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Re-structuring Science and Engineering Research Support in the UK

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R&D in the UK

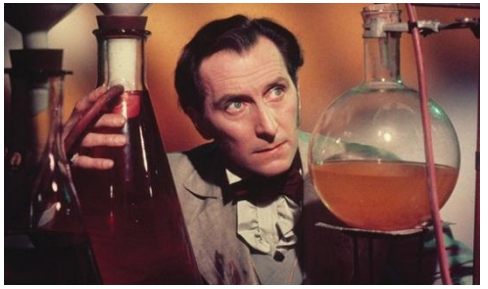
- Traditionally a research powerhouse.
- A history of invention.
- Industrial success often based on romantic pioneering – brilliant inventors with rich/powerful sponsors.
- Excellent at working under pressure, cutting corners….. War time, Formula 1.

- Less successful at developing national industrial strategies, strategies for innovation and poor at exploiting intellectual property.

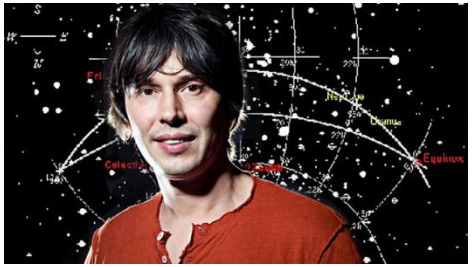
Problems

- Highly innovative scientists and engineers but not enough focus on translating those ideas into commercial product.
- Poor communication between universities and business to help relevant ideas become commercialised/start-ups.
- Technology innovation centres underfunded and support is too short term.
- Funding gap after initial venture has been established.

The Traditional British Academic



- Traditionally fiercely independent.
- Highly focused.
- Suspicious of commerce and industry.
- Wary of government.
- Naive regarding intellectual property.
- (OK, its changing……..)



UK research results

The UK's academic performance

- Excellent record of publications, traditionally in or around second place only to the USA with Japan and Germany now pretty much on a par and China recently overtaking all but the USA.

	China	USA	UK	Germany	France	Japan	EU-25
1993	1.69	34.73	8.89	7.45	5.98	8.49	35.04
1994	1.70	33.66	8.97	7.54	5.99	8.57	35.90
1995	2.05	33.54	8.88	7.62	6.09	8.65	36.21
1996	2.31	32.29	9.02	7.93	6.18	8.94	37.08
1997	2.66	31.94	8.73	8.32	6.31	8.98	37.60
1998	2.90	31.63	9.08	8.82	6.48	9.42	38.82
1999	3.44	31.24	9.08	8.67	6.44	9.52	38.68
2000	3.89	30.93	9.22	8.69	6.31	9.49	38.67
2001	4.30	31.01	8.90	8.68	6.33	9.52	38.77
2002	4.98	30.75	8.60	8.50	6.10	9.43	38.16
2003	5.51	30.68	8.46	8.35	6.10	9.40	38.02
2004	6.52	30.48	8.33	8.14	5.84	8.84	37.59
2005	7.42	29.65	7.88	7.88	5.67	8.21	37.04
2006	8.42	29.50	7.84	7.72	5.56	7.82	37.05

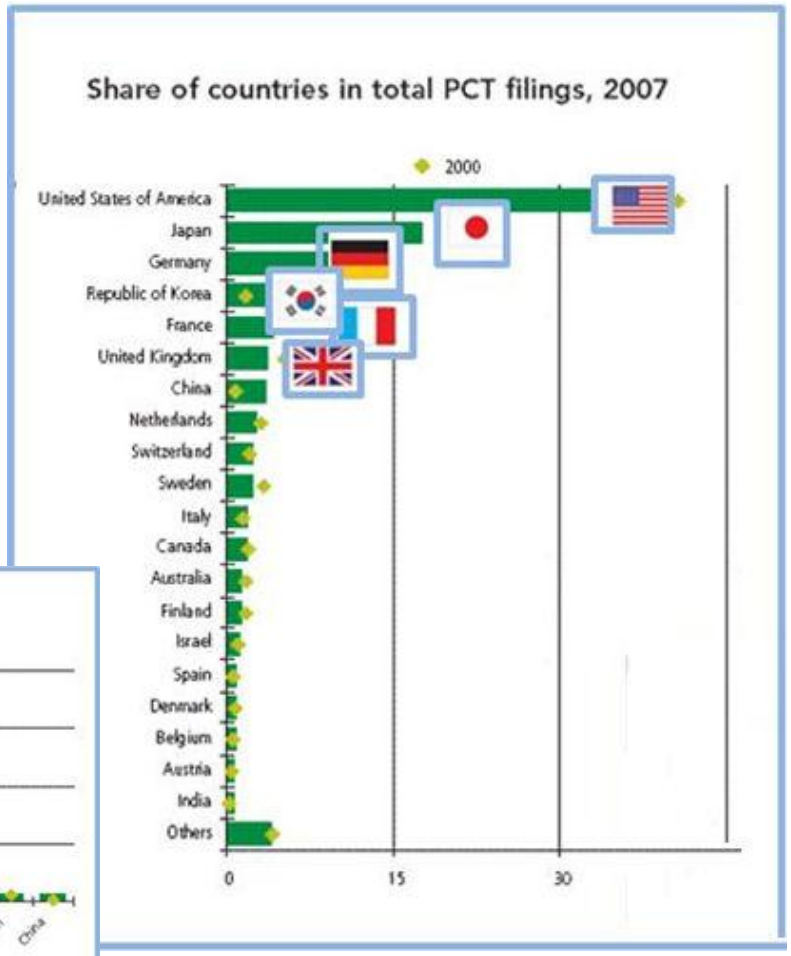
Table: Percentages of world share of publications using the 'Science Citation Index-Expanded version' at the ISI Web-of-Knowledge.

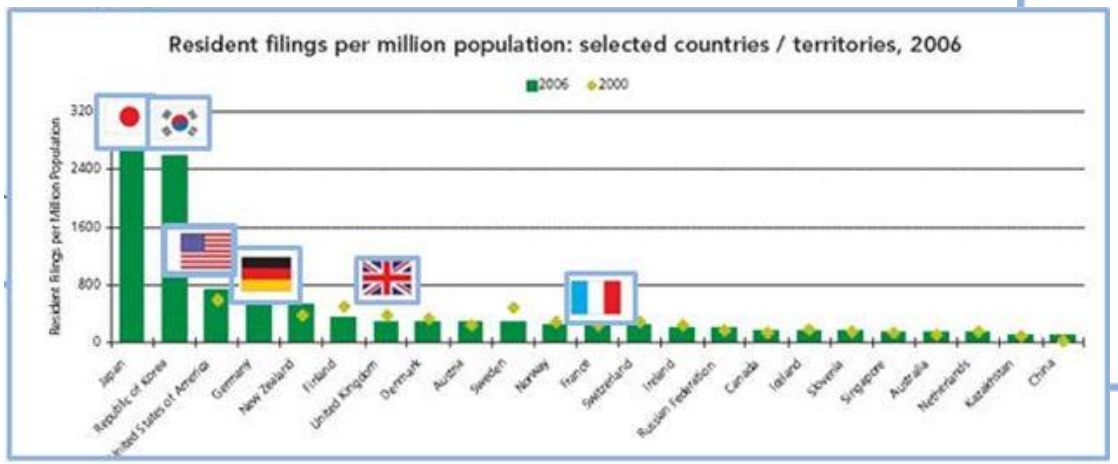
Second in citations in absolute numbers and first on citations per "funding dollar"

But… Patents relatively low

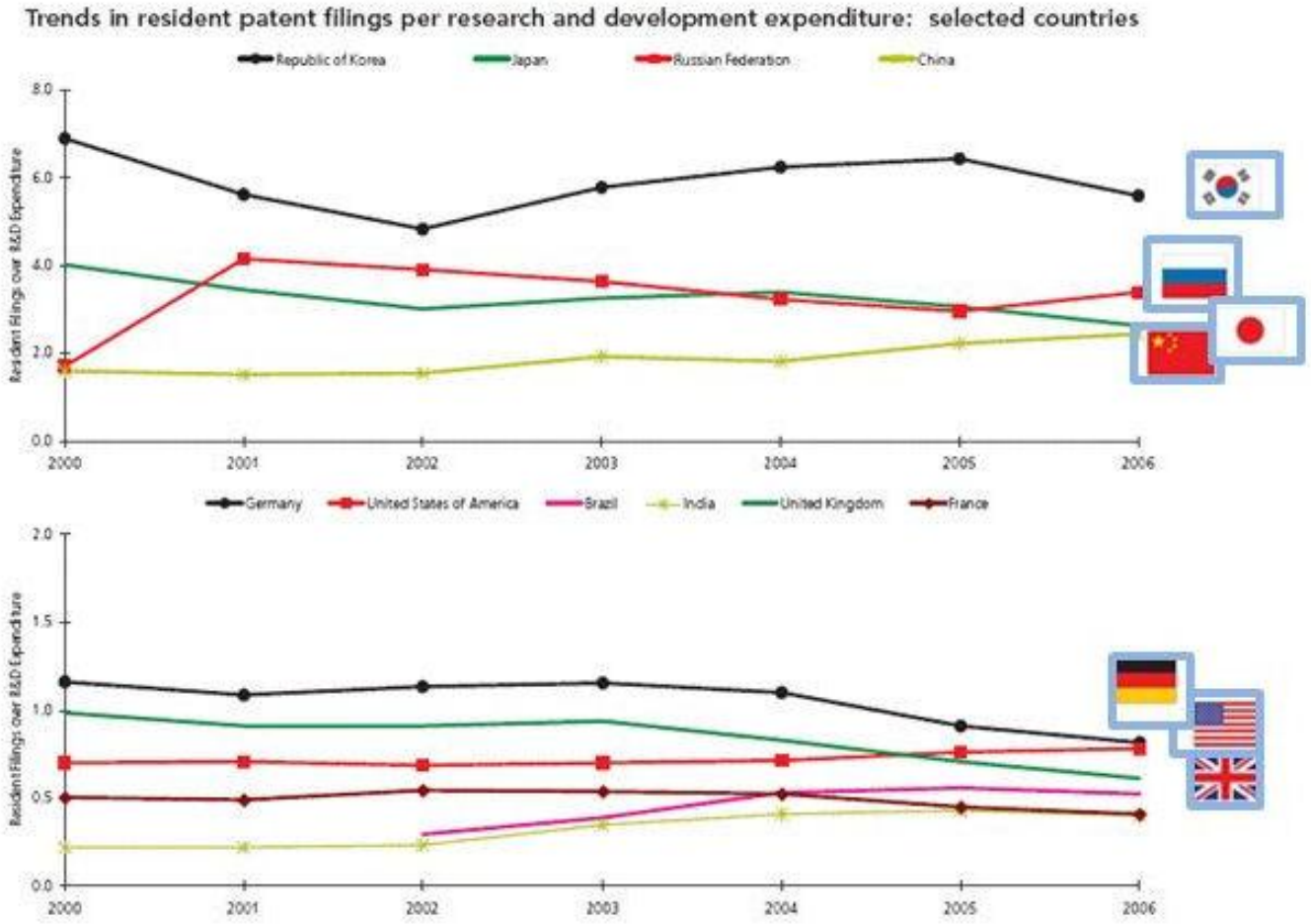
- Germany and Japan file more patents despite having roughly similar outputs of academic papers.
- France publish less but files more and Korea is especially effective at patenting ideas.

Source of data – WIPO Statistics and World Bank





Comparing patents/research spend



Note: Research and development expenditure are in millions of constant US dollars, based on purchasing power parities and lagged by 2 years to derive the resident filings to R&D ratio.

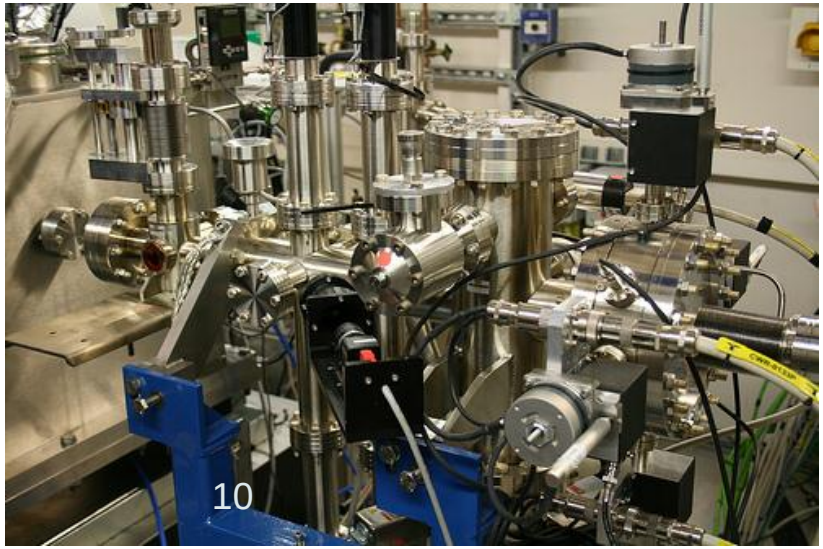
Source: UNESCO and WIPO Statistics Database

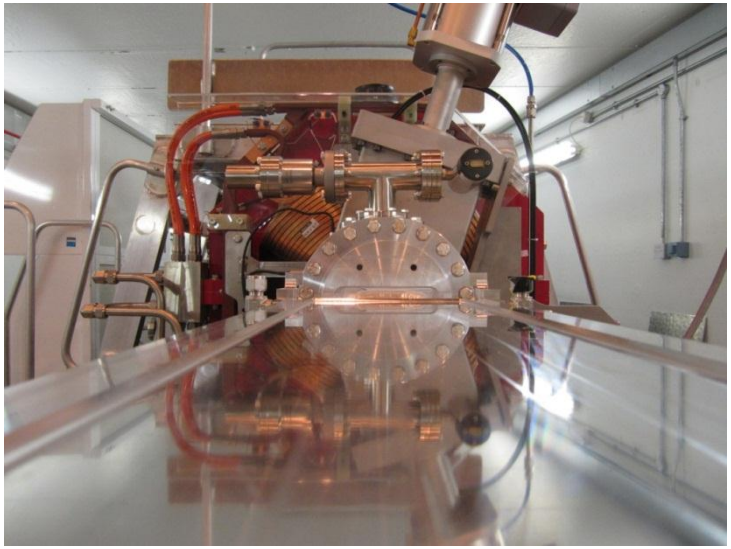
Changes being made

Gradual move to focus and maximise benefits of research over 30 years:

- Improve research quality.
- Focus research on industrial/economic benefit.
- Recognise that UK cannot/will not compete in all new technology sectors.
- Ensure mechanisms are in place to facilitate research moving through the TRL levels (technology readiness levels).
- Place more focus on high value manufacturing.

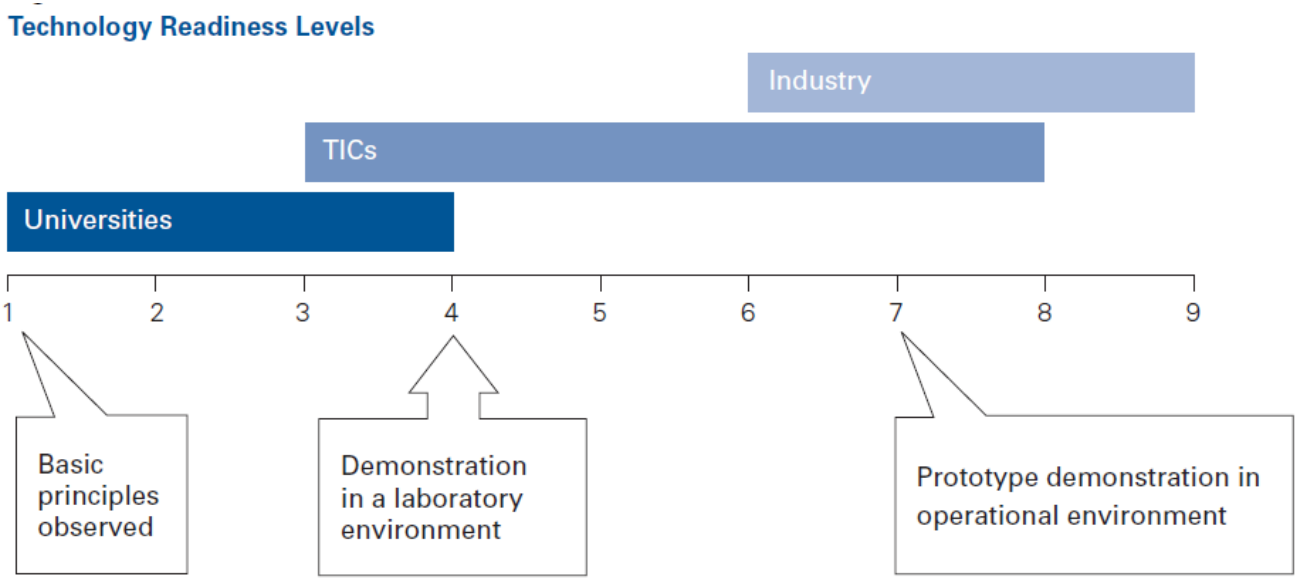
Improving Research Quality





Research Quality

- Recognition that research for economic benefit must start at low TRL levels and move towards implementation, all of the technology chain needs to be improved – starting with the universities



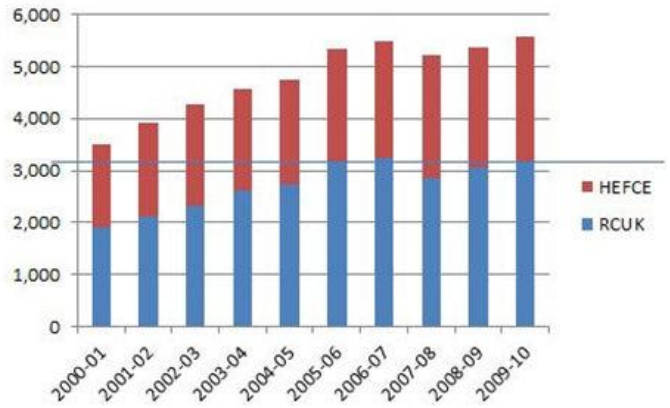
Research Quality

Gradual implementation of measures:

- 1986 introduction of research assessment exercise (RAE) for universities – links direct government funding of academic research departments to measured research quality –followed by further RAE's in 1989, 1992, 1996, 2001, 2008
- No attempt to set national agenda for research but total funds for specific subject areas set by government and then distributed amongst universities according to RAE rankings.
- Initial RAEs were coarse grained (and a little subjective)- departments ranked 5* (excellent) to 1* poor
- From RAE 2008 departments (units of assessment) were rated according to a quality profile including outputs, environment, prestige with a 4* to 1* ranking for each measure.
- Initially funding given to 5* depts = 2x 4* with similar differentials between 3* , 2* and 1*.
- Now with a research profile, departments only get funded for the 4* or 3* parts - research rated at 2* or 3-1* received NO financial support from government.

Effects of RAE

- Increased pressure on academics/universities to perform well in research – to publish in high quality journals, to hunt for research grants, to collaborate.
- Tendency for larger critical mass academic centres to build up – transfer of academics with groups common to boost RAE.
- Poorly performing academics gradually eliminated from the system – universities no longer able to "carry" poor colleagues who either became teaching focused or left. Over the period from 1983, poor research output has been eliminated from receiving funding.



Quality standards gives government confidence to increase research funding (until financial crisis)

- But….. Not always the direct link between research quality and industrial impact that the Government would have hoped for. Applied research not always rated as highly (by academic panels) as pure research.

Lambert report 2003

- Major survey of UK University-business collaboration reveals that the best exponents of applied research do not always feature at the top of an RAE survey (as evidenced by QR funding)!

Table 6.1: Distribution of research funding in England for QR funding, Research Council grants and industrial research grants and contract income

	RESEARCH FUNDING STREAM		
	QR funding, Higher Education Funding Council for England	Research Council Grants	Industrial research grants and contracts
1	Oxford	Cambridge	Imperial College
2	University College London	Oxford	Oxford
3	Cambridge	University College London	Cranfield
4	Imperial College	Imperial College	Nottingham
5	King's College London	Manchester	The Open University
6	Manchester	Southampton	Cambridge
7	Birmingham	Birmingham	King's College London
8	Leeds	Sheffield	University College London
9	Sheffield	Leeds	Southampton
10	Bristol	Nottingham	Leeds
11	Southampton	Bristol	Birmingham
12	Nottingham	King's College London	Loughborough
13	Newcastle-Upon-Tyne	UMIST	Sheffield
14	Liverpool	Leicester	Manchester
15	Warwick	Liverpool	Newcastle-Upon-Tyne

Ranking based on RAE

Improving industrial/economic benefit

Ensure research has a purpose

- Make academics realise research has to be useful and be able to be used.
- Focus research funds on areas where the UK can realise an economic benefit.
- Build research capacity in targeted areas by targeting of funds to centres with critical mass.
- Move from government funding research to acting as sponsor of research.

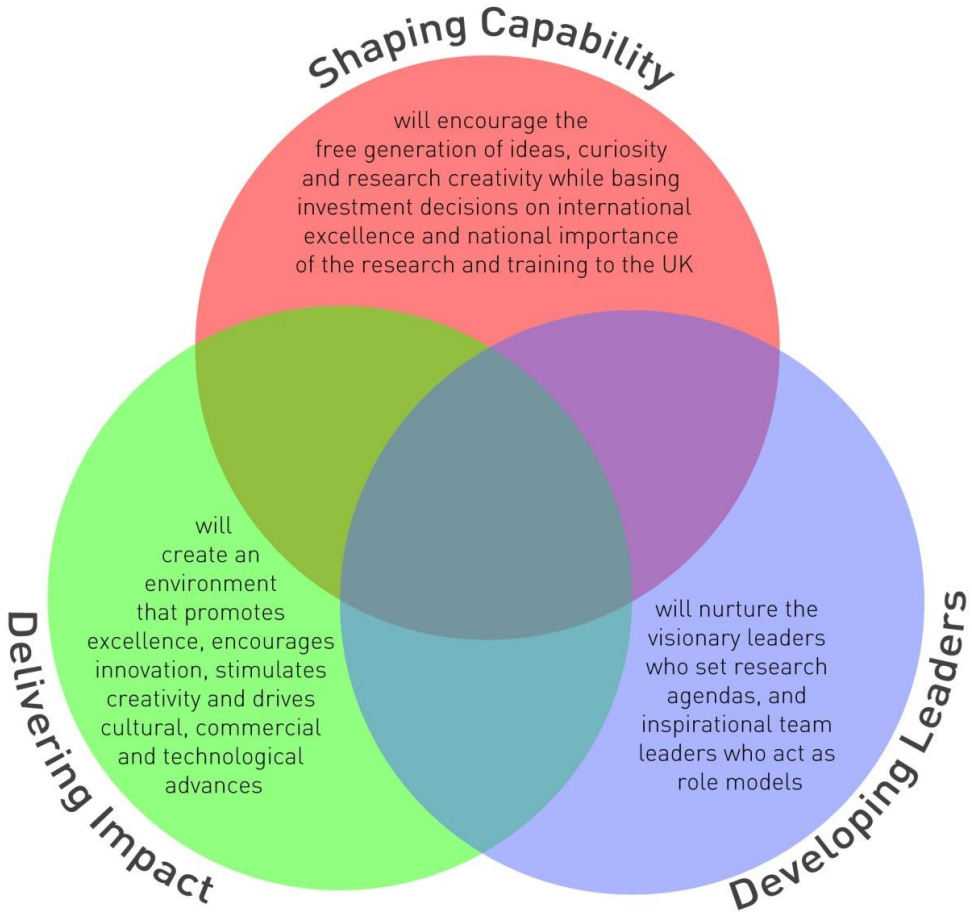
REF 2014

- Research Evaluation Framework.
- RAE with a difference.
- 20% weighting on research impact.
  - Impacts on industry.
  - Policy.
  - Society.
- Impact rated according to significance and reach with universities required to submit case studies of impact based on the last 20 years.
- REF 2018 to increase importance of Impact in overall rankings from 20% to 25%.
- Academics now challenged to think – why am I doing this research? Who does it benefit (academic impact is not eligible!). NB this applies to all areas of research – including the Arts

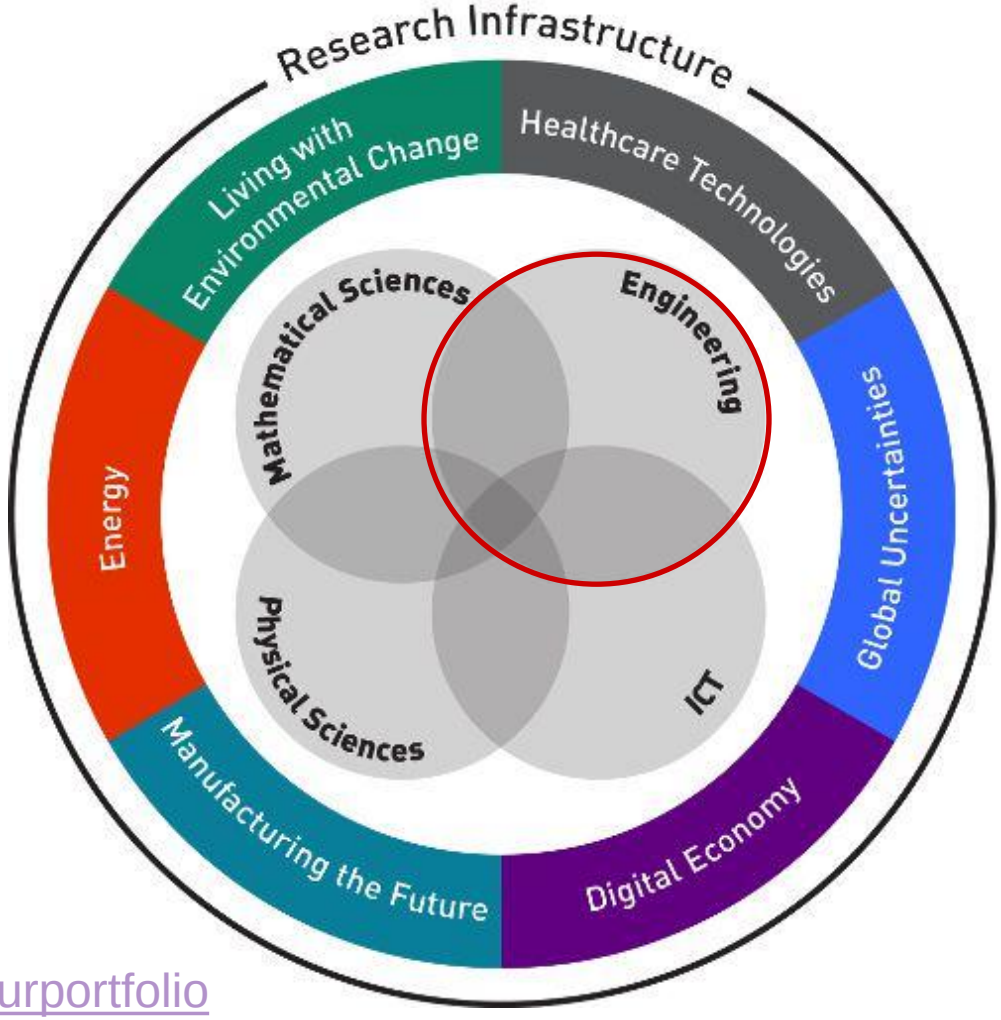
Funder to Sponsor

- The Engineering and Physical Sciences Research Council (EPSRC) is now under the control of the Department of Business Innovation and Skills.
- It has adopted a proactive sponsoring research approach.
- National areas of interest have been identified and funding focused on those area.
- Research expertise has been mapped nationally.
- Funding channelled though Managed Programmes – with requirements for universities to collaborate and to create centres of critical mass.
- Capacity building in focused areas. Ability to deliver research is rated as importantly as research ideas.
- Impact agenda.

EPSRC Strategic Goals



EPSRC Portfolio



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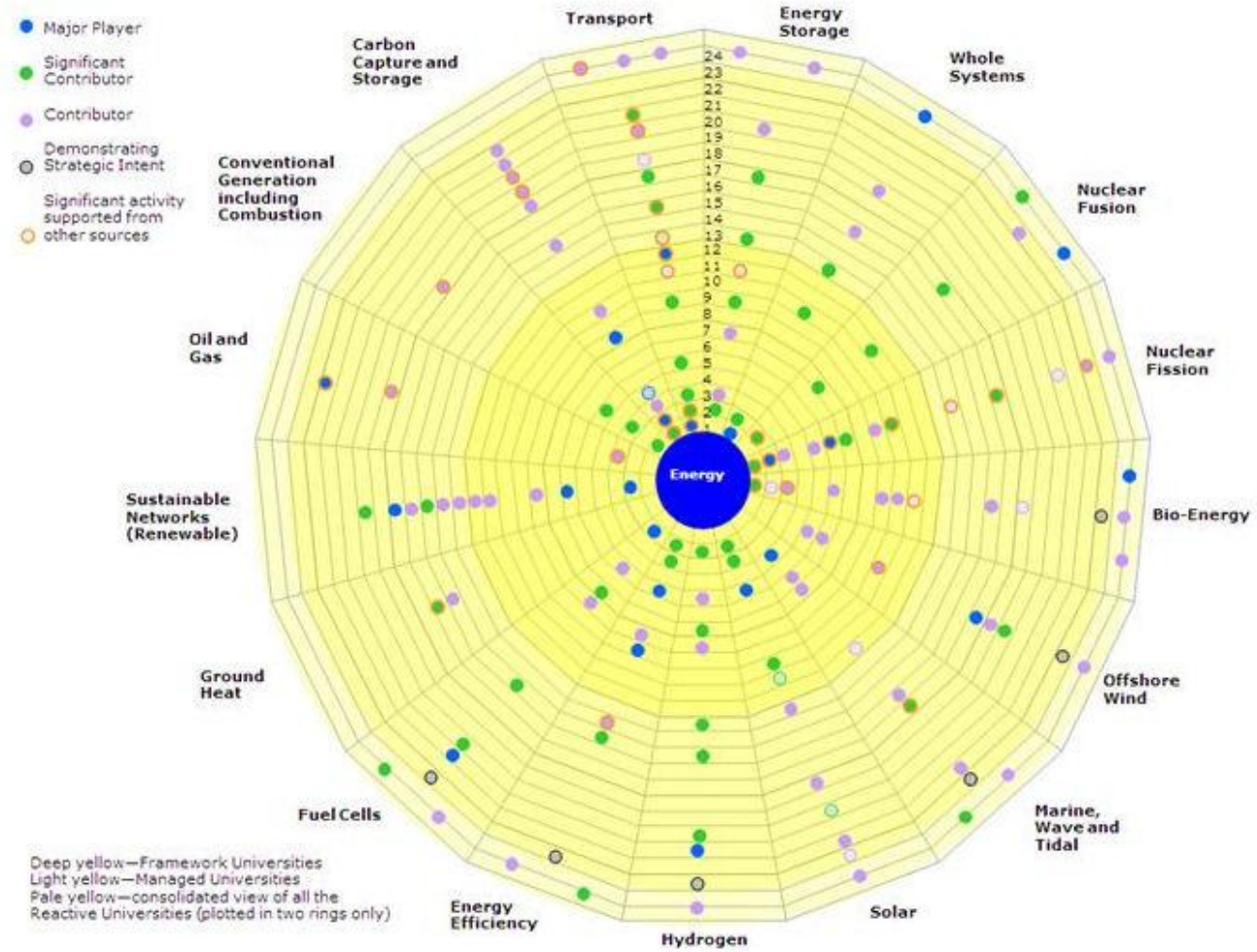
Knowledge Map

- Search for Critical mass - Example is energy research.



Programme and Platform grants

Flexible mechanisms to provide funding to world-leading research groups to address significant major research challenges.

- Programme grants are intended to support a suite of related research activities focussing on one strategic research theme. Although it is expected that most proposals will be interdisciplinary and collaborative in nature, they can address key challenges in a single discipline.

- Platform Grant funding provides a baseline of flexible support (a platform) that can be used for the retention of key staff, feasibility studies, longer-term research and International Networking. This flexibility should enable the group to take a strategic view of their research which will be enhanced by the submission of additional, more conventional applications during the lifetime of the Platform Grant.

Smaller numbers of grants but – larger (>£5 million) and favouring multi-institutional and interdisciplinary bids

Redefining Doctoral Training

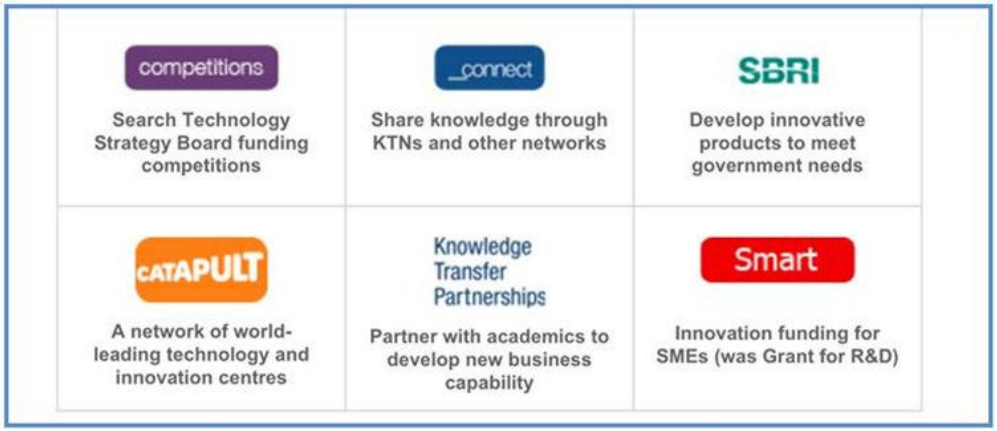
- Engineering Doctorates (4 year professional doctorates undertaken largely in company on real problems with management training)
- Enhanced PhDs (4 years with training/skills remit to complement narrow research focus)
- Funding concentrated on Doctoral training Centres
  - Identifying key themes…allowing academic freedom and imagination to bid for centres under the broad themes.
  - Focusing resources and creating large cohorts of students that can self motivate, energise and stimulate research. Facilitates interdisciplinary approaches

Again big funding >£5 million and encouraging collaboration between Universities to provide a comprehensive set of capabilities/expertise

Moving up the TRL levels

Technology Strategy Board

- The Technology Strategy Board (TSB) is the UK's national innovation agency. Their goal is to accelerate the economic growth by stimulating and supporting business-led innovation.
- The TSB has its roots as an advisory body within the former UK Dept of Trade and Industry (DTI) established in 2004, before becoming an independent body in July 2007.



- Operates like a research Funding Council, but for business at TRL levels 4-7 and funds at 50-75% governed by EU State Aid Rules.

TSB Output

Since 2007, TSB has:

- Invested over £2bn in UK innovation, working with its partners and businesses.
- Funded projects to move ideas and technologies closer to market in more than 3,000 businesses.

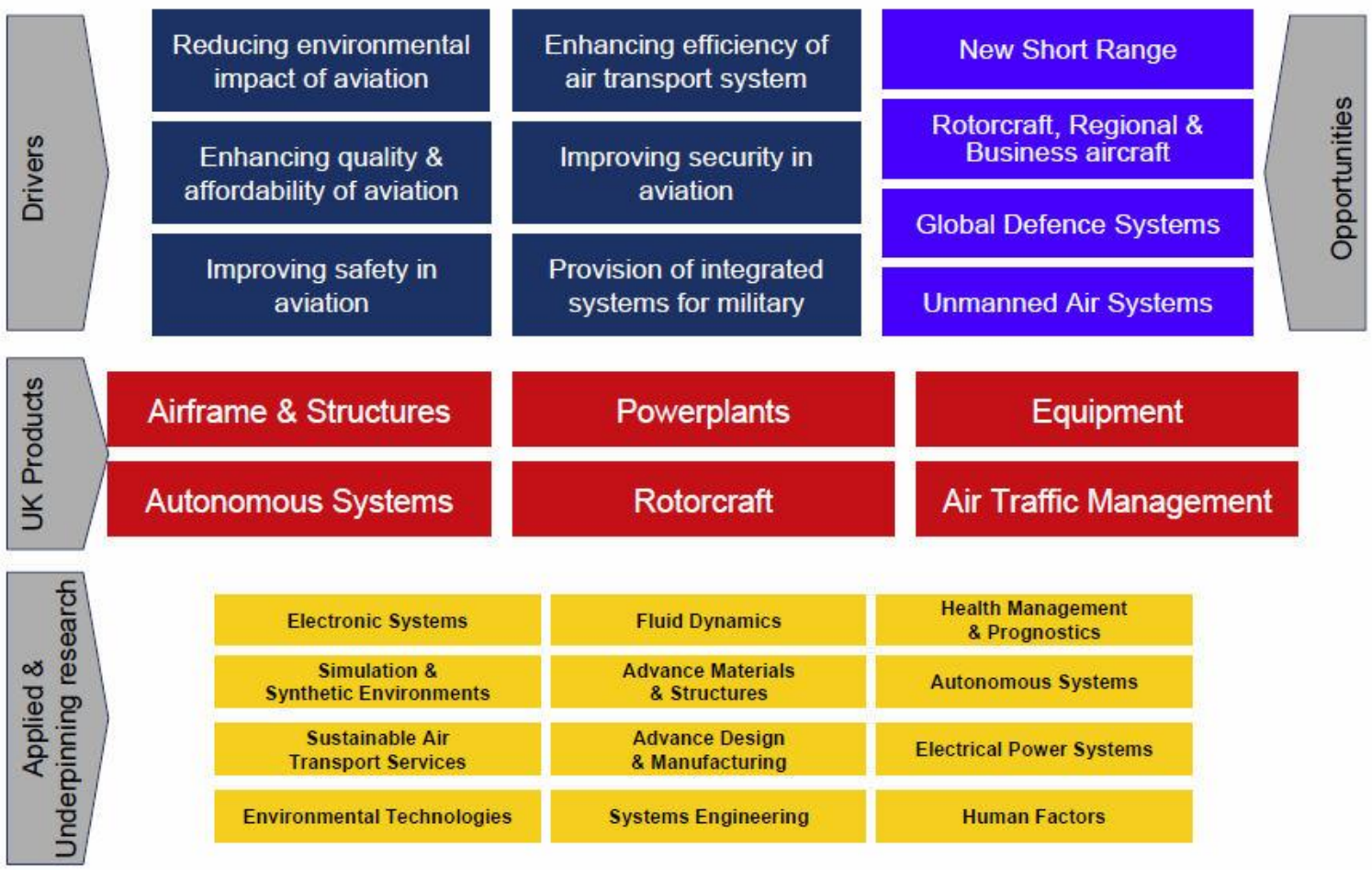
Key Activities

- Creation of KTNs – Knowledge Transfer Networks, linking industry, academia, RTOs and Government.
- The KTNs can provide the forum for National Strategy Groups to form on a sector basis to develop roadmaps and identify research priorities – which feed back to TSB for competition funding and EPSRC for long term “blue skies” initiatives.

AA&D KTN

- The Aerospace, Aviation & Defence Knowledge Transfer Network (AA&D KTN) is a single overarching network spanning Government, Industry and Academia with the principal aim of promoting and enabling innovation in the UK.
- Fully funded by the Technology Strategy Board, all services are FREE and available to anyone with an interest in Research and Technology development relevant to the Aerospace & Defence sectors.
- As the Custodian of the National Aerospace Technology Strategy (NATS), the A&D KTN enables its delivery by ensuring maximum awareness, engagement and alignment within the A&D sectors.

National Aerospace Technology Strategy

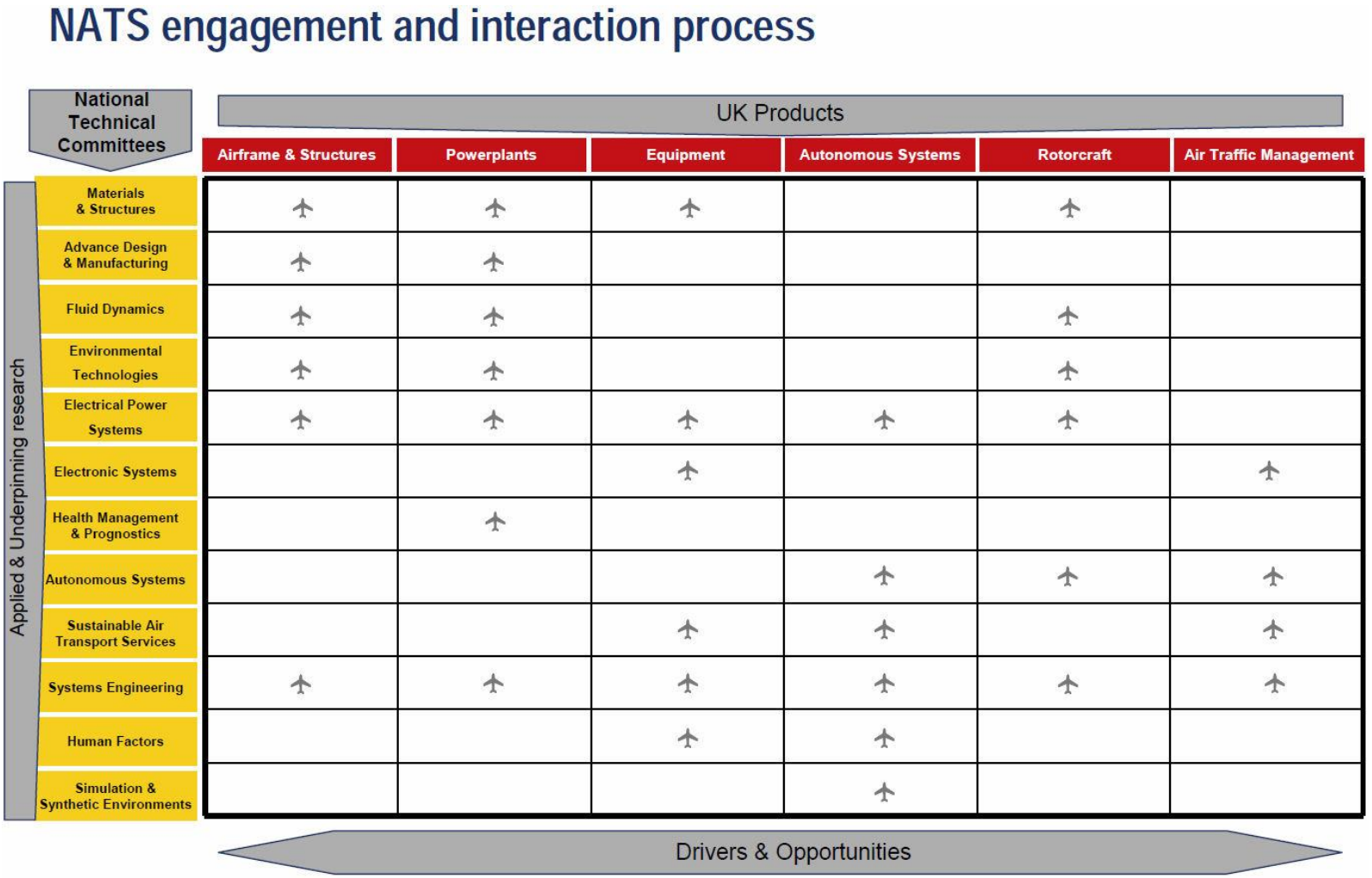


National Technical Committees

- The Aerospace and Defence KTN is now responsible for the management of the National Technical Committees (NTCs), which have been set up to advise the KTN, Government and Industry on key technological themes, as well as the future research and technology priorities that should be invested in.
- Current NTCs:
  - Advanced Design & Manufacturing NTC
  - Autonomous Systems
  - Electrical Power Systems NTC
  - Electronics Systems NTC
  - Environmental Technologies NTC
  - Fluid Dynamics NTC
  - Health Management & Prognostics NTC
  - Human Factors NTC
  - Materials and Structures NTC
  - Simulation and Synthetic Environments NTC
  - Sustainable Air Transport Services NTC
  - Systems Engineering and Open Architecture NTC

https://ktn.innovateuk.org/web/national-technical-committees-ntcs

NTC Engagement in Roadmaps



Aerospace Technology Roadmaps

The objective of the Technology Roadmaps is to inform stakeholders from across the Aerospace and Defence community of the expected research and technology development programmes and estimated investment required until 2020.

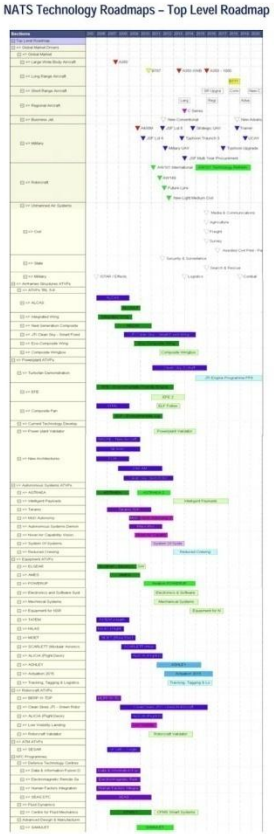
The Roadmaps identify the activities necessary to ensure the UK Aerospace sector remains in a formidable position to compete in the foreseeable market opportunities.

The Roadmaps show:

- Top down review of global market drivers and indicate service entry dates
- How, where and when UK products will fit into global market
- The Technology and Innovation Programmes (TRL 1-4) and Validation and Demonstration Programme (TRL 4-6) that need to develop to ensure UK industry is in a strong position to make the most of the market opportunities.

Aerospace Technology Roadmaps

- There are currently 5 roadmaps.
- Top level Roadmap aggregated from individual Roadmaps:



Airframes and Structures

https://ktn.innovateuk.org/web/national-aerospace-technology-strategy-nats/articles/-/blogs/roadmaps-airframes-and-structures?ns_33_redirect=%2Fweb%2Fnational-aerospace-technology-strategy-nats%2Farticles

Autonomous Systems

https://ktn.innovateuk.org/web/national-aerospace-technology-strategy-nats/articles/-/blogs/roadmaps-autonomous-systems?ns_33_redirect=%2Fweb%2Fnational-aerospace-technology-strategy-nats%2Farticles

Equipment

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Powerplants

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Rotorcraft

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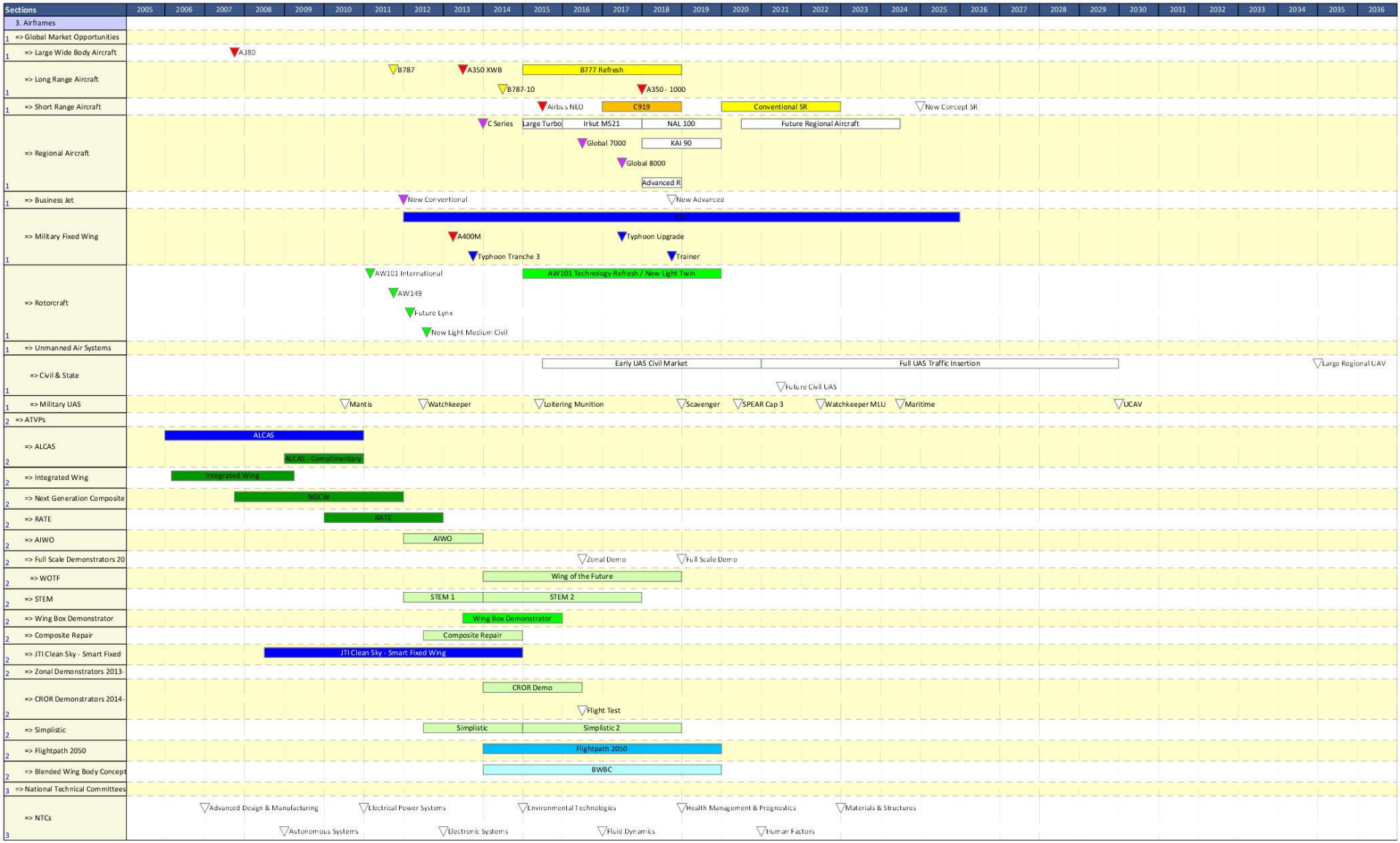


1 - Prime

Prime | Airbus | AgustaWestland | BAE Systems | Boeing | Bombardier | Comac

2 - Funding

Funding | UK - Funded | UK - Bid | UK - Aspiration | MOD - Funded | MOD - Bid | MOD - Aspiration | EU - Funded | EU - Bid | EU - Aspiration

3 - TRL

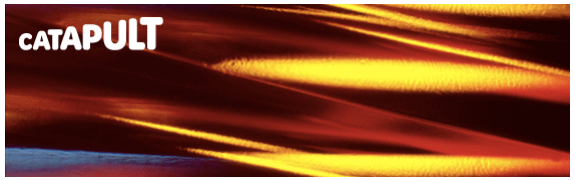
TRL | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9

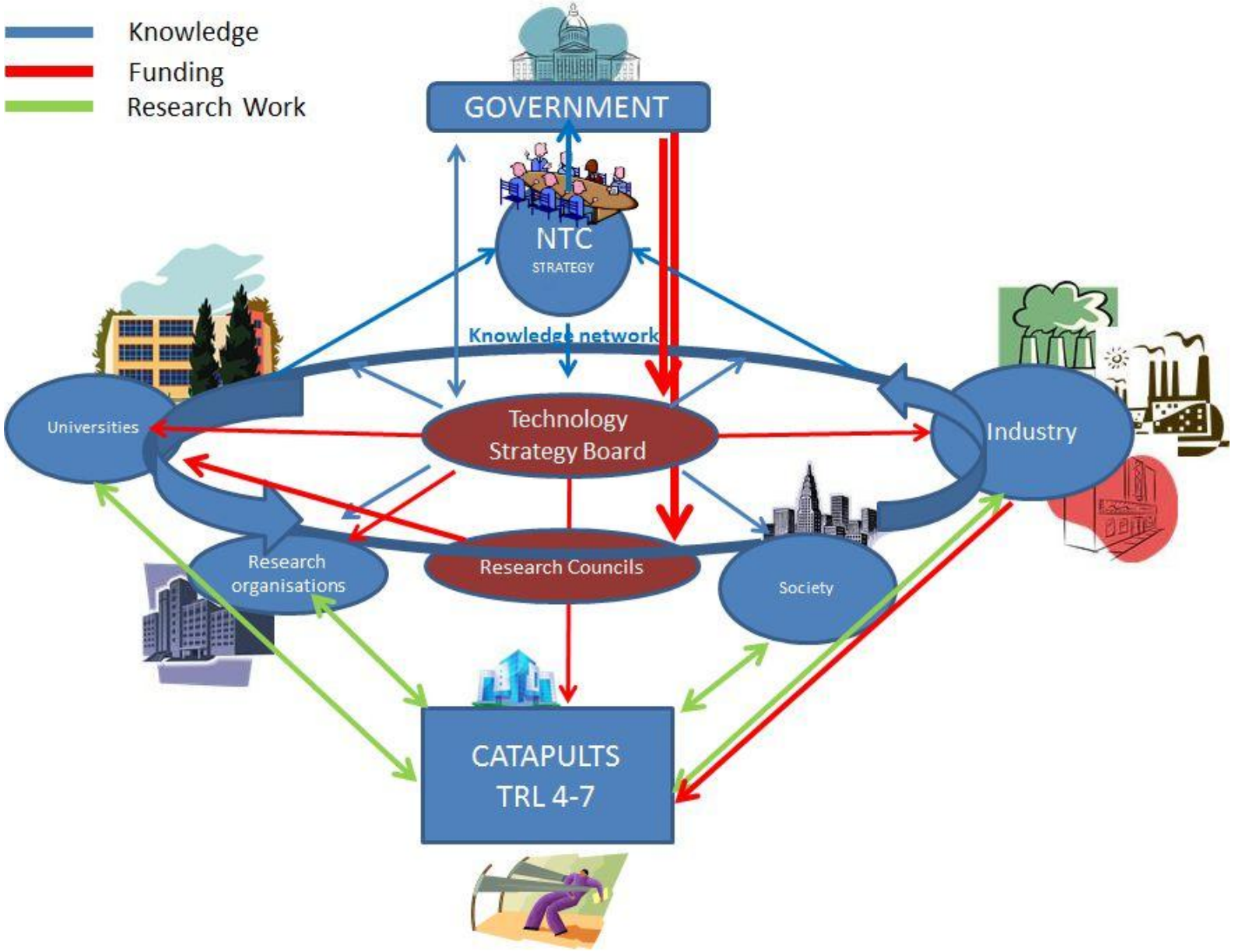
Centres for Innovation

- The UK has periodically tried to address the problems of knowledge transfer from research to industry, the TRL 4-7 gap, by creating “Research Centres”. Most have initial success and then fade away after the pump priming government money has been spent.
- The Hauser Report, 2009, looked at the UK and compared with other more successful countries (e.g. Germany). The German exemplar was the various centres of the Fraunhofer Institute
- Hauser concluded that the UK spends too little in too small amounts so that the overall effect is a waste of resources.
- Example - Micro and Nanotechnology centres. The original plan in 2004 was to create two big national centres - instead ended up as 24 centres using the same amount of cash! Now almost none are still operating.
- This has lead to a new initiative to create technology innovation centres that are well funded for a sensible period of time – THE CATAPULTS!!

Catapult

- *What are Catapults?* Catapult centres, formally known as technology and innovation centres, are centres of excellence that will bridge the gap between business, academia, research and government. They are a powerful new element in the UK economy, helping businesses develop exciting ideas into commercial products.
- Catapult centres will drive economic growth in the UK by facilitating business and research innovation. The centres will focus on specific business areas where the UK has established expertise or where there is an opportunity for the UK to become a world leader.
- Once established, the Catapult centres will enable businesses to test product concepts and bring commercial products to market quickly and cost effectively. This will give UK businesses a competitive advantage against international competitors.
- So far, the Technology Strategy Board has announced five business areas it will support:
  - **High Value Manufacturing (£200 million)**
  - **Cell Therapy,**
  - **Offshore Renewable Energy,**
  - **Satellite Applications**
  - **Digital technologies**.





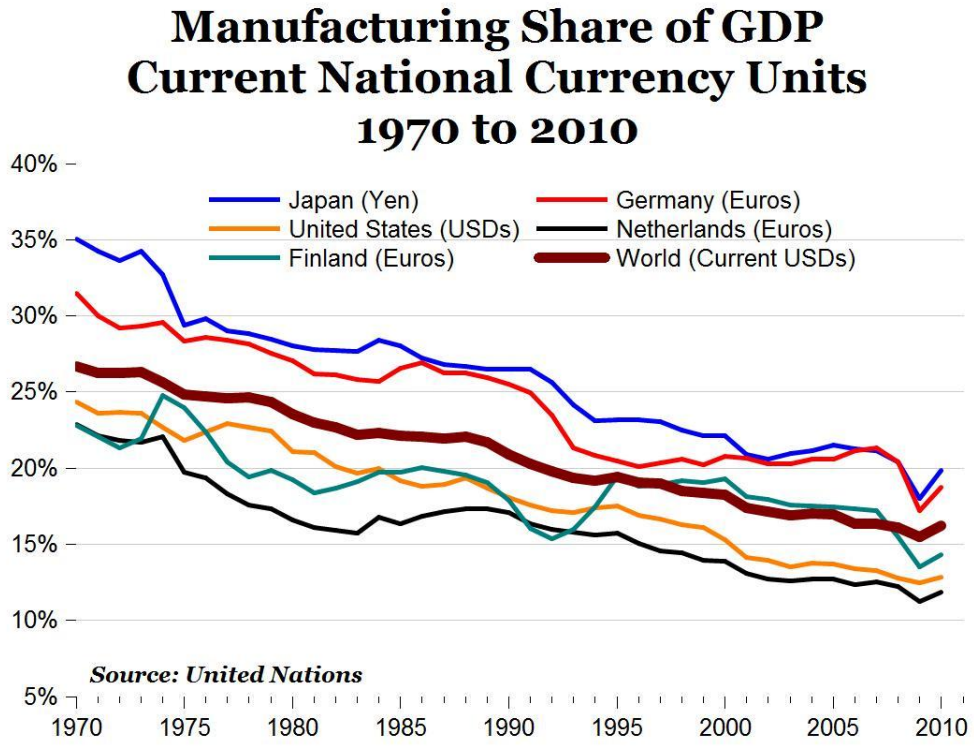
Focus on manufacturing

A re-focus on manufacturing

- In the 1970's and 1980's, inefficient traditional industries, where technology and efficiency had not kept pace with the rest of the world, were gradually, often brutally swept away. The UK economy re-structured and placed increasing emphasis on the service sector……. A process that was effective for a while but which is generally considered to have gone too far. Manufacturing in the UK is currently about 12% of GDP, (down from 30% in 1970) similar to France and the USA but behind Germany at about 20%.
- The government has re-discovered (high value) manufacturing and made it a priority for the future and a cornerstone of its current national research strategy.

Manufacturing trends

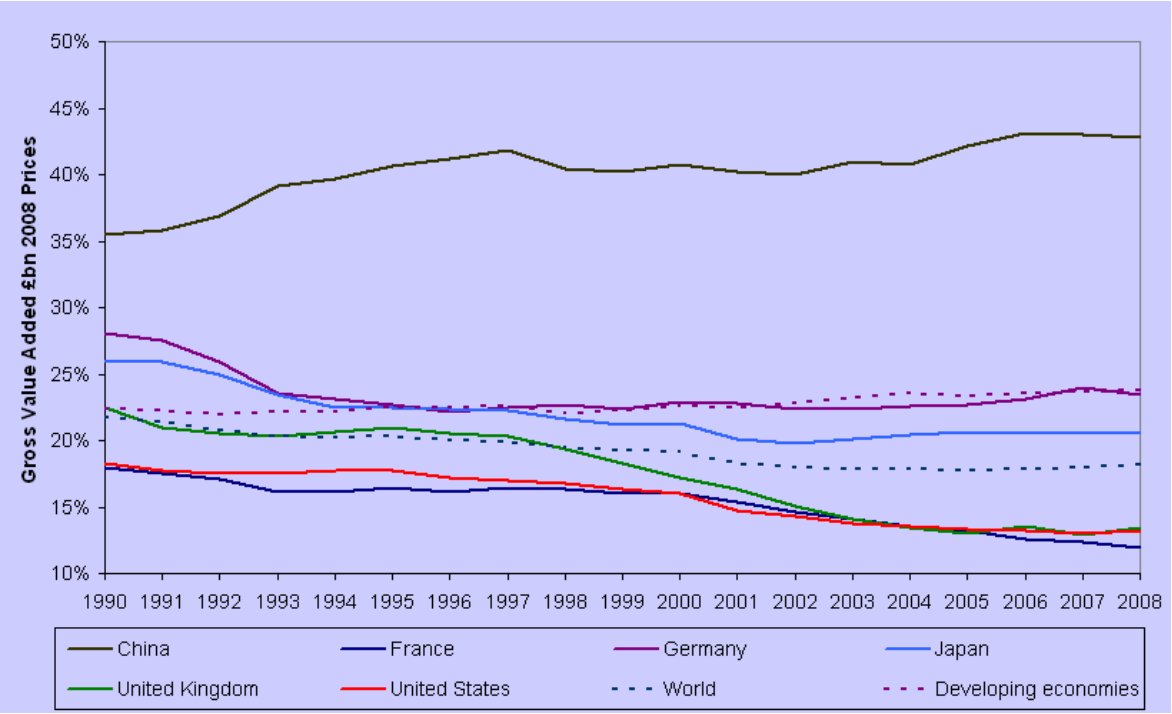
- Most developed Nations have experienced a reduction in the value of manufacturing, as has the world.
- We make more things now but we make them cheaply!



Manufacturing trends

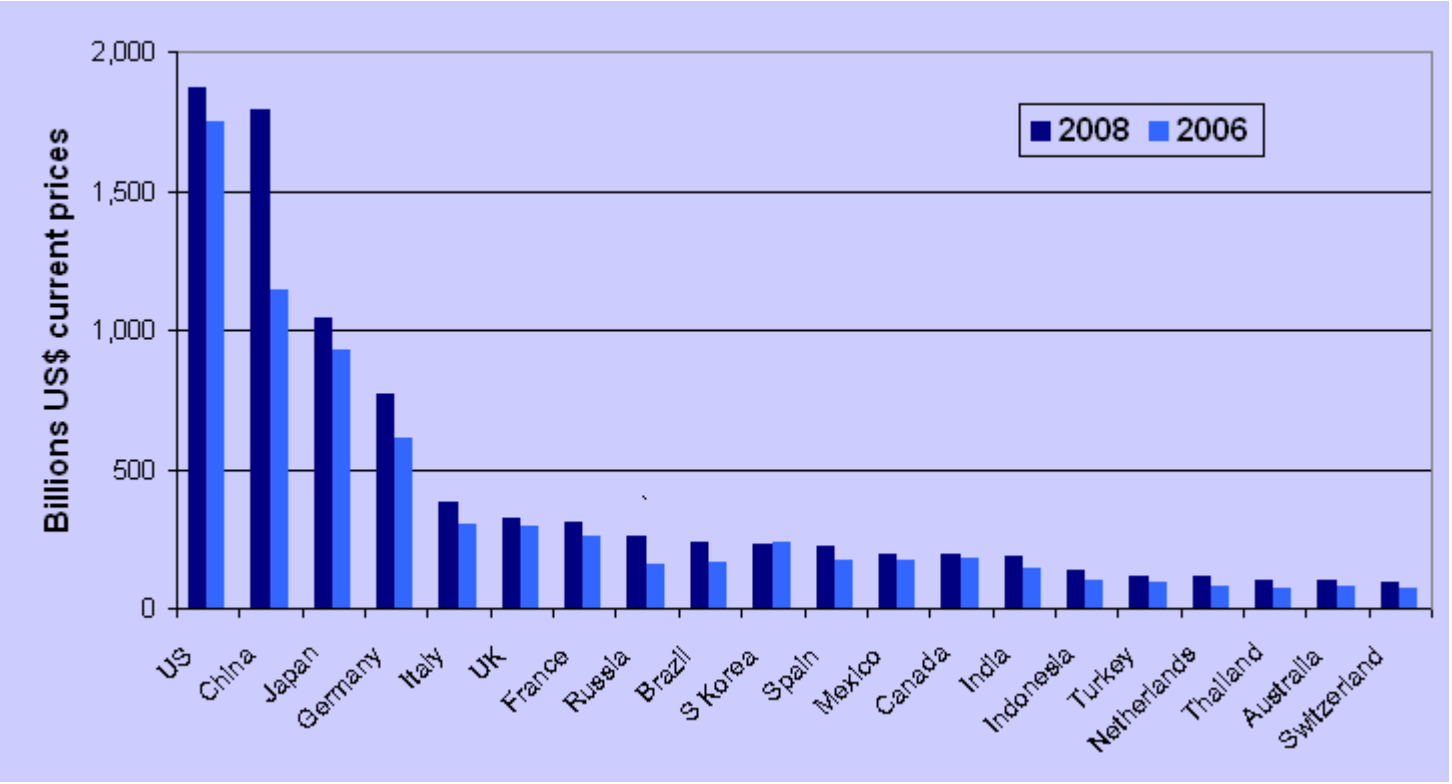
Manufacturing as a percentage of GDP globally and across comparator countries

Source: UNCTAD Handbook of Statistics 2



Manufacturing trends

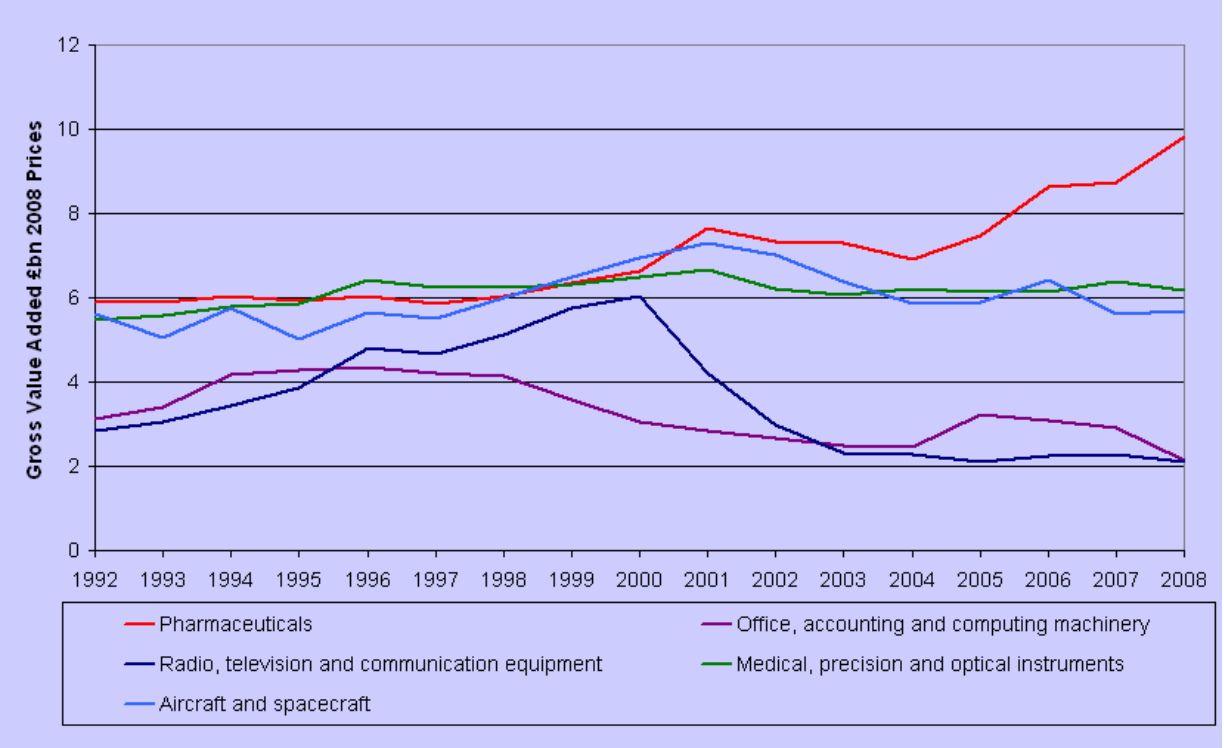
Manufacturing output, US$ in current prices



GVA of Sectors

Gross Value Added of UK high technology sectors
(£bn 2008 constant prices)

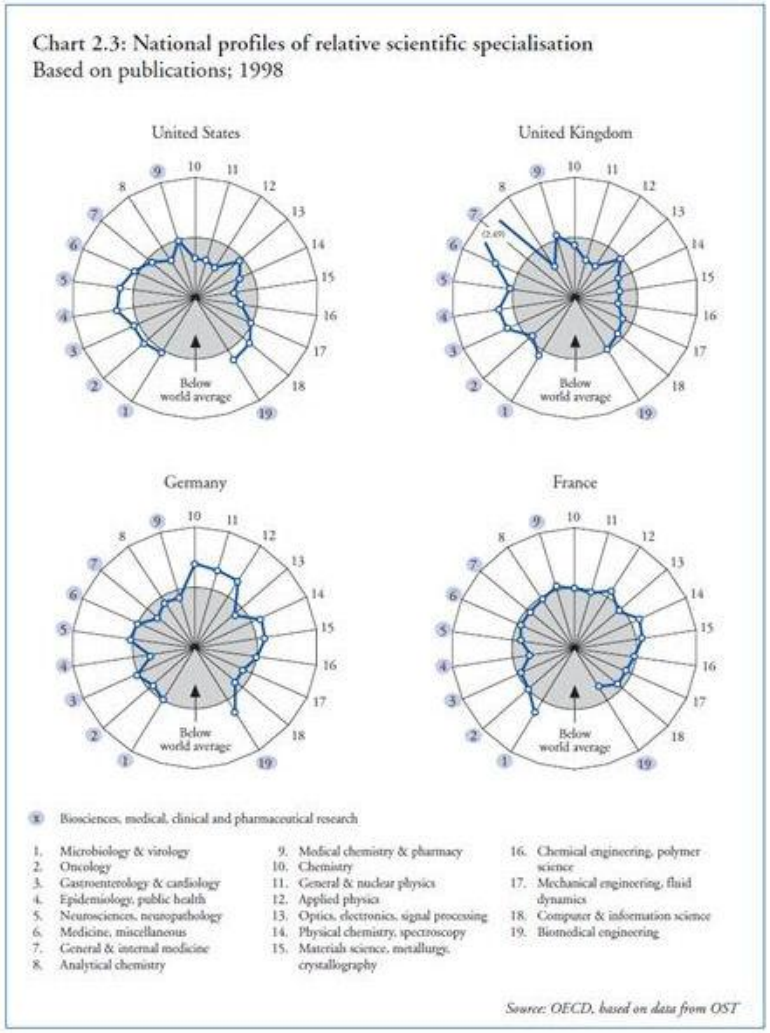
Source: ONS National Accounts



Some industries are more valuable to the UK economy than others

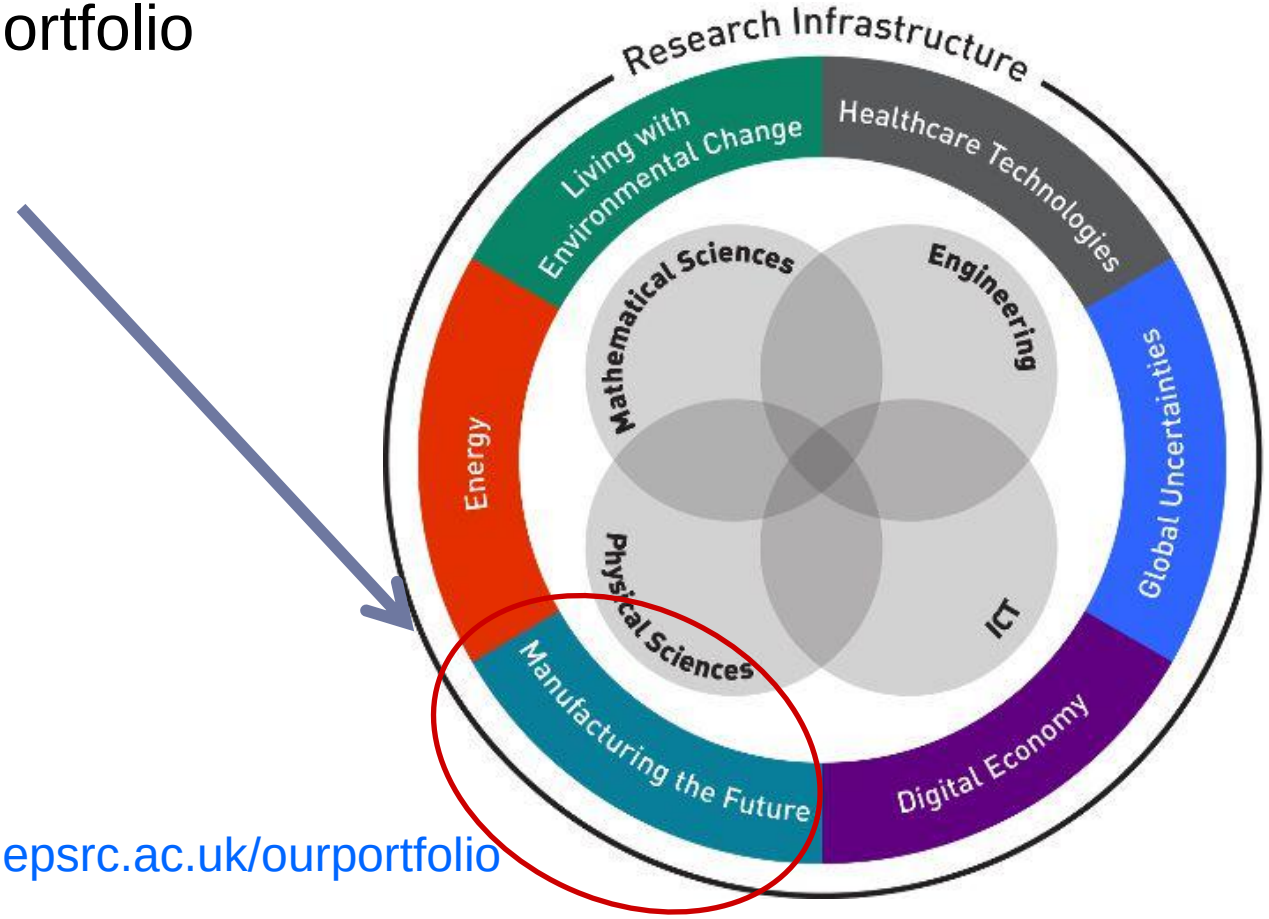
Success in sectors

- The UK CAN focus and has been successful in medical and health related sectors.
- Can it do the same in Manufacturing?



EPSRC Portfolio

- Now Manufacturing is THE focus of EPSRC research portfolio



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MANUFACTURING THE FUTURE

An EPSRC Challenge Theme

- The challenge for Manufacturing the Future is to create, capture and accelerate the benefits of ground-breaking research for the benefit of UK manufacturing.
  - Economic and political realities.
  - Global governmental focus.
  - Technological changes.
  - National research landscape.
  - Emerging opportunities.

Research Challenges

Innovative Production Processes

Transformative processes and technologies for advanced and emergent manufacturing industries.

Manufacturing Informatics

Novel ICT and computer science applied to manufacturing processes and systems.

Sustainable Industrial Systems

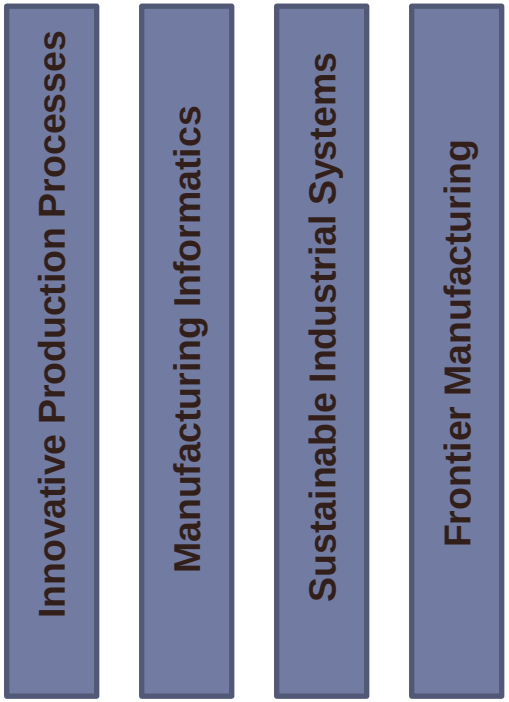
Technologies and operations to reduce usage of material, water and energy resources in manufacturing processes.

Frontier Manufacturing

Translation of new scientific insights into potential future manufacturing processes and systems.

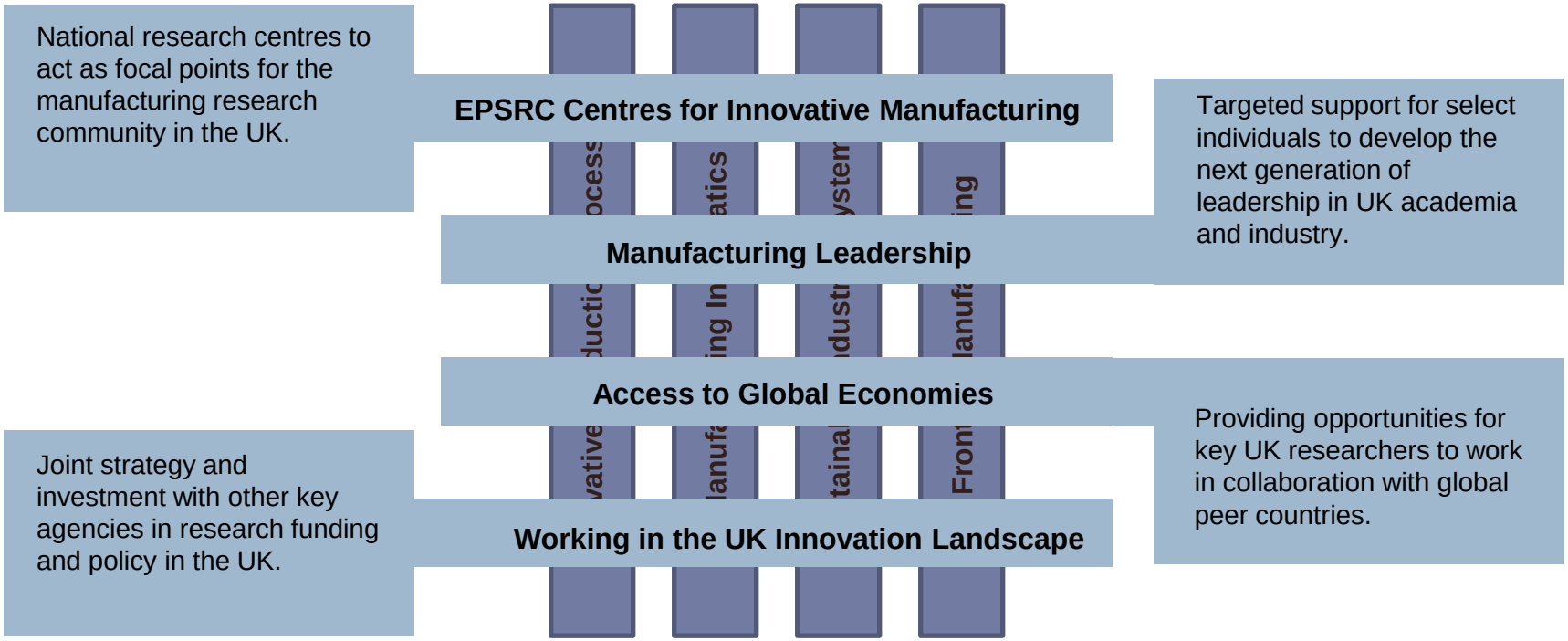
Priorities for Investment

- Research challenges.



Priorities for Investment

- Research challenges and cross-cutting strategies.



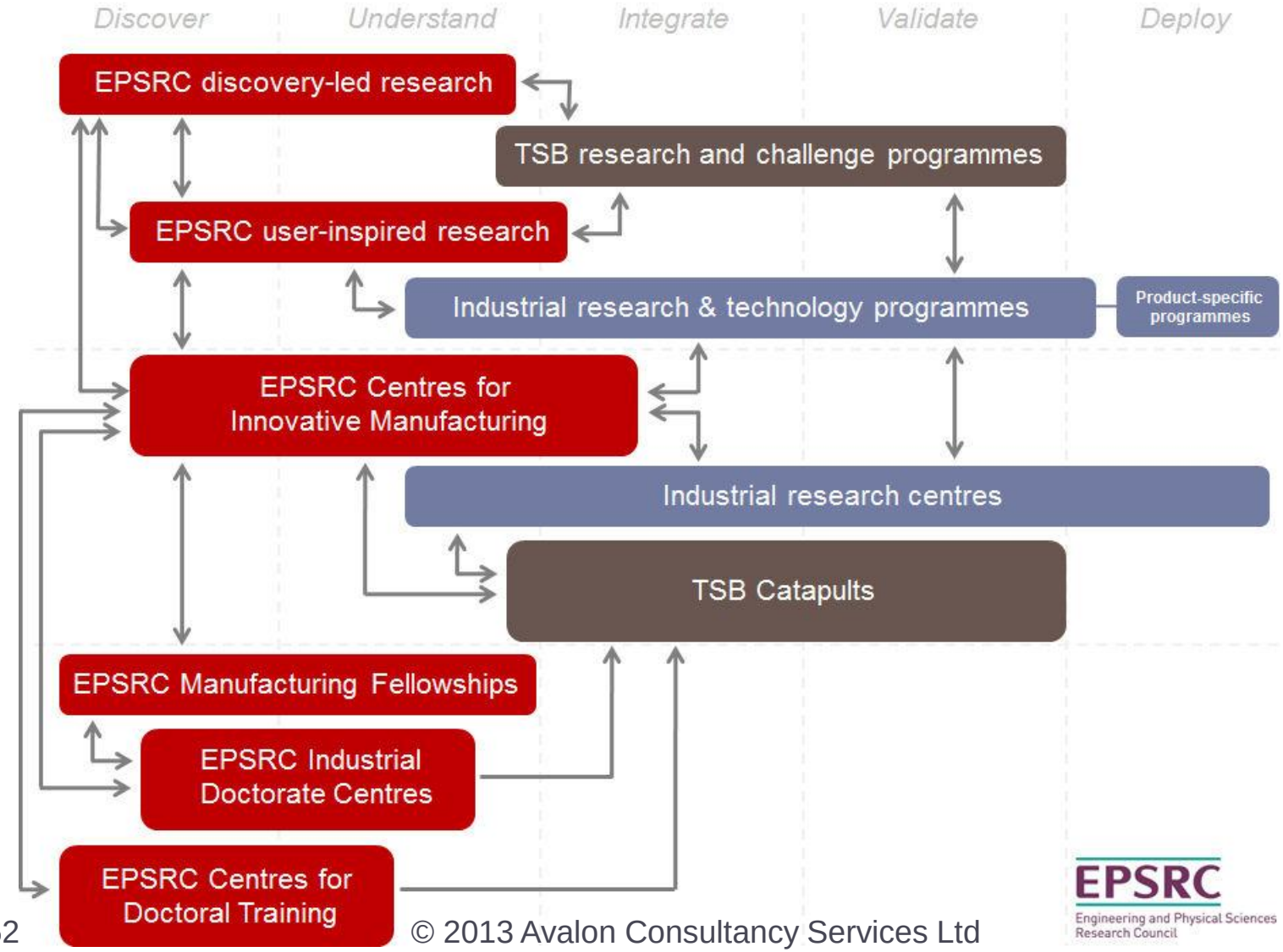
Centres for Innovative Manufacturing

EPSRC Centres

- Co-created with users.
- Director led strategy.
- Explicit national role.
- £5M+ budget.
- Five year duration
- Considerable co-investment and post-investment.
- Platform element in the funding.

Current Centres

- **Additive Manufacturing -** Combining multiple materials and functions for complex electrical, optical and structural properties in a single manufacturing process.
- **Advanced Metrology -** Creating and developing a 'factory on the machine' linking measurement and production to minimise cost, increasing complexity and quality in manufacturing.
- **Composites -** Developing the next generation of composite manufacturing processes based on low cost, short cycle times, efficiency and sustainability.
- **Continuous Manufacturing and Crystallisation -** Better products and processes through continuous manufacturing technology in the chemical process industries.
- **Emergent Macromolecular Therapies -** Creating the capabilities to select drug candidates for clinical trials based on clinical efficacy and feasibility to manufacture the drug.
- **Industrial Sustainability -** Rapidly reducing the resource and energy-intensity of the production of existing goods, and investigating options for a redesign of the industrial system.
- **Intelligent Automation -** Changing the way manufacturing machinery is designed, operated, supported, upgraded, re-used and retired.
- **Liquid Metal Engineering -** Equipping the UK metal-casting industry to become more cost-effective and sustainable, whilst improving casting quality.
- **Photonics** - Research into advanced manufacturing of new photonic materials, fibres and components.
- **Regenerative Medicine -** Translating ideas into treatments through pinpointing commercially robust practices and processes.
- **Through-life Engineering Services -** Designing high value systems such as aircraft engines that require less engineering service, and incur less whole life cost.
- **Ultra Precision -** Creating ultra precision manufacturing processes and machines capable of producing emerging products of differing scale with nanometre accuracy.



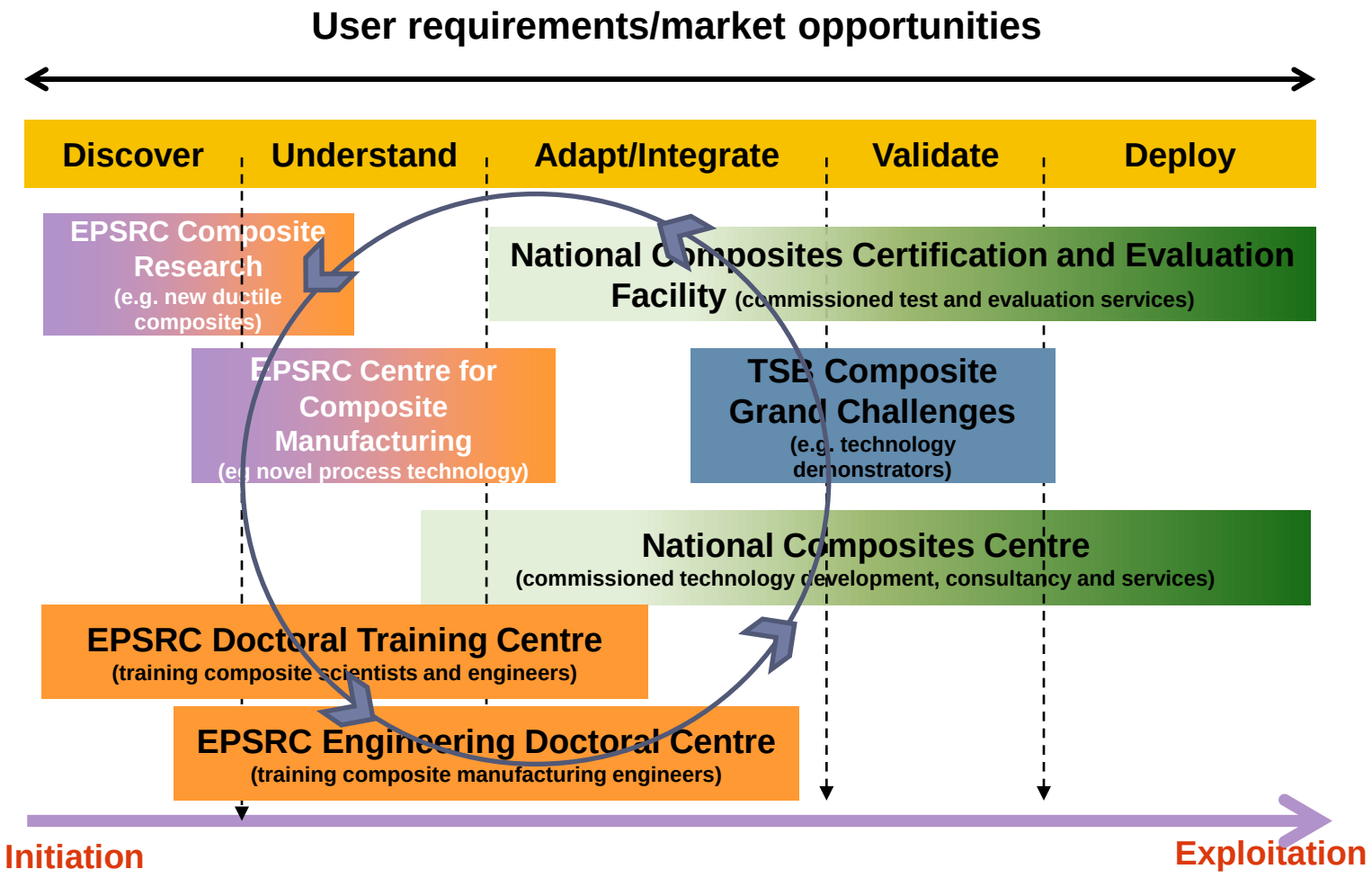
Exemplar – Composite Materials

- The UK invented advanced composites.
  - Carbon fibres at the Royal Aircraft Establishment, followed by the first use of carbon fibre for a safety critical part – the Rolls Royce Fan blade.
- The Country let its lead in Europe slip.
- Composites are now critical not only to aerospace but to the automotive and the renewable energy sectors, priorities for the UK.
- Traditionally about 20 universities had significant research programmes in composites.

Actions taken

- 2008 NATS identifies composites as key technology in structures roadmap.
- 2008 TSB funds big programmes, ALCAS, NGCW.
- 2009 Government responds to develop National Composite Strategy.
- 2009 EPSRC funds – PhD doctoral Training centre at Bristol.
- 2010 National Composite Centre (NCC) launched at Bristol.
- 2010 Regional centre for test and certification (NCCEF) to complement NCC at Manchester.
- 2011 EPSRC Programme grant links Bristol and Imperial College.
- 2011 Composites Centre for Innovative Manufacturing links Bristol, Cranfield, Nottingham and Manchester.
- 2011 NCC incorporated as part of High Value Manufacturing Catapult.
- 2012 Centre for Industrial doctorates links Cranfield, Bristol, Manchester and Nottingham –students based at NCC.

Manufacturing research, innovation and impact



- The net result – a comprehensive capability for development, taking ideas through to application.
- Located near the major industrial companies (Airbus, GKN, Rolls Royce).
- Supported by five top universities, Bristol, Nottingham, Cranfield, Manchester and Imperial College. Facilities ready with a supply of trained engineers to support the industry.

Facilitating the widespread industrial exploitation of composites

The UK and Composites

Everything in place – watch the industry grow!

The Original Problems

- Highly innovative scientists and engineering but not enough focus on translating those ideas into commercial product
- Solved: Impact agenda embedded in university culture, mechanisms for funding with industry; Platform funding encourages long term developments with industry
- Poor communication between universities and business to help relevant ideas become commercialised/start-ups
- Solved: Knowledge transfer networks, Industrial Doctorate centres, Centres for Innovative manufacturing
- Technology innovation centres underfunded and support is too short term.
- Solved: Catapult technology innovation Centres properly funded for the long term, linked with industry and universities
- Funding gap after initial venture has been established
- Not solved completely – hope is that Catapult will bring in capital alongside continued developments

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