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The Future is not what it used to be! The position of the creative scientist in a changing world

John Wood

Faculty of Engineering, Imperial College London, SW7 2AZ, UK.
j.wood@imperial.ac.uk

Abstract

We discuss the position of the creative scientist in a changing world. The challenges facing society in the future are immense. Our ability to model and predict what affects our environment and ultimately our survival is becoming ever more sophisticated. In addition to the magnitude of the challenges, there is an increasing investment in global research infrastructure. The sociological and psychological interdependency of these interacting networks linked in real time is a fascinating study in its own right as each person depends on every other player to undertake their part of the jigsaw puzzle. This approach to global research is becoming endemic for large areas of research. The question I ask and will look in this paper is what is the role of an individual as a creative being in this seemingly unstoppable approach.

"Time present and time past
Are both perhaps present in time future,
And time future contained in time past."[1]

1. Introduction

The challenges facing society in the future are immense. Our ability to model and predict what affects our environment and ultimately our survival is becoming ever more sophisticated. The current investments in petascale computing power combining capacity and capability coupled with adaptive meshing codes enables us to see what will happen as the environment changes whether by global heating or changes in the methane content of the oceans. Few of these make comfortable reading. While there may be arguments on the causes of these effects there is a general agreement that hiding from the predictions is not a responsible attitude. Fragmentation of effort to both understand and allay these challenges will not achieve lasting solutions. Politicians are waking up to the fact that these are global

challenges needing global solutions.

In addition to the magnitude of the challenges, there is an increasing investment in global research infrastructure. At one extreme this is aided by super grids connecting very large data sets and high performance computing power that is going up by orders of magnitude each year. At the other end, there are the very large international facilities such as the Large Hadron Collider at CERN. The result is that there are thousands of researchers communicating all around the world on a 24/7 basis. The sociological and psychological interdependency of these interacting networks linked in real time is a fascinating study in its own right as each person depends on every other player to undertake their part of the jigsaw puzzle. The resulting trust in each other transcends national and racial boundaries. Here a common vision in the end goal has to be owned by each party.

This approach to global research is becoming endemic for large areas of research, not just high-energy physics. Population and genetic studies, longitudinal social surveys and atmospheric monitoring are all moving in the same direction. The question I ask and will look at in the rest of this paper is what is the role of an individual as a creative being in this seemingly unstoppable approach. Are researchers of the future just cogs in a machine? Who will be the person who sees that in some cases "The Emperor has no clothes on!"

There is also the political belief (justified as it happens) that investment in research pays economic dividends as witnessed by the following public statements:

> *The nations that can thrive in a highly competitive global economy will be those that can compete on high technology and intellectual strength - attracting the highest-skilled people and the companies which have the potential to innovate and to turn invention into commercial opportunity. These are the sources of the new prosperity.*
>
> *(Gordon Brown as Chancellor of the Exchequer 2004)*

> *In today's global economy, investment in science and innovation is not an intellectual luxury for a developed country, but an economic and social necessity, and a key part of any strategy for economic success.*
>
> *(Lord Sainsbury as the UK Minister for Science 2007)*

> *Promoting the 'knowledge triangle' (education-research-innovation) is central for the Europe of the future and for the development of knowledge-based economies...Human resources for science and technology in Europe need to be increased and the attractiveness of Europe for highly qualified scientists boosted... The Lisbon agenda and the European Research Area are delivering!*
>
> *(European Council Presidency Conclusions, December 2007)*

In the UK, the booklet "Allocations of the Science Budget 2008-2011" (2) outlines the political approach to scientific research funding. The justification is for solutions and approaches to:

- Energy supply and conservation
- Environmental change

- Personal and Civic security
- An ageing population
- The impact of the digital economy
- Economic returns from nanotechnology

Similar messages come from other leaders of advanced countries, viz:

> *To build a future of energy security, we must trust in the creative genius of American researchers and entrepreneurs and empower them to pioneer a new generation of clean energy technology... So I ask Congress to double Federal support for critical basic research in the physical sciences and ensure that America remains the most dynamic nation on Earth.*

These are the words of George W. Bush in his State of the Nation speech in January 2008. Fine words indeed, only to be followed by the political reality when Congress slashed the basic science budget by up to 15% which sent ripples across the globe and resulted in many researchers and other governments wondering whether they could trust US promises in the future. Since then various fudges to counter the reduction have been made but the damage was done.

While these high level decisions are being made, we return to the humble researcher who sees things in a completely different light. They are in research for several reasons, namely:

- The thrill of discovery - because it is there.
- Thinking the unthinkable
- Helping society
- Defending national values
- Working with other across the world.

For academics in the UK, those undertaking research are nationally assessed in the periodic Research Assessment Exercise. In many universities, not achieving a good assessment is seen as a reason for dismissal, and given there is no tenure in the UK, this approach has been exercised several times. Why then do academic researchers enter this rat race? What gives them a buzz? From my experience the main driver is peer group recognition. It is certainly not money or even worldly esteem. For most it must be fun, a good reason to go to work.

Marrying the aspirations of the politicians and funders with those of the individual researchers will always result in tension. However I believe that it is essentially a mark of a civilised society to constantly strive into the unknown. It is here that the creative process in science comes to the fore.

2. The Fifth Freedom

Within the European Union there is an increasing emphasis of working together more coherently. Under the European Treaty there were initially four basic freedoms:

- Freedom of movement of goods
- Freedom of movement of services
- Freedom of movement of capital
- Freedom of movement of labour.

To these has recently been added the fifth freedom under the so called Ljubljana process. This is stated as the "Freedom of movement of knowledge." A new European Research Advisory Board has recently been formed to look at this concept within the context of:

- Modernisation of many European Universities
- Maximising the effectiveness of the link between public and privately funded research
- Achieving more engagement with the general public on research
- Increasing internationalisation of research.

The concept of the freedom of movement of knowledge is still being worked through but it is intended to look, among other things, for mechanisms that allow researchers to move about more freely without loosing out financially or socially. When Alcuin founded the library at Aix-la-Chapelle at Charlemagne's request scholars from all around Europe flocked to this edifice of learning and research. Since then national boundaries and outmoded learning institutions have largely undone this freedom of movement apart from the very start of a research career. In the US the need to achieve tenure has had the same effect.

So, the present and upcoming issues that will force us to rethink the creative process are:

- Increasing globalisation of research
- The impact of every expanding e-science
- The need to deliver 'whole body solutions'
- The impact of large international research infrastructures.

I want to look at two of these in more detail since the impact of globalization and the need for whole body solutions is fairly evident. I will concentrate on the impact of e-science and large international research infrastructures using the European X-ray Free Electron Laser as an example.

3. E-science and the Virtual Research Environment

The term e-science or e-infrastructure is evolving in its impact. It generally refers to ICT based infrastructure to support the research process including:

- Networks
- Access management and other "middleware" to manage the use of networked resources
- Computer facilities and specifically the linking together of High Performance Computers
- Online content (research data, papers and journals, bibliometric data and increasingly grey content).

As we move towards electronic publications that will be linked back to the original data for further interrogation we must ask two basic questions. The first is, for how long can the data be kept private where the fifth freedom is exercised, and secondly, who preserves and guarantees the data are true. The two are intertwined.

Several specific issues are coming up and are indeed almost with us. They are:

- Data deluge
- Curation and provenance of data
- Interoperability between data sets
- Increasing multi-disciplinary research
- Linking of publications to data

A further question is how much supercomputing power does a country need for basic research? Currently, computers with petaflop capacity are already operating and plans are already in progress to go up by three orders of magnitude to exaflop machines. While it is acknowledged that the codes and vision of researchers to use these machines at their full capability is restricted, nevertheless there is an insatiable desire to have the biggest and best. The only restriction is the amount of power needed for both running and cooling which is becoming excessive.

Physically, data deluge is not a problem although making sure it is still in a readable form is. How many computers can handle floppy discs now? I have already alluded for the need for access and long-term data management to protect the data. However the rate it is being produced at is increasing exponentially and in reality, most researchers will access metadata where an interpretative step has already taken place. This is not new. Conventional academic papers are a form of metadata. However there is one difference. The academic papers are peer reviewed which is at least one check on the truthfulness of the data and its

interpretation. The rate of content/data deposition and the engines for interpreting it are not open to scrutiny in the same way. Commercial companies do offer data management services but many researchers are wary of handing their content freely to such bodies that may not necessarily have the long term interests of the scientist as a key driver. Several countries are undertaking studies on the best way to preserve key research data and to the governance models required.

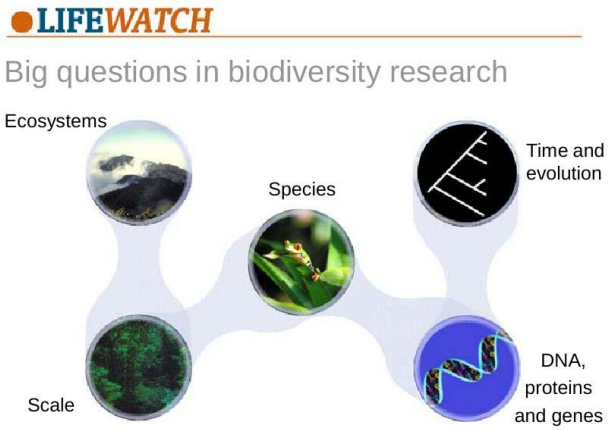

Figure 1 The range of data sets/models for integration in the Lifewatch Project (Courtesy of W.Los).

A further impact of e-science is that researchers can access facilities around the world and data sets that are outside their own narrow range of expertise. Sitting in Imperial College London, I can currently operate microscopes in real time at Georgia Tech. An example might be where a biologist sends samples to the LCLS X-ray source in California to the spallation neutron source at Oakridge, Tennessee, to advanced NMR facilities outside Tokyo without attending any of the facilities themselves. The data generated comes to the researcher who then has to integrate the information with other studies from environmental monitoring and modeling, and so on. The biologist may not be an expert in any one technique. They may act more as a conductor of an orchestra. Although there have been experiments with remote conducting, it is normal for the conductor to be present in the concert hall to achieve maximum emotional impact. A good example of such a project is one that is being initially funded by the European Union called "Lifewatch" which illustrates the issue well (figure 1). The Virtual Research environment underpinning this project is shown in figure 2 where

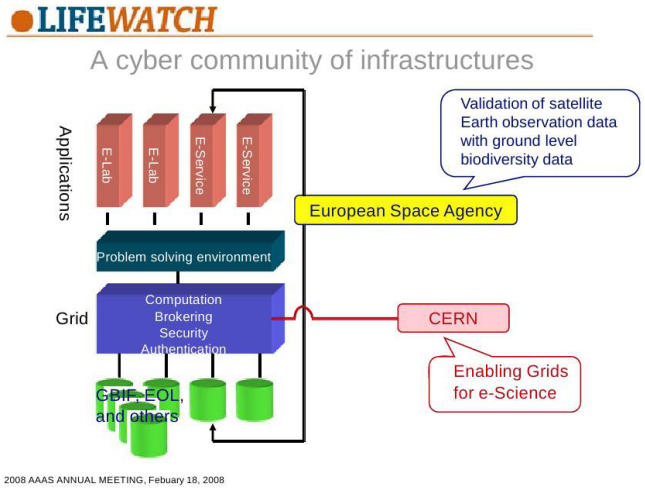

Figure 2 The underlying Virtual Research Environment behind Lifewatch (Courtesy of W.Los) .

information from satellites and links to the computing facilities at CERN are all integrated. Figure 3 shows this in more general terms. The nature of the Virtual Research Environment where the researcher creates the knowledge and wants subsequently to access the full body of information wherever it comes from yet be assured that the curation, authentication etc are in safe hands.

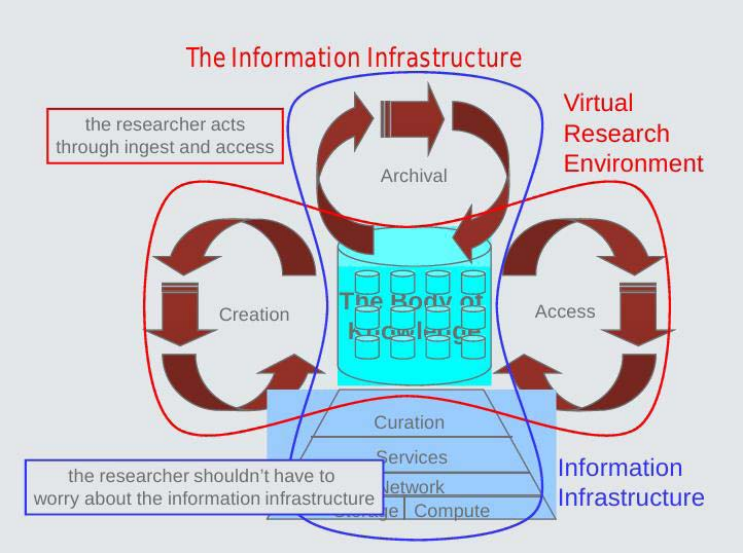

Figure 3 A more general schematic diagram of the Virtual Research Environment (courtesy STFC)

4. Large International Research Infrastructures

In 2002 the European Council launched the European Strategy forum for Research Infrastructures (ESFRI) and in 2006 it published its first Roadmap of 35 large-scale research infrastructures [3]. A similar exercise had been undertaken by the Department of Energy in the USA a year or so earlier. ESFRI have now published an updated version at the end of 2008 adding a further 10 projects and removing one from the original list. One of the continuing projects is Lifewatch (above). Individual Member States and other regions of the World are now publishing their own roadmaps, often with budgetary commitments. A number are already being funded in a preparatory phase.

The infrastructures cover a wide range of disciplines from humanities and social science to enormous telescopes. Perhaps the best known in Europe is the Large Hadron Collider at CERN. It is impossible to gain a feel for the size of these facilities and figure 4 shows some of the components prior to full assembly that have gone into one of the detectors.

It is also becoming clear that co-location of facilities allows researchers to have one stop shops and they also foster new ideas and collaborations. An example in figure 5 is the Rutherford-Appleton Laboratory in the UK. Here is sited the UK synchrotron "Diamond", the spallation neutron source "ISIS", the lasers "Vulcan" and "Astra-Gemini" in addition to particle physics, computing and space laboratories. Other examples can be found at Oakridge National Laboratory and in Grenoble where the Institut Laue-Langevin, the

European Synchrotron Radiation Facility and a branch of the European Molecular Biology Laboratory are located on the same site.

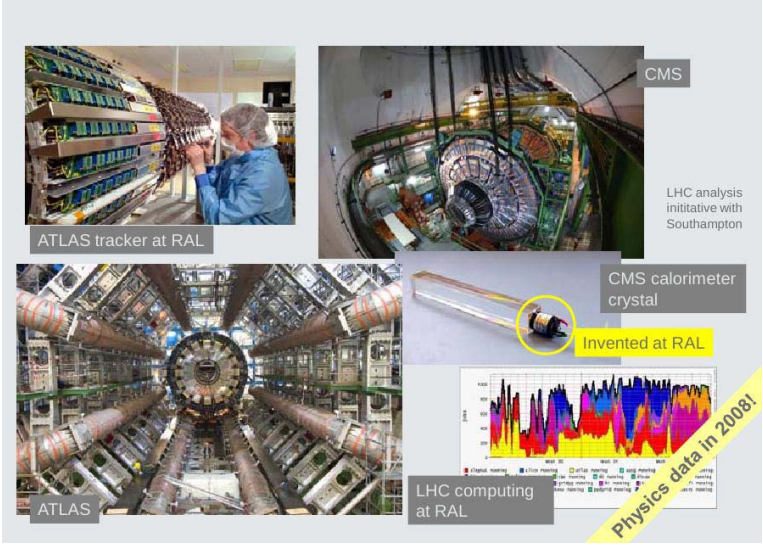

Figure 4 Some of the components being assembled for the ATLAS detector at CERN (courtesy STFC and CERN)

One of the projects on the ESFRI Roadmap is entitled "CLARIN" (figure 6) which is a semantic web approach to looking at language in the context in which it is used and when. This project has raised considerable interest in many countries outside the EU.

Figure 5 The Rutherford-Appleton Laboratory

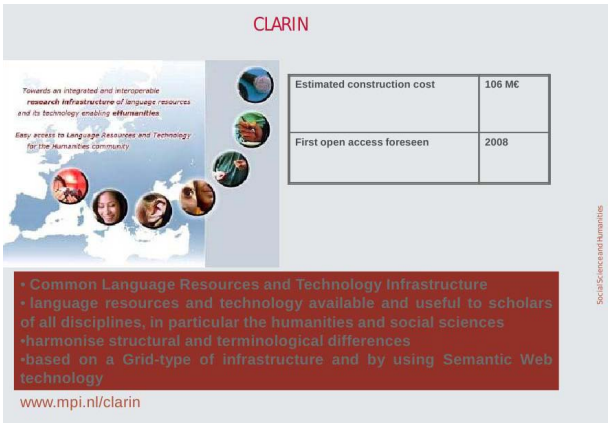

Figure 6 A Humanities based large research infrastructure (ESFRI Roadmap 2006)

These infrastructures are now discussed at G8 ministerial and there is active interest in many emerging countries in participating. I now wish to take one example of a facility that will be built in Hamburg similar to facilities under construction in Japan and the USA. It is the European X-ray Free Electron Laser. It is an X-ray source with a peak brightness a billion times greater than state of the art synchrotrons at the moment which will give atomic resolution. More importantly the pulse duration is of the order of a few tens of femtoseconds or the time taken for an individual atom to make one displacement. Thus it is effectively an atomic movie camera. Figure 7 shows the essential features: an electron accelerator is followed by a series of magnets of opposite poles that flick the electron beam from side to side to cause photon emission. These photons form a laser which gives the very intense and sharp pulses of X-rays. A new X-ray source is needed for studies of new non-

equilibrium states of matter at atomic resolution in space and time

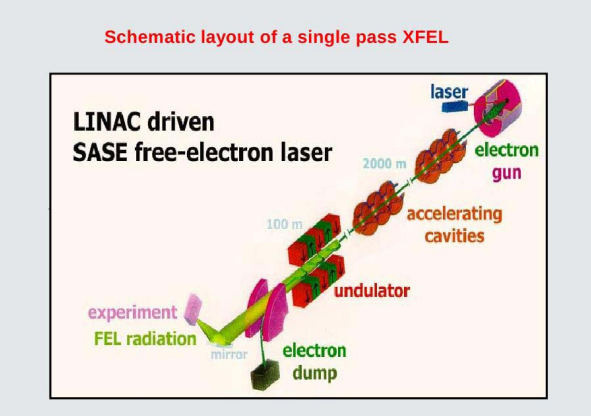

Figure 7 European X-ray Free Electron Laser to be built in Hamburg (courtesy DESY)

Currently 12 countries (including Russia and China) have agreed to fund this facility at an initial capital cost of 1.2 billion euros. The facility is just over 3km in length and will not be operating as a facility before 2016. Many of the visionaries who conceived the initial idea have retired and this is one of the key elements of these large facilities that many scientists work for years on prototypes and simulations without seeing the final result. At the experimental end of the facility are detectors for the photon pulses that will arrive with alarming regularity (figure 8). The sheer volume of data that will have to be stored has been estimated at DESY and is shown in figure 9.

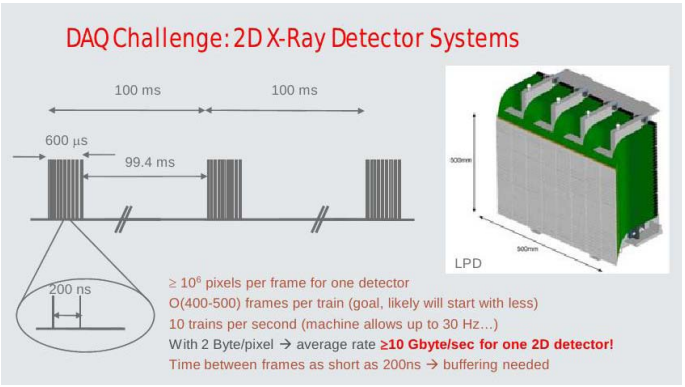

Figure 8 Data Acquisition Challenge for Detectors (courtesy E-XFEL)

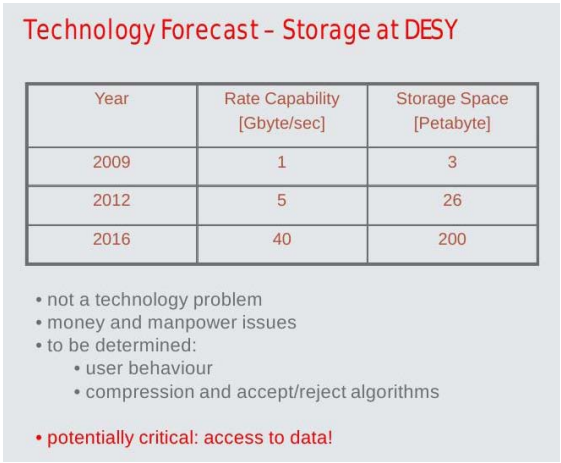

Figure 9 Potential Data Explosion at DESY (Courtesy E-XFEL)

With all these data being available to the creative scientist there is a great fear that new ideas will be buried or that data generation becomes an end in itself. The widely quoted sonnet X from Huntsman, "What Quarry?" by Edna St.Vincent Millay are relevant here:

"Upon this gifted age, in its dark hour,
Falls from the sky a meteoric shower
Of facts…they lie unquestioned, uncombined.

Wisdom enough to leech us of our ill
Is daily spun; but there exists no loom
To weave it into fabric;…"

5. Looking to the future. "To be a machine or not to be. That is the question."

How indeed is the creativity of the individual scientist to be fostered in this changing world of research? Just who will have the passion to drive things forward when the community is so diverse? Are there "no go" limits in certain areas such as cloning or in producing designer babies? Who will be the international police - is there a need for a World Research Council or will this be a Tower of Babel? We face the potential that the truly creative scientist will be ignored as the mighty machine moves forward in an unstoppable way. Indeed, will the scientist merely be a machine in the future?

The Oxford English Dictionary has a number of definitions of "machine." Summarising those that are relevant here:

- A structure of any kind
- A vehicle or ship
- A military engine
- An apparatus for applying mechanical power
- The human frame
- A combination of parts moving mechanically as contrasted with a being having life, consciousness and will. Hence applied to a person who acts purely out of habit or obedience to a rule…

However the building of a machine can be a highly creative process and it is important that this distinction between the creation of a machine and treating a scientist like a machine is fully realised. I recently heard a quote on the BBC World Service by a CEO of a major international corporation, "The Corporation is not a machine; it is made up of highly creative people."

Yet we live in a fallen world where we can act like machines in much of what we do. Likewise we can be so creative as to be ungovernable. So yes we can be like machines following without question the norms of society. Likewise we can reflect the Creator in being free to "think God's thoughts after him." In the end all can decide on how we will act. Senior figures in scientific research need to think again on what form research training should take to encourage creativity in this new world, for "without a vision the people perish!"

7. Summary and Conclusions

- The challenges before society are complex and complex interacting solutions are needed - who decides the agenda?
- Linking research with economic performance is fine for politicians but can be a turn off for the researcher.
- Achieving a balance between top down and bottom up research is essential
- Who do we trust to take the real decisions?
- How is the governance of research transparent and open to account?
- Is international co-operation merely a pipe dream?
- More remote science will be done by people who rely on other experts entirely.
- The range of scientific research techniques available is becoming increasingly large and diverse.
- Data deluge is almost upon us. How to handle the challenges ahead is going to require trust and openness.
- The underlying e-infrastructure is critical for looking at whole body problems. Managing this will require a different type of research support in the future.
- There are big issues at stake concerning personal freedom. Why are faith communities so silent?
- Within this new environment we need to think again about how young research scientists are trained.
- "Open our eyes to see wonderful things from your Law!" It is truly a wonderful world!

Figure 10 The European Southern Observatory at Paranell in Chile (author's own photograph)

Acknowledgements

I have been extremely fortunate to have been involved with so many scientists and policy makers during my career that it is impossible to individually name them. I have drawn on the outputs from the then Council for the Central Laboratories of the Research Councils when I was chief executive, from the staff at DESY, Germany and the European XFEL team, from ESFRI delegates and the team at DG Research supporting them in Brussels, from the many people around the world such as Ray Orbach at the Department of Energy in the USA, Jie Zhang then at the Chinese Academy of Sciences and so the list goes on. I am particularly grateful to my family who has endured my restlessness and absence. It could not have been too bad since both offspring have decided to follow a scientific research career -the future is theirs!

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