DoD MEMS Fuze Explosive Train Evaluation & Enhancement

61st Annual NDIA Fuze Conference, San Diego, CA
Wednesday, May 16th 2017, Open Session IIIA

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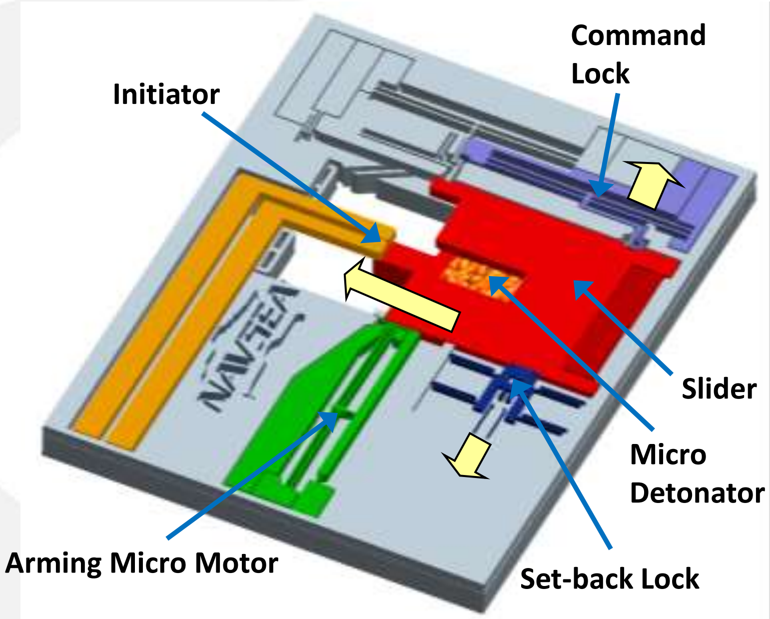
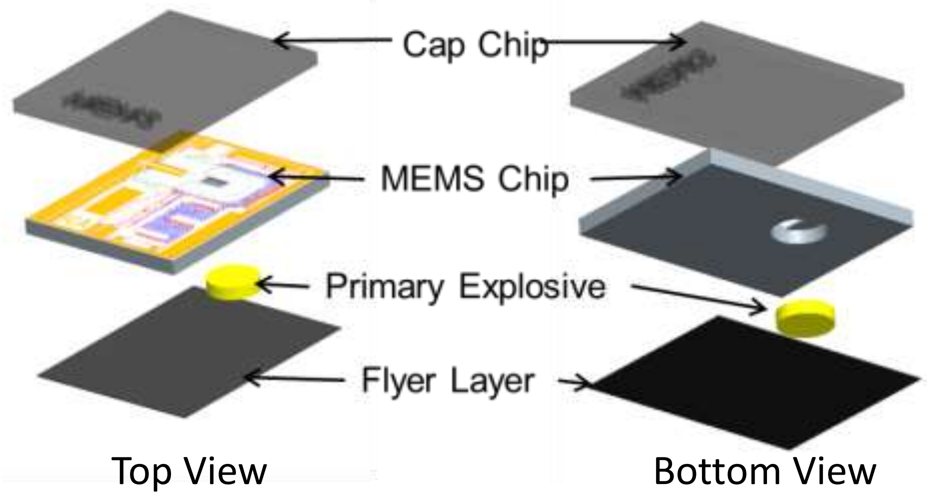
MEMS Safe and Arm

- MEMS S&A offers the potential for small volume, low cost, and low energy.
- NSWC IHEODTD has nearly two decades of silicon/SOI MEMS design, fabrication, and packaging experience.
- Safety locks: integrated micromachined direct acting and command actuated lock architectures
- Arming: environmentally derived and command architectures
- All non-explosive components fabricated on SOI wafers using established semi-conductor processes.

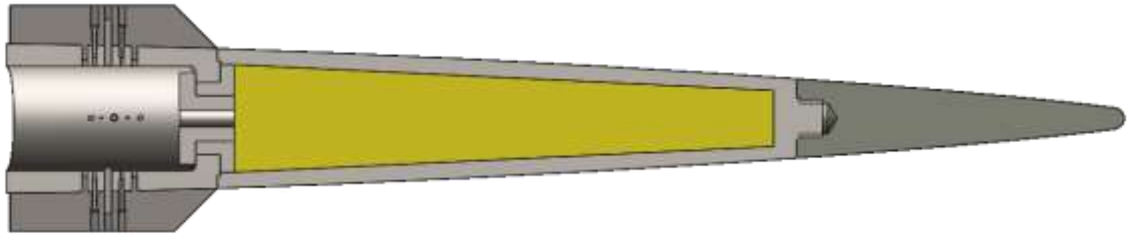




MEMS Fuzing Applications

40 mm Grenade

Gun Launched Projectiles



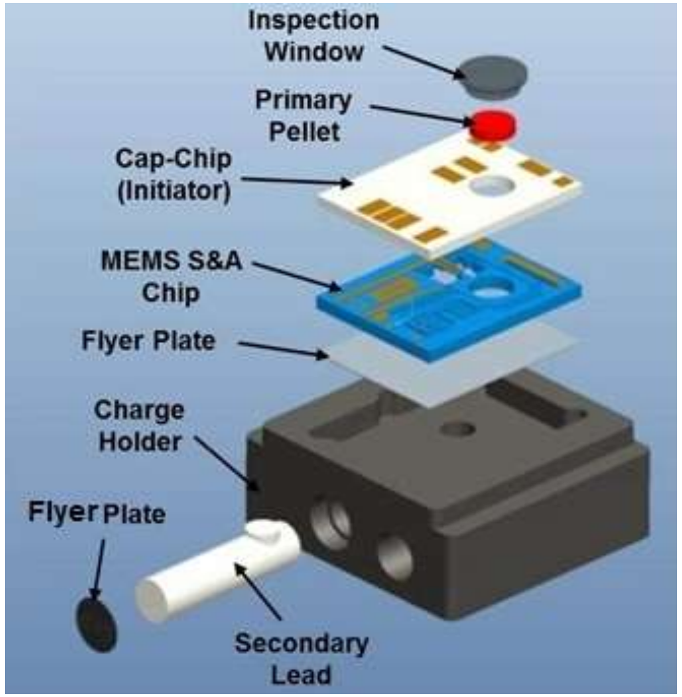
Underwater Systems

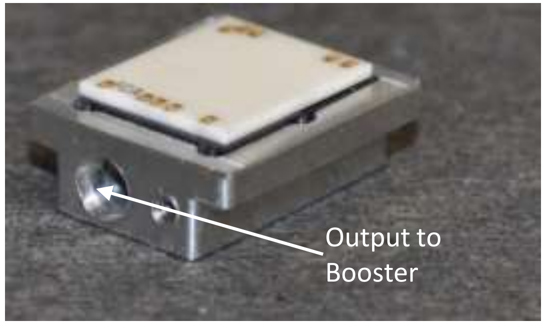
Mortars

Explosive Train Overview

- Studying the explosive trains of both the Navy and Army MEMS Fuze
- Both designs have been demonstrated to TRL6
- Navy Design
  - Vaporizing metal foil bridge initiator fabricated onto the cap chip
  - Pressed silver azide pellet assembled with the MEMS S&A chip drives a flyer to initiate an explosive ink output lead
  - Lead make 90° turn and initiates a booster
- Army Design
  - Metal foil bridge
  - Deposited energetic ink drives small flyer into explosive ink transfer charge
  - Transfer charge makes two 90 ° turns and initiates output lead

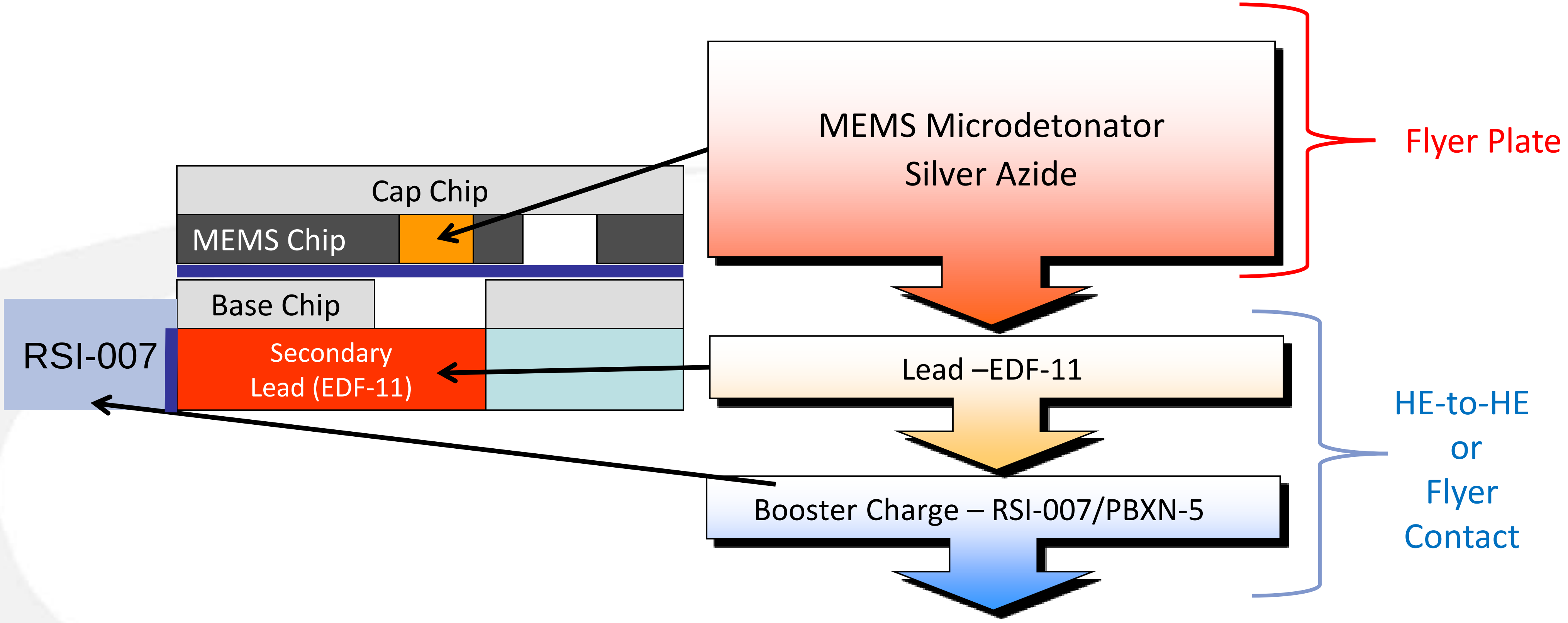
Navy MEMS Fuze Stack up





μDetonator Package

Navy Explosive Train (Basics)



Explosive Train Reliability

- MEMS intentionally pushes the lower limits of explosive component size. We want the smallest size detonators and leads that will work reliably.

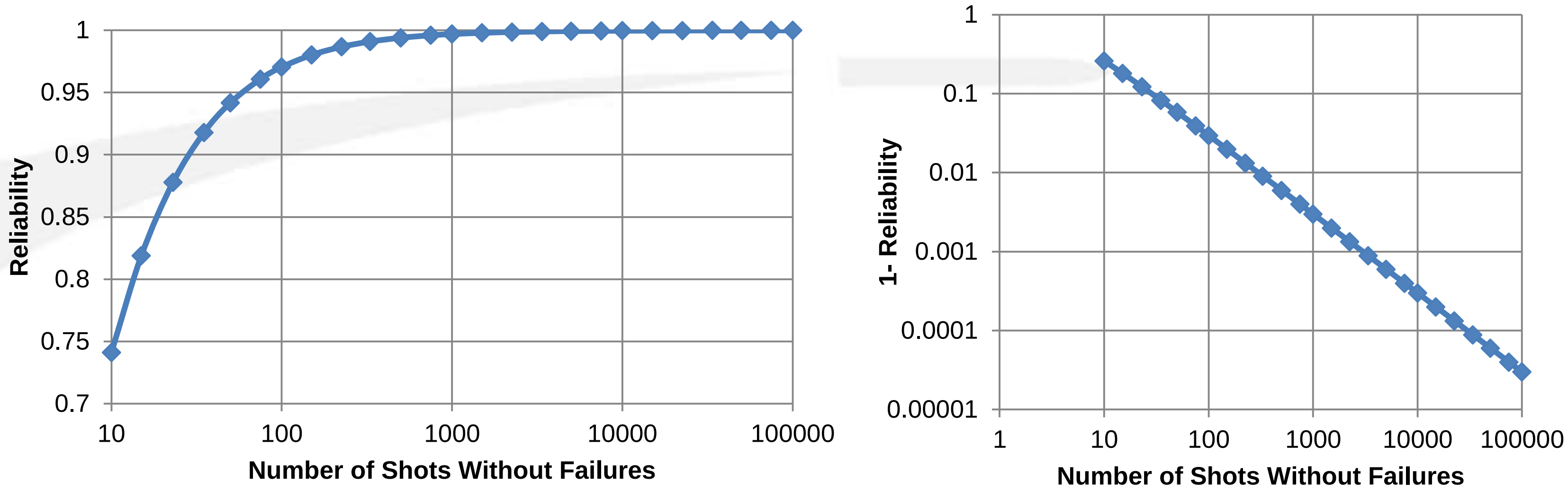
- The need for credible reliability estimates pushes us towards to employ more advance diagnostic techniques such as Hugh James Initiation Criteria.

Brute Force Methods

Brute force demonstrations requires excessive number of shots to prove reliability.

99.9% Reliability @ 95% CL: 3000 Shots

Binomial Reliability at 95% Confidence Level (one sided)

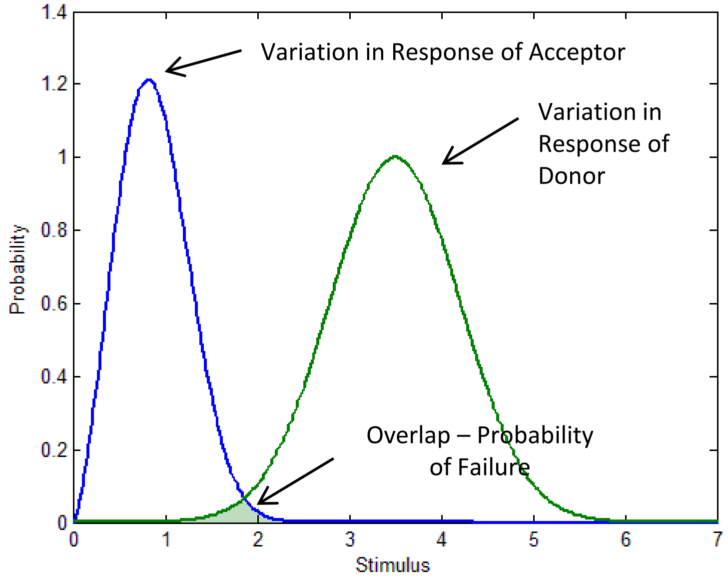


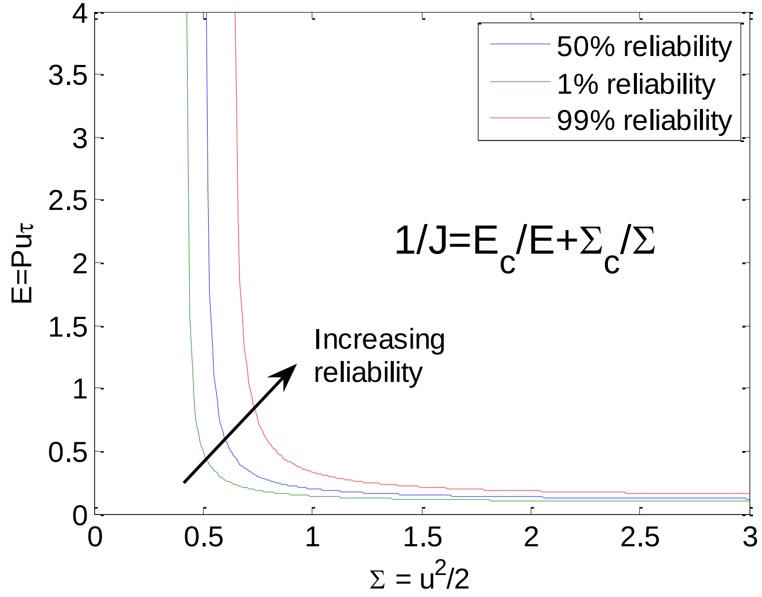
100 shot test series only demonstrates reliability to 97% (@ 95% CL)

Extremely expensive and becomes impractical for an evolving design

Background – Probabilistic Hugh James Space

Hugh James formalism can be used to map out statistical response of acceptor explosive



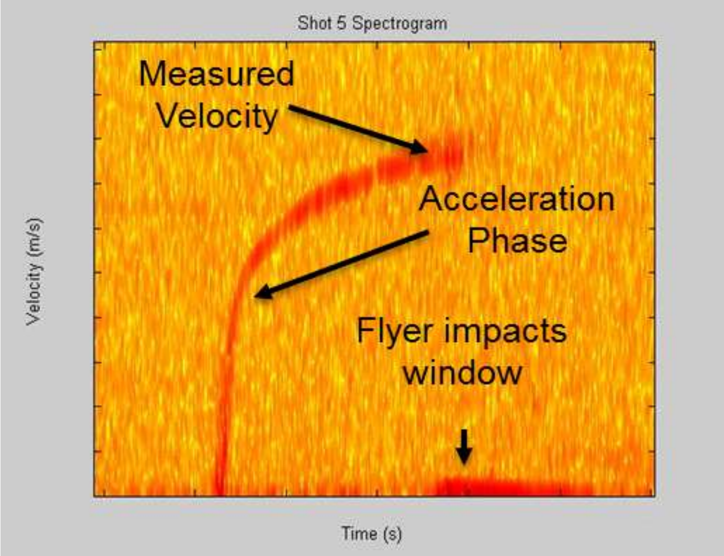


E_c (critical minimum energy) & Σ_c (critical minimum 'power') are defined by the acceptor explosive material. E & Σ can be calculated from variable flyer and gap tests and inherent explosive properties.

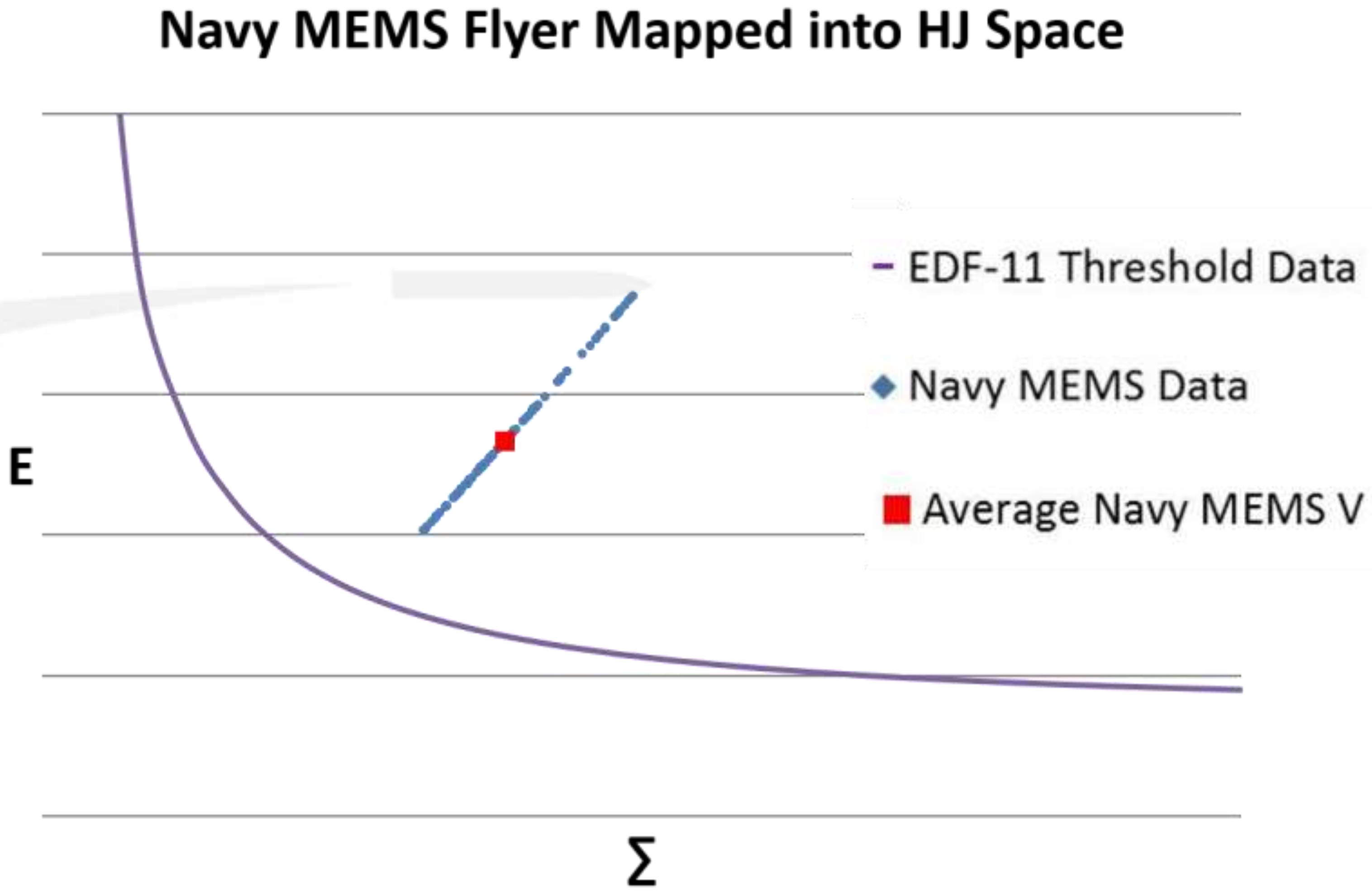
Data can better be used to evaluate a family of similar designs, provide more insight into the system and can be used to optimize designs

These methods were developed at AWE and LLNL and implemented at AFRL.

Detonator Characterization



- AgN_3 flyer velocities measured with PDV
- 107 shots analyzed. Standard deviation 6.3% of mean value



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Further MEMS Miniaturization

IHEODTD is also investigating alternative energetic materials and pellet dimensions of the primary explosive pellet with the goal of further miniaturizing the MEMS fuze

- Deflagration to detonation (DDT) length is the main factor controlling performance at these small scales which is very difficult to predict and, at the MEMS scale, no material is a perfect point detonate

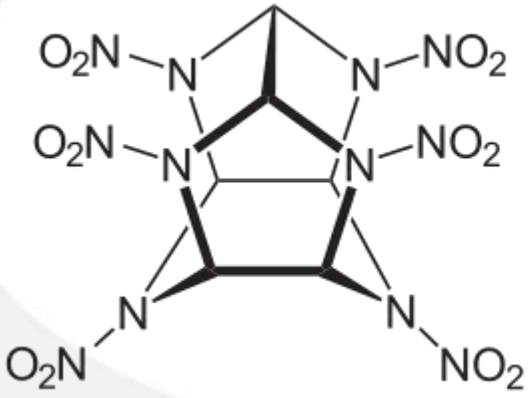
- Potential improvements in MEMS fuze manufacturing are also being investigated

Alternate Primary Energetic Materials

NSWC IHEODTD is looking at replacing the Silver Azide pellet with:

CL-20/AgN_3 Blend

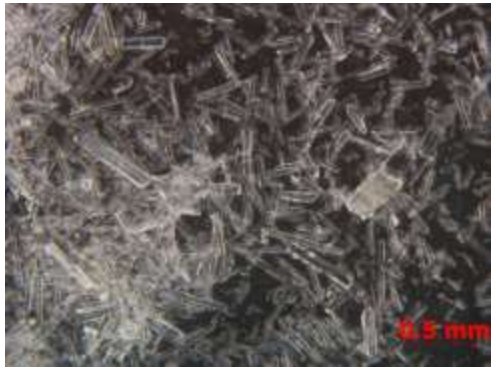
- Homogeneous blend with increased sensitivity and output
- AgN_3 at the initiation side, CL-20 at the output



http://en.wikipedia.org/wiki/Hexanitrohexaazaisowurtzitane

CL-30

- New molecule developed at China Lake
- Multiple formulations exist, IHEODTD is mostly investigating neat material



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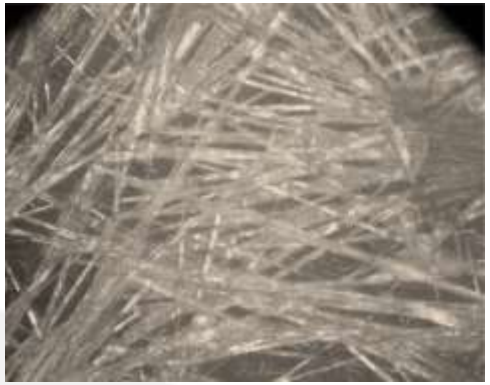
Alternate Primary Energetic Materials - Cont

DAHA/DATA

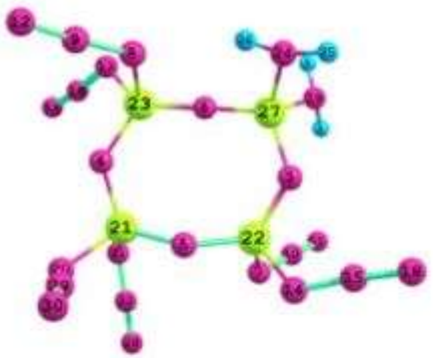
- Melt castable – 72° C melting temp, 230° C decomp temp
- Successfully loaded into MK-1 detonator with increased performance
- Green/Non Toxic



Zhang, Jianguo, et al. *International journal of molecular sciences* 10.8 (2009): 3502-3516.

FTDO

- Has been synthesized by IHEODTD, previously only seen in Russian literature
- Shown to be highly sensitive
- Predictions of detonation properties comparable to CL-20



Simonenko, V. N., et al. "Comb... I. Binary systems." *Comb., Expl. and SW* 50.3 (2014): 306-314.

Pellet Dimension Study

- Investigating reducing the size of the AgN_3 pellet while maintaining reliability
  - Pressing tooling fabricated at multiple sizes

- Designing and fabricating surrogate test hardware to reduce testing time and complexity

- Successful transfer tests to EDF-11 of a particular pellet size will lead to PDV measurements of AgN_3 flyers

Additional Ongoing Testing

- Out of line safety testing
- Transfer lead output test series
  - PDV measurements of lead output
  - Verigap testing to typical booster material
- Cold temperature reliability testing
- Tactical layout Neyer series testing

Conclusions

- New explosive trains require new methods of analysis.
- These new methods can better aid data driven design.
- We are utilizing a new method to quantify the reliability of small explosive trains with a reasonable number of asset firings.
  - 1st DoD MEMS detonators (Navy and Army) to be mapped into Hugh James Initiation coordinates for reliability assessments
- Both and the Navy and Army are employing novel methods to ensure that MEMS fuzing achieves the highest degrees of reliability possible.

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Acknowledgments

Thanks to the Joint Fuze Technology Program (JFTP) for funding this work.

Thanks to Chadd May and Lawrence Livermore National Labs (LLNL) for the loan of the electric gun.

Thanks to Eric Welle and the Air Force Research Laboratory for Hugh James implementation support.

Thanks to those who have helped work on the project:

NSWC IHEODTD
Daniel Lanterman
David Muzzey
Matthew Buckler
Kevin Phelps
G. Shane Rolfe

ARDEC
Roger Cornell
Daniel Stec
Charlie Robinson
Jeffrey Smyth
Brian Fuchs

Questions?

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