NDIA 48th Annual Fuze Conference

Weapon Fuzing / Safety & Arming Technology Programs Overview

NSWC / Indian Head Division

John Hendershot

(Code 4420: Phone 301-744-1934 or e-mail hendershotje@ih.navy.mil)

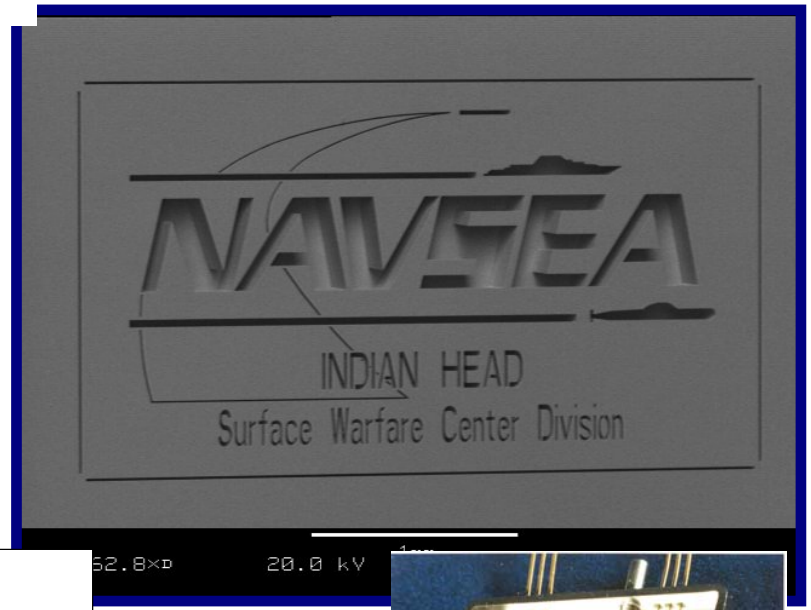
Fuze Safety & Arm Branch Lead

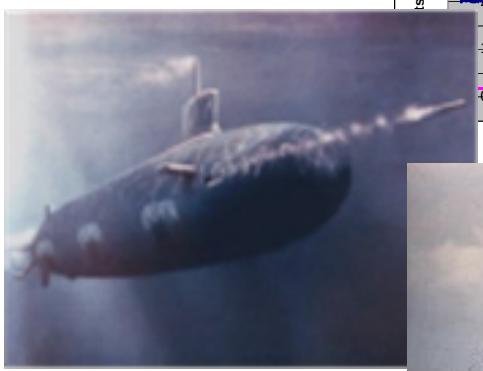
NAVSEA WARFARE CENTERS

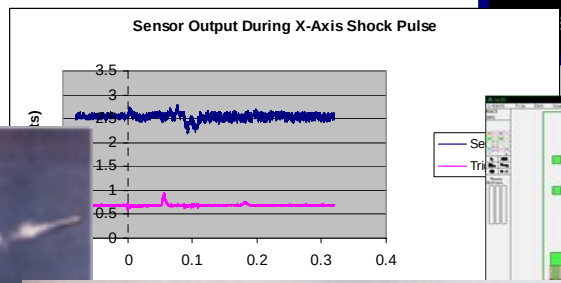
NAVAIR

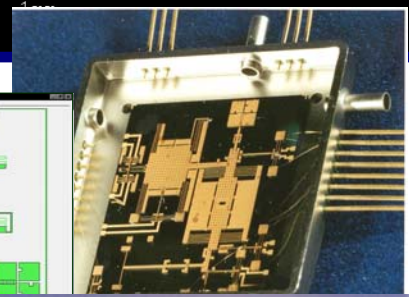
OUTLINE

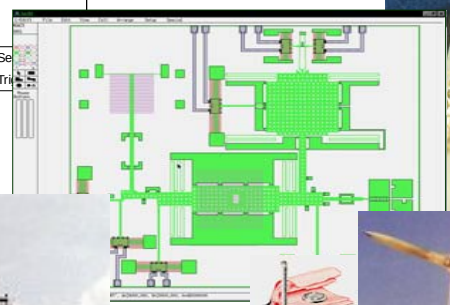
- Torpedo Fuze/S&A Technology Efforts
- MEMS G-Sensor Technology
- Next Generation Miniature Fuze/S&A Technology
- Summary







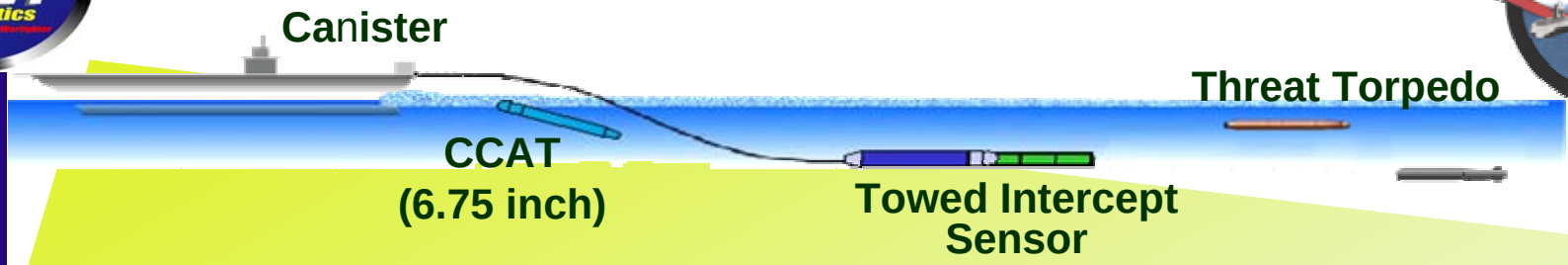




NAVSEA WARFARE CENTERS

NAVAIR

Torpedo S&A Technology



- CCAT - Engineering Development Model Prototype (Pre-SDD)
- Multi Mission (MM) Torpedo S&A Technology Program
  - Defense & Offense Missions
  - Multiple Launch Platforms

MK 21 Exploder (118 cu in)

MK 22 Exploder (75 cu in)

CCAT Exploder (15 cu in)

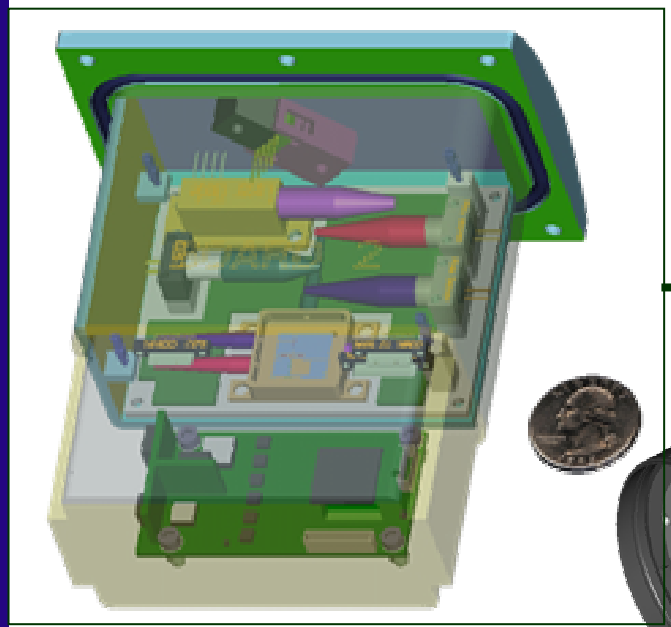
Why MEMS Technology?

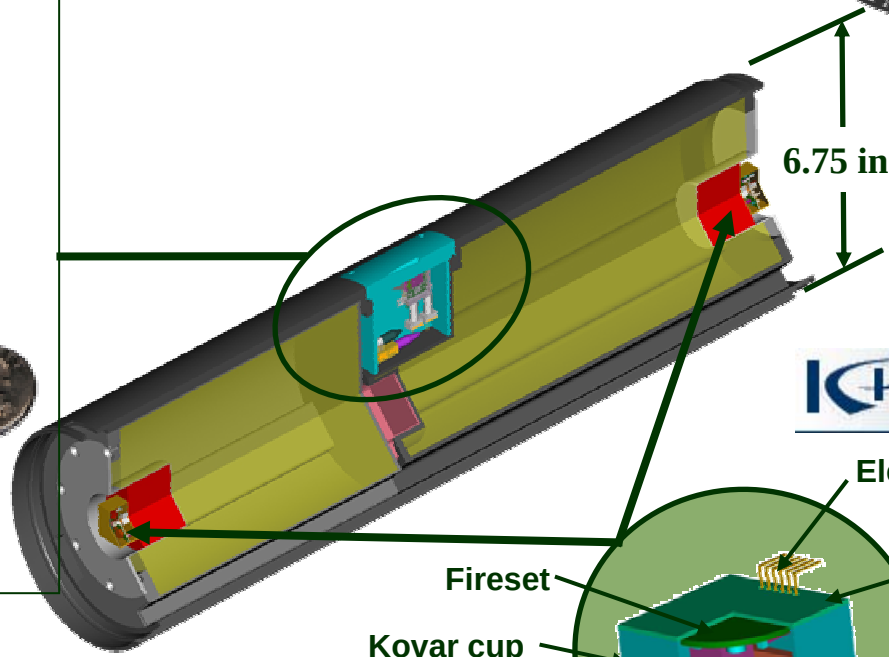
- ✓ **Smaller, Lighter Fuze/S&A**
- ✓ **Increase S&A safe-separation accuracy**
- ✓ **Modular Architecture: adaptable to multiple platforms (sub & air) and missions**
- ✓ **Lower Total Ownership Cost for the Fleet**
- ✓ **Safety – Mil-STD-1316 complaint, fail-safe design**

Miniaturized Fuze/S&A Technology for Next Generation of Navy Underwater Weapons

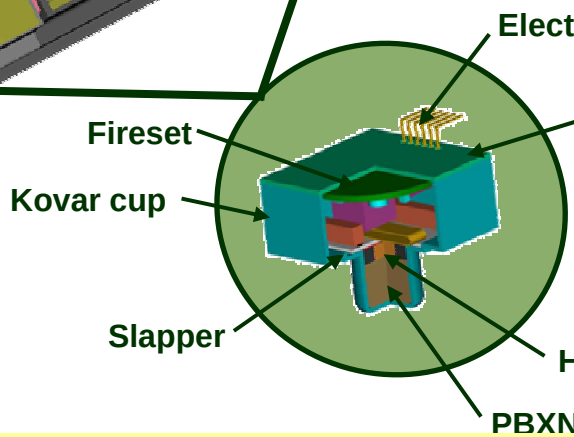
Torpedo S&A Technology

- *Dual Point Initiated CCAT W/H*
- *MEMS S&A*





Kansas City Plant



- Integrated high voltage Initiator package (Fire-set, Slapper, Leads)

- No external high voltage stripline required

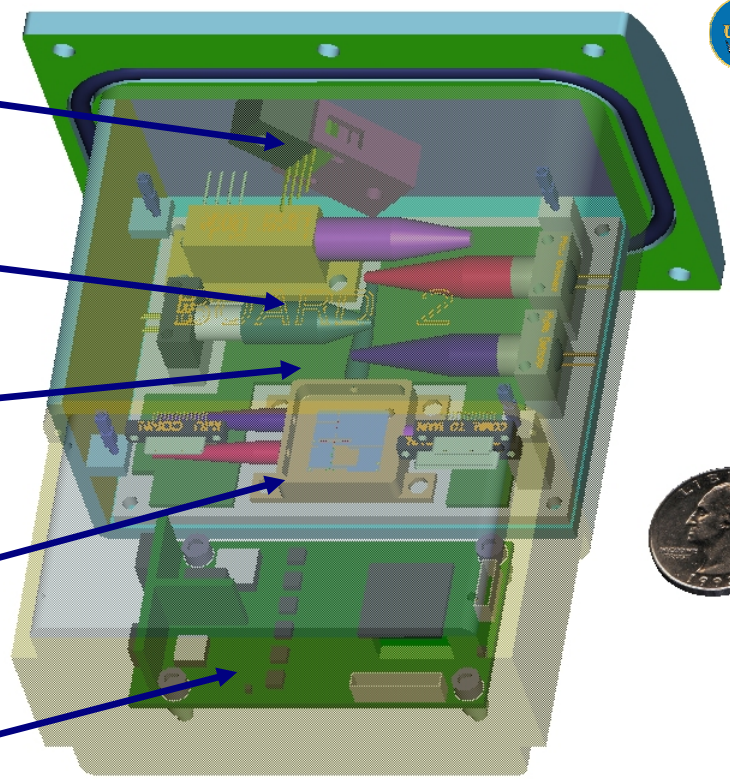
MEMS Technology Provides Arming & Firing Energy Control

NAVSEA WARFARE CENTERS

NAVAIR

Torpedo S&A Technology - CCAT S&A EDM-1 Design

- Integrated MEMS based COTS pressure sensor for water flow sensing
- Optical Charging System
- S&A Electronics - Processor and logic Circuit
- MEMS Safe-Arm chip package <1 cu inch
- Low Cost & High Accuracy MEMS based IMU
- Integrated initiator Fire-set, slapper, lead



MEMS Safe-Arm Chip Provides Interruption and Arming Energy Control

Torpedo S&A Technology

- CCAT S&A Program Status

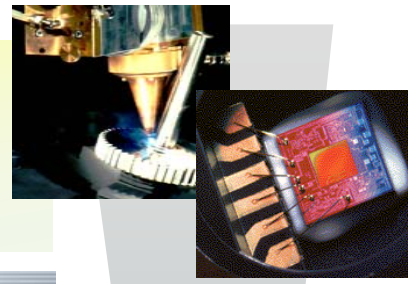
- Design and fabrication proven through prototype development (FY02-03)
- Successful WSESRB Executive session brief – March 03
- Currently refining EDM-1 S&A design and integration for CCAT
  - Over 150 integrated initiator tests, additional 200+ shots planned for CY04
  - Advanced IMU sensors development for CCAT S&A (ONR-FNC)
  - MEMS S&A environmental & life cycle test (HALT) series on going
  - System launch & CCAT sea-tests with fully integrated S&A scheduled for CY 04

Torpedo S&A Technology

- Integrated Initiator Effort

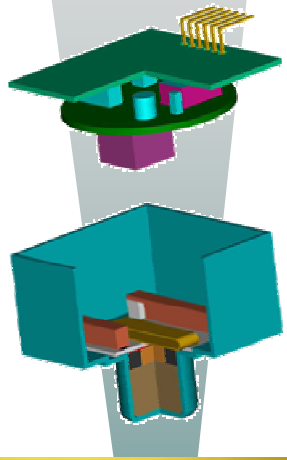
Objective:

- Develop Miniaturized,Low-Cost, Integrated, High Voltage Slapper Initiation System



Approach:

- Team with DOE (Honeywell FM&T) to develop Advanced Miniature High Voltage Initiation System
- Integrate all high voltage lines into package, minimize input requirements…power, ground, trigger signal, system on
- Small total size…~1 cu in



Status:

- Completed Phase I initiation system functional & explosive performance & characterization tests (125)
- Executing Phase II, refining fire-set, slapper & explosive component design to reduce parts & assembly steps
- Integrating into dual point initiated CCAT warhead

Briefed in Session IV-B

Torpedo S&A Technology
- IMU for Close-In Ship Defense

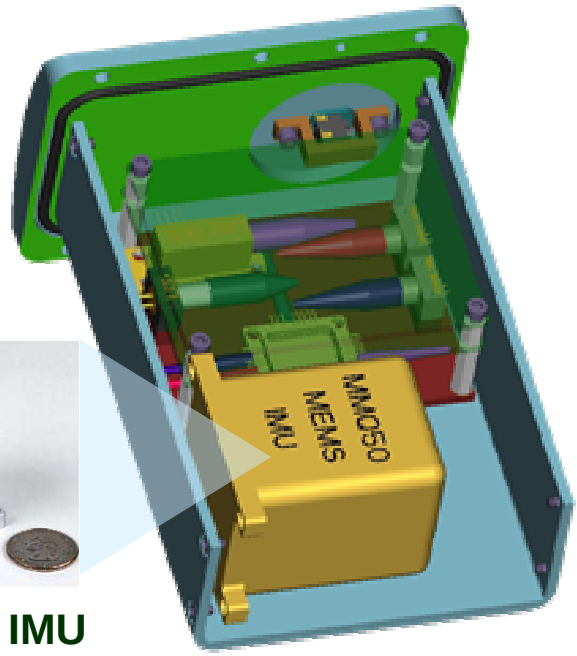
OBJECTIVE:

- Adapt a low cost, small volume Inertial Measurement Unit (IMU) for accurate determination of safe separation

STATUS:

- Evaluated COTS IMU's for CCAT S&A
  - IMU Simulation Analysis
  - Bench tests
- Selected Systron-Donner MMQ50 for further development tests
- Conducting IMU algorithm development
- Developing IMU electronics and packaging

MMQ50 IMU



CCAT S&A

Allows **close-in engagements** at **minimum safe separation distance**

Torpedo S&A Technology
- Micro-Systems Packaging Technology

Objective:

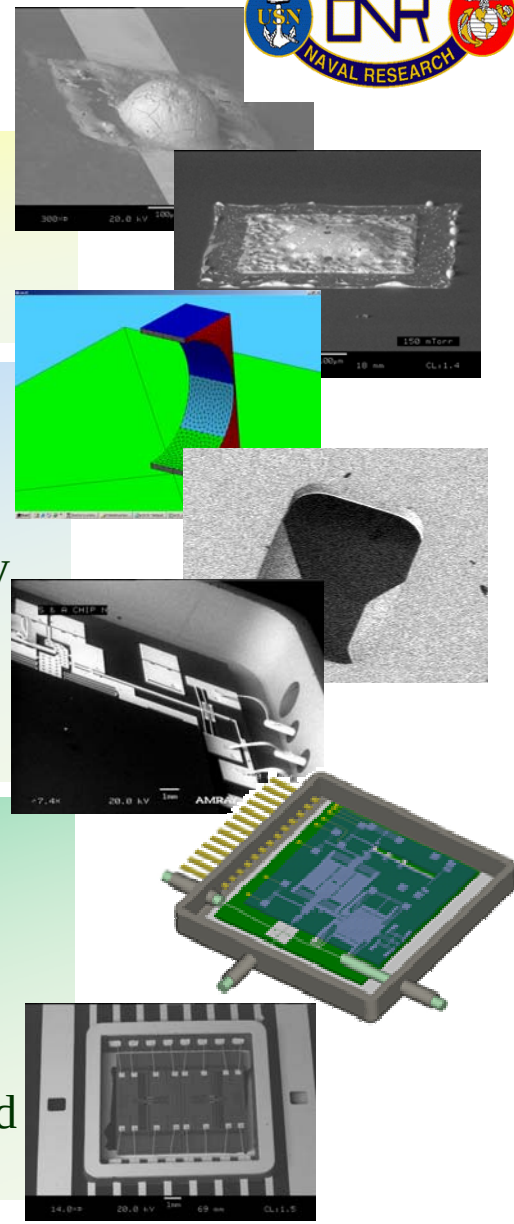
- Develop & demonstrate robust, reliable & manufacturable MEMS packaging technologies for CCAT S&A application

Approach:

- Integrate packaging structures/features with MEMS devices and fabrication techniques
- Adapt low cost MEMS and IC industry packaging technology
- Robustness evaluation through Highly Accelerated Lifecycle Testing (HALT) & MIL-STD 331 tests

Status:

- Successfully demonstrated all individual MEMS (CCAT) S&A packaging steps
- Near completion: integration of all packaging steps in assembly sequence
- Fully packaged CCAT S&A to be demonstrated in at-sea field testing starting in 1Q FY05



Torpedo S&A Technology
- Highly Accelerated Lifecycle Testing (HALT) of S&A

OBJECTIVE:

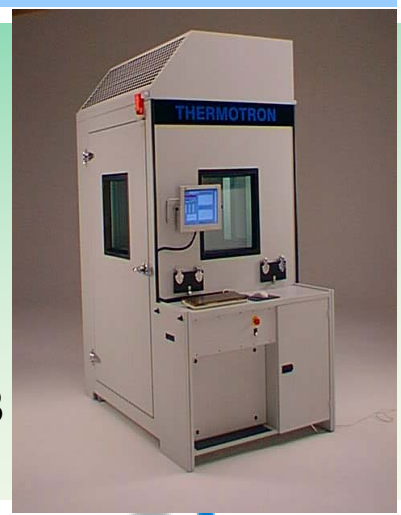
- Determine failure modes in current MEMS S&A components caused by harsh temperature and vibration environments using Sandia National Laboratory HALT facilities ➖ ***leveraging DOE TCG-X Investment***

BENEFITS:

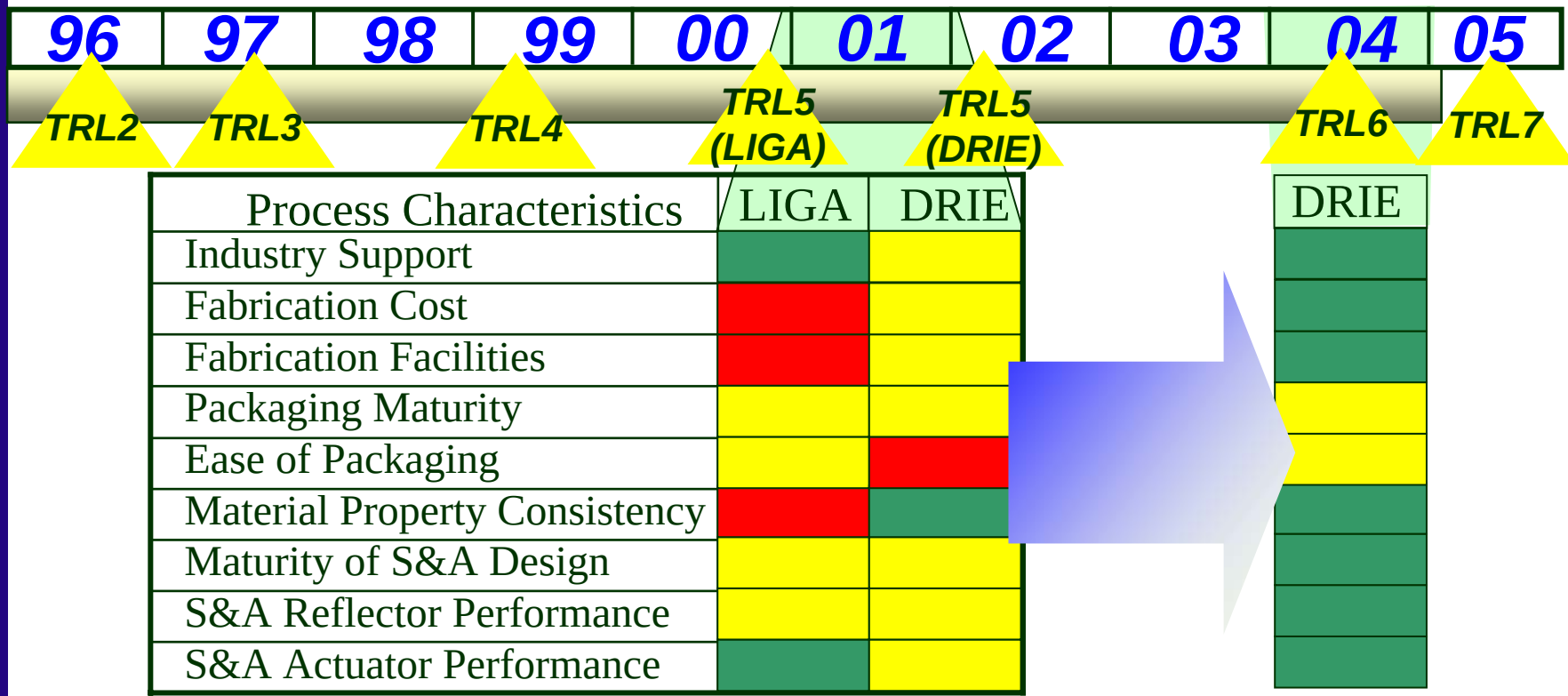
- Provide an early look at MEMS device level vulnerabilities
- Induce environmental failures in MEMS S&A packaging
- Determine temperature compatibilities of system materials beyond MIL-STD levels
- Receive insight into monitoring features to be incorporated into subsequent MEMS S&A designs

STATUS:

- Indian Head packaged MEMS devices for test
- Sandia developed HALT compatible visual and electrical data acquisition systems
- Phase I HALT scheduled at the end of April on discrete MEMS components
- Phase II HALT to be performed on a more integrated system 2-3 months after Phase I



Torpedo S&A Technology
- Technology Maturity



Process Characteristics	LIGA	DRIE
Industry Support		
Fabrication Cost		
Fabrication Facilities		
Packaging Maturity		
Ease of Packaging		
Material Property Consistency		
Maturity of S&A Design		
S&A Reflector Performance		
S&A Actuator Performance		

DRIE

MEMS Technology for CCAT S&A Matured to TRL 6+

Torpedo S&A Technology
- Technology Maturity cont.

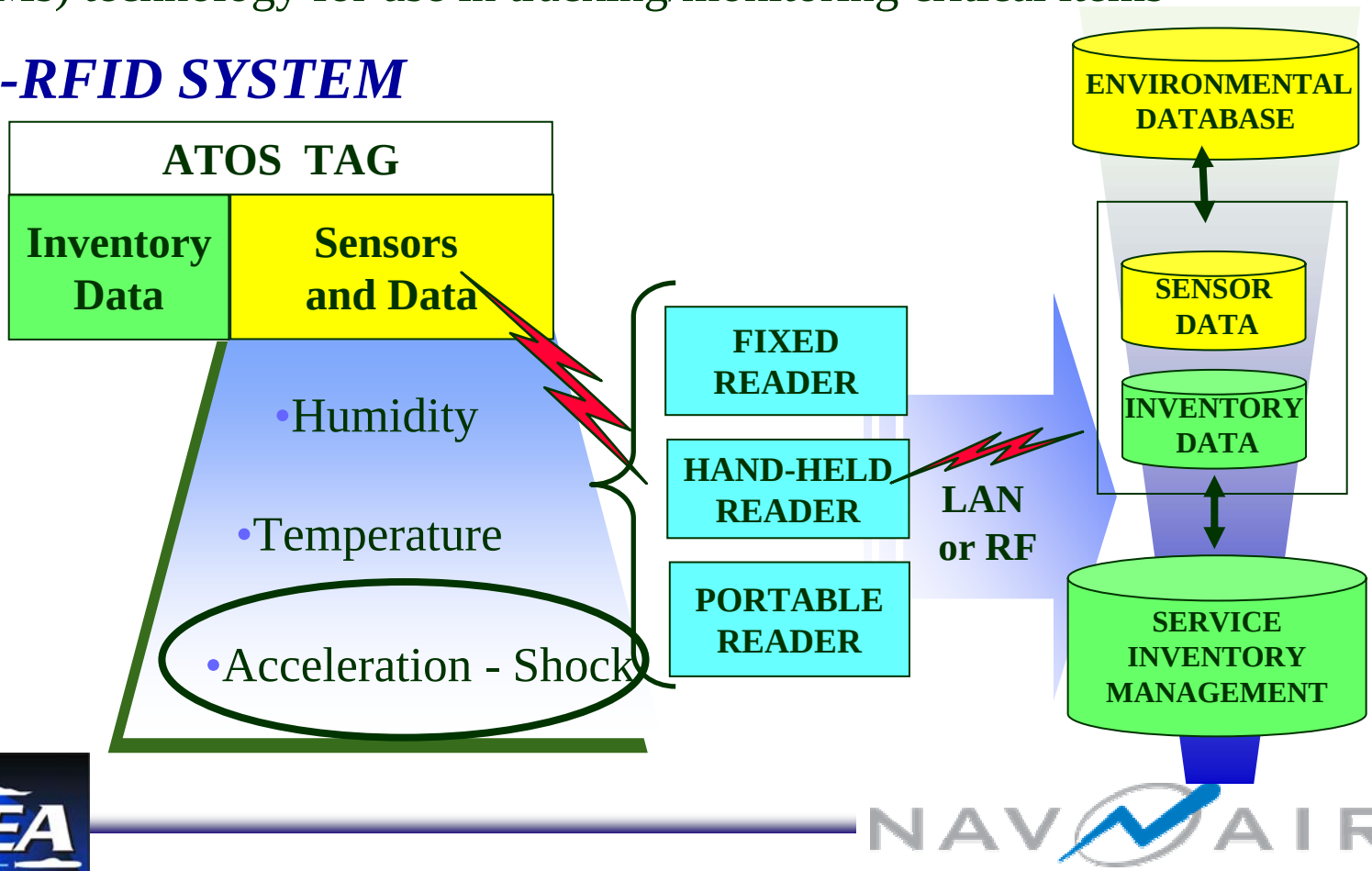
CCAT S&A prototype development successfully transitioned technology

	S&A Technology Prototype	S&A Spiral 2 Prototype
MEMS Processing Method for S&A Chip	**LIGA; ~$1000 per chip (FY2000)** (qtys of 100's)	**DRIE; $200 per chip** (qtys of 100's)
Arming Time	> 5 seconds	< ½ second
CAT Interfaces	Not networked with CCAT	Fully networked and interfaced with CCAT
S&A Explosive Train	Discrete initiator components	Integrated initiation system
IMU – Drift rate accuracy	300 deg / hr	Current 100 deg / hr (FNC IMU = 30 deg / hr)
S&A Chip Packaging	Non-hermetic, labor intensive package	Hermetic, robust and producible packaging

Advanced Technology Ordnance Surveillance (ATOS)

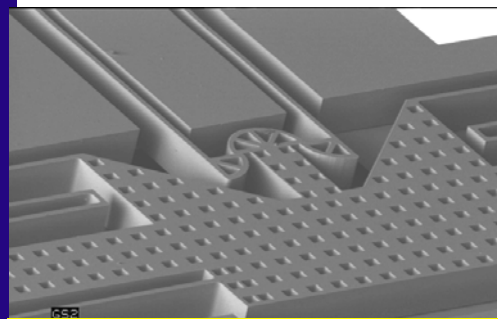
- Advanced Concept Technology Demonstration – FY 01 - 04
- Demonstrate operational utility of miniature radio frequency identification (RFID) tags coupled with micro-electromechanical sensor (MEMs) technology for use in tracking/monitoring critical items

ATOS-RFID SYSTEM



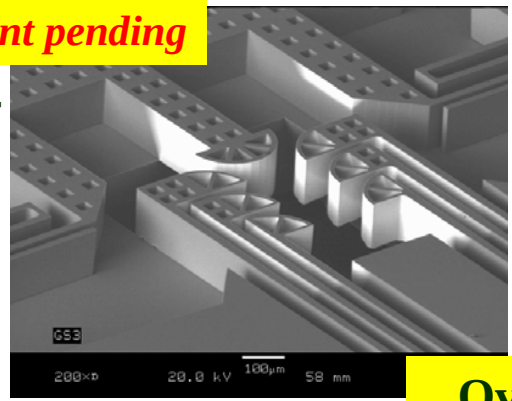
ATOS-RFID SYSTEM
- Integrated MEMS G-Sensor(s) Technology

- Spring supported mass deflects into latch when G-Sensor undergoes a defined shock.
- ATOS-RFID records shock event when G-Sensor latched



NSWCIH patent pending

Latched Sensor



Multi-Level Sensor

Status of Sensor Development

- Five design iterations completed to date.
- All sensors tested have been accurate to within ±3%.

Sensor Attributes

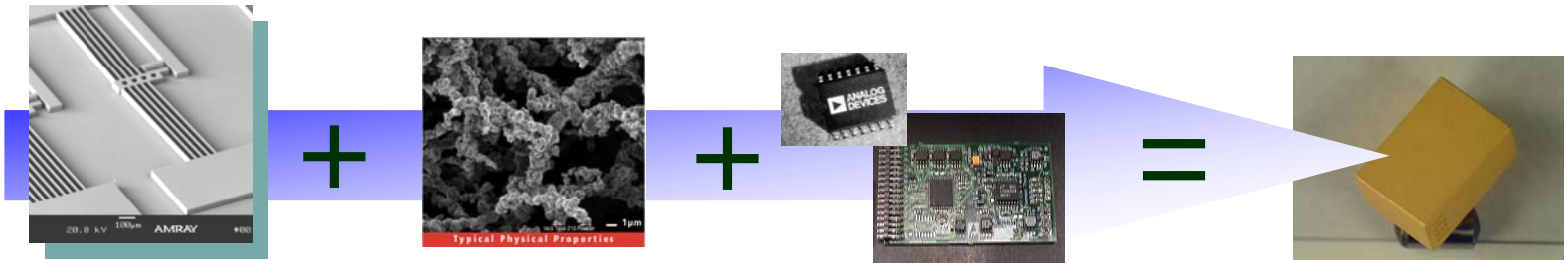
- No power needed to record shock.
- Can be electronically reset.
- Latch levels from 25 to 1500 g's.
- Advanced designs include multi-level and multi-directional.
- Sensor size: 6 by 3 mm.

Over 1000 MEMS G-Sensors Successfully Fabricated to Date

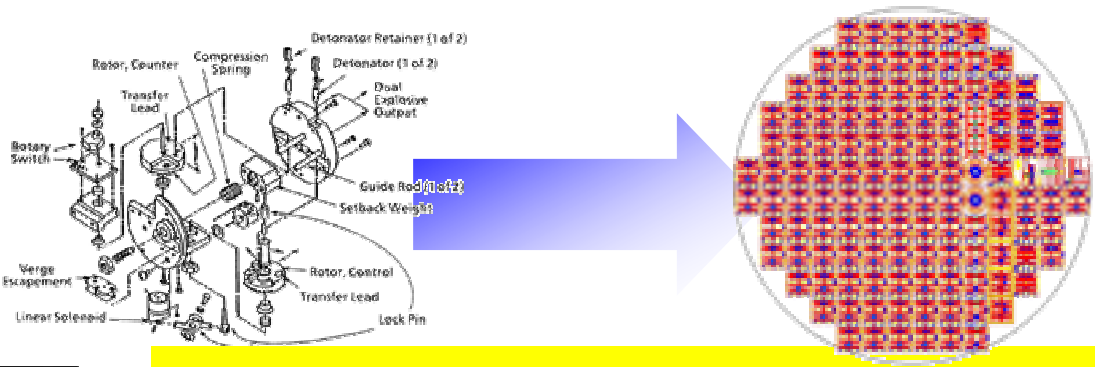
MEMS F/S&A Next Generation Technology

- Modular MEMS Fuze

- Integrate Electronics, S&A, Explosives into a Multi-Chip Module to:
  - Reduce Cost and Size
  - Increase Shock Survivability, Reliability, & Robustness
  - Modular Design enables swapping sensors and electronics while retaining standard S&A and explosive design



MEMS S&A Chip | Micro-Detonics | Sensors and Electronics | Multi-Chip Module Fuze



From 100 Parts Per S&A to 100 S&A's Per Part

NAVSEA WARFARE CENTERS

NAVAIR

MEMS F/S&A Next Generation Technology - MEMS G sensor for High G Application

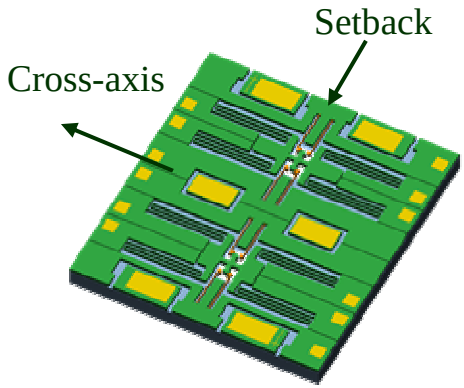
- ***NEE Collaborative effort with Dahlgren Fuze group***

- **Test samples not designed for high shock survivability**

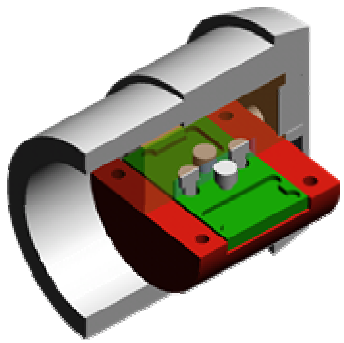
- DRIE SOI MEMS Sensors

- Two ATOS (prototype) sensors per chip designed to latch at 360 and 720 G

- Conducted 14 Setback tests from 1500 to 30,000 G's & 2 Cross-axis test (28,700 G max)



- Test Results
  - No observable damage to the substrate
  - 1 of 96 latches damaged below 25,000 G's
  - Approximately 10% of the components damaged between 25,000 & 30,000 G's



*** Damage attributed to non-optimized design features**

High Shock Functionality & Survivability Demonstrated with MEMS G-Sensor

Micro Detonics for Next Generation - Miniature F/S&A Applications

Objective:

- Develop MEMS based S&A technology with integrated energetic materials
  - Goal: Develop detonator that is less than 400μm thick

Approach:

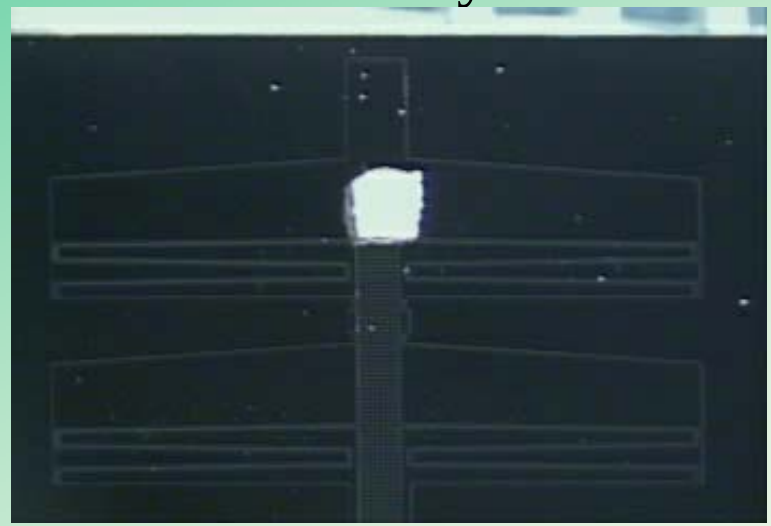
- An ***in situ*** formed explosive compatible with MEMS processing requiring no assembly
- No explosive waste or contact with MEMS processing equipment
- Physically out of line system utilizing inorganic salts as donor explosive
- Develop batch MEMS and explosive forming processes to minimize fabrication costs
- Leverage COTS MEMS processing
- Low initiation energy and power requirements

NSWCIH patent pending

Micro Detonics for Next Generation - Miniature F/S&A Applications

Status:

- Initial explosive forming reactions have been very successful
- On-going efforts
  - Characterization
    - Pre-reacted material
    - Explosive material
  - Process optimization.
  - Testing
    - Basic explosive output characterization
    - Demonstrated 1500µm translation
  - Integration
    - Developing batch process for building S&A device
    - Initiated MEMS & micro detonics compatibility investigations & spark initiated integrated detonator

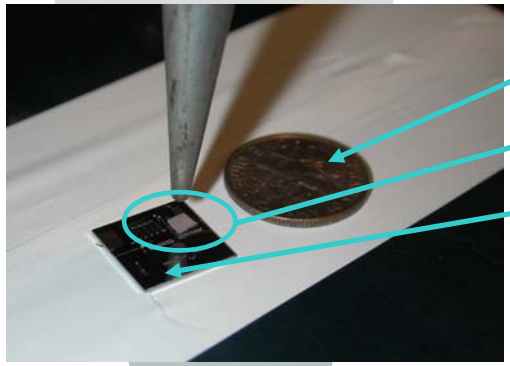


NSWCIH patent pending

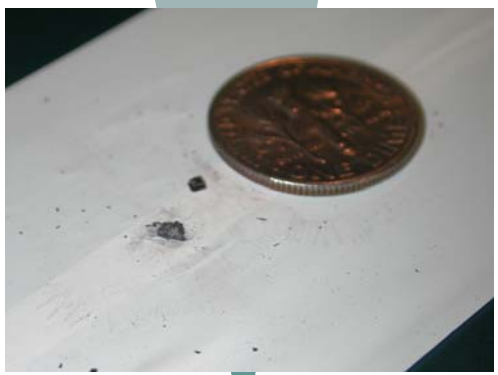
Micro Detonics for Next Generation - Miniature F/S&A Applications

Integrated Detonator Proof of Principal Experiment

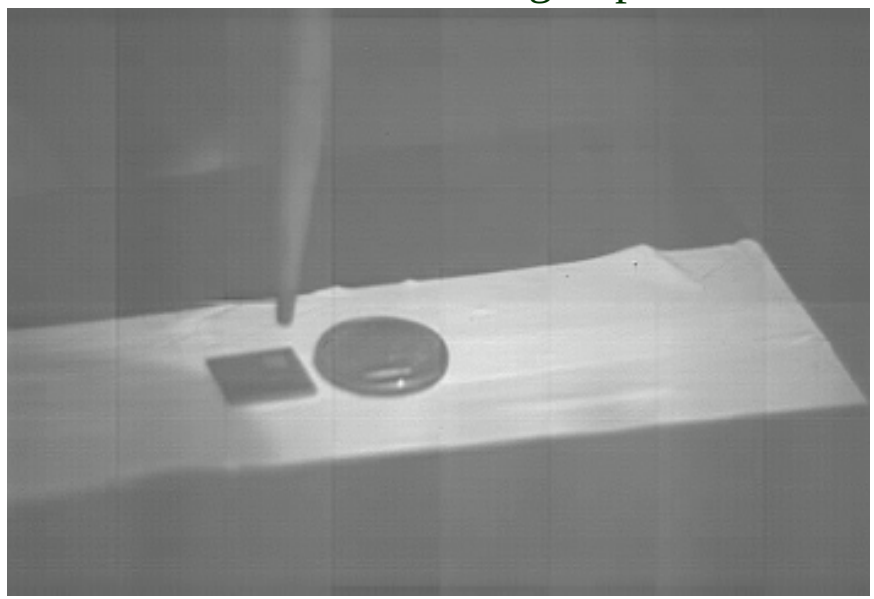
- Before Detonation



- After Detonation



High Speed Video



Micro Detonics Technology Status = TRL 3

NSWCIH patent pending

Indian Head Division Micro-System Technology Development Partners

- **MEMSCAP, MEMS Exchange**
  - **MEMS and slapper foundry processing**
- **Applied Physics Lab – JHU**
  - **MEMS packaging and processing**
- **University of Maryland**
  - **Optics and packaging R&D**
- **Rensselaer Polytechnic Institute**
  - **MEMS packaging, manufacturing research**
- **Honeywell FM&T**
  - **Miniature Fireset and Optical Interrupt**

Summary Slide

The Path Forward …

- Coordination & collaboration between the Navy Energetics Labs … the NEE
- Tri-Service & DOE coordination & collaboration … DoD Fuze IPT & TCG
- Teaming with Industry & Academia … DOTC, BAA's
- S&T in Advanced Sensors, Miniaturized (MEMS) & Modular S&A Architectures, and Miniaturized Energetics …

Fuze Technology for the Warfighter

NAVSEA WARFARE CENTERS

NAVAIR