Particle Size Image Analysis of Explosive Formulations & Ingredients ABSTRACT NUMBER

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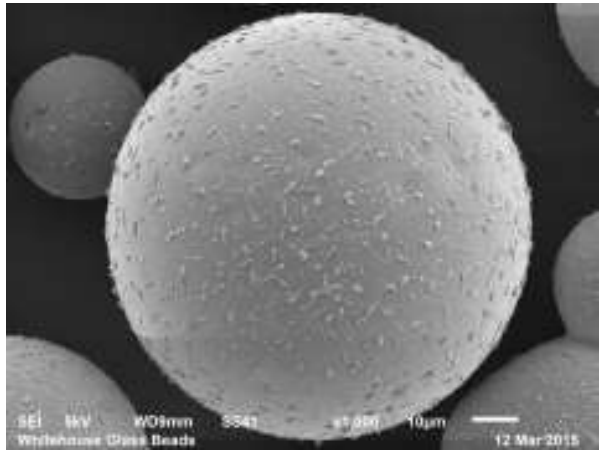
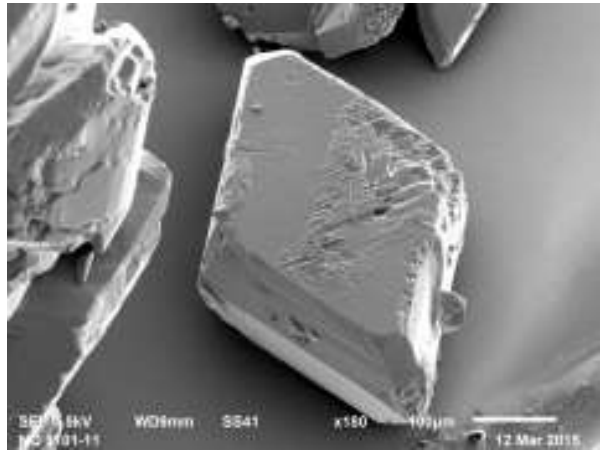
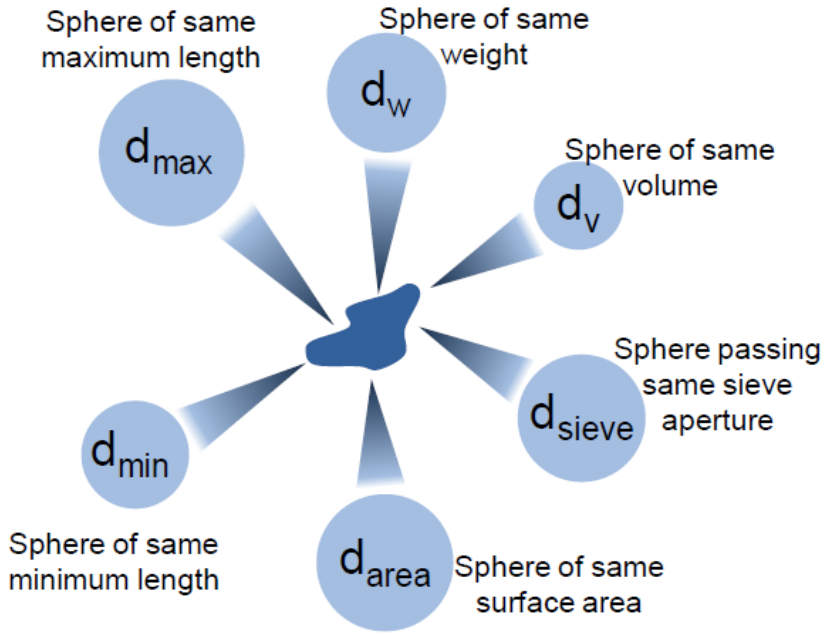
Particle Size Analysis



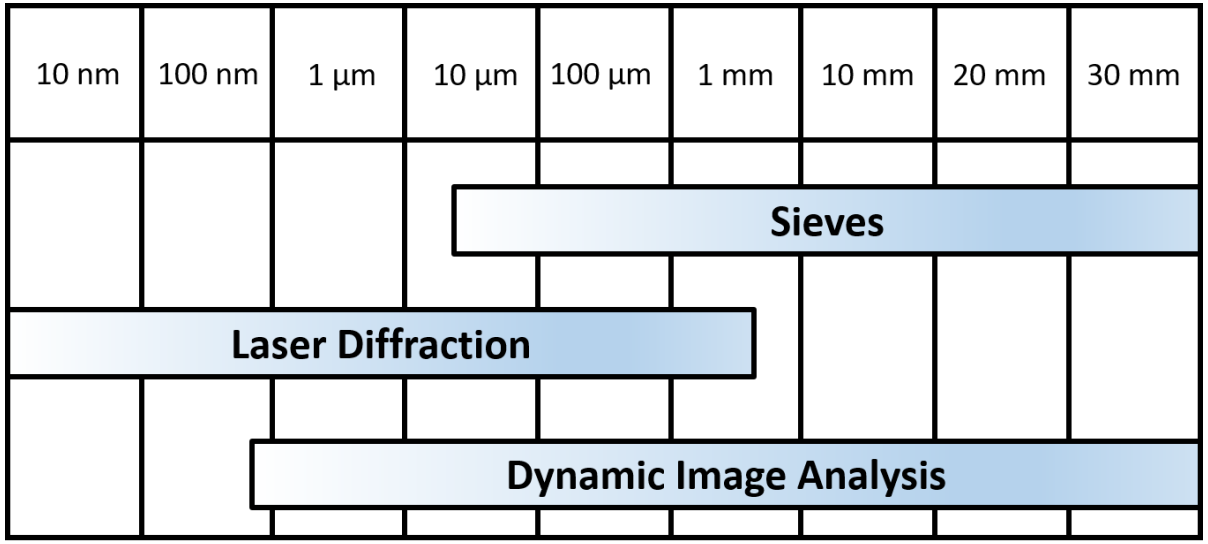


- Particles are 3-dimentional objects
- Unless the particles are perfect spheres, they cannot be described by a single dimension, such as radius or diameter
- Most methods define the particle size as an equivalent sphere having a shared property with the actual particle, such as volume, area, or length.
- Different measurement techniques use different equivalent sphere models and therefore will not give the same results for a given particle.



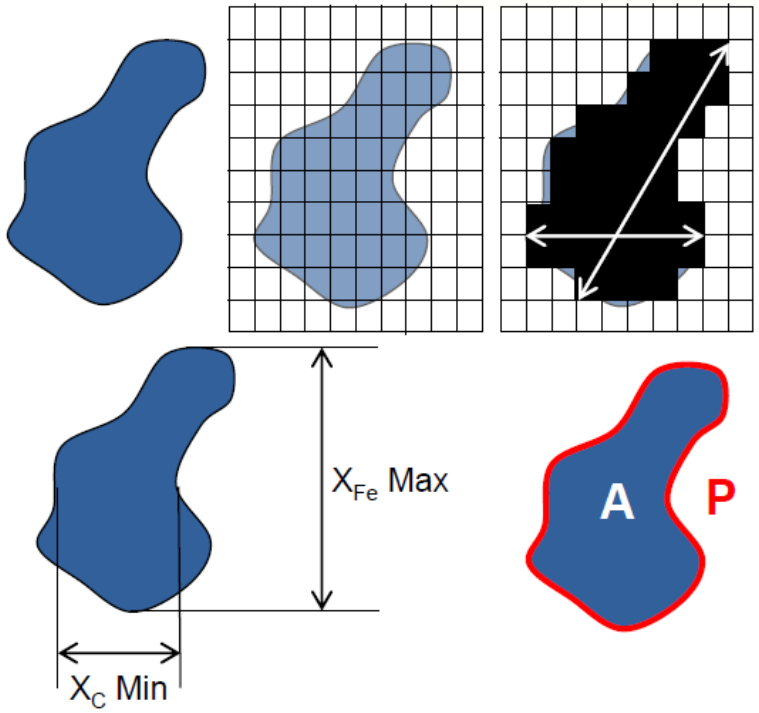
Particle Imaging Analysis

- Currently most explosives ingredients and granular formulations have particle sizes ranging from approximately 1 micron to 10 millimeters.
- Historically particle size analysis of explosive formulations have been performed by sieving.
- Particle size analysis of explosives ingredients have been done by sieving or laser diffraction methods.
- Particle Imaging Analysis is an alternative technique that can also be used to measure particles in these size ranges.



Particle Imaging Analysis

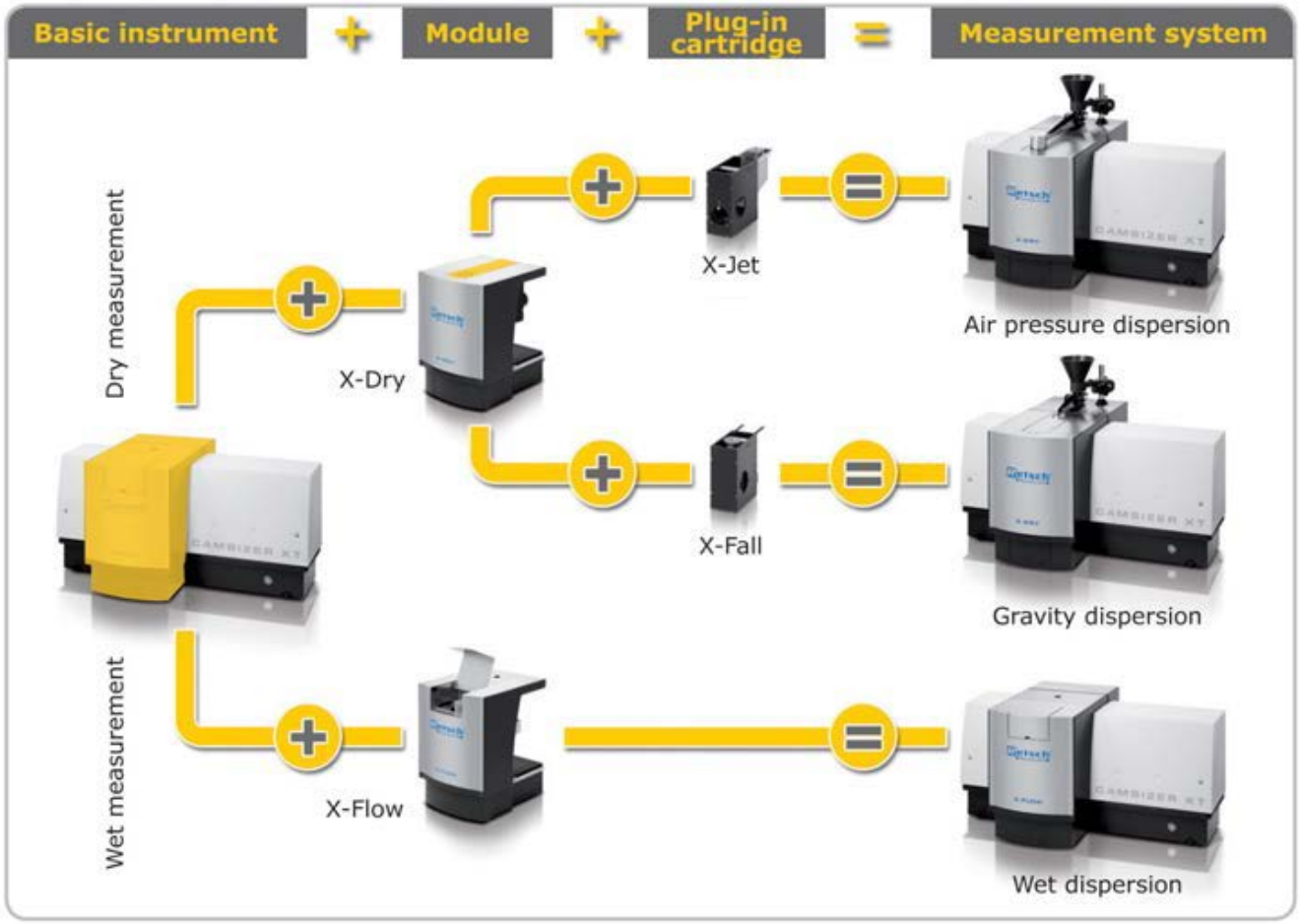
- Samples are dispersed and passed in front of a digital camera where images are acquired.
  - Static
  - Dynamic
- The images are processed via software to segregate particles from background and to perform image analysis operations on each particle resulting in dimensional measurements.
- These particle measurements can be used to evaluate both size and shape.



$$Aspect\ Ratio = \frac{X_{c\ min}}{X_{Fe\ max}} \qquad Sphericity = \frac{4\pi A}{P^2}$$

Particle Imaging Analysis

- Interchangeable module and cartridges makes the system highly adaptable to different sample types.
- X-Dry - X-Jet: Air dispersion
- X-Dry - X-Fall: Gravity dispersion
- X-Flow: Wet dispersion



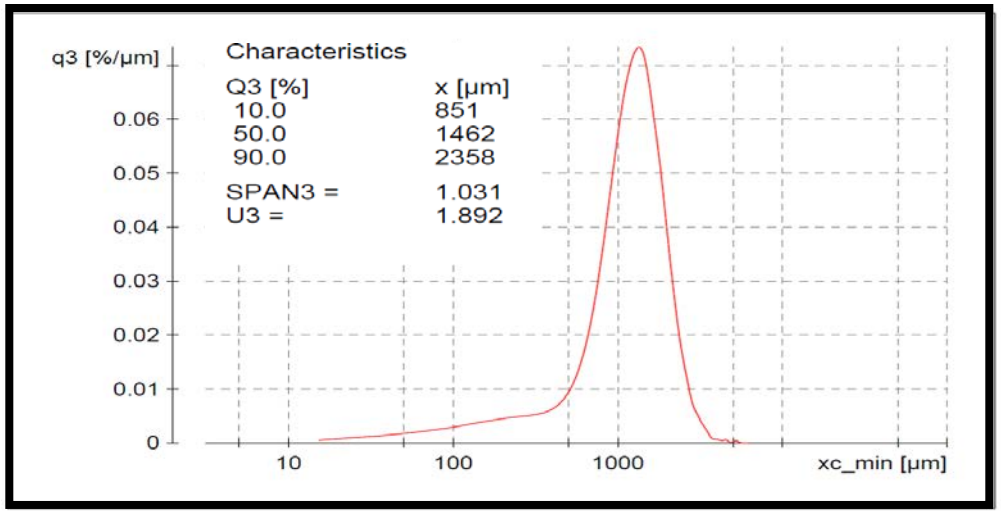
Explosive Formulations by Dynamic Image Analysis

- Particles that are dry and free flowing can be analyzed by a vibration feed table and gravity dispersion.
- Materials fall freely past the camera.
- There is no physical means of dispersing agglomerates of particles in the system.

Formulation Methods Developed
Composition A5
CXM-AF-7
LX-14/17
HMX Mains
IMX- 101/104
PBX-9502
PAX-3
PBXN-X (7, 9, 10…)

Explosive Formulations by Particle Image Analysis

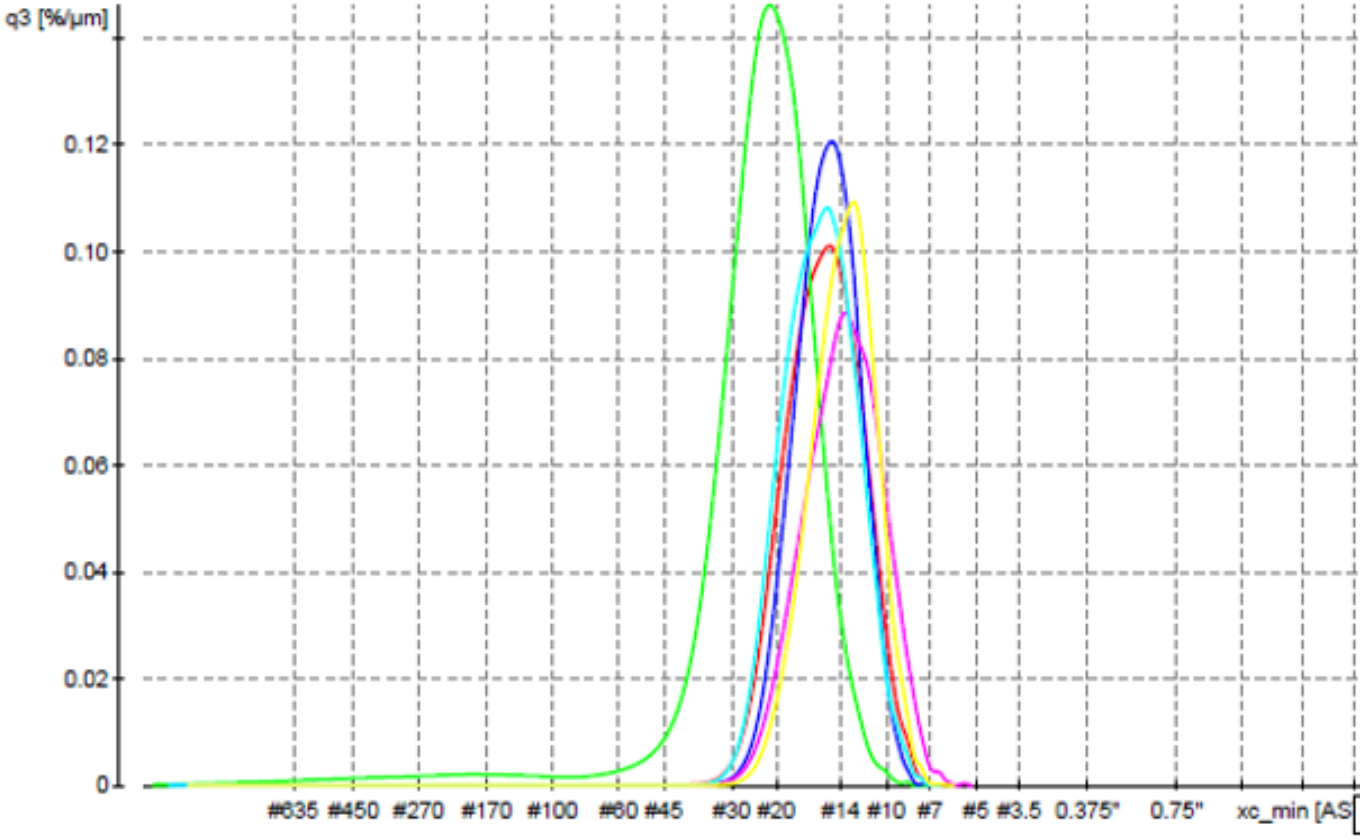
- Data
  - % Passing/Retained
  - Shape Parameters
  - Distribution curve
- Dynamic Image Analysis
  - Batch Information Retained
    - Reprocess data in the future
    - Assess Performance Issues or Optimize PSD Parameters



Size class	[µm]	p3 [%]	Q3 [%]	SPHT3
> 4750		0.2	100.0	
2360 -	4750	9.8	99.8	0.894
1700 -	2360	24.7	90.0	0.902
1400 -	1700	19.9	65.3	0.904
1180 -	1400	16.2	45.4	0.901
850 -	1180	19.2	29.2	0.895
180 -	850	9.5	10.0	0.879
0 -	180	0.5	0.5	0.823

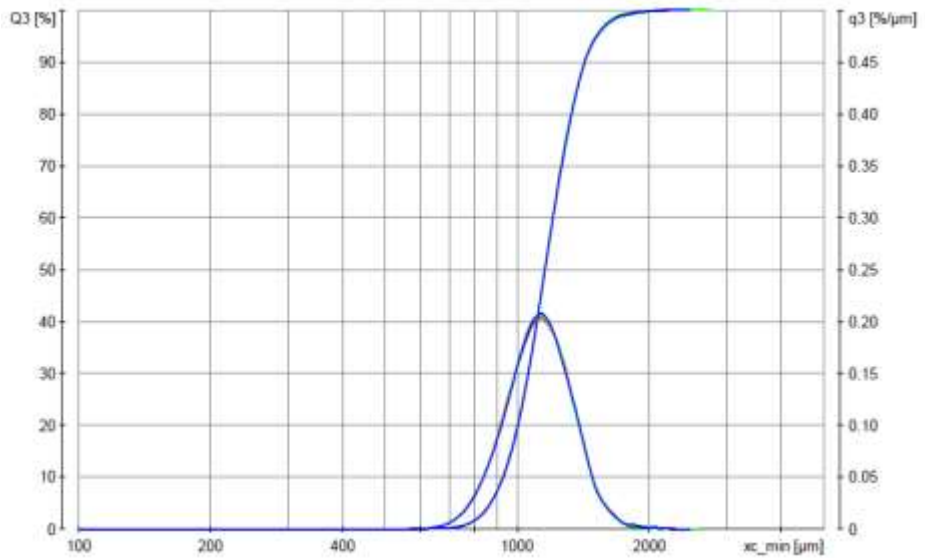
Size class	[µm]	p3 [%]	Q3 [%]	SPHT3
> 3350		1.5	100.0	
2360 -	3350	8.5	98.5	0.894
1700 -	2360	24.7	90.0	0.902
1400 -	1700	19.9	65.3	0.904
1180 -	1400	16.2	45.4	0.901
850 -	1180	19.2	29.2	0.895
710 -	850	4.5	10.0	0.885
600 -	710	2.1	5.5	0.879
425 -	600	1.6	3.4	0.876
180 -	425	1.3	1.8	0.865
45 -	180	0.5	0.5	0.825
	< 45	0.0	0.0	0.761

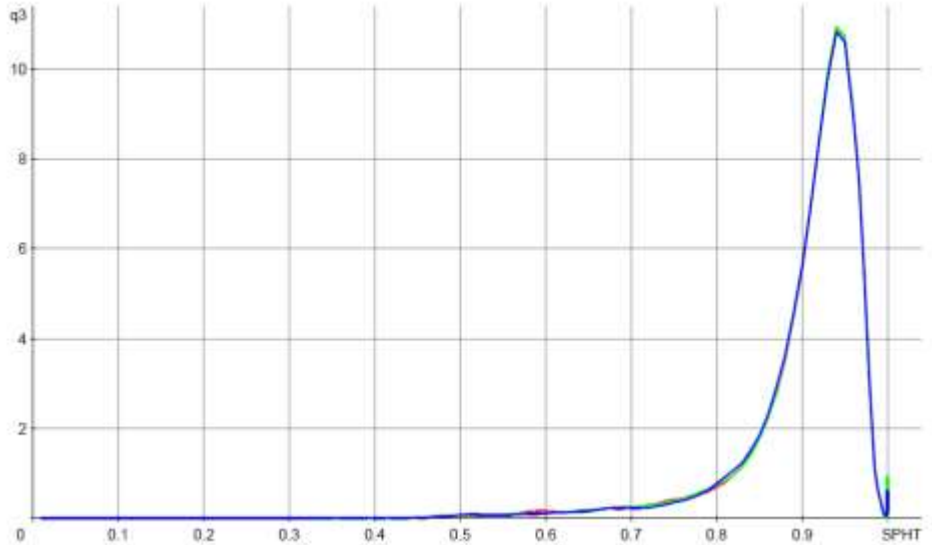
Explosive Formulations by Particle Image Analysis



- PBXN-X
  - All data passed MIL-SPEC PSD
  - PSD curve highlights differences.
- Formulation Advantages
  - Full Sieve Range
  - Information collected rapidly
  - Small sample size
  - Distinguishes PSD variation between batches that traditional sieving overlooks.

Explosive Formulations by Particle Image Analysis





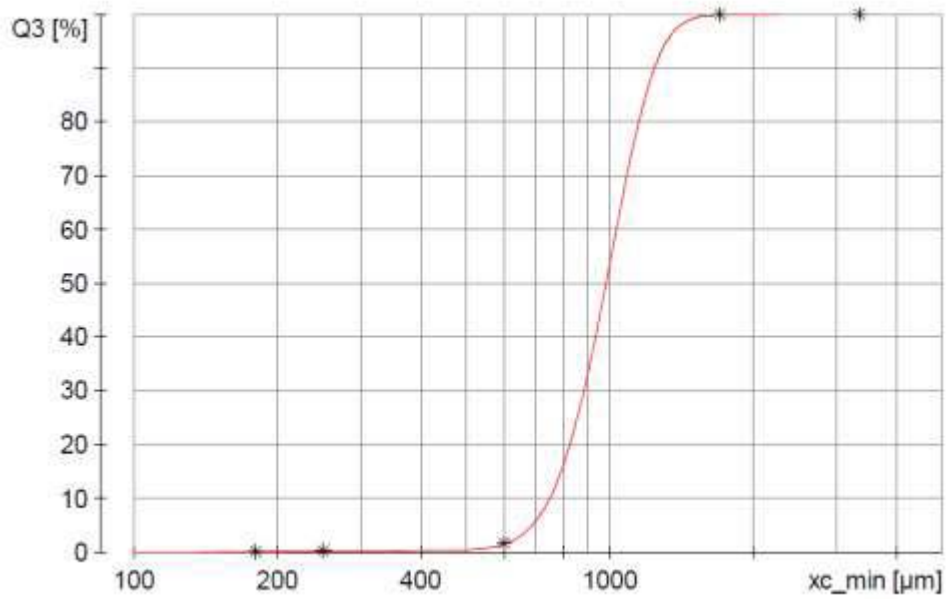
Replicate	D10 (µm)	D50 (µm)	D90 (µm)
1	926.1	1156.3	1425.7
2	928.3	1154.8	1422.8
3	928.9	1156.7	1425.7

Replicate	Sphericity	Symmetry	Aspect Ratio
1	0.908	0.928	0.765
2	0.908	0.929	0.766
3	0.908	0.928	0.766

Replicate analysis of formulation products indicate good repeatability for both size and shape analysis

Explosive Formulations by Particle Image Analysis

- Sample was analyzed by Image Analysis and then by sieving using sieve sizes from product specifications
- Good Agreement to sieving data however data only describes the extremes.



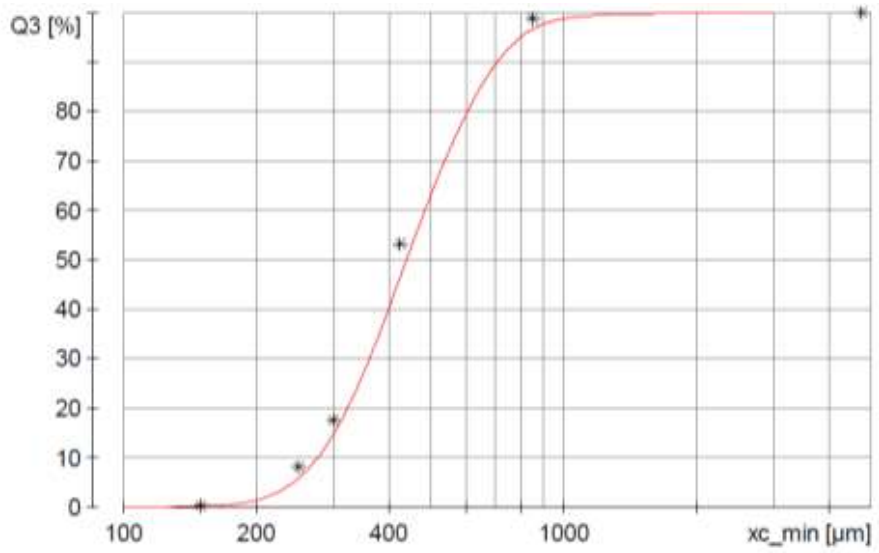
RED – Cumulative Distribution (% passing)

* - Sieving Data

Sieve #	Sieving (% passing)	PIA (% passing)
#6	0.0	0.0
#12	0.0	0.1
#30	98.5	98.4
#60	1.4	1.4
#80	0.0	0.
PAN	0.1	0.1

Explosive Formulations by Particle Image Analysis

- Another sample was analyzed by Image Analysis and sieve sizes were selected based upon these results to better described the sample by sieving.
- Generally good agreement to sieving data
- Slight differences based upon orientation of particle when image acquired



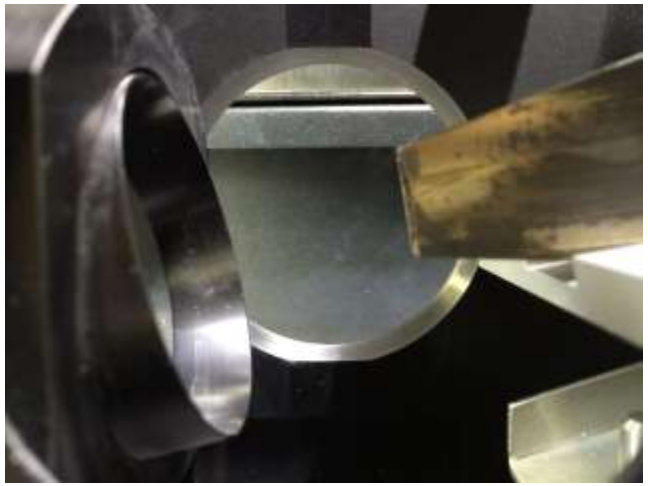
RED – Cumulative Distribution (% passing)

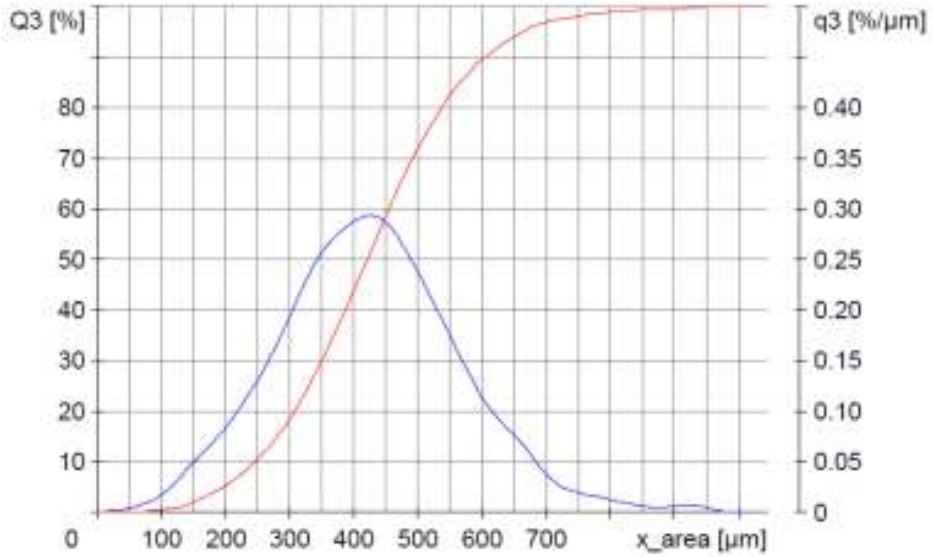
* - Sieving Data

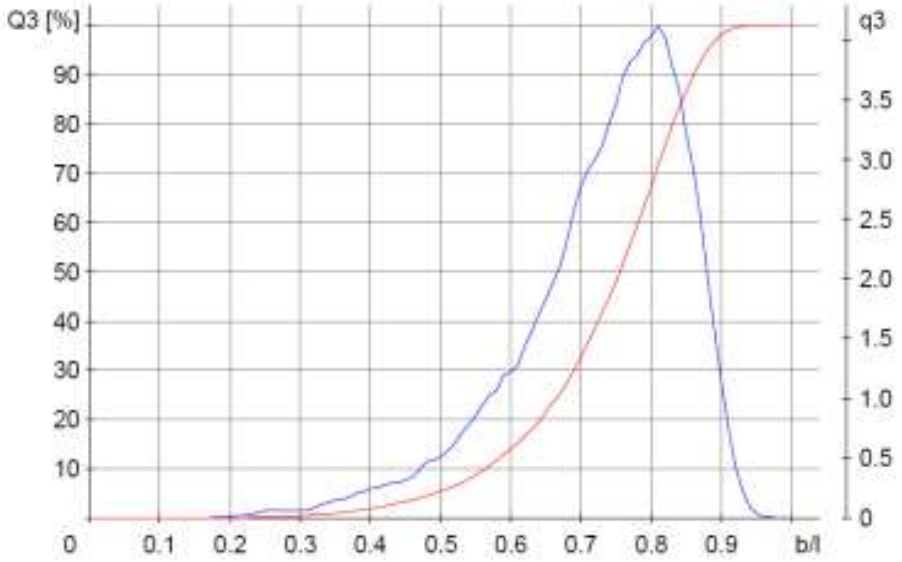
Sieve #	Sieving (% passing)	PIA (% passing)
#4	0.0	0.0
#20	1.2	3.3
#40	45.5	50.3
#50	35.7	31.7
#60	9.4	8.8
#100	7.9	5.7
PAN	0.3	0.2

Energetic Materials by Particle Image Analysis

- Dry fine particles that agglomerate can be analyzed by vibration feed table and air pressure dispersion
- Particles are mixed with a stream of compressed gas to break up agglomerates.
- Particles and gas stream exit out of a nozzle past the camera for measurement.

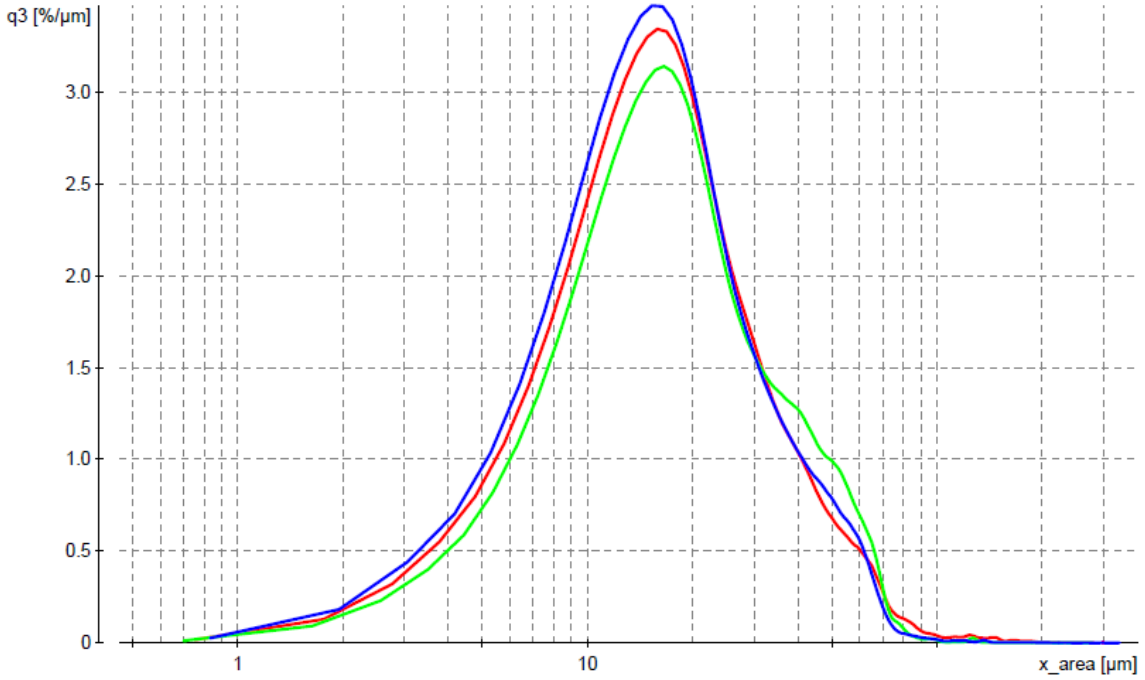






Energetic Materials by Particle Image Analysis

- Fine particles that agglomerate can also be analyzed using a wet mode
- Particles are slurried in water. Agglomerates are broken up by sonication
- The slurry is pumped through a liquid cell past the camera for measurement.



Energetic Materials Methods Developed
TATB
NQ
NTO
RDX
HMX

Summary

- Particle Imaging has been used to evaluate a variety of explosive formulations and ingredients.
- Imaging analysis has shown good agreement with sieving data for explosive formulations. Method is faster, less hands on, and easier to clean-up.
- Particle imaging analysis has shown the ability to distinguish differences in particle shape that other methods cannot detect.
- Data files can be stored and reprocessed to incorporate different discrete sizes in order to better characterize particle size for materials that have been shipped and for which a file sample is no longer available.