Safe Electric Solid Propellants

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Energetics Safety & Performance

Essential to Navy Programs

- Energetics continue to be dangerous to manufacture, transport and use
- Few weapons able to meet current Mil Stds for shipboard safety
- Controllable solid rocket motors are complex, heavy and expensive

*Accidents are still occurring**

Jalalabad, Afghanistan, 10 Aug 02

26 killed, 90 injured

Spin Boldak, Afghanistan, 28 Jun 02

32 killed, 70 injured

USS Nimitz, 26 May 81

14 killed, 48 injured. $79M in losses: Sparrow Missile

1960s

USS Oriskany, USS Enterprise and USS Forrestal

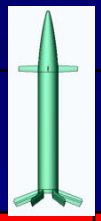
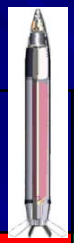
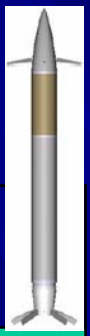
206 killed, over 600 injured *and*
$321M in losses

** More recent incidents information is restricted*

5” Rocket Propelled Projectiles:

Longer Range but More Hazardous

RED is a NO PASS

MIL-STD-2105C Tests	ERGM 	BTERM 	LRLAP 
Slow Cook-Off	Rocket Motor	Rocket Motor	Pass
**Fast Cook-Off*	Rocket Motor	Rocket Motor	Rocket Motor
**Bullet Impact*	Rocket Motor	Rocket Motor	Rocket Motor
Fragment Impact	Warhead & Rocket Motor	Warhead & Rocket Motor	Warhead & Rocket Motor
Shape Charge	Warhead & Rocket Motor	Warhead & Rocket Motor	Warhead
Sympathetic Detonation	Warhead & Rocket Motor	Warhead & Rocket Motor	Pass

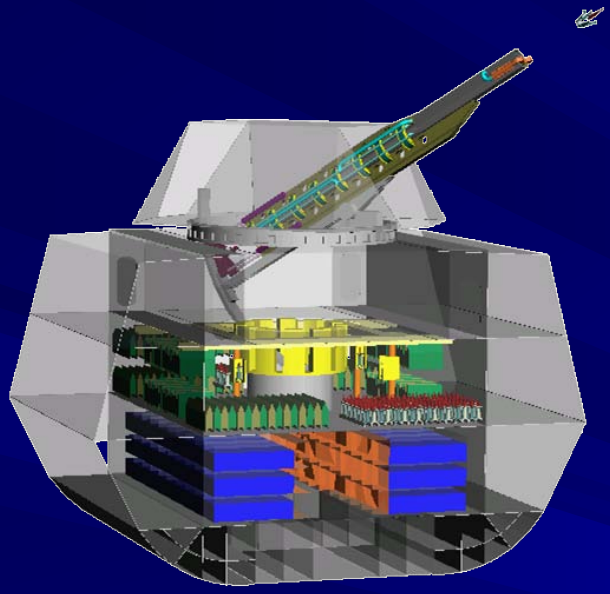
* videos

Baseline Technologies

Some 50 years old…..

- Solid propellants contain sensitive ingredients like nitroglycerin and perchlorates
- Liquid rocket motors are not easily stored and use toxic materials such a hydrazine
  - *Not acceptable on Navy ships*
- Controllable solid rocket motors
  - *Very low mass fractions*
  - *Mechanically complex*
  - *Very expensive*

Customer Need



- New long range projectiles will require exo-atmospheric adjustments/targeting
  - Can only be done with thrusters
  - Must withstand *extreme* G-loading
  - Low cost is essential
- Missile systems need longer ranges and flexible multi-mission roles
- ACS and DACS need longer operation times and higher mass fractions
- Nano-satellites need a viable propulsion option

Our Solution:

A New Class of Energetic Material

"ELECTRIC SOLID PROPELLANTS"

- **World's first "Smart" energetic materials**
  - **Safe, CANNOT be ignited by spark/flame**
  - **CAN BE electrically switched off/throttled with NO moving parts**
  - **Manufacturing/Shipping is safer & easier**
    - **No high shear mixing**
  - **Non-toxic exhaust & environmentally safe to manufacture**

First-of-Its-Kind:

"Smart Energetic Material"

Safe, Nontoxic Byproducts-
Green Technology

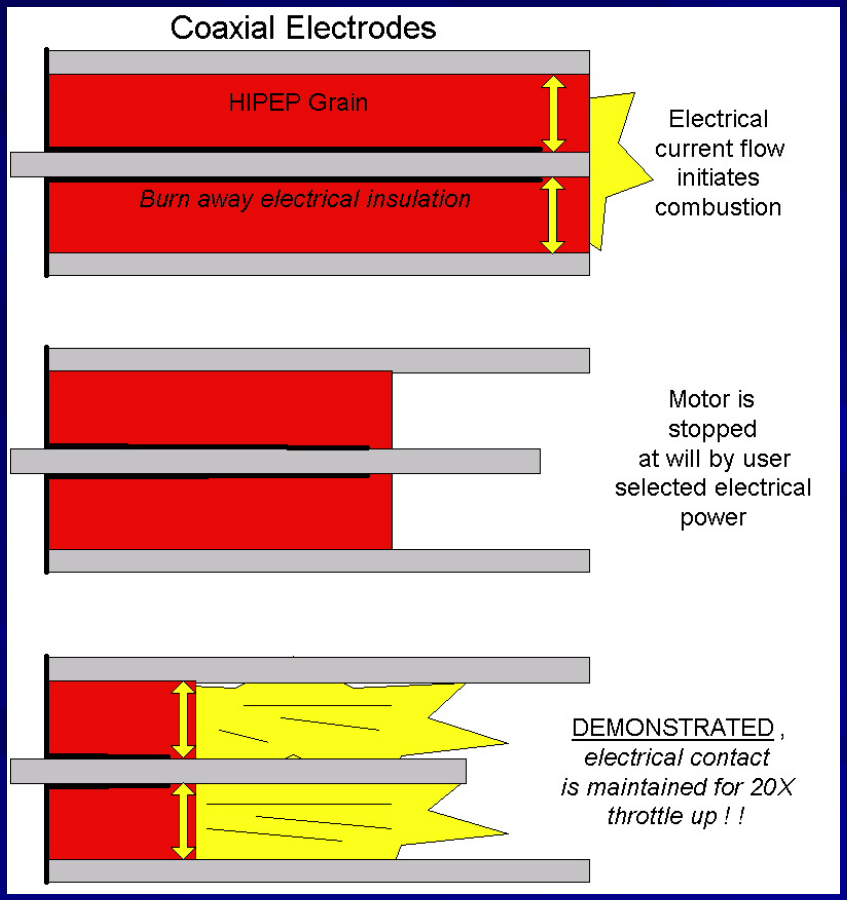
Electronics Manufacturing with Energetics

Safer to Manufacture and Use

ESP Functions

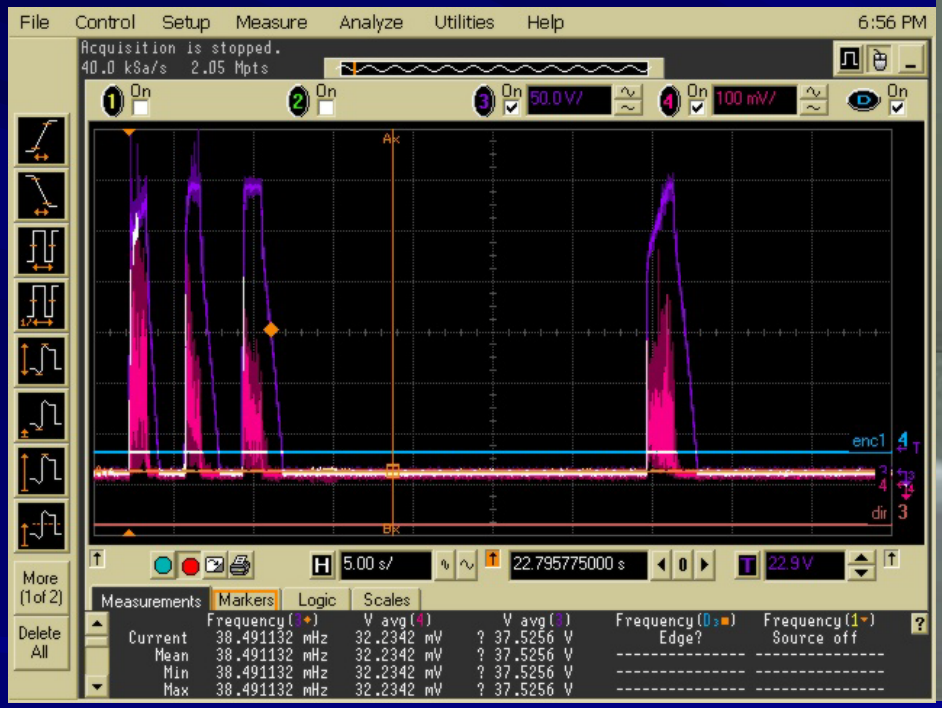
- **Throttle 6-20x**
  - Proportional to electrical power supplied
- **Extinguishment**
  - User selected pulse widths/on-off cycles
- **No Moving Parts**
  - Low part count

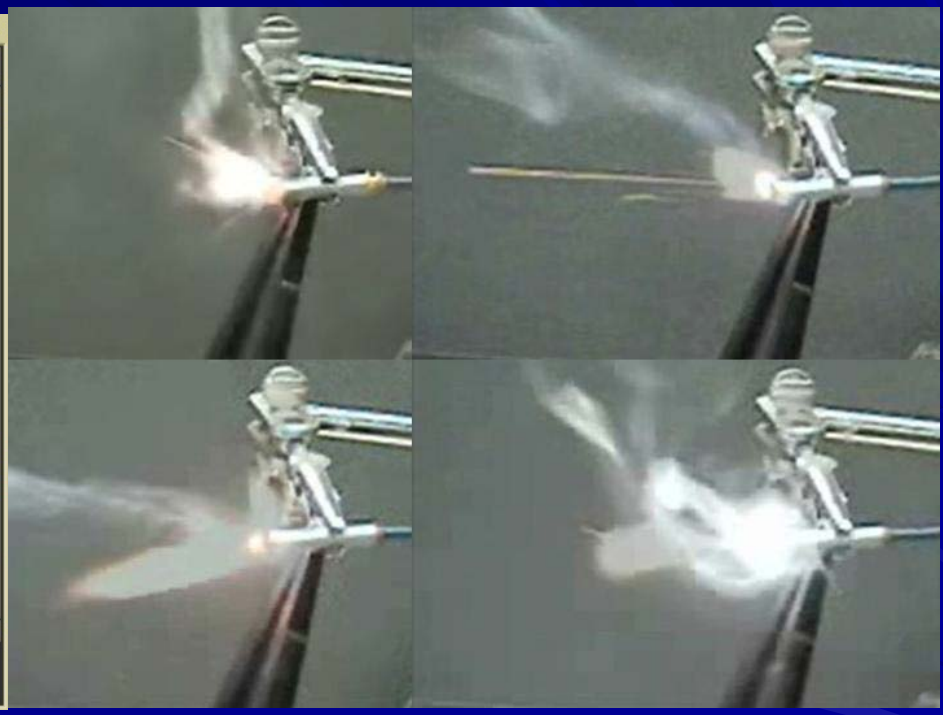
ESP Coaxial Grain Burn Away Insulation



- Insulation
  - Central electrode only
  - Directs electrical power to burning surface
  - Recesses ahead of burning propellant maintaining contact

Electric Solid Propellant Provides Discrete Pulse Widths





Clusters Balance Electrically and Ignite Simultaneously

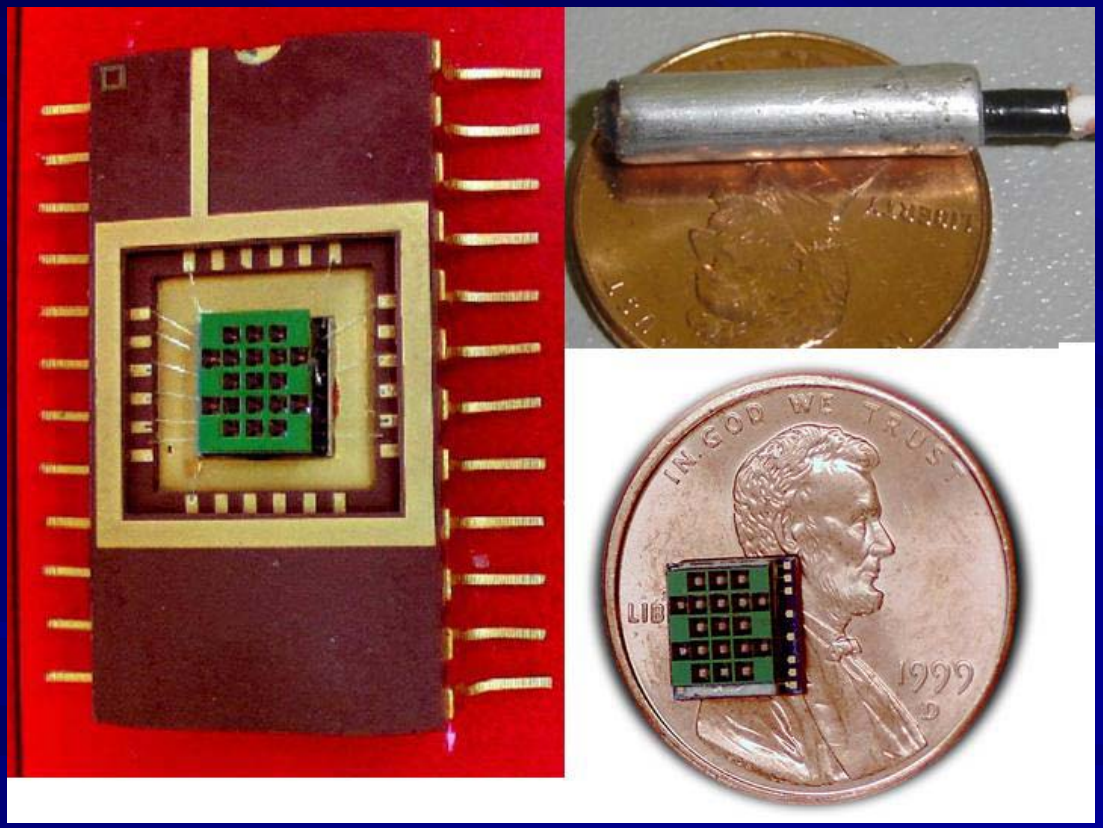
Electric Solid Propellants are Safer To Use and Can Be Controlled

Cannot easily be ignited with spark or flame

Insensitive to high velocity tracer bullet impact

Solid state on-off-on electric control

DSSP Coaxial ESP
Better, Faster, Cheaper than a DARPA Chip Thruster



- Higher mass fraction
- Lower part count
- Variable thrust
- Fewer wires
- Lower powder

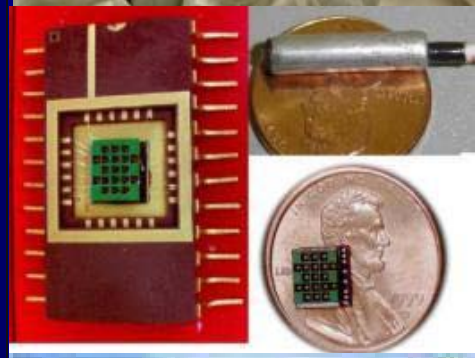
Why Are Electric Solid Propellants So Much Better?

Feature	Advantages	Benefits
Propellant Controllability	Many applications *Even explosives….*	Lower cost Better smart weapon systems
Green Safe Propellant Class 1.4S *(pending)*	Fewer accidents and less hazmat handling disposal	Lower cost: manufacturing, transportation, and storage
High Performance*	About the same current solid propellants	Higher mass fractions for longer missions

** ITAR Restricted*

Current State of Development

- **DOD Development Programs**
  - **Navy: Miniaturized ACS for Exo-atmospheric Projectiles**
    - **IM Testing being accelerated via CRADA w/ NAVAIR China Lake**
  - **MDA: Mil Std. 1901A Compliant Ignition Systems**
  - **MDA: Igniterless Rocket Motors**
  - **MDA: Advanced DACS**
- **Commercial Development**
  - **Oil Service: "**2009 Top Ten Inventions" by *Oil and Gas Innovation*
- ***7 Patents and Counting….***



Further Applications

- Multi-fire igniters for solid and liquid rockets
- Advanced gun propellants
  - Dial in range: non-lethal to lethal
- True variable yield explosives




Further Information On ESPs

- **JANNAF Conference Papers in:**
  - 2005 Monterey, CA
  - 2007 Denver, CO
  - 2009 Las Vegas, NV
    - Distribution C
- **Small Satellite Conference 2007**
  - Logan, UT
    - Distribution A
- ***Acknowledgements***
  - MDA and Navy SBIR Programs
  - ONR, Fires Program