MSIAC

Munitions Safety Information Analysis Center

Supporting Member Nations in the Enhancement of their Munitions Life Cycle Safety

Science of Cook Off Workshop

IMEMTS, Rome, Italy
18th – 21st May 2015

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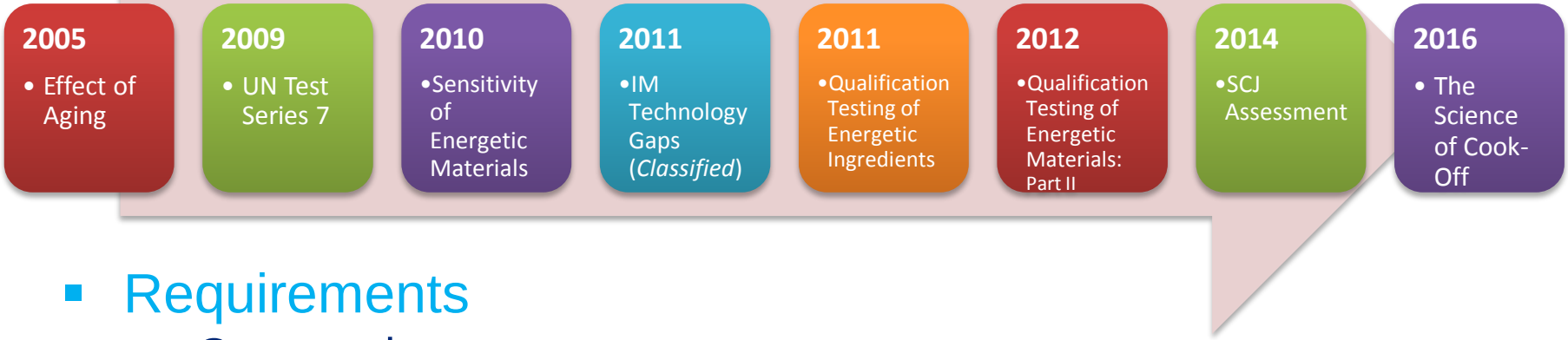
Workshops

- Primary Aim
  - Development and exchange of fundamental science between MSIAC nations



- Requirements
  - Community
    - ➢ Topic of interest & need for information exchange
  - MSIAC Office
    - ➢ Proposal to SC for delivery of workshop
  - Steering Committee
    - ➢ Work Element initiated Fall 2014

History

- NIMIC/MSIAC workshops
- 1993
  - Proceedings of the Workshop on Cookoff
- 1996
  - NIMIC/KTA-4-20 Workshop on Cookoff and XDT Mechanisms Summary
- 2000
  - The NIMIC Workshop on Small-Scale Testing and Modelling

Gaps: Damage and Fracture

- **1996**
  - Thermal damage in non/energetic materials
- **2000**
  - Investigation of confined and unconfined burning phenomena including damage difficult

Violence of Response

- **1996**
  - Need for good experimental results and material characterisation

Modelling

- **1996**
  - Comparing damage models seems a good scope for collaboration

Thermal Threats

- **1993**
  - Slow heating or constant temperature test based on a realistic hazard assessment
- **1996**
  - Slow heating rate considered a scientific test

Protocol for Cook-Off

- Protocols
  - Developed during 1990's through TTCP
- Included in AOP-39 Annex C
- Accepted that science of fast and slow heating are the same
- Detailed protocols cover
  - 1. Initial thermo-chemical system description
  - 2. Thermo-chemical/thermo-mechanical system description and their response to new boundary conditions (i.e. time steps and thermal variation.)
  - 3. Self sustained exothermic reaction.
  - 4. Evaluation of burn criteria with the possibility of thermal explosion.
  - 5. Evaluation of the confinement and its effect on the reaction.
  - 6. Evaluation of the status of the energetic material.
  - 7. Change in the thermal loading and its effect on the system.

Basic data required for such evaluations will include chemical descriptions of all energetic material components in the high temperature conditions identified. **Temperature and pressure-dependent decomposition kinetics** and energetics of these materials are still being **developed**. This is an area where a significant effort is required to setup a valuable database.

AOP-39 Ed 3 (2010)

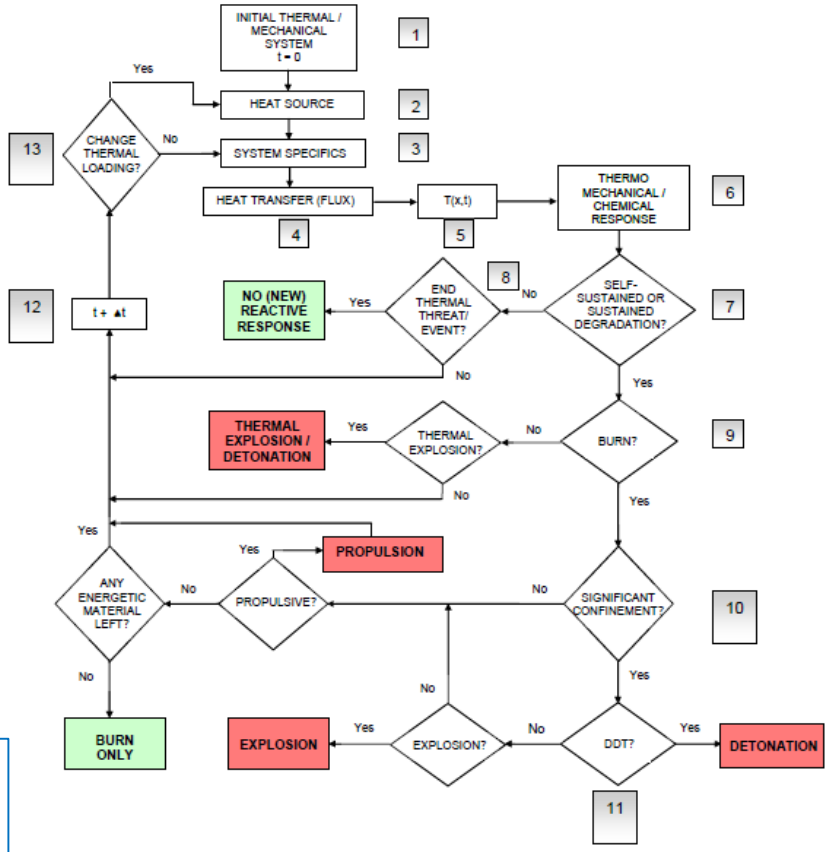
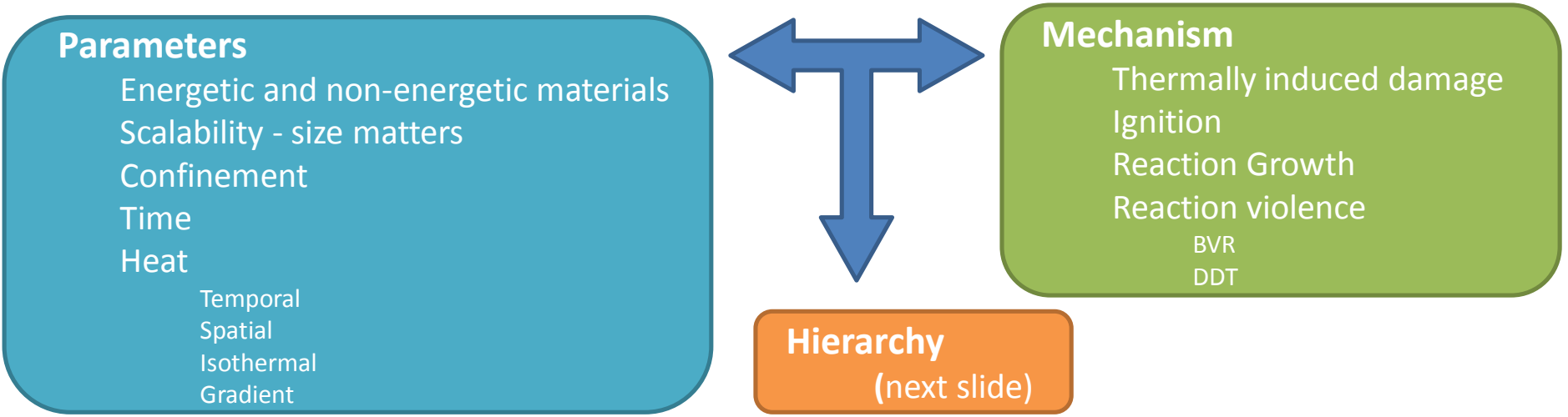


Figure C-2 Detailed Hazard Protocol – Fast/Slow Heating

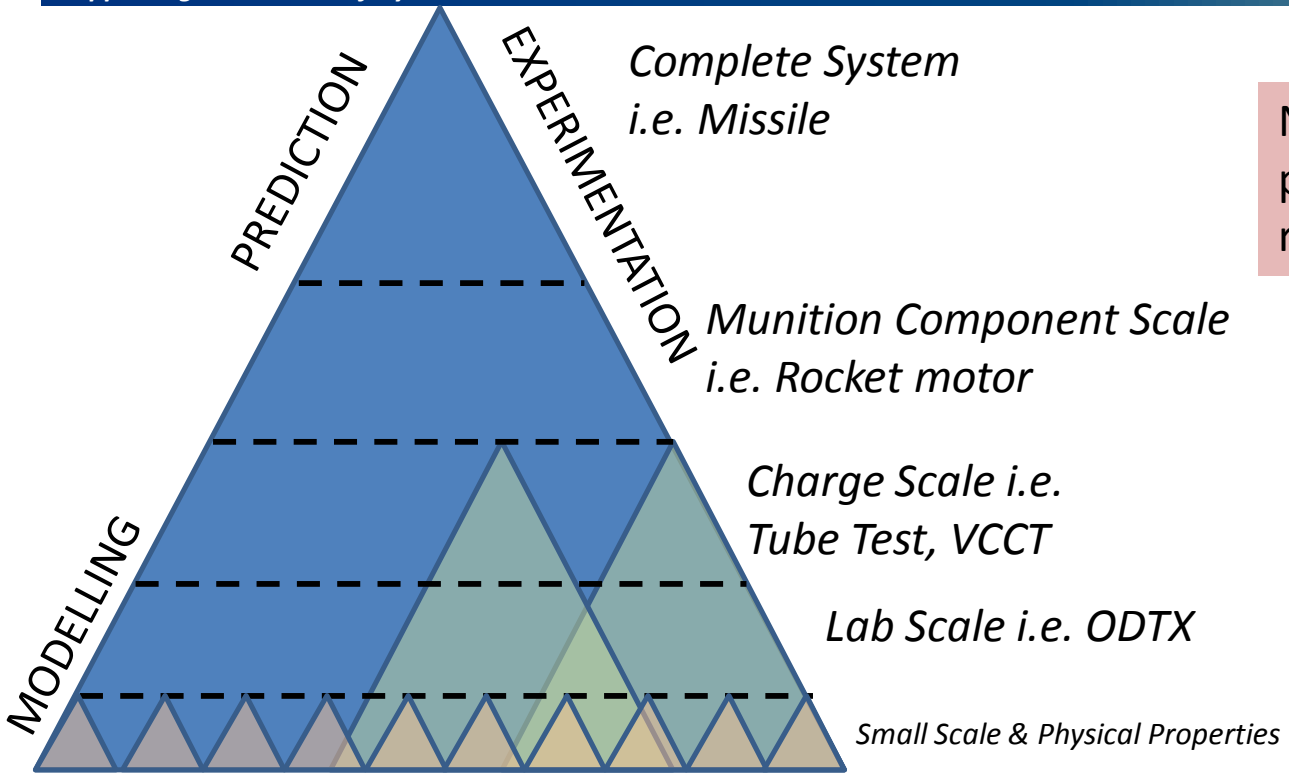
MSIAC Workshop Proposal

- MSIAC Workshop: The Science of Cook-Off

- Factors



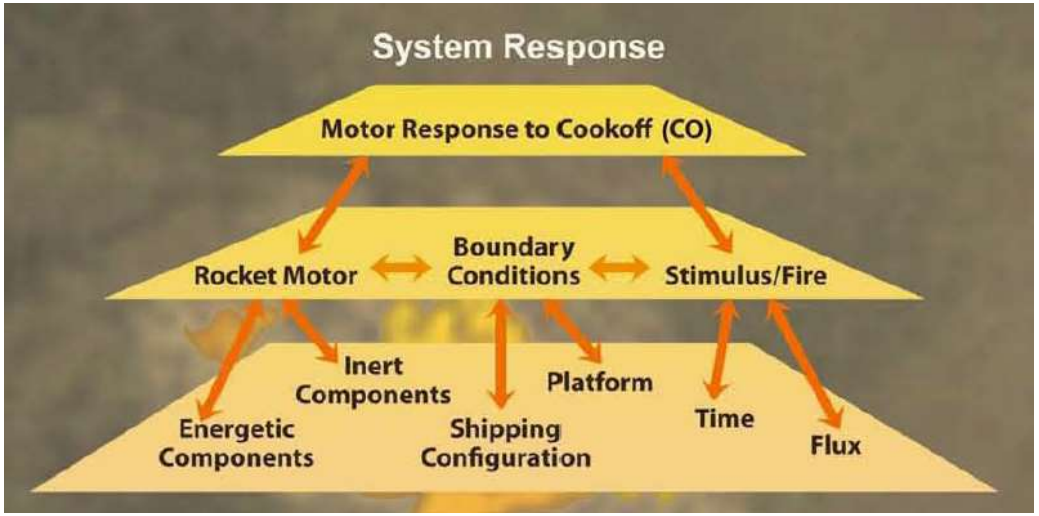
Hierarchy

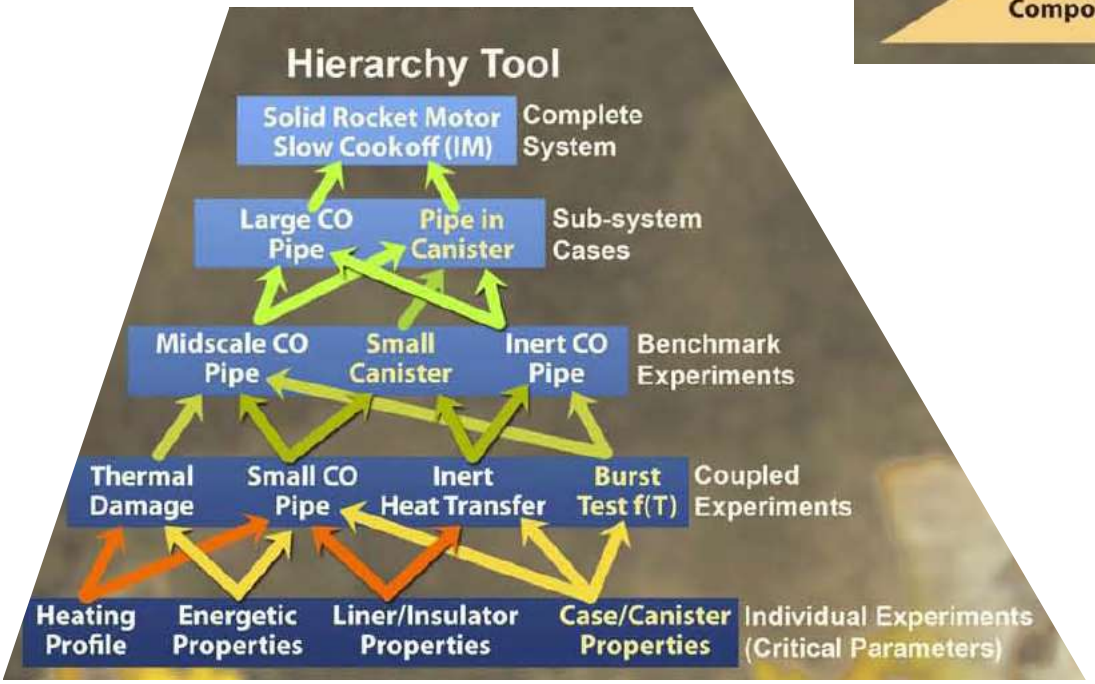


Need to relate chemical & physical properties to AUR response

- Approach
  - Simple, lower cost lab and charge scale tests
  - Each test determines different parameters
    - E.g. decomposition kinetics, time to initiation
  - Information lower in the pyramid helps to understand the mechanisms higher up
- Moving up the pyramid the more complex the problem
- Hierarchy aims to
  - Connect mechanisms such as mechanical to thermal
  - Generate predictive models

Development of Scaling Hierarchy





Atwood, A.I.; Daniels, A.L.; Davis, N.C.; Washburn, E.B.; Ford, K.P.; Farmer, A.D.; Wheeler, C.J.; Curran, P.O.; Glorian, A.; Gennrich, M.T.; "*Development of a scaling hierarchy for cook off hazards*". **2010** Insensitive Munitions & Energetic Materials Technology Symposium, 11 – 14 October, München Marriott Hotel, Munich, Germany

MSIAC's Identified Needs

- Discussion topics
  - Improve overall aim/objective(s) to the workshop to
    - Focus literature review
    - Focus discussions
    - Focus deliverables
- Input sought from SMEs

Discussion on

- What effect does heating rate have on the reaction of the material under test?
- What is happening to materials across heating rates from 0.05ºC min^{-1} to 1111ºC min^{-1}?
- Are we currently capturing all the response mechanisms for a material?
- Is it possible to quantify violence of an event?
- Growth of reaction and material/thermal/mechanical models what is the current state of the art?
- What are the key parameters/material properties that change across the heating rate?
- Point of ignition/initiation parameters

Developing Workshop Focus

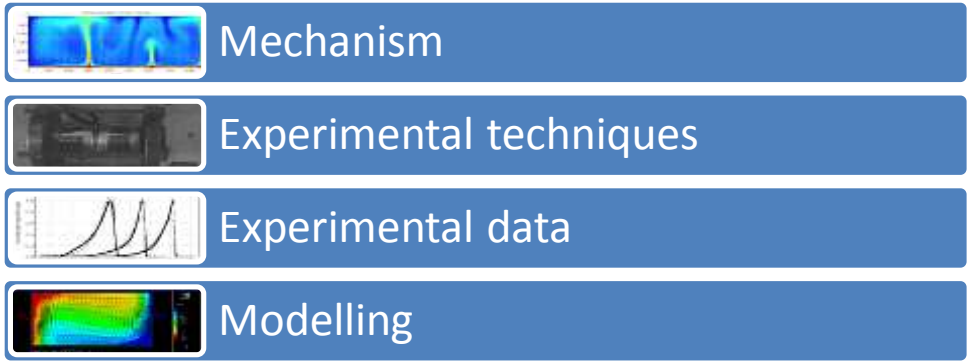
- SME's
  - Ensure that the workshop has a clear focus/goal
    - Update of TTCP Protocols (AOP-39)
    - Advance the state of the art with respect to M & S (mentioned by several)
  - Agreement that the following topics are current and of interest to the community
    - Determining a metric for violence of reaction (difficult)
    - Focus on the point of ignition/initiation
- Support for the workshop
  - AC/326 SG/B
  - TTCP
    - Will overlap with Slow Cook Off CP
    - Information from the nations will be presented at the MSIAC workshop
  - National Interest i.e.
    - UK – focus on a number of areas including Cook Off
    - US – funding stream associated with CO and IM
- Other
  - IMEMTS
  - IMEMG
  - US DoE

Recommendation

- Need to focus workshop to deliver outputs that can be exploited by the community
  - Develop understanding on the role of heating rate (conditions) in determining reaction violence
    - ➢ Improve understanding of chemical and physical changes leading to critical ignition and growth conditions
    - ➢ Improve understanding of reaction phenomenology
    - ➢ Provide guidance on scope of validity of system level tests
  - Improve and update methodologies to predict response
    - ➢ Advance methodologies to predict response mechanisms e.g. TTCP hazard protocols, hierarchy approach
    - ➢ Advance knowledge and tools to assess munition response
      - Hierarchical approach to building response understanding from chemical and physical properties and sub scale testing (identify properties and tests)
      - Assess models, the capabilities and limitations to predict response mechanism

MSIAC 2015

- IMEMTS
- Literature Review
  - Starting point 1996 KTA-4-20 workshop on Cook Off and XDT
  - Breakdown of topics e.g.
    - Material response across heating rates
    - Initiation mechanism
    - Test methods for determining cook off and thermal threats at reduced scale
    - Current models and modelling
  - Will require community to review output



ODTX: 448 entries
Tube Test: 1050 entries
VCCT: 441 entries
AIMS: SCO 180 entries (3.3 - 83; 5 – 4; 22.2 - 8; 27.8 - 20) , FCO: 203

What next

- Location
  - East coast of America
    - Steering committee (Spring 2015) required further information before confirmation of final location
- Timing
  - April/May 2016
- Duration
  - 1 week (Monday to Friday)
- Workshop will follow SCJ WS model
  - Venue and hosting will be covered by MSIAC
  - Participants will cover accommodation and travel costs
  - Participation numbers maybe limited (Steering Committee will assess)

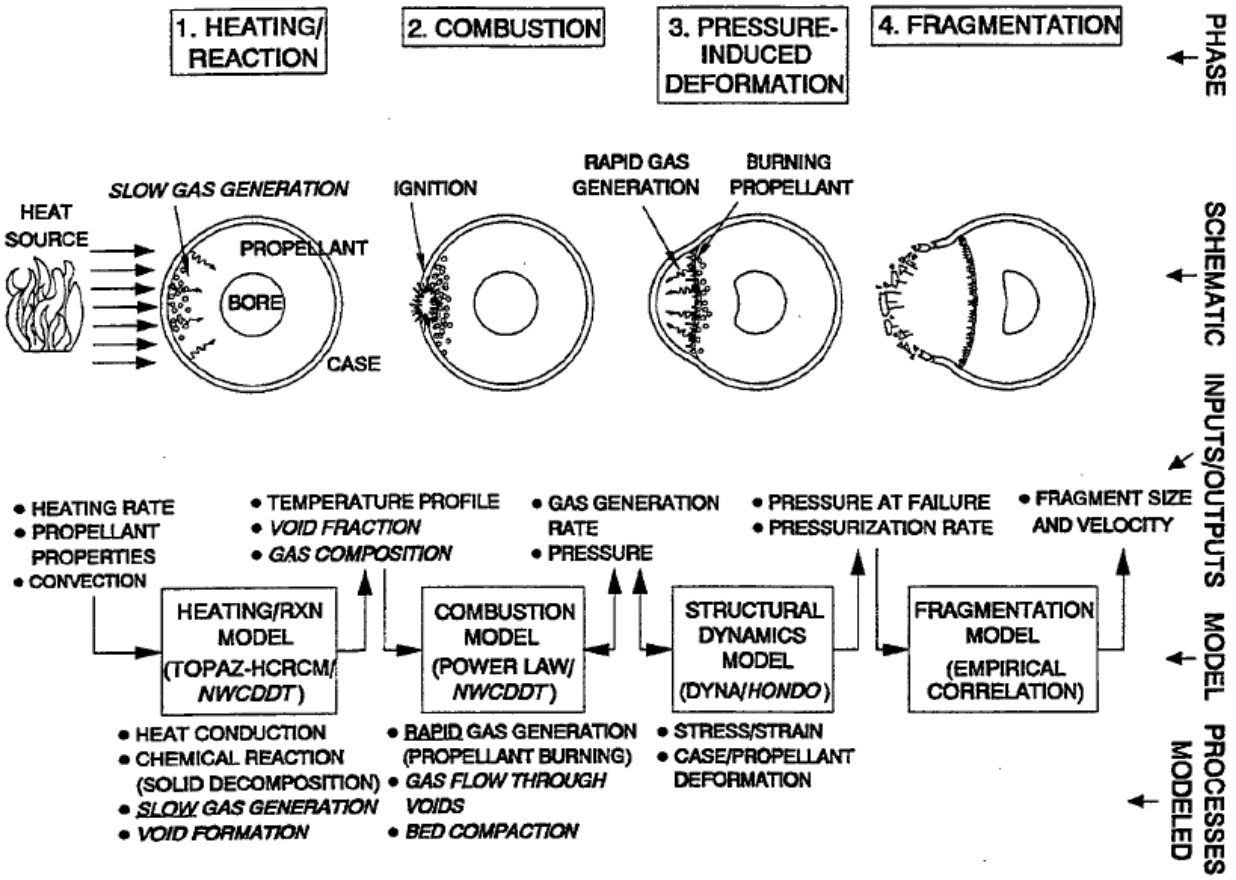
- Visit MSIAC stand to register interest
  - Open to MSIAC member nations
- Expression of interest
  - What can you provide
    - E.g. experience in thermal, heat transfer, mechanical damage, material properties, energetics, testing…….
- Further information and announcement will be made in the Summer 2015
  - Newsletter, website and mail

Workshop Output

- Objectives
  - To improve understanding of cook-off through
    - the role of heating rate (conditions) in determining reaction violence
  - To provide an update of protocols in AOP-39

Questions?

Back Up – Thermal Model



Cocchiaro, J. E. "Subscale fast cookoff testing and modeling for the hazard assessment of large rocket motors". CPTR 72, 2001