Perspectives on Science Advice in Emergencies

Robin Grimes

Imperial College London &
MoD Nuclear Chief Scientific Adviser

Problems 1990-2010

Do we have to learn through adversity?

- Kings Cross Fire
- Hillsborough Stadium
- Potters Bar
- Port Talbot Blast Furnace
- Buncefield Oil Storage Depot
- Liverpool Crane Incident
- Grayrigg Rail Incident

Some principals of Engineering Design Safety

- Failures in engineering systems can occur as a consequence of: i) component failure, ii) human error & iii) external events.
- Defence in depth: consists of multiple independent protections against the occurrence and propagation of accidents.
  - If one component fails, another component is present whose failure is independent of the operation of the first.
  - No single point failure mechanisms.
- DID should prevent accident scenarios but also provide sufficient protection that should the initial system fail it would prevent the escalation of failures and mitigate the risks from accidents.

Some principals of Engineering Design Safety

- DID compensates for weaknesses in the ability to evaluate the risks and protects against common cause failures (CCFs).
- DID is implemented through the engineered mechanisms of:

    i) Redundancy,

    ii) Diversity,

    iii) Segregation

- The DID design must withstand the consequences of postulated (most severe) accidents, including the loss of systems, structures and components that assure health and safety. These are known as **design basis accidents** (DBA).
- Accidents due to human error can be DBA but can lead to circumstances which are **beyond design basis accidents.**

Perception of risk varies depending on circumstances

- Risk
- Hazard
- Uncertainty
- Vulnerability
- Randomness

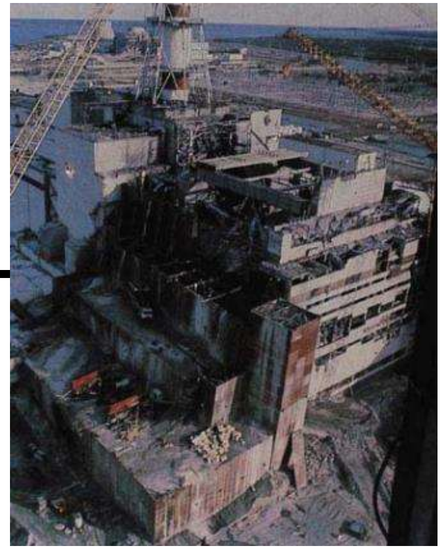
Many risks have common consequences:

This determines the National Planning Assumptions

Different departments are involved in both mitigation & response

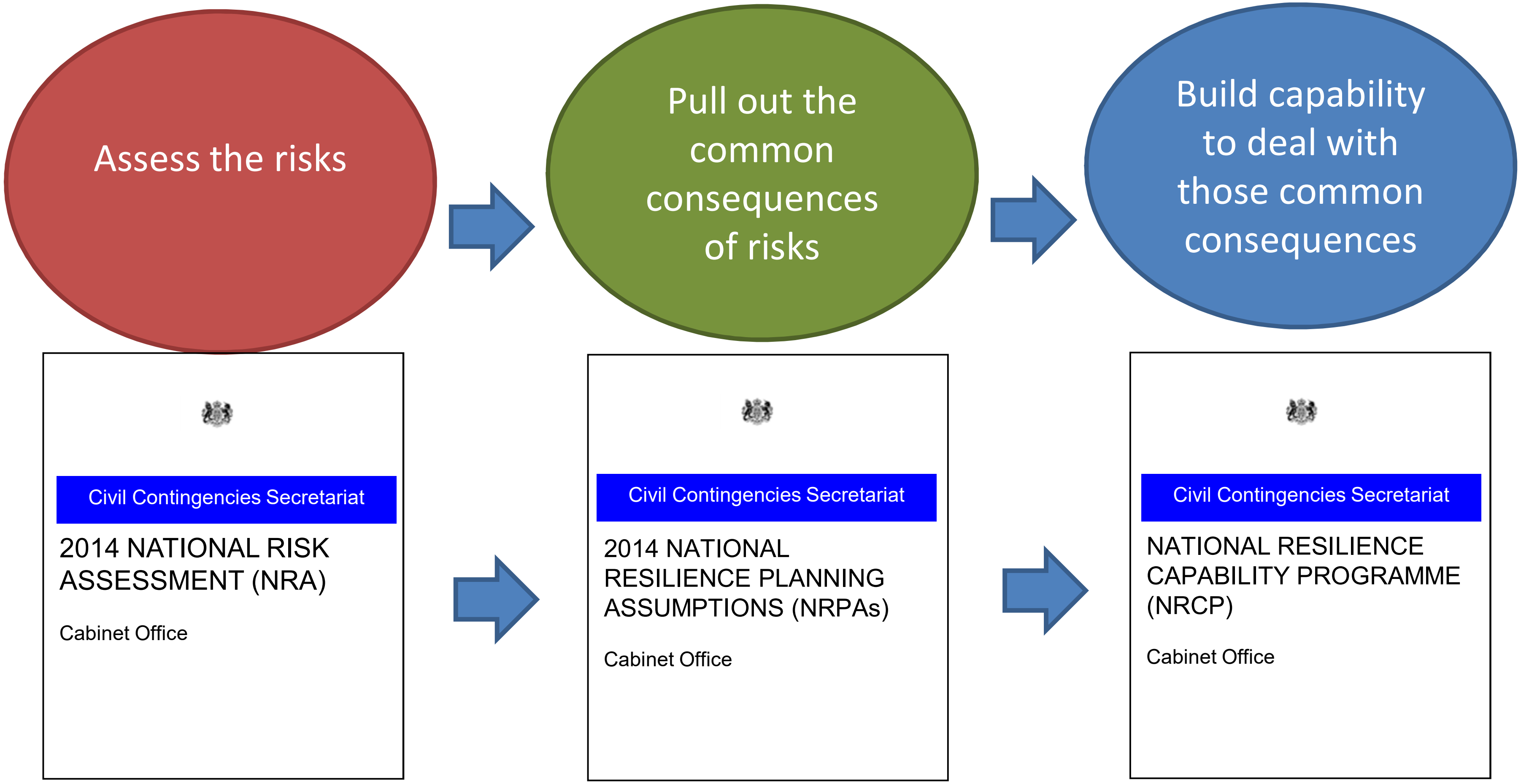
Terrorist attack

- Mass Fatalities
- Mass Casualties
- Biological Release
- Radiological Release
- Chemical Release
- Debris / Rubble
- People requiring evacuation & shelter
- Influx of British Nationals
- Disrupt. to Water Supply
- Disrupt. to Transport
- Disrupt. to Oil & Fuel
- Disrupt. to Gas
- Disrupt. to Electricity
- Disrupt. to Telecoms
- Disrupt. to Health
- Disrupt. to Financial Services



Major industrial accident

How the UK prepares for the common consequences of risks



6 month Forward Look: Provides departments with an indication of the relative likelihood and impact of **unfolding or emerging** civil domestic risks. It is produced every quarter.

There are different facets to disaster risk response

Prevent

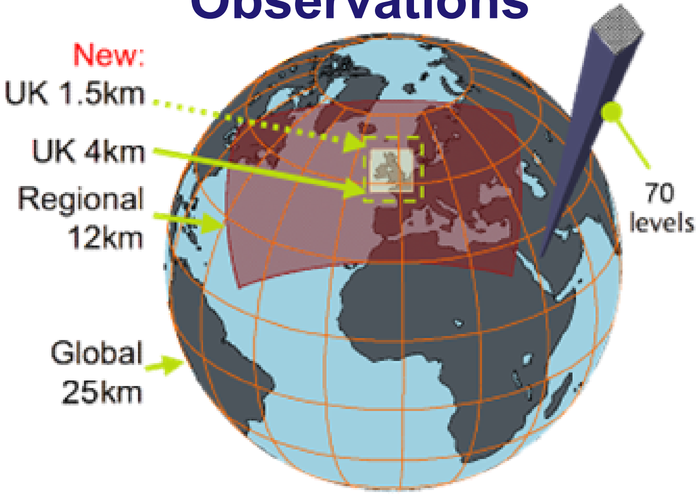
Mitigate

Manage

Clear-Up

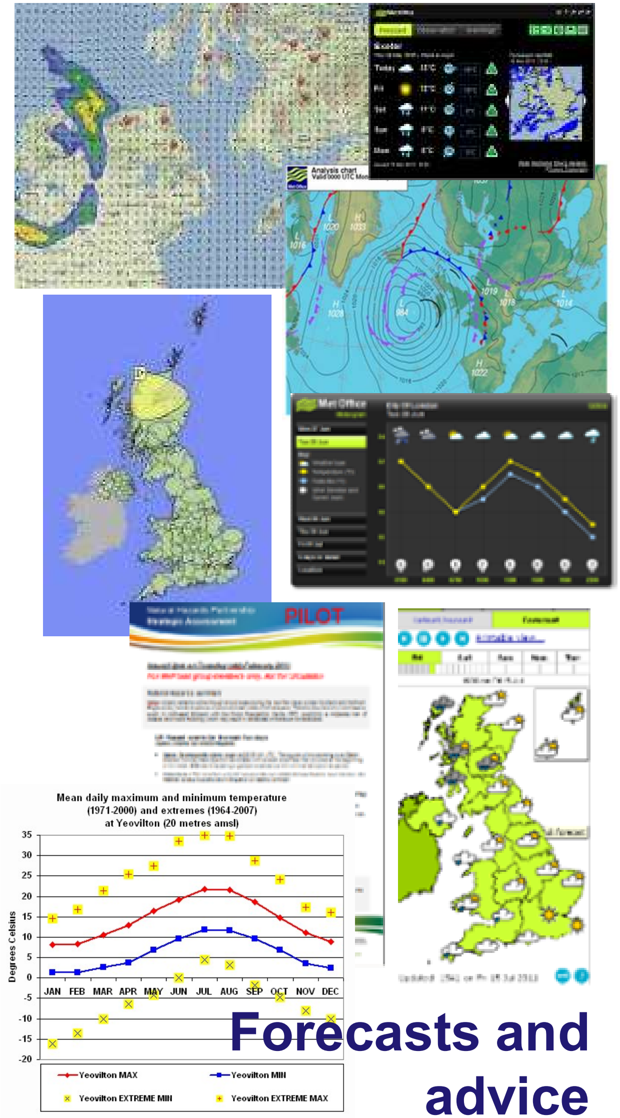
Our ability to respond to disaster risk relies on a scientific value chain

Observations



Forecast model output

Interpretation, Risk Analysis & Communication



Forecasts and advice

…so we rely on understanding (the science) which often relies on experience.


Image Credit: DigitalGlobe
Image Annotation: ISIS
Image Date: March 14, 2011
Smoke or dust plume from the explosion
After the explosion at Unit 3, damage to the reactor building can be seen. Steam can be seen venting out of the reactor building
Steam venting out of the building
After the explosion at Unit 1, the top of the reactor building is damaged

Some factors leading to disaster

- The complexity of a multifactorial process not considered explicitly (leading to single point**s** of failure)

  earthquake → landslide (offsite power) & tsunami (basement flooding)

- The design did not prevent the escalation of failures

  i) Redundancy, ii) Diversity & iii) Segregation

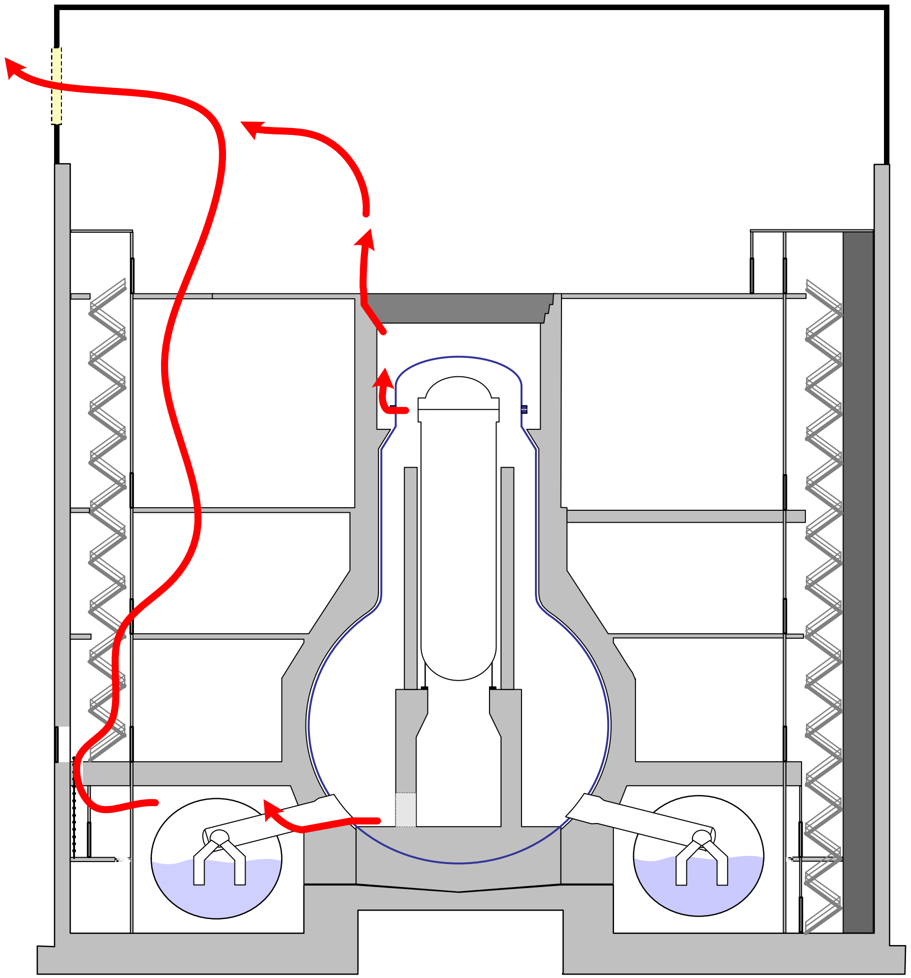
- The relationship between the regulator and generator
- Historical evidence of tsunami height not taken into consideration
- Evacuation zone 'conservative'

What happened at unit 4?

Concerns around the spent fuel pond and a lack of data…

Containment Failure: Initiate Environmental Source Term

- Failure modes (Mark I):
  - Drywell liner melt-through
  - Leakage through drywell head flange
  - Others
  - H_2 combustion not a concern in containment due to inert atmosphere, however..
- Leakage into reactor building before release to environment



Status of nuclear power plants in Fukushima as of 10:30 March 15 (Estimated by JAIF)

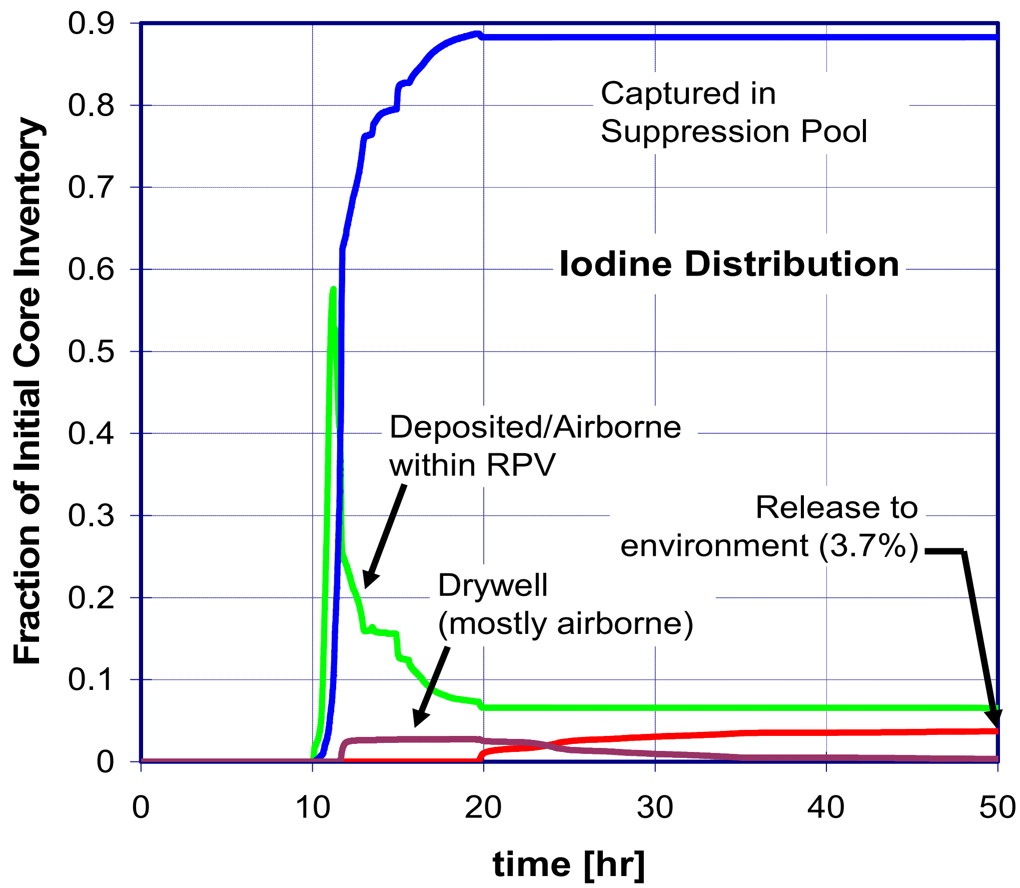
Power Station	Fukushima #1 Nuclear Power Station					
Unit	1	2	3	4	5	6
Power output (MWe)	460	784	784	784	784	1100
Type of Reactor	BWR-3	BWR-4	BWR-4	BWR-4	BWR-4	BWR-5
Operation Status at the earthquake occurred	Service	Service	Service	Outage	Outage	Outage
Fuel Integrity	Severely Damaged	Slightly Damaged	Severely Damaged	Not Damaged	Not Damaged	Not Damaged
Containment Integrity	Not Damaged	Damage Suspected	Not Damaged	Not Damaged	Not Damaged	Not Damaged
Core cooling requiring AC power	Not Functional	Not Functional	Not Functional	Not necessary	Not necessary	Not necessary
Core cooling not requiring AC power	Not Functional	Not Functional	Not Functional	Not necessary	Not necessary	Not necessary
Building Integrity	Damaged	Not Damaged	Damaged	Not Damaged	Not Damaged	Not Damaged
Environmental effect	Radiation monitor detect radiation increase in the environment (NPS border: 8,217 μ Sv/h at 8:31)					
water level of the pressure vessel	Unknown	Recovering after Dried-up	Unknown	Safe	Safe	Safe
pressure of the pressure vessel	Stable	(No info)	Stable	Safe	Safe	Safe
Containment pressure	Stable	D/W: Unknown, S/P: Atmosphere	Stable	Safe	Safe	Safe
Sea water injection to core	Done	Done	Done	Not necessary	Not necessary	Not necessary
Sea water injection to Containment Vessel	Done	to be decided	to be decided	Not necessary	Not necessary	Not necessary
Containment venting	Done	Preparing	Done	Not necessary	Not necessary	Not necessary
Evacuation Area	20km from NPS					
INES	Level 4 (estimated by NISA)					

Status of nuclear power plants in Fukushima as of 16:00 March 20 (Estimated by JAIF)

Power Station	Fukushima Daiichi Nuclear Power Station					
Unit	1	2	3	4	5	6
Electric / Thermal Power output (MW)	460 / 1380	784 / 2381	784 / 2381	784 / 2381	784 / 2381	1100 /3293
Type of Reactor	BWR-3	BWR-4	BWR-4	BWR-4	BWR-4	BWR-5
Operation Status at the earthquake occurred	In Service -> Shutdown	In Service -> Shutdown	In Service -> Shutdown	Outage	Outage	Outage
Core and Fuel Integrity	Damaged	Damaged	Damaged	No fuel rods	Not Damaged	Not Damaged
Reactor Pressure Vessel Integrity	Unknown	Unknown	Unknown	Not Damaged	Not Damaged	Not Damaged
Containment Vessel Integrity	Not Damaged	Damage Suspected	Might be "Not damaged"	Not Damaged	Not Damaged	Not Damaged
Core cooling requiring AC power	Not Functional	Not Functional	Not Functional	Not necessary	Not necessary (AC power available)	Not necessary (AC power Available)
Core cooling not requiring AC power	Not Functional	Not Functional	Not Functional	Not necessary	Not necessary	Not necessary
Building Integrity	Severely Damaged (Hydrogen Explosion)	Slightly Damaged	Severely Damaged (Hydrogen Explosion)	Severely Damaged (Hydrogen Explosion)	Open a vent hole on the rooftop for avoiding hydrogen explosion	
Water Level of the Rector Pressure Vessel	Fuel exposed partially or fully	Fuel exposed partially or fully	Fuel exposed partially or fully	Safe	Safe	Safe
Pressure of the Reactor Pressure Vessel	Stable	Unknown	Stable	Safe	Safe	Safe
Containment Vessel Pressure	Unknown	Low	Stable at higher level after increase (March, 20th)	Safe	Safe	Safe
Water injection to core (Accident Management)	Continuing (Seawater)	Continuing(Seawater)	Continuing(Seawater)	Not necessary	Not necessary	Not necessary
Water injection to Containment Vessel (AM)	Continuing(Seawater)	to be decided(Seawater)	Continuing(Seawater)	Not necessary	Not necessary	Not necessary
Containment venting (AM)	Temporally stopped	Temporally stopped	Temporally stopped	Not necessary	Not necessary	Not necessary
Fuel Integrity in the spent fuel pool	Water injection to be considered	(No info)	Water level low. Water injection continue and certain effect was confirmed	Water level low. Water injection started Hydrogen from the pool exploded	pool cooling capability was recovered	pool cooling capability was recovered
Environmental effect	The West Gate: 269.5 μ Sv/h at 05:40, Mar. 20 North of Service Building: 3054.0 μ Sv/h at 15:00, Mar. 20 Radio nuclides were detected in milk produced in prefecture and spinach from Ibaragi prefecture.					
Evacuation	20km from NPS * People who live between 20km to 30km from the Fukushima #1NPS are to stay indoors.					
INES (estimated by NISA)	Level 5	Level 5	Level 5	Level 3	—	—
Remarks	Immediate threat is damage of the fuels in the fuel pool outside the containment vessel. The operation for filling the pool with water is in progress at uni-3 and 4 and certain effect was confirmed. Work to recover AC power is in progress . The pressure of the containment vessel increased at unit-3 in this morning (20th) . The pressure became stable at higher level after this increase.					

Transport & Deposition of Iodine

- Mostly transported as CsI (aerosol)
  - Very small fraction I_2
- Efficient transport to and capture in suppression pool
  - Near-complete release during in-vessel damage
  - Transport via open S/RV
- High RPV temperatures prevent long-term retention
- Retention in RPV distant from core
  - Recirculation loop piping



Fukushima: it's all about mass transport

- Initially, transport of particles containing radiotoxic species.
  - So-called aerosols
  - Crucial isotope ^{131}I, half life of 8.04 days
- Subsequently about transport of radiotoxic species suspended or dissolved in water
  - Crucial isotopes ^{137}Cs with a radioactive $t^{1/2} = 30.2$ y, ^{90}Sr $t^{1/2} = 28.8$ y and tritium $t^{1/2} = 12.3$ y. (bio: 70d, 18y, 7-14d)
- We are now also concerned with waste materials entrained with radiotoxic species
  - materials from decommissioning and clean-up.

Scientific Advisory Group for Emergencies (SAGE)

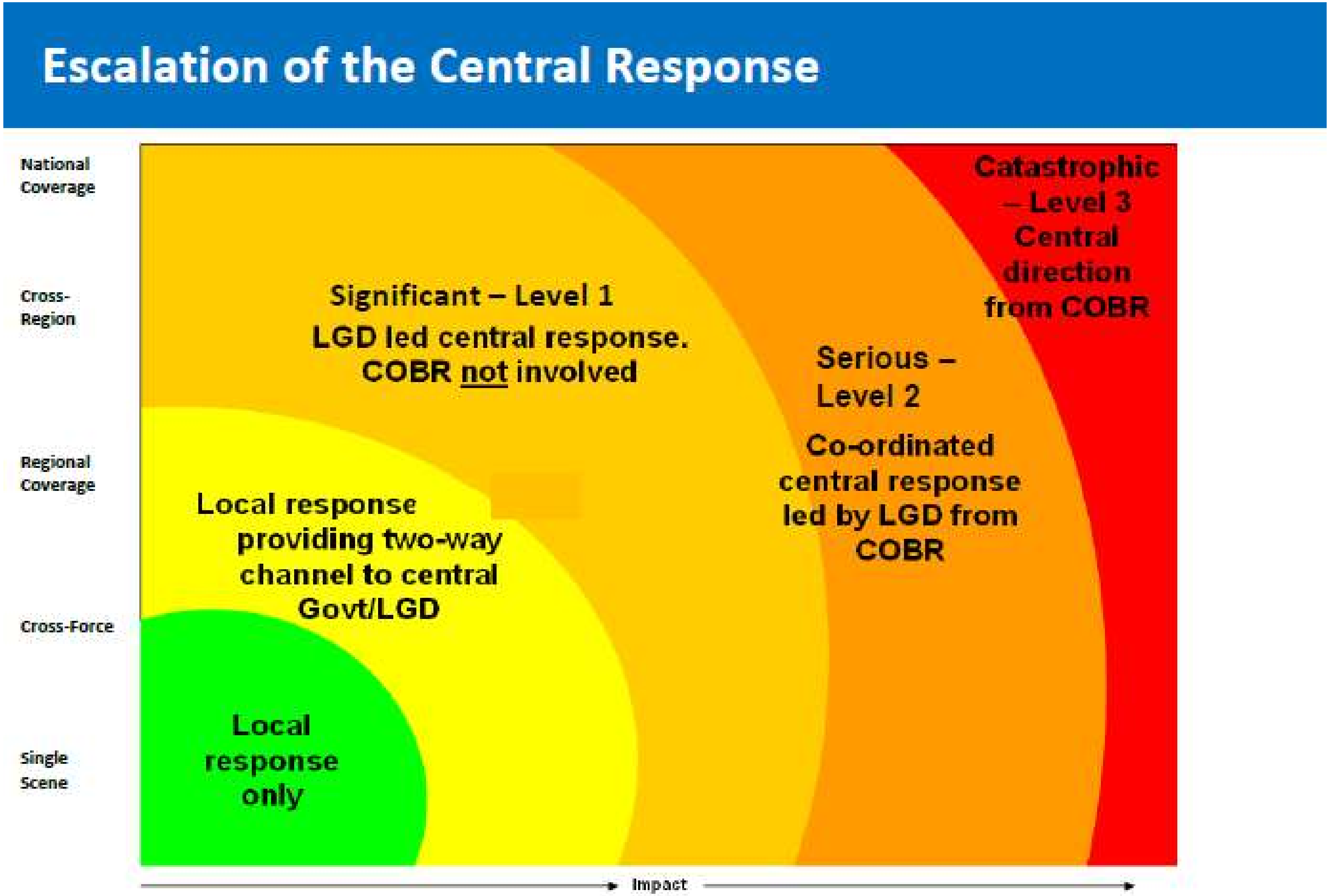
How science supports the UK's emergency response

COBR - The decision making process

COBR

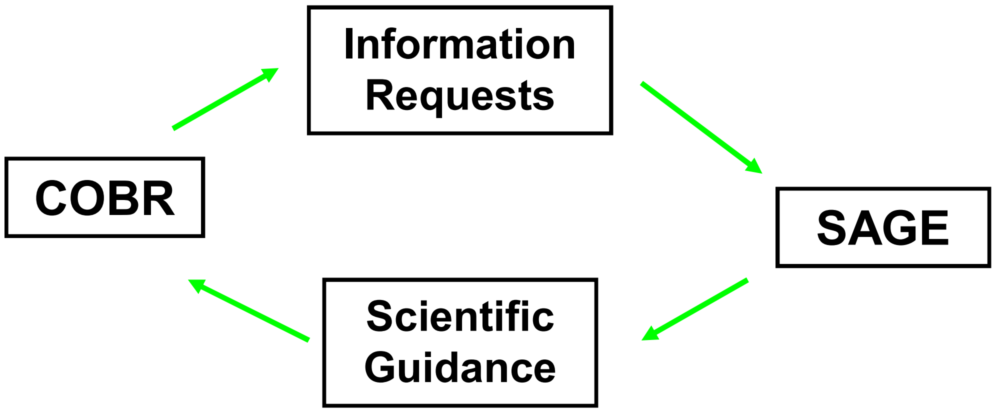
- Facilitates rapid co-ordination of the central government response and effective decision-making.

Calling COBR



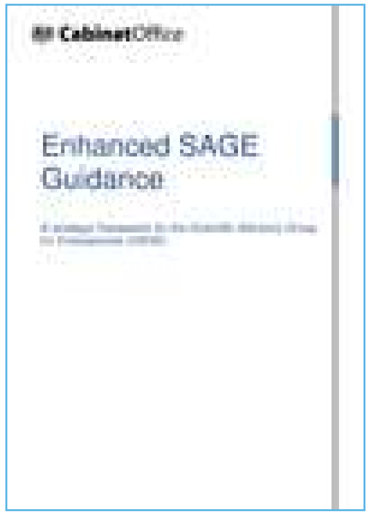
SAGE's purpose

- COBR must decide whether it is necessary to call SAGE
- The aim of SAGE is to "ensure that coordinated, timely scientific and/or technical advice is made available to decision makers to support UK cross-government decisions in COBR"

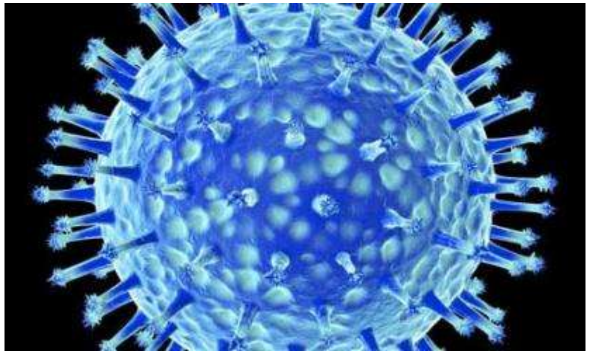


- Practice, practice, practice…what's missing?

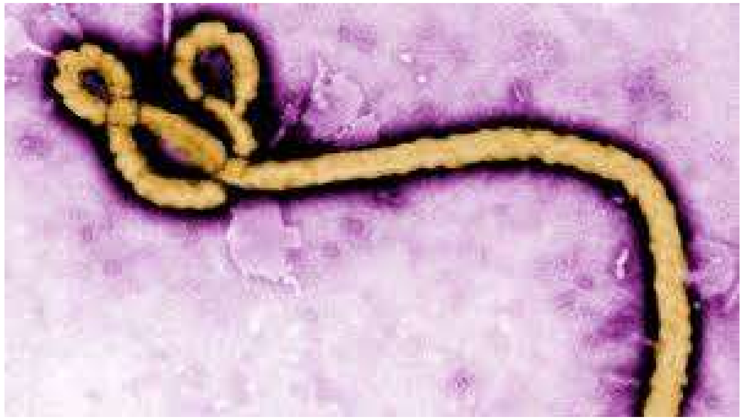
http://www.publications.parliament.uk/pa/cm201011/cmselect/cmsctech/498/49809.htm



SAGE in action: Recent challenges that led to international collaboration action

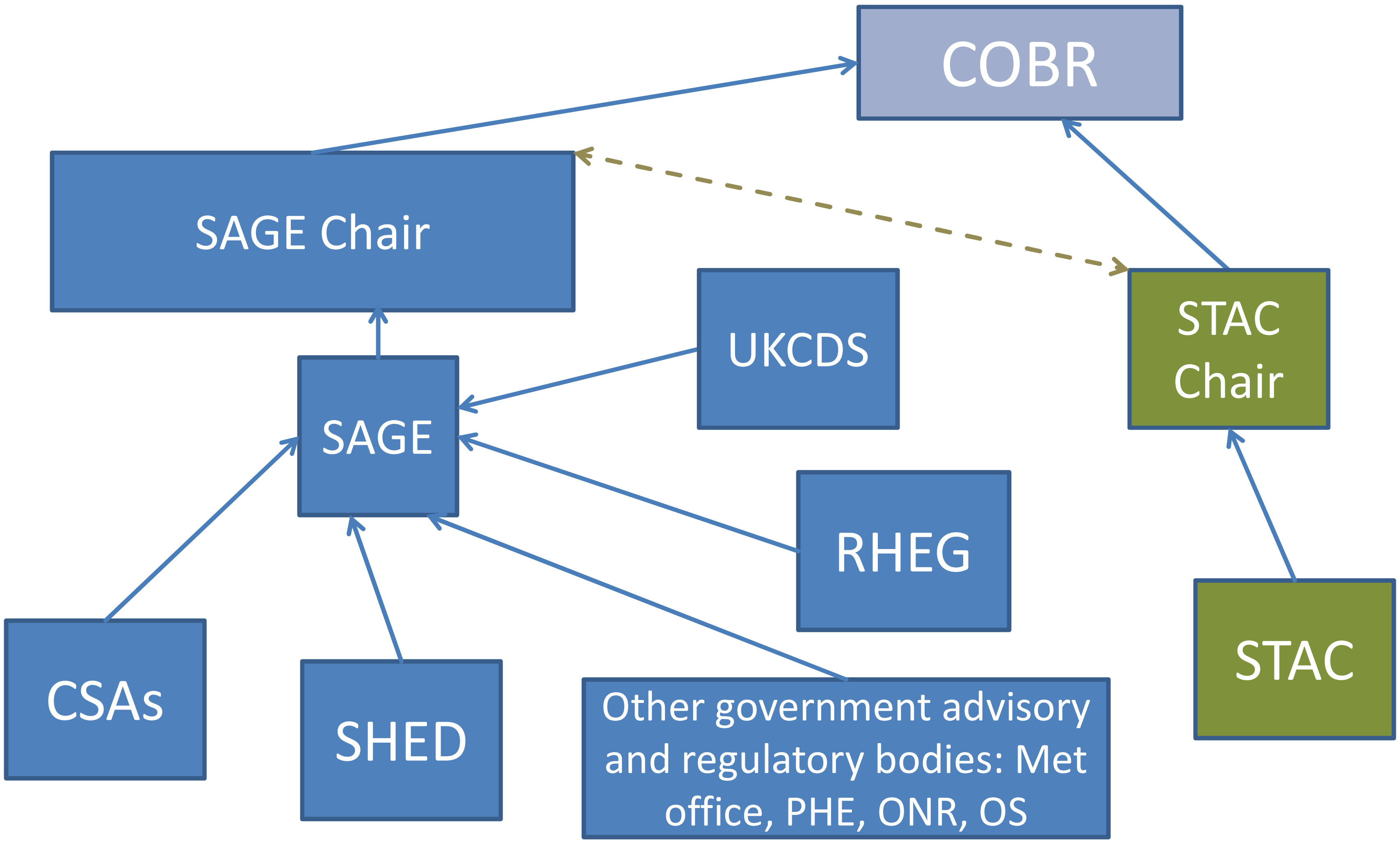


2009 – Pandemic Flu
2010 – Volcanic Ash
2011 – Fukushima
2014 – UK Floods
2014 – Ebola
2015 - Zika



Where does CSAs advice fit during a crisis?

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/80087/sage-guidance.pdf



STACs and SAGE:
1. Local v Cross-government

STACs should support ***local*** *decision making, whilst the focus of SAGE should be to support UK* ***cross-government*** *strategic decision making."*

STAC - Science and Technical Advice Cell within the multi-agency Strategic Co-ordination Centre (SCC)

STACs and SAGE:
2. Known v Uncertain

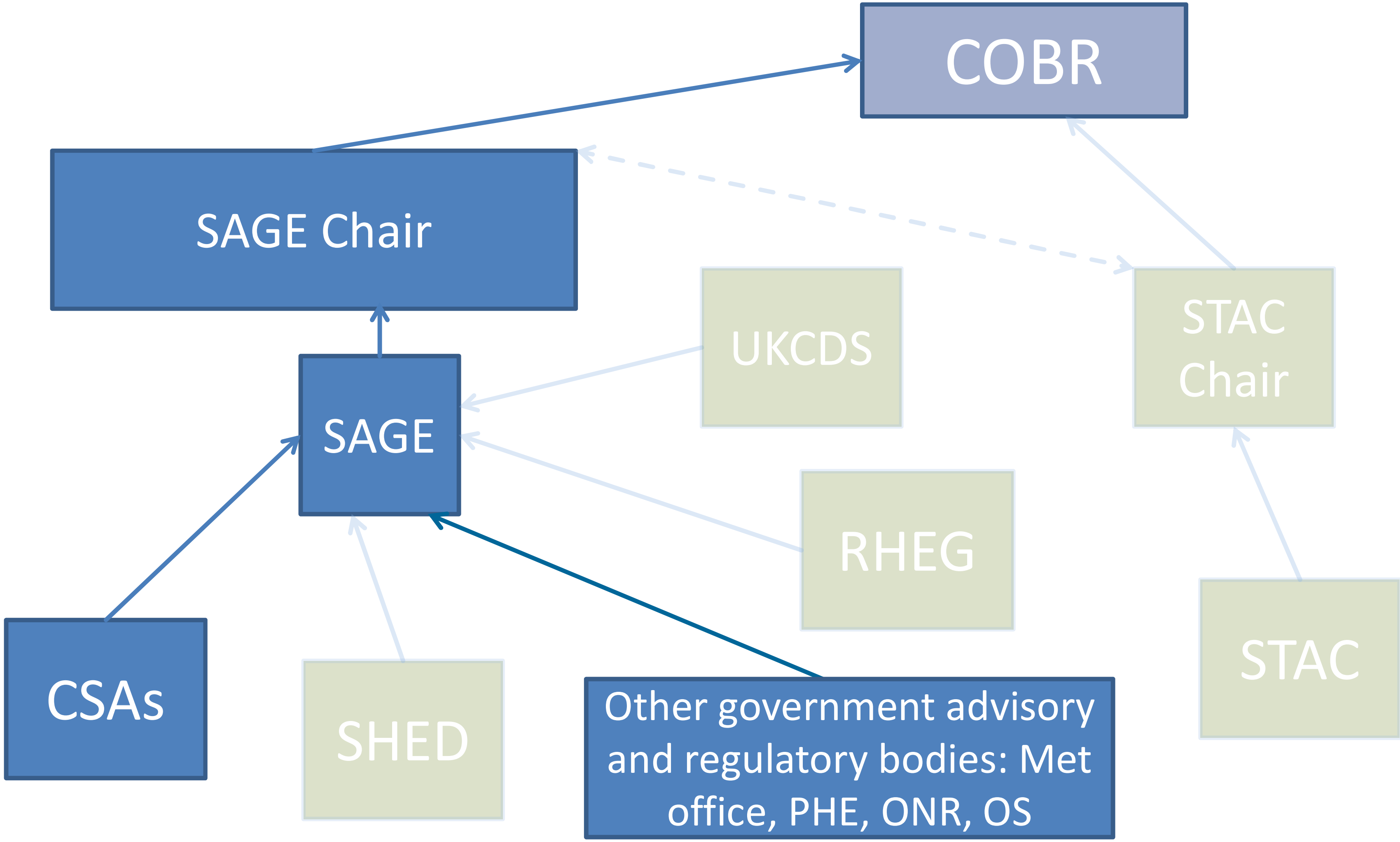
*STACs will focus on **"pre-prepared known"** whilst SAGE will focus on more **uncertain advice** where there are knowledge gaps.*

Communication between STACs and SAGE

"STACs and SAGE should regularly communicate with each other to share information and knowledge to ensure that there is a commonly recognised understanding of the scientific and technical advice."

Enhanced SAGE Guidance

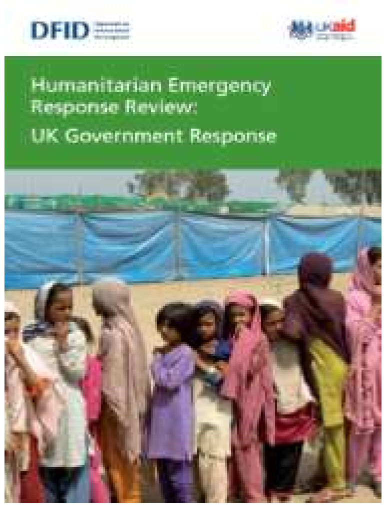
Where does CSAs advice fit during a crisis?

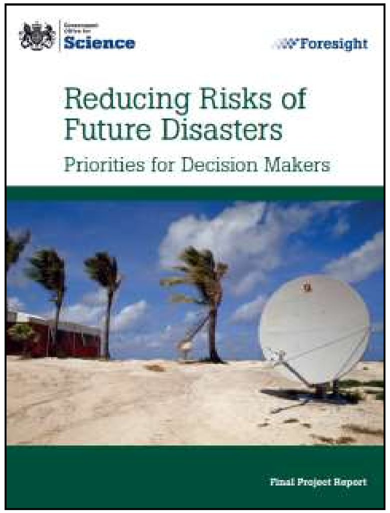


Science in Humanitarian Emergencies and Disasters

How science supports the UK's emergency preparedness and response overseas

A similar approach is being taken for international natural hazards



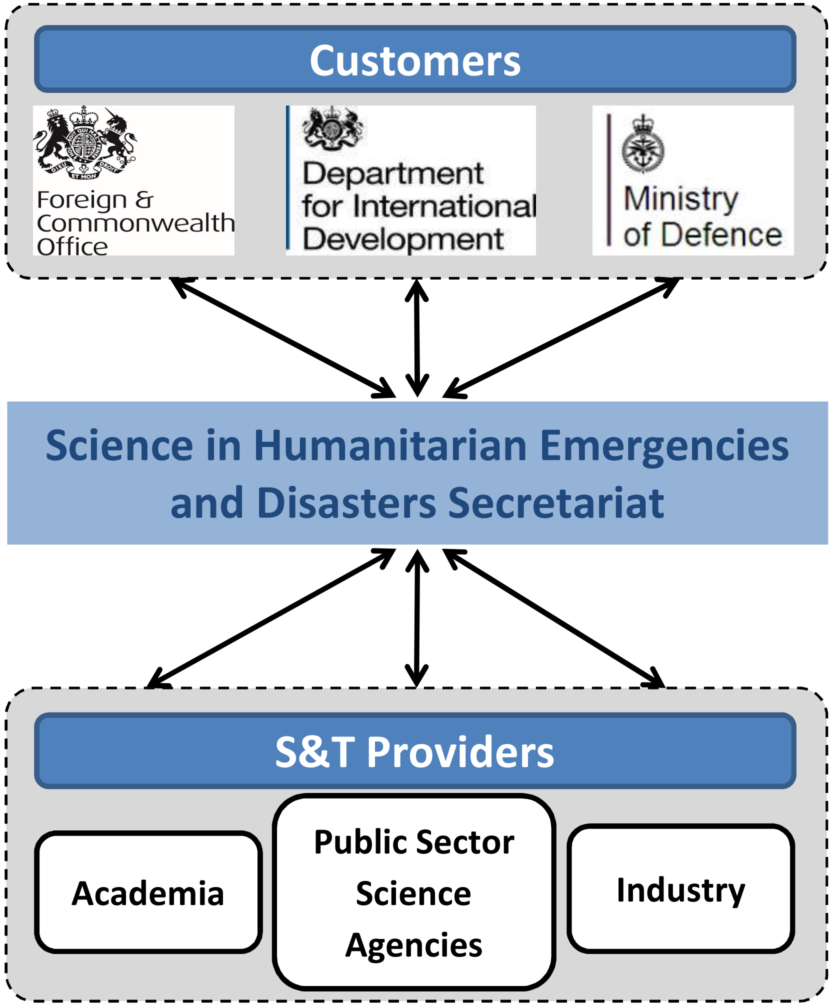


Humanitarian Emergency Response Review:

“If we are to meet the challenges ahead, we have to be ‘ahead of the curve’…preparing for disasters, as well as reacting to them”

“improve our use of science in both predicting and preparing for disasters, drawing on the Chief Scientific Advisors network across government.”

Responding to international emergencies



- Acts as a **coordinating body** and a **"one-stop-shop" for S&T advice** in emergencies when COBR not called.
- Coordinates the provision of **timely S&T advice to support the UK Government response to overseas emergencies**.
- **Facilitate interaction** between policy makers / crisis management teams and scientists.
- **Multi-disciplinary and multi-hazard approach.**

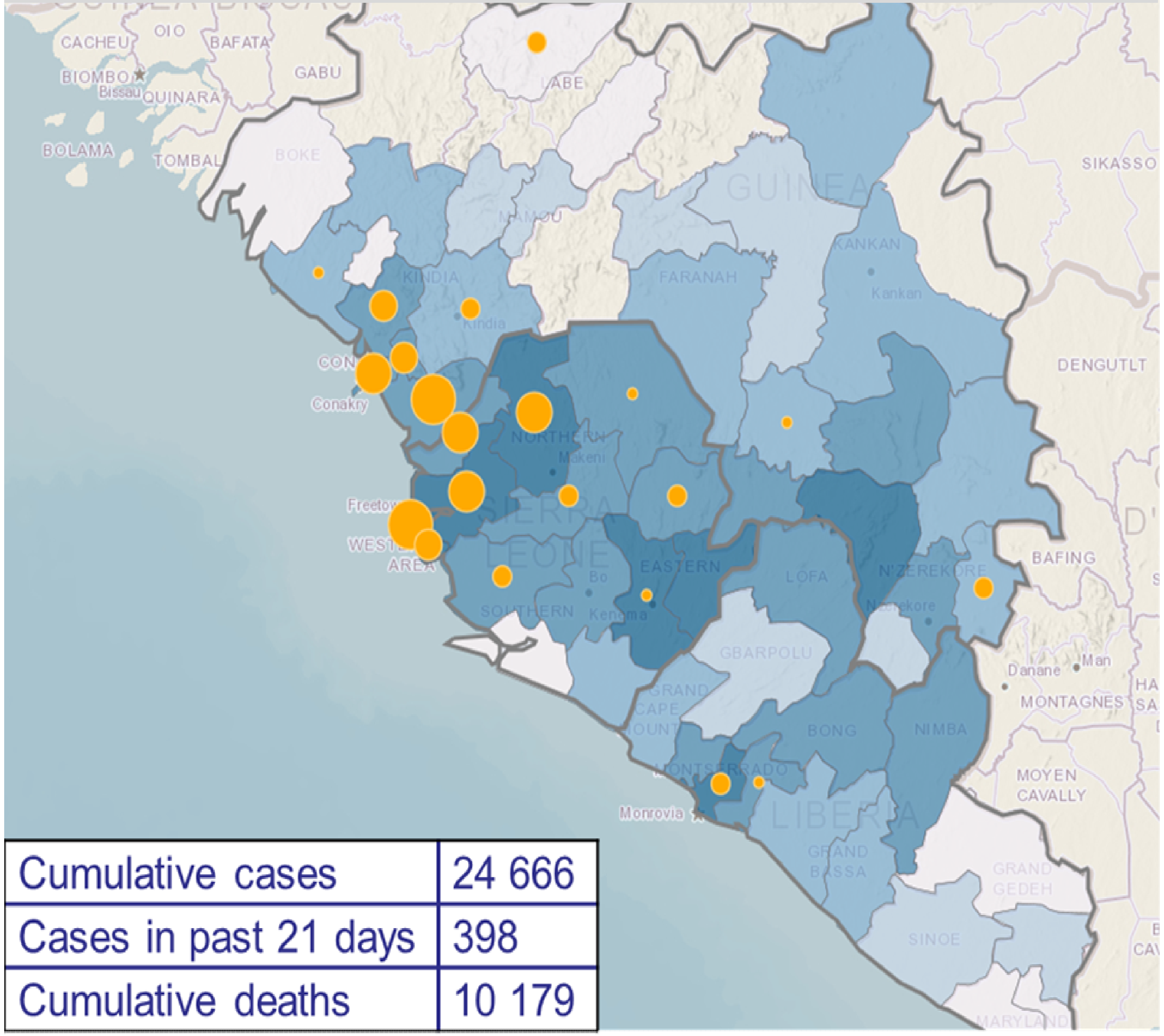
Government Office for Science

Help policy makers solve their problems: Dealing with an emergency

2014 Ebola Outbreak

- Modelling
- Risk to UK
- Screening
- Virus survival
- Vaccines
- What else can we do?

WHO Ebola Situation Report - 18 March 2015



Cumulative cases	24 666
Cases in past 21 days	398
Cumulative deaths	10 179

ONR: the UK Approach to Compliance Inspection

Purpose of Inspection

To provide assurance that the

- Duty holder's operations comply with the law and any limits and conditions identified in the nuclear safety case
- Arrangements and resources remain adequate to ensure sustained compliance
- Facility safety case remains valid.

UK Approach to Safety Regulation

All regulators aim to ensure operators properly control nuclear hazards and manage risk.

Many regulators set out rules telling operators how to do this – a ‘prescriptive’ approach.

UK instead has a ‘goal-setting’ approach, which makes it a legal duty to meet the safety goals, but does not set out in detail how operators should meet this duty, e.g. “reduce the risk to workers and the public so far as is reasonably practicable.”

SCIENTIFIC ADVICE:

TRANSNATIONAL CO-OPERATION AND EXCHANGE OF INFORMATION DURING CRISES

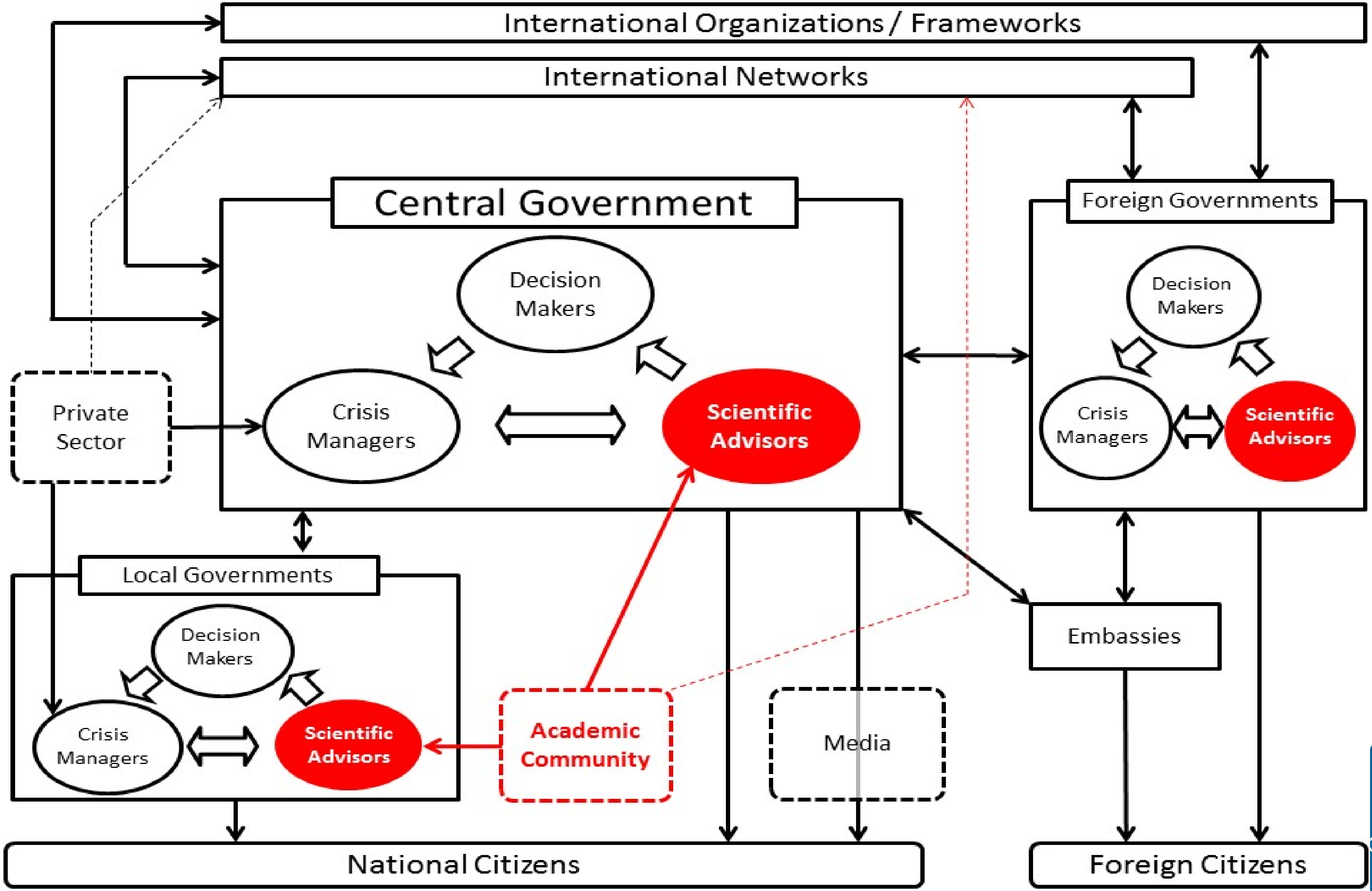
- KEY ISSUES AND POLICY RECOMMENDATIONS

Institutional mechanisms for scientific advice in crises

- **A breadth of institutional mechanisms** for scientific advice: centralized, distributed, mixed or temporary centralization

Distributed	Centralised
Activated via local crisis responders	Top down activation via central Government
Well adapted to federal decision-making systems	Rapid response at central Government level
Local ownership and legitimacy	Clear interface with central decision-makers
Multiple contact points	Single contact point
Redundancy and resilience	Efficiency versus single point of vulnerability
Cross-checking and reproducibility comparison	Central (exclusive) quality control
Local familiarity with issues	National consensus
International contact complex	International contact straightforward
Customised to a specific type of crisis	Inter-disciplinary
Flexible and independent	Planned and coordinated

Scientific advice ecosystem for transnational crises



Frameworks and networks

- **International frameworks** (bilateral, regional and global) are an important enabler for the **transnational exchange** of scientific data and information during crises.
- **Formal networks** often developed around frameworks.
- **Informal networks** can complement formal mechanisms, particularly in the early stages of a crisis.

Bilateral	Regional	Global
• Bilateral early notification treaties • Bilateral agreements for data exchange (e.g. Regensburg Treaty AT-DE on the exchange of hydrological data, joint water-commissions,…) • ……	• EU Early warning and information mechansims (EWS, ECURIE, RAS-BICHAT, CECIS) • ICG/PTWS (Intergovernmental Coordination Group for the Pacific Tsunami Warning and Mitigation System). • ……	• WMO Health Regulations • International Charter - Space and Major Disasters • ……

Barriers and challenges

1. Building capacity to produce, absorb and use scientific advice
2. Identifying institutions and contact points for co-operation
3. Quality assurance
4. Incentives and liabilities
5. Legal and Cultural barriers
6. Cross-sector communication and brokerage
7. Public communication and social media
8. Trust and mutual understanding

RECOMMENDATIONS

Recommendations (1)

Fostering domestic capacity for scientific advice in crises:

1. Where not already present, **national mechanisms for the provision of scientific advice in crises should be established**, in particular for sense-making in complex and novel crises.
2. Knowledge generated and **lessons learned** regarding scientific advice, during crises, including novel and complex events, need to be structured, recorded, systemised, preserved and disseminated.
3. The international community should **assist interested countries in developing their domestic systems** for providing and utilising scientific advice in crises.

Recommendations (2)

Enabling transnational scientific cooperation in crises: structures and frameworks:

4. Countries should identify, and share details of, domestic and international contact points.

5. Existing frameworks for the exchange of data and information during crises should be strengthened and new frameworks developed as necessary.

Recommendations (3)

Promoting mutual understanding and trust: people and networks:

6. Regular interactions and **building of mutual understanding between providers of scientific advice** (government scientists, academics, science advisors) **and crisis managers** should be encouraged at the national level.
7. **International science networks**, operating in areas of relevance to actual or potential, trans-national crises should be considered as potentially **part of the infrastructure for crisis response**.
8. Mechanisms to enable the **exchange and mobility of interested individuals from different institutional settings** and countries should be used to promote mutual understanding and trust.

Recommendations (4)

Being prepared:

9. **Regular drills and exercises** that bring together both crisis managers and those involved in providing scientific advice, should be encouraged and supported.

10. **Mutual-learning and training scenarios**, for novel, complex trans-national crises **should be developed**.

Recommendations (5)

Communicating with the public:

11. **The public communication** of scientific advice during crises should normally be **embedded in a broader crisis communication strategy**.
12. **Responsibility** for public communication of scientific advice in crisis response situations needs to be **clearly defined**.
13. **Further experimentation with the use of social media and on-line tools** for gathering and communicating information from, and to, the public during crises is required.