The Promise Of Energetic TPE Gun Propellants – From Notebook To Full Scale Verification

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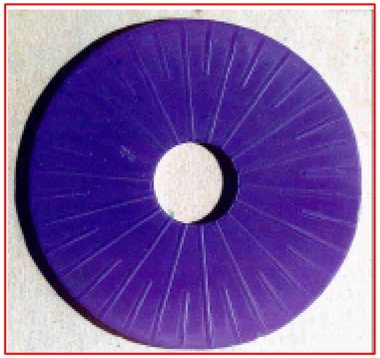
P. Braithwaite, G. Dixon, M. Rose, and R. Wardle

Thiokol Propulsion



Acknowledgements

- **Advances in these new propellants are the results of cooperative efforts with many organizations including:**
  - ARL
  - TACOM-ARDEC
  - DTRA
  - NSWC/IH
  - ONR
  - GD
  - SAIC
  - United Defense

Outline

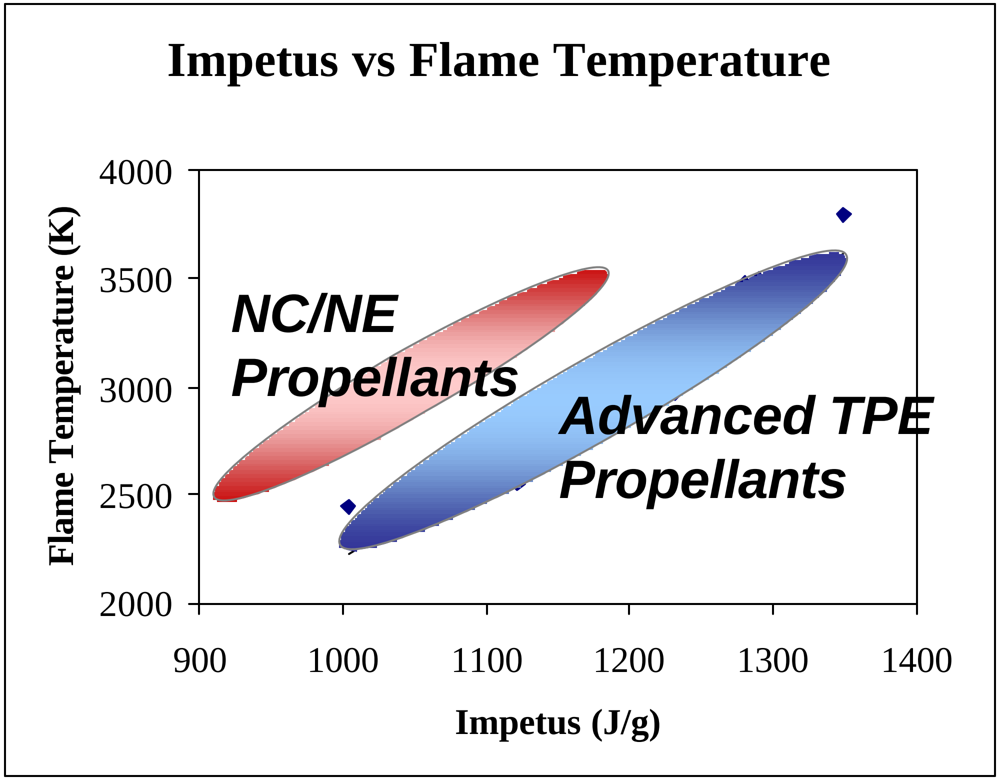
- Background
- Typical ETPE propellant ingredients
- Propellant processing
- Propellant characterization
- Gun testing
- Summary and conclusions

Background

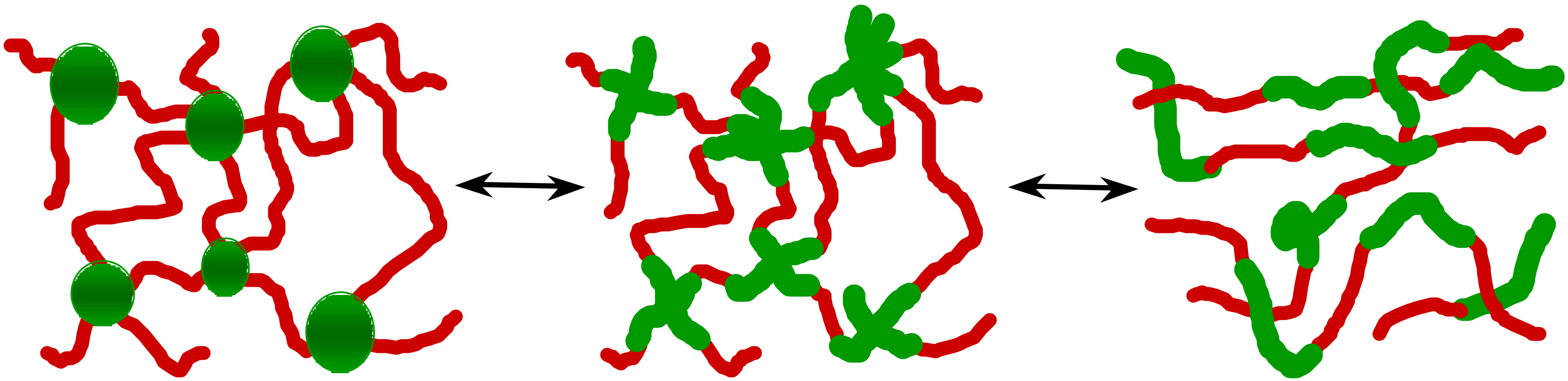
- **The potential advantages of TPE gun propellants were seriously discussed in the early 1980's**
    - Performance
    - Environmental benefits - R3
    - Superior burning rate control
        - No plasticizers are used
    - No sensitivity to moisture
- **Early feasibility studies were successfully performed in coordination with ARL/ONR and others**
    - Identified areas of critical technical needs
    - Developed initial data to verify attractiveness
- **Recent efforts have demonstrated these propellants on a larger scale**

Background (cont.)

- Early calculations using ETPE propellant formulations indicated they had performance advantages when compared with NC based compositions
- Burning rate tailorability suggested by early low pressure tests indicated these propellants could be used in conventional and layered geometries

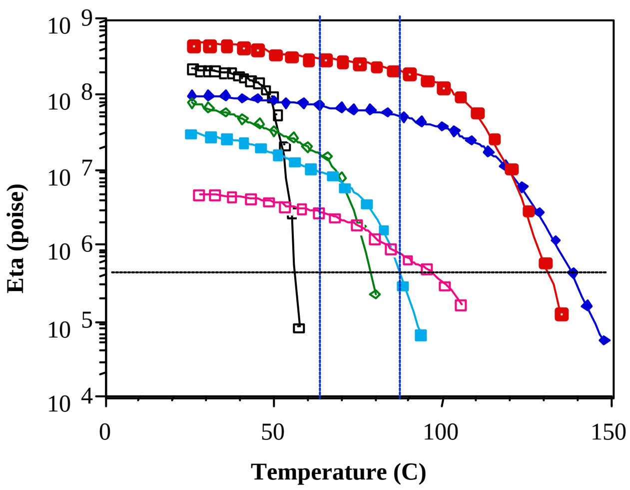


Oxetane Thermoplastic Elastomers

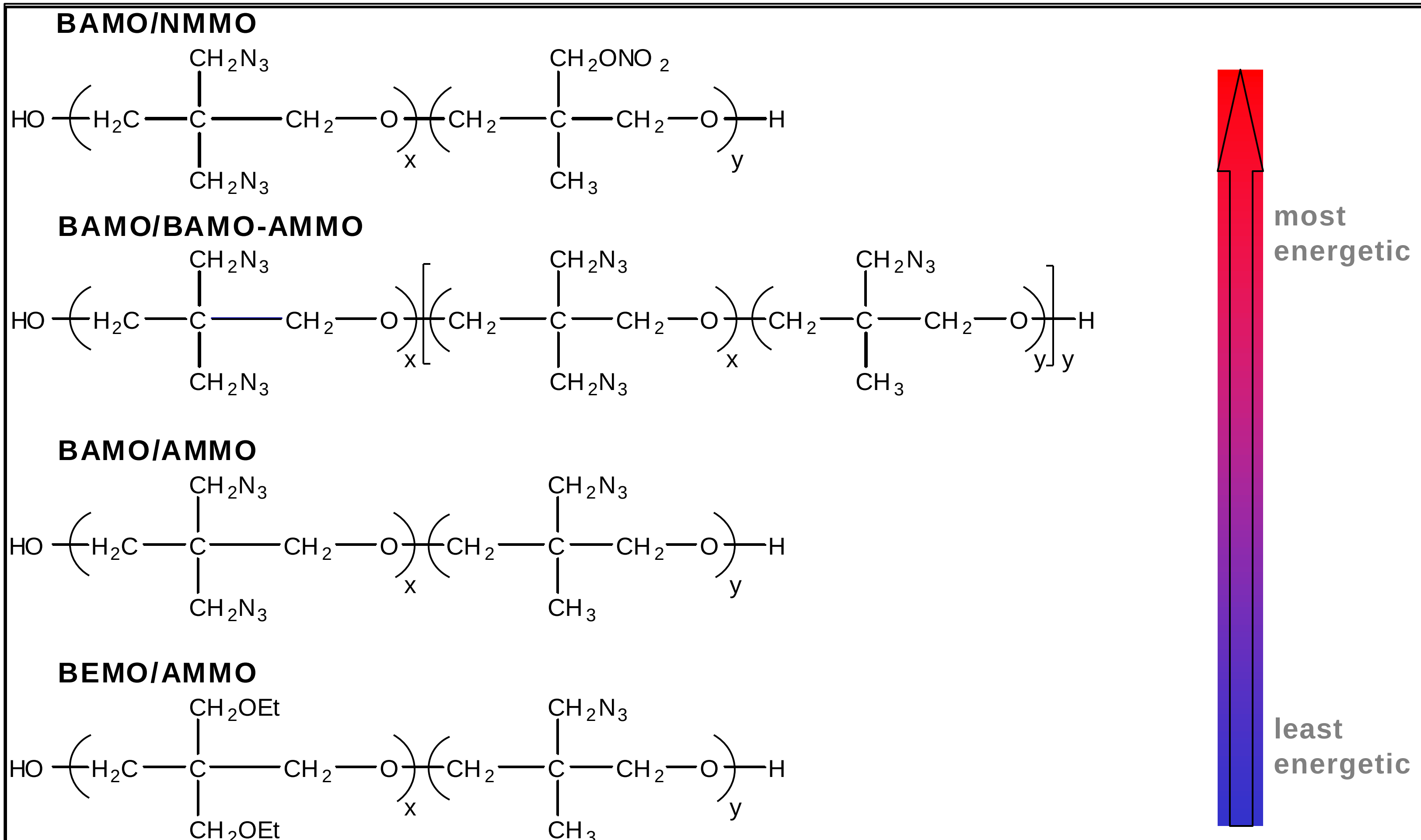


Below Tm of Hard Block	Above Tm of Hard Block	Flows and Mixes under Shear
Hard Block Crystalline Sphereulites Soft Block Elastomers	Hard Block Melts Blocks phase separated	Hard and Soft Blocks Mix Annealing needed for phase separation

- Melting materials behavior critical to energetic processing
  - need narrow transition from hard to processible
  - m.p. too low and won't survive environment (<65°C)
  - m.p. too high and energetic solids can't be processed safely (>90°C)
  - dynamic viscosity data show attractiveness of crystalline hard block oxetane TPE (green line)
- Novel TPEs allow continuous processing and recycling
  - production scrap can be well below 1 percent
- TPE nature allows unusual geometries
  - better energy management maximizes performance

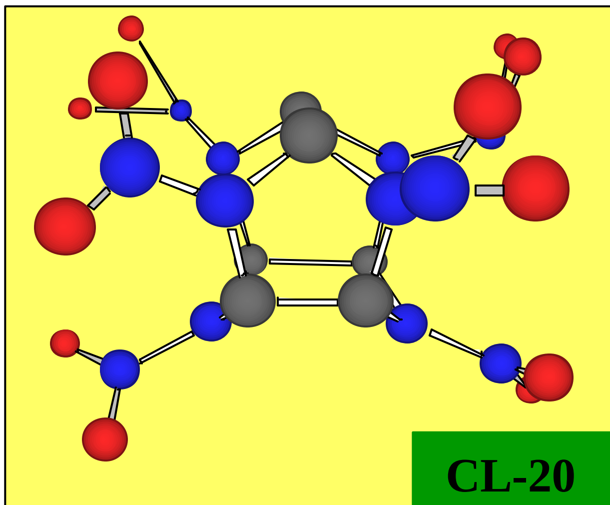


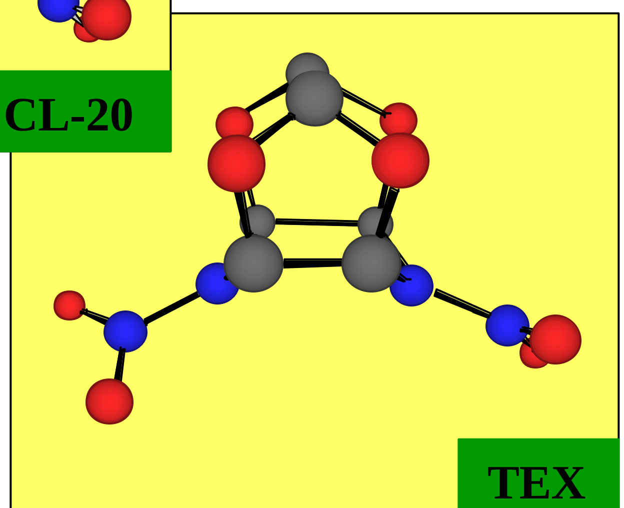
TPE's Offer Formulation Flexibility



New Energetic Solids

- Energetic solids provide additional burning rate and energy tailoring capability



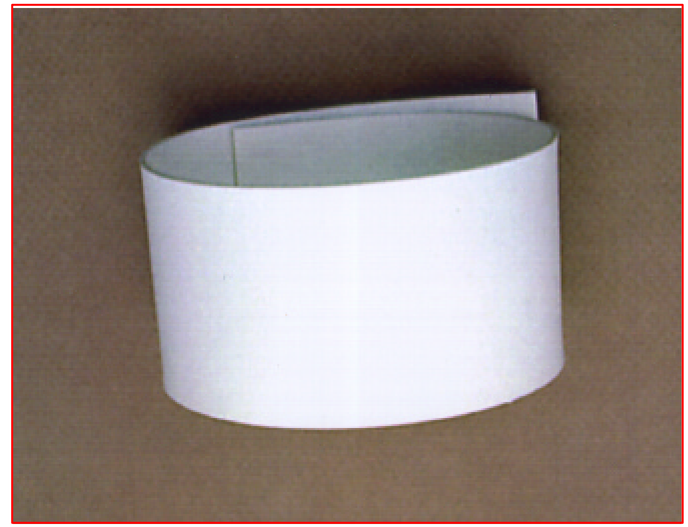


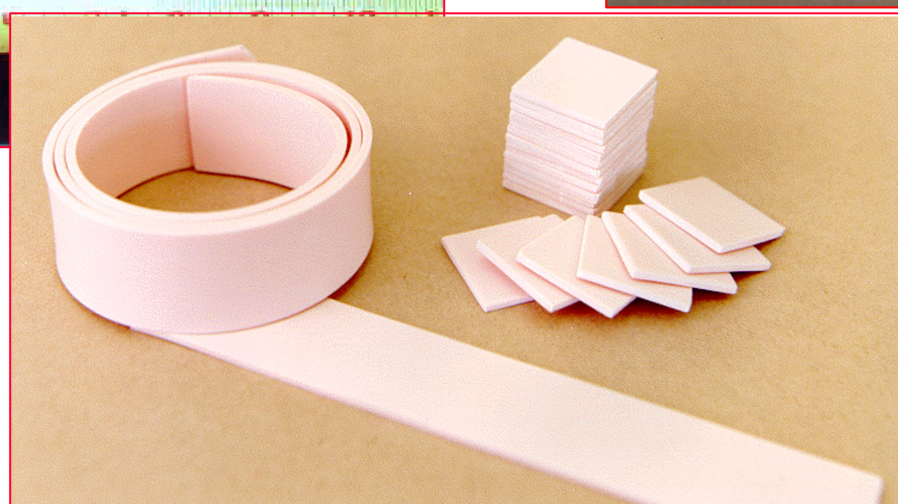
- Burning rates at 40 kpsi from less than 4 in/sec to over 15 in/sec
- Impetus levels above 1350 J/g

Twin Screw Extrusion

- **Twin screw extrusion has been found to be the best way to mix and extrude pilot scale lots of ETPE based propellants**
- **No solvents are required during mixing and extrusion**
- **Multiple formulations have been extruded into a wide range of geometries**

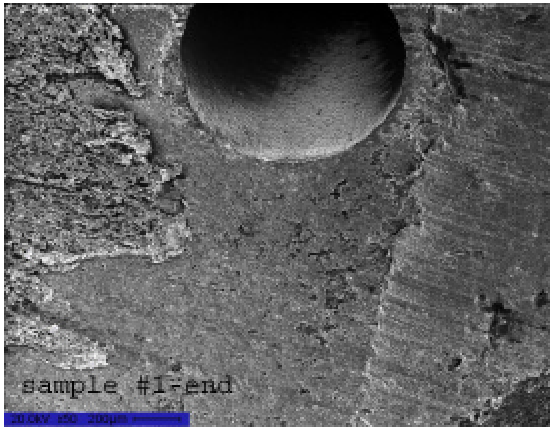
Multiple Geometries Have Been Successfully Manufactured

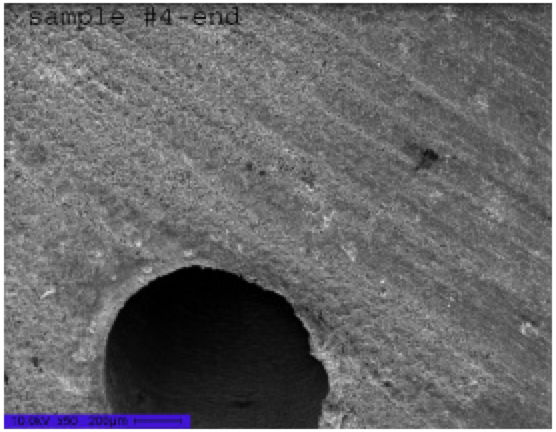


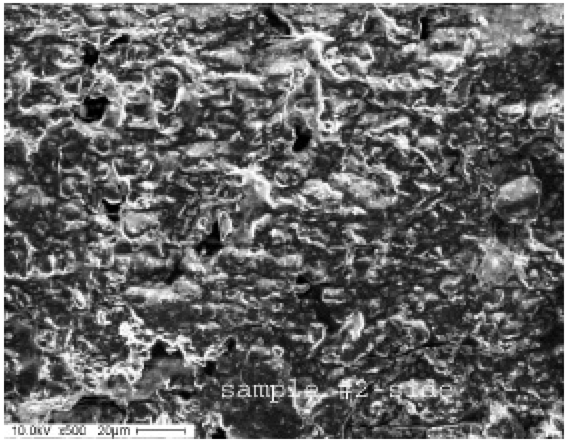


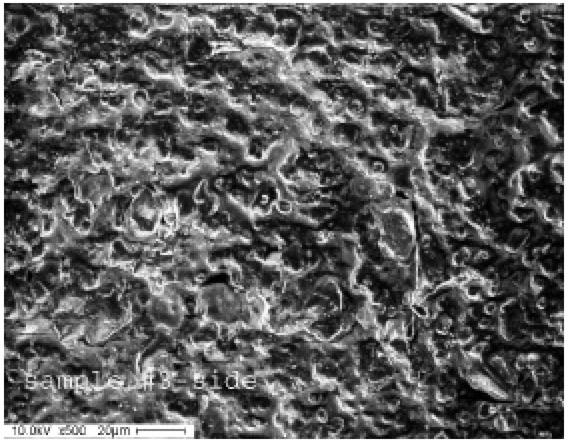
SEM Evaluation

- **Careful examination indicates excellent adhesion between solid ingredients and ETPE**









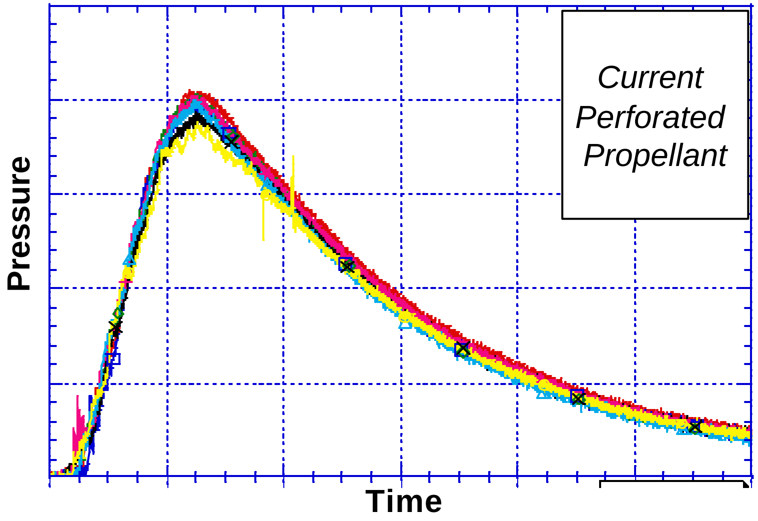
Gun Testing

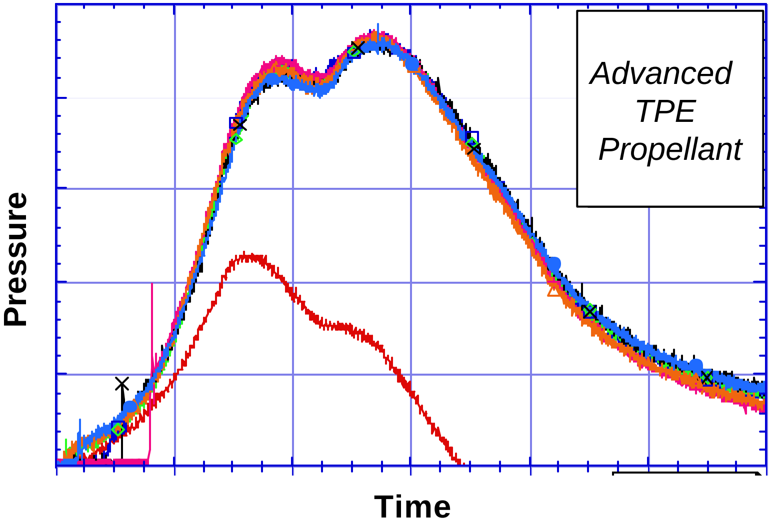
- **ETPE propellants have been tested in multiple gun systems**
  - 30 mm
  - 35 mm
  - 40 mm
  - 60 mm
  - 120 mm
  - 5-inch
  - 155 mm

120 mm Firings

- **ETPE propellants have been tested in 120 mm gun systems using advanced geometries**

- **Results were great!!!**





Summary

- **ETPE propellants have matured significantly during the past several years**
  - Formulation
  - Processing
  - Testing and characterization
  - Quality control
  - Recycle and reclamation
  - Grain design

- **Multiple gun test firings unequivocally demonstrated the performance potential of these promising new propellants**