Experience in developing fire safety science and public safety technology in China: Past, present, and future

Weicheng FAN

Institute of Public Safety Research, Tsinghua University

State Key Laboratory of Fire Science, University of Science and Technology of China

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Outline

- Developing fire safety science in China
- Challenging problems of fire safety
- Developing public safety technology in China
- Challenging problems of public safety
- Conclusions

My research

1 1970 - 1990

Combustion： Engine combustion, Numerical simulation of combustion

2 1984 - 2003

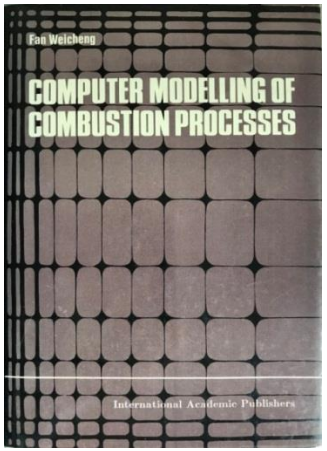
Fire Safety： Fire dynamics, Fire detection, Fire risk assessment

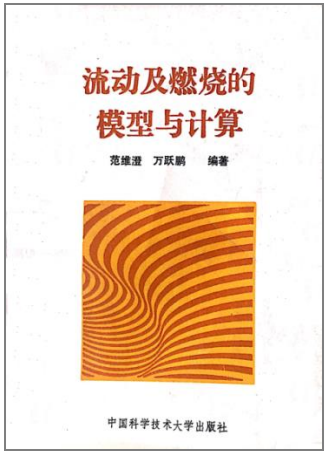
3 2003 - now

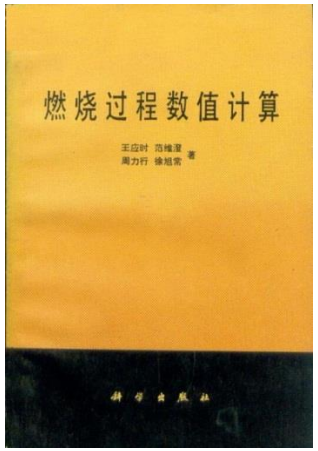
Public Safety： Emergency management, Strategic study of public safety S&T in China

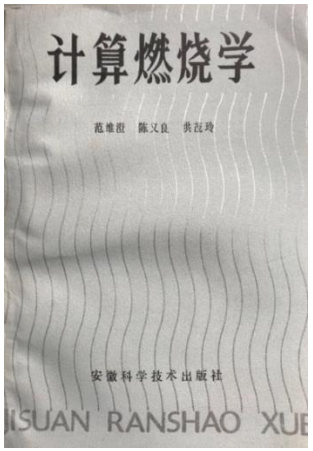
Combustion research (1970 - 1990)

- Interaction of flow, heat and mass transfer and chemical reactions in the combustion chamber
- Combustion process and combustion efficiency of biogas burners
- Computer simulation of parabolic and elliptical combustion processes
- Computer simulation of turbulent combustion process
- A two-fluid model of turbulent combustion









Example: Two-fluid model of turbulence

- **Two-fluid model of turbulence: Two types of fluid (with different velocity, temperature and species) co-exist and interact with each other**
  - ✓ Considering that turbulence can be transformed into non-turbulence by decay and dissipation
  - ✓ Considering the heat exchange between the two fluids and the chemical reaction inside the unburnt gases

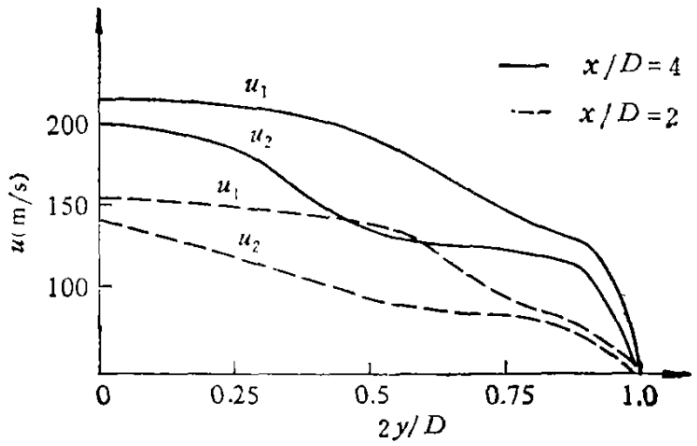


图 3 两种流体速度的径向分布

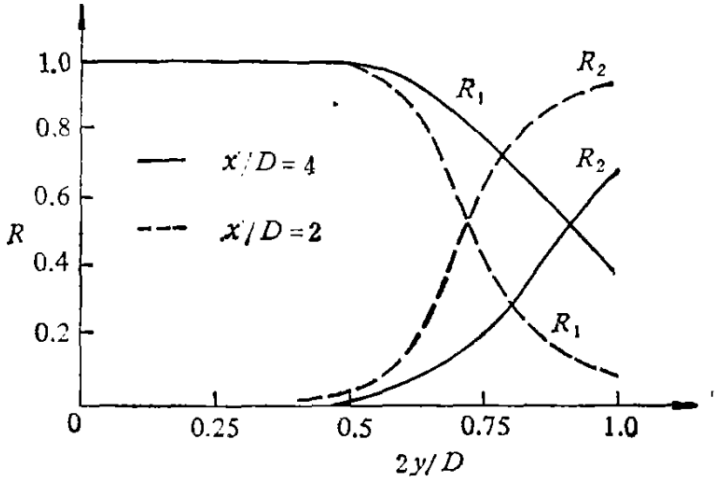


图 4 两种流体体积分数的径向分布

Learning from combustion scientists

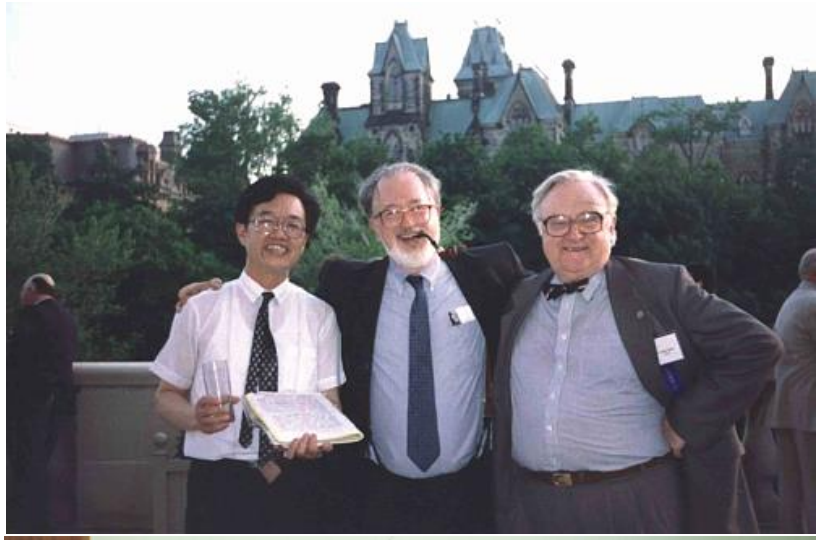
Visiting Prof. Dudley B. Spalding (1979.11 - 82.4)

Visiting Prof. Brian Launder (1986)

Prof. Brian Launder and Prof. Brian Spalding:
We can develop a lot of **boundary work** --
Interdisciplinary sciences involve a great space of innovation

Learning from fire scientists

with Prof. H. W. Emmons



with Dr Kunio Kawagoe

with Prof. P. H. Thomas

Motivation for establishing SKLFS

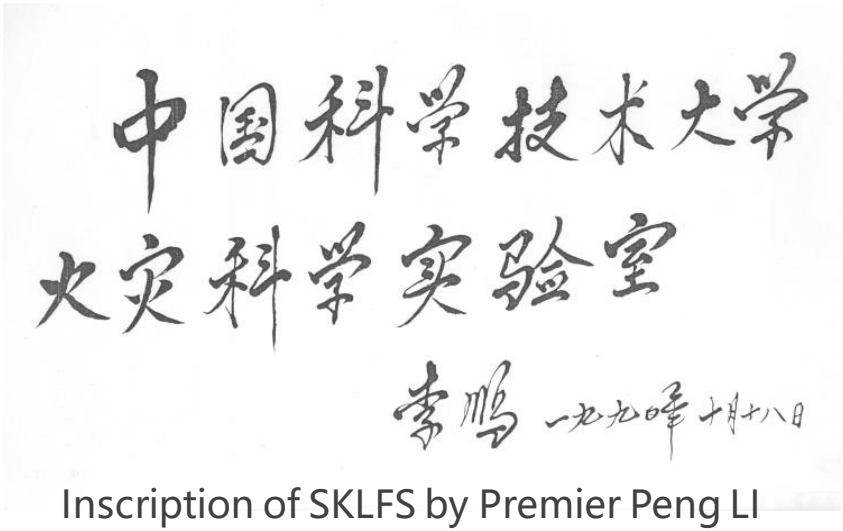
1987 Daxinganling Wildland Fire——

- Fire Area: 13700km^2
- Deaths: 197

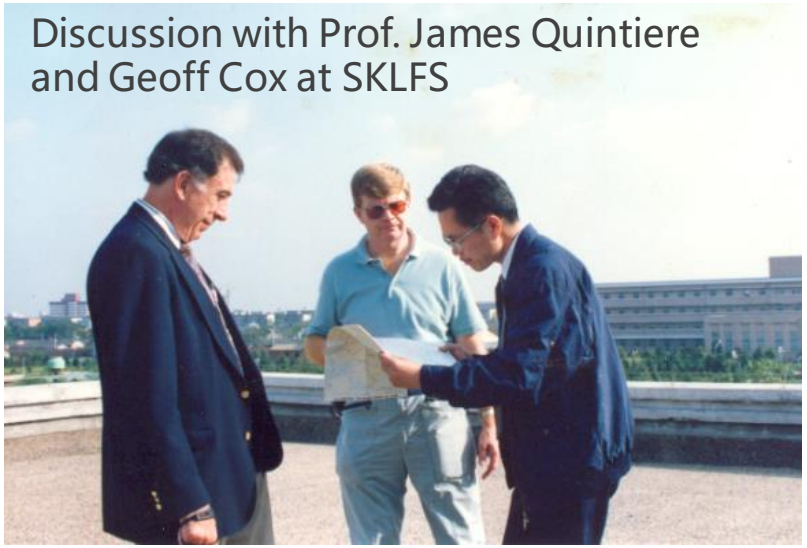
Xi Lin Ji

Mo He

Establishing SKLFS (1990)



Inscription of SKLFS by Premier Peng LI



Discussion with Prof. James Quintiere and Geoff Cox at SKLFS

Foundation-laying ceremony of SKLFS (1990)

Example: FZN modeling of building fire

- **Field-Zone-Network (FZN) modeling methodology**
  - ✓ **FZ modeling:** use field modeling for the spaces of fire origin with strong ventilation and complicated geometry, and use zone modeling in other spaces of the building.
  - ✓ **FZN modeling:** use network modeling in the spaces far away from fire origin.
  - ✓ **Focus:** dealing with the interfaces between the contiguous spaces with different models.
  - ✓ **Major merit:** simulating fire smoke movement in long and narrow space and multiple rooms

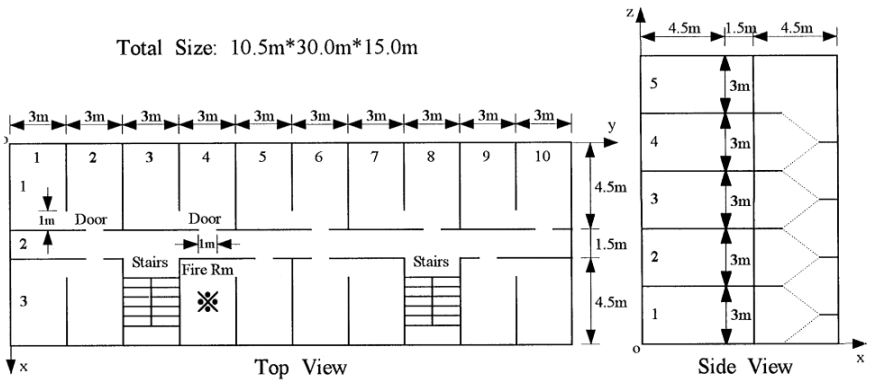


Fig. 4. Structure of the full-scale high-rise building.

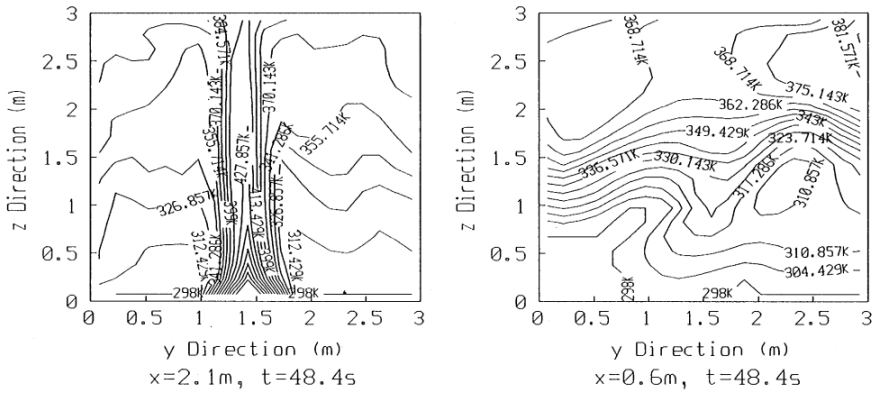


Fig. 5. Temperature distribution on different sections in the fire-modeling room.

Example: Duality model of building fire

- **Combination of deterministic and probabilistic models**
  - ✓ **Considering:** the uncertainties of fire occurrence due to the variety of human behaviour , fuel, environment condition and fire source
  - ✓ **The deterministic part:** determines the heat release rate of the combustibles, fire dynamics and hazard by experiment and computer modeling.
  - ✓ **The probabilistic part:** determines the ignition probability by statistical analysis.
  - ✓ **Serving** the fire risk assessment

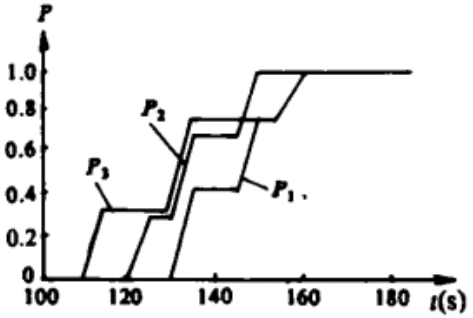


图 3 对应不同家具布置火灾的伤害几率曲线

Fig. 3 Hazardous probability under three arrangements

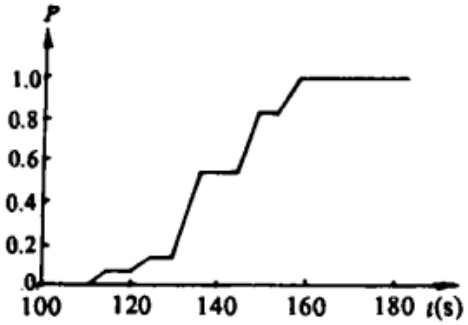
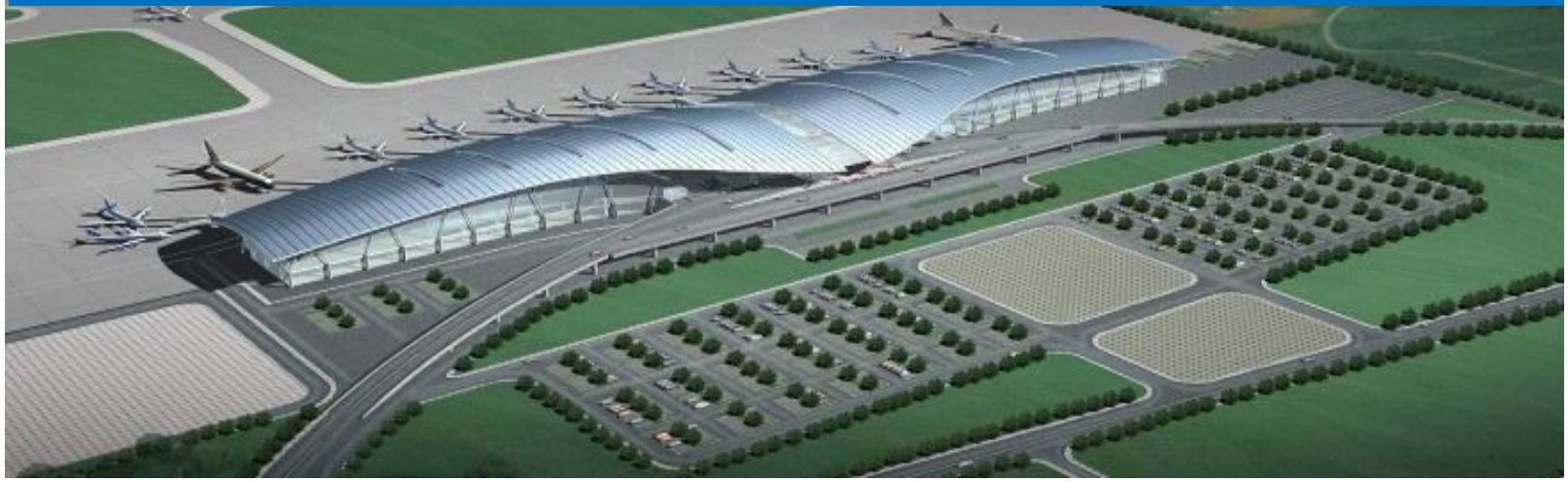


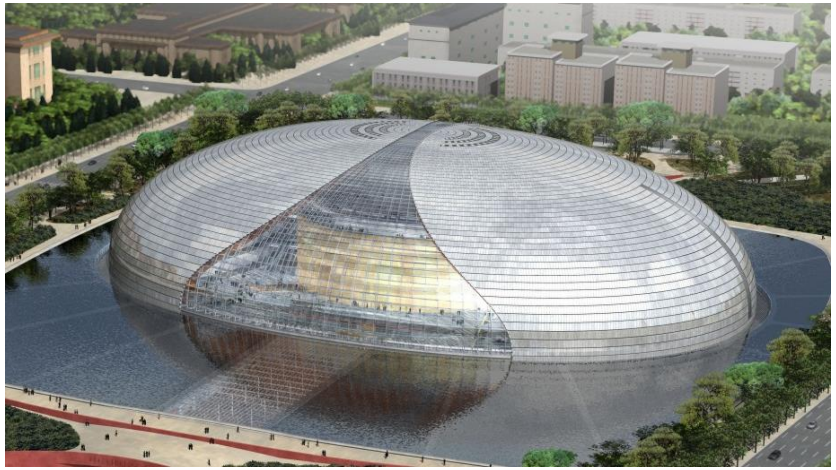
图 4 随机火灾总伤害曲线

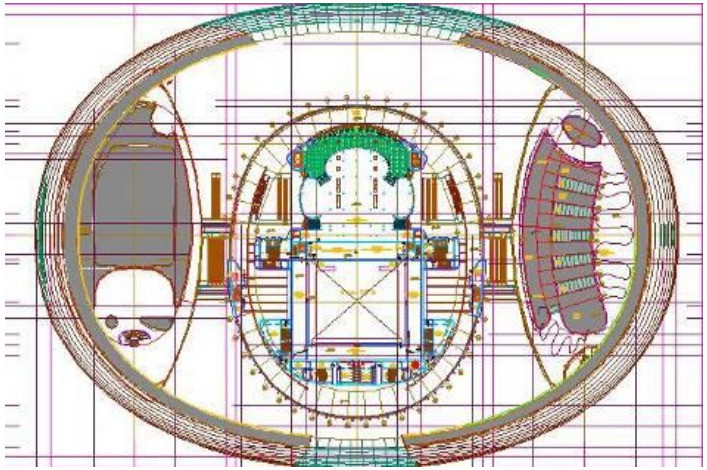
Fig. 4 Total hazardous probability of probabilistic fire

Example: Developing fire risk assessment method

Fire risk assessment of new terminal of Jinan international airport







Fire risk assessment for steel structure of Beijing opera

Key figures & facts of SKLFS

- State Key Laboratory of Fire Science
- Engineering & Technology Research Center for Thermal Safety, CAS
- Department of Safety Science and Engineering

  —— Bachelor, Master, PhD., Training and Consultation.
- National Science Education Base
- Faculty members: **56**
  - Professors: **22**; Asso. Professors: **18**
- Master students: **160**; Ph. D students: **120**; Postdoctoral: **11**




Key figures & facts of SKLFS

- **Papers publication**
  - ☑ International journal papers (2000-2016): >2000
  - ☑ Papers accepted by IAFSS symposium (2015-2016): >50

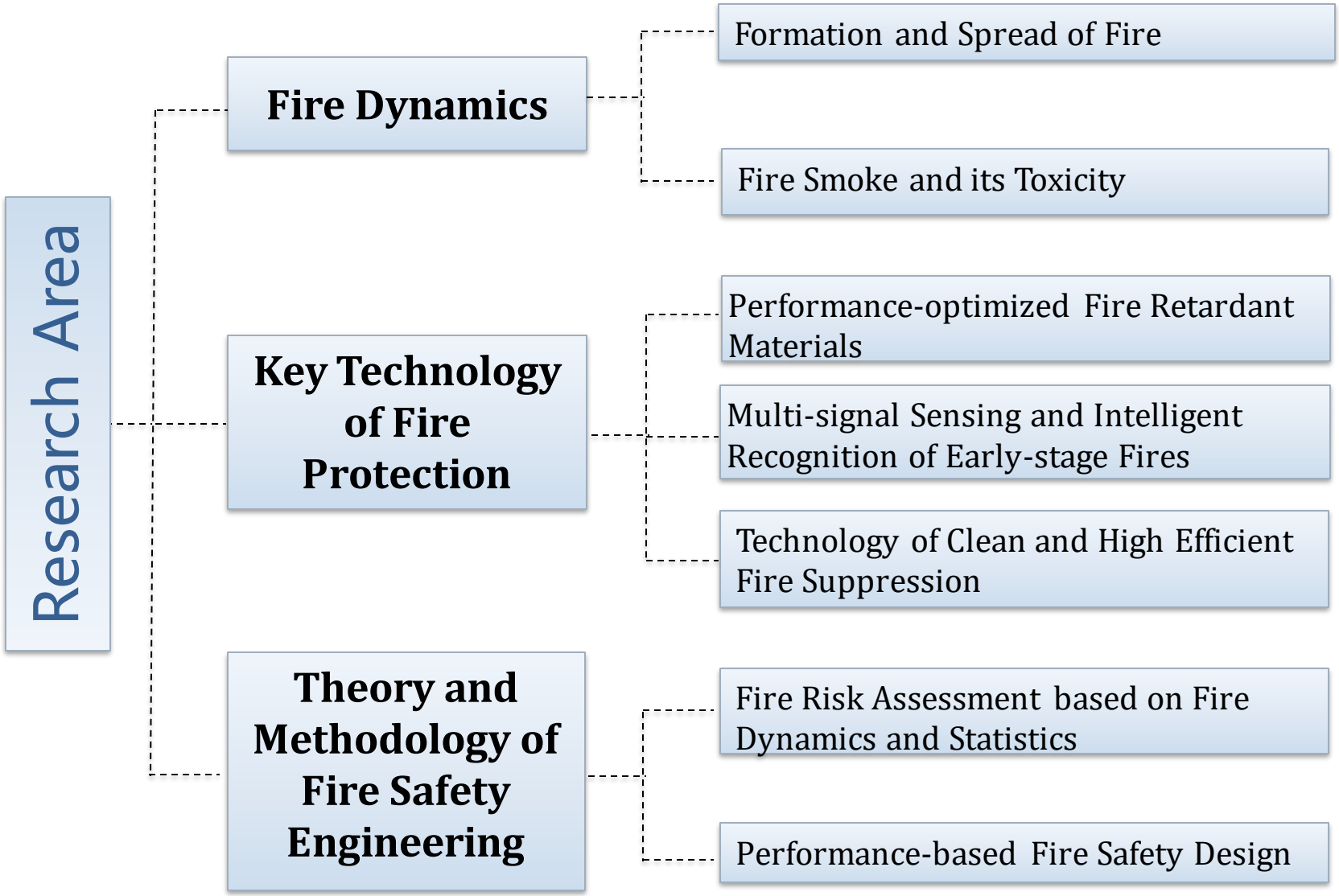
  —— **highest among world fire research institutions**

  —— **>90 papers published in Combustion and Flame and Proceedings of the Combustion Institute**

  —— **highest among world fire research institutions**

- **Invention patent**
  - ☑ >150 invention patents authorized
  - ☑ Many technologies have been widely used in hundreds of large buildings in China

Outline of SKLFS researches

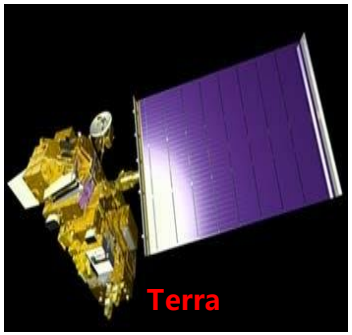


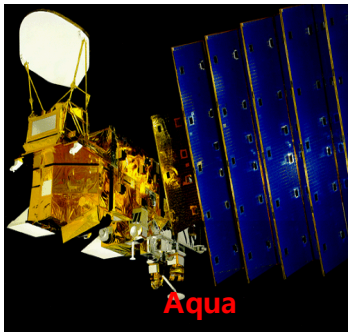
Fire Formation and Its Propagation

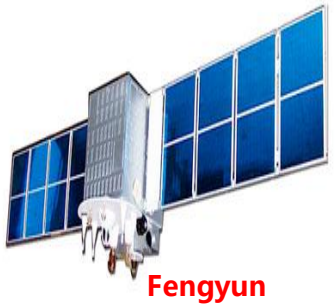
- **Fire Formation Mechanism**
  - ☑ Pyrolysis and Ignition Models of Combustibles Under Different Conditions
  - ☑ Mechanism of Smoldering and its Transition to Flame

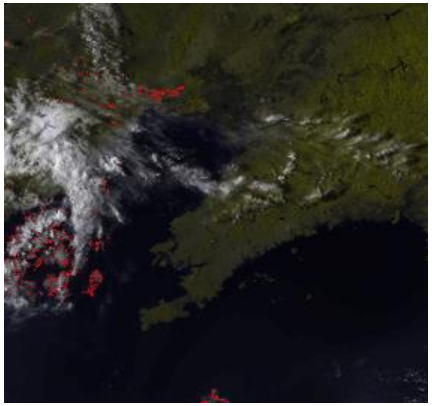
Fire Formation and Its Propagation

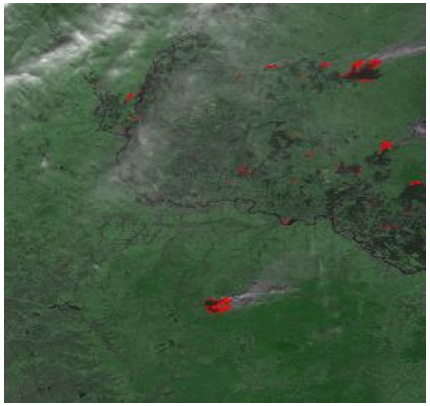
- **Recognition and Forecasting of Forest Fire**
  - ☑ Satellite Remote-sensing Recognition of Forest Fire
  - ☑ Self-organization Behavior of Forest Fire
  - ☑ Forecasting Large Forest Fires

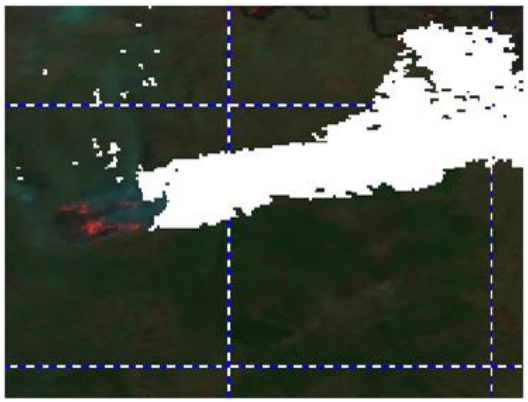












Fire Formation and Its Propagation

Fire Propagation and Dynamics

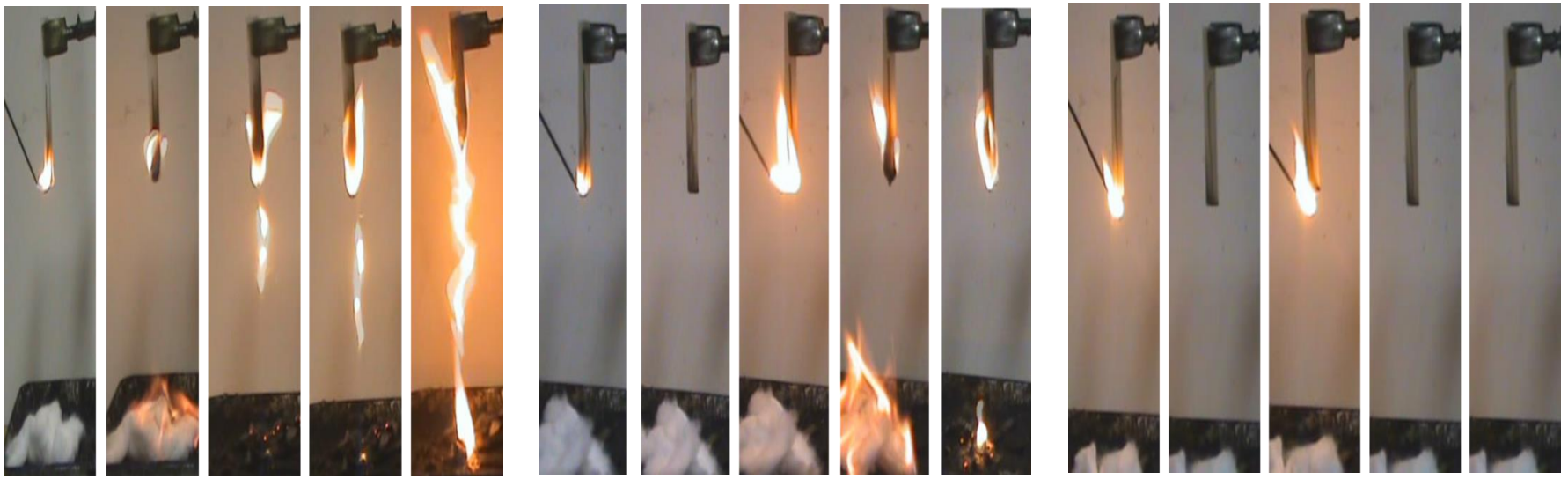
- ☑ Interaction of Pyrolysis, Phase Change, Fluid Flow, Heat Transfer and Combustion
- ☑ Nonlinear Dynamical Models of Fire Phenomena

Fire Smoke and Its Toxicity

- Movement of Fire Smoke
- Interaction of Smoke and Fire
- Formation of Toxicity in Smoke
- Effect of Smoke Toxicity to Human Body

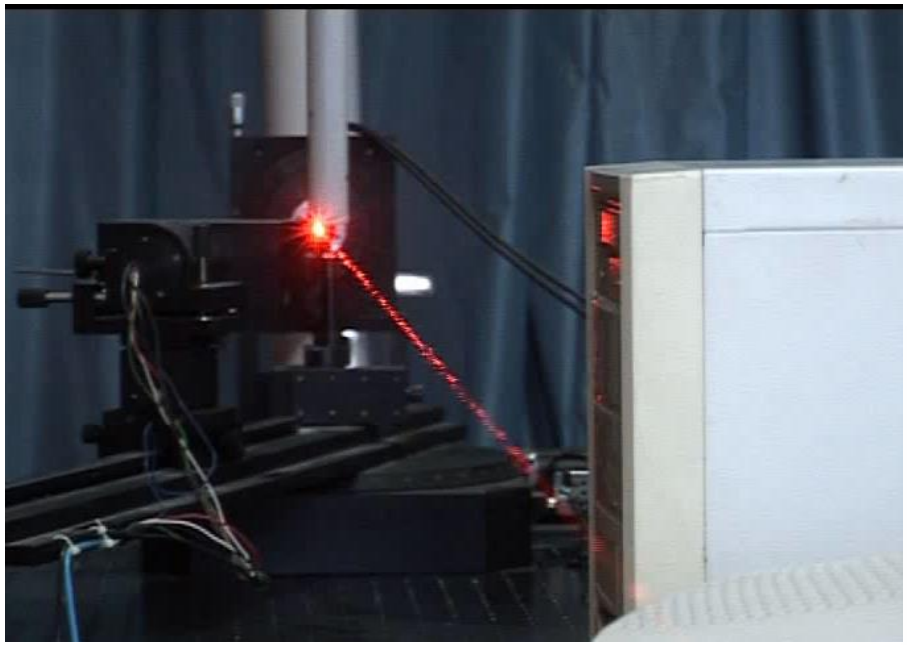
Fire Retardant Materials

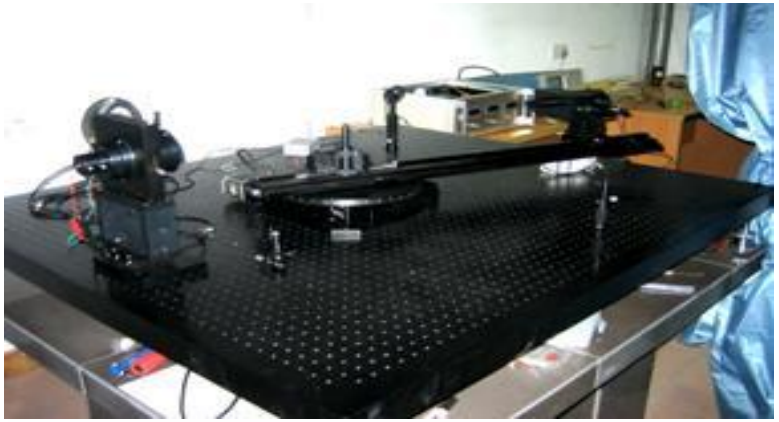
- Nanometre Fire Retardant Materials
- Fire Retardancy Mechanism of Halogen Free Materials

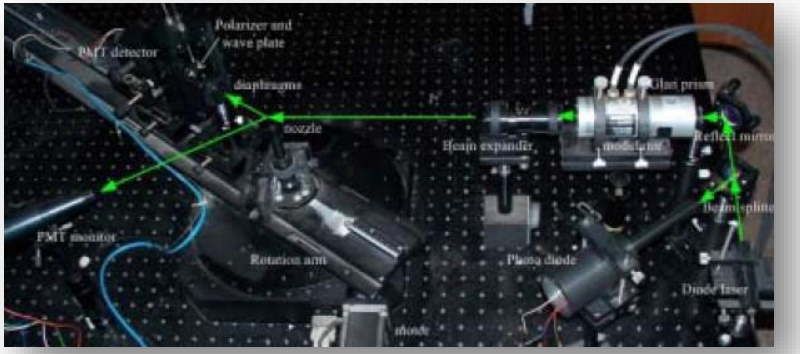


Intelligent Recognition of Fire Signals

- Characteristics of Light, Smoke (heat, gas and solid particles) and Sound in Fire
- Multi-criteria Fire Signal Recognition Models







Fire Suppression with High Efficiency

- Water Mist and its Characterization
- Gaseous Fire Suppression
- Interaction among Fire Suppression, Fire and Smoke

Recent research Focuses

- Fire Safety in Wildland-Urban Interface (WUI) Regions

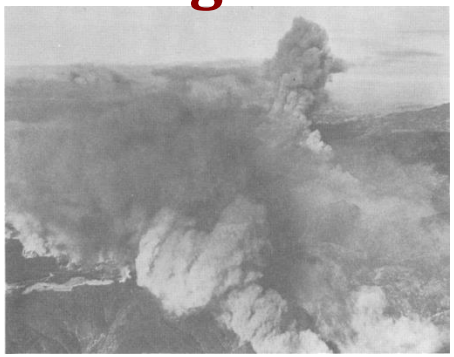
Extreme Fire Behaviors in Wildland Fires

Crown fire

- http://en.wikipedia.org/wiki/Yellowstone_fires_of_1988

☑ Transition to burn forest fuels at the canopy level

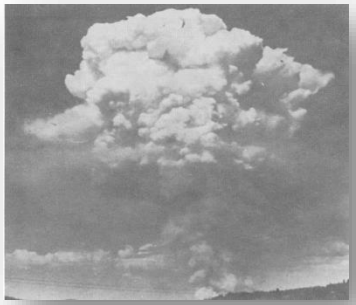
Conflagration

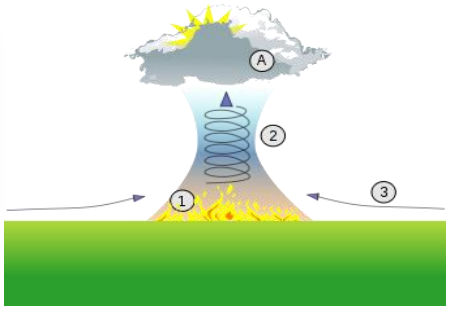


- [Left] Countryman, C.M. "Mass Fires and Fire Behavior,", 1964, 53 pp.
- [Right] http://www.rivco4.org/web/news/archive/200804/

☑ Moving fronts with large fire sizes and narrow depth

Fire storm





Firestorm-made thermal column. Fire (1) makes hot air (2) to rise forming storm-winds (3) towards the fires.

- [Left] Countryman, C.M. "Mass Fires and Fire Behavior," 1964, 53 pp.
- [Right] http://en.wikipedia.org/wiki/Fire_storm

☑ Great convective activity; little outward spread of fire

Spot fire

- Koo, E., et al., International Journal of Wildland Fire, 2010. 19(7): p. 818-843.

☑ Producing numerous ignitions beyond major fire area

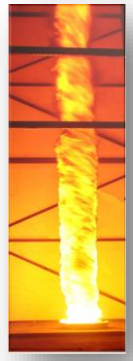
Extreme Fire Behaviors in Wildland Fires

Fire merging

- **[Left]** Viegas, D.X. Forest fires, 6th ISFEH (Slides)
- **[Right]** Fire merging experiments by group of N. Liu

☑ **Significant interactions among multiple fires**

Fire whirl



- **[Left two pictures]** Fire whirls reported in news
- **[Right two pictures]** Fire whirl experiments by group of N. Liu

☑ **Concentrated vortex structure with combustion**

Eruptive fire

- Dold, J., et al., Some Forest Fire Related Accidents in Europe, DX Viegas (Ed), JRC, Ispra, 2009.

☑ **Typical in canyons or steep slopes; quick acceleration**

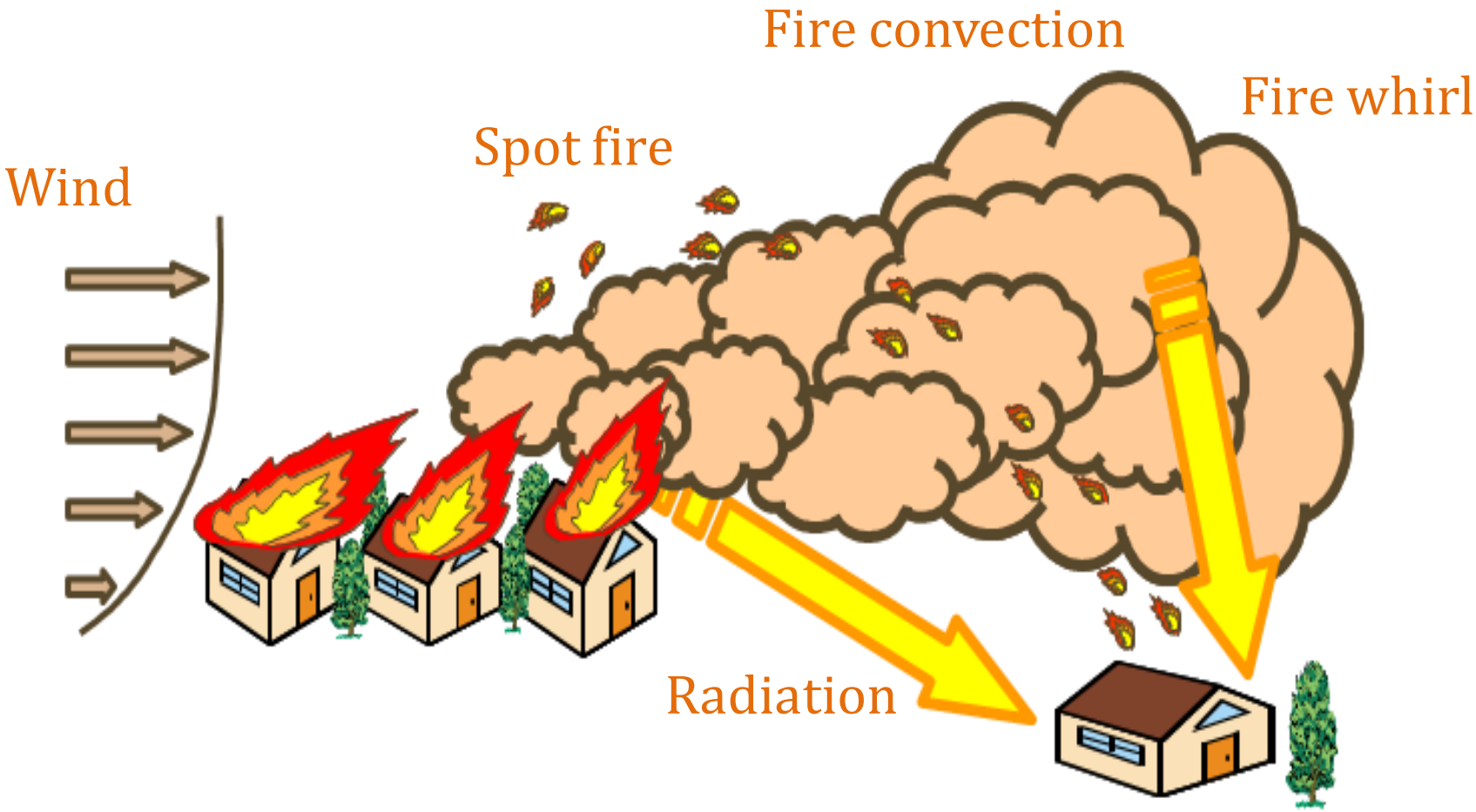
Jump fire

- Viegas, D.X., et al. International Journal of Wildland Fire 21(7): 843-856 (2012).

☑ **Merging of fire fronts with a small intersection angle**

Recent research Focuses

- Mass Urban Fire Safety

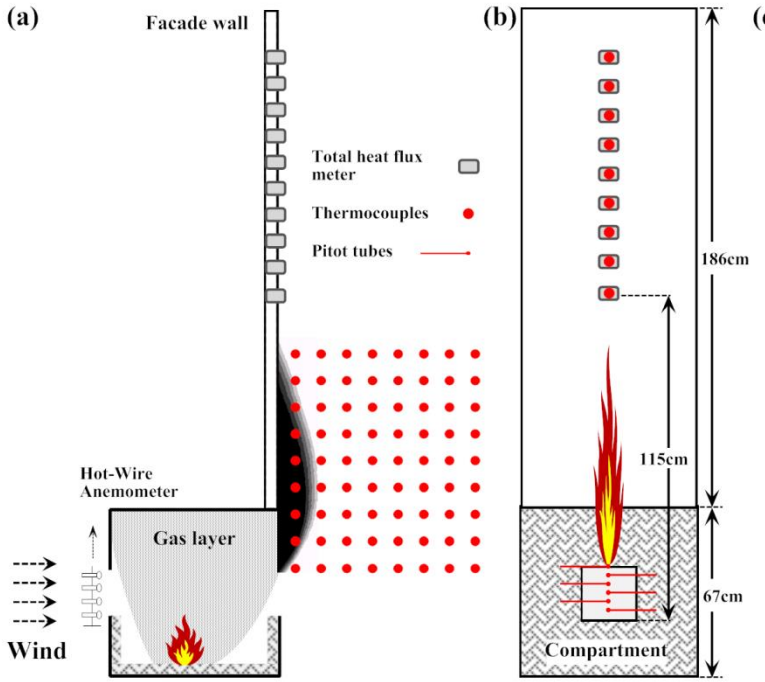


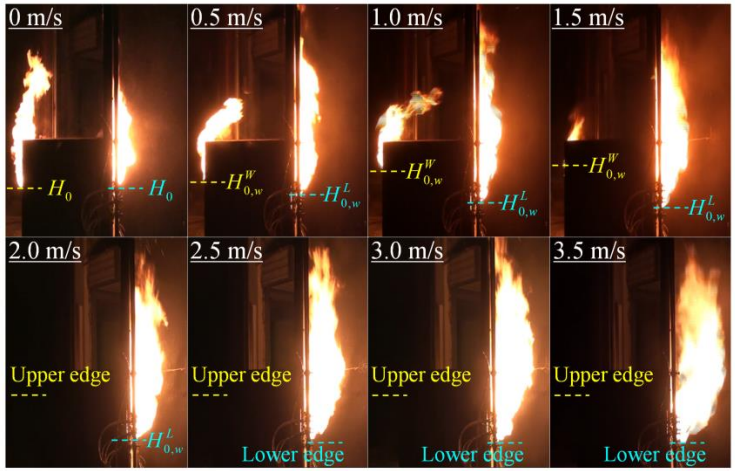
Recent research focuses

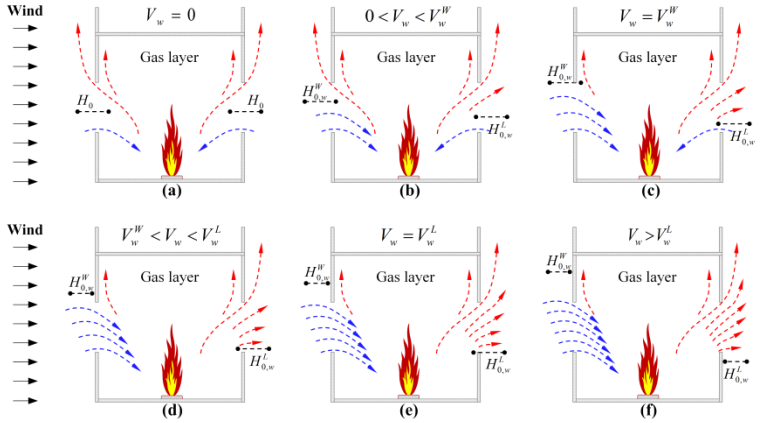
- Fire Safety in High-rise Buildings



Wind effect on compartment fire

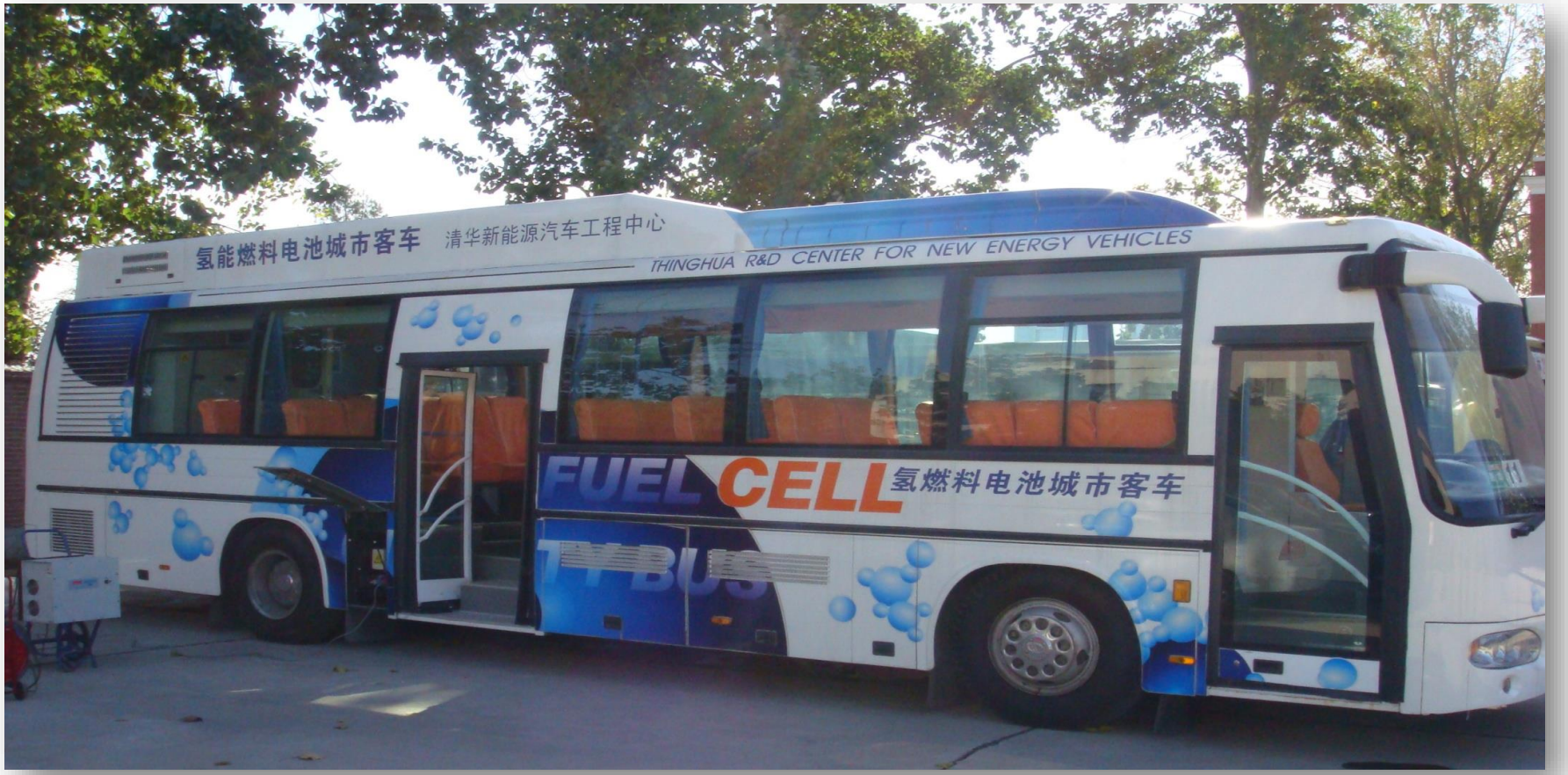






Recent research focuses

- Fire Hazards in Energy Systems



Recent research focuses

- Fire Safety of Historic Buildings

Ancient town fire in Yunnan, Jan 2014

Recent research focuses

- Fire Safety of Historic Buildings

Institute of Public Safety Research (IPSR)

- Found in **Tsinghua university**, 2003.
- Leading research center on **public safety** in China

Institute of Public Safety Research (IPSR)

Multidisciplinary Institute with **14** Key research bodies

- ★Institute of Safety Science and Technology (**Engineering Physics**)
- ★ State Administration of Work Safety Key Lab on Fire Safety (**Eng. Physics**)
- Laboratory of Particle and Radiation Imaging (**Engineering Physics**)
- Center for Nuclear Safety (**Nuclear Technology**)
- Institute of Disaster Prevention and Mitigation (**Civil Engineering**)
- Department of Construction Safety Management (**Civil Engineering**)
- Institute of Hydraulic and Hydropower Engineering (**Civil Engineering**)
- Center for Crisis Management Research (**Public Policy & Management**)
- Center for Chemical Processing Safety (**Chemical Engineering**)
- Laboratory of Control and Simulation of Power Systems (**Automotive Eng.**)
- Center for Safety Eng. and Technology Research (**Aeronautic & Aerospace**)
- Institute of Thermal Engineering (**Thermal Engineering**)
- Institute of building Environment and Facility Eng. (**Architecture Science**)
- Institute of Software Theory and System (**Software**)

Key research directions of IPSR

Social mission

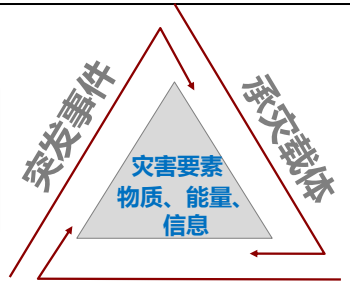
- National Safety
- Public safety
- Urban safety

Safety priority directions

- Risk assessment and personnel safety
- Monitoring early warning and resilience
- Integrated emergency technology

Public safety system and key technologies

- Risk assessment and prevention
- Monitoring and forecasting
- Emergency disposal and rescue



Academic Influence

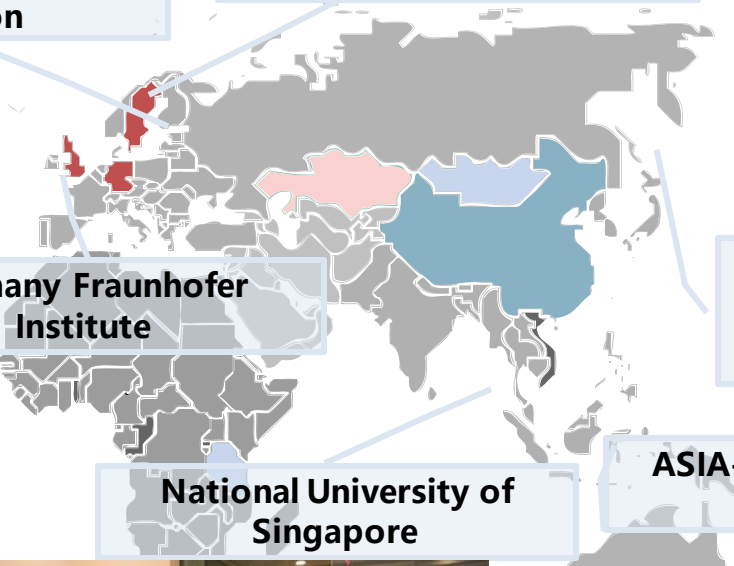
- Chairman member of Asia-Pacific Association of Public Safety Science and Technology
- Chairman member of Chinese Association of Public Safety
- Training base of national and municipal emergency management cadres
- Beijing Key Laboratory of Comprehensive Emergency Response Science
- Key Laboratory of Work Safety State Administration of Work Safety

International R&D Collaboration

Worcester Polytechnic Institute
Harvard University
Stanford University
Boeing Company
United Technologies Corporation

Chalmers University of Technology Sweden

University College London



Germany Fraunhofer Institute

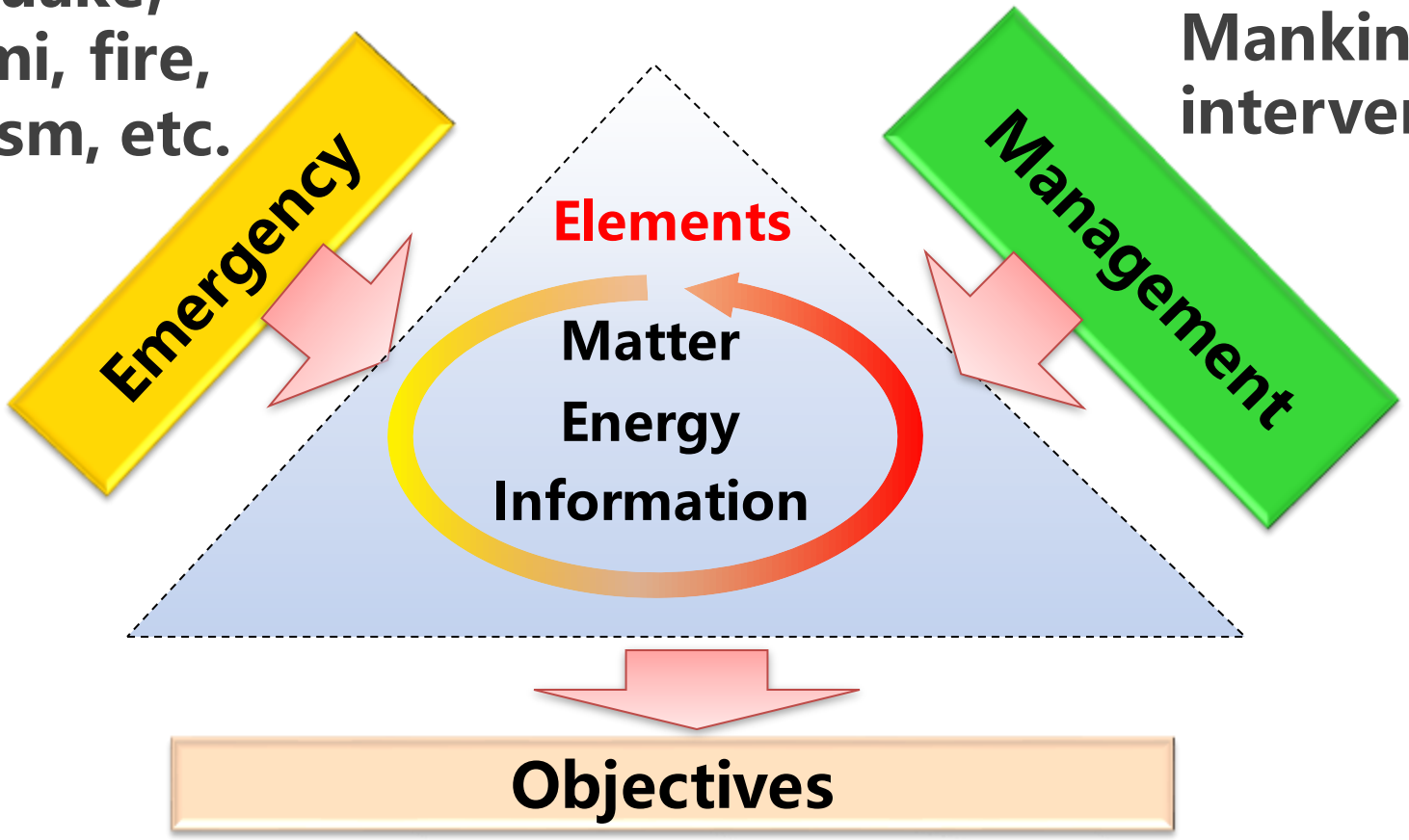
The University of Tokyo
Kyoto University
Mitsubishi Heavy Industries

National University of Singapore

ASIA-Pacific Safety Institute of Science and Technology

"Triangle Model" of Public Safety

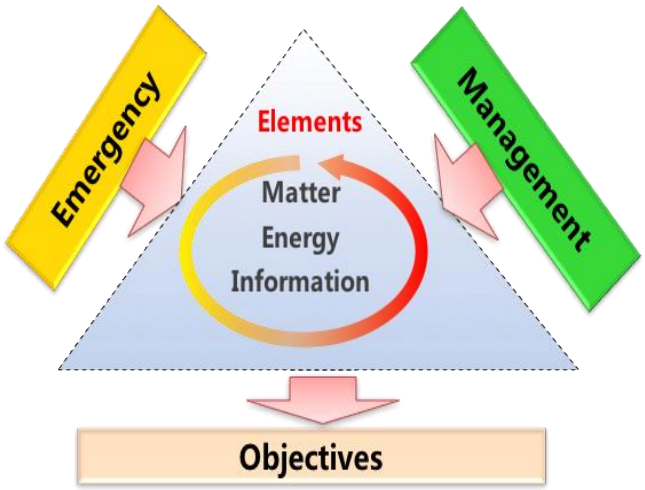
Earthquake, Tsunami, fire, terrorism, etc.

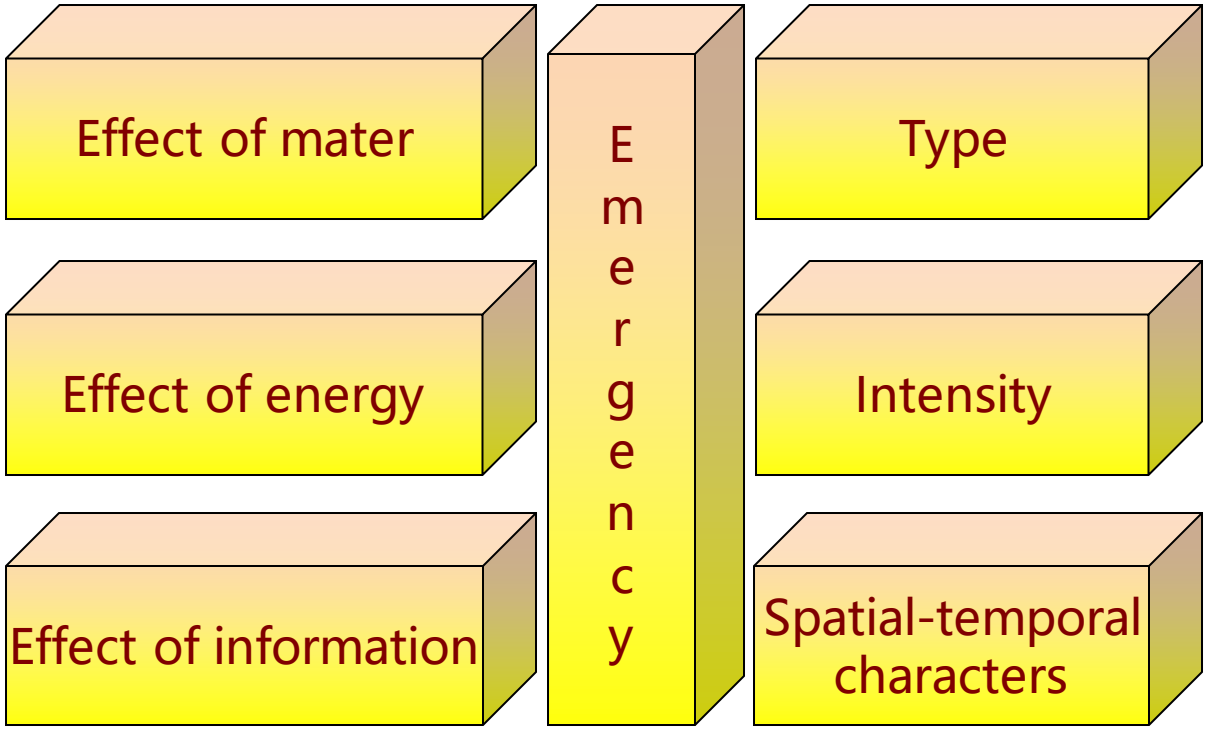


Mankind's intervention

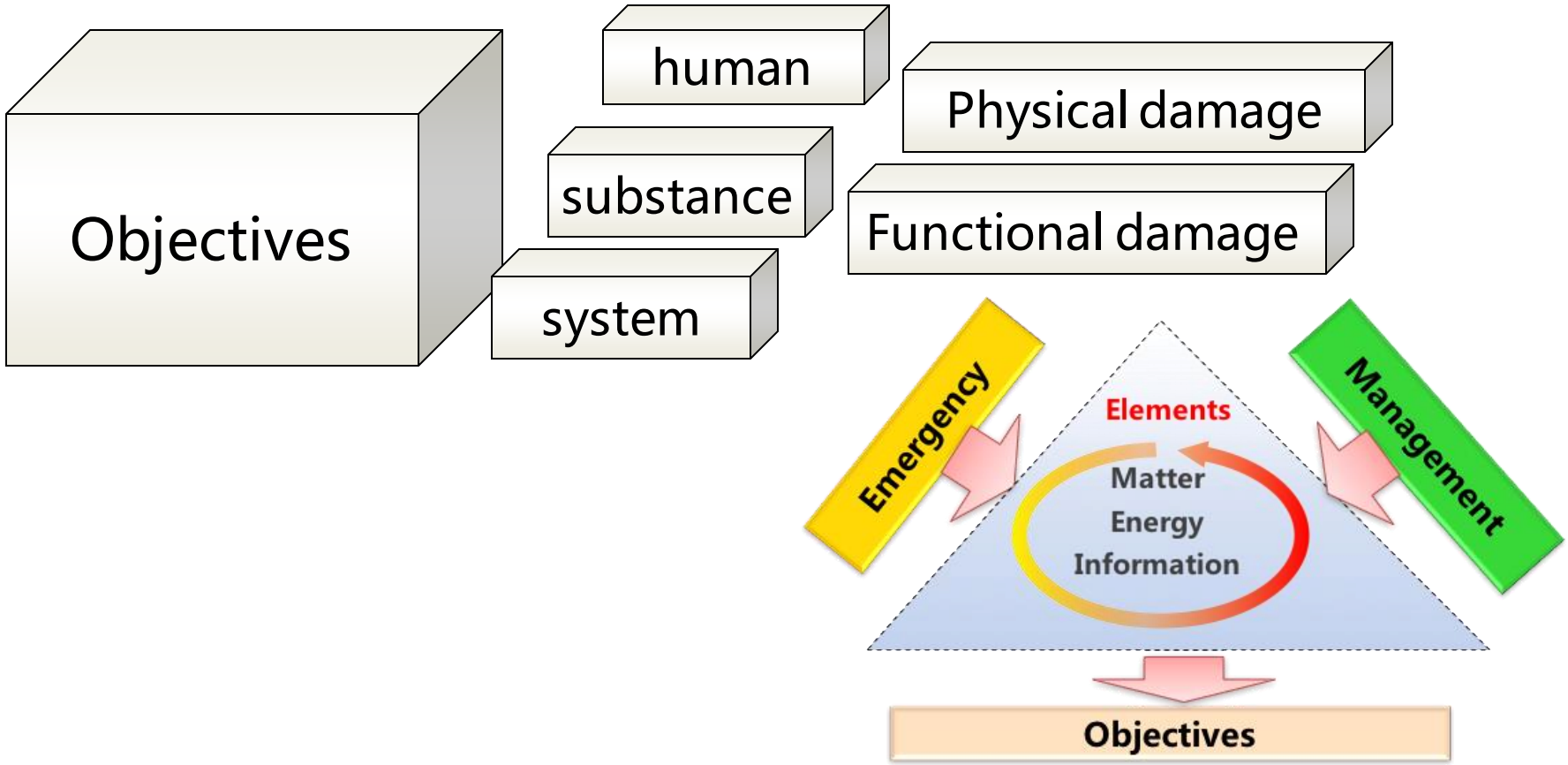
objects which receive the hazardous actions

“Triangle Model” of Public Safety

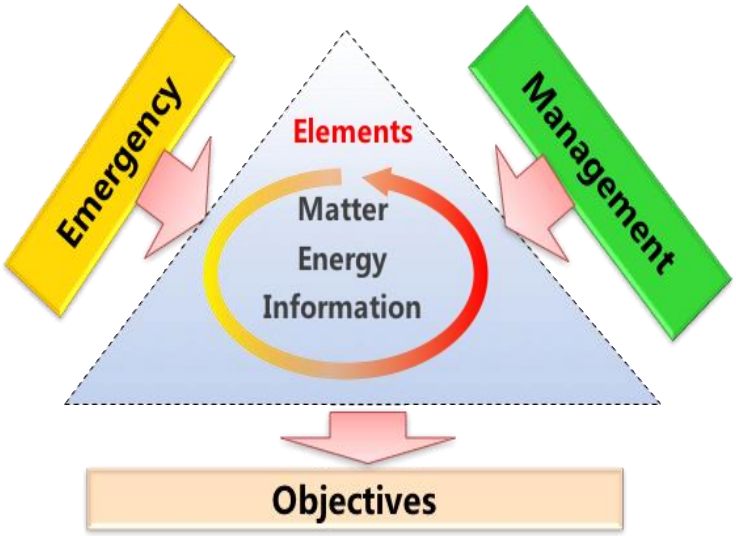


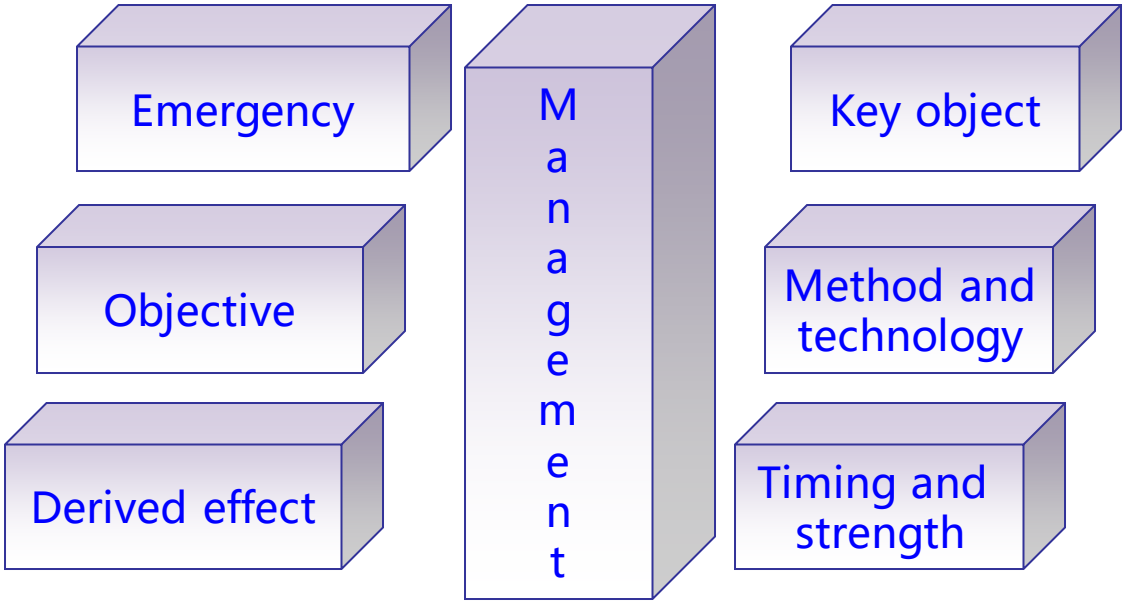


“Triangle Model” of Public Safety

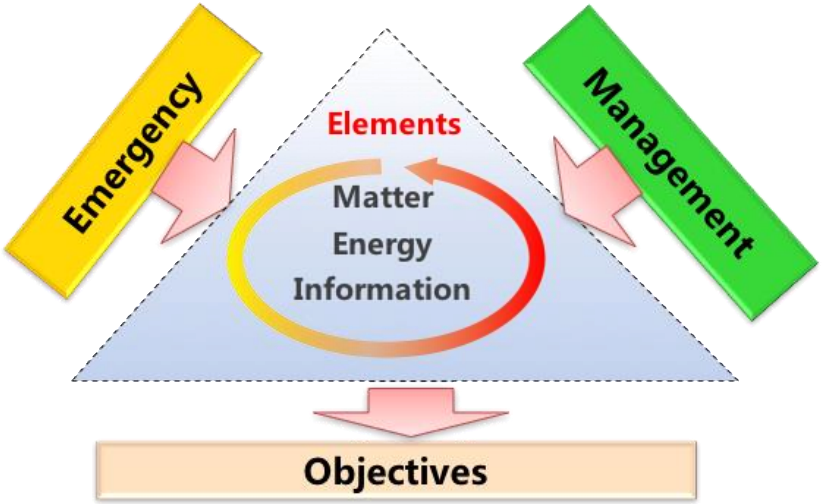


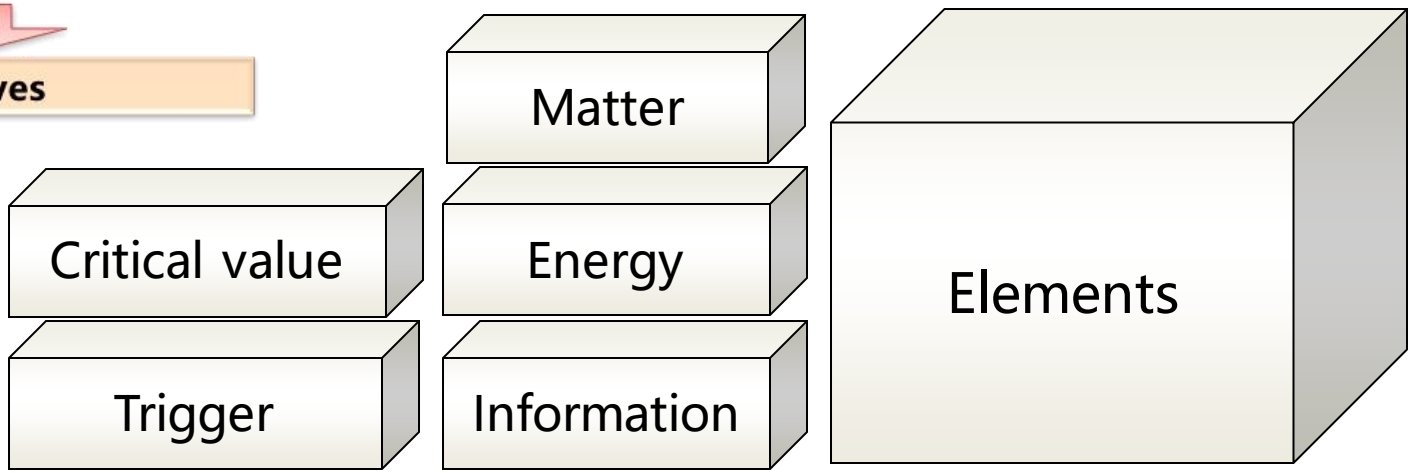
“Triangle Model” of Public Safety





"Triangle Model" of Public Safety





Internet of Things

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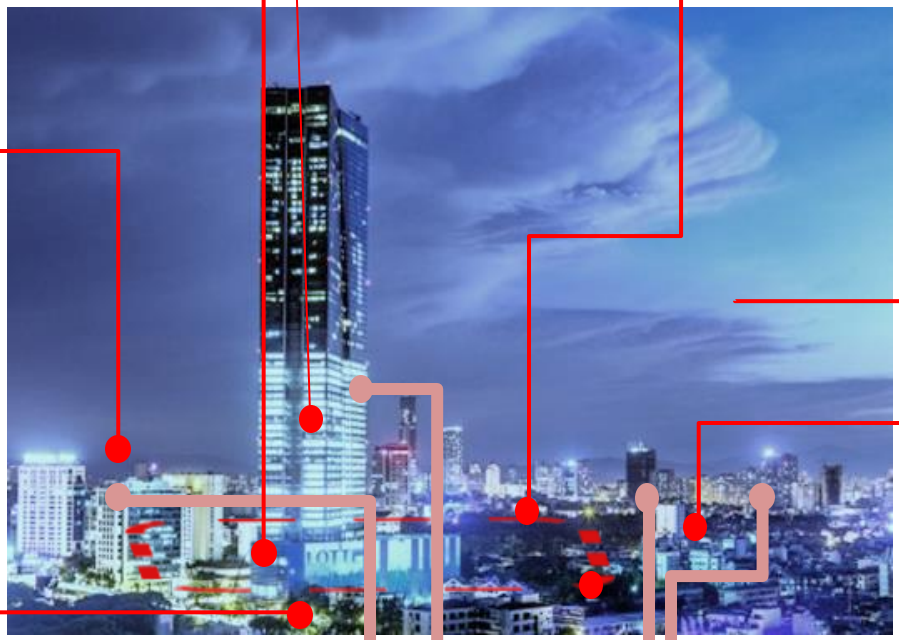
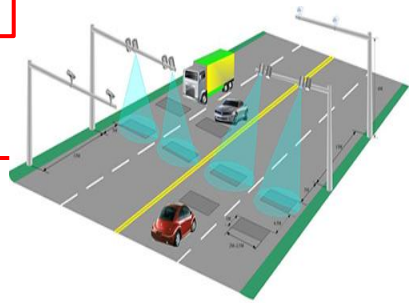
Fire Fighting

Smart Law Enforcement

Hazardous Substance Detection





Smart Transportation

Video surveillance

On-Site Mobile System

Prediction & Analysis

Intelligence Fusion


Traffic

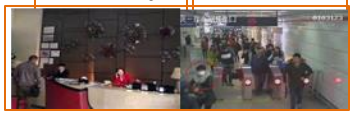
Highway


Critical Area

Money Transfer


Security

Telecom


Hotel Record

Video Surveillance

Telecom

Internet

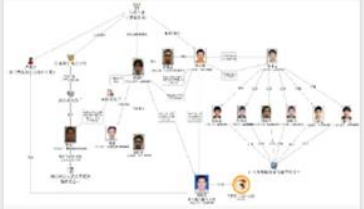
Bank

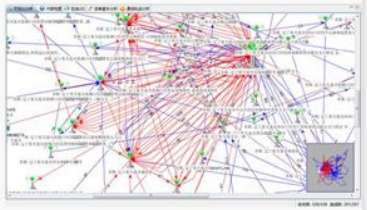
Transport

Hotel

Immigration

Video Surveillance


Criminal Network Analysis

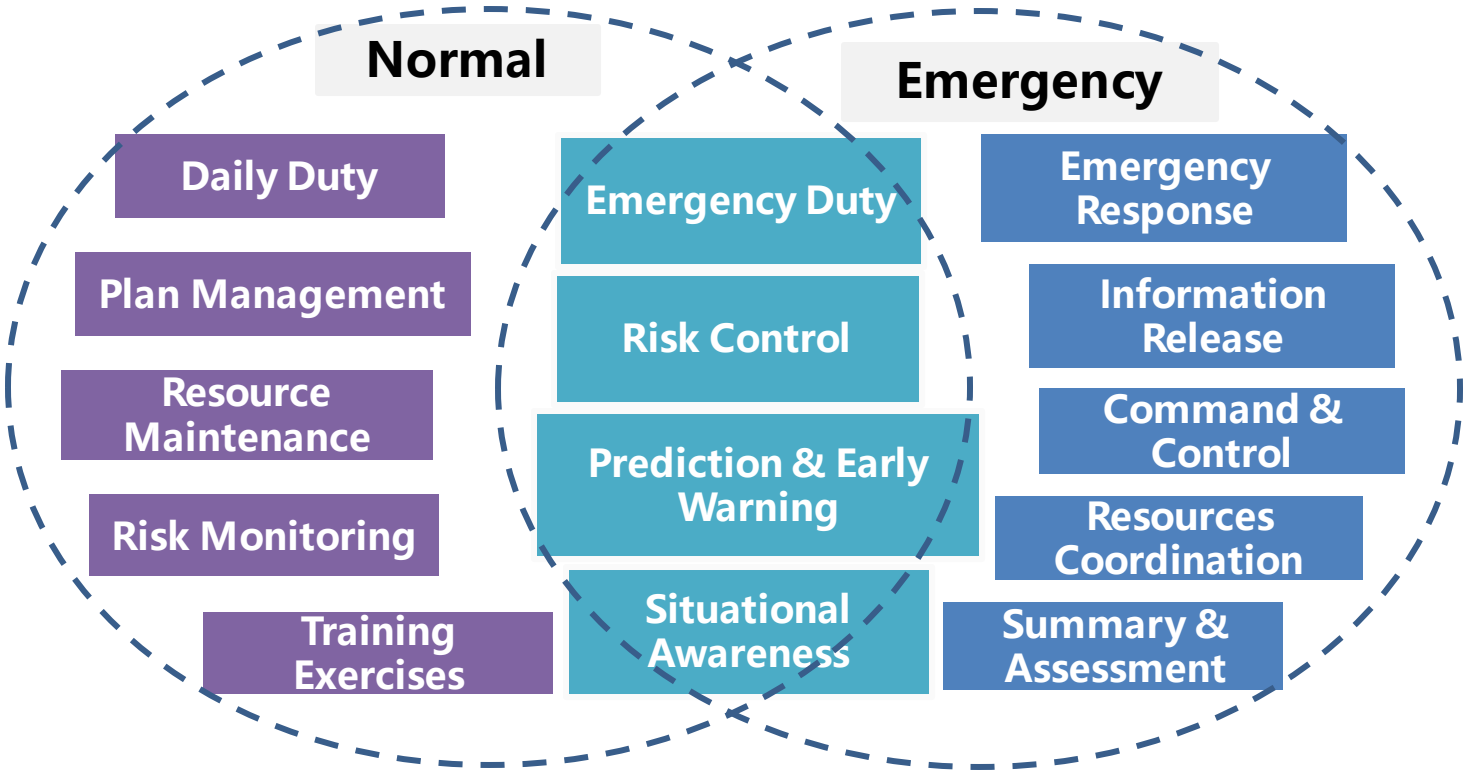

Companion Analysis


Abnormal Event Detection


Active Area


Trading Network Analysis

Emergency Response and Management

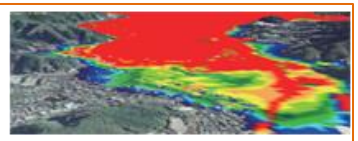


Prevention & Emergency Preparedness → Monitoring & Early Warning → Emergency Response & Rescue → Post-disaster Reconstruction

Emergency Response and Management

Intelligent analysis for decision making

Impacts of Explosion



Hazardous Chemicals Disper

Technical Support

Command and Control

Collaboration

Command Center

Other Rescue Forces

Main Screen

Supporting Information

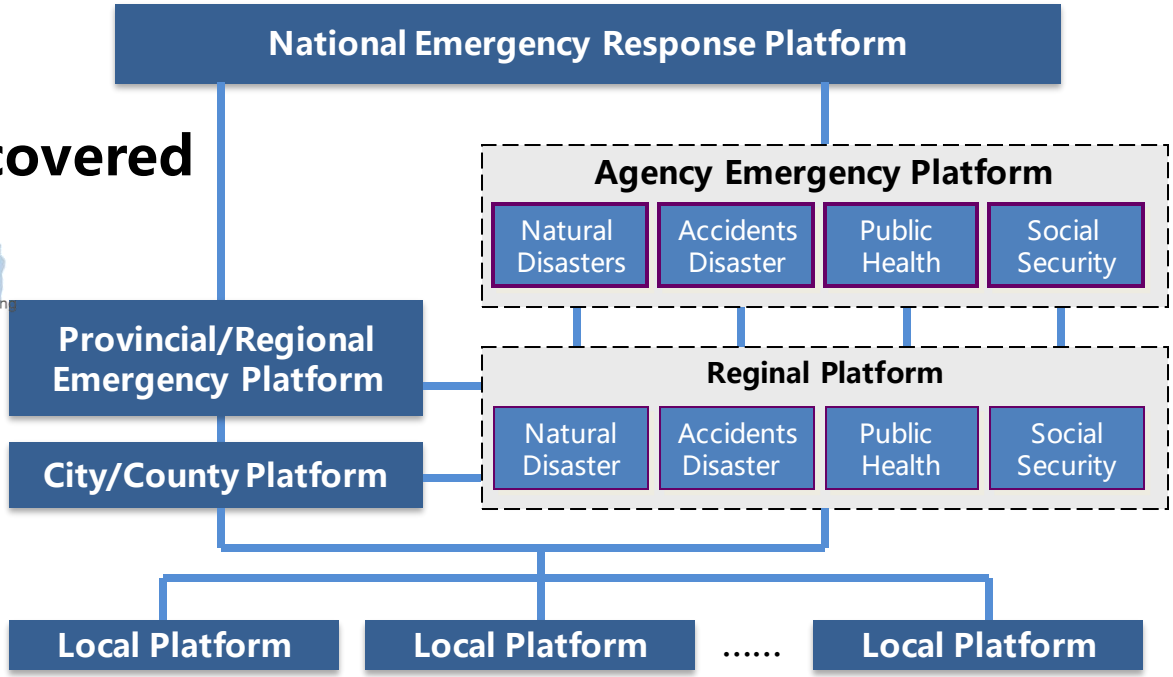
GIS data

Prevention & Emergency Preparedness → **Monitoring & Early Warning** → **Emergency Response & Rescue** → **Post-disaster Reconstruction**

China’ s National / Provincial / City EMR Platform

China National Emergency Response Platform

- 1 National center
- 31 reginal center
- 2/3 mainland China is covered

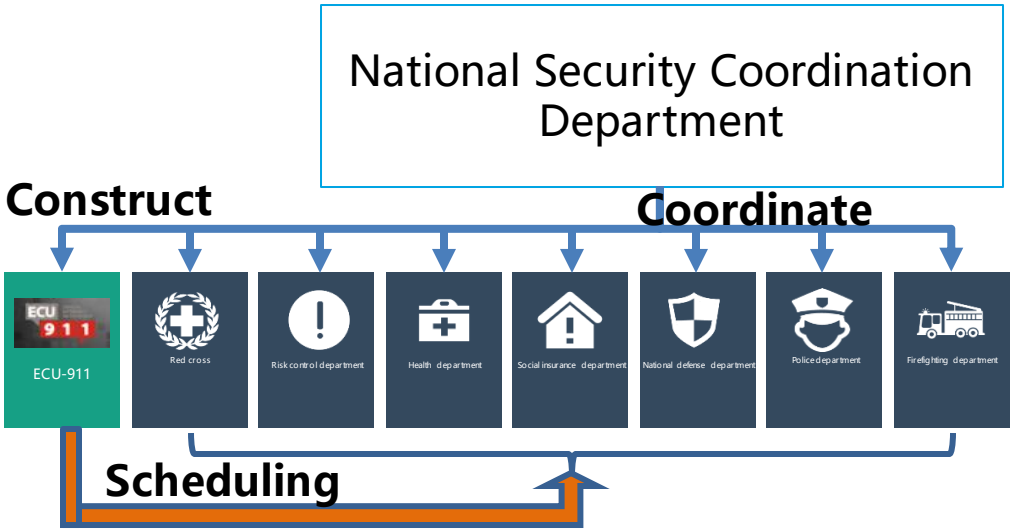


National Early Warning Information Release System

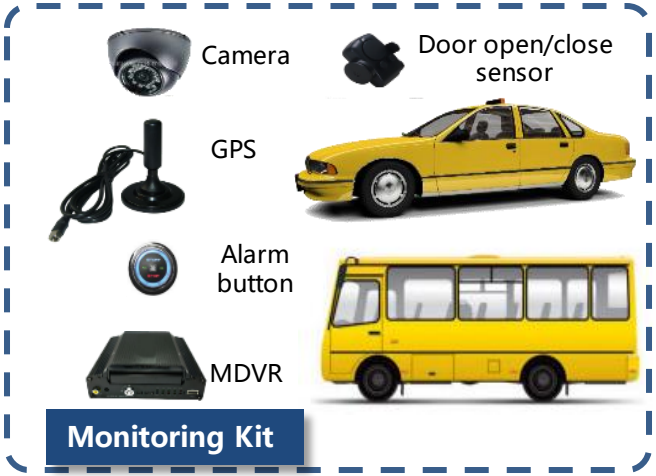
National emergency pre-warning information release monitoring platform

- Emergency public pre-warning information released through China Meteorological forecast systems
- Beijing public emergency warning information release system
- Tianjin public emergency warning information release system
- Guangxi Meteorological Disaster Emergency Warning Information Release System
- Hebei Province Meteorological Service Center Early Warning Information Release System
- Ningxia Emergency Warning Information Release System

Public safety management system for Ecuador (ECU 911)



Ecuador ECU-911



Ecuador ANT

Trend in public safety

Risk assessment, precaution and protection

Monitoring, prediction and pre-warning

Emergency response and rescue

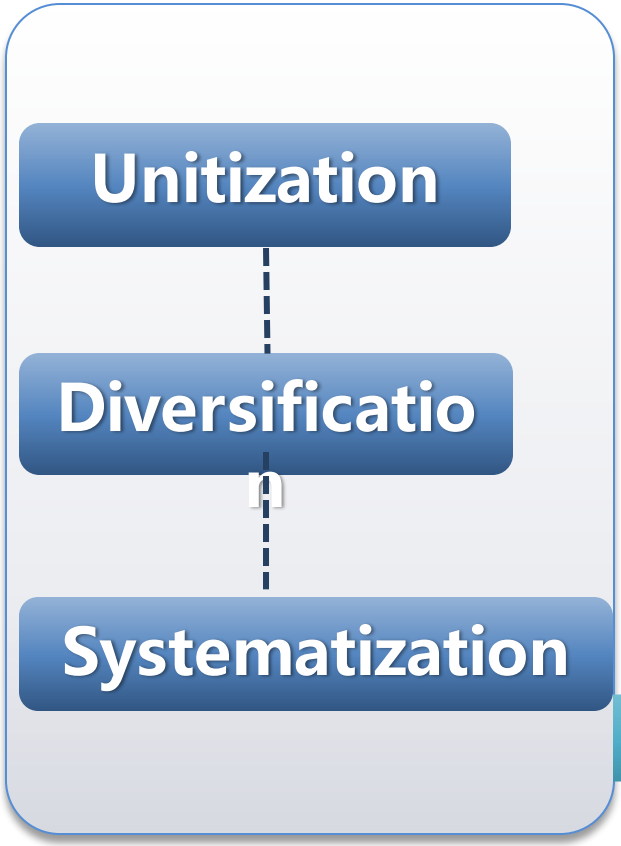
Integrated Support

Triangle model of public safety

Comprehensive public safety network

Active cognition public safety network

Challenge of Public Safety



- Emergency-driven to data-driven
- Thing-centered to human-centered
- Subjective decision to intelligent decision
- Passive emergency response to active safeguard

Comprehensive public safety network

Intelligentization

New goal of Public Safety

Resilience

Sensing in resilience with Internet of Everything

Prediction in resilience for active risk assessment

Precaution in resilience with deep integration of data and knowledge

Key problems of public safety

① **Modeling** of emergency with evolutionary dynamics and information processing

② **Resilience** in public safety

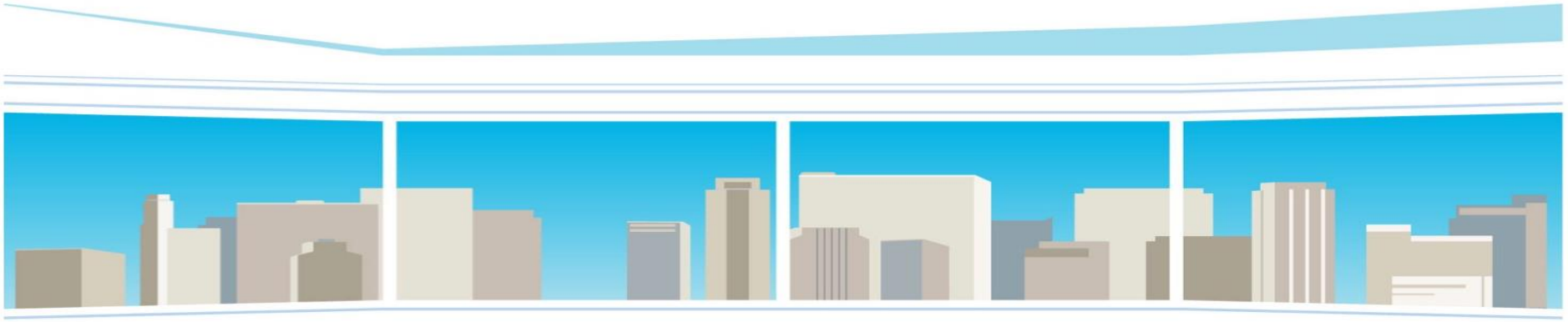
③ **Psychology and behavior** of individual and group under emergency

④ **New decision making** theory of emergency

⑤ Emergency response with **advanced technology**

Concluding Remarks

- Public safety relates directivity to human life, social and economical development.
- Science, technology, management and culture coordinately support public safety.
- International exchange and cooperation are needed for promotion of science & technology of public safety



- **Contact**

  Weicheng Fan (wfan@tsinghua.edu.cn)

- **Open discussion**

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