You can never predict in physics.....

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The law of unintended consequences provides a rather solemn warning against disorder. Not being able to predict the effects of one's actions in a modern and rational society is a matter for concern. Physics however is a discipline that defies this law. Sometimes that which starts as academic research, undertaken purely to extend the boundaries of our knowledge, can result in extraordinary, occasionally life-changing, spin-offs.

There are many examples of how physics has changed society for the better, perhaps with no targeted intention of doing so from the outset. Below are a few illuminating examples.

The iPod

The Nobel Prize for Physics in 2007 is a good place to start. It is a prime example of how fundamental physics research not only affects people's day-to-day lives but can also energise economies. People do not generally connect the existence of MP3 players with fundamental physics research. Frenchman Albert Fert and German Peter Grunberg received the Nobel Prize for Physics in 2007 for their academic research into Giant Magnetoresistance (GMR). Researching GMR made it possible to miniaturise hard disk drives and create, for example, the iPod.

In 1988, both Fert and Grunberg independently concluded that weak magnetic charges which give rise to differences in electrical resistance could help create a perfect tool for reading data from hard disks. The work was initially applied to sensitive read-out heads but has been advanced commercially for a range of different products. The iconic iPod is possibly the best known spin-off from this research. Since 2001 it has been bought by more than 4 million UK music lovers and is often credited by economists as one of the most important new consumer products in national economies.

At the time of winning the award, Albert Fert was asked whether he foresaw how significant his discovery was and whether he had predicted how widely-used it would become. He responded, "You can never predict in physics. These days when I go to my grocer and see him type on a computer, I say, 'Wow, he's using something I put together in my mind.' It's wonderful." Fert and Grunberg provide a very clear example of how fundamental breakthroughs in physics can sometimes have hugely significant effects on national economies and individual lifestyles that go far beyond the original academic purposes of the research.

GPS

Another product that derived from fundamental physics research which has had a dramatic effect on lifestyle, and in particular for drivers, is the proliferation of global positioning systems (GPS). Now more than 1.5 million UK cars have GPS systems fitted but few drivers consider what GPS actually came from. It was research undertaken in stages by organisations such as the United States Department of Defense and the UK's National Physical Laboratory (NPL).

In the mid-1950s, Louis Essen finished work on the first precise atomic clock at NPL. An atomic clock keeps accurate time by keeping track of atomic frequencies. It defines a second as more than nine billion cycles of radiation, corresponding to the transition between two energy levels of the atom caesium-133. This impeccable precision is used to measure the time taken for a signal to be sent from a satellite to a user which allows the global positioning systems to determine an extremely accurate location.

Applying the atomic clock for use in global positioning systems was largely inspired by military activity in the Cold War. During the Cold War, a team of American scientists were monitoring the movement of the Soviet Union's Sputnik and they realised that as they knew their own location, they could pinpoint where the satellite was along its own orbit using the Doppler Effect, measuring the changes in the frequency of the signal being transmitted by Sputnik. Inspiration from military techniques, fundamental physics research and a consumer demand for easy-to-understand navigation systems have changed the way many of us get from a to b.

Space physics is also an integral part of GPS systems as GPS currently uses signals from more than twenty satellites orbiting the globe. This emphasises a further aspect of developments in physics research which lead to the development of modern technology – international co-operation across disciplines. The UK is widely respected in the international science community. Teams of researchers in the UK contribute massively to advances in international science and international science often provides information which underpins UK breakthroughs.

MRI Scanning

An equally striking spin-off from fundamental physics research now dominates the world of medicine. UK physicist Sir Peter Mansfield received the Nobel Prize in 2003 for his work on magnetic resonance imaging (MRI). The technique emerged from fundamental physics research demonstrating that some atomic nuclei which can be aligned by a magnetic field absorb particular frequencies of radio wave and then release characteristic signals as they relax back to their original state. Mansfield is credited with showing how the radio signals from MRI can be mathematically analysed, making interpretations of the signals into a useful image.

MRI scanners have become a crucial tool in early detection of fatal diseases such as cancer. MRI scans allow medical practitioners to visualise the structure and function of the body to help spot dangerous anomalies such as tumours. MRI scanners create a powerful magnetic field which aligns the magnetisation of hydrogen atoms in the body, allowing an image of the body to be constructed. This technique is particularly advantageous because it is non-intrusive, causing minimal physical damage to gain important results.

There are more than 500 scanners at work in Britain and they form a crucial frontline in the NHS's fight to minimise cancer-related deaths. In 2007 alone, almost three quarters of a million scans were undertaken in UK hospitals and, to date, no rival imaging technique has been developed that has such a remarkable success rate with so little harm caused in use.

Climate modelling and green technology

Hard disk drives, GPS and MRI scanners are all perfect examples of how physics research shapes our modern world. When prioritising UK concerns, the economy and health care are certainly somewhere near the top but there is an even more pressing concern that fundamental physics research has made significant headway in addressing – climate change. Some of the most significant advances in our understanding of how the climate is changing stem from fundamental physics research.

Climate modelling has given scientists and environmentalists the most conclusive evidence to prove that our own emission of noxious greenhouse gases is contributing to climate change. The computer models used to predict climate change take account of the range of factors that play a role in modulating the climate, such as solar activity, atmospheric particles, and feedback factors. The models help us predict the future rate of change and have highlighted how urgently action is required. Without fundamental physics research, we would not understand how pressure, volume and temperature interact in our atmosphere, nor would we understand the way the electromagnetic spectrum is reflected and absorbed, and we would not be able to forecast the future.

Politicians have been influenced by one crucial document that drew its conclusions from extensive use of computer modelling systems, the IPCC Summary for Policymakers of the Scientific Assessment. No doubt it was this document that world leaders will have been re-reading on the way to Bali last December.

The problem of climate change can not be solved by physics research alone but physics research can play a key role in helping us understand the scale of the threat mankind is facing. Equally, it can help us in developing new, green technologies. While in the Twentieth Century World Wars and a subsequent Cold War dominated international concerns, if the Twenty First Century continues as it has begun then climate chaos will be the biggest concern. It was physicists and mathematicians that broke the code and helped end the Second World War: physicists can play just as key a role in saving the environment.

A Happy New Year for physics?

Physics enjoyed a good 2007. For the first time in twenty years, the number of A and AS Level Examination entrants saw a small but significant increase. As encouraging were statistics that showed the gender gap in physics classrooms decreasing as the proportion of girls choosing to study physics increased. Lord Sainsbury's 'Race to the Top' Review emphasised the need for us to further develop high-value technologies as part of our knowledge economy if we want to avoid becoming global losers. So, at the grass roots physics is on the rise and there is official acknowledgement from our current Government that physics research needs to be nurtured.

However, funding for fundamental physics research is under pressure. In December 2007 the Department for Innovation, Universities and Skills (DIUS) announced the Science Budget for 2008-2011. While the new budget was welcomed by the majority of the UK's science community, there was alarm among both the fundamental physics research community and astronomers as it became apparent that the Science and Technology Facilities Council (STFC) was being allocated less money than it needed to maintain its current commitments.

STFC was formed in April 2007 through the merger of the Council of the Central Laboratory of the Research Councils and the Particle Physics and Astronomy Research Councils. Its main responsibilities are to fund university departments through grants for research in particle physics, space science, astronomy and nuclear science while managing world-class scientific facilities in the UK and part-sponsoring international science facilities to allow UK researchers access to the very best facilities around the world.

The shortfall in STFC's budget has resulted in a delivery plan that will lead to job losses at universities and three leading research laboratories; a 25 per cent cut in university grants; and withdrawal from a number of high-profile programmes such as the International Linear Collider.

In light of these concerns, the Government has commissioned a review of the health of physics. It is crucial that all concerned keep in mind the importance of fundamental research to both the health of the UK's science base and to the economy.