

# **Emerging Technologies & Innovation Systems Change: Introduction & Key Concepts**

**Philip Shapira**

Manchester Institute of Innovation Research  
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Email: [pshapira@mbs.ac.uk](mailto:pshapira@mbs.ac.uk) | Twitter: [@philipshapira](https://twitter.com/philipshapira)

# Emerging Technologies & Innovation Systems Change: Introduction & Key Concepts

- 1. Introduction:** to the Summer School
- 2. Key Concepts:** Emerging Technologies & Innovation Systems
- 3. Opportunities & Challenges:** Questions and issues related to the promise and challenges of emerging technologies (Monday)

# Introduction to the Summer School

## Objectives

1. **Enhance understanding of concepts** of real-time research and innovation systems assessment and innovation policy development for transformative emerging technologies.
2. **Enhance capabilities** to conceptualize and use advanced methods of analysis to probe and anticipate research and innovation trajectories and their outcomes
3. **Advance strategies for linking research** questions, methods, and results with broader concerns related to research, management, and policy in emerging and convergent technology domains including science networking, commercialization, and responsible research and innovation.
4. **Examine economic, societal and policy implications** of emerging technologies in (1) advanced economies and in (2) rising power economies such as Brazil, Russia, India, China, and South Africa

# Key Concepts

- Technology
- High Technology (High Tech) & Emerging Technology
- Innovation
- Entrepreneur
- Innovation Systems
- Technology Assessment
- Responsible Research and Innovation

# What is Technology?

## Different perspectives on “technology”

- Technology as *artefact* (e.g. jet engine, TV, computer)
- Technology as *knowledge*
  - Codified (e.g. a patent or a drawing)
  - Tacit (e.g. the know-how of a scientist or engineer)
- Technology in a *socio-technical* organizational perspective:
  - Inter-relationships between people, organizations, and technology (including organizational structures, procedures, knowledge)
- Technology as *capability* (e.g. Sony’s capabilities based on its pioneering use of transistors in radios).

# High Technology

- **High Technology (High Tech) (c. 1957)**
  - Industries using advanced or leading-edge technologies
    - Expectation of high growth (enterprise formation, sales, jobs)
  - Often defined as those industries with
    - Above average science and technology personnel
    - Above average R&D spending
  - Results in a “product-based” focus
    - Note: There are other forms of technological innovation
  - Distinction between high-tech sectors and high tech-occupation
    - High-tech sectors - relatively small part of the economy
    - High-tech occupations – more widely distributed

# Emerging Technology

- An emerging technology offers major new capabilities or functions when compared with conventional (current) technology.
- Often claimed to have revolutionary or transformative economic and societal impacts and targeted to societal grand challenges.
- Current examples include: nanotechnology, synthetic biology, digital manufacturing, advanced neuroscience, geo-engineering.
- More likely to raise significant concerns about ethics, environmental health and safety, economic displacement, equity, and other societal impacts.

# What is Innovation?

- Innovation is a process of turning opportunity into new ideas and putting these into widely used practice.
- Distinguish between *invention* and *innovation*.
- Invention: an idea, sketch or model for a new or improved device, product, process or system.
- Innovation implies a application, use, or commercialization.
- Innovation often uses new and emerging technologies, but there is also non-technological innovation (in business models, social innovation).
- Types of innovation: continuous & incremental v. disruptive or radical innovation.



# Innovation & Entrepreneurship

- **Innovation**

- The introduction of novelties; the alteration of what is established by the introduction of new elements or forms (C16) (OED).

- **1596** [SHAKES.](#) *1 Hen. IV*, V. i. 78 Poore Discontents,  
Which gape, and rub the Elbow at the newes Of hurly  
burly Innouation

- **Entrepreneur**

- One who undertakes an enterprise; one who owns and manages a business; a person who takes the risk of profit or loss (C19) (OED).

# Entrepreneurial Innovation

## Schumpeter (1934)

- Introduction of a new good
- New method of production
- Opening of a new market
- Development of a new source of supply of raw materials or half-manufactured goods
- New organization of an industry

Schumpeter, J. (1934) The Theory of Economic Development

# OECD Definition (2005)

An **innovation** is the implementation of:


c.f. "invention"

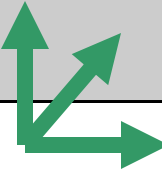
- New or significantly improved
  - Products (goods or services)
  - Processes
- A new marketing method
- A new organizational method in
  - Business practices
  - Workplace organization
  - External relations

c.f. earlier OECD definitions

# Innovation Spectrum

## INNOVATION FORM

INNOVATION FOCUS 	<b>Physical</b> (material, hard)		<b>Immaterial</b> (organizational, soft)	
<b>Process</b>	<b>Process innovations</b> <ul style="list-style-type: none"> <li>Improved technologies in manufacturing process, use of informatics</li> </ul>	<b>Organizational innovations</b> <ul style="list-style-type: none"> <li>New production concepts, teamwork</li> <li>Networking, supply-chain management</li> </ul>		
<b>Product</b>	<b>Product innovations</b> <ul style="list-style-type: none"> <li>R&amp;D based innovations in new or improved products</li> </ul>	<b>Service innovations</b> <ul style="list-style-type: none"> <li>Value-added services to support products</li> </ul>		

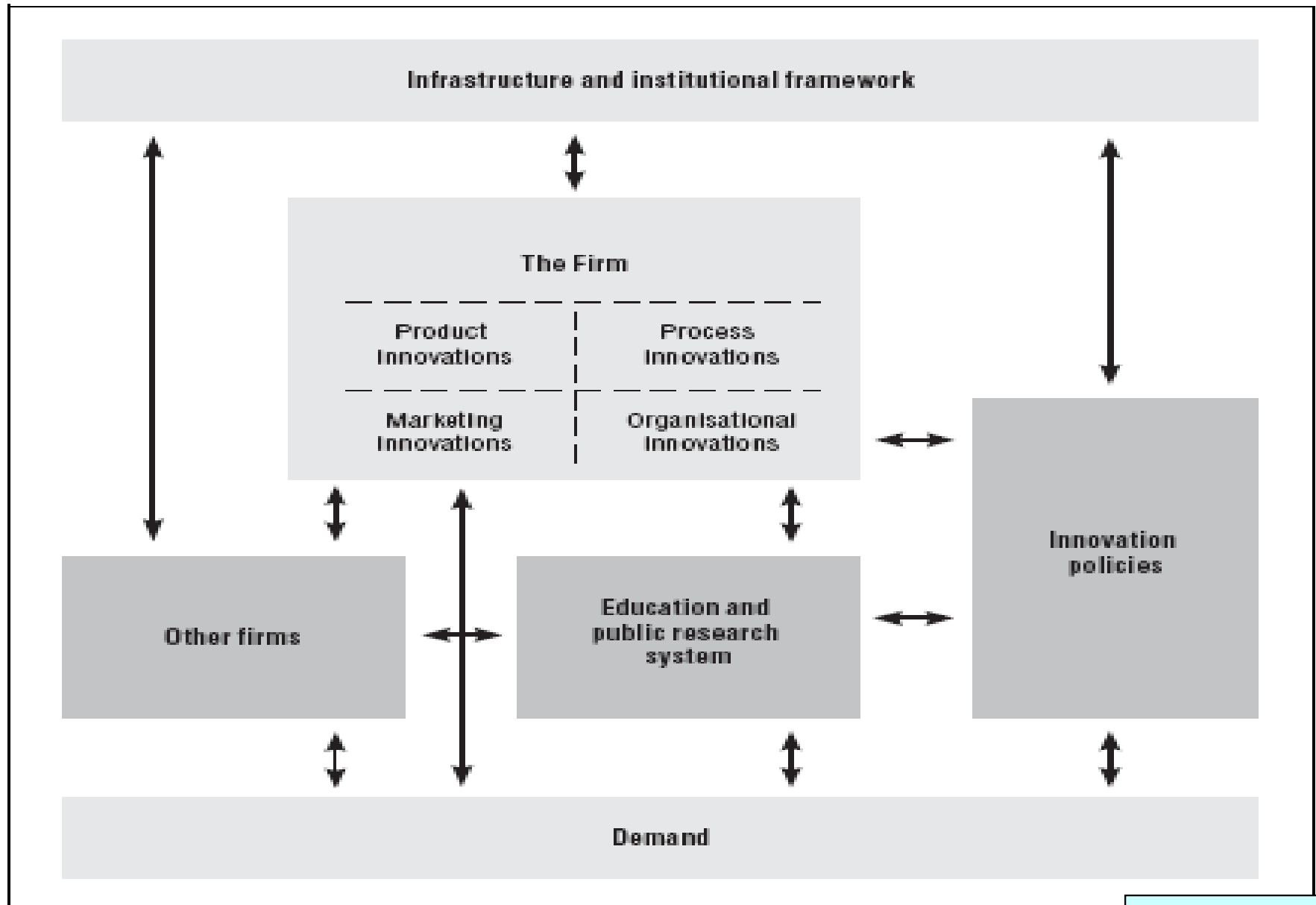


Source: Based on Wengel and Shapira (2004), "Machine Tools: The Remaking of a Traditional Sectoral System; and Wengel, et. al. (2000), Surveying Organisational Innovation on a European Level - Challenges and Options

# Innovation Systems

- Innovation System
  - *the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies (Freeman, 1995)*
  - *the elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge ... and are either located within or rooted inside the borders of a nation state. (Lundvall, 1992)*
- National Innovation System v Regional Innovation Systems
- Sectoral Innovation System (Malerba)
  - Value-chain of innovation
  - Machine tool manufacturers <> Precision-machining companies <> End users (now evolving boundaries, with more S&T involved)

# Innovation – in an interactive framework



# External Environment: Elements influencing the take-up of emerging technologies

- Infrastructure and institutional framework
- Complementary assets (cf. Teece 1986)
- Human capital and knowledge production
- Nature of demand and acceptability to users and society
- Macro-economic context
- Regional context
- Policy orientation and incentives
- Technological regime (path dependencies)
- Improvements in incumbent technologies.

# Technology Assessment

- **Technology assessment:**
  - Knowledge development and dissemination to investigate and consider the full range of impacts and consequences of technological applications.
  - Emerges in US (and Europe) in mid-1960s – rising concern about modern technologies and impacts – pollution, supersonic transport, agricultural pesticides, natural resource exploitation, nuclear power
- **Core principles:**
  - Science and technology developments have implications – economic, societal, ethical, environmental, health, security
  - Implications not always obvious at an early stage yet, once deployed negative implications can be difficult and costly to remedy
  - Early assessment and examination of options and their implications can inform technological decision-making and investment
  - Not anti-technological: addresses opportunities and barriers to desirable technological adoption, as well as highlighting potential issues, risks
  - Technology assessment tools include (but not limited to): expert advice, scenarios, foresight, undertaken in an interdisciplinary context



## US Office of Technology Assessment, 1974-1995

### Commentary

- “My job is not to resolve the debate but to enhance and inform it” (Nancy Lubin, OTA project director)
- Congress has too much information not too little – OTA was really good at being able to “sift through that and figure out what is and isn’t a problem” (Bruce Bimber, UCSB)
- OTA is a “defense against the dumb” (Rep George Brown, 1965)



### Examples of OTA insight and foresight

- 1975 study - new tanker designs needed (decade before Exxon-Valdez spill in 1989)
- 1982 study anticipates that email will obsolete the post service
- 1985 assessment of multi-billion dollar Strategic Defense Initiative (Star Wars) finds it would not work
- 1993 study emphasizes dangers of fertilizer bombs (c.f. Oklahoma City bombing in 1995)
- 1994 assessment of Social Security computer upgrades yields \$368m savings

Sources: Peter Blair, Congress's Own Think Tank: Learning from the Legacy of the Office of Technology Assessment (1972-1995), 2013; Bruce Bimber, The Politics of Expertise in Congress: The Rise and Fall of the Office of Technology Assessment, 1996; T. Murphy, T Raja, You Can Also Blame Newt Gingrich for the Obama Care Website Screwup, Mother Jones, December 6, 2013. L. Kelly, Congress' Wicked Problem: Seeking Knowledge Inside the Information Tsunami, New America Foundation, 2013; J Sadowski, Atlantic Monthly, Oct 26, 2012

# Meanwhile ...times change

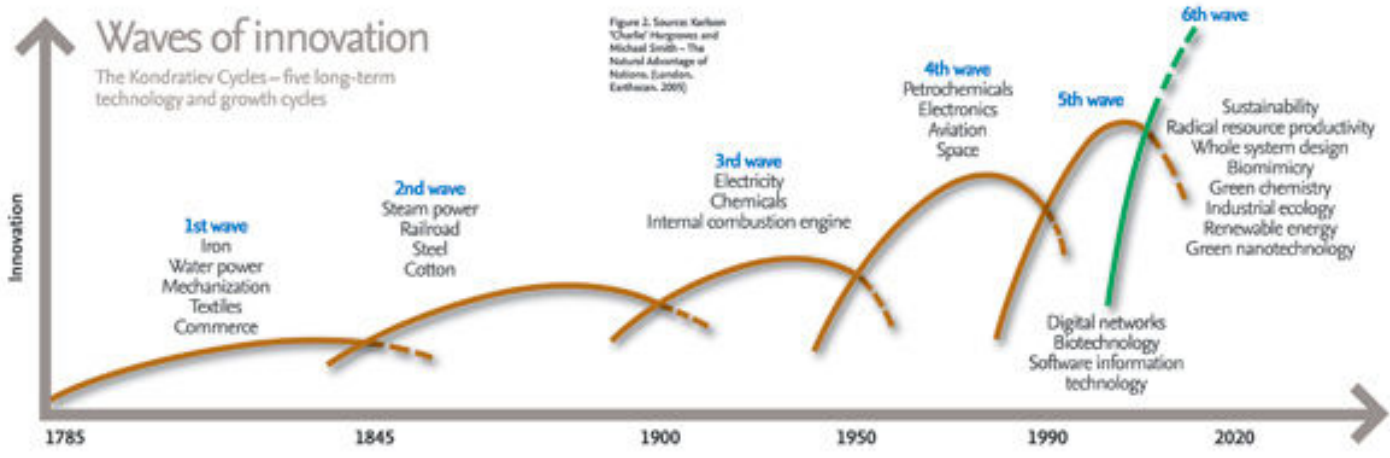
- ❑ Development of innovation systems approaches
- ❑ Advances in ICT & knowledge systems
- ❑ New TA concepts
  - **Strategic Intelligence** (Kuhlmann, Smits)
    - Multiple instruments: Technology Forecasting, Technology Foresight, Technology Assessment, Evaluation, and Road Mapping
  - **Participatory TA; Technology Consensus Conferences** (DK)
    - Broaden participation & engagement in TA decision-making
  - **Constructive TA** (NL); **Real-Time TA** (Guston, Sarewitz); **Anticipatory Governance** (Guston); **Midstream Modulation** (Fisher)
    - Use TA, other methods to modify / modulate technology development

# Responsible Research and Innovation

- **EPSRC (UK) 2013 - Framework for Responsible Innovation**
  - Responsible Innovation is a process that seeks to promote creativity and opportunities for science and innovation that are socially desirable and undertaken in the public interest.
- **Key elements - ANTICIPATE, REFLECT, ENGAGE AND ACT (AREA)**
  - **Anticipate** – describing and analysing the impacts, intended or otherwise, (e.g. economic, social, environmental) that might arise. This does not seek to predict but rather to support an exploration of possible impacts and implications that may otherwise remain uncovered and little discussed.
  - **Reflect** – reflecting on the purposes of, motivations for and potential implications of the research, and the associated uncertainties, areas of ignorance, assumptions, framings, questions, dilemmas and social transformations these may bring.
  - **Engage** – opening up such visions, impacts and questioning to broader deliberation, dialogue, engagement and debate in an inclusive way.
  - **Act** – using these processes to influence the direction and trajectory of the research and innovation process itself.

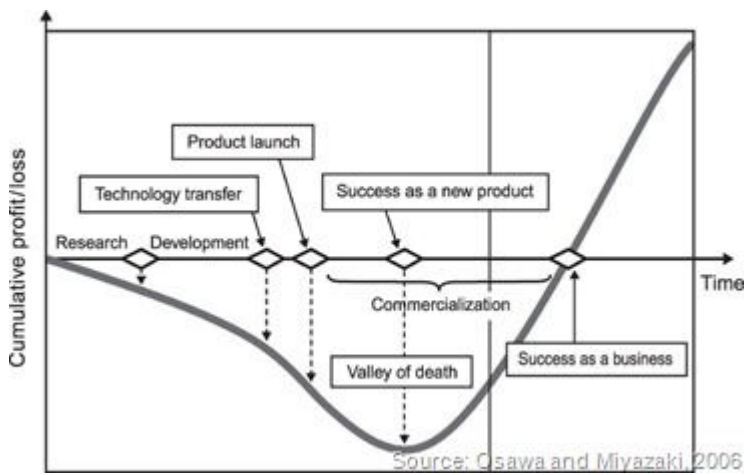
# The promise and realities of emerging technologies

## Waves & cycles of technological innovation



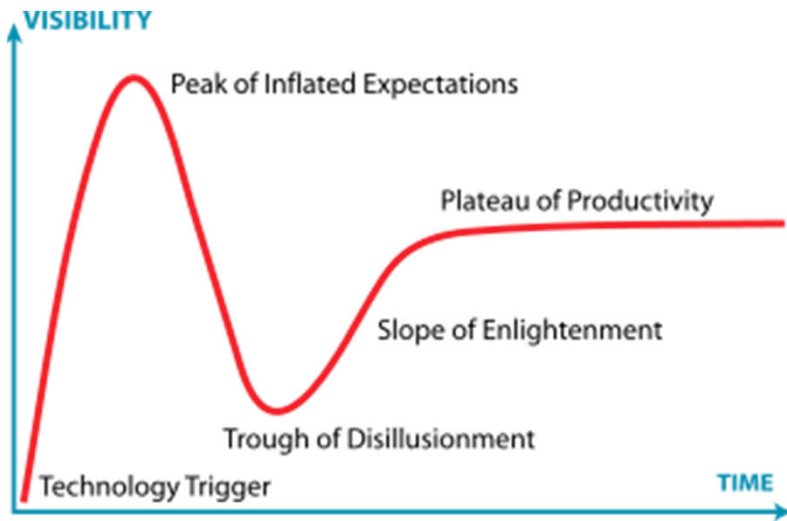
See also: Schumpeter  
“Creative destruction”  
(medium-term, drivers of change view)

Long term technology and growth: Kondratiev Cycles (Source: MakingItMagazine.net)



Short term profit and loss: “Valley of Death”  
(Source: Outlier Magazine)

# A “process of emergence” for emerging technologies

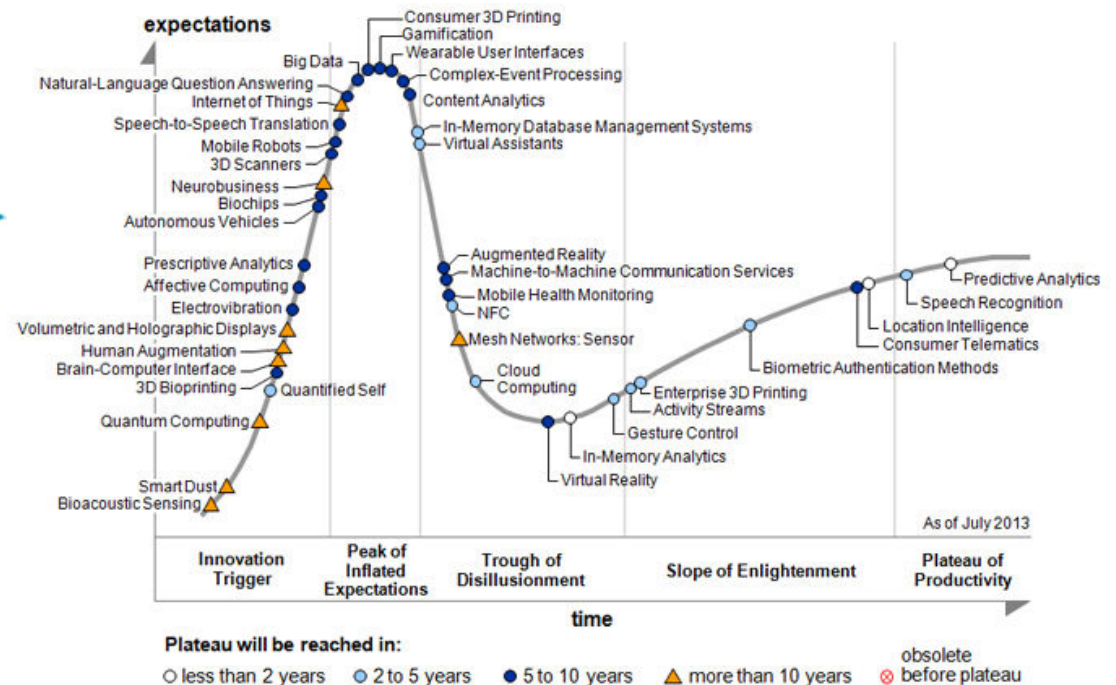


## Gartner “Hype” Cycle

See also:  
 “Double Boom” Schmoch, 2007

## 2013 Emerging Technologies Hype Cycle

Source: Gartner, August 2013



# Assessment Challenges

- Drivers: What is the technology?
  - Who is developing it, how, and at what pace?
- Applications: What are the potential applications?
  - Can the technology scale up and be economic and sustainable in production and use (added value compared with incumbents or competing new technologies?)
  - Who will be the likely users? Where is the market, and what size?
- Adoption: What are the opportunities and barriers to technological adoption, also potential issues, risks?

## Technology Emergence

# Societal Challenges

- The Grey Goo / GMF problem

- Avoid negative results
- Responsibility and a precautionary approach

2006-05-03 23:10:00

Scientist warns of nanotechnology dangers

LONDON, May 3 (UPI) -- A British scientist is warning that hundreds of...

- The targeting problem

- What are the goals? (esp. of public investment in science & tech)
- Society as the frontier: Equity, quality of life

- The process problem

- Who decides? Can decision-making be inclusive?
- Can decision-making be reflective and anticipatory?



# Summer School



*"The future ain't what it used to be."  
Peter "Yogi" Berra*

- **Monday:** technology emergence challenges – concepts, drivers, applications, global contexts
- **Tuesday/Wednesday:** novel methods for research and innovation systems assessment
- **Thursday:** foresight processes
- **Friday:** governance, societal challenges, responsible research and innovation