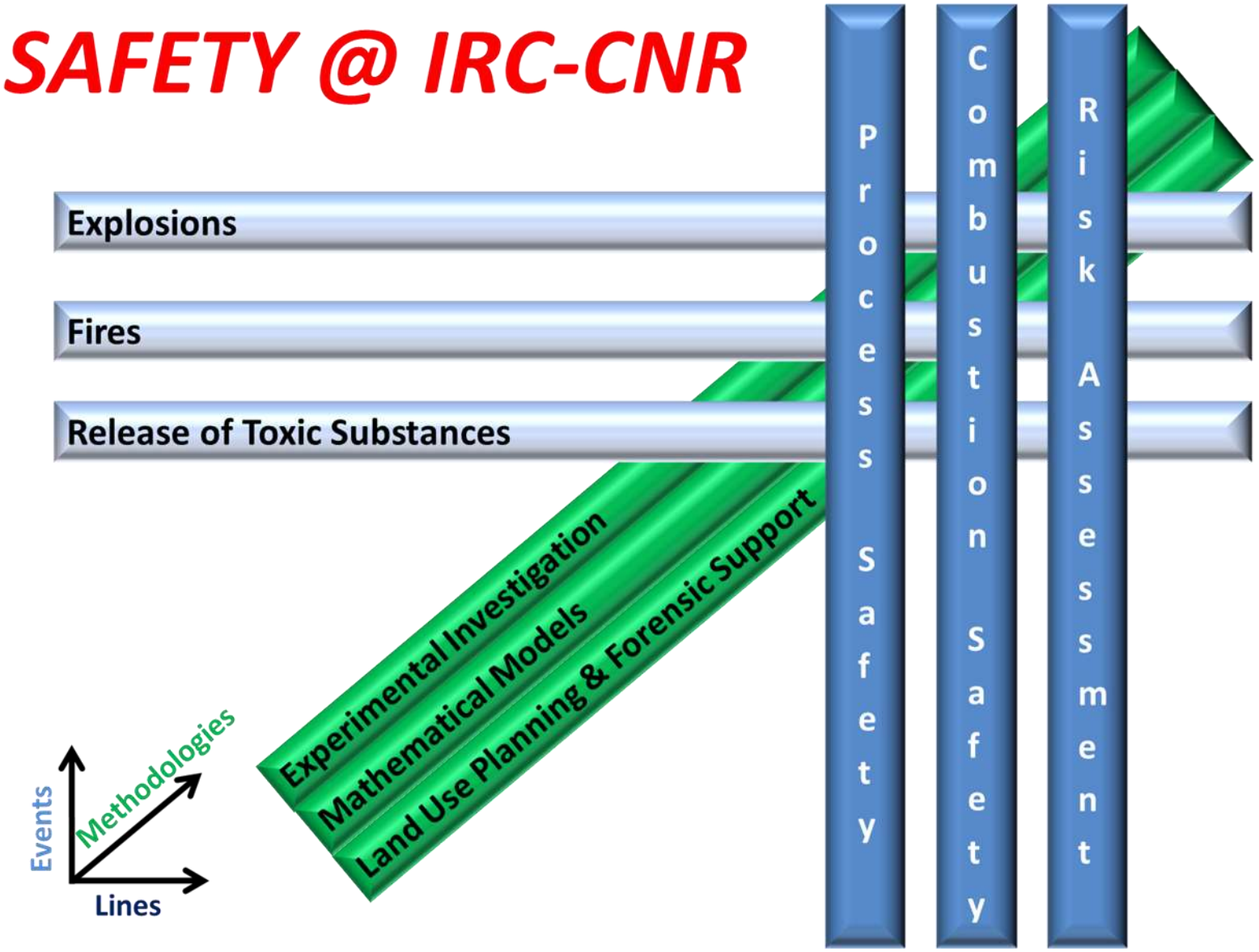
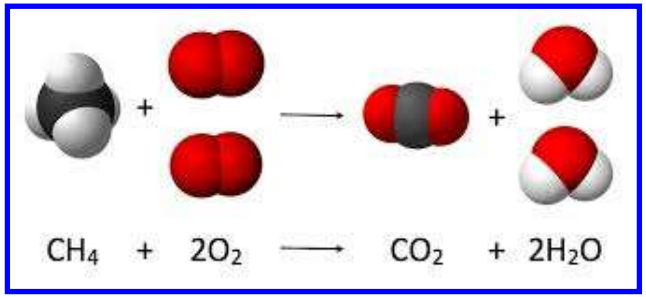
Process safety and accidental combustion phenomena

CONTEXT


SAFETY @ IRC-CNR
Explosions
Fires
Release of Toxic Substances
Experimental Investigation
Mathematical Models
Land Use Planning & Forensic Support
Process Safety
Combustion Safety
Risk Assessment
Events
Methodologies
Lines

CHALLENGE

from FUNDAMENTALS



to LARGE SCALE

through

- ✓ ***Process Safety***
- ✓ ***Combustion Safety***
- ✓ ***Risk Assessment***

SKILLS, METHODOLOGIES AND INSTRUMENTS

Ability to develop experimental prototypes/ protocols and **predictive mathematical models** for analysis, prevention and mitigation of the risk associated with explosions, fires and release of toxic substances

Siwek bomb

High-pressure stirred reactor

High-pressure tubular reactor

PC clusters for High Performance Computing

Phi-TEC

DSC-HPLC

Project lines

Process Safety: Loss of control of a chemical system (runaway phenomena); chemical instability; thermal explosion; industrial toxicology

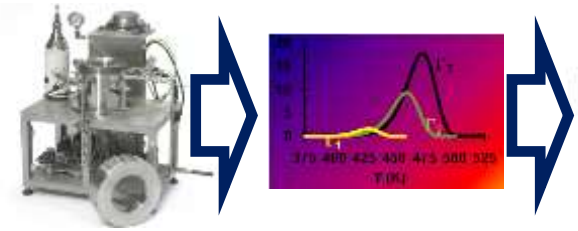
Combustion Safety: Explosions of gas, dust and hybrid (gas-dust) systems; propagation and extinguishment of fires; response of materials to fires

Risk Assessment: Development of methodologies for security, domino effect and Na-Tech; land use planning for industrial sites; methodologies for analysis of industrial hazards

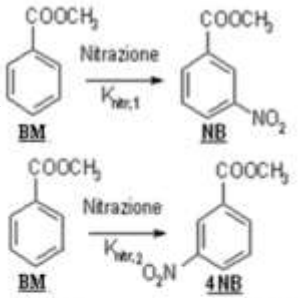
Line 1: Process Safety

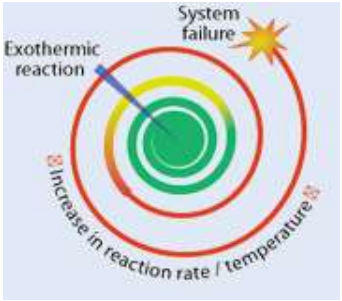
- ✓ **Thermo-kinetic characterization of runaway phenomena:** extrapolation of dynamic DSC data under conditions close to industrial operating conditions
- ✓ **Identification of reactive species and reaction network in runaway phenomena:** by means of calorimetric techniques and chromatographic analysis
- ✓ **Global and detailed kinetic models of runaway phenomena**
- ✓ **detection of instabilities of chemical processes:** Non-linear analysis and application of the bifurcation theory
- ✓ **Chemical, physical and toxicological characterization of organic and inorganic particulate produced by combustion systems**

Thermo-kinetic characterization: Runaway

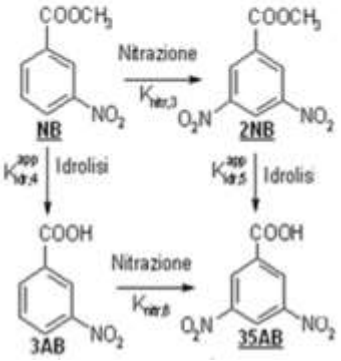


Monitoring **Identification**





Control



Risk reduction **Assessment**

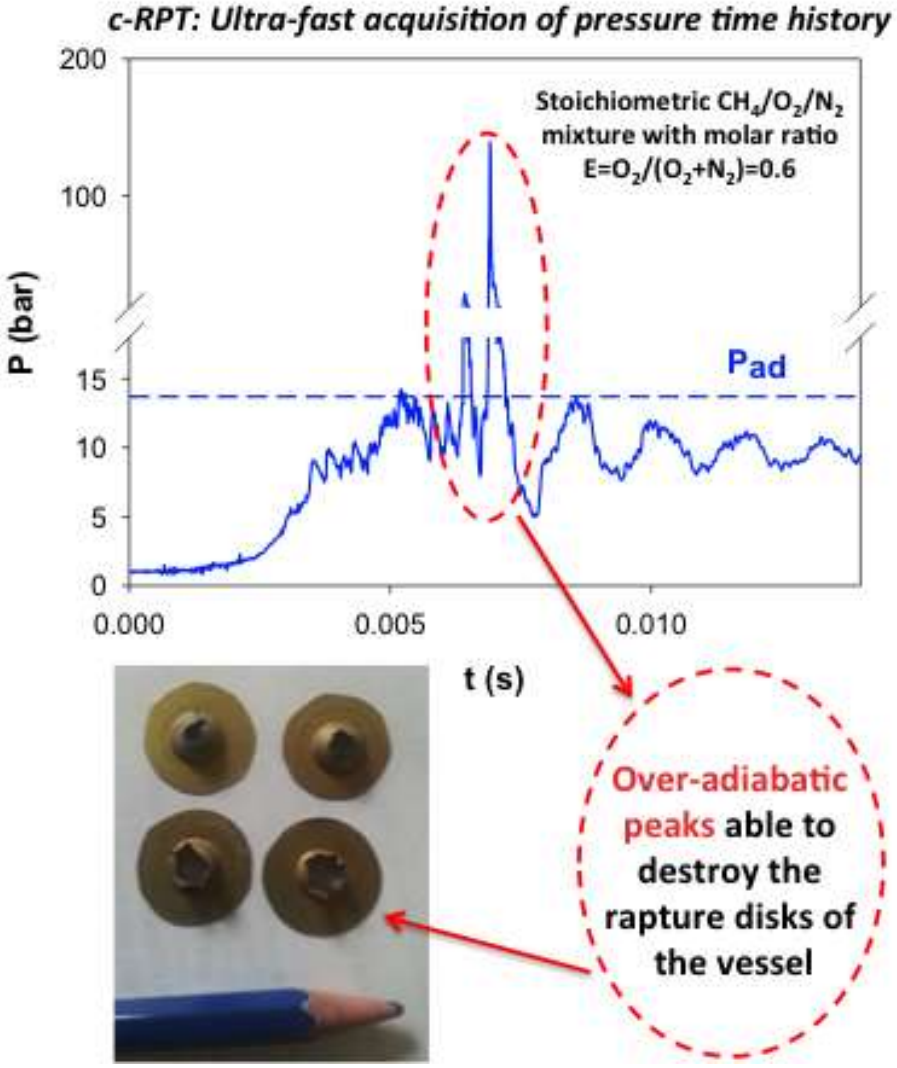
Toxicology

Nanoparticulate and products of thermal decomposition

Line 2: Combustion Safety

Experimental

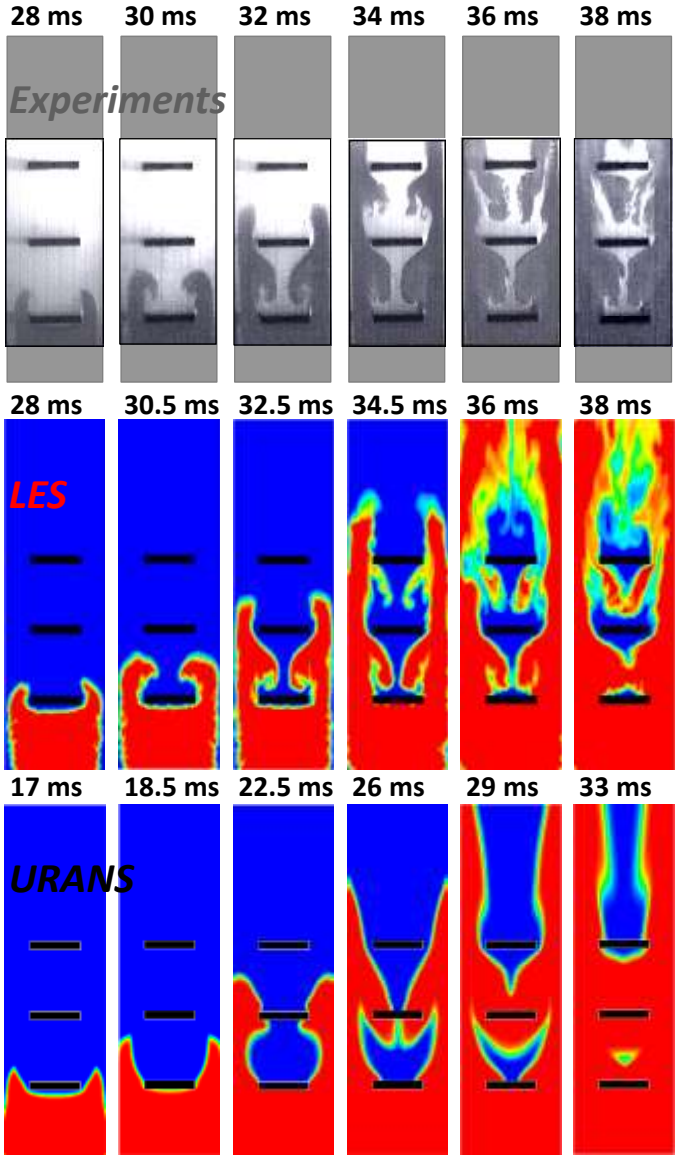
- ✓ **Fiammability and explosibility** of gas, dust and hybrid (gas-dust) systems, even under **extreme process conditions**
- ✓ **Flame propagation** during deflagration, fast deflagration, deflagration-to-detonation transition, direct detonation and **combustion-induced Rapid Phase Transition** (c-RPT)
- ✓ **Flame extinction** by means of **ultra fine water mist**
- ✓ **Response of composite materials to fires**



Line 2: Combustion Safety

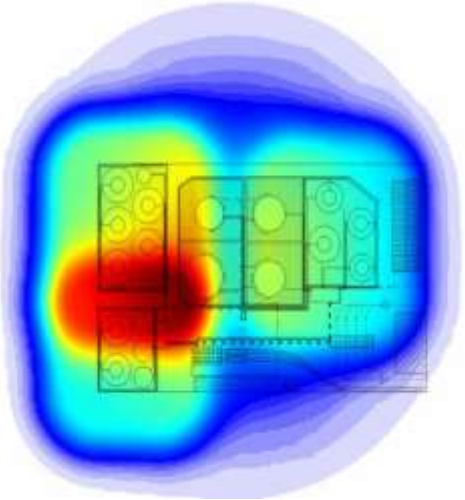
Modelling

- ✓ **Detailed kinetic models** to quantify **flammability and explosibility parameters** for gas, dust and hybrid (gas-dust) systems
- ✓ **CFD models** (URANS and LES) for simulation of **unsteady reactive phenomena** (explosion of gas, dispersion and ignition/explosion of dusts in turbulent fluid flow, flame extinction, etc.)
- ✓ **Models based on cellular automata** for real time prediction of propagation of **forest fires**
- ✓ **Kinetic models** for **decomposition/combustion of composite materials** and their char
- ✓ **Transport models** for **ignition and combustion of polymeric materials** in the cone calorimeter



Line 3: Risk Assessment

- ✓ Risk assessment for the process industry, with specific reference to **natural disaster interaction** (NaTech)
- ✓ **Cascading effects**
- ✓ Security vulnerability assessment: **Development of procedures for the assessment of large-scale accidental scenarios due to deliberate attacks and sabotages**
- ✓ Land use planning for industrial sites (**Seveso Directive**)
- ✓ **Consequence-based vulnerability functions** for industrial equipment related to the loss of containment or energy



COLLABORATIONS/PROJECTS

National Projects

PON – BioPolis, 2014-2016
ENI SpA – Security Vulnerability Assessment, 2014-2015
Dipartimento Protezione Civile – Na-Tech Rischio Vesuvio, 2009-2011
Prin 2008 – Na-Tech Rischio Etna, 2010-2012
MiSE/CNR, 2007-2014
Progetto Esecutivo Convenzione DPC/ReLUIS, 2014-2018
DSM SpA – Analisi di polveri esplosive, 2009-2014

European Projects

7FP STREST (AMRA), 2014-2017
7FP Large Scale Project INTEG-RISK, 2009-2013
Fike Europe Bvba, Belgium, 2013
Airlight Energy Manufacturing SA, Swizerland, 2014

PERSPECTIVES

Definition of an international R&D station for:

- ✓ Experiments and modelling of chemical processes, with specific reference to process safety (runaway phenomena, thermal explosion)
- ✓ Production - through experiments and CFD models/simulations - of new experimental standards/prototypes and new software tools for the design of prevention and mitigation measures for accidental combustion phenomena (explosions and fires), in order to fulfill the future needs of chemical and manufacturing industry, as well as of fuel storage and distribution systems
- ✓ Development of software tools for the analysis of cascading effects (domino, security vulnerability assessment, natural and technological disasters) within the analysis of disaster resilience, for the aims of civil protection actions and following H2020 requests
- ✓ Support to forensic actions