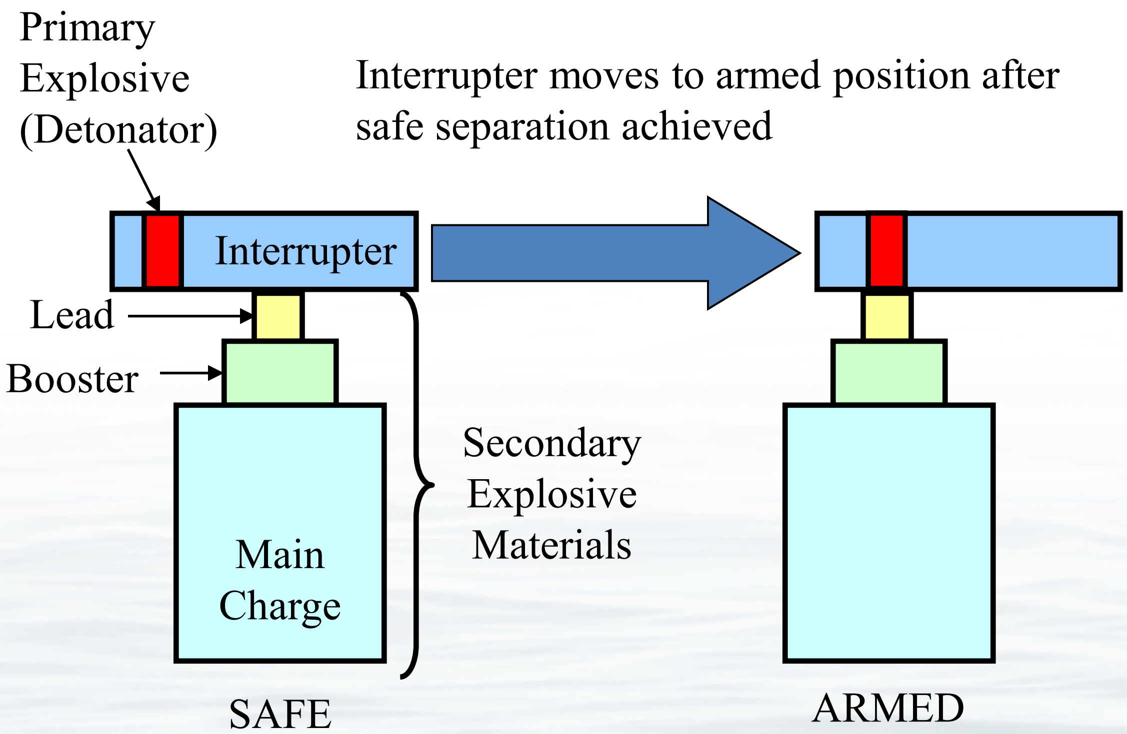
- Generic Safe/Arm Architecture
- MEMS and Fuzing Background: Why MEMS?
- MEMS vs ESAD
- Detailed MEMS Design
- Component Position Monitoring
- Summary



# Safe/Arm Safety Architecture Background

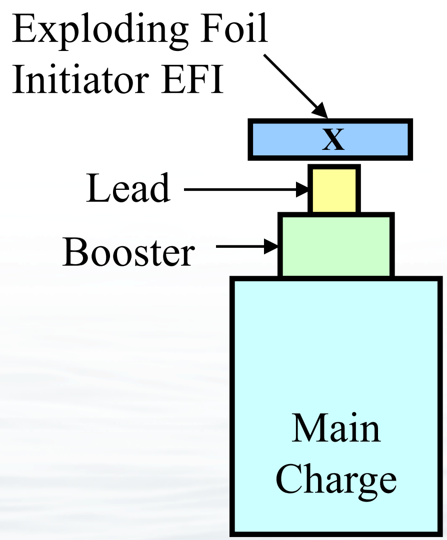
## Interrupted

- "Out-of-line"
- Electro-mechanical
- Pure mechanical




## Non-Interrupted

- "In-line"
- Electronic Safe Arm Device (ESAD)
- High voltage system

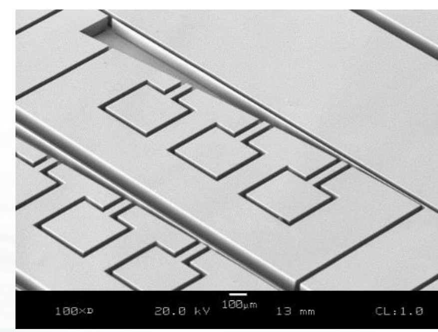



Electronic based system, no moving parts required

# MEMS: Why Use Them?

- New or more accurate function
  - Small size creates new possibilities
    - Features size ~1 micron
    - Embedded sensing
    - Complex mechanics
  - Low power requirements
    - Energy harvesting
    - RFID tags/embedded sensors
- Cost reduction
  - Batch fabrication enjoy benefits of economy of scale
  - Leverage IC foundries…infrastructure in place
- Reliability
  - Silicon has attractive mechanical properties (compared to conventional engineering materials)
- Assembly-free complex mechanisms

Sandia Dust Mite

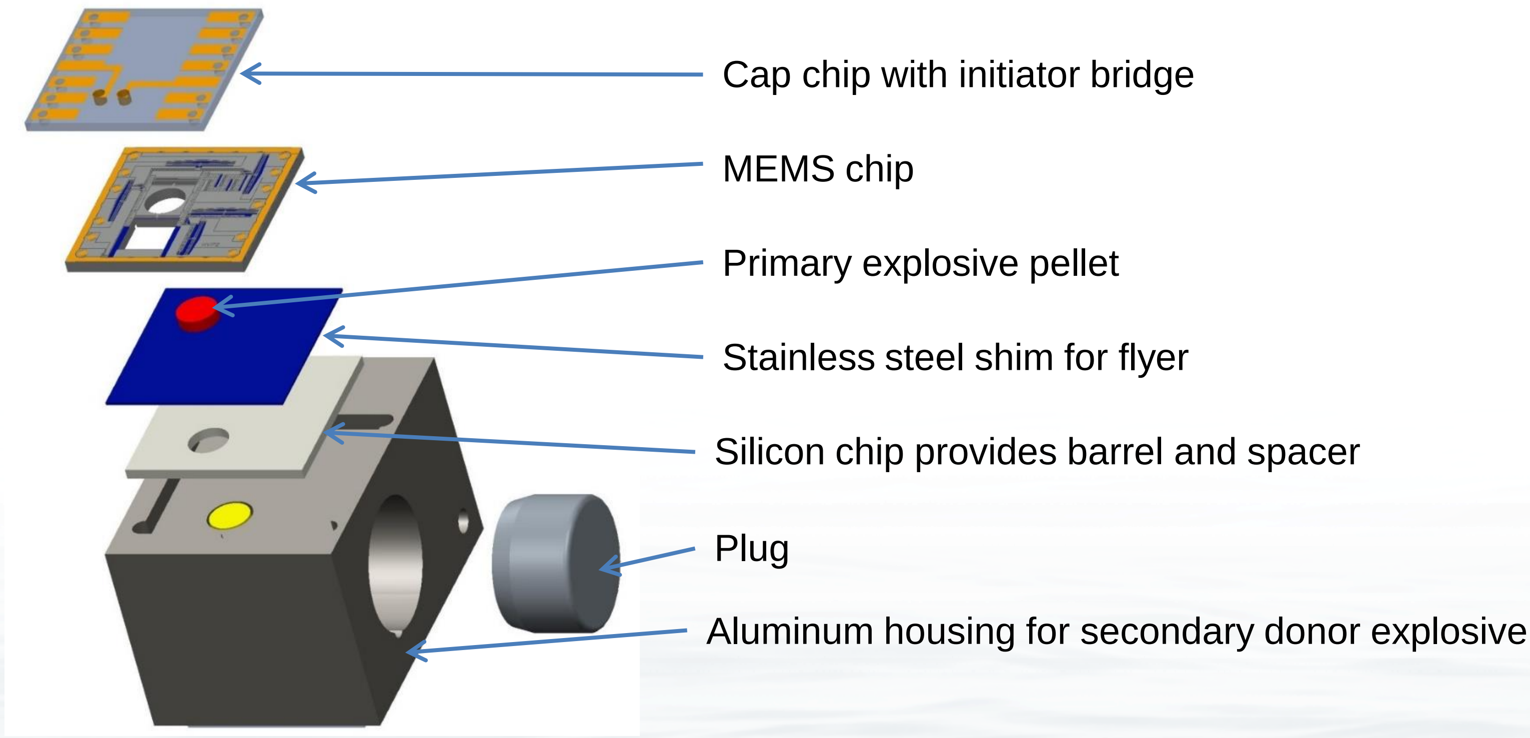


NSWC curved electrode actuator

# Fuzing: MEMS vs ESAD

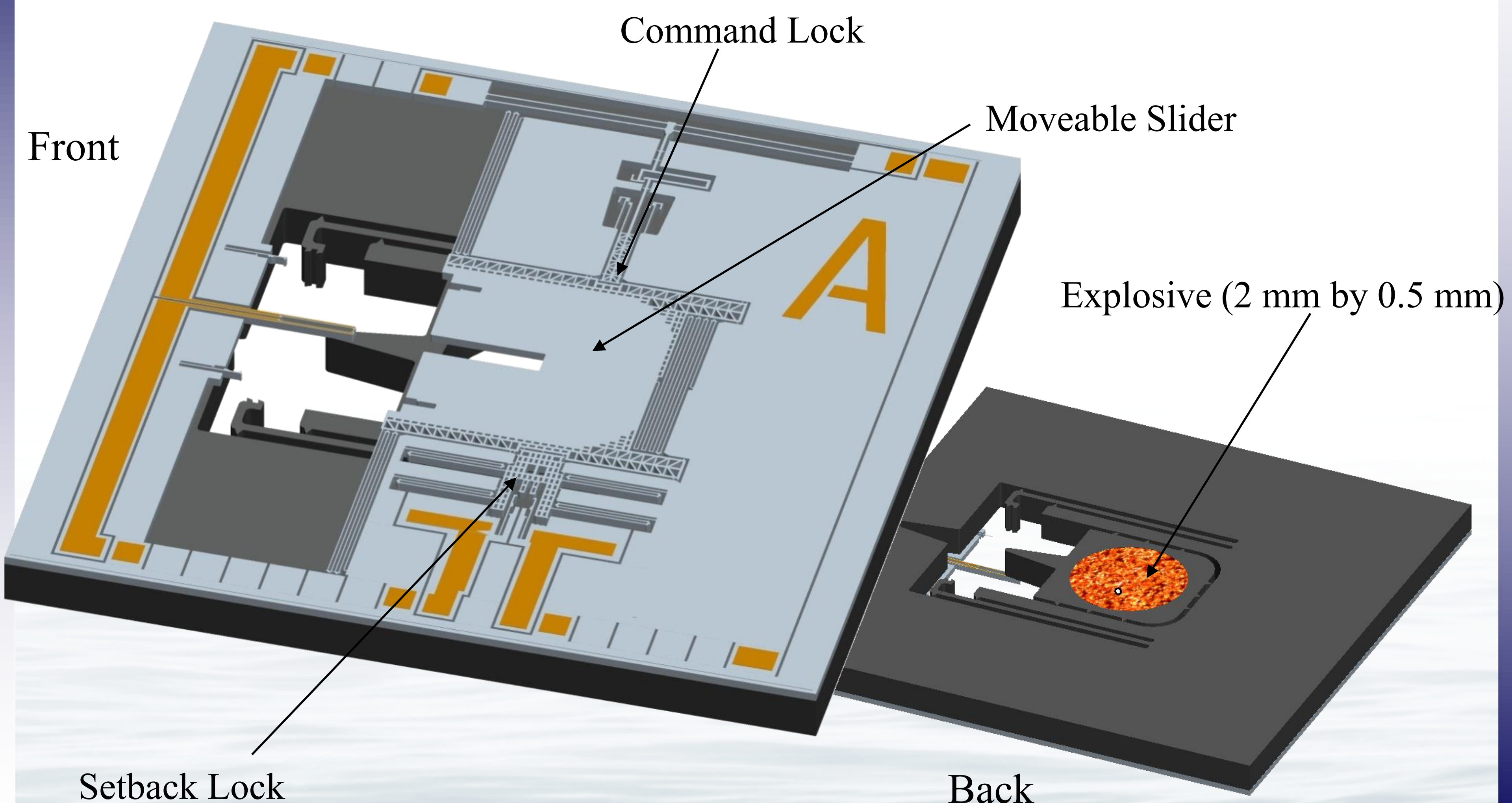
- Size: MEMS
  - A MEMS fuze design is typically smaller, especially in less complex systems (smaller, simpler munitions). As complexity is added, the differences in safe/arm technology contributes less to overall fuze size.
- Reliability: ESAD
  - ESADs have more data in this area, but MEMS also have the potential for high reliability
- Technical Maturity: ESAD
  - ESADs are fielded, while MEMS fuzes are in the prototyping stage
- Cost: MEMS
  - At low volumes, the cost is similar (<1,000 units per year). At higher volumes, MEMS has the potential to be less expensive.
- Power: MEMS
  - MEMS fuzes are typically lower power, especially if an inertial arming environment is available (such as spin). In addition, the MEMS fuze can hold the armed state without drawing any power. No high voltage generation is needed for MEMS.

# Typical MEMS Safe/Arm Assembly



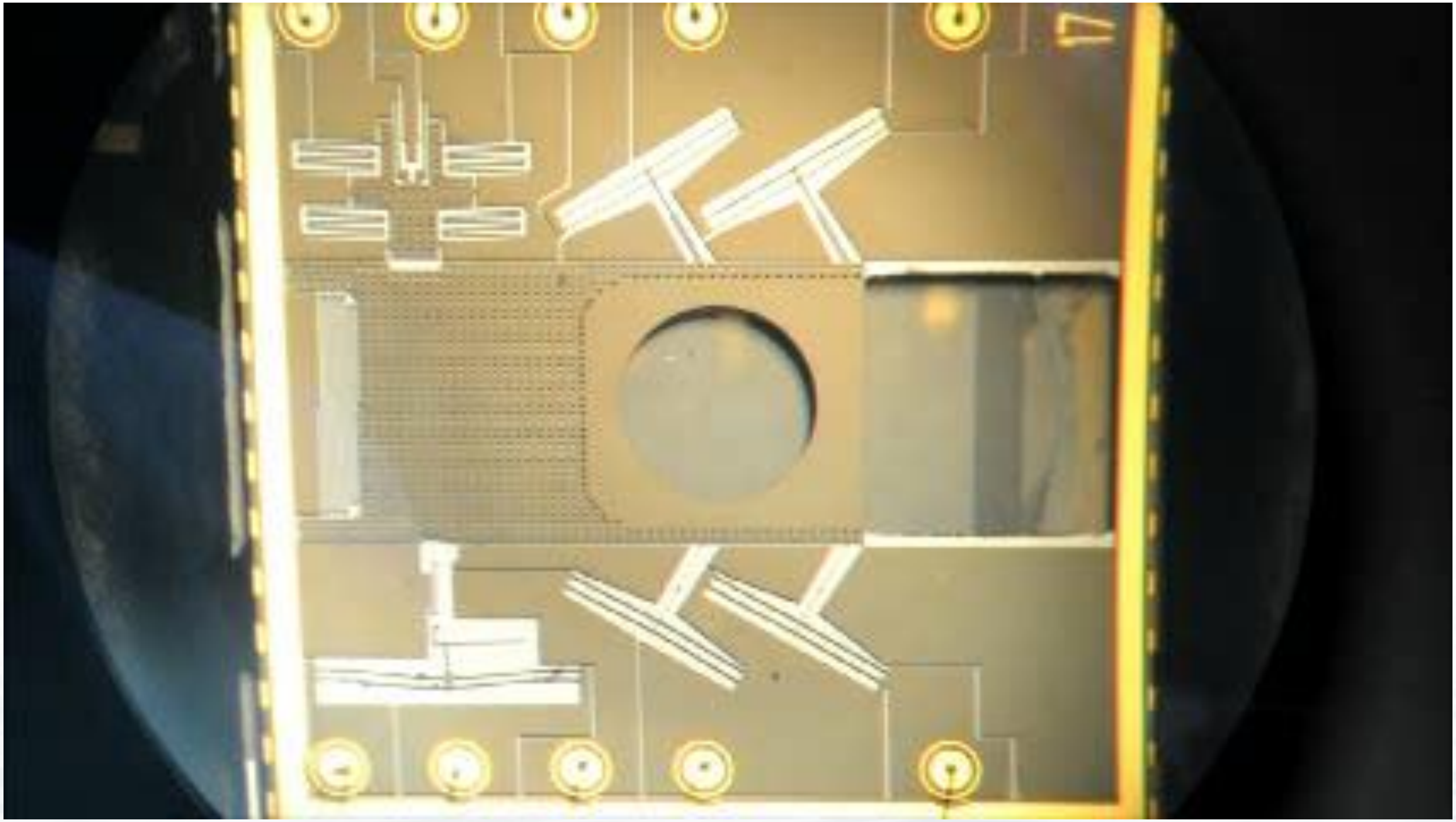
# MEMS with Explosives

## Micro-Electromechanical Safe Arm Device: 9 x 9 mm




Distribution A (20-087): Approved for public release; distribution is unlimited

# MEMS Command Arming in 40 ms



NAVSEA WARFARE CENTERS Indian Head EOD Technology Division

# Resettable MEMS Fuze

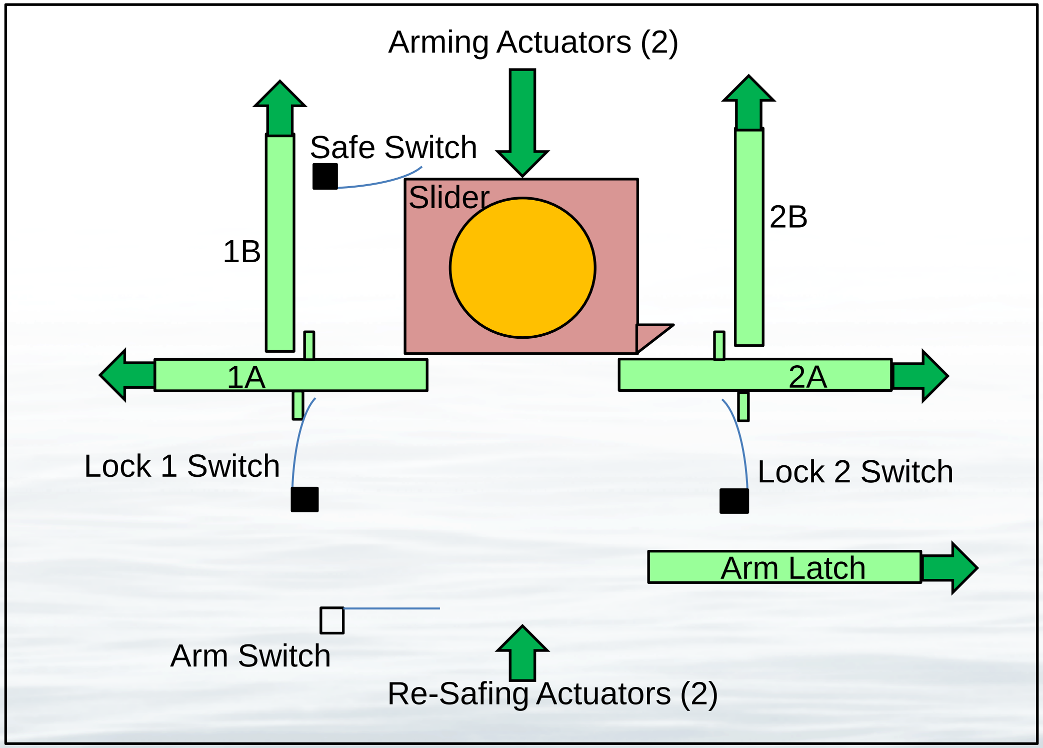
- Slider Locks (2)
  - Command actuated to unlock, latched in unlocked state with no power
  - Command actuated to lock, remain in locked state with no power
  - Each lock features a queryable switch that is closed in the lock state and open in the unlocked state
- Slider
  - Command actuated to arm; latches in armed position with no power
  - Command actuated to safe
  - Two switches on slider: one in safe position and one in armed position
- Safe/Arm Indication
  - Safe State
    - Both lock switches are closed
    - Slider safe position switch closed
    - Slider arm position switch open
  - Arm State
    - Both lock switches are open
    - Slider safe position switch open
    - Slider arm position switch closed
    - <u>OR</u> any switch state not matching Safe State conditions (unsafe state)

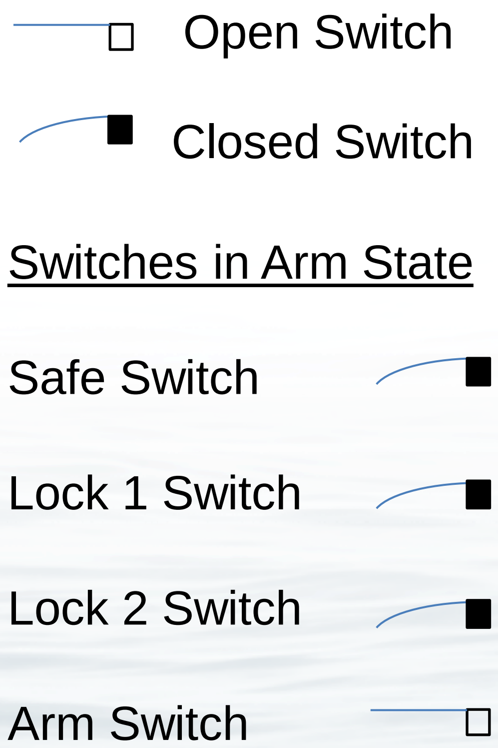
# Advantages of Component Position Monitoring

- Enhances safety by providing information on status of device
  - Feedback from lock switches to show if locks are in place or not
  - Feedback from safe position switch to show position of slider
- Enhances reliability of device
  - Opening and closure of lock switches to show lock function
  - Closure of arm switch to properly time initiation of explosive
- Provide additional capability
  - Allow arm-disarm function testing prior to final assembly with safety assurance from feedback
  - Allow arm-disarm if required by system

# Resettable Fuze Schematic: Safe

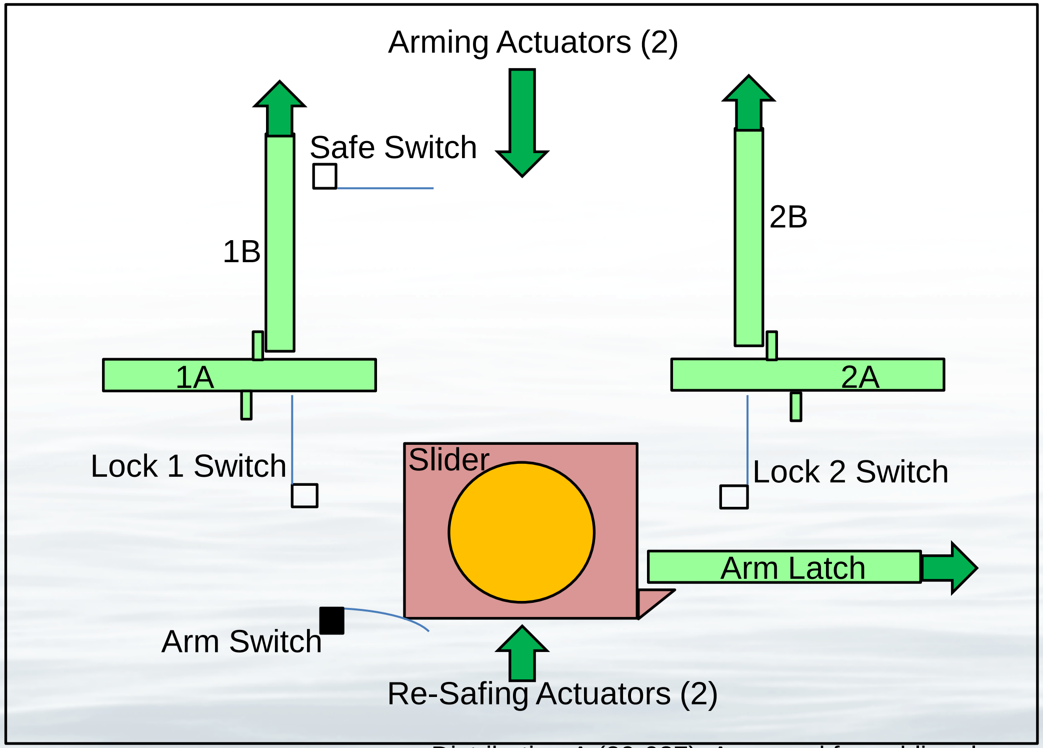
- Total # of actuators: 9
  - Two actuators to remove locks
  - Two actuators to hold locks
  - Two actuators to arm
  - One actuator to unlatch slider
  - Two actuators to disarm



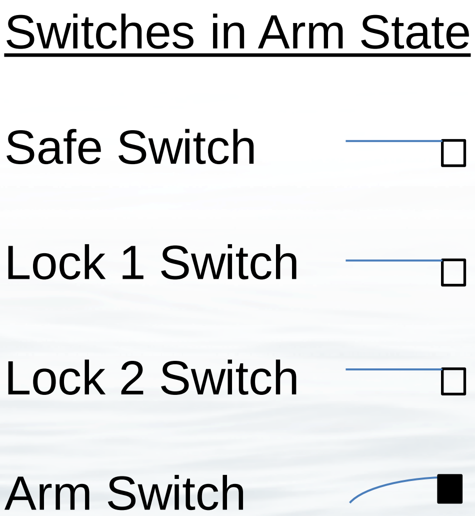



# Resettable Fuze Schematic: Armed

- Low power draw
  - Single pulse actuators, few hundred millijoules for each pulse
    - Lock actuators 1A, 1B, 2A, 2B, and Arm Latch
  - Cycled actuators, less than half a joule for complete slider travel
    - Arming Actuators and Re-Safing Actuators




Once armed, no power is drawn



# Resettable Fuze Status

- Chip design and fabrication complete; prototype MEMS chips functioning well in laboratory
- Over 500 safe/arm cycles and counting on a single demonstration chip (unlock, arm, re-safe, re-lock)
- Lock and safe switches tested to survive and function for more than 100 cycles
- Latest arm switch design currently in fabrication; expected to function over 100 cycles
- Future work: insertion into prototype fuzes and field testing

# Summary

- MEMS fuze design provides needed and new capability
  - Capability to reset as needed by mission/system requirements
  - Capable of numerous safe-arm cycles
  - Provides feedback of safe/arm status when queried
  - Low power draw
    - Little power needed to actuate locks
    - Little power needed to move slider
    - No power draw in armed state

# U.S. ARMY COMBAT CAPABILITIES DEVELOPMENT COMMAND – ARMAMENTS CENTER

## Fuze Conference
## Fuze and Power STO
## Next Gen Large Cal Setter (NGLCS)

Maxim Keyler

Technical Lead

Organization: METC, Fuze Division, FCDD-ACM-FF

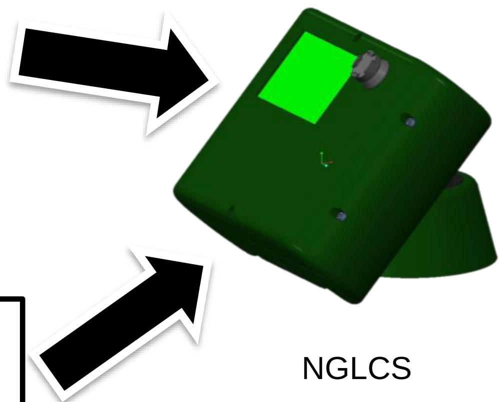


July 2020

# NEXT GENERATION LARGE CALIBER SETTERS (NGLCS)

## FUZE AND POWER TECHNOLOGIES FOR MUNITIONS (FY15 STO)

Current EPIAFS



NGLCS

- New SBC
- Direct Set
- Advanced Data Transfer
- Smaller/Lighter
- Hand-held or auto-loader capable

### *Schedule & Cost*

| MILESTONES | FY15 | FY16 | FY17 | FY18 | FY19 |
|---|---|---|---|---|---|
| Requirements Development | | | | | |
| Concept Development & Preliminary Design | | | 4 | | |
| Engineering Experimentation & Test | | | | 5 | |
| System Design & Integration | | | | | 6 |

**Purpose:**

One of four projects under the Fuze and Power Technologies for Munitions STO

- Develop and demonstrate the next generation of smaller and lighter large caliber setters for use in auto-loading cannons and guided mortar applications
- Develop a government designed and owned Single-Board-Computer (SBC) for use with current and next generation programmable fuzes
- Develop new capabilities for direct-set fuze applications and advanced data transfer requirements
- Reduce size and weight of setter system for use with auto-loading systems and reduced warfighter burden (hand-held applications)

**Results/Products:**

- Smaller and lighter large caliber fuze setter for use in auto-loading cannon systems and guided mortar applications, as well as maintains legacy capabilities
- New SBC that combines the functions of the iPIK/wand/user interface
- New setting capabilities: direct set and advanced data transfer

**Payoff(s):**

Advanced communication and programming schemes for a large number of current and future applications, all in one system

Reduced warfighter and weapon platform burden

**Endorsement(s):**

PEO AMMO 27 April 2015

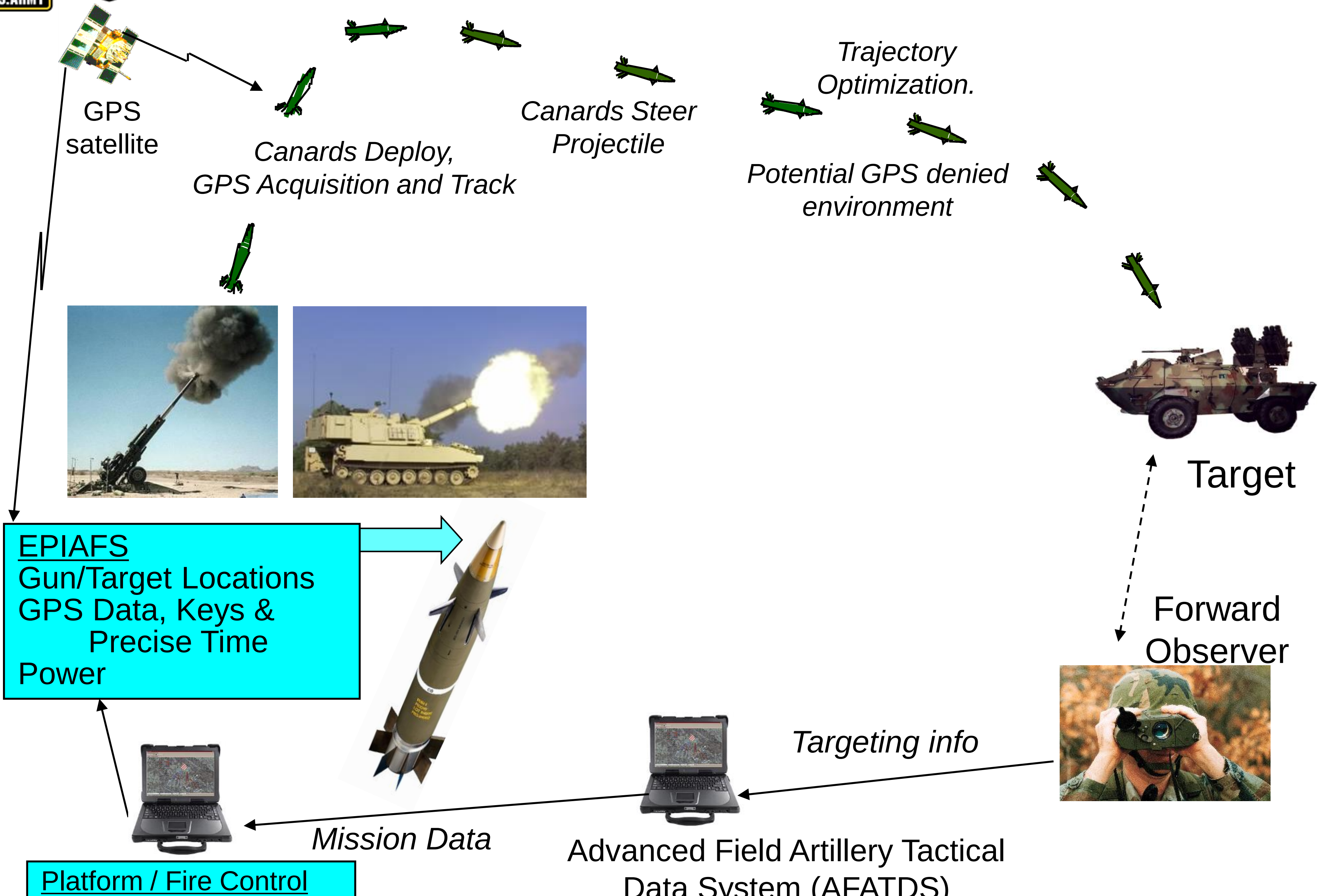
Fires Center of Excellence 28 April 2015

Maneuver Center of Excellence 13 May 2015

TTA DRAFT for HEGM - OCT 2017 - cancelled

**Transition(s):** ERCA, Long Range PGK (LR-PGK), XM1155, legacy artillery PoRs

# REPRESENTATIVE PRECISION GUIDED MUNITION ENGAGEMENT



# FIELDED PRECISION GPS GUIDED MUNITION AND FUZES

## Excalibur Precision Guided Munition – M982A1

- Original Development started in the 1990s
- Fully guided 155mm munition
- Raytheon Missile Systems is the contractor
- Artillery launched - precision strike

## Precision Guidance Kit (PGK) – M1156

- A course correcting fuze to use with 155mm artillery projectiles
- Northrop Grumman (formerly Orbital ATK) is the contractor

Disposable Cover for Inductive Interface to Setter

PGK

## Mortar Guidance Kit (MGK) – XM395

- Leveraged PGK development to add similar capabilities for mortars
- A course correcting fuze for 120mm mortars
- Northrop Grumman (formerly Orbital ATK) is the contractor
- Mortar component of the Advanced Precision Mortar Initiative (APMI)

# FUTURE PRECISION GUIDED MUNITION APPLICATIONS

- XM1155 Extended Range Artillery Projectile
- Excalibur Hit to Kill
- Long Range PGK
- Image based guided munitions

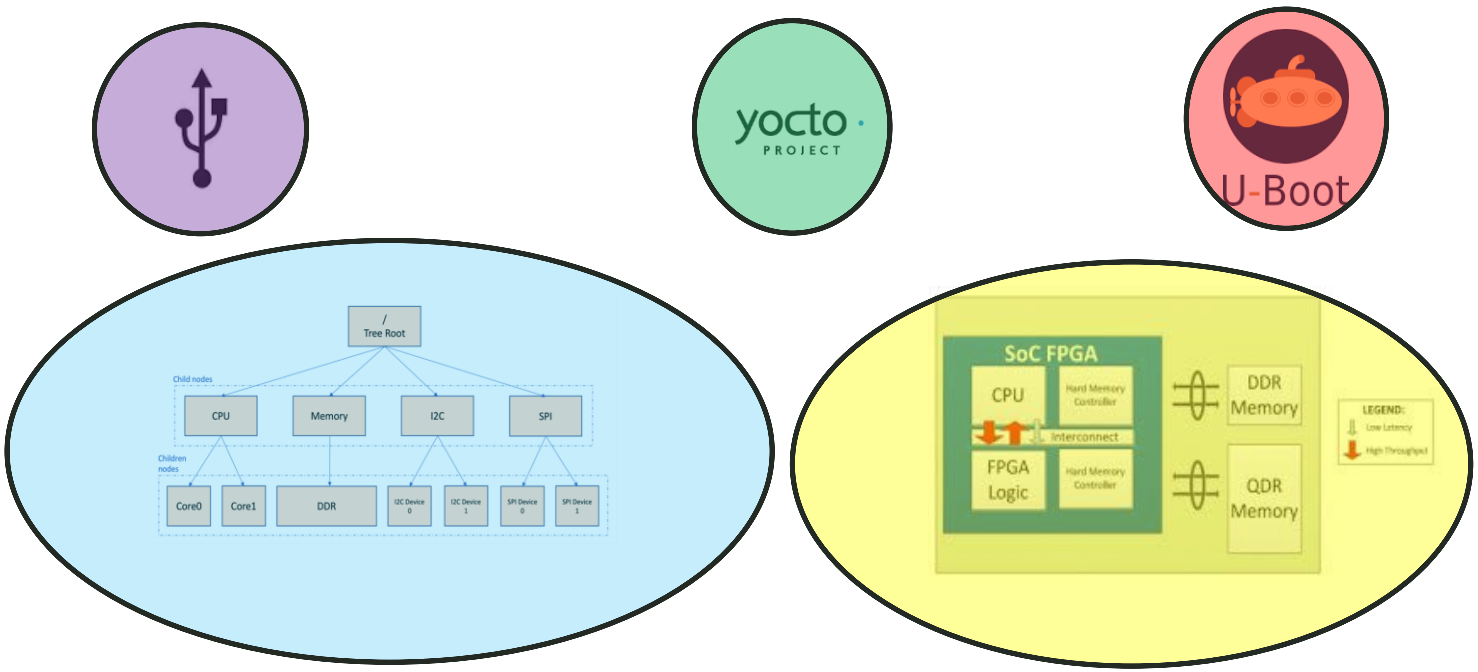
NGLCS can be tailored/augmented to support future munition interfaces.

# OVERVIEW OF NGLCS ACCOMPLISHMENTS

- Expanded capability of EPIAFS and condensed all circuitry onto 3 boards - in a single hand held unit
- FPGA designed with significantly more processing power
  - Enables future re-designs for point solutions
  - Enables wireless setting for future development
- Custom Linux operating system
- Maintained compatibility
  - Standard fuze
  - Precision Guided Munitions
- Added capability with interfaces
  - Low speed direct set
  - High speed direct set

# GOVERNMENT OWNED IP

- **Government owned design**
- Not tied to proprietary intellectual property
- Capability exists to update system in-house



# NGLCS ELECTRONICS

## Circuit boards

- **Interface Board**: Connectors, Buttons, LCD
- **Power Board**: Power regulation
- **Logic board**: digital logic, FPGA

## Customizable

- May remove/reconfigure LCD, buttons, connectors, inductive coil, GPS antenna, etc
- Circuit board designs are government owned and thus can be reconfigured to suit requirements.
- Allows government freedom to sustain design indefinitely without implications of proprietary data.

# SUPPORTED FUZES

| Fuze Name | Type | Country |
|---|---|---|
| M762/M762A1 | Standard | USA |
| M767/M767A1 | Standard | USA |
| M782 | Standard | USA |
| C32 | Standard | Canada |
| DM-52 | Standard | Germany |
| DM-74 | Standard | Germany |
| DM-84 | Standard | Germany |
| FUCHSIA | Standard | France |
| L163A1 | Standard | Great Britain |
| L166A1 | Standard | Great Britain |
| M1156 | PGM | USA |
| XM982 | PGM | USA |
| M982 | PGM | USA |
| M982A1 | PGM | USA |
| XM395 | PGM | USA |

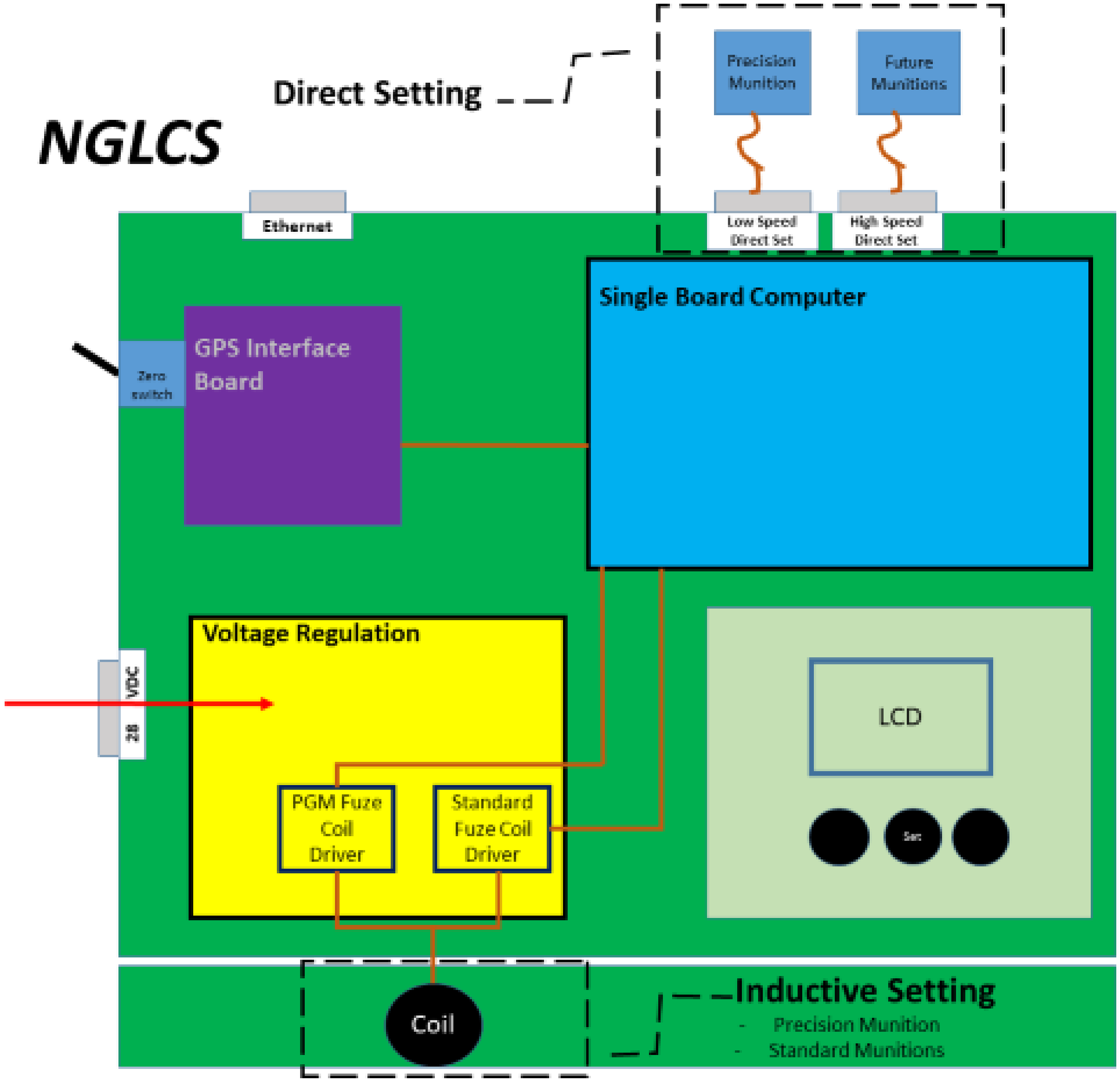
# PICTORIAL OVERVIEW

EPIAFS
(Case, Power, PIK, Cables, Wand)

EPIAFS ➡ NGLCS
Reduced Size
Single handheld unit
Added functionality

NGLCS

# NGLCS BLOCK DIAGRAM




**Signal and Data Overview**

## 4 Boards

- SBC
- GPS
- Voltage Regulation
- LCD

## 4 Setting Modes

- High Speed Direct
- Low Speed Direct
- Standard Inductive
- Precision Inductive

# NGLCS HIGH SPEED DIRECT SET

*Challenge:* Future image based fuzes will require much larger size of initialization data and faster communication link to set fuze.

| Communication Link | Data Rate | Small Data Size 80 to 8500 bytes | Large Data Size 20 MB |
|---|---|---|---|
| Inductive Set (72 KB/sec) | 72 KB/s | < 1 sec. | 278 sec |
| Low Speed Direct Set RS422 (1 Mbps) | 1 Mbps | < 1 sec. | 20 sec. |
| High Speed Direct Set USB 2.0 (35 MB/s) | 35 MB/s | < 1 sec. | 0.57 sec. |

Inductive Set – currently used by fielded EPIAFS
Direct Set – Communication is via direct electrical connection

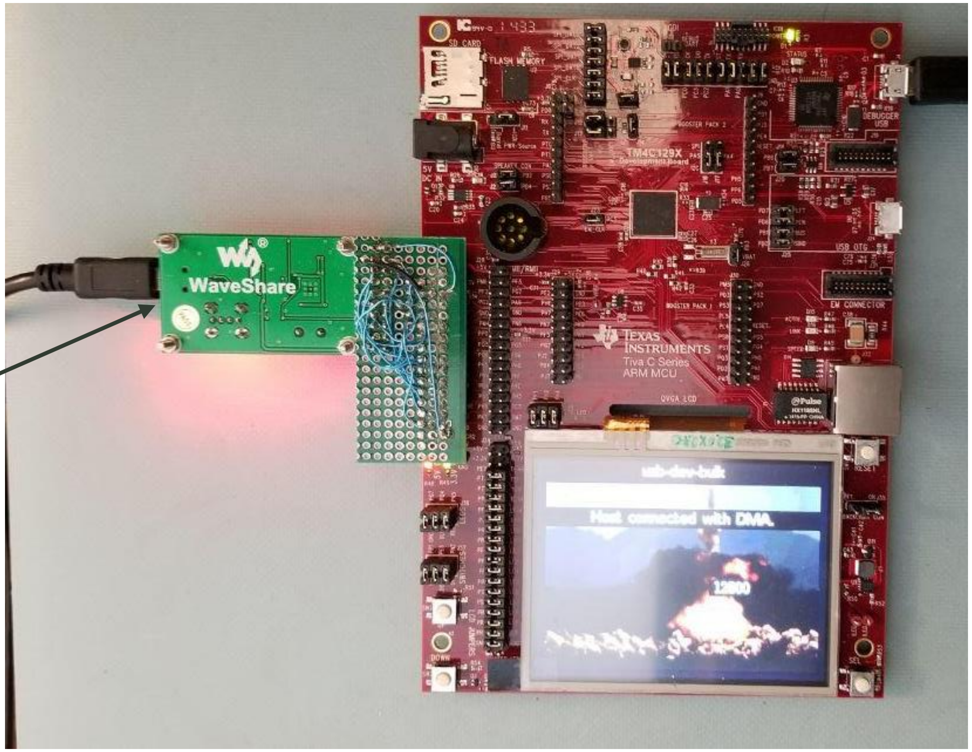
# NGLCS HIGH SPEED DIRECT SET

- Direct Set – Communication link is through direct electrical connection.
- NGLCS system supports USB 2.0 High Speed protocol
- NGLCS PIK application can send initialization data via USB link at effective data rate up to 35 MB/sec.
- NGLCS sends data at a rate compatible with USB capable fuzes

# NGLCS HIGH SPEED DIRECT SET

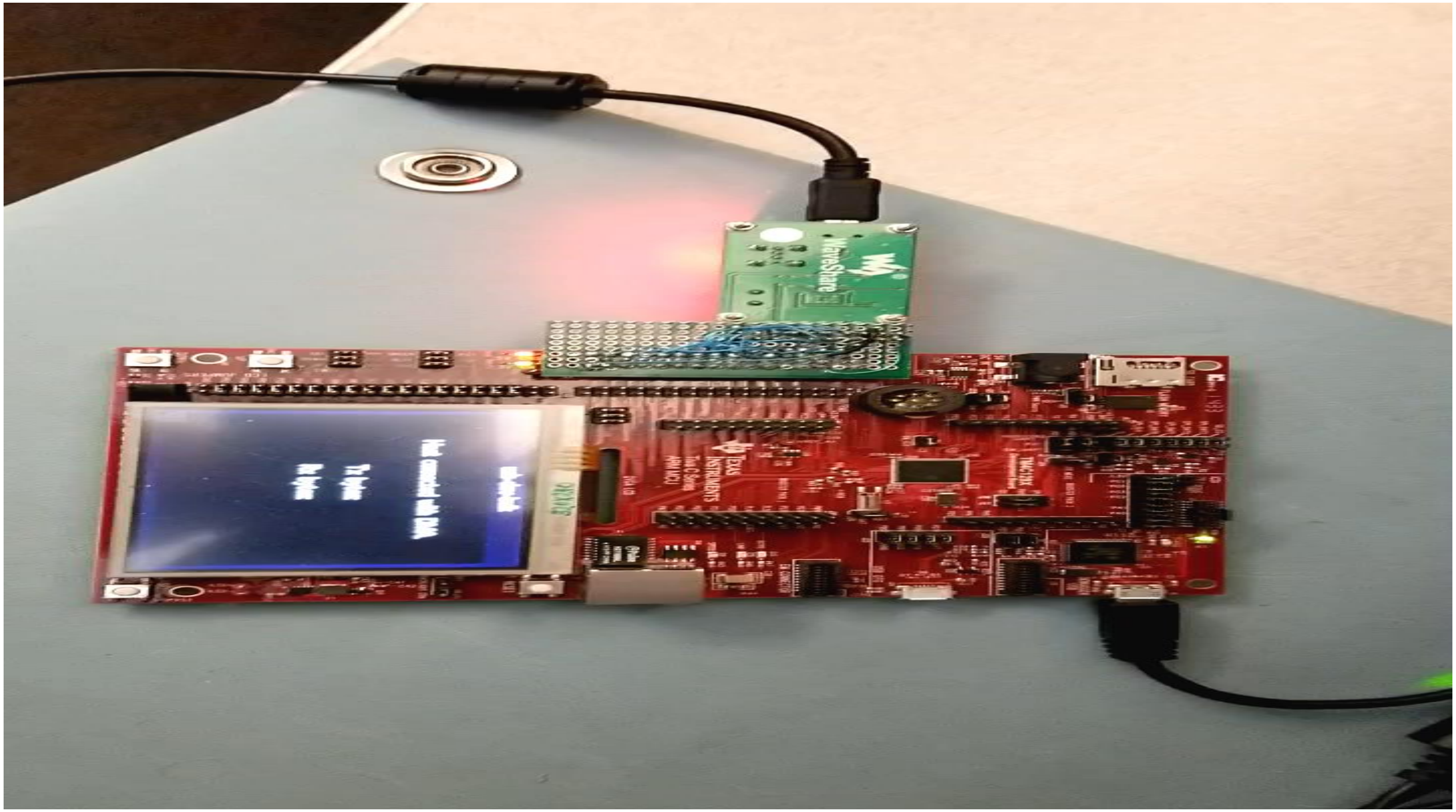
- There is no existing high speed direct set capable fuze. Emulation board was built to demonstrate high speed direct set capability.
- Developed firmware that can receive a series of image data at 35 MB/s, and display them in sequence on a color LCD screen.

High Speed
USB 2.0 Link

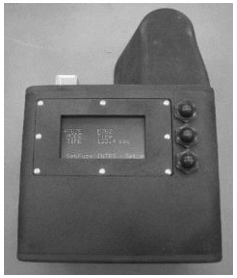


# HIGH SPEED DIRECT SET DEMONSTRATION

NGLCS sends 70 frames of video image (80KB per frame) to emulation board via High Speed USB 2.0 link at 35 MB/s.



# SUMMARY AND PATH FORWARD



- The Next Gen Large Cal Setter developed under the Fuze and Power Science and Technology Objective exceeded size and weight objectives

- Handheld setter replicates all capabilities of existing EPIAFS while adding both high and low speed direct set capability.

- Verified inductive interface on existing Precision Guided fuzes

- Developed direct set interface to demonstrate high speed setting of 70 frames of video/80KB per frame over USB 2.0 interface at 35MB/sec

- Anticipate supporting ERCA autoloader to facilitate rate of fire goals
(*Munition interface was not addressed under this program)