DNGU: Synthesis, Formulation and Testing of an Affordable, Less-Sensitive Energetic Material

Dr. David Price, Dr. Jacob Morris, Brian Alexander, Matt Hathaway
Presented by Dr. Neil Tucker

BAE Systems Ordnance Systems
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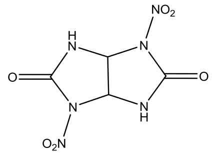

DNGU-Background

- DNGU has been known for years and has been studied by Chinese and French researchers.
- It was evaluated in the 1980s as a potential high performance explosive to replace HMX.
  - However, its measured performance did not match the predicted performance and was subsequently abandoned.
- Its actual properties may better lend itself to be used as an IM ingredient, being slightly less powerful than RDX and NTO, and as a potential replacement for NQ or TATB in some formulations.
- It also has the advantage of being a very affordable explosive ingredient, with a projected cost between RDX and HMX

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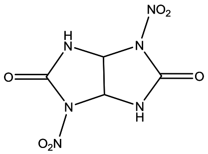
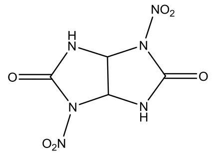


DNGU-Properties

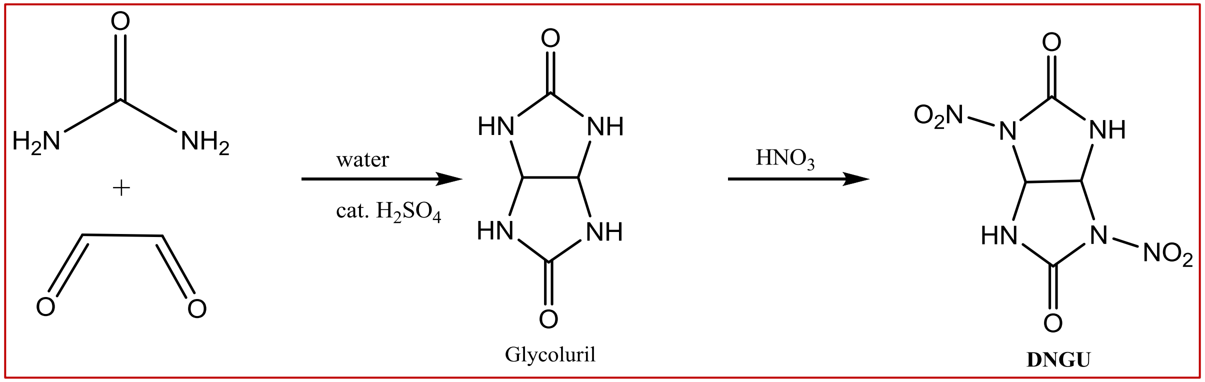
- DNGU may be comparable to TATB in terms of sensitivity and superior in performance.
- Although VoD may be somewhat low, high density of DNGU boosts performance
- Data from multiple sources is contradictory at times
  - ➢ It was decided that DNGU needed to be evaluated in-house in an effort to resolve discrepancies and determine the potential applications of DNGU
- DNGU has been shown to have a faster burn rate (1.2x) than HMX.

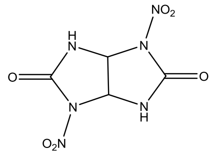
	RDX	NQ	DNGU	TATB	NTO
m.w. (g)	222.1	104.1	232.1	258.2	130.1
Oxygen Balance (%)	-21.6	-30.7	-27.6	-55.8	-21.6
Nitrogen Content(%)	37.84	53.83	36.21	32.55	43.07
Vol. Explosive gases(l/kg)	903	1042	*	*	855
Heat of Explosion (kJ/kg)	6322	2730	*	3062	2993
Density (g/cc)	1.82	1.71	1.94, 1.97	1.938	1.91
lead block test (cc/10g)	480	305	*	175	*
VOD (m/s)	8750	8200	7580,8450, 8950	7350, 7950	7860
Impact Sensitivity (Nm)	7.5	49	5 (questionable)	50	1200
Friction Sensitivity (N)	120	353	200-300	353	353
Impact Sensitivity (cm)	30	>177, 73	88-124	>177	292
Impact Sensitivity (J)- Julius Peters	5.5	*	8		
30 kg shock drop height on 100g (meters)	2.5	*	>4	>4	
Card gap test (cards)	*	*	210	190	
SSGT		NA (11.8% voids)	0.18 mm (11% voids)	0.51 mm (12% voids)	
Pressure CJ (GPa)	34.6	27.4	34.2	31	~28
DSC (onset of exotherm)	220	210	210-234, 240-250	350	270



DNGU-Synthesis

- DNGU is produced from a simple nitration of glycoluril (inexpensive)
  - Glycoluril produced from very inexpensive materials (urea and glyoxal)
    - Glycoluril is commercially available and can be made at HSAAP
- Cost of DNGU estimated to be between RDX and HMX
- OSI R&D has made over 40 pounds of DNGU.
- Currently optimizing synthesis process
  - Original DNGU product particle size was ~15-20 microns
  - New route can provide much larger material (200-300 microns)
  - Yields typically 90-95% with purities >99%

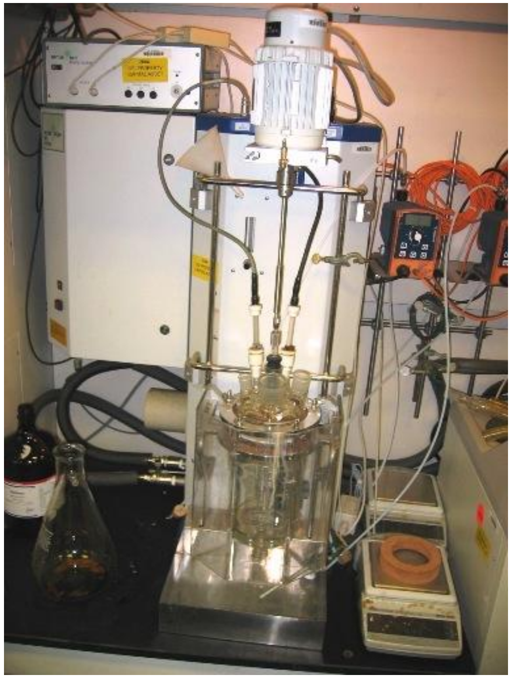




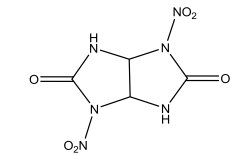
DNGU-Reaction Calorimetry

Batch	Enthalpy per Mole Glycoluril	ΔT(ad)
1106-17	-97.6 kJ/mol	65.0 °C
1106-19	-101.8 kJ/mol	75.8 °C

- Reaction calorimetry (RC1) performed to quantify exotherms and assess scale-up safety
    - Batch 1106-17: 0.5 lb batch
    - Batch 1106-19: 1.0 lb batch
- Exothermicity of reaction appears relatively mild (especially for a nitration)
- Reaction deemed safe for scale-up within R&D

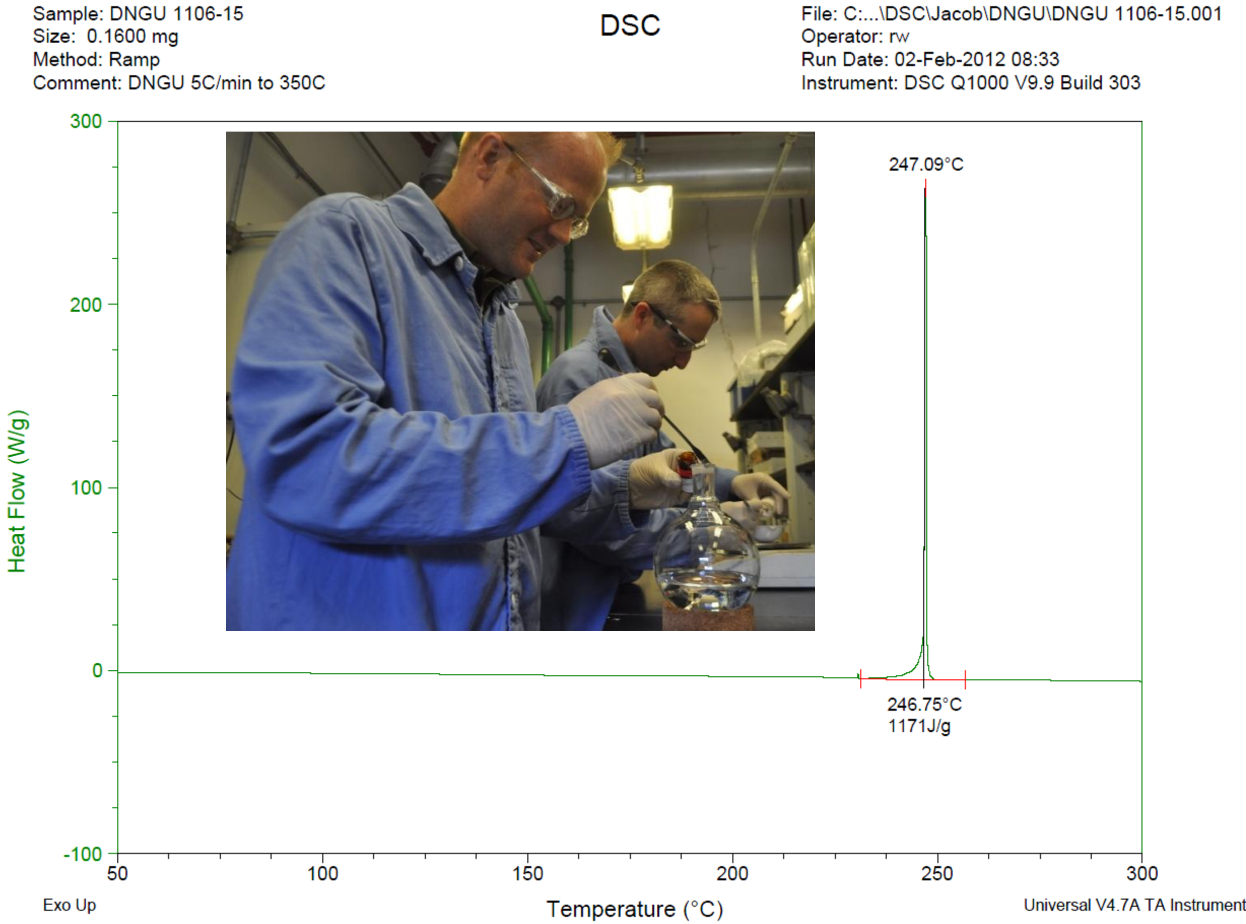


•Mild, straight-forward, easily-controlled synthesis

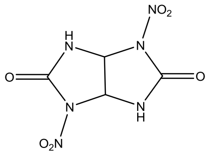


DNGU-Thermal Analysis

- DNGU has no melting point before decomposition.
- DNGU has sharp exothermic transition at 245-250°C
    - Between RDX (200-250°C) and NTO (270-280°C)
    - DNGU seems to have a faster decomposition rate than RDX.
- VTS: 0.41 cc/g
- Future planned work includes TGA and ARC (accelerated rate calorimetry)

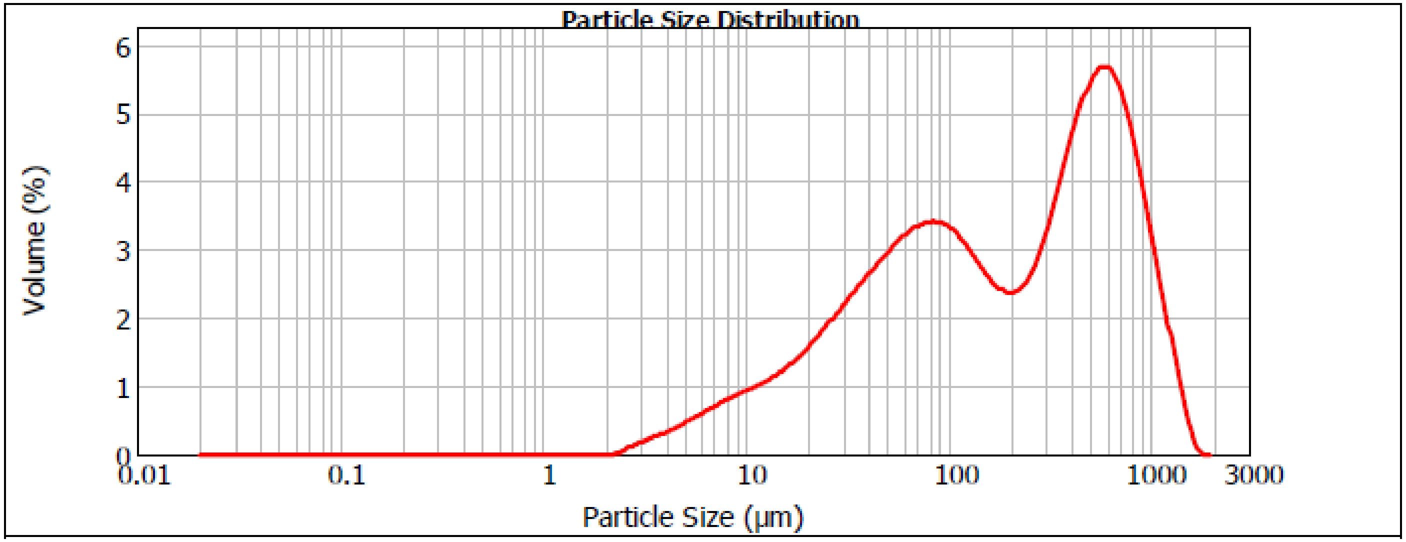


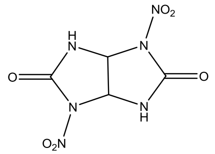
DNGU-Analytical



- Impact Sensitivity: 80-100 cm (Holston apparatus)
  - RDX: 17 cm
- Friction Sensitivity: >360 N
  - RDX: 164 N
- Surface Area (BET): 1.3-1.4 g/m^2
- Particle Size (typical below):

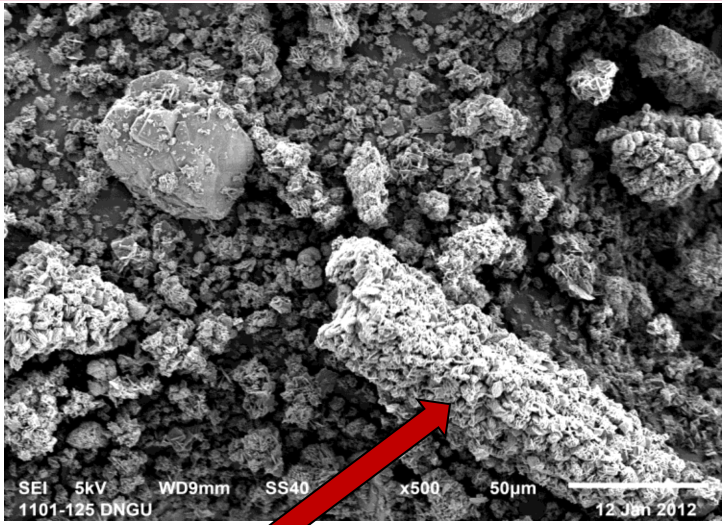
d(0.1):	20.577	um	d(0.5):	190.546	um	d(0.9):	822.608	um



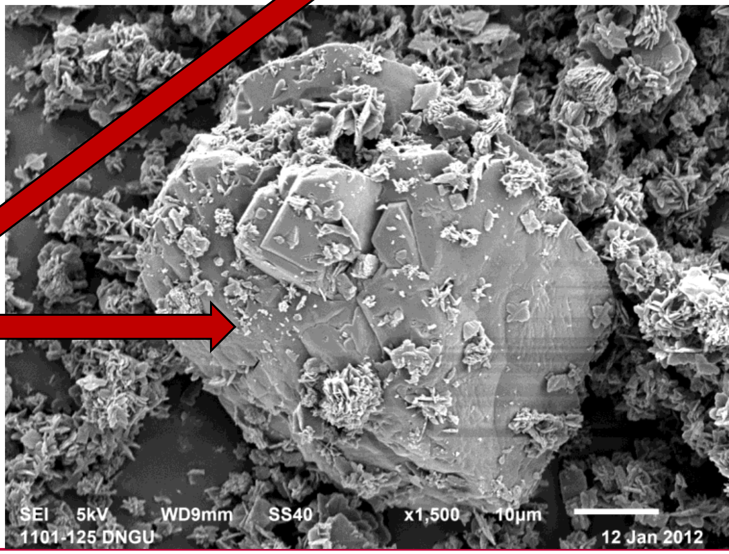


DNGU-SEM Analysis

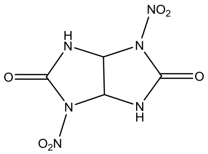
- DNGU material from early in development program has rough “coral reef” appearance and looks like agglomerates of small particles.
  - Probably not good for formulating

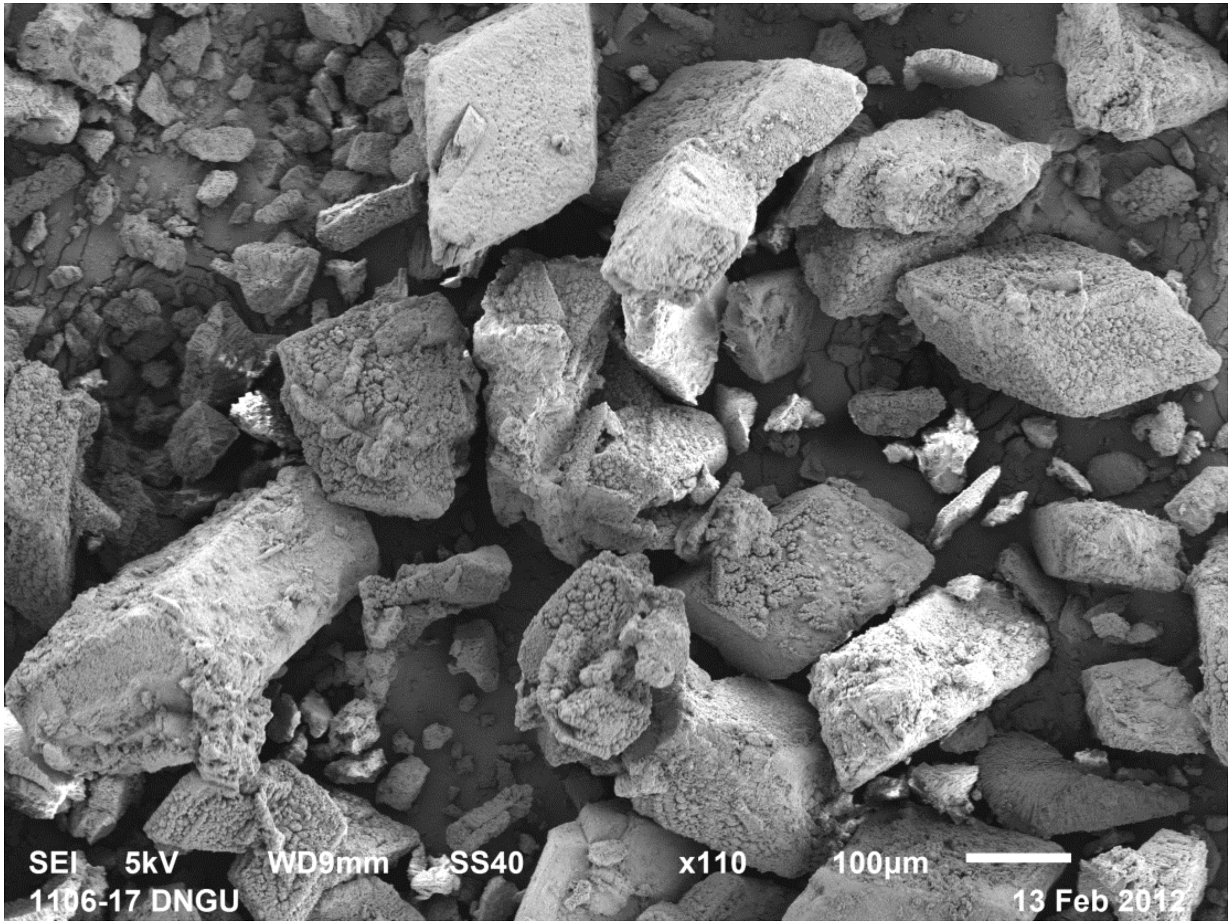


- However, there appear to be large crystals hiding in some of the “agglomerates”…..



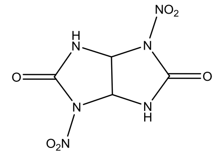
DNGU SEM Analysis



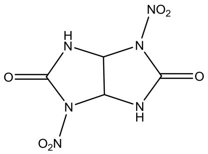


- DNGU produced after optimization efforts has more defined and larger crystal shapes

DNGU Formulations

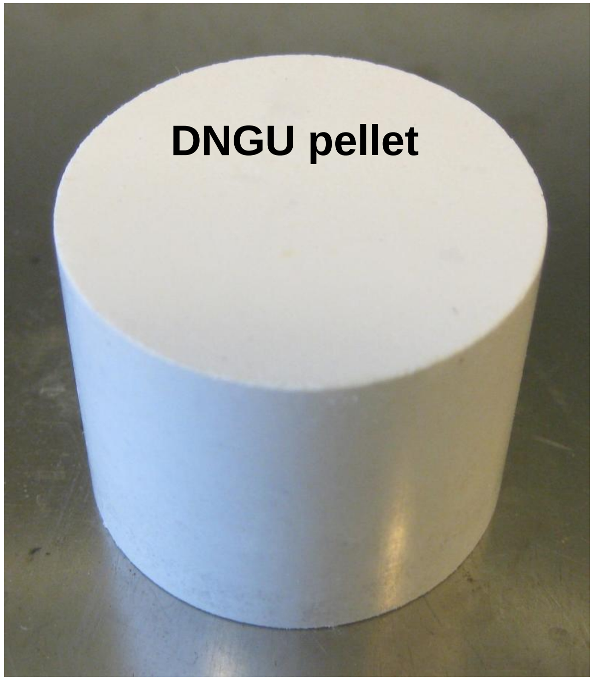


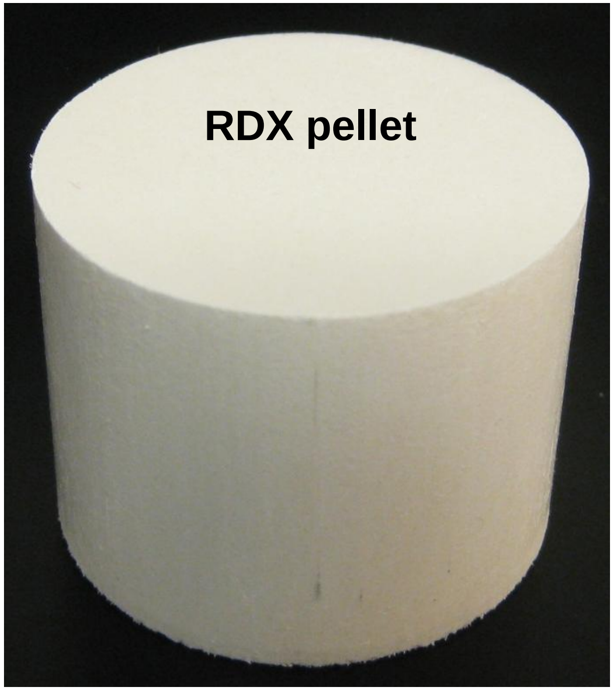
- Purpose: Prepare coated DNGU and RDX for pellet pressing and performance/sensitivity evaluations.
- No optimization performed at this time.
- DNGU is compatible with:
  - RDX,HMX,C-4 binder, TNT, Aluminum, DNAN, Viton
- DNGU was coated with 5% Viton through a standard Holston slurry coating process.
- 2.5 lb batch size
- RDX was processed same as DNGU.

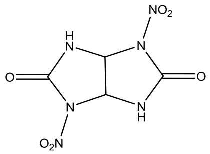


DNGU Molding Powder

- Over 150 pellets of each formulation were pressed
- Average press densities
  - DNGU: 1.65-1.66 (84% TMD)
  - RDX: 1.65-1.66 (91%TMD)





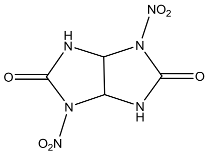


DNGU-Cheetah Calculations

- DNGU coated with 5% Viton compared against RDX (class 1) coated with 5% Viton and TATB (PBX-9502).

	%TMD	Density	VoD (m/s)	Pressure (GPa)
DNGU	98	1.93	8400	31.0
RDX	98	1.78	8444	31.8
TATB	98	1.89	8015	27.0
DNGU	84	1.65	7200	21.7
RDX	91	1.65	8000	27.2
TATB	86	1.65	7300	20.8

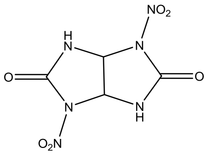
•At high TMD, DNGU comparable to RDX. At low TMD, DNGU comparable to TATB



DNGU Testing-Performance

- VoD and Blast pressure measured together (unconfined)
- Pressure measured at 5, 10, and 15 feet intervals.
- DNGU pressure: ~73% of RDX
  - (TATB: PBX—9502 (95% TATB) has a pressure of ~ 76% of RDX/Viton-calculated at similar TMD)
- RDX /Viton VoD: ~8000 m/s
- DNGU/Viton VoD: ~7600 m/s
  - (TATB: PBX—9502 (5% KelF) has a VoD of ~7600 m/s)
    - Reported value
- All data is preliminary.

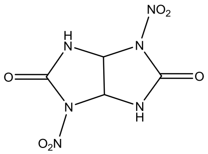
•Data indicates DNGU has TATB-like performance



DNGU Testing-LSGT

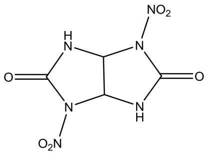
- DNGU coated with 5% Viton compared against RDX (class 1) coated with 5% Viton
- DNGU: 130 cards
- RDX: 301 cards
- (TATB: PBX—9502 (5% KelF) has a card gap of approximately 70 cards (50% point at 97% TMD))

•DNGU is much less shock-sensitive than RDX



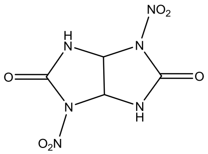
Conclusions

- DNGU is an affordable, insensitive energetic material that may find use in explosives and propellants
- DNGU shows promise as:
  - An alternative to TATB (better on cost)
  - An alternative to NTO (no water solubility)
  - A way to reduce use of RDX in energetic formulations



Path Forward

- Further development (synthesis and recrystallization) needed to optimize particle shape and size.
- Evaluate DNGU as a TATB alternative in pressable formulations such as PBXN-7 and PBXW-14.
- Evaluate DNGU as an NTO alternative in melt-pour formulations such as IMX-101 and IMX-104.
- Use these formulations to generate more performance (VoD, pressure) and sensitivity (LSGT) data for DNGU
- Evaluate DNGU for propellant applications.



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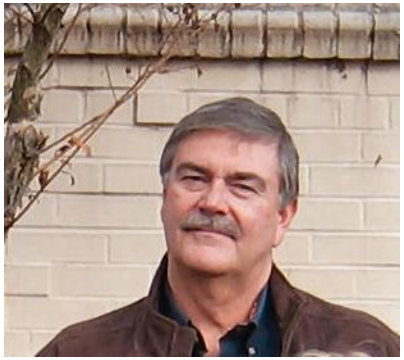

POC: David Price,
423-578-6350,
David.w.price@baesystems.com