Challenges and Opportunities in Fire Science

Professor Guillermo Rein

Department of Mechanical Engineering

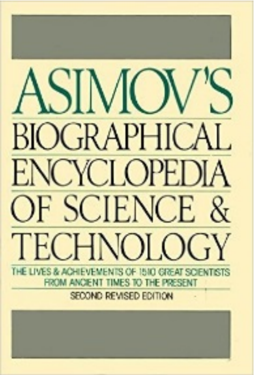
Imperial College London

5 Nov, 2018

Fire Science 1.5 million years ago

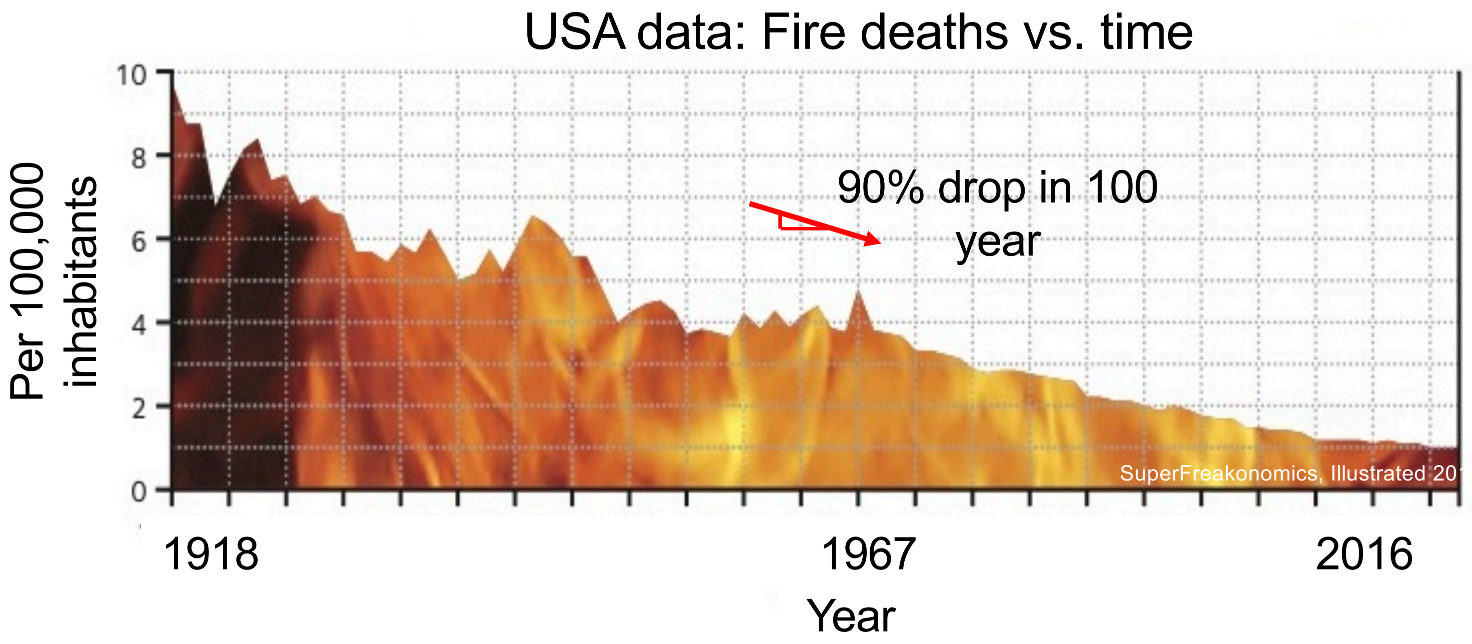
“Fire is the greatest single discovery in human history”

Prof. Isaac Asimov (1920-1992)



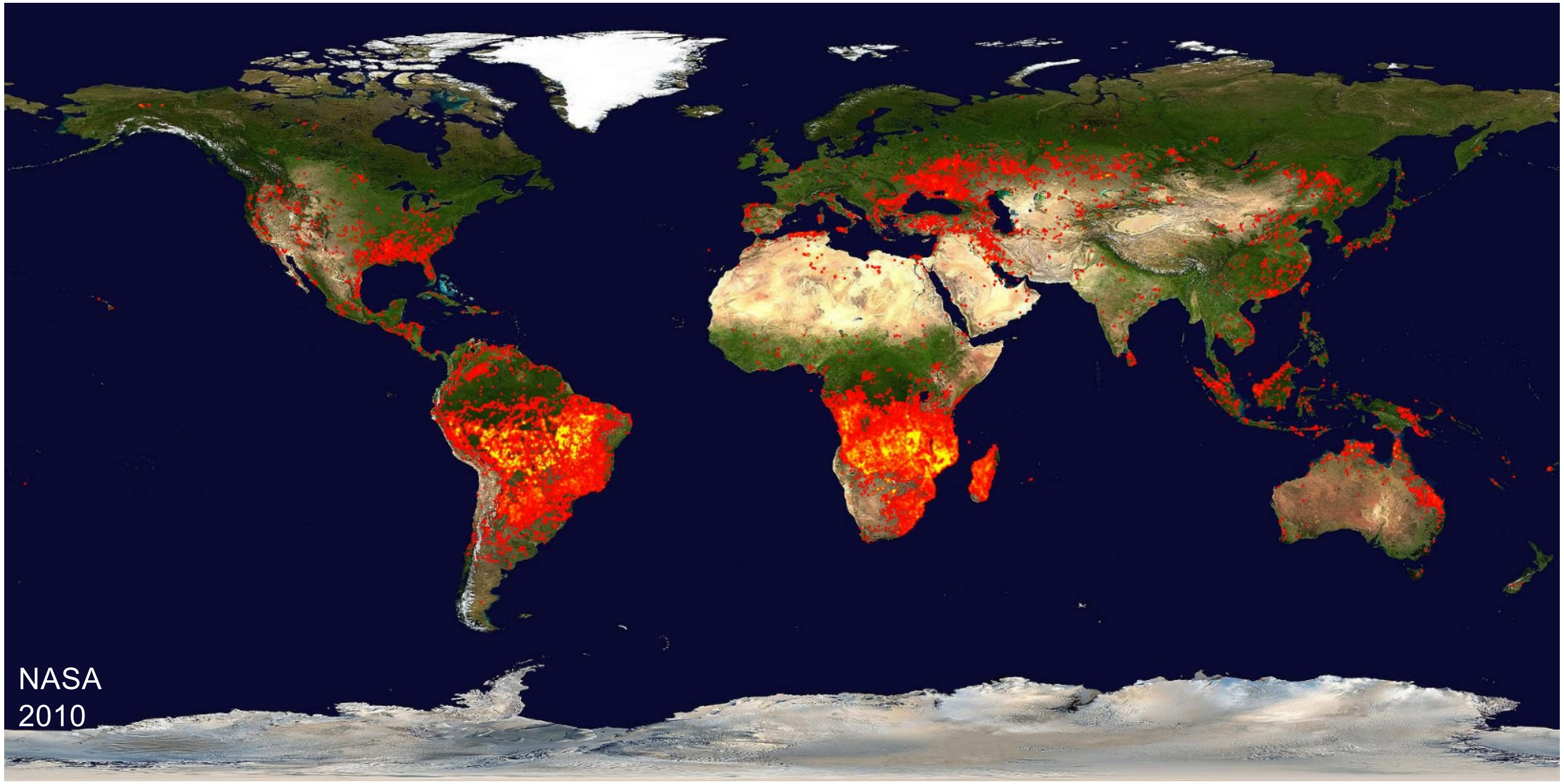
JH Matternes

Building Fires



- Despite tremendous progress in protecting lives from fire, it is still causing 5% of deaths worldwide (war causes 2%).
- 95% of these deaths are in low or medium income countries.
- Because protecting from fires is costly (UK: £10 billion/yr).

Wildfires



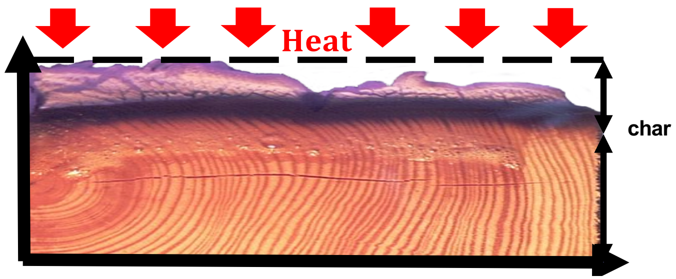
- Multiple £ billions are spent annually worldwide to protect communities and ecosystems from wildfires.
- If we were to extinguish all wildfires, we would be stopping life on Earth (because of the O_2 and C cycles).

Timber Buildings

Heavy timber ⇒ more beautiful and sustainable tall buildings

Driven by Sustainability
& **Novel Architecture**

- The perceived lower fire safety is the <u>only market barrier</u> to tall timber construction.
- *"it fuelled the Great Fire of London"* vs. *"the building materials of 21^{st} Century".*
- But debate is poorly informed… Despite 1.5 million years of burning wood, we still cannot predict reliably its behaviour in fire.



Building Façades

Introducing polymers ⇛ light and insulating but flammable

Driven by Sustainability & **Novel Architecture**

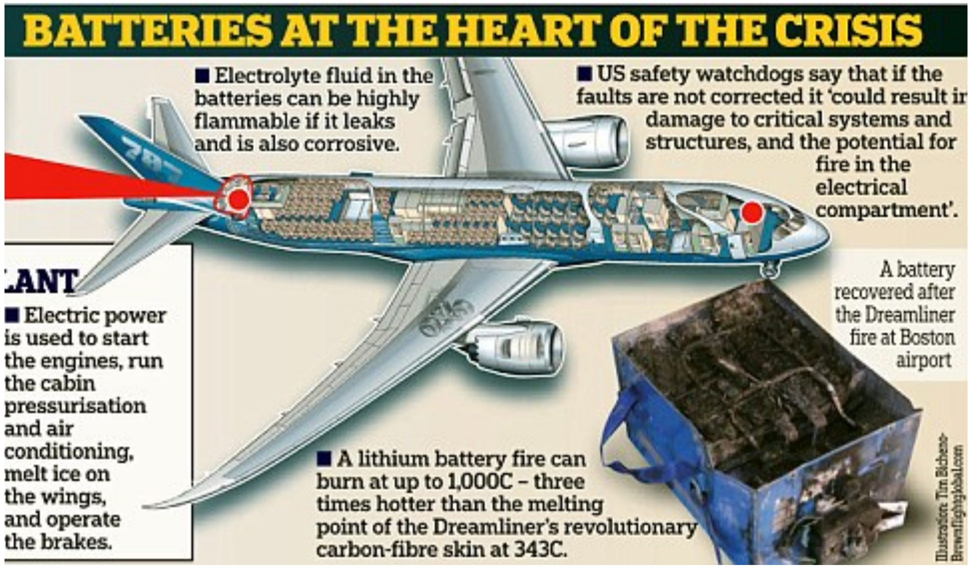
- Increasing number of large façade fires buildings worldwide: 5 per year (7 times larger than 1980).
- Millions of flammable facades in buildings (and construction continues).
- State of the art is so poor, even desperate, only way to "see" the flammability of a façade is to burn it in large scale.

Li-ion Batteries

Lithium-ion batteries ⇒ Flammable and self-ignition

Driven by Sustainability & **Novel Architecture**

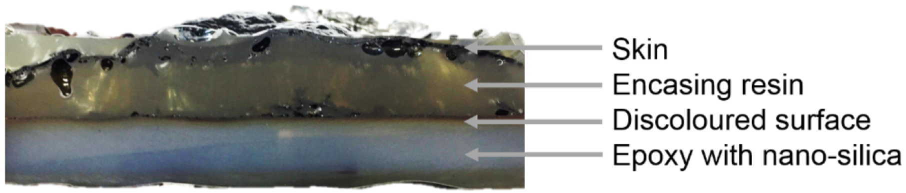
- Boeing, Samsung, Tesla, IBM, hoverboards, children toys, ESS...
- As energy density of batteries grows, reactivity and self-ignition potential grow too.
- The fire problem of self-ignition is hardy addressed by fire experts.
- **Elephant in the room of energy innovation?**



Composites Polymers

Flammability vs. Strength

- Polymer composites are tough, light and easy to manufacture.
- **But very flammable**.
- Composites often fail to pass requirements on fire response.
- Only solution is flame retardants, which reduce strength, and reduce ease of manufacture.

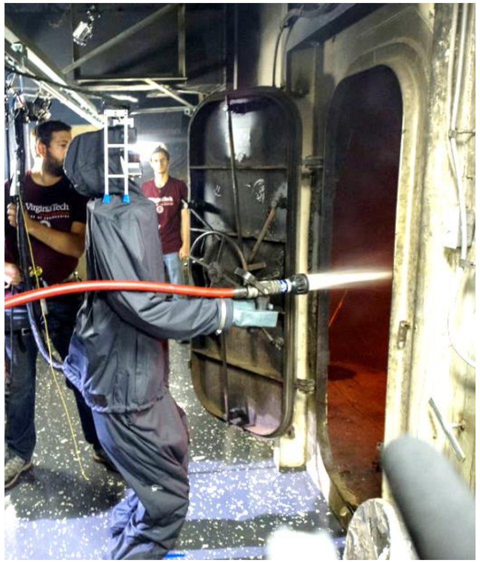


Smart Firefighting

the Digital Revolution ⇒ Future fire protection

- **Big data** – extract knowledge from massive collections of real data from fire events. Related to Internet of Things and Artificial Intelligence.

- **Smart buildings** – forecast and anticipate fire behaviour using data from previous fires.
- **Smart firefighting** – Real time knowledge of the fire ⇒ Paradigm shift in emergency response and including firefighting robots.



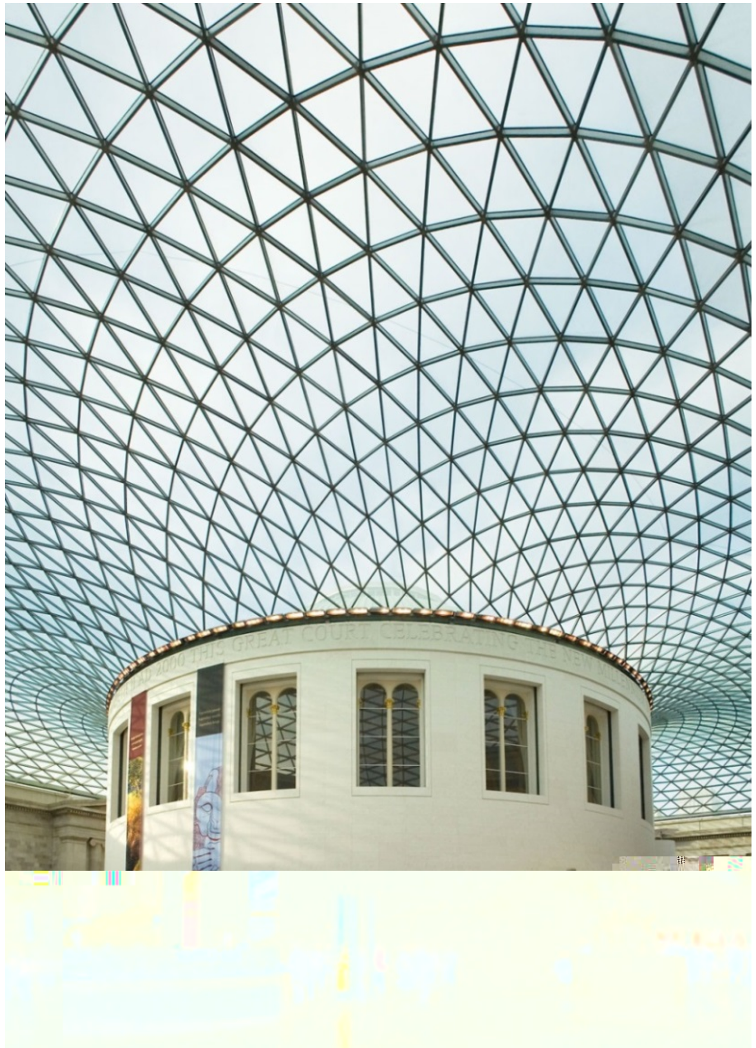
Conclusions

- **Fire Science and Engineering** makes the world safer: protects people, their property and the environment.
- **Fire is a very old problem, but it keeps morphing:** novel materials and new systems are arriving at unprecedented rate, before we understand the basics of their fire behaviour.
- Multidisciplinary field **rapidly evolving**.

- Fire is unwanted combustion in the form of **turbulent diffusion flames.**
- It is in dire need for a **flame spread theory**, **high-fidelity experiments** for model validation, and embracing the **digital revolution**.
- The fields belongs to the forefront of technology and innovation. But it must grow substantially its scientific base. **UK can lead**.
- Exciting years ahead.

DRIVER#1: Performance Based Design

PBD – prescribed the safety goals, not the design method



- Designers must **demonstrate (not assume)** compliance with requirements.
- **Game Changer, globally.**
- **True engineering**, built on top of accumulate wisdom of prescriptive codes.
- **Impact □:** creates need for more well prepared fire protection **engineers**.
- **Impact □:** Problems with **inconsistency.** eg, 10 engineers would typically produce 10 different design fires.

… only engineers can make them safe

"The Titanic complied with all codes.
Lawyers can make any device legal, only engineers can make them safe"

Prof Vincent Brannigan
University of Maryland

SYSTEM #9: Flame Retardants

Flammability vs. Toxicology

DRIVEr#2: Sustainability & DRIVER#3: Science/Technology

- Polymers are naturally flammable and involved in most residential fires.
- Safety requirements are typically met by addition of flame retardant (halogen, mineral filler, intumescent)
  = $4b industry worldwide.
- Some flame retardant chemistries (eg, halogen) are suspected toxicants to the body or environment.
- **Real live experiment:** 2015 California/USA removed requirements of flame resistance in upholstery (18% of fire deaths). Pressures in EU and UK follow USA.

SYSTEM#1: New Buildings

Protection of Buildings is fundamentally changing

DRIVER#1: Performance Based Design,
DRIVER#2: Sustainability & DRIVER#4: Novel Building Architecture

All layers of protection affected:

Prevention || Fuel control || Passive systems || Detection || Suppression || Evacuation || Structural Resilience

DRIVER#2: Environmental Protection and Sustainability

Sustainability – eliminate negative environmental impact

- Designing the **life cycle** of the system according to principles of social, economic, and ecological sustainability (eg, energy, waste, carbon footprint).
- **Impact ⍰:** Responding to modern ethos in society.
- **Impact ⍰:** Green buildings bring fire challenges including large batteries, flammable façades, solar panels, downgraded fire requirements (eg, TB117).

DRIVER#4: Novel Building Architecture

Novel Systems –Engineers must keep up with innovation

- Architect dreams of impossible buildings, which the engineer has to built (taller, lighter, faster).
- **Impact ?:** Dynamism and excitement. Challenges arrive and new solutions create new markets.
- **Impact ⚠:**

Systems most affected by change (n=54)

(colours do not mean anything, just for visual aid)

https://www.mentimeter.com/s/a9e8bf6e6dd685985c562eefdb3b4649/461713a17364