Responsible innovation and synthetic biology

Prof Phil Macnaghten
Knowledge, Technology and Innovation
Wageningen University (NL)

WAGENINGEN UR
For quality of life

1. What is ‘responsible innovation’ – and what is different about it?

2. Why is it important – and why in particular for synthetic biology?

3. Ways forward for science policy?

Defining Responsible Innovation

"Responsible Research and Innovation is a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view on the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products (in order to allow a proper embedding of scientific and technological advances in our society)"

(von Schomberg, 2011)

"taking care of the future through collective stewardship of science and innovation in the present"

(Stilgoe, Owen and Macnaghten 2012)

Responsible (research and) innovation: what is it?

- (How) can we steer the development of science and technology so that it meets widely shared societal goals?
- An old idea – but set within a new science and innovation policy context

Enlightenment dream of emancipation through science

What about the unexpected consequences?

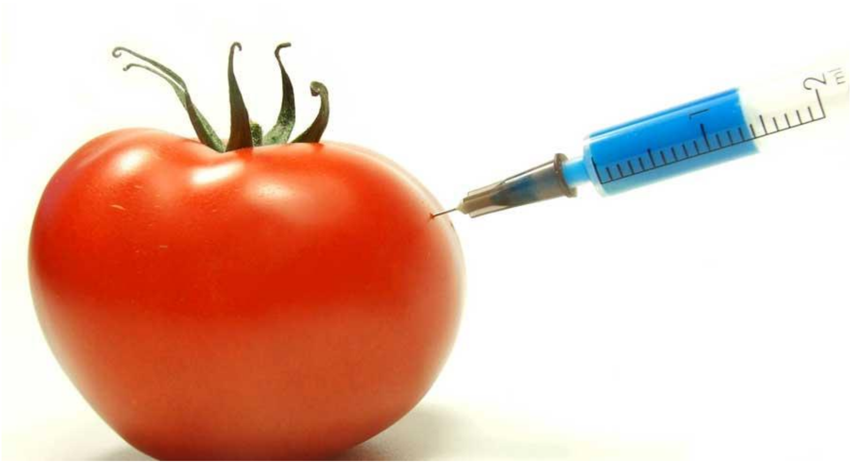
the more disruptive the science

the bigger the questions for society

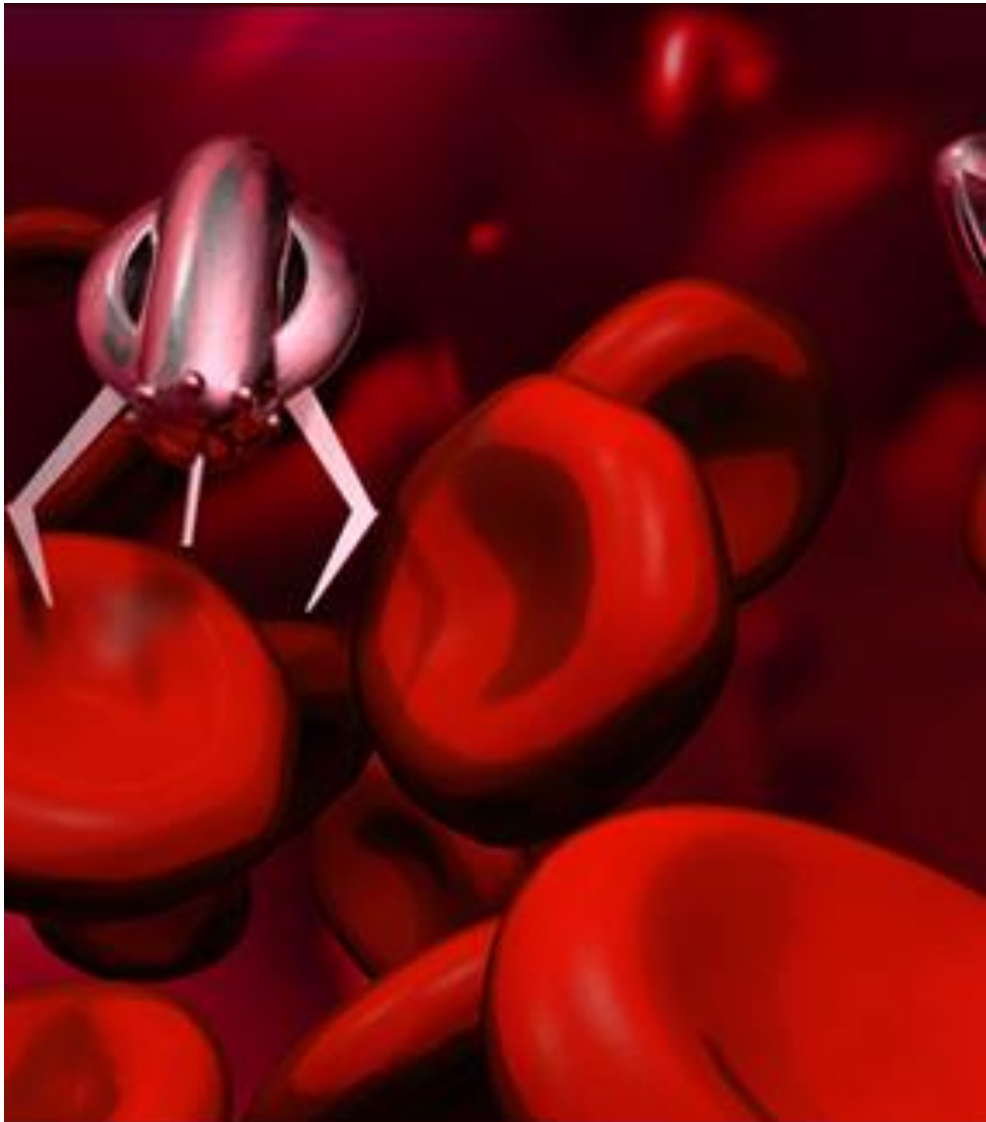
the more responsibility that is required

Nuclear technologies

Agricultural biotechnologies

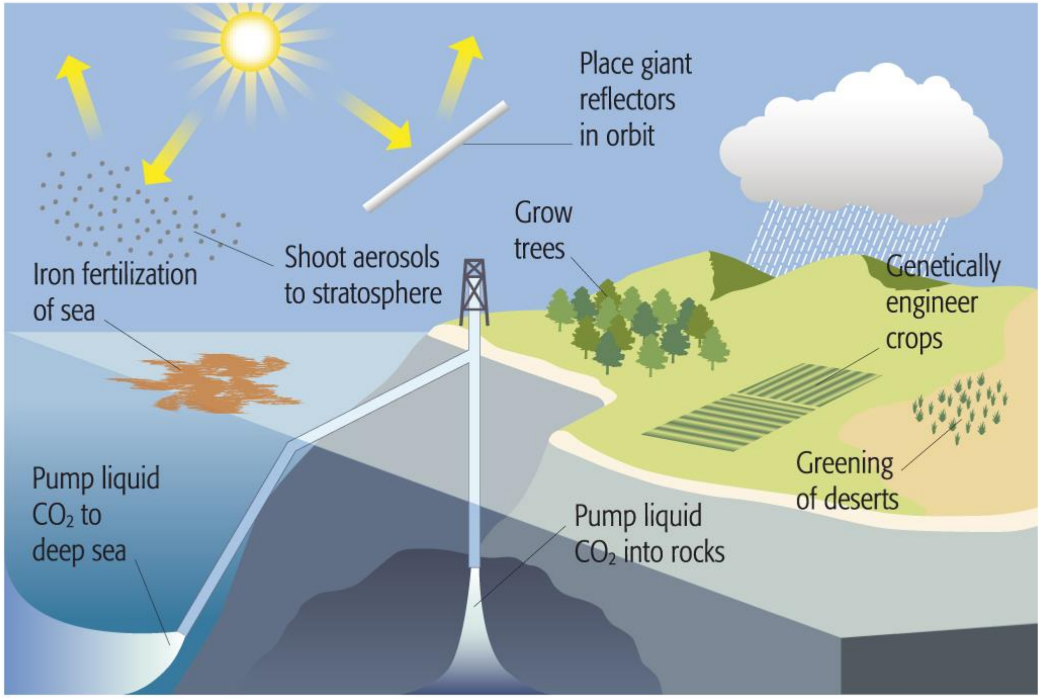


Nanotechnologies

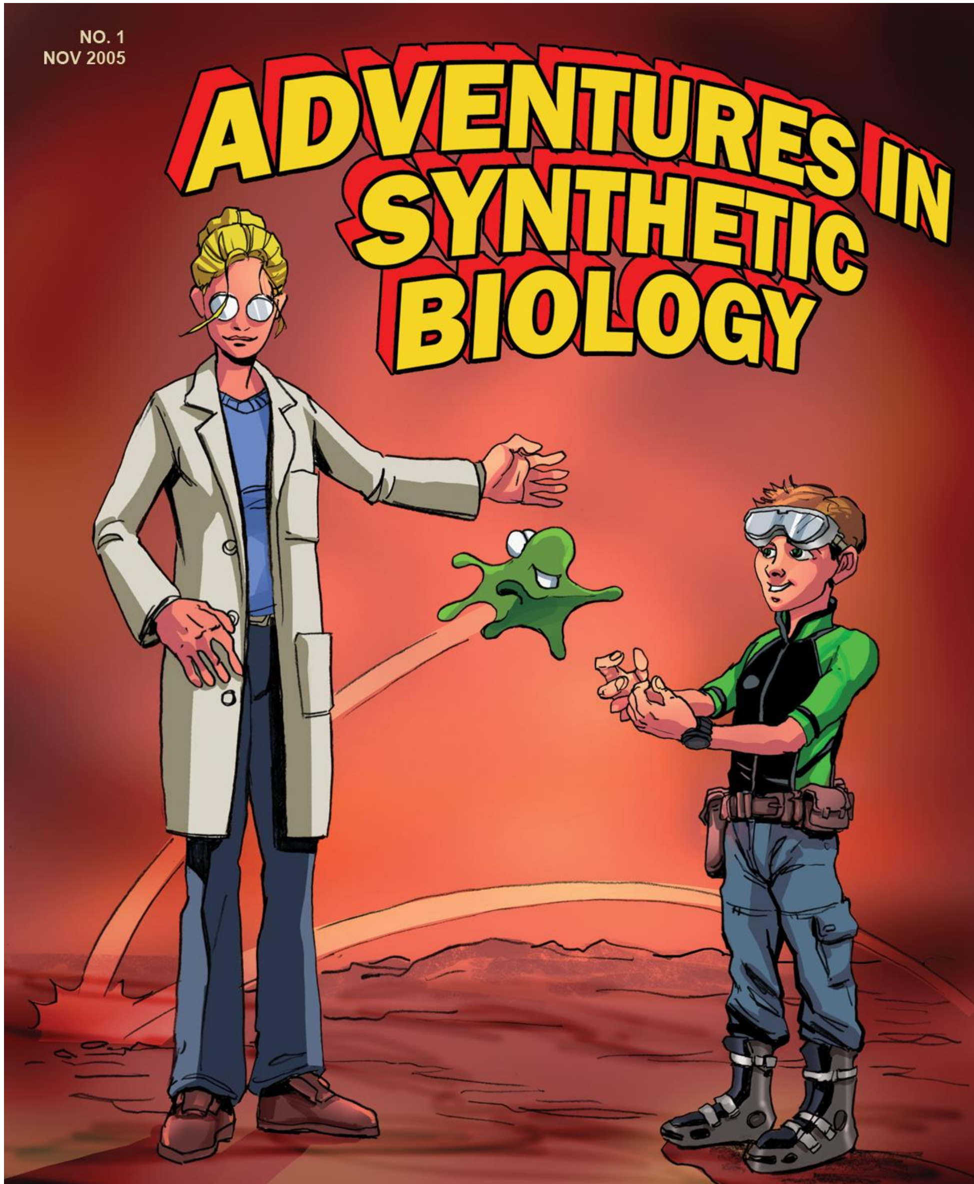


Climate engineering

GEOENGINEERING SOLUTIONS TO CLIMATE CHANGE



Synthetic biology



ESRC ECONOMIC & SOCIAL RESEARCH COUNCIL

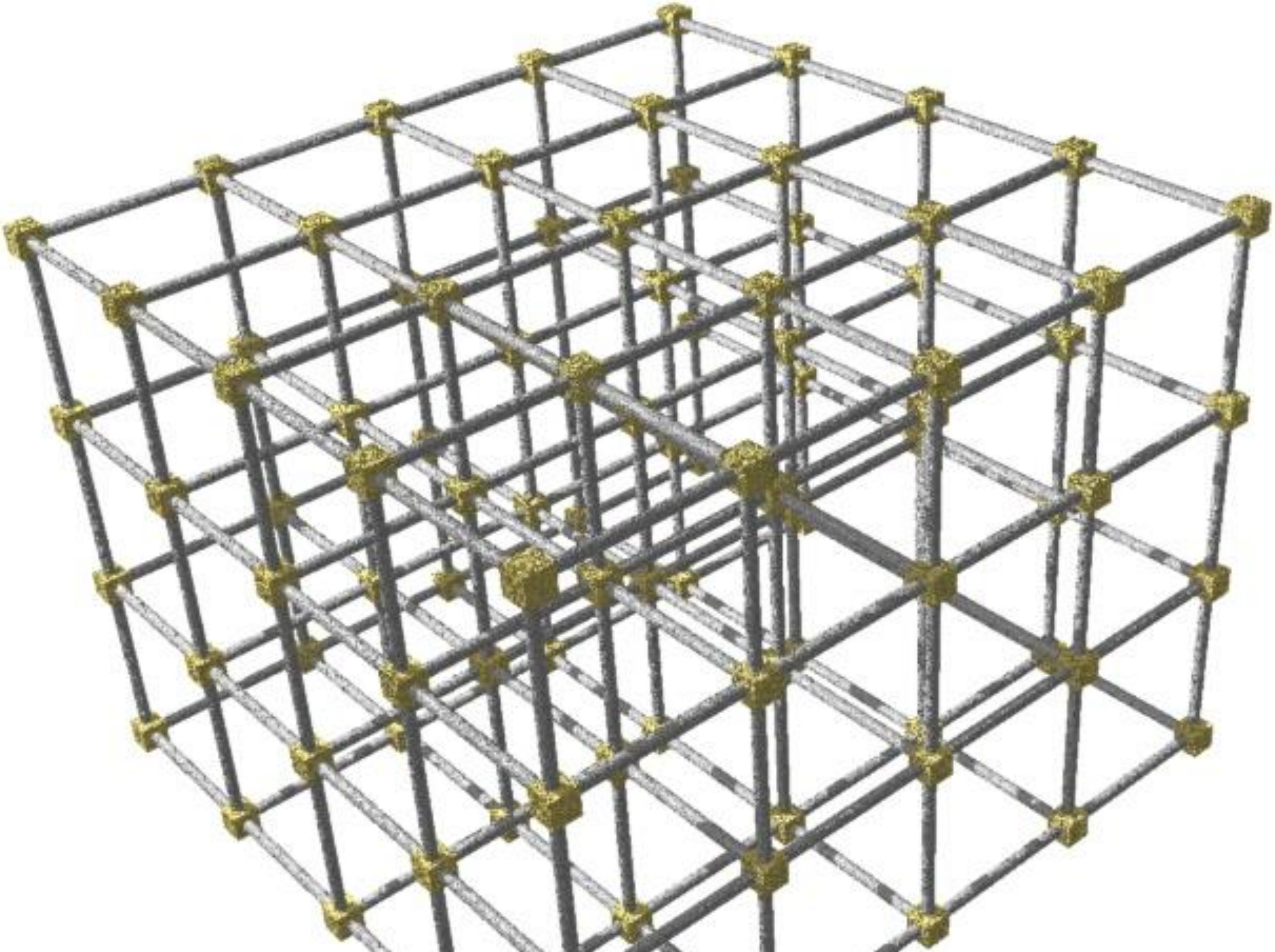
EPSRC Engineering and Physical Sciences Research Council

1. What is 'responsible innovation' – and what is different about it?

2. Why is it important – and why now?

3. What could it involve – and what is the role of Research Councils?

Objective: to build a framework for responsible science governance



Our approach:

Responsible innovation needs to respond to kinds of questions that publics typically ask of scientists and innovators, or would like to see scientists ask of themselves

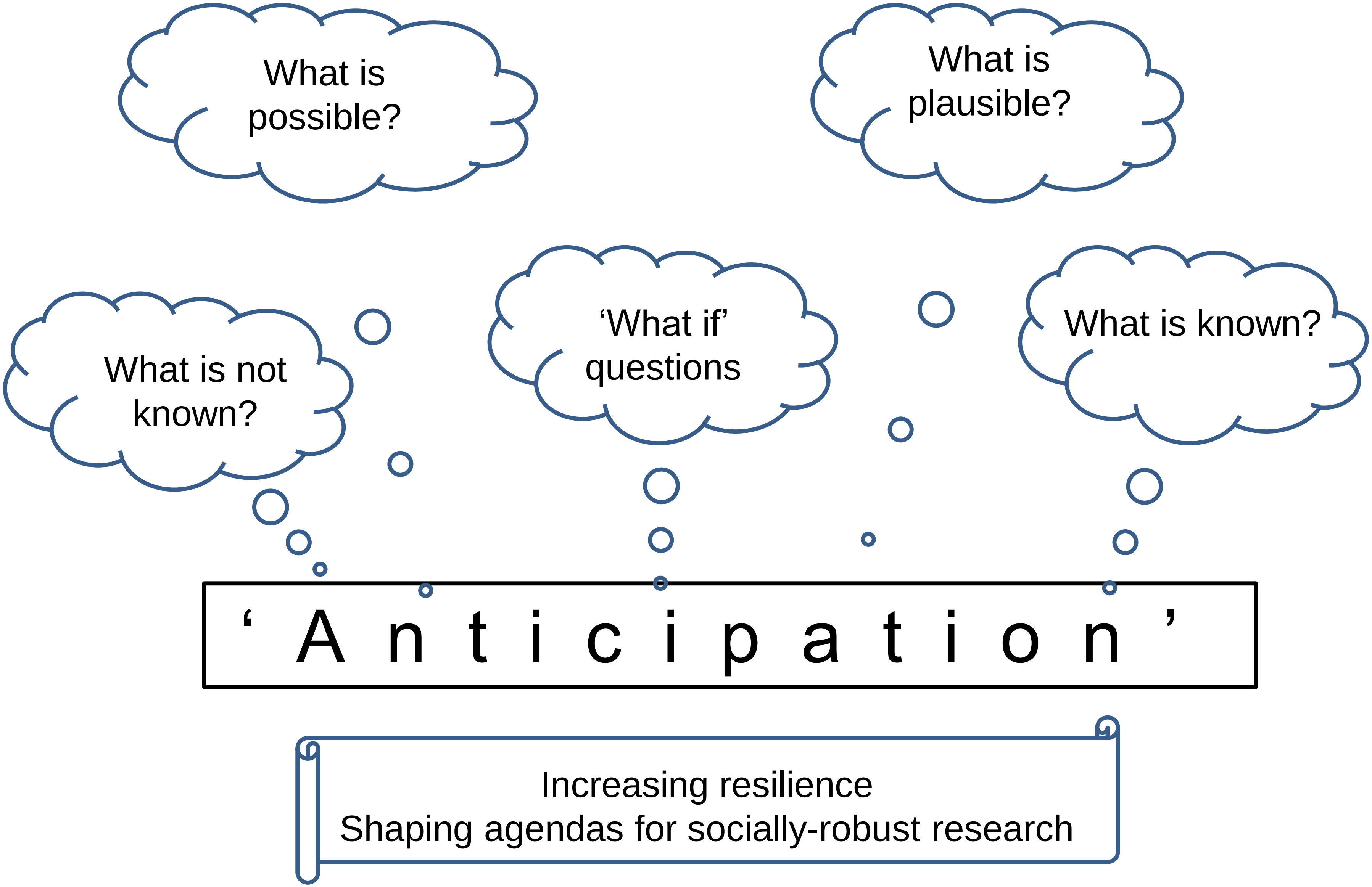
a. Purposes
b. Trust
c. Inclusion
d. Speed and direction
e. Ethics and trade-offs

Lines of questioning on responsibility (derived from public dialogues on new science and technology)

Product questions	*Process questions*	*Purpose questions*
What are the likely risks and benefits ?	How should research and innovation take place?	Why should this research be undertaken?
How will the risks and benefits be distributed ?	How should standards be drawn up and applied?	Why are researchers doing it?
What other impacts can we anticipate?	How should risks and benefits be defined and measured?	Are these motivations transparent and in the public interest?
How might these change in the future?	Who is in control?	Who will benefit?
What don't we know about?	Who is taking part?	What are they going to gain?
What might we never know about?	Who will take responsibility if things go wrong?	What are the alternatives?
	How do we know we are right?	

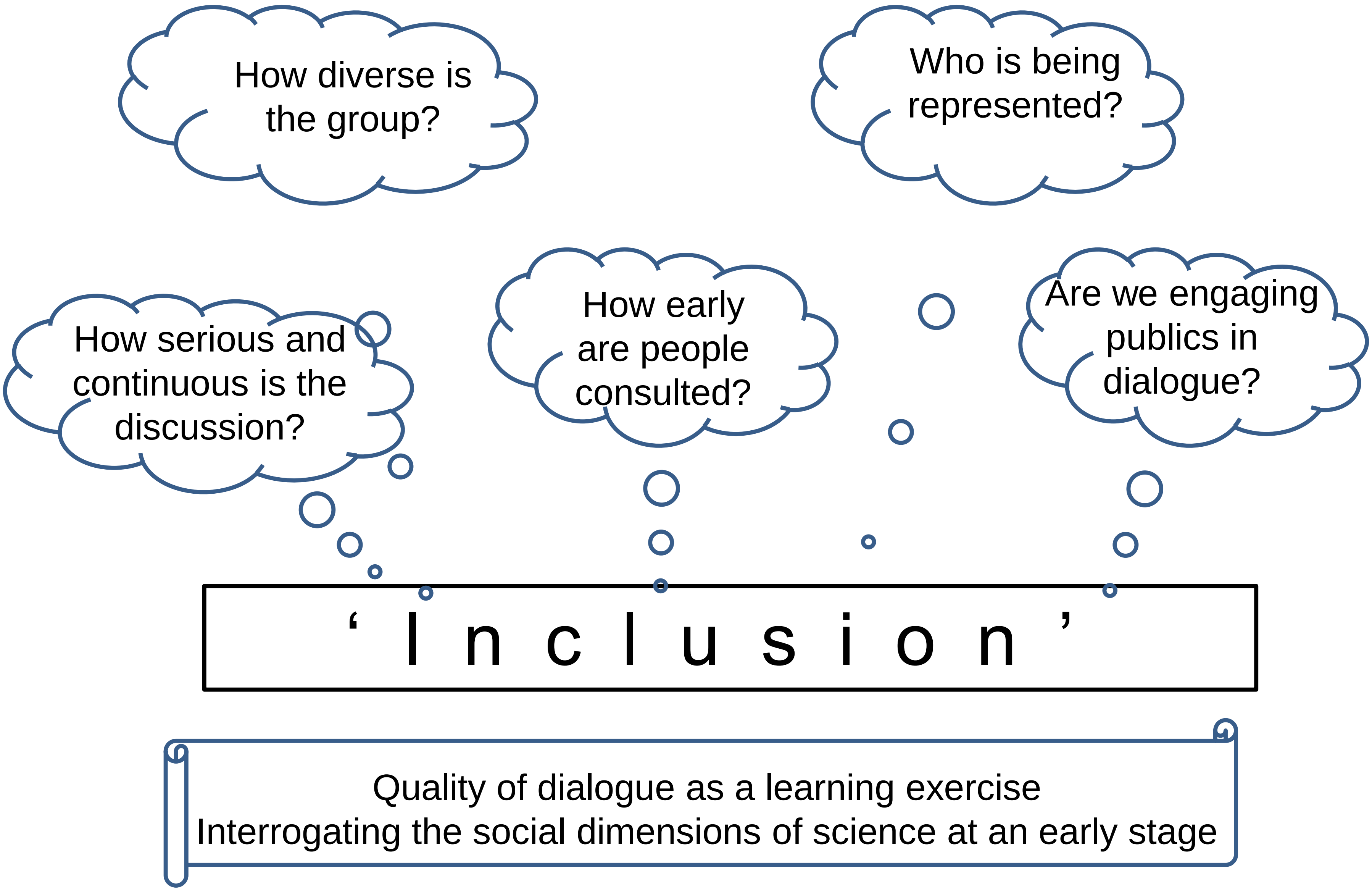

Anticipation
•From predictive to participatory
•Expectations and Imaginaries
•Tools
•Anticipatory Governance
•Vision assessment
•Scenarios
•Barriers to anticipation
•Guston, 2012; van Lente, 1993;
•Fortun, 2005; Barben et al, 2008
Inclusion
•The 'new' scientific governance
•Dialogue and 'mini-publics'
•The challenge of legitimacy
•Input and outputs
•Wilsdon and Willis, 2004; Grove-White et al, 1997;
•Goodin and Dryzek, 2006; Irwin et al, 2013;
• Lovbrand et al 2011
Responsible innovation
Reflexivity
•From 1st to 2nd order
•Tools
•Codes of conduct
•Midstream Modulation
•Wynne, 1993; Schuurbiers, 2011;
•Swiestra, 2009; Fisher et al, 2006
Responsiveness
•Answering and reacting
•Diversity and resilience
•Value-sensitive design
•De facto governance
•Political economy of innovation
•Responsibility as metagovernance
•Pellizoni, 2004; Collingridge, 1980; Friedman,
•1996; Stirling, 2007; Kearnes and Rip, 2009

Anticipation!

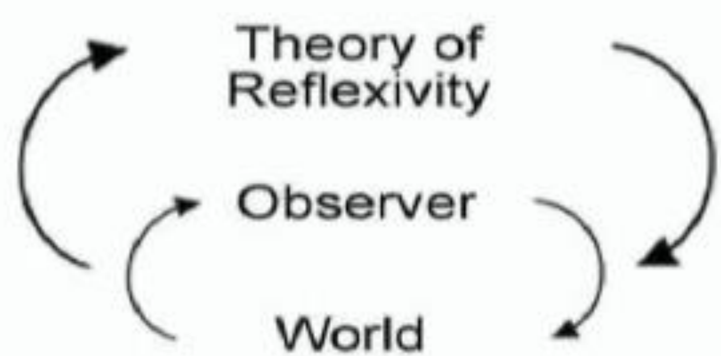

What is possible?
What is plausible?
What is not known?
'What if' questions
What is known?
'Anticipation'
Increasing resilience
Shaping agendas for socially-robust research

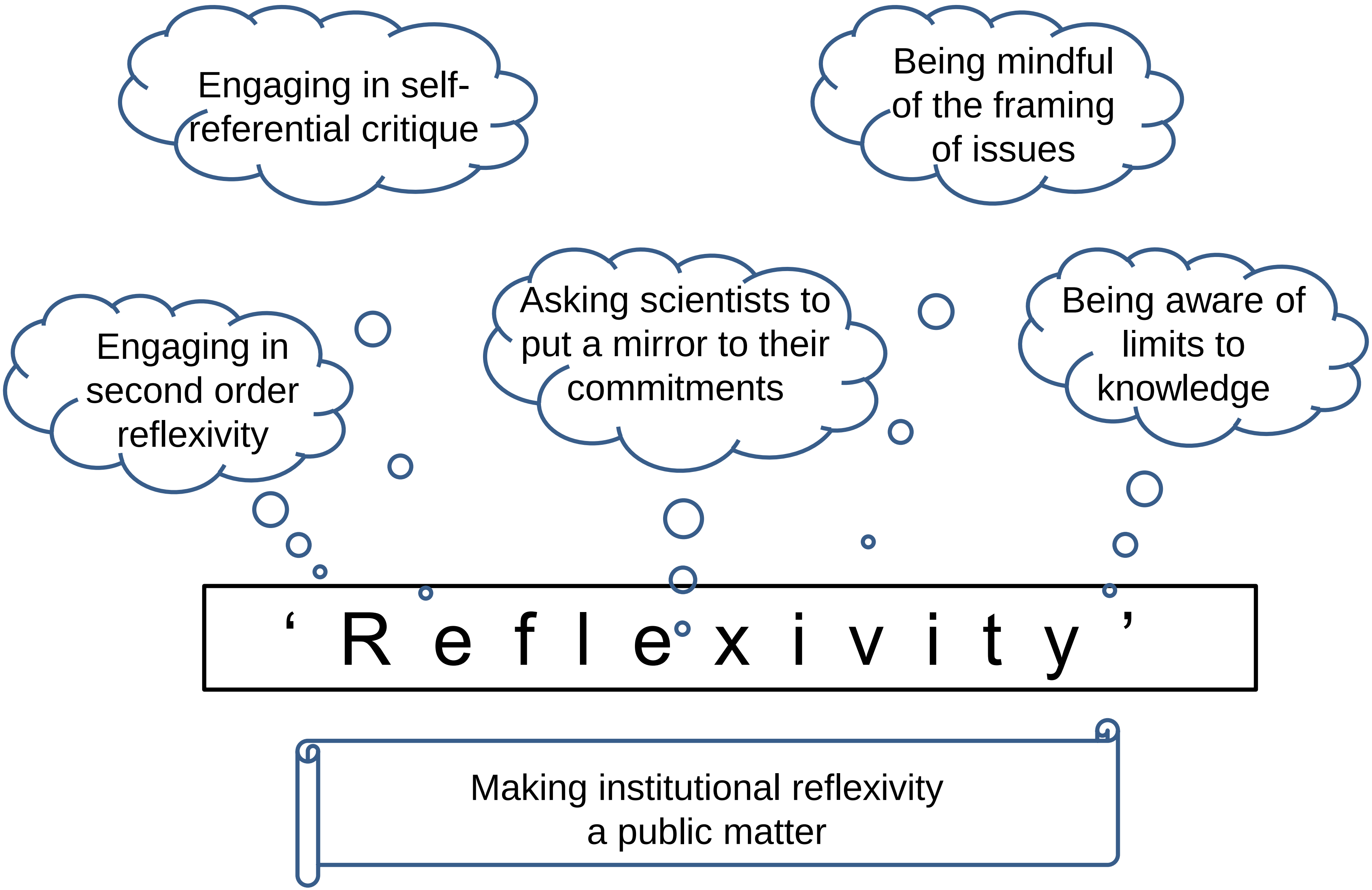
Dimension	Indicative techniques and approaches	Factors affecting implementation
Anticipation	Foresight	Engaging with existing imaginaries
	Technology assessment	Participation rather than prediction
	Horizon scanning	Plausibility
	Scenarios	Investment in scenario-building
	Vision assessment	Scientific autonomy and reluctance to anticipate
	Socio-literary techniques	


inclusion


How diverse is the group?
Who is being represented?
How serious and continuous is the discussion?
How early are people consulted?
Are we engaging publics in dialogue?
'Inclusion'
Quality of dialogue as a learning exercise
Interrogating the social dimensions of science at an early stage

Dimension	Indicative techniques and approaches	Factors affecting implementation
Inclusion	Consensus conferences Citizens' juries and panels Focus groups Science shops Deliberative mapping Deliberative polling Lay membership of expert bodies User-centred design Open innovation	Questionable legitimacy of deliberative exercises Need for clarity about, purposes of and motivation for dialogue Deliberation on framing assumptions Ability to consider power imbalances Ability to interrogate the social and ethical stakes associated with new science and technology Quality of dialogue as a learning exercise

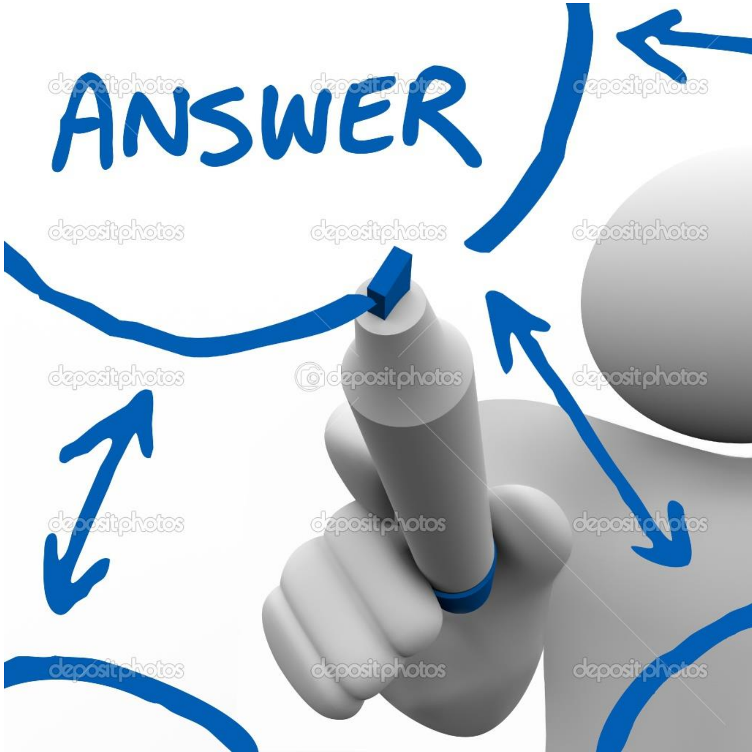

Theory of
Reflexivity
Observer
World

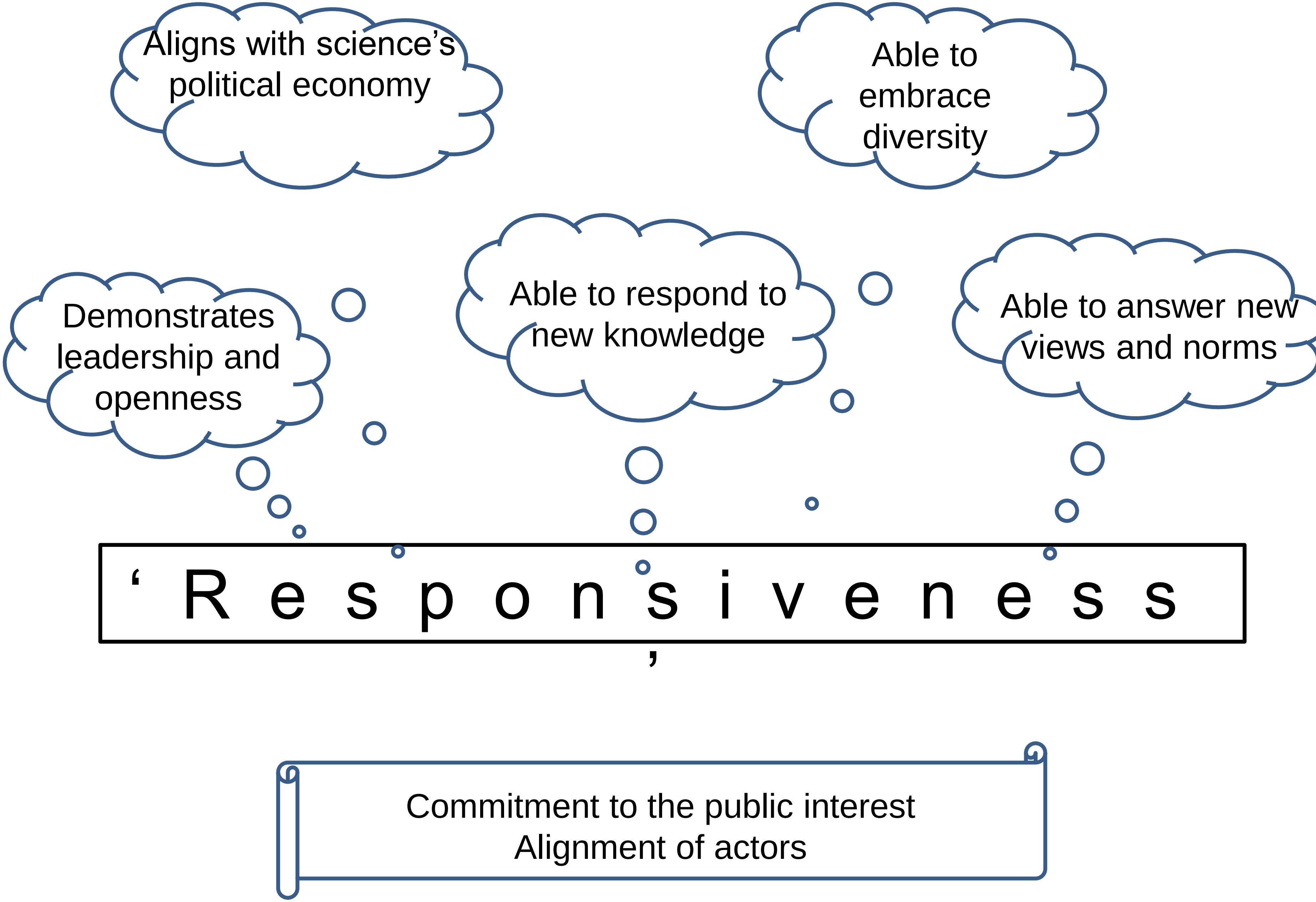

Engaging in self-referential critique
Being mindful of the framing of issues
Engaging in second order reflexivity
Asking scientists to put a mirror to their commitments
Being aware of limits to knowledge
'Reflexivity'
Making institutional reflexivity a public matter

Dimension	Indicative techniques and approaches	Factors affecting implementation
Reflexivity	Multidisciplinary collaboration and training Embedded social scientists and ethicists in laboratories Ethical technology assessment Codes of conduct Moratoriums	Rethinking moral division of labour Enlarging or redefining role responsibilities Reflexive capacity among scientists and within institutions Connections made between research practice and governance

RESPONSIVENESS

react




Aligns with science's political economy
Able to embrace diversity
Demonstrates leadership and openness
Able to respond to new knowledge
Able to answer new views and norms
'Responsiveness'
Commitment to the public interest
Alignment of actors

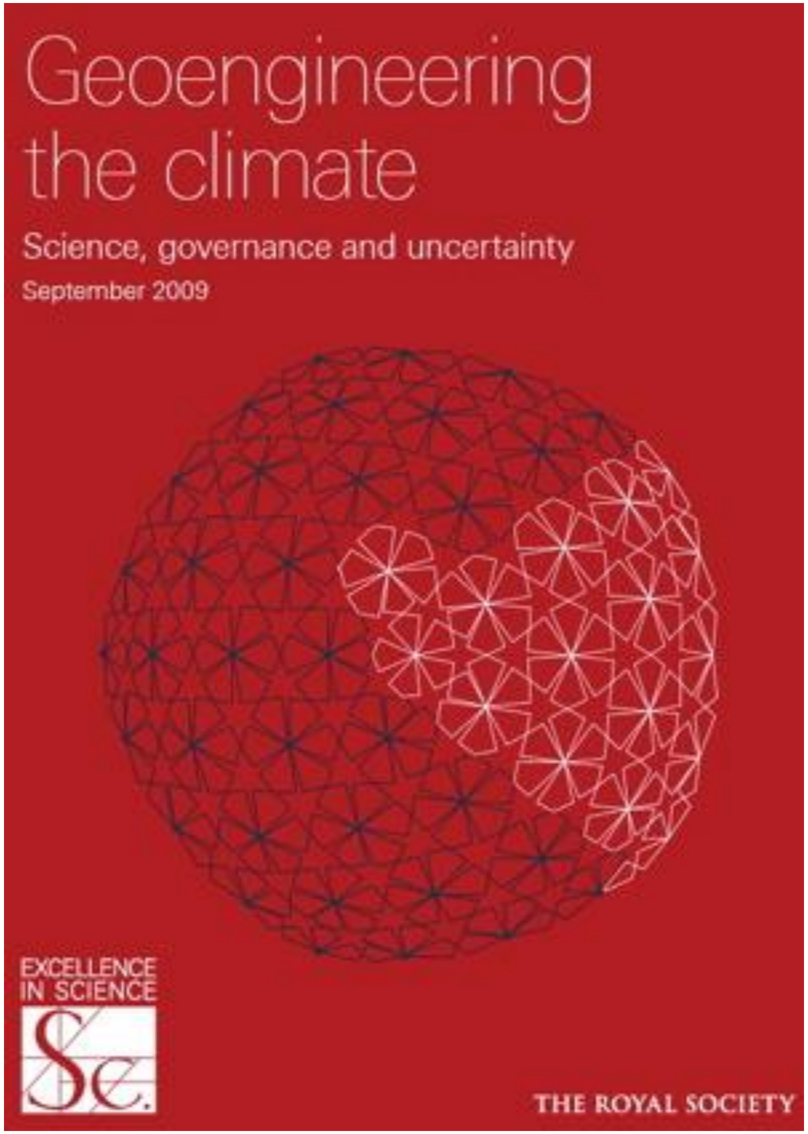
Dimension	Indicative techniques and approaches	Factors affecting implementation
Responsiveness	Constitution of grand challenges and thematic research programmes	Strategic policies and technology ‘roadmaps’
	Regulation	Science-policy culture
	Standards	Institutional structures
	Open access and other mechanisms of transparency	Institutional cultures
		Institutional leadership
	Niche management	Openness and transparency
	Value-sensitive design	Intellectual property regimes
	Provision of information	Technological standards
	Labelling	
	Moratoriums	
	Stage-gates	
	Alternative intellectual property regimes	
	New institutional structures and norms	

Responsible innovation in action

Climate Engineering

“Most nations now recognise the need to shift to a low-carbon economy…. But if such reductions achieve too little, too late, there will surely be pressure to consider a ‘plan B’ – to seek ways to counteract the climatic effects of greenhouse gas emissions by ‘geoengineering’.”
Lord Rees: foreword

“Key recommendations (Research)
Relevant UK government departments (DECC and DEFRA) in association with the UK Research Councils (BBSRC, ESRC, EPSRC, and NERC) should together fund a 10 year geoengineering research programme at a level of the order of £10M per annum.”



Climate Engineering:

CO_2 removal & Solar Radiation Management Approaches

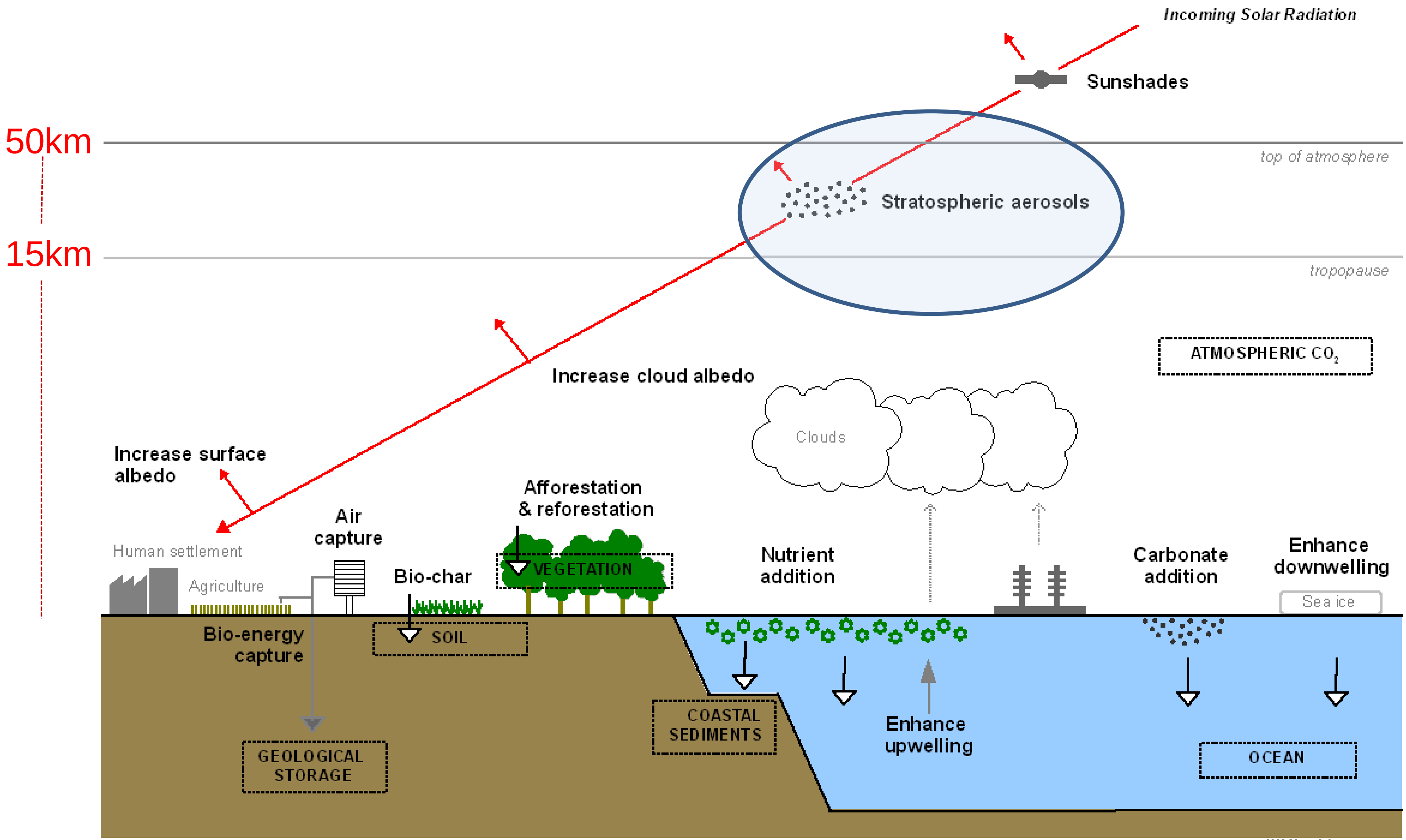


Fig courtesy of Nem Vaughan & Tim Lenton

The Stratospheric **P**article **I**njection for **C**limate **E**ngineering (SPICE) project

SPICE project: **S**tratospheric **P**article **I**njection for **C**limate **E**ngineering

EPSRC, NERC, STFC funding

Objective: to investigate the effectiveness of reflecting heat & light back into space using stratospheric particles.

Evaluating candidate particles: what would be an ‘ideal’ particle to inject into the stratosphere (maximizing solar radiation scattering while having minimal impact on climate, weather, ecosystems and human health).

Delivery Systems: feasibility and design of using a tethered-balloon to inject particles into the stratosphere. Use data from **the 1km high test-bed project** in computer models to investigate how a full-scale system might work at an altitude of 20km.

Climate and environmental modelling:
what can be learned from past volcanic eruptions. Also modelling the potential impact on ozone layer concentrations, regional precipitation changes and atmospheric chemistry.

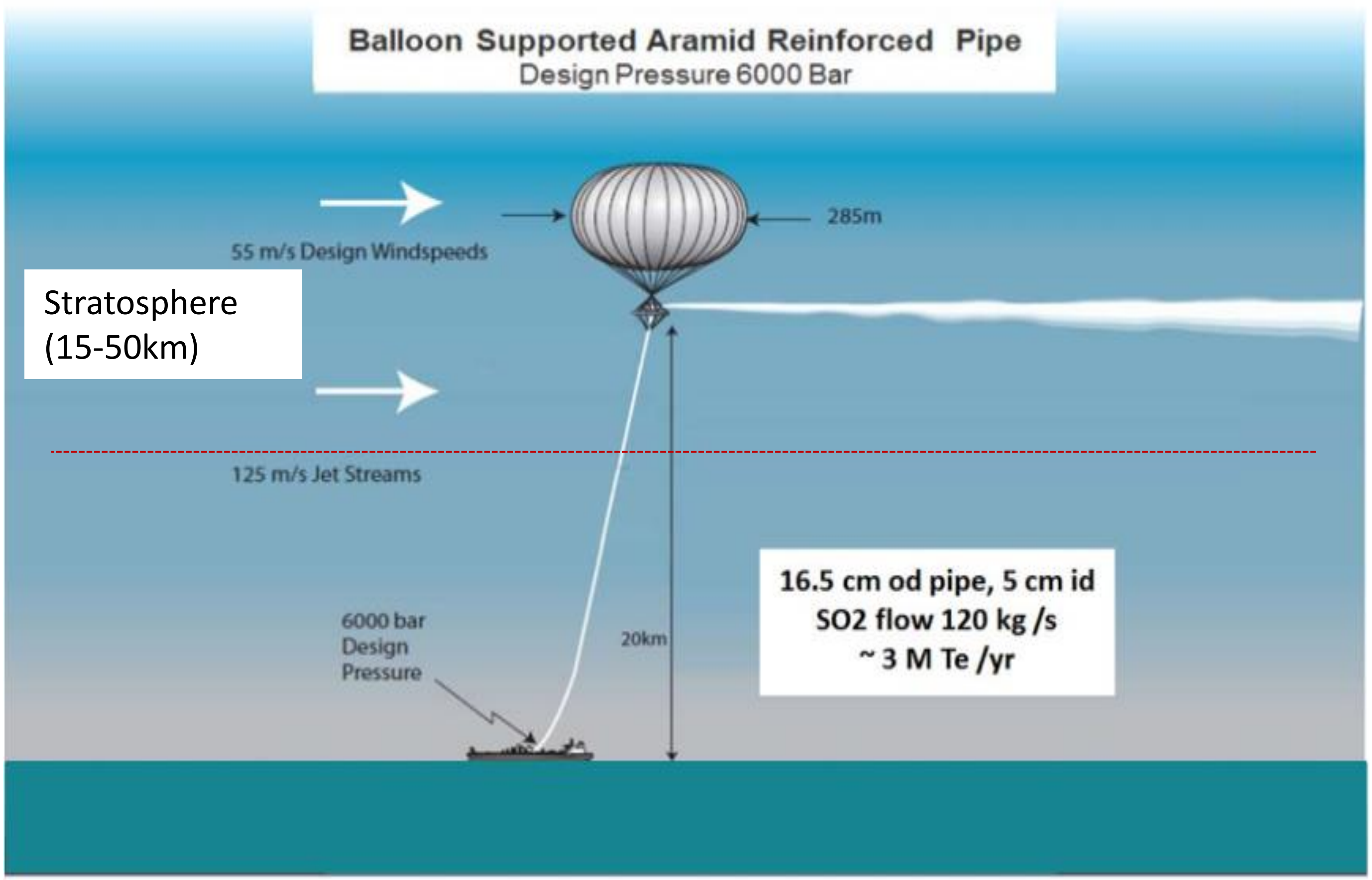


Fig courtesy of SPICE project team

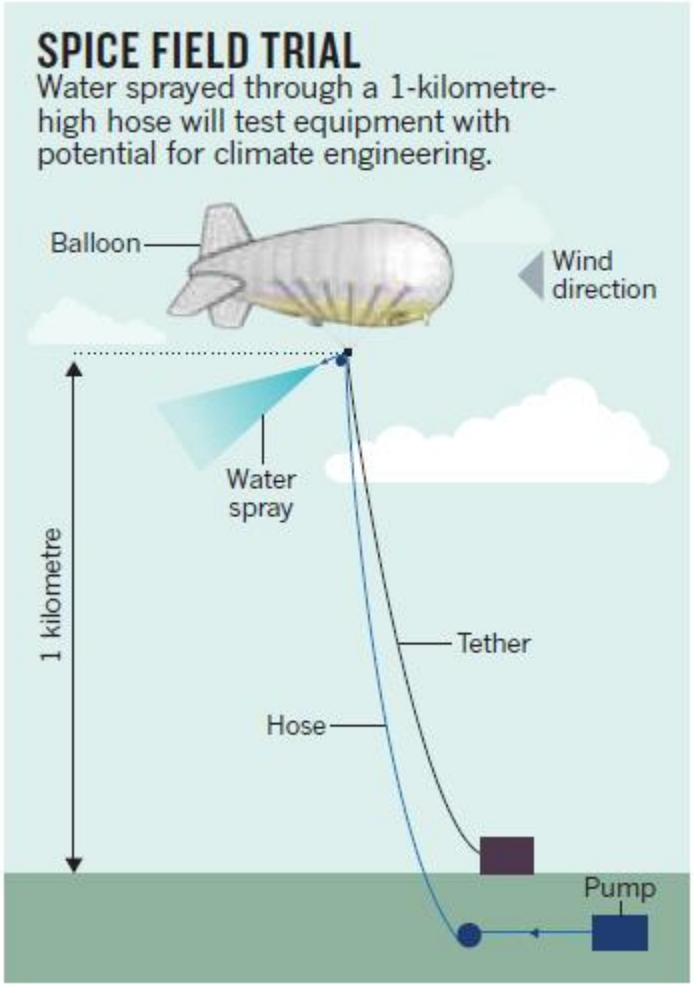


Figure Macnaghten and Owen, 2011

The Stakes:

A balloon 1 km high spraying water over Cambridgeshire

or

UK's 1st field trial of climate-engineering technology

Stage gating – oversight and governance

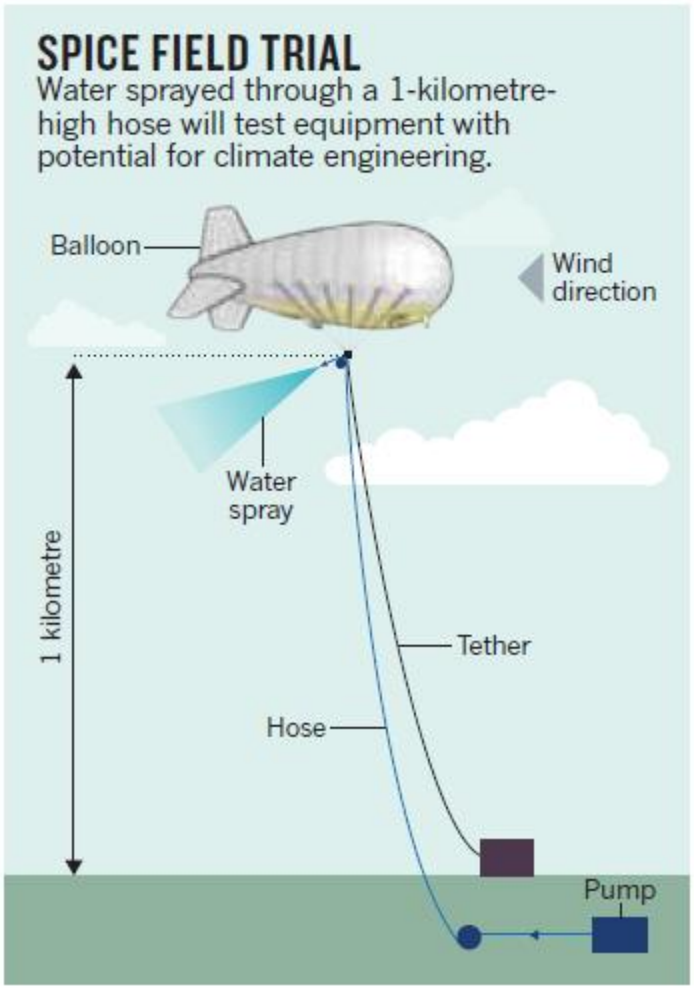
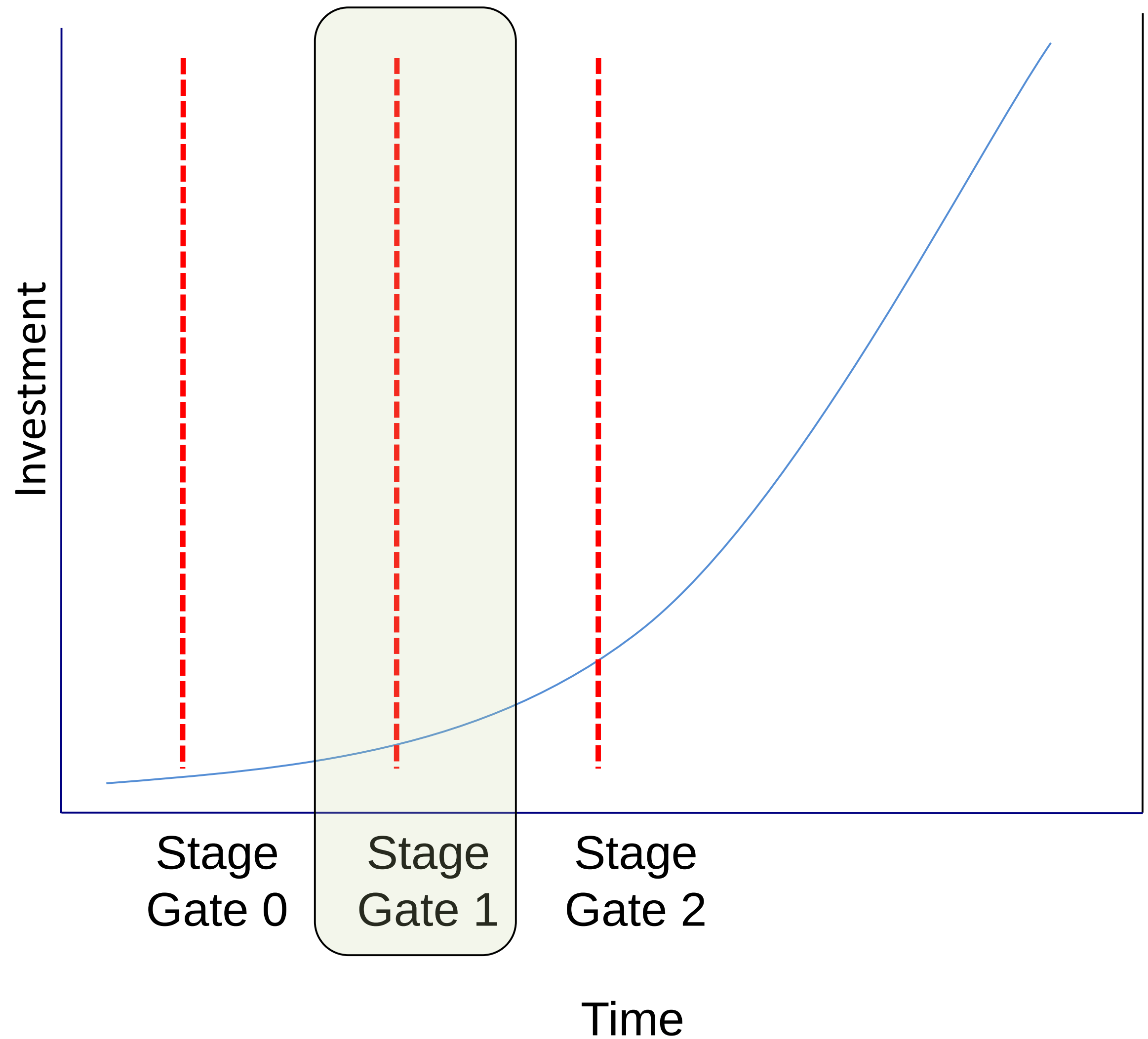


Figure Macnaghten and Owen, 2011



Responsible innovation (AIRR dimensions)

Anticipative
(describing and considering possible intended and unintended broad impacts)

↕

Inclusive
(deliberating with and involving stakeholders, users and wider publics)

↕

Reflexive
(reflecting upon embedded commitments and assumptions)

↕

Responsive
(answerable to outside questions and flexible enough to adjust)

||

Responsible Innovation

The Panel

- Aerospace engineer
- Atmospheric scientist
- Civil society actor
- 2 social scientists





Stage gating – oversight and governance

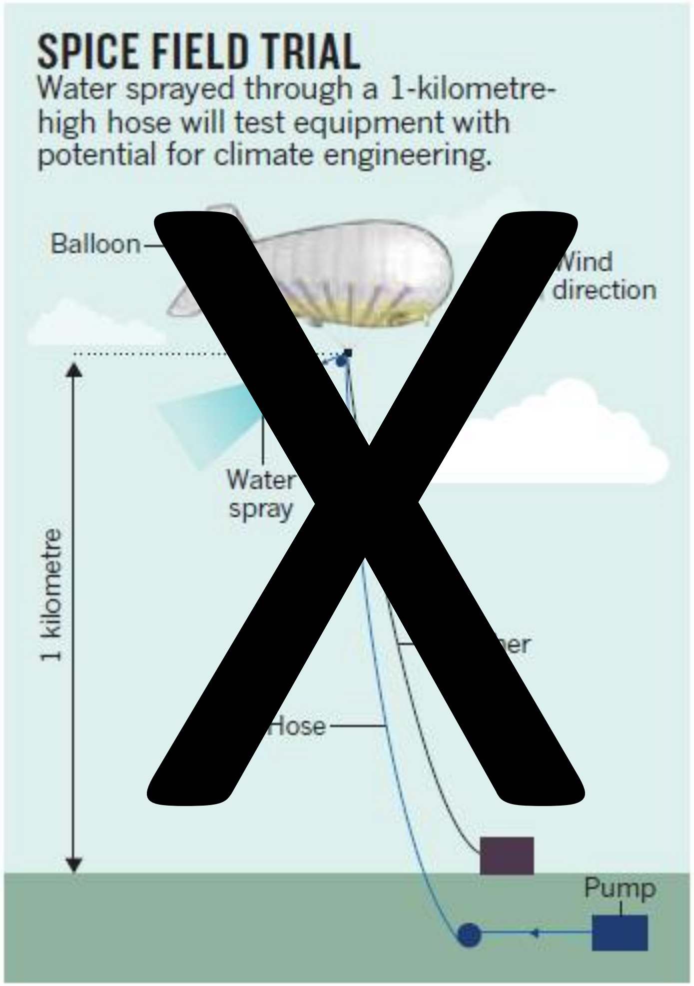
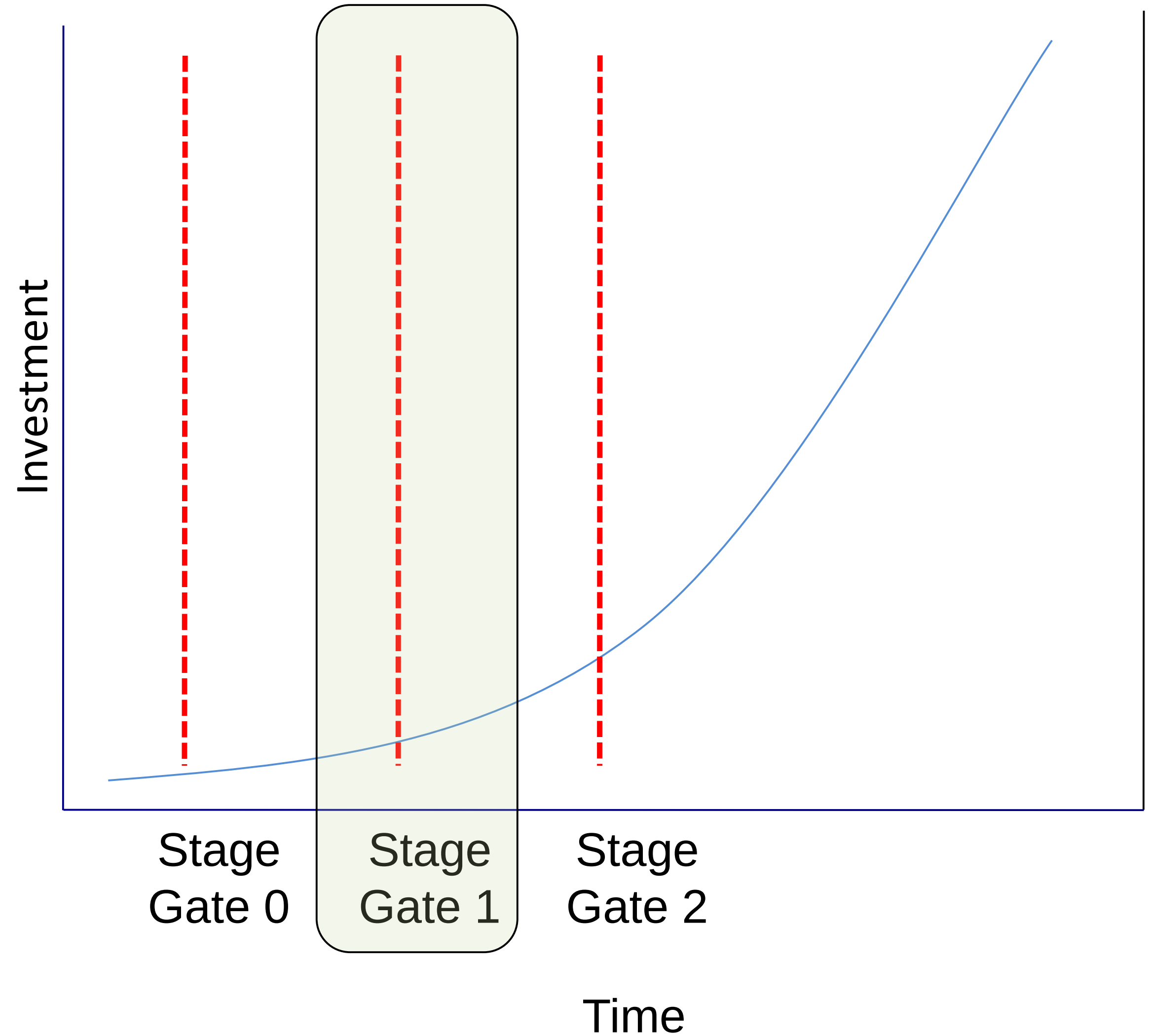


Figure Macnaghten and Owen, 2011




Stop Geoengineering!
Hands Off Mother Earth
Our home is not a laboratory

Want to mimic a volcano to combat global warming? Launch a Wembley-size balloon

Monster blimp would fire water into atmosphere

Scientists hope droplets can reflect the sun's heat

John Vidal
Environment editor

It sounds barmy, audacious or sci-fi: a tethered balloon the size of Wembley stadium suspended 20km above Earth, linked to the ground by a giant garden hose pumping hundreds of tonnes of minute chemical particles a day into the thin stratospheric air to reflect sunlight and cool the planet.

But a team of British academics will later this month formally announce the first step towards creating an artificial volcano by going ahead with the world's first major "geo-engineering" field test in the next few months. The ultimate aim is to mimic the cooling effect volcanoes have when they inject particles into the stratosphere that bounce some of the sun's energy back into space, so preventing it from warming the Earth and diminishing the effects of man-made climate change.

Before the full-sized system can be deployed, the research team will test a scaled-down version of the balloon-and-hose design. Backed by a £1.6m government grant and the Royal Society, the team will send a balloon to a height of 1km over an undisclosed location. It will pump nothing more than water into the air, but it will allow climate scientists and engineers to gauge the feasibility of the plan. Ultimately, they aim to test the impact of sulphates and other aerosol particles sprayed directly into the stratosphere.

If the technical problems posed by con-

Scientists hope to replicate the

So imagine how big a helium balloon you need to hold several double-decker buses

Good governance for geoengineering

Phil Macnaghten and **Richard Owen** describe the first attempt to govern a climate-engineering research project.

Climate-engineering research must have strong governance if it is to proceed safely, openly and responsibly[1,2]. But what this means in practice is not clear. The Stratospheric Particle Injection for Climate Engineering (SPICE) study demonstrates the difficult judgements involved. As chairman of the panel that supported decisions by the UK Engineering and Physical Sciences Research Council (EPSRC) as to whether and how this project should proceed (P.M.), and the architect of the project's governance process (R.O.), we draw lessons from these challenges.

In mid-September 2011, SPICE announced the go-ahead for the United Kingdom's first field trial of climate-engineering technology. SPICE aims to assess whether the injection of sulphur particles into the stratosphere would mimic the cooling effects of volcanic eruptions and provide a possible means to mitigate global warming. An equipment test — spraying water at a height of 1 kilometre — was proposed (see 'SPICE field trial'). No climate engineering would result from the test, but response to the announcement was dramatic, and the project was soon at the centre of a storm of criticism.

CAREFUL REVIEW

On 26 September 2011, the EPSRC, one of the study's main funders, postponed the trial after a review. Later the same day, the council received a letter and open petition[3], also sent to UK energy and climate-change secretary Chris Huhne and signed by more than 50 non-governmental organizations (NGOs) and civil-society organizations, demanding that the project be cancelled. The signatories saw the research as a first, unacceptable step towards a fix that would deflect political and scientific action away from reducing greenhouse-gas emissions. Others, by contrast, saw the research as urgently needed to find possible ways of coping with climate change[4]. The question at the heart of this debate was: should work in this controversial field proceed at all, and if so, under what conditions?

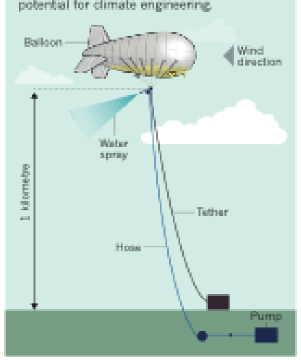
The strong feelings about the first test of SPICE's equipment show how important it is to have robust governance, and for scientists and funders to ensure that the public and other parties are consulted at the earliest opportunity. This is an unfamiliar and difficult process, but it is crucial for the evaluation of climate-engineering approaches.

SPICE was conceived in March 2010 at an EPSRC interdisciplinary workshop, at which researchers were invited to develop innovative geoengineering proposals. The project's funding incorporated field testing, but release of money was conditional upon it passing a 'stage-gate' review — a governance process in which funding for each phase of research and development is preceded by a decision point. To pass the review, SPICE scientists were required to reflect on the wider risks, uncertainties and impacts surrounding the test and the geoengineering technique to which it could lead — solar-radiation management.

On 15 June 2011, the stage-gate panel (including atmospheric scientists, engineers and social scientists, as well as an adviser to an environmental NGO) evaluated the SPICE team's response to five criteria for responsible innovation. These were that: the test-bed deployment was safe and principal risks had been identified, managed and deemed acceptable; the test-bed deployment was compliant with relevant regulations; the nature and purpose of SPICE would be clearly communicated to all relevant parties to inform and promote balanced discussion; future applications and impacts had been described, and mechanisms put in place to review these in the light of new information; and mechanisms had been identified to understand public and stakeholder views regarding the predicted applications and impacts.

SPICE FIELD TRIAL

Water sprayed through a 1-kilometre-high hose will test equipment with potential for climate engineering.



Recognizing the efforts of the SPICE team, the panel concluded that although the first two criteria had been met, more was required on the remaining three. It asked the team to develop a revised communications plan to inform further public debate, a review of the risks and uncertainties of solar-radiation management — including social, ethical, legal and political dimensions — and a thorough process of engagement with stakeholders.

The test bed was delayed by EPSRC in September to allow the team to undertake these outstanding actions. When the panel reconvenes, it will independently assess a revised response; until then, the project remains under review.

LESSONS LEARNED

Aspects of SPICE's governance could have been improved. The framework should have been in place before the project's conception; the test date should not have been announced until the stage-gate criteria had been met; and the structures and resources to support the social research should have been in place earlier. Even now, the decision on whether to proceed will not be easy. There are few right or wrong answers to the many questions about climate engineering. But it is vital that we make space to listen to and discuss these questions, and that the debate transparently influences the decisions that are taken.

For geoengineering technology to progress, its developers must be mindful of wider impacts from the outset; and it must proceed under robust governance mechanisms. The SPICE responsible-innovation framework is one evolving approach to achieving it. ■

Phil Macnaghten *is professor of geography at Durham University, UK.* **Richard Owen** *is chair in responsible innovation at the University of Exeter Business School, UK.*
e-mail: p.m.macnaghten@durham.ac.uk
R.J.Owen@exeter.ac.uk

1. Royal Society working group *Geoengineering the Climate: Science, Governance and Uncertainty* (Royal Society, 2009) available at http://go.nature.com/zxpwun
2. Rayner, S., Redgwell, C., Savulescu, J., Pidgeon, N. & Kruger, T. *Memorandum on Draft Principles for the Conduct of Geoengineering Research* (House of Commons Science and Technology Committee Enquiry into The Regulation of Geoengineering; 2009).
3. http://www.handsoffmotherearth.org/hose-experiment/spice-opposition-letter/
4. Nurse, P. Letter to *The Guardian* 8 September 2011 available at http://go.nature.com/efnybg

Responsible innovation is not

Responsible innovation is <u>not</u>

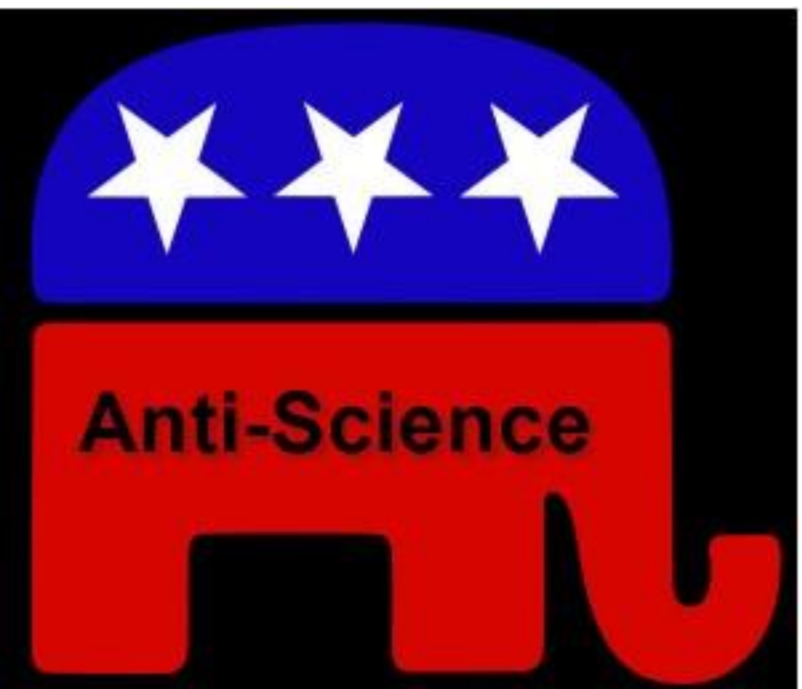
Responsible innovation is <u>not</u>

Scientists

Social scientists & ethicists

Responsible innovation is <u>not</u>

Responsible innovation is not




THE WAY
FORWARD

Embedding these kinds of questions into scientific practice and science policy

Product questions	*Process questions*	*Purpose questions*
What are the likely risks and benefits ?	How should research and innovation take place?	Why should this research be undertaken?
How will the risks and benefits be distributed ?	How should standards be drawn up and applied?	Why are researchers doing it?
What other impacts can we anticipate?	How should risks and benefits be defined and measured?	Are these motivations transparent and in the public interest?
How might these change in the future?	Who is in control?	Who will benefit?
What don't we know about?	Who is taking part?	What are they going to gain?
What might we never know about?	Who will take responsibility if things go wrong?	What are the alternatives?
	How do we know we are right?	

Training and courses

Embedding social science and ethics in the lab

Co-design at the ‘upstream’ stage

Impacting on science policy

Changing the culture of science