



# Energetics Science & Technology Outside the United States



Professor James Short  
jshort@umd.edu  
301 405-5246



# CECD

**CENTER FOR ENERGETIC CONCEPTS DEVELOPMENT**



DEPARTMENT OF MECHANICAL ENGINEERING  
A. JAMES CLARK SCHOOL OF ENGINEERING



# Energetics Science & Technology Outside the United States

1970s

**Berkeley**  
UNIVERSITY OF CALIFORNIA

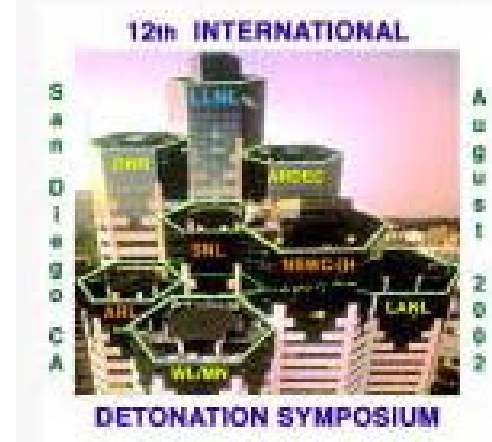
1980s



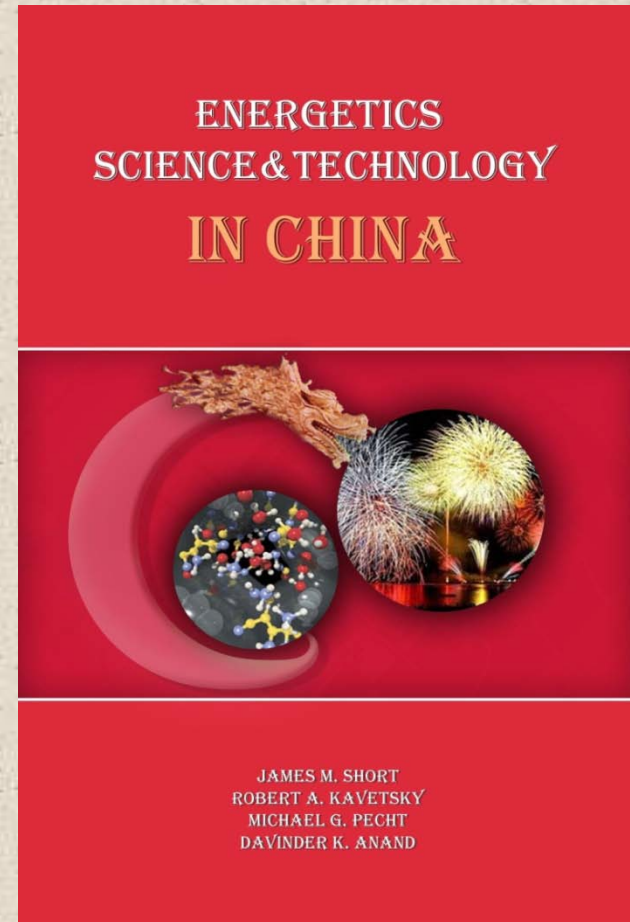
The Legacy of the  
White Oak Laboratory



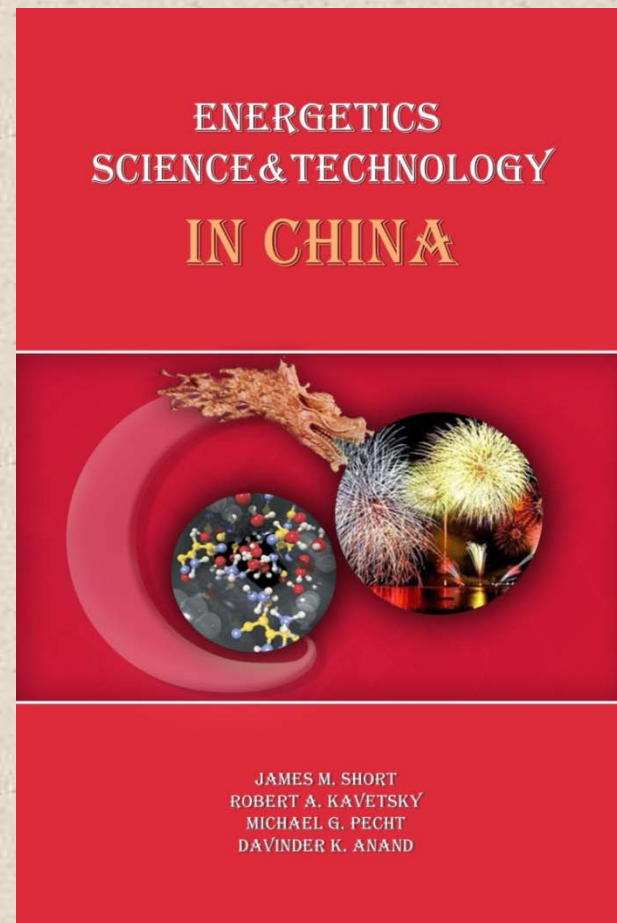
1980s & 1990s



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# Energetics Science & Technology Outside the United States





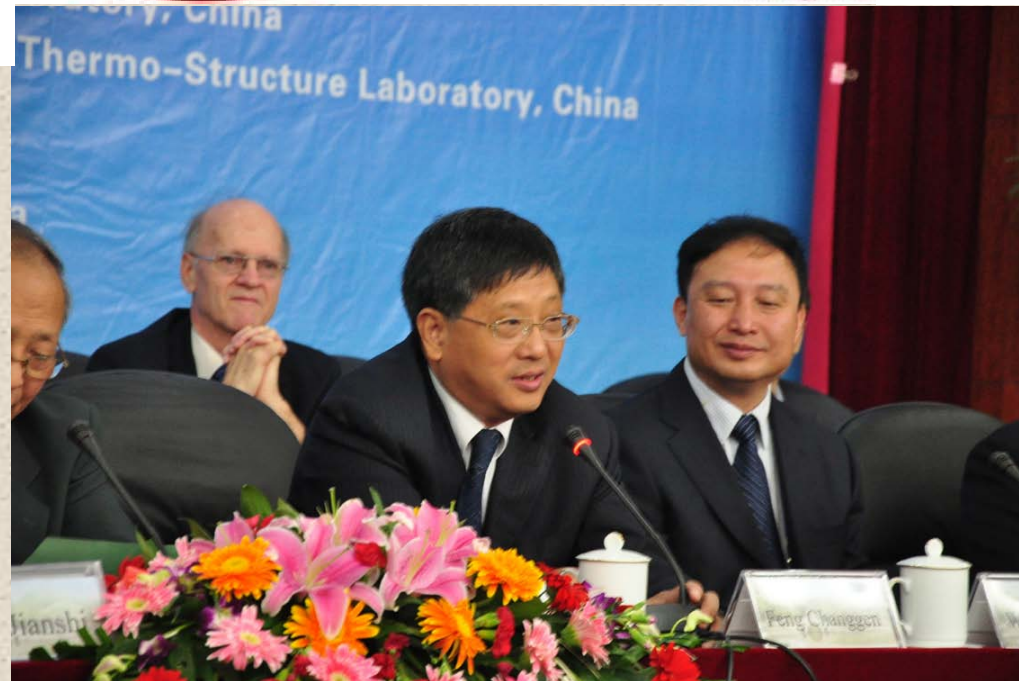
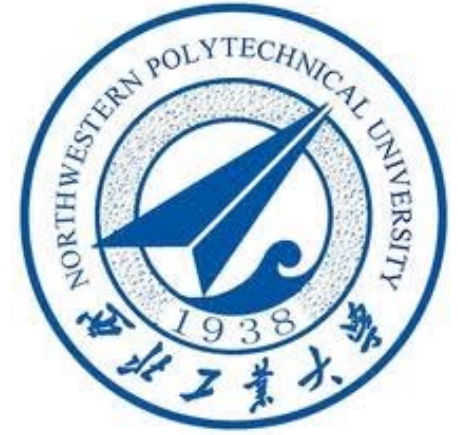
Energetics  
Science & Technology  
Outside the United States

China

## 2011 International Autumn Seminar on Propellants, Explosives & Pyrotechnics



# Energetics Science & Technology Outside the United States



# Energetics Science & Technology Outside the United States

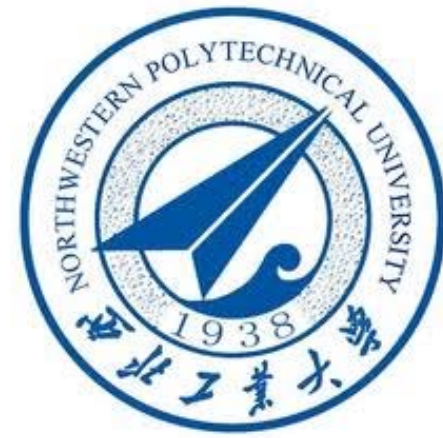


# Energetics Science & Technology Outside the United States



- Experimental methods of detonation physics
- Spectroscopy
- Molecules @ high density
- Clusters of explosive molecules
- Detonation product chemistry
- Intermolecular forces
- Spectroscopy of shocked materials
- Diagnostics of shocked materials
- Diagnostics of detonating materials
- Real-time studies
- Spectroscopy of highly excited molecules

# Energetics Science & Technology Outside the United States



- Energetics synthesis chemistry
  - Organic energetics—
    - CHNOF
    - Metals & beyond
  - Inorganic energetics
    - All nitrogen & all hydrogen
- Energetic formulation chemistry
- Thermobarics
- Reactive materials
- Fragments that are independently inert & react when striking target
- Physics & chemistry of reaction
- Gun propellants
- Nanomaterials in formulations
- Energetics manufacturing science
  - Batch processing
  - Extruder (or twin-screw) processing
  - Barriers to scale-up

# Energetics Science & Technology Outside the United States



- Energetics Fundamental Research domains China expects to pursue:
- Theoretical & experimental methods providing fundamental understanding of detonation physics and energetics chemistry.
- Theoretical methods of detonation physics
  - Ab initio intermolecular potentials
  - Dense molecular fluids
  - Semi-empirical molecular potentials
- Hydrodynamics
  - Shocked-state measurements
  - Unreacted equations of state
  - Experimental diagnostics of shocked material
  - Shocked state measurements
  - Detonation state measurements
- Computational fluid dynamics

THEORY AND PRACTICE  
OF ENERGETIC MATERIALS

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(VOL. IX)

*Edited by*

LI Shengcai  
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***SECTION ONE***  
**SYNTHESIS AND MANUFACTURE**

42 papers, 26 Chinese papers

- hexa-nitrohexaaza-iso-wurtzitane,
- tetrazines ( $C_6N_{12}H_6O_{12}$ )
- nano-HMX
- FOX-7 ( $C_2H_4N_4O_4$ )
- furoxan ( $C_2H_2N_2O_2$ )
- energetic polymers e.g., glycidal azide polymer
- high nitrogen salts  
(e.g., nitro-amino tetrazoles,  $CH_2N_4$ )
- lead-free primary explosives

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***SECTION TWO***  
**CHARACTERIZATION AND ANALYSIS**

38 papers, 29 Chinese papers

- furoxans ( $C_2H_2N_2O_2$ )
- HTPB propellants
- ammonium nitrate ( $NH_4NO_3$ )
- ammonium perchlorate ( $NH_4ClO_4$ )
- ammonium dinitramide ( $H_4N_4O_4$ )
- characterization of high nitrogen materials
- pyrotechnic materials and molding powders
- thermal decomposition
- effects of aging
- crystal defects
- dynamic fracture

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***SECTION THREE***  
**COMBUSTION AND DETONATION**

81 papers, 53 Chinese papers

- shaped charges
- explosively formed penetrators
- pore collapse initiation
- chain branching reaction mechanisms
- structural integrity of solid rocket propellant

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**SECTION FOUR**  
**MODELING AND CALCULATION**

21 papers, 13 Chinese papers

- “*A Microscopic Model Predicting Hot-spot Ignition of Energetic Crystals under Drop-weight Impact*” by Wu & Huang
- Harold Sandusky & Steve Coffey
- Micro-mechanics model of HMX hot spot ignition in drop-weight impact test
- Meso-scale model
  - particle-particle contact, no sliding friction,
  - contact between particles & anvil
  - sliding friction heating induces plastic deformation & melting along the maximum shear stress faces

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***SECTION FIVE***  
**MISCELLANEOUS**

12 papers, 7 Chinese papers



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China



Energetics  
Science & Technology  
Outside the United States

China



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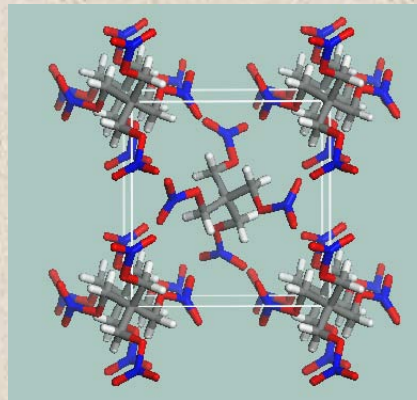
Xi' an Modern Chemistry Research Institute (largest chemical energetics research center)  
Beijing Institute of Technology (Project 985 Tier 2)  
Nanjing University of Science & Technology (Project 985 Tier 2)  
China Academy of Engineering Physics @ Mianyang (nuclear weapon design)

A distant 4th is North University of China (ordnance, defense industry college)

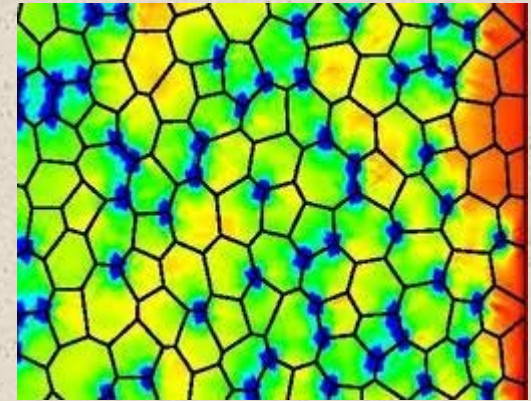
Followed by

National University of Defense Technology (Project 985 not Tier 2)  
2nd Artillery Engineering Institute (strategic nuclear establishment)  
University of Science & Technology of China (C9 League member, 154th @ US News ranking)  
Northwest University @ Xi' an (Project 985 not Tier 2, defense industry college)  
Southwest University of Science & Technology (founded in 2000)  
213th Research Institute of China (armor)  
Tianjin University (Project 985 not Tier 2)

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Molecular Scale



Mesoscale