Issue 11, Autumn 2013

A Global Village

WHERE POLICY AND POLITICS MEET SCIENCE AND ENGINEERING

Biotech

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Space: The Next Suburbia?

Astrobiology | Space Stations | Space Propulsion | Space Biomedicine

E-Democracy

Imperialism 2.0 | Access Services | European Citizens' Initiative

imperial college union

Foreword

Twelve people have walked on the Moon, and quite a few more have gone into orbit around Earth, but in terms of the universe human space exploration has not gone so far. Nonetheless, most of us who remember the Apollo programme felt we went vicariously to the Moon with the astronauts. Even today, as we enter an era where lots of people have put down deposits for tourist trips to the edge of space with Virgin Galactic, many feel that there is something special about getting off our planet. I think that it is visceral. Could humans eventually live out there? Space is the final frontier of our world and it calls to be explored and understood.

In a real sense we (or at least, the stuff we are made of) came out of the universe. At the most extreme, all the material in us came out of the Big Bang. However between the Big Bang and today much more has happened. The idea of the Big Bang was derived from astrophysics but today we also have new sciences such as astrochemistry and astrobiology. These are emerging to allow us to trace the way in which, from the original chaos, the order that we see in life on our planet developed. How did the Cosmos come to create the stars and the planets? How did environments form that allowed something as complicated as us to evolve? How did the teeming life we see on our planet come together? We can ask these questions today as our technology now allows it. Moreover these questions give rise to even more intriguing questions. The surprise discovery of planets outside our solar system about a decade and a half ago has now led us to realise that planets are common. Could there be life elsewhere?

At the same time, the ability to get to some of the nearest celestial bodies allows us to ask why the siblings of our Earth now have environments very different to Earth and in many respects quite inimical to life. Was there once life on Mars? How or why did it fail? Why did the greenhouse effect occur on Venus so catastrophically that metal can melt on the surface? Could life eventually come to exist on Mars? The strange Moons of the outer solar system - Europa, Ganymede, Enceladus and perhaps Titan - seem to be likely to contain liquid water. Are there some nascent processes even now slowly developing in the subsurface ocean of one of these objects that will lead to life in the future? We can even fantasize that in the far distant future, when the Sun becomes a red giant as we know it must, that one day these places may seem more hospitable than our Earth.

The technology of the space age has expanded our horizons over the last half century. It has pushed back the final frontiers of our universe and it is not over. What a great age to be living in!

Prof. David Southwood
President of the Royal Astronomical Society and Senior Research Investigator at Imperial College London, and former Director of Science and Robotic Exploration at the European Space Agency (ESA).

From the Editors

Are we witnessing a new age of space exploration? In this issue of *A Global Village* we explore the accelerating race to visit and ultimately inhabit nearby 'rocks' such as Mars and beyond. From new innovations in space medicine, propulsion and space-station design, as discussed by *Dr. Simon Evett & Dr. Iya Whitely*, *Les Johnson* and *Fiona Larner* respectively, to the development of new scientific techniques looking for signs of life, as explored by *Louise Preston* and *Angelica Angles*, it seems that a renaissance in spaceflight engineering is truly underway!

Neave O'Clery Editor In Chief

In recent years a number of online platforms have become tools for campaigns on a range of economic, political and environmental issues. In this issue *Marc Rea* and *Prisca Merz* discuss e-forums aimed at catalysing a transition to more participative democracies worldwide. Interpreting democracy in terms of equal opportunity, *Emmanouela Patiniotaki* reflects on the role technology can play in giving disabled people access to education, while *Steve Fuller* considers ethical and practical questions surrounding the promotion of Western technology to achieve economic growth in the developing world.

Antonio Torrisi Deputy Editor

Biotechnology is a quickly evolving and expanding area of research, encompassing a wide range of disciplines and crossing boundaries between academic fields and industry. *Kiran Nandra* tackles the positives and perils of biotech and its future with the pharmaceutical industry. Enormous investment and hope are resting on this emerging industry to develop novel clinical treatments and drugs - can biotech live up to this expectation?

Georgia Lockwood-Estrin Global Health Editor

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Biotech

Biotech and Big Pharma: Bringing Innovative Technology to the Patient

Dr. Kiran Nandra, Oxbridge Biotech Roundtable

There are more than 250 biotech healthcare products and vaccines currently on the market. More than 13.3 million farmers use agricultural biotech to improve farming techniques and yields, and more than 50 bio refineries are currently being built in the US for the production of biofuels. From improving the process of food production to keep up with the demands of a rising population, to developing novel and sophisticated biological treatments for life-threatening diseases, biotech can and does impact multiple aspects of our life.

Biotechnology, or biotech, is defined as "the use of molecular processes at a cellular level to fuel modern technology". Biotech covers a wide range of techniques including both yeast-based fermentation and single cell phage assays, which allows for the development of novel bioengineered products such as modified genes, monoclonal antibodies and biotherapeutics.

The term biotechnology was first coined by Karl Ereky in 1919 as a "technology which converted raw materials into a more useful product". The first use of biotech processes in the pharmaceutical industry was in the production of penicillin in the 1940s. At this time during World War II, large quantities of penicillin were needed, and so a fermentation technique was devised and used. A species of bacterium called P. chrysogenum was irradiated with x-rays, resulting in a mutant form that could quickly produce penicillin in fully aerated large metal tanks at rates a thousand times faster than before. In recent years the commercialisation of this science has resulted in what is commonly known as the biotech industry.

Ernst & Young reported an increase of 37% in net income for the world's most established biotech centres

As an industry, biotech is beginning to thrive. Ernst & Young, a UK-based accounting firm, reported an increase of 37% in net income for the world's most established biotech centres (including the US, UK, Canada and Europe) in the year 2012[1]. This was reflected in a 27% increase in market capitalisation in these centres. Although biotech is not out of the woods yet, this financial success is set to continue. But what impact does the biotech industry have on the general public?

Many biotech products are often under patent protection for 20 years, and once they are delivered to the market they are expensive and difficult to access. A prime example is the therapeutic use of monoclonal antibodies; the first of which was used clinically in 1986. Recently, Humira or adalimumab; a fully humanised anti-tumour necrosis factor (TNF) antibody developed by Abbott for pain relief and to reduce inflammation in a number of autoimmune diseases, accrued worldwide sales of approximately $9 million in 2012[2]. The excessive cost of biological treatments such as these puts a strain on the cost of healthcare and the resultant effect is limited patient access to the treatment.

This article provides an insight into the impact of the biotech industry, particularly focussing on the implications of the collaboration between big pharma companies and smaller biotech firms in order to deliver novel drugs to the healthcare industry, and ultimately the patient. We will see that, in general, biotech is beneficial to the patient and the industry but it is not without its flaws, a few of which will be discussed here.

Biotech Blockbusters

The contribution of the biotech industry to the development of novel pharmaceutical products is significant. Big pharma is under continual scrutiny, and the development of a drug from the initial discovery of the molecule through clinical trials and to the market is a long and treacherous path. However, in 2012, The FDA approved 33 new molecular entities and 6 biologicals for clinical use, which is the highest number of approvals since 1997[1]. Working together with larger pharma companies could maintain this progression, yet high failure rates and the limited protection of intellectual property have resulted in few drugs making it to the patient, and when they do they are very expensive.

Big pharma is under continual scrutiny, and the development of a drug from initial discovery of the molecule through clinical trials and to the market is a long and treacherous path

The main problem that pharma has encountered in past 20 years is that it is simply too big[3]. In order to bring novel and innovative products to the market a company needs to be big enough to register new drugs and sell them globally. However, they also need to be small enough to develop and investigate different ideas at the early stages. This is where the biotech industry can help. Biotech companies, in general, have smaller scale laboratories than pharma companies which are usually run by experts in their field. This allows an idea to be developed on a small scale from its inception until it is ready to be taken into human trials and, later, to market.

However, the biotech industry is equally too small to do this alone, leading to a plethora of pharma-biotech mergers and acquisitions[4]. This allows the development of novel ideas managed by small biotech companies to be exploited by big pharma, hence ensuring that innovative technologies reach the patient in a more timely and cost-effective manner. This particular business model is called Partnered External Development (PED), and leads to a collaborative approach to the development of products that favours both industries and the patients.

Perhaps the most successful example of a pharma-biotech merger is that between Roche and Genentech. Genentech was founded in 1976 by venture capitalist Robert A. Swanson and biochemist Dr Herbert Boyer, and is thought of as a pioneering company in the biotech industry. In 2009, Roche acquired Genentech for $46.8 billion. This saw the beginning of a profitable partnership driven by the influence of Genentech's biotech approach to investigating the pathophysiology and treatment of disease. In fact, four of Roche's latest blockbuster drugs began development at Genentech and now contribute to 55% of Roche's sales[5].

This partnership has given Roche the edge needed to maintain their standing as a leading pharma company, and provided Genentech with a platform to be directly involved in drug development and ultimately deliver their technology to patients. In order to build on this example, emerging and existing biotech companies need to work as part of similar networks to aid their expansion. One such organisation is the Oxbridge Biotech Roundtable (OBR). OBR aims to bridge the gap between academia and the pharmaceutical industry by providing a platform to discuss science and the business associated with it from both perspectives. OBR has a strong interest and involvement in the biotech industry and often liaises closely with emerging start-ups to help push their ideas forward. With eight chapters across the UK and US, they have a prominent presence in the Golden Triangle of Oxford, Cambridge and

[1] Ernest & Young (2013) Beyond borders, matter of evidence, biotechnology industry report.
[2] Oxbridge Biotech Roundtable (2013) OBR London: Therapeutic use of monoclonal antibodies and future trends in biotherapeutics [online] [Accessed 5 July 2013].
[3] Forbes (2012) The truly staggering costs of inventing new drugs [online] [Accessed 12 June 2013].
[4] Oxbridge Biotech Roundtable (2013) Pharma biotech mergers: the potential and the problems [online] [Accessed 12 June 2013].
[5] Reuters (2012) Analysis: After Roche merger, biotech tail wags big pharma dog [online] [Accessed on 5 July 2013].
[6] Forbes (2010) The World's Most Expensive Drugs [online] [Accessed on 5 July 2013].

Combining biotechnology and pharmaceutical process engineering, bioreactors are key tools in bio-engineering novel products.

London and the Silicon Valley in San Francisco, and are actively playing a role in changing the dynamics of the biotech industry.

Funding and resources for the biotech industry are also improving. Recently, Imperial Innovations, a leading technology commercialisation and investment group, has announced that they have received a 12 year loan of £30 million from the European Investment Bank to invest in new healthcare ventures[9]. Imperial Innovations builds ventures based on intellectual property, often associated with spin-out biotech companies, developed at, or associated with, the UK's four leading universities: Imperial College London, Cambridge, Oxford and University College London.

[7] Oxbridge Biotech Roundtable (2013) The current funding environment in the UK biotechnology sector [online] [Accessed 12 June 2013].
[8] Fierce Biotech (2012) Bristol-Myers Squibb Discontinues Development of BMS-986094, an Investigational NS5B Nucleotide for the Treatment of Hepatitis C [online] [Accessed 13 June 2013].
[9] Imperial Innovations (2013) £30m, 12-year loan to Innovations from European Investment Bank for healthcare investment [online] [Accessed on 5 July 2013].

Pricing Perils
Collaboration between pharma and biotech to produce cheaper drugs sounds almost too good to be true, and to an extent it is. The cost of pharmaceutical products has not been significantly reduced by the growth of the biotech industry. Novel biotech products are often developed using sophisticated techniques and mass-production is difficult as many of these products are in an injectable form which varies in dosage. An analysis performed by Forbes clearly demonstrated that some of the most expensive drugs in the world are biotech products.

The single most expensive drug, Soliris or eculizumab, is a monoclonal antibody which specifically inhibits the complement cascade and is used to treat the rare disease paroxysmal nocturnal hemoglobinuria (PNH). It was developed by Alexion Pharmaceuticals, a US based biotech company, and costs a jaw-dropping $409,500 to treat one patient for one year[6]. In fact, it seems many biotech companies are focussing on the treatment of rare diseases and, as the number of effected individuals

is low, the cost of these treatments is subsequently very high in order to recoup the money invested in the development of the treatment.

This focus on expensive products is due to an inherent problem with the biotech industry, and it lies at the very early stages of the process. The biotech industry thrives mainly due to external investment from either pharma, venture capitalists (VCs) or angel investors. This funding provides sufficient financial and business support at the early stages of this process in order to kick-start the development of a drug. In general, biotech companies are required to perform Proof of Concept (PoC) studies on the proposed drug which can take 5-7 years at a cost of $100 million. However, investment in early stage biotech development is a high risk activity, and such funding is in decline as a result of the current economic climate. This equity gap or 'valley of death' at the very early stages of development is common in small biotech companies and poses a great problem for those trying to win funding to support their business ideas[7].

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There are many examples of large pharma companies acquiring small biotech companies, such as Merck & Co. acquiring Inspire Pharmaceuticals, and Novartis acquiring Genoptix; however these deals were worth less than $1 billion. More recently, GlaxoSmithKline acquired Human Genome Sciences for $2.6 billion[5]. Although these transactions can result in the delivery of the biotech's product to the market, the process of acquisition is still a high risk strategy. Bristol-Myers Squibb Co. recently acquired Inhibitex for $2.5 billion with the promise of developing a novel Hepatitis C treatment. Unfortunately, a death in the Phase I clinical trial of this drug resulted in a halt in development and a substantial loss to the pharma company[9]. Therefore, issues surrounding initial funding for high risk investments must be tackled, or

management of investment needs to be re-structured in order for biotech companies to succeed and deliver their products to the healthcare industry.

A Bright Future for Biotech
When considering both the positive and negative impacts of the biotech industry on development of new treatments, it seems that the future is bright. Small biotech companies provide employment where big pharma has had to cut back, and their focus is very much on the cutting edge of science. Reports from both Ernst & Young and the FDA suggest that the biotech industry, and its collaboration with the pharma industry, has significantly impacted the number of novel drugs and biologics being introduced to the market each year. Ultimately, this benefits the patient.

However, the cost of the drugs produced by these companies is increasing at an alarming rate and this will continue to happen so if the funding of research at the earliest stages is not improved. Overall, biotech is an essential bridge in the current climate to ensure that an evolution occurs from the current business model to a cost-effective and proliferative one – but this can only happen with continued investment and support from pharma.

Biotech has the potential to make a significant difference to the healthcare industry and to the lives of patients across the world. By working with pharma, biotech can ensure that the novel products reach the market and the patient. Over the past year, the biotech industry excelled and it is expected that it will continue to do so. This success has caught the eye of many investors and it is hopeful that this will result in financial backing ensuring stability and longevity of the industry. Consequently, the biotech industry can continue to have a positive impact on the lives of patients, and the negative impact on the cost of healthcare can be minimised.

Dr. Kiran Nandra is a PhD graduate from the University of London and she has recently started working in the medical communications industry. She was the former London Correspondent for the Oxbridge Biotech Roundtable's (OBR) interactive blog..

Metabonomics:

The Future for Clinical Treatment?

Kyrillos Adesina-Georgiadis, Imperial College London

Glossary

Systems Biology: *An inter-disciplinary research field focusing on interactions within biological systems.*

Strains: *A genetic variant or subtype of an organism.*

Phenotypes: *The observable physical or biochemical characteristics of an organism, resulting from their genetic make up and environmental influences.*

Genotypes: *The entire set of genes in an organism.*

Homeostasis: *The property of a system that regulates its internal environment in order to maintain its stability.*

Metabonomics is primarily concerned with the observation of small molecules within a biological sample and emerged because of the necessity for novel approaches to genetic and biomedical research. From the conception of molecular biology techniques during the early 90s, in particular after the decoding of the human genome, it was generally believed that the key to understanding disease processes was through characterisation of genetic variations and gene expression. However, the complexities underlying biological mechanisms and their interactions with the environment required a shift in research focus. This led to the development of various array based techniques, allowing researchers to investigate large numbers of genetic variations within a sample. Unfortunately, this approach produced results with limited therapeutic usefulness and few clinical applications. The utility of many current genetic techniques may, therefore, have reached their natural limit, leading to the development of novel approaches in this area, one of which is Metabonomics.

Metabonomics [...] emerged because of the necessity for novel approaches to genetic and biomedical research

Metabonomics has been defined by Nicholson[1] as "the quantitative measurement of the dynamic multiparametric metabolic response of living systems to pathophysiological stimuli or genetic modification". In essence, Metabonomics quantitatively measures changes within metabolic processes during an alteration of the 'normal' state due to a disease or other intervention. This field sits closer to the phenotype than conventional studies, as the collection of all metabolites in a biological cell is effectively the end point of the biochemical processes of that cell. Metabonomics is a 'top-down' systems biology approach that utilises global profiles describing the biological status of an individual. By studying the changes within the biological 'system' it is possible to efficiently model complex, multi-stage processes such as disease progression or drug metabolism, and correlate them to biomarkers.

In complex organisms, levels of biomolecular organization (genes, proteins, metabolites) and their control are inter-dependent and affected by environmental events. Changes at any level are presented to the world as biological 'endpoints'; metabolic changes are an example of such endpoints and can be used to extract information of diagnostic or prognostic value. Many disease processes such as cancer and heart disease can be studied using Metabonomics. This research has identified metabolic profiles of cancer cells that have proved to be a useful tool for understanding tumour development and progression[2], whereas biomarkers have been identified for obesity as well as heart disease and vascular disease[3].

[1] Nicholson et al, (1999) 'Metabonomics': understanding the metabolic responses of living systems to pathophysiological stimuli via multivariate statistical analysis of biological NMR spectroscopic data. Xenobiotica. 29(11): 1181-1189

[2] Griffin and Shockcor, (2004) Metabolic profiles of cancer cells. Nature Reviews Cancer. 4, 551-561

[3] Anwar (2012) A Review of Familial, Genetic, and Congenital Aspects of Primary Varicose Vein Disease. Circulation. 5:460-466

[4] Dumas et al, (2007) Direct quantitative trait locus mapping of mammalian metabolic phenotypes in diabetic and normoglycemic rat models. Nat Genet. 39(5):666-72

Another core result of Metabonomics has been the characterization of various animal models for human disease achieved through metabolic profiling. Metabonomics is used to generate strains of phenotypes from either experimentally altered genotypes (transgenic models) or those derived by selective breeding. This allows the researcher to understand the biochemistry of their experimental model. Furthermore, the technology allows for the discrimination between phenotypically similar strains, which has allowed a deeper understanding of the underlying genetic mechanisms.

It is possible to provide unique real-time phenotypic information on the tissue state of the patient

Metabonomics in Toxicology

Perhaps the most widely used application of Metabonomics in research is concerned with testing the adverse effects of chemicals on living organisms. This is especially important when testing a new pharmaceutical drug's toxicity. Understanding the mechanisms of toxicity is a challenging endeavour. In the past the organ specific toxic effects of a drug have eluded detection in clinical trials and have only become apparent after the drug's introduction into the market. Examples include Vioxx (rofecoxib) for pain and osteoarthritis and the weight-loss drug Acomplia (rimonabant), both of which had to be withdrawn due to safety concerns. The underlying issue is that while new drugs are tested in various in vitro, cell and animal models, the resulting data is not always applicable to humans. Furthermore clinical trials do not always reproduce real-world administration of medication and while clinical trials are typically very large, the sample size may often still be insufficient to detect rare side effects.

Metabonomics is important in this context because it establishes the ability to detect biomarkers of drug metabolism. Initially, known toxic effects can be investigated using a traditional metabolic approach. With this data, it is then possible to predict a toxic event in a novel drug before the occurrence of clinical events (biomarkers of early effect), to evaluate the severity of the poisoning (biomarkers of effect), and also to monitor exposed patients (biomarkers of exposure). Critically this allows for toxicity to be detected far earlier in the development process, leading to more efficient selection of drug candidates for further clinical trialling. Additionally, this generates significant financial benefits to the pharmaceutical company.

In 2005 the Consortium on Metabonomic Toxicology (COMET) was established to develop expert models for the identification of toxicity based metabolic analysis, led by the Department of Surgery and Cancer at Imperial College with participation from several pharmaceutical companies. So far more than 200 drugs have been screened for toxicity in this project. Among these studies, acetaminophen (also known as N-acetyl-p-aminophenol, APAP) is frequently used as a model drug for liver injury (hepatotoxicity). By understanding the metabolic pathways of these compounds, it is possible to stipulate possible mechanisms of toxicity.

Clinical Applications

The health state of the body is directly linked to the metabolic activity of the individual; therefore, changes within the homeostasis and chemical equilibrium are reflected in the metabolic profile of that individual. It would be of great clinical benefit to measure the metabolic activity of an individual during a surgical treatment so that prognostic or diagnostic information can be increased. By extending some already well-understood principles of magnetic resonance imaging (MRI) to the Metabonomic field, it is possible to provide unique real-time phenotypic information on the tissue state of the patient. For example chemical fingerprints of tissue samples taken during surgery could be used to immediately analyse the type of tissue or disease state, greatly enriching the information available to the surgeon.

Scientists and clinicians have long since realised that not all patients respond equally to various treatments. Pharmacogenetics, which studies the genetic differences of metabolic pathways that affect an individual's response to drug intake in terms of therapeutic effects and toxicity, has been established to address this problem. Information predicting drug response has led to the development of individualised treatment plans and patient stratification into responder groups. However, genetics is not the only factor that contributes to differences between patients' response to drug treatment. Each human should be regarded as a complex ecological being. In addition normal metabolic states must be recognised as a complex continuum encapsulating both genetically and enzymatically controlled metabolism. Using this paradigm for future treatment strategies will pave the way towards truly personalised healthcare.

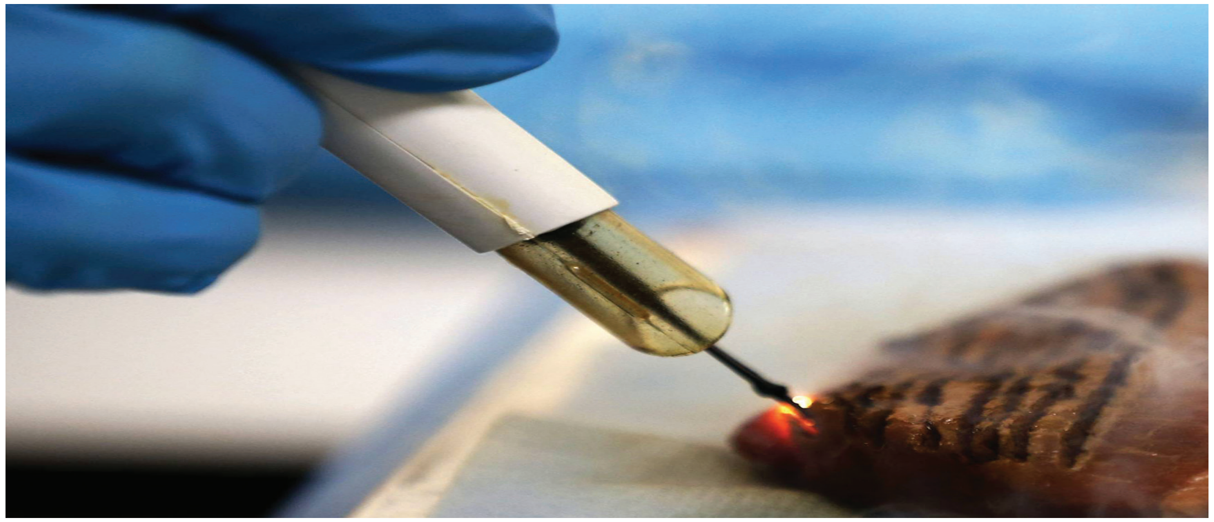
Integration of the Omics

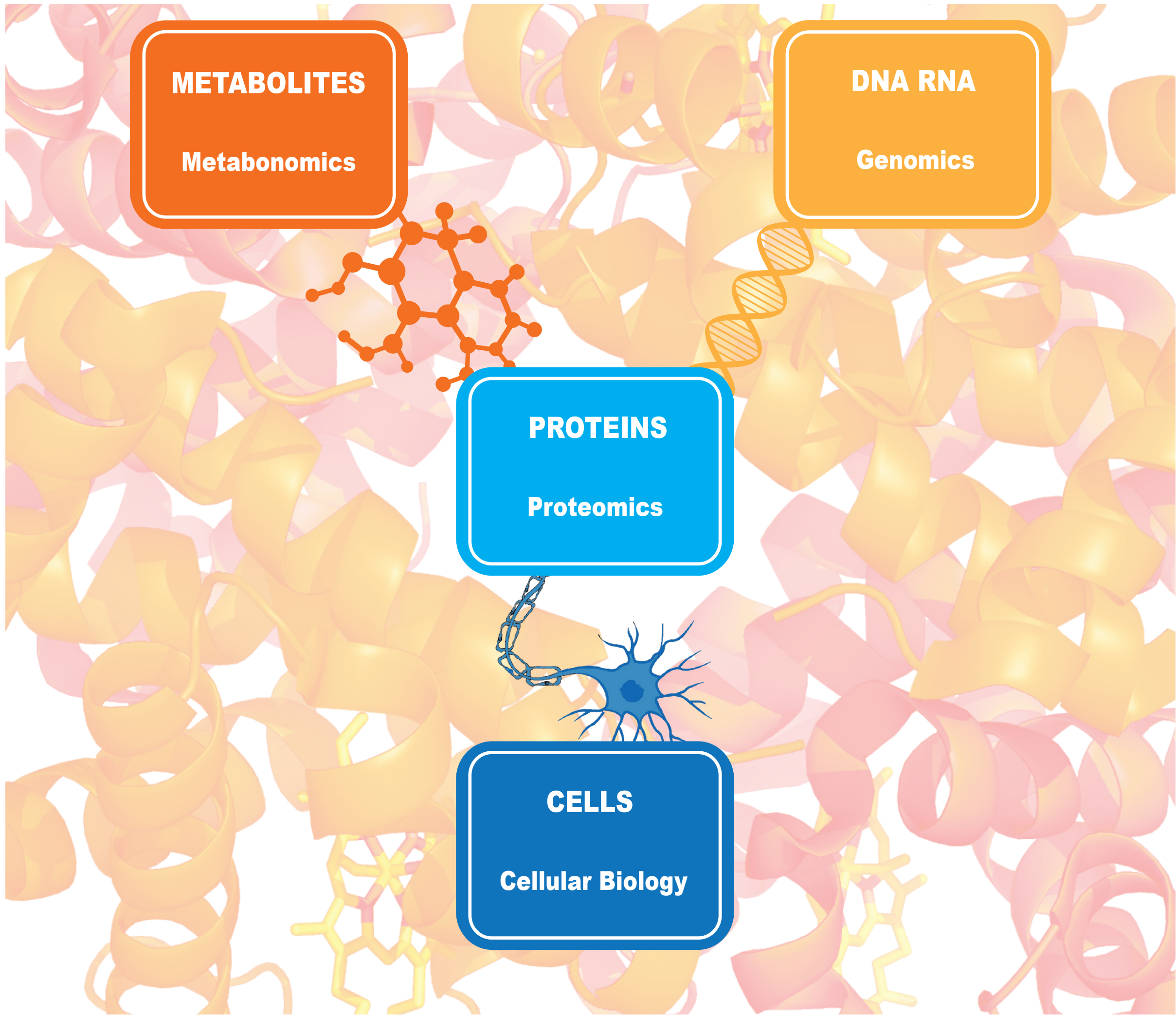
For a comprehensive view of the biology of an organism it is necessary to identify and characterise all levels of biomolecular organisation, and correlate the various components in a network of overall interaction (what is now being called the 'interactome'). The intuitive way to proceed would be to directly integrate the various '-omics' into a global framework. However this poses various problems and there are many hidden stumbling blocks, mainly due to the complexities of cellular interactions.

Various combinations of '-omic' technologies have been attempted including integration of genomics, transcriptomics, proteomics, localizomics and phenomics. Metabonomics has also been a part of this integration, and combined studies with genetic data have become commonplace. It is possible to use measurements of metabolic concentrations and traditional genomic mapping to pinpoint the precise genetic contribution to phenotype. This approach has been named metabolomic QTL (mQTL) mapping and was first introduced in plant and rodent models [4], and recently in humans. Metabolomic data is also routinely correlated with gut microbial data, especially in the study of obesity and of nutrition on the human genome and health. These extensions and combinations of technologies confirm the important role of metabonomics in the systems biology field.

While the use of metabolic profiling in toxicology and pathology is still in its infancy, this technology provides an additional layer of detail to biological or pathological change. In the future, development of ways to increase output coupled with better understanding of cellular metabolism will allow for the quick and precise description of biological status. Metabolic profiling can also complement other emerging technologies such as proteomics

An 'intelligent' knife, the i-knife, that can sniff out tumours to improve cancer surgery has been developed employing metabonomics.





Metabonomics provides complementary information to genomics and proteomics in the understanding of biological systems.

and transcriptomics, allowing for a complete systems view of biology. In the future it is expected that profiling will be able to be used in the clinical setting, as well as for the investigation of any change in the normal metabolic state of an organism.

One of the biggest remaining hurdles is the challenge of structural identification. This challenge arises due to the difficulty of distinguishing between similar compounds and the extensive training necessary to be able to perform the analyses. Initiatives such as a community-wide common database cataloguing various metabolites, along with their spectral representations and their associations, similar to what is currently available for genes, would allow for quicker identification. Furthermore the development of automated computational tools of identification and modelling would also expedite biomarker discovery.

Like many emerging technologies, metabonomics is associated with very high expectations, but has yet to reach maturity and be considered a mainstream research area. However, metabonomics has been readily adopted by industry, while the academic community is just starting to catch up. This is due to the fact that it is able to close the biological circle of gene to protein to metabolite; furthermore it allows the opportunity to work from the phenotype end-point backwards, which may prove easier than trying to untangle the distal effect of thousands of nucleotide changes and the downstream modifications. Further research and resources are needed for this exciting field to reach its potential.

Kyrillos Adesina-Georgiadis is an Imperial College PhD student in the Faculty of Medicine, Department of Surgery and Cancer, applying genetic and metabonimic techniques in research areas such as Vascular Disease and Cancer.

Synthetic Biology:

From DNA to Dolly and Beyond

Dejana Jovicevic, Imperial College London

Biotech

Synthetic Biology, initiated in 2007, has quickly evolved into a fast-paced and exciting research field. Extensive future applications surrounding this diverse subject have earned it a strong reputation amongst scientists, and led to it being deemed a 'top research priority' by the UK government. Whilst previous centuries evolved around the harnessing of fossil fuels, and the resulting agricultural and industrial revolutions, the 21st Century has been witness to a biological revolution.

Synthetic biology combines the skills of a variety of professionals, such as mathematicians, (molecular) biologists, physicists and chemists, all collaborating in an endeavor to engineer synthetic life. This research initiative is of the greatest importance as it holds the potential to re-direct the use of fossil fuels to new platforms such as consumable and renewable energy, cure life-threatening diseases such as cancer, and even create new cell types all-together.

Like other leading fields there are a plethora of ethical questions and issues, especially surrounding some aspects of 'creating life'. But, with so many arguments in favour of progress in this unique field, such debate largely serves to ensure safe practice for research in this area. Ultimately, the applications of synthetic biology can only be limited by our imaginations.

From the initial discovery of DNA by Franklin, Wilkins, Crick and Watson in 1953, research in this field quickly progressed, leading to Robert G. Edwards' development of *in vitro* fertilization (IVF) in 1978 and the subsequent first successful conception of an IVF baby. A few decades later, in 1997, Dolly the Sheep, possibly the most famous animal in academia and beyond, was cloned by nuclear transfer heralding yet another milestone in genetic engineering.

In parallel to advances in molecular biology, the development of technological tools used for research within this field has been equally paramount to the success of breakthrough experimentation. For example, in the '60s, integration of chemistry and biology created the first synthetic oligonucleotide, which is short single stranded strings of DNA or RNA; this process was promptly automated by the '70s. The following decade gave rise to the first synthetic gene.

Synthetic biology (is) described as the design and construction of new biological parts, devices, and systems, and re-design of existing, natural biological systems for useful purposes'

Over time the cost of DNA sequencing technology has plummeted almost 100,000 fold due to technological development. At the start of this century, the average cost per megabase of DNA was as high as $5,292.39 whereas now the same length can be sequenced for $0.06. Without these combined factors genetics and molecular biology could not have evolved into synthetic biology.

[1] Synthetic Biology (2007) Synthetic Biology Community. [online] Available at: <http://syntheticbiology.org/> [Accessed 25th July 2013].
[2] Carr P. A. et al (2012) Enhanced multiplex genome engineering through co-operative oligonucleotide co-selection. *Nucl. Acids Res.* 1;40(70)
[3] Jessica S. Dymond et al. Synthetic chromosome arms function in yeast and generate phenotypic diversity by design. *Nature* 471–476 (2011).

Glossary

In vitro **fertilization** *is the process of an egg being fertilized by a sperm, outside the body.*

Genetic engineering *is the design, modification and manipulation of any DNA sequence part of a genetic code.*

DNA sequencing *is an array of technology designed to "read" the specific nucleotide order found within a DNA sequence.*

A megabase of DNA *is a collection of one milion base pairs of DNA (a base is equivalent to a nucleotide).*

A genetic circuit *is analogous to an electrical circuit. In biology genetic circuits are a cluster of genes, put in a particular order, that impact the expression of each other given a set of stimuli.*

Prokaryotic organisms *are organisms that lack a nucleous and membrane bound organelles. The majority are unicellular.*

Eukaryotic organisms *are multicellular organisms that contain a nucleus and membrane bound organelles.*

A wild-type strain *is a non-modified type of species or strain that exists naturally in the wilderness.*

Extensively drug resistant TB (XDR) *is the property of resistance to MDR TB, plus resistance to any fluoroquinolone (a class of second line drugs); plus resistance to at least one of the injectable second line drugs. XDR TB was famously first documented in Africa in 2006.*

Synthetic biology researchers have a well-established definition for their topic, described as 'the design and construction of new biological parts, devices, and systems, and re-design of existing, natural biological systems for useful purposes'[1]. To be more specific, biological parts are sections of a DNA sequence that encodes anything within the sphere of genetics, such as promoters. Promoters are a section of DNA that initiates transcription of a particular gene. The characterization of parts like promoters, contributes to the modularity of the system. By manipulating the DNA sequence of a promoter, researchers are able to produce a 'library' of a promoter ranging in function and strength. The ability to tailor a promoter sequence for a particular function enables very precise tuning of the gene(s) we wish to express. Scientists have since successfully reprogrammed bacteria with new machinery and abilities.

Challenges and Applications

Despite the fast-paced, novel research emerging from the field of synthetic biology, there are limiting factors that remain to be overcome. A primary example is the significant shortage of characterized key components of genetic circuits such as promoters, terminators, repressors, etc. Few have been identified, assessed and evaluated under specific conditions and parameters. Furthermore, of this minority, characterization was performed largely in prokaryotic organisms, chiefly *Escherichia coli*. The next step is to work with the eukaryotes, such as yeasts and mammalian cells.

An additional setback is the lack of technology that aids our ability to edit and engineer genomes, such as next generation sequencing methods. Two leading groups working on precisely this area are Isaacs and Church, from Yale and Harvard respectively. Progress on developing new technology platforms like CAGE (Conjugative Assembly Genome Engineering) and MAGE[2] (Multiplex Automated Genome Engineering) is a step forward to assisting us in using high throughput and automated methodologies.

On the other hand, synthetic biology has progressed in leaps and bounds in recent years. Particular areas of focus are unsurprisingly the most pressing issues that mankind faces today, including life-threatening diseases such as cancer, tuberculosis and malaria. Other major topics of interest lie in environmental areas including non-renewable energy sources, carbon emissions and fixations.

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SYNTHETIC BIOLOGY

Developing new drugs from the (re)programming of prokaryotic or eukaryotic cells, and creating new, renewable energy sources, are all part of ongoing research that is well underway.

For example, Jay Keasling's lab at UC Berkley is engineering microbial factories to counteract the effects of malaria by producing the drug artemisinin using a yeast platform to manufacture it at an affordable price, and therefore making it accessible to the people who need it most. His team is also looking to create novel and environmentally friendly compounds, as well as biofuel substitutes for gasoline, diesel and jet fuel. At Harvard University, Pam Silver is researching the rapid and predictable programming of cells of all types for a multitude of purposes. One of her research interests is to replicate the photosynthetic machinery in non-photosynthetic bacteria to engineer the fixation of carbon dioxide, and to try and exploit sunlight exposure as a stimulus for the production of useful compounds such as sugar. Her team is also working on developing memory in engineered bacteria, enabling them to report the state of the gut.

Other fascinating achievements have included the production of spider silk from goats' milk. Randy Lewis, Professor at the University of Wyoming, has expressed the silk gene in goats in such a way that the silk is secreted with their milk. Spider silk is an exceptional material, one of the strongest known to man and more so than Kevlar and more elastic than rubber. An additional positive observation was that there was no change to the health, phenotype or quality of life of the goats.

Genome Engineering

As the understanding and knowledge of biological engineering continues to expand, so have branches of synthetic biology and other new fields. Genome Engineering is a much talked about and compelling new genre. This new niche is dedicated to creating entirely novel organisms, and as its title suggests to engineer new genomes from a bottom-up approach, as opposed to synthetic biology that takes on a top-down approach. As the newest chapter in synthetic biology, this field is still very much in its infancy, yet has massive potential: as the late physicist Richard Feynman once said, 'what I cannot create I do not understand'.

Bacteria that could potentially help coral resist the devastating disease white pox have been found by researchers at the University of Florida and Mote Marine Laboratory.

Already significant headway has been made. In 2010 Daniel Gibson of the Craig Venter Institute chemically synthesized a slightly altered version of the parasitic bacterium, *Mycoplasma mycoides, a* one million base pair genome, and successfully implanted it into a DNA-free *Mycoplasma capricolum* cell. Other significant research has been conducted by Prof. Jef Boeke and his collaborators, who are working on a 'yeast evolution on hyper-speed'[3] by creating the first man-made synthetic yeast genome, with the new strain being significantly different from the wild-type strain. This new species will have a range of potential uses from environmental to medical applications.

The first man-made synthetic yeast genome [...] will have a range of potential uses from environmental to medical applications

A Quarter Million Pounder Anyone?

Where could biological engineering go next? The most astounding cell biology project to hit the headlines recently is the production of in vitro meat (IVM). Scientists from the Netherlands led by Prof. Mark Post used stem cell technology to create 140 grams of laboratory cultured beef meat, which was cooked, tasted and critiqued. While it might not yet taste as delicious as a T-bone steak, it is an amazing feat for researchers.

Whilst this work has great implications for the future, the technologies are not yet fully established, and the cost of this research was close to a quarter of a million pounds. Furthermore, the majority of the public made aware of IVM were repelled at the thought of laboratory-grown meat. Hence, while there is potential to turn some vegetarians into omnivores and there are significant potential environmental benefits, in vitro meat is a long way off from reaching the supermarket shelf.

Ethical Concerns

Synthetic biology is still plagued by a number of socio-ethical issues and concerns. Amongst the most relevant are: 1) What if a genetically modified organism was to escape into the environment in an unplanned manner? 2) Could the engineering of living cells fall into the wrong hands – of so-called Bioterrorists? The answer to both these questions is much more complicated than a simple yes or no.

Social scientists look into issues related to the applications of synthetic biology research, and provide us with insights into the dangers, risks and hazards that are associated with 'new life'. There is now active ongoing research into how to manage GMOs (genetically modified organisms), as well as SOP (standard operating procedures), laboratory health and safety and risk assessments. Plans of action for a variety of scenarios, as well as consideration of what if's and how to deal with worst case scenarios, have also been developed.

Apart from dedicated social scientists, there are a number of preventative measures to stop non-qualified and non-organizational groups from harnessing synthetic biology in the same way that qualified laboratories achieve this. The US government has created a watch group for these purposes, and supervises the sources that order DNA. Most DNA synthesis companies, such as Life Technology or IDT, will only outsource to registered practicing laboratories. Further discussion of the ethical implications surrounding synthetic biology are publicly available online at the Synthetic Biology Community webpage[1].

The fields of synthetic biology and genome engineering continue to produce excellent research, and the potential applications continue to expand as our knowledge and understanding of these respective fields grows. The future holds exciting prospects, and although we are far away from bringing back the mammoth or the dodo, we are one step closer uncovering the fundamental building blocks of human life.

Dejana Jovicevic is a second year PhD student in the Ellis Lab at the Centre of Synthetic Biology and Innovation. She has a particular interest in novel gene expressions in yeast.

Astrobiology:
Searching for Life in Space

Dr. Louisa J. Preston, The Open University

"Science and science fiction have done a kind of dance over the last century, particularly with respect to Mars. The scientists make a finding. It inspires science fiction writers to write about it, and a host of young people read the science fiction and are excited, and inspired to become scientists to find out more about Mars, which they do, which then feeds again into another generation of science fiction and science"

Carl Sagan

Many space scientists, if you ask them and they are being honest, were inspired to become the next generation of Universal explorers due to influences in the media during their childhood. It may have been a wish to 'Hitchhike' around the galaxy, to work alongside Kirk or Spock, fly space craft fighting the Cylons in Battlestar Galactica, or they were simply inspired by one of Sir Patrick Moore's broadcasts about the stars. Whatever the cause, science fiction and science fact are intricately linked driving forward innovation and imagination. This has never been truer than now!

The human mind is fascinated by the possibility of other life in the universe. As early as the fifth century B.C., the Greeks considered the possibility of an infinite universe housing an infinite number of civilizations. Much later, in the 16th century, the Copernican model of a heliocentric solar system opened the door to all kinds of extra-terrestrial musings. Since then speculation about alien life kept pace with scientific progress well into the twentieth century, but it wasn't until the 1950s that anyone proposed a credible way to look for these distant, hypothetical neighbours. The space age dawned and science was anxious to finally know what existed beyond the confines of our planet. With this, astrobiology was conceived and in the last 60 years has gained momentum to become one of the most exciting multi-disciplinary fields of planetary science. It is a completely unique discipline, as it strives to study and understand a subject matter, i.e. life in space, which has not actually been discovered yet. But through detailed investigations into the ability of life on Earth to survive even the harshest environments, we are beginning to understand what life might exist on other planetary bodies, where it might be hidden and how we can find it.

Where on Earth?

Scientists looking for signs of life outside of the Earth have a very different idea of what these life forms might look like compared to popular culture. They aren't looking for little green men but instead are looking for micro-organisms, organic molecules such as amino acids, and biosignatures indicative of past life. At present the search is focused on investigating habitable environments on other planets and moons, and not the identification of life itself. We are looking for places where conditions exist now, or have existed in the past, that are conducive for life, namely regions that exhibit evidence of liquid water, an energy source, and organic molecules. Target worlds include Venus, Mars, Europa, Enceladus, Titan and even the Moon.

The search for habitable environments on Mars is currently underway thanks to NASA's Curiosity rover that landed on Mars in 2012. In 2018 the search for biosignatures of past or present life in its subsurface will begin with the launch of the ESA/Roscosmos ExoMars rover. Today Mars has the most clement environment in the Solar System after the Earth despite its sub-zero temperatures (on average -63°C), thin CO_2-rich atmosphere and savage global dust storms. It also displays abundant evidence that a warmer, wetter environment existed in its past and that liquid water once flowed across its surface[1]. The Earth's other neighbour, Venus, although nearer to the Sun than the Earth, might still have the potential to house evidence of life. Under the influence of a runaway greenhouse effect with surface temperatures of a sweltering 460°C, today Venus is a desiccated world where no life could survive. However, it seems likely that it once also had liquid water oceans just like on Mars, and that any life originating in these oceans may have migrated upwards into the atmosphere as the conditions on the surface turned hostile.

We are beginning to understand what life might exist on other planetary bodies, where it might be hidden and how we can find it

Some of the moons of the many planets in the Solar System are proving to be even more interesting than the planets they orbit, and may even harbour evidence of life. In particular, the ice-covered moons Europa, Enceladus and Titan have been observed by orbiting satellites to display evidence indicating that subsurface liquid bodies, organic molecules and even atmospheres are present. Europa is a key astrobiological target, with the search for habitable niches focusing on possible deep-sea hydrothermal vents at the base of its ocean. These vents are fissures in the moons crust from which heated water erupts. Currently we cannot study these as they are hidden from view by Europa's icy shell, so the surface of the moon, and the sulphates seen on its fractured icy exterior, has to act as our window into its possible ocean ecosystem. This potential habitat for life will be investigated by the JUpiter ICy Moons Explorer (JUICE) mission, launching in 2022.

Saturn's moon Enceladus has attracted a lot of interest recently thanks to dramatic images of icy jets of water vapour, simple organic molecules and volatiles such as nitrogen and methane, shown erupting from its south polar region. All these components must have come from a subsurface source region that feeds the jets implying that organic molecules used by life are present deep inside the moon. Finally one of Saturn's other moons, Titan, with its substantial atmosphere and Earth-like lakes and seas, is a crucial target in the search for life. Surface temperatures of around 94 Kelvin have led to suggestions that the liquid bodies on the surface are composed of a mixture of methane and ethane with heavier hydrocarbons and possibly dissolved atmospheric gases. Life might be present here within a range of habitats, from the liquid hydrocarbon lakes on the surface to kilometre depths into the subsurface, creating a potential biosphere volume double that of the Earth.

Alien Life

The study of planets and moons other than our own highlights the diversity of habitats that life might have to contend with. Therefore any life that we find on these worlds will be very different to us. This life falls into the category of extremophiles, a group of some of the hardiest microorganisms that can withstand and thrive in extremes of temperature, pressure and radiation, as well as salinity, toxicity, pH and limited availability of liquid water[2]. The best-known examples are thermophiles, such as 'Strain 121' and *Methanopyrus kandleri*, that savour the conditions around geothermal hot springs found in volcanic environments and at the bottom of the ocean.

[1] Carr, M.H. (1996) Water on Mars. *Oxford University Press, New York*.
[2] Rothschild, L. J. & Mancinelli, R. L. (2001) Life in extreme environments. *Nature* **409**:1092-1101.
[3] Dartnell, L. R. (2011) Biological constraints on habitability. *Astronomy & Geophysics* **52**:1.25-1.28.
[4] Benaroya, H., Bernold, L., Chua, K.M. (2002) Engineering, Design and Construction of Lunar Bases. *Journal of Aerospace Engineering* **15**(2): 33.

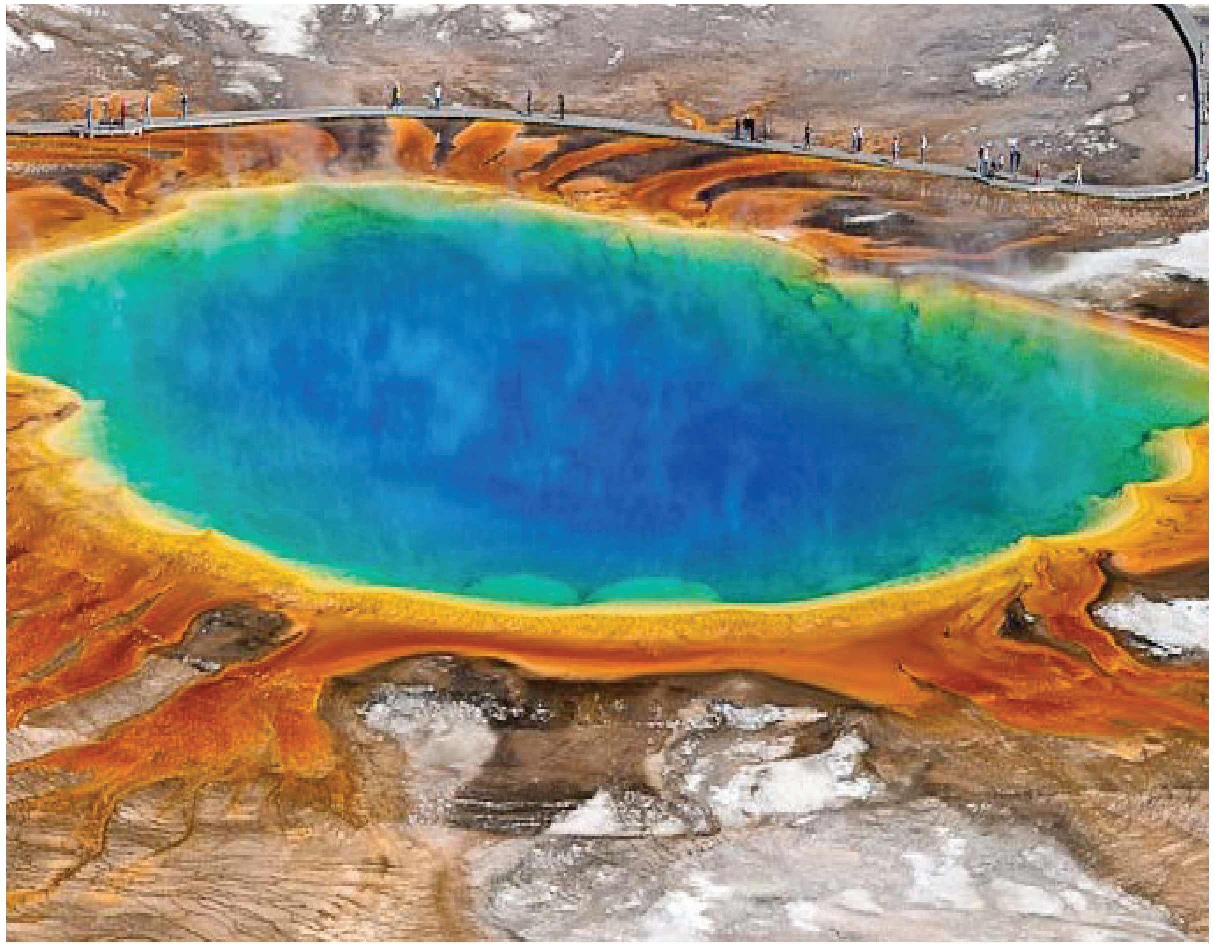
Types of Extremophiles	Features	Bacteria
Acidophile/alkaliphile	Grow at pH levels <3 or >9	*Bacillus boroniphilus*
Anaerobe	Grow without presence of O_2	*Spinoloricus Cinzia*
Cryophile	Capable of survival, growth or reproduction at temperatures of -15°C or lower	*Psychrobacter*
Halophile	Grow in salty envirnoment (at least 0.2 M concentrations)	*Salinibacter ruber* *Halobacterium halobium*
Hypolith/Cryptoendolith	Live underneath rocks in cold deserts/microscopic spaces within rocks	*Streptomyces hypolithicus*
Lithoautotroph	Live in presence of CO_2 and derive energy from mineral compounds	*Nitrosomonas*
Metallotolerant	Tolerate high levels of dissolved heavy metals in solution	*Ferroplasma sp.*
Osmophile	Grow in environments with a high sugar concentration	*Saccharomyces cerevisiae*
Piezophile	Live at high hydrostatic pressure	*Methanopyrus kandleri*
Radiosistant	Resistant to high levels of ionizing (UV) and nuclear radiation	*Deinococcus radiodurans*
Thermophile	Thrive at temperatures between 45–122°C	*Thermococcus barophilus*
Xerophile	Grow in extremely dry, desiccating conditions (deserts)	*Dunaliella algae*

Currently, life on Earth has been shown to survive and reproduce at an impressive 121°C but these limits are continually being tested. In contrast, the lower record limit for life is at -20 °C, around the temperature at which water inside cells freezes. The majority of chemistry in terrestrial life functions well around pH 7 or neutral, but life has been found in the most acidic (pH 0) and most alkaline (pH 12.5) of environments. Most impressively, life can also adapt to more than one extreme condition. It can be subjected to a combination of very acidic waters, limited to no oxygen availability, and extremely high pressures in a single environment and survive[3].

The Future for Humanity

Investigating the habitability of other worlds does not only benefit our understanding of the versatility of life, but also enables us to take a step towards to answering one of humanities oldest questions, are we alone? Not only that, we also want to understand how humans might be able to live and work on them one day as our home. We are not talking about the moons of Jupiter and Saturn just yet, and definitely not Venus, but Mars and our own Moon are prime targets for future human outposts. In the long term i.e. another 3 billion years, our Sun will start to expand and enter its red giant phase as its gets closer to its death. It will engulf Venus, and even if it doesn't swell enough to reach the Earth it will still boil off the oceans and heat the surface to temperatures that even the hardiest extremophile couldn't survive. This, however, is a long way off. Until this time we have a number of other reasons why we might want to leave the Earth. Life is fragile and any number of natural or man-made catastrophes could occur such as another ice age, global warming, asteroid impact, nuclear war or complete depletion of our natural resources. This paints a very bleak picture of our future but the chances are that we will simply choose to leave Earth because we want to explore.

Our first port of call so to speak might be the Moon. It is an ideal staging post where we can accumulate materials, equipment and manpower outside of the confines of Earth's gravitational well. From the moon we can send missions onwards to Mars or into deep space, set up astronomical stations to view the cosmos without



Microorganisms living in the giant geysers of the Yellowstone Park (USA) can tolerate extreme environmental conditions, similar to those present on planets and moons in outer space.

the interference of an atmosphere or Earth's radio chatter, and even support a bustling space tourism industry. We already have the means of getting to the Moon and our technology has proven to be advanced enough to sustain human and plant life in space: we just need to begin building.

To build a habitat on the Moon is no easy feat; it requires a number of considerations including understanding how building materials will respond to the vacuum on the Moon, the extreme temperature variations between day (120°C) and night (down to -153°C), impacts by micrometeorites (up to 10Km/s), outward forces from pressurised habitats, radiation damage, and the 1/6th gravity of that of the Earth. These habitats will be a lifeline for future colonists by providing oxygen for them to breathe, water to drink, protection from the harsh radiation of the sun, providing light and power during the 14 day nights, and keeping them comfortable in all temperatures.

One design put forward so far is a stereotypical inflatable dome. These are light weight and would be relatively easy to erect on the surface, however, they would need protection. Local materials such as the lunar regolith could be used to cover the inflatable habitats providing an addition layer of defence against radiation and micrometeorite strikes. Habitats could also be erected within ancient lava tubes. These natural cavern systems provide a structure within which habitats could be built and easily sealed, the rock provides protection from the harsh surface environment and impacts, and they are commonly interconnected allowing for the habitat to grow. A great review of how building a lunar base could become a reality has been written by Benaroya et al. (2002) titled "Engineering, Design and Construction of Lunar Bases".

Building an outpost on Mars will require a lot more work, even though we have much better conditions than on the Moon. This is because of the greater distance

A manned mission to Mars would take about 440 days to complete with astronauts visiting the surface of the planet for a period of two months.

between the Earth and Mars (at its closest point Mars is a mammoth 55,000,000km away), the difficulty of transporting materials, and the effects on human physiology and psychology. The total journey time from Earth to Mars could take between 150-300 days depending on the distance between the planets at the time of launch and the rockets, or fuel, being used. The benefits of moving to Mars are that it has a similar length of day, axial tilt and seasons to Earth. It also has an atmosphere, water ice, and habitable environments. There are a number of geological landforms such as impact craters and lava tubes which could house habitats and there is a never-ending list of scientific investigations that can be carried out.

The benefits of moving to Mars are that it has a similar length of day, axial tilt and seasons to Earth.

The environment on Mars is the main challenge to be overcome as the 95% CO_2 atmosphere is toxic to humans and promotes low atmospheric pressures (6 mbar), it only has 38% gravity of that on the Earth, it's always cold (-85 to -5°C), and there are no liquid bodies of water. As with habitats on the Moon, oxygen will need to be produced for humans to breathe and suits will need to be worn whenever the inhabitants leave the outposts. Due to the time taken to travel between Mars and the Earth (not to mention the cost), any habitat on Mars will need to be self-sustainable, growing its own food, extracting its own water from the frozen ground and producing its own oxygen. Many studies are currently being conducted into the logistics of how this might be done.

We are living in a time where science fiction and scientific research are converging and, thanks to the internet and social media, the entire world can be involved. We are living in a time when humanity is capable of sending people and robots to other planetary bodies, and we are about to witness the Voyager-1 probe leave the confines of our Solar System and enter interstellar space. Who knows what lies in store for humanity in the future?

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Space Biomedicine:

UK Research For Health in Space

Dr. Simon N. Evetts and Dr. Iya Whiteley, UK Space Biomedicine Consortium

The human exploration of space and its associated research are pushing the boundaries of what is technically feasible. The recently established space biomedicine and space environments communities in the UK are preparing for the New Space era, the momentum for which will emanate from the commercial human spaceflight sector. With many distinctive technical challenges to be overcome, the spaceflight paradigm allows numerous psychological and behavioural aspects, as well as biological and physical systems to be examined under unique and unusual circumstances which in turn drive a significant amount of terrestrial research and, in particular, healthcare innovation.

The number of viable commercial human spaceflight companies with significant hardware either undergoing testing or involved in space trials is in double figures. Akin to the aviation industry's early years after the Wright Brothers demonstrated powered flight, the near future will see an explosion of human traffic in low earth orbit which is expected to result in a world as different to the present as today is to the pre-flight era.

While the UK has traditionally taken a 'back seat' in human spaceflight, world-class space environments research is undertaken domestically

Research and development (R&D) in this field requires us to examine questions in the physical and life sciences that cannot be investigated within the normal terrestrial environment including aspects of the space environment such as reduced gravity, radiation and isolation. Furthermore, the constraints imposed by operating in space often lead to innovation in terms of size, power and volume reduction. For example, recent NASA space environments research has led to new applications of medical ultrasound practices in hospitals across the United States. Other examples include innovation in closed loop water supply technologies that have better enabled long duration space missions and which also benefit isolated and impoverished communities suffering from water supply and quality issues on Earth.

While the UK has traditionally taken a 'back seat' in-human spaceflight, world-class space biomedicine research is undertaken domestically, under the broad umbrella of space environments R&D. Currently, British biomedical research provides a return on investment second only to the United States. Given that the progression from terrestrial biomedical research to space biomedical activities is a relatively small step due to common approaches and questions, the potential exists for the UK to excel at this field as well. It is broadly accepted that a coordinated biomedical science approach is fundamental to fully understand and prevent most of the adverse and still unresolved physiological problems faced by humans during spaceflight, examples of which are muscle wasting, bone loss, cardiovascular deconditioning and loss of neuromuscular control. Increased knowledge of these conditions will not only improve the health of humans in space but also on Earth, as most of them are characteristics of ageing.

Human Health in Space

Upon return from International Space Station (ISS) long-duration missions (usually six months) astronauts must undergo at least a month of intensive rehabilitation. This rehabilitation is required to counteract the deconditioning of multiple physiological systems resulting from time spent in space. To date approximately 530 people have

Microgravity has a great effect on water cohesion and fluid re-distribution to the upper body. Causing bulging of neck and veins, microgravity changes the autonomic regulation of blood pressure that ultimately determines the orthostatic intolerance of astronauts on their return to Earth.

flown in space, with this number expected to expand many times during the course of the next decade as commercial human space flight becomes economically viable. These future 'space flight participants' will be exposed to the rigors of space, and many will do so despite possessing pathologies that have yet to be exposed to the stresses of space. This latter point is particularly note-worthy as, due the expense involved, the typical commercial space-goer in the near future is likely to be middle-aged with an associated health profile.

The absence of gravity causes the human circulatory system to equalize i.e., blood normally pulled to the lower body on earth, rises to the upper body in space. This equilibration increases stimulation of receptors in the upper body and decreases stimulation of certain lower body receptors. Over time the normal responses of these receptors to the stimulation experienced on earth is altered, albeit temporarily. This, coupled with reductions in blood volume, deconditioning and atrophy of muscle tissue and alterations in hormonal responses to stress, leads to several days of poor blood pressure control upon return to Earth. This condition, termed orthostatic intolerance, causes astronauts to faint if left standing unaided for more than a few minutes during their first few days back on Earth. The effects of space travel on orthostatic tolerance remain one of the space industries' intractable problems. Fluid loading regimes to try to increase blood volume prior to re-entry, lower body negative pressure routines in flight and lower body positive pressure garments worn on landing, are used to try to minimise the occurrence and severity of this condition. However, it has not been resolved yet.

One commonly cited effect of time in space is the leaching of calcium from bones and a general reduction in their density and strength over time. For some astronauts the density of some bones does not recover even years after their space mission. When the stimulus for bone formation is reduced, for example by taking away impact forces felt during locomotion, it weakens, adopting a structure relevant to the new environment. In certain ways this condition is like accelerated ageing. Space R&D teams are investigating the aetiology and treatment of this condition. The use of drugs, such as bisphosphonates, and activities such as impact and vibration exercise are all under evaluation as countermeasures. In-flight countermeasure programmes, in particular since the advent of NASA's Advance Resistive Exercise Devise, do reduce the degree of bone deconditioning seen on ISS, but a fully effective remedy has yet to be found.

The most recently noted adverse effect of spending time in space is a condition termed 'Visual Impairment with raised Intracranial Pressure' (VIIP). The head-ward shift of body fluids in space is likely to be associated with increased

fluid pressure in the cranium. This in turn may be linked with changes in eye morphology and vision as noted in many astronauts on their return from space. This effect was revealed so recently that the research community is only able to look into its aetiology now in sufficient detail to attempt elucidating the mechanisms of VIIP.

Most of the adverse effects of spaceflights that we are familiar with are associated with long spells in space. Only a few relatively benign conditions, such as space motion sickness, occur in the first few hours or days. However, our 'subjects' to date have been individuals selected for their almost faultless health profiles. With the advent of commercial human spaceflight, many spaceflight participants will enter the extreme environment of space with conditions which, although benign or manageable on earth, could be worsened or lead to unforeseen effects in space. For example, the off-loading of the spine in microgravity leads to an increase in height in the first few hours, something that appears to be related to the low back pain experienced by most astronauts in the first days of their mission. Subsequent changes in spine morphology and associated stabilizer muscles over time are likely to be related to the increased risk and incidence of post mission Herniated Nucleus Pulposus (slipped disc). Low back pain is a common condition across developed societies and as such can be expected to be prevalent amongst commercial human spaceflight customers. This condition may not be affected by only a few minutes of microgravity, but once orbital flight and low earth orbit holidays are available it will become important that these potential effects are understood.

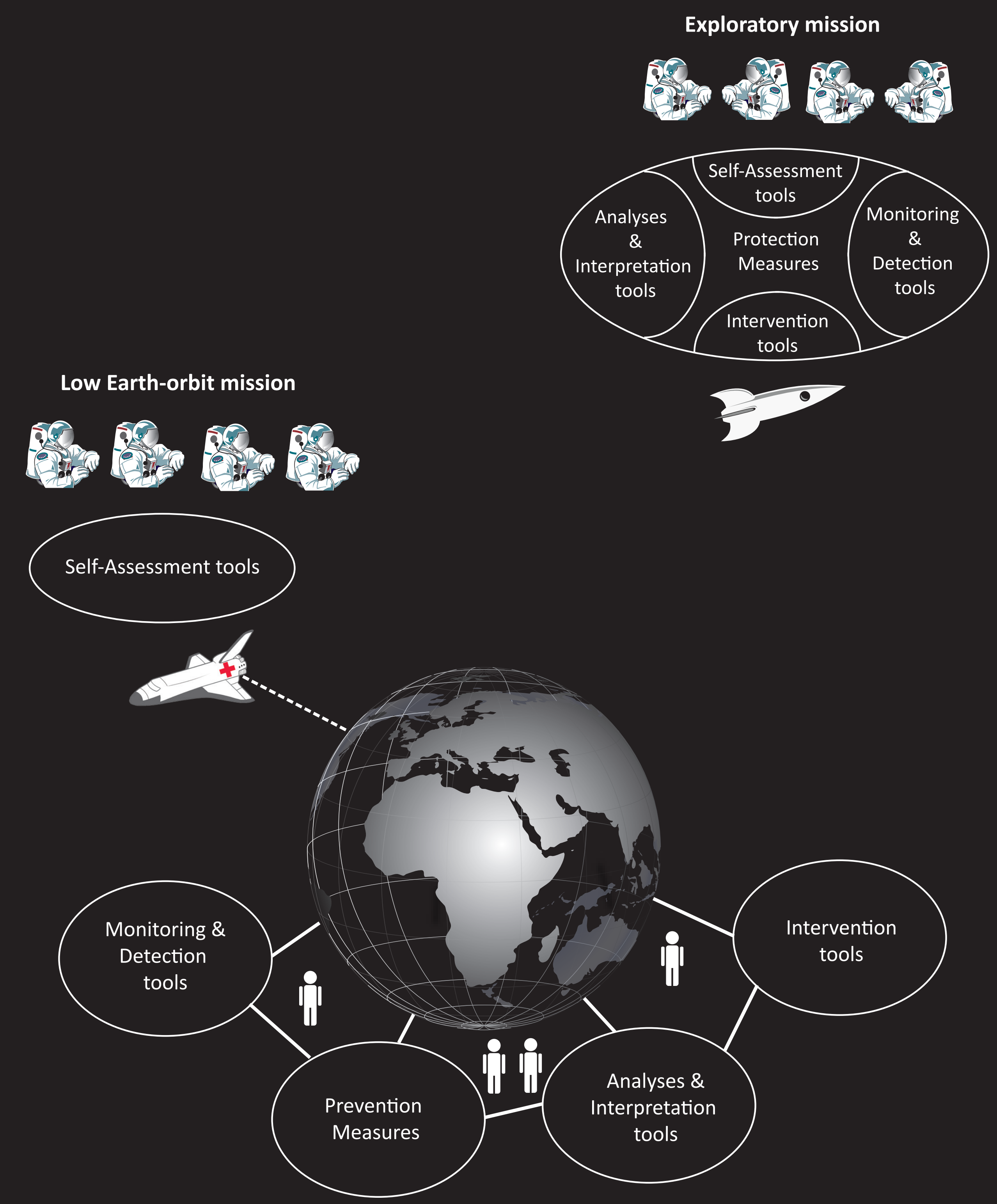
The nature of the psychological support during long-duration missions, extending beyond Earth's orbit, will primarily rely on the resources available on board the spacecraft

R&D Solutions in Space and on Earth
Although the UK has some catching up to do in terms of spaceflight research, the Centre of Human Aerospace & Physiological Sciences at King's College London is currently evaluating an intravehicular garment, the 'skinsuit', which acts to constrict the body by placing an axial load along the spine. The skinsuit appears to be able to passively replace much of the Gz (a measure of gravity) stimulus lost in microgravity and may prevent spinal lengthening when worn. The skinsuit may also reduce the headward movement of body fluids that occurs in space, which could have a bearing on post flight orthostatic tolerance. At University Hospital Southampton, researchers have developed a non-invasive means to measure changes in intracranial pressure. This system is to be evaluated on the ISS in 2015 and could provide an important improvement in our ability to monitor the development of VIIP leading to treatment or prevention of the condition. Finally, improved means of rehabilitation from the effects of spaceflight are being researched by Northumbria University. A novel device, the Functional Readaptive Exercise Device (FRED), has been developed which appears to preferentially target and train spine stabiliser muscles. This simple exercise device may lead to much more efficient and effective recovery post mission, with a decrease in the risk of back injuries such as slipped discs.

Directing limited R&D funds towards resolving space-related biomedical conditions offers humanity a means to improve its ability to live and work in space in the future. It is clear, however, that Earth-based healthcare gains must also result from these efforts. In particular, biological and physical systems examined under unique and unusual circumstances drive a significant amount of terrestrial research, something that is clearly seen on the continent in countries such as Germany, the Netherlands and France. For example, it is recognised that the skinsuit technology might be suitable for support clothing for cerebral palsy sufferers; FRED technology may provide an effective treatment for low back pain sufferers, and it is hoped that a non-invasive intracranial pressure measuring system will provide a valuable new tool to hospital A&E departments for the treatment of patients with head injuries.

Psychological Support for Long-duration Missions
Human travel and residence on other planets and moons will be extremely challenging – so much so that there is a need to revise attitudes toward the crew on these missions, and the nature of the psychological support that can be provided for them. Scientists at the Centre for Space Medicine at the University College London have conducted extensive research on these issues.

Currently the nature of psychological support relies on a live communication link with Earth where the majority of the responsibility remains with specialists on the ground. However, the nature of the psychological support during long-duration missions, extending beyond Earth's orbit, will primarily rely on the resources available on board the spacecraft mainly due to delays of up to 20mins or potential loss of communication with Earth. Consequently, the responsibility for the optimal functioning of the crew throughout the mission will need to reside with the crew on the spacecraft. Hence, it is



The Crew Psychological Support model for long missions (EPSILON) aims to develop a more active role for the space crew in psychological support, with astronauts involved in different aspects of assistance such as self assessment, monitoring problems, preventing accidents and guaranteeing prompt intervention. This model substantially differs from the present set-up for low Earth-orbit missions where the space crew deals only with self-assessment while relying entirely on the Earth base for all other supporting functions.

recommended that the crew be equipped with the knowledge, skills and responsibility to monitor their own psychological well-being. Crew members will need to monitor each other, to promote positive group interaction and continuous self-development, and to alert and request assistance from the ground crew if needed.

Technological assistance in this field is also under development. The psychological support toolset has been developed to consist of three main parts: Preventive measures, monitoring/detecting and resolution tools. Preventive measures will focus on providing the means to support the digestion and sharing of the crew's mission experiences with ground crew, family and friends. Monitoring and detection measures are envisaged, for example, to be based on pattern recognition techniques that will record behavioural patterns, facial and voice expressions of individual crewmembers and analyse these in relation to surrounding conditions and actions of other crewmembers. Resolution technology will focus on providing the crew with assistance, when preventive measures, training and warning measures could not prevent the development of a situation or an issue.

A coordinated biomedical science approach is fundamental to fully understand and prevent most of the adverse and still unresolved physiological problems faced by humans during spaceflight

The Embedded Psychological Support Integrated for LONg-duration missions (EPSILON) is designed to be embedded throughout the spaceship and integrated with the equipment and tools the crew will use in order to provide comprehensive psychological support. The technology will have two interlinked databases: one will contain all the information collected during prevention and monitoring phase and the second database will allow the crew to systematically search and identify applicable resolution tools.

Space Biomedicine in the UK

In recent years it has become increasingly clear that a national body was needed in the UK to facilitate intra-and international liaison and collaboration in the field of space biomedicine. Five students formed the UK Space Biomedicine Association in 2000 (then called the Space Medicine Group) as a product of the 1999 'Futures in UK Space Biomedical Research' conference established by Kevin Fong at University College London. Then, in 2011, the UK Space Biomedicine Consortium was established with the support of the UK Space Agency, University College London and King's College London. The Consortium has since grown to a membership of over 30 organisations, including Imperial College, and has embarked upon a process of drawing up a national space biomedicine strategy underpinned by four research programmes which will benefit Earth-based healthcare and the UK's preparation for the era of commercial human spaceflight. A parallel and complementary activity is the establishment of a Microgravity Working Group by the UK Space Agency also in 2011, which evolved into the Space Environments Working Group, a UK Space Agency sub-committee.

In November 2012 the UK subscribed to the European Space Agency's Life and Physical Sciences Programme (ELIPS) and will participate in the International Space Station (ISS) Utilisation Programme. The UK Space Environments community will bring together the various groups involved or interested in ELIPS related research from space biomedicine and astrobiology to materials science and microgravity physics.

A strong and vocal space environments research community will support the government in its deliberations concerning future UK contributions to optional ESA programmes such as ELIPS and ISS Utilisation and other bilateral space flight opportunities. A strong UK participation in the international human spaceflight effort is necessary to prevent the nation from falling further behind the rest of the world in a technological field that will increasingly become integral to the economic foundations of any developed society. The new movement spearheaded by the UK Space Biomedicine and Space Environments communities is offering a means to prepare and, when appropriate, to participate in the exploration of our solar system and to enable British men and women to live and work routinely in low Earth orbit alongside the citizens of other nations.

Dr. Simon Evetts is contracted by the company Wyle, to manage the Medical Projects and Technology Unit of the European Astronaut Centre, Cologne, Germany. He is the Coordinator of the UK Space Biomedicine Consortium. *Dr. Iya Whiteley* is a Human Computer Interaction and Cognitive System Engineer and a Deputy Director of the Centre for Space Medicine at Mullard Space Science Laboratory, UCL. The authors thank Major Tim Peake, European Astronaut Centre, European Space Agency and Prof Charles Cockell, University of Edinburgh for their contributions. The UK Space Environments Conference will be on 9-10 November 2013: www.uksbaconference.co.uk

Space Stations:

Designing Human Habitats in Space

Dr. Fiona Larner, Imperial College London

Space stations have served a variety and ever-growing list of purposes. While primarily providing a base for scientific research and acting as a source of national prestige, they have also been used as a cover for military missions. In the near future, however, space stations will not only orbit Earth, but other close planetary bodies such as the moon, and act as a docking port for manned missions further afield.

These inter-planetary ports will not only be a station for transient passengers, but permanently host communities of both scientists and the support staff such as nurses, barbers and chefs. Hence, the design and construction of innovative and flexible habitable space environments presents a new challenge for tomorrow's space scientists.

In the Seventies, NASA commissioned a series of artists to design futuristic visions of space stations which [...] combine psychedelic visions with solid foundations in space technology

Space stations have been in our skies since 1971, when the USSR launched the relatively small Salyut 1. The orbit around Earth is a busy place, with numerous dedicated satellites for metereologic-scientific, communication and military observations; however, space stations are currently the only orbiting objects to be designed for human habitation. Since the first deployment, space stations have been getting larger and longer-lived, with the International Space Station at the top of the chart. China's Tiangong Space Station is the newest addition to the family. Launched in 2011, this first phase is due to be joined by two more, leading to the largest space station in Earth's orbit in 2020[1].

Study of Space Habitats

NASA's commitment in designing future space stations for manned exploratory missions goes back to the Sixties, with the design of several settlements based on Apollo hardware. A first prototype, the Skylab space station, was the direct result of the development of a Saturn moon rocket, including compartments for the astronauts to live in, with tables, floors and large windows, decks for storing food, water, clothing, space suits, experiment equipment, and solutions for moving in the absence of gravity.

In the Seventies, NASA commissioned a series of artists to design futuristic visions of space stations which, although very different from the prototypes developed by the space agency, combine psychedelic visions with solid foundations in space technology. These designs have largely influenced the popular sci-fi imaginary that has been shown in films and games for the last four decades.

At the beginning of the Eighties, NASA established a Space Station Task Force and a Concept Development Group at the Lyndon B. Johnson Space Centre (Houston, Texas), with the purpose of studying space station habitability requirements and defining a set of parameters, such as hatches, tunnels, and module compartments for the future space stations, which could satisfy those requirements.

Nowadays, the Johnson Space Centre, Houston, Texas holds the annual International Space Settlement Design Competition (ISSDC) where school students from around the world team up to address this ever-closer reality of permanent human residences in space. They are challenged with the task of designing a city in space for over 10,000 people. Via a highly selective application process, each of the 12 countries currently involved send only 12 students aged 15-18 years. Imperial College London hosts the UK Space Settlement Design Competition (UKSDC) semi-final each spring to find our brightest sparks amongst 160 competitors, in a unique event amongst science outreach activities for school students.

The participants adopt a business structure based on working in teams to develop the Request for Proposal (RFP) of a space settlement in as short as one day. Each business has five levels: The CEO, the President, 5 Vice-Presidents, and 4 Directors who head the engineering teams. The CEO, the only adult member of the team, is brought in for the competition and is a highly successful business or engineering executive in real life. Past and current CEOs include Solicitor Rodney Taylor, Imperial College Engineering Lecturer Dr Richard Ghail, and Chemical Engineering alumna Marit Mohn.

Over the past years, students have been asked to design both long and short term settlements under a variety of scenarios, from a moving ground settlement on Mercury [...] to a sun-orbiting Earth-Mars transfer station

The CEOs often take a back-seat observational role as the project is principally in the hands of the students. The vice-presidents have one responsibility in the design – either engineering, marketing and sales, finances, manufacturing or human resources – and must make sure the activities of the different engineering departments all provide the needs and information required to fulfil the RFP. The other team members choose whether to focus on structural, operations, human or automation engineering. This business organisation needs to be in place within the first hour of the competition, after which departmental representatives from each team are sent for training by Technical and Engineering Specialists that include undergraduate and postgraduate students, post-doctoral researchers from Imperial College and industry engineers.

UKSDC

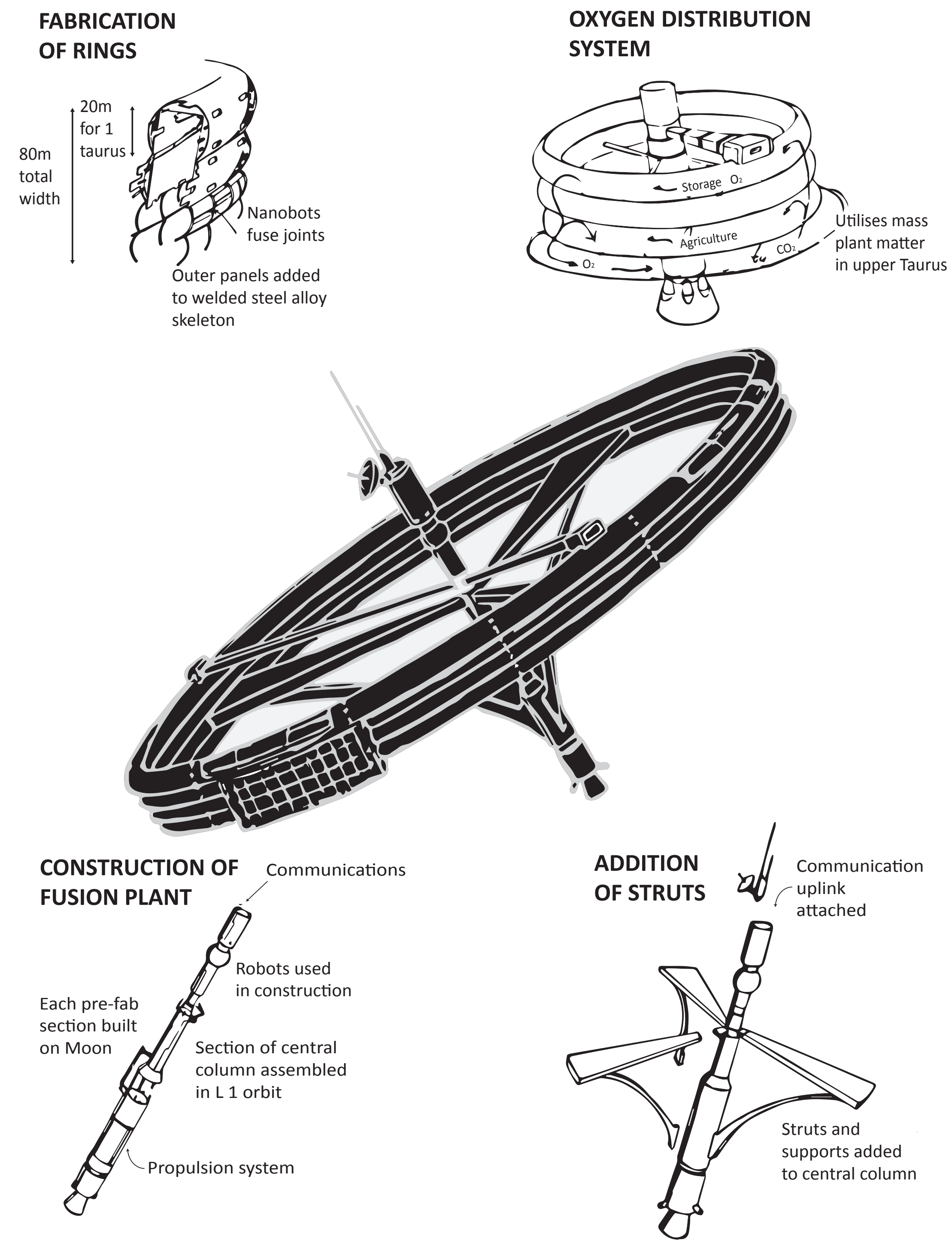
In Spring each year, the Space Science & Engineering Foundation hosts the UK Space Settlement Design Competition (UKSDC; www.uksdc.org) at Imperial College London, where students from around the country go head to head for a place at the International competition held at NASA. The UKSDC involves four teams, each composed of 40-50 students between 15 and 18 from different schools, colleges and science clubs. The event is funded by sponsors and supporters, including an Ingenious Grant recently awarded by the Royal Academy of Engineering.

Futuristic Stations

The RFP outlines the principles for the settlement and tells the students exactly what the funders want. Over the past years, students have been asked to design both long and short term settlements under a variety of scenarios, from a moving ground settlement on Mercury specifically engineered for mining, to a sun-orbiting Earth-Mars transfer station and a mining settlement for a 5 year mission to nearby asteroid Nereus 4660.

This year's UKSDC RFP asked for the design of a settlement in lunar orbit, which was to operate as a transfer station for cargo and people in transit between Earth and space. The port was to hold 5,000 permanent inhabitants with room to accommodate a transient population of up to 600 individuals. The students not only had to design the port's structure, power and food supplies, communication systems and industrial quarters, but also residential requirements, paying

[1] David L. (2011) China Details Ambitious Space Station Goals. Available at <http://www.space.com/11048-china-space-station-plans-details.html> [Accessed: 22 Aug 2013]



The Cassandras project from the 'Grumbo Aerospace' (2011) team is a space station for 10,000 people with a total surface area of 360,000 m^2. Designed to be assembled in Zero-G due to weight restrictions, the ring structure spins to create artificial gravity. Plans for automated construction are included together with details on the design of the interior, materials to be used in the construction, operational logistics, habitability, space suits and services. An estimate of the total financial cost is about £22 billion pounds.

particular attention to the psychological needs of the citizens. Advanced robotics, space suits and computer systems were part of the required plan, including back-up systems and contingency plans, whilst providing a reasonable schedule and cost framework.

The international final in Houston asked the students to design an expandable lunar base and port to be operative in 2038. The teams were expected to provide dimensioned drawings of the facility, which needed to accommodate up to 17, 000 people at one time. Computer types, numbers and networks were required at a high level of detail, and teams were warned of important issues such as superfluous amounts of destructive lunar dust that could bring their designs crashing to the ground.

Communication systems are an important component of every design, and many teams find innovative replacements for mobile devices, making them more compact and harder to misplace. To combine security clearance passes and communication devices, one team designed wristbands which provides a holographic display on your hand, and has your essential medical details and security clearance level integrated. Although privacy is always a source of debate when looking at how space settlement residents will be kept safe but accounted for in each presentation, the students show an exceptional awareness of growing technological capabilities, with the never ceasing compaction of devices. The social needs of residents were also catered for in innovative ways. The 2013 UK semi-final saw the invention of SPACEBOOK, a realistic illustration of a social media network for homes away from home.

Lead by Anita Gale, co-founder of the ISSDC, the judging panel is made of experts in engineering and business, including representatives from the UK Space Agency, NASA and the occasional celebrity appearance. The judges aren't afraid of asking hard questions which push students to think on their feet and defend their design to the end. The judges also like students that think 'outside of the box', encouraging new and potentially risky ideas with unique innovations.

Sci-Fi Solutions
An illustrative example is the winning design of a Sun-orbiting space station that periodically passed close to both the Earth and Mars, thereby allowing up to 8,500 residents to travel between the two planets in a period of roughly 80 days. The project featured a rotating torus with a radius of 500m called Cassandras, assembled in lunar orbit over a period of 12 years. Cassandras got its power from an array of solar panels and, as per the design requirements, was propelled through space by a prototype fusion engine. On board social facilities included restaurants, a gym, a shopping mall, places of worship and a library.

Ideas that have been science fiction in the past are now becoming available and are included in many designs: in vitro meat, aeroponics and algal energy are expected to be routinely used in future space missions. Some exceptionally novel ideas include a net to intercept solar flares, both with a protective function and as a source of energy, and the creation of bioluminescent tress as a lighting source through genetic engineering. Nanotechnology also features heavily in settlement construction and maintenance. Nano-bots are allocated tasks ranging from excluding destructive space dust from key mechanisms, health monitoring in residents, cleaning, waste treatment and recycling.

Ideas that have been science fiction in the past are now becoming available and are included in many designs

Space Scientists of Tomorrow
The Space Design Competition is meant to inspire, excite and educate students about science and engineering, and has a primary objective of helping school students determine if a career in science and engineering is the right choice for them. Although a purely educational exercise, participants are often told when their new ideas hit a gap in the market. For example, at least once a year a project presented at UKSDC is deemed patentable by the judges demonstrating how the creative power of young minds, combined with scientific and technical knowledge, can drive innovation and success in this exciting field.

"This competition is a very exciting project...[you] are the children of today, and the scientists and space researchers of tomorrow".

Sir Patrick Moore
Broadcaster and Amateur Astronomer

Dr. Fiona Larner is a postdoctoral researcher in the Department of Earth Sciences at the University of Oxford and is the Regional Organising Chair for the UKSDC. Many thanks to Dr. Daniel Went, a postgraduate alumnus from Imperial College, for the updates about space exploration.

NASA's visionary artistic space station designs from the 1970s aim at hosting from 10,000 to 1 million inhabitants. One of these designs (Space Station V) was recreated in Stanley Kubric's movie '2001: A Space Odyssey'.

Curiosity Seeks Clues to Past Life on Mars

Angelica Angles, The University of Hong Kong

After Earth, Mars is the planet with the most hospitable environment in the Solar System. So hospitable that it may once, well over 3.5 billion years ago when liquid water was present, have harboured primitive microbial-like life. Channels, gullies and other geological features provide plenty of evidence that liquid water once flowed on the Martian surface, but where did the water go? What caused the change in the Martian climate? Could microbial life be present in the subsurface today?

Unfolding the story of water on Mars will be crucial not only to reveal its past climate history, but also to study its geology and possible planetary habitability. Water is a fundamental ingredient to life and could hold clues to past or even present life on Mars. If humans are ever to travel to Mars, the availability of resources such as water will also play a crucial part in the planning of such missions.

Since its landing, Curiosity has sent to Earth more than 190 gigabits of data, fired its laser more than 75,000 times and returned more than 70,000 pictures

Mars, the closest planet to Earth, was once very Earth-like. Its surface has been altered over the years by impacts from other planetary bodies, volcanism, atmospheric effects such as dust storms, or movements of its crust. Mars has some remarkable geological characteristics: it is home to both the deepest valley in the solar system, Valles Marineris, and the highest mountain, Olympus Mons, which is about three times as tall as Mount Everest. It also has the largest volcanoes in our solar system, about 370 miles in diameter, and many other types of volcanic landforms, from enormous plains coated in lava to small steep-sided cones.

Gullies, channels and valleys are found all over the planet's surface, suggesting that liquid water was present in recent times, and may still lie in pores and cracks in the subsurface. While it may not have been so earlier in the history of the solar system, Mars is nowadays much colder than Earth, with an average temperature of -60 °C. This is not only due to its greater distance from the Sun, about 130 million miles away at the closest point in its orbit, but also because Mars has lost most of its atmosphere.

With a gravity that is only 38% that of Earth, many of the gases needed to retain heat close to the surface have escaped into space. Mars also lacks a spinning, molten core, precluding the generation of a magnetic field, without which Mars is constantly exposed to solar winds and cosmic and galactic radiation. These bombard the atmosphere, blowing away more gases needed to heat the surface.

Mars' current atmosphere, mainly formed of carbon dioxide, is too thin to allow liquid water to remain in the surface for long. However, despite being roughly 100 times less dense than Earth´s, it remains thick enough to support winds, weather and clouds.

Why has Mars changed so dramatically? This is the question that leads us to explore Mars today. By studying the reasons for climate change, we may begin to understand the geological and biological processes that have shaped Mars. As we begin to explore the planet, we wonder: did Mars once exhibit the minimal conditions necessary for the formation of life?

Mars Exploration

Robotic spacecraft were first sent to Mars by NASA in the 1960s, with Mariner 4, followed by Mariner 6 and 7 a few years later. They all revealed a desolate world, without any signs of the life or even civilizations that had been imagined there. Public attention focussed on Mars again in 1997, when Mars Pathfinder touched down on the Martian surface. Two months later, Mars Global Surveyor was inserted into orbit, sending back pictures of volcanoes and chasms at resolutions never seen before. In 1998 and 1999 another lander and orbiter were launched, and every 26 months over the following decade, when the alignment of Mars and Earth was suitable for launches, more robotic spacecraft ventured to Mars.

In 2003, when Mars was the closest to the Earth in nearly 60,000 years, NASA landed two rovers, Spirit and Opportunity, at two very different sites on opposite sides of Mars. Spirit landed in the crater Gusev, a massive lava plain. The rover sent home a frustrating panorama of dry rock, evaporating the hopes of many water hunters. However, Opportunity detected sediments formed by the presence of water all around its landing site at the equator, in Meridiani Planum. It found abundant evidence of past water, and scientists believe that perhaps Meridiani Planum once held an actual sea, most likely during Mars´ earliest geological stages well over three billion years ago.

Most recently, in 2012, NASA´s Mars Science Laboratory's rover Curiosity successfully landed in Gale Crater, near the equator. Gale Crater, a fascinating 96 mile-wide crater (the remnant of a very old impact which occurred three billion years ago), is considered to be the thickest pile of sediments yet identified on Mars. It was the chosen landing location for Curiosity as these sediments record a very long history of rock erosion and deposition, representing a direct view into the processes that have occurred on Mars over a huge amount of time. This choice of location also reflects the `follow the water´ strategy in the effort to find life on Mars.

Signs of Life?

Curiosity was designed to identify organic compounds, determine the isotope ratios of key elements, investigate the building blocks of life, identify possible biosignatures, determine planetary processes such as atmospheric processes or cycling of water and characterize the surface radiation on Mars.

The presence of minerals means that water was surely flowing at some point in the Martian history

Organic (carbon-based) molecules are considered the crucial ingredients of life. Finding organic molecules is a real challenge however, as they easily break down when exposed to harsh environments such as extreme radiation or chemical oxidants from dust storms. A good place to find ancient organic molecules nowadays is in rock layers, which can preserve organic molecules that were suddenly trapped and buried in layers of sediment or mud.

Scientists believe that the Gale Crater contains rocky layers that formed in ancient times, when liquid water was present. Even though the water has since dried up, the layers could still preserve some organic compounds. If Curiosity finds organic compounds in ancient rocks, it would not prove that life existed on Mars, but it will surely prove that Mars once had the right ingredients for life to exist.

As part of its exploration, the rover has also measured the radiation exposure inside the spacecraft, both on its way to Mars and on the surface of the planet. These data, never measured before, are crucial for planning future manned missions to the Red Planet.

A Monster Truck of Science

Curiosity, with its six-wheel drive, suspension system and mounted cameras, is a nuclear-powered monster truck of science, worth 2.5 billion dollars. Its 20-inch aluminium wheels tear over different obstacles and explore over 660 feet per day on Martian terrain. The rover is equipped with the most advanced tools available for drilling and analysing rocky Martian samples. A truly sophisticated mobile laboratory, it has the most advanced instruments ever built and sent to Mars. It is able to drill holes, collect rock powders and analyse them.

Unlike its predecessors, Curiosity uses onboard test instruments. One of them, using fluorescence and X-ray diffraction, can identify minerals in the rocks and soil samples. Other sets of instruments, such as a gas chromatograph, a laser spectrometer and a mass spectrometer, can identify organic compounds, including carbon and oxygen. Scientists are therefore not only receiving images of rocks that could represent an ancient water-rich environment, they are also able to test these hypotheses directly in the field.

The NASA Deep Space Network (DSN), an international network of antennae, provides communication links between spacecrafts and rovers on Mars and the scientists on Earth.

This network of antennae consists of three deep-space communication facilities spread around the world, which allow constant observation of spacecrafts as the Earth rotates.

Curiosity also uses the DSN to communicate to Earth, but messages from the rover are first sent to the spacecrafts orbiting Mars, rather than directly to Earth. This is for several reasons: the orbiters are closer to the rover (250 miles above the surface) than the DSN antennae on Earth and have Earth in their field of view for much longer periods of time than Curiosity on the ground. They also have bigger antennae and a lot more power than the rover. The data rate from Curiosity to the orbiter can be as high as 2 million bits per second. When an orbiter passes over the rover and is able to communicate with it, it can collect between 100 and 250 megabits of data and transfer them to Earth within a few hours. That same 250 megabits would take up to 20 hours to arrive to Earth directly from Curiosity.

Evidence of Water

Curiosity has found evidence that a lake once existed, which contained fresh water and other chemical ingredients suitable for the existence of life. A big surprise was to find clay minerals near the landing site, since there were no signs of them from orbit. The presence of minerals means that water was surely flowing at some point in the Martian history.

Curiosity also found conglomerates. Conglomerates are rocks made of little round pebbles encrusted in a finer sandy or muddy component called the matrix. On earth these rocks are formed in riverbeds. The key to pebbles in a river conglomerate on Earth is that they are round. These round edges are the result of the pebbles being lifted and transported by flowing water. As the water moves the rocks around, they collide with one another, slowly causing the sharp edges of the transported clasts to be chipped off, eventually becoming smooth. Finding a conglomerate on Mars with features identical to those we find here on Earth proved once again that, for an extended time, water must have flowed on the surface of the planet.

Curiosity also measured the natural cosmic and solar radiation on its way to Mars. This is extremely important since Curiosity came into contact with the same environment that human explorers are expected to experience one day. As it turns out, the radiation arriving from both the sun and interstellar space will pose a significant challenge for future Mars astronauts: Curiosity absorbed much more radiation than astronauts are allowed to over their entire career.

In the past few years, both Mars orbiters and terrestrial telescopes detected methane on Mars; a gas that could be the result of present biological activity. However, Curiosity has so far detected very little methane in the Gale Crater. So while it appears that the conditions of Mars in the past were at some stage conducive to life, today´s environment seems to be too harsh for life to exist.

What Next?

Since its landing, Curiosity has sent to Earth more than 190 gigabits of data, fired its laser more than 75,000 times and returned more than 70,000 pictures. Just a year into its mission, Curiosity has already achieved its main goal: to further our understanding of the Martian environment.

The remnants of the ancient Mars environment found by Curiosity confirm that fast-moving, deep water existed on the planet's surface at some stage in its history. It has also determined that Mars could have hosted living oxygen-producing organisms. The rover found traces of oxygen, hydrogen, sulphur, nitrogen, carbon and phosphorus. It also found clay minerals and calcium sulphate, suggesting not only that water was present, but also that it must have been freshwater, favourable for living organisms to thrive in.

Future missions are already being planned to look for evidence of microbial life. The ExoMars mission, due to launch in a few years, will have similar onboard instruments in order to visually, mineralogically and chemically analyse the environment right down to the microscopic level. It will look for biosignatures left in rocks that could only be explained by the presence of ancient life. In addition, the rover will collect samples and store them for a later mission to bring them back to Earth.

Knowing as much as we can about Mars and its past will help us verify whether life was ever present on our planetary neighbour. Each technological advance in space exploration provides new opportunities to take us further and further along the way. But regardless of how far we get with these incredible rovers, one problem remains to be solved: to determine how humans can live in space and function in these harsh environments. The next 30-40 years will see a lot of activity in space exploration, with the hope that man will keep on pushing the boundaries of our human ability. All of this, together with previous missions and space projects, sum up how we truly explore space – one step at a time.

Angelica Angles is currently doing a PhD in Astrophysics and Planetary Exploration at The University of Hong Kong. She has a MSc in Planetary Science at University College London.

A Revolution in Space Propulsion

Les Johnson, NASA's George C. Marshall Flight Space Center

A revolution in the way we conduct deep space exploration may soon be upon us thanks to recent advances in lightweight materials, the advent of small, inexpensive satellites called 'Cubesats' and a renewed willingness by policy-makers to consider new technologies and approaches. Many of these new technologies are in the area of propulsion for a spaceship or satellite which is already out of Earth's atmosphere, and are considered 'propellantless' because they don't use fuel in the conventional sense. NASA's George C. Marshall Space Flight Center in Huntsville, Alabama, USA, is at the forefront of development many of these new space propulsion technologies.

Solar electric rockets are the most efficient rockets known today and, for propulsion in deep space where distances are vast, efficiency is king

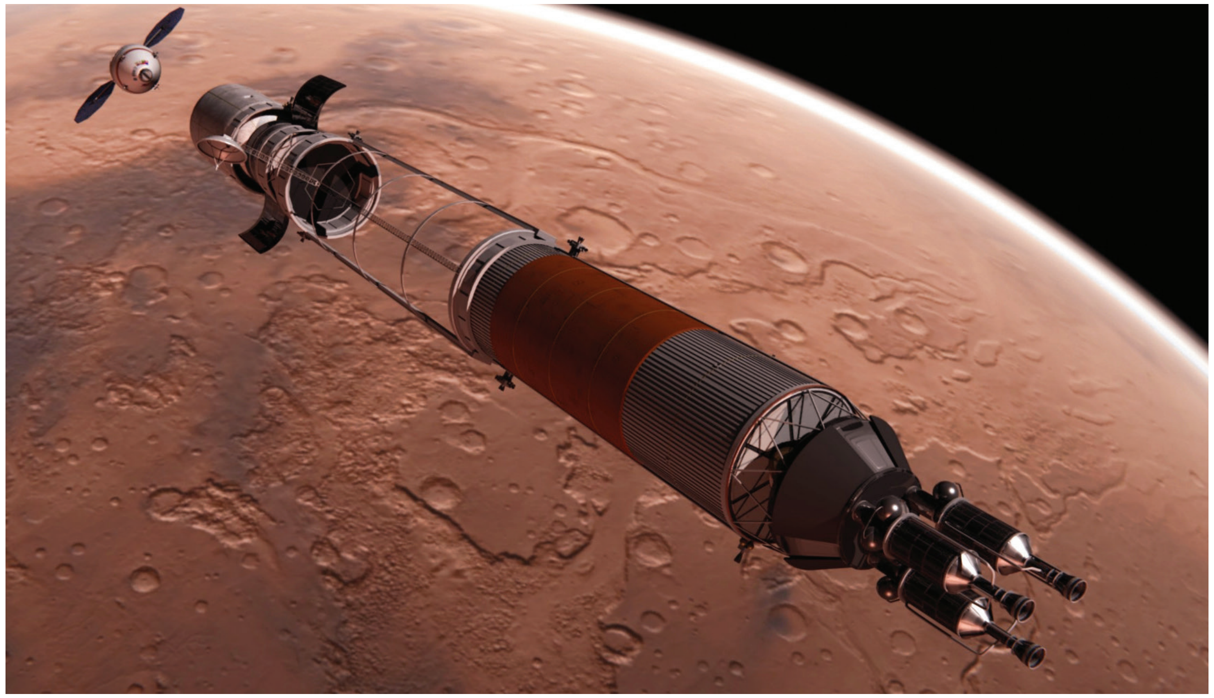
Since the beginning of the Space Age, we have explored space using exclusively rockets propelled by chemical energy and more recently using rockets that accelerate their exhaust electromagnetically. The former are simply called chemical rockets and the latter are generically called electric propulsion. In recent years there have been significant technological advances in both that dramatically increase our ability to explore the solar system.

Next Generation Rockets

Chemical rocket propellants may be solid, like the ammonium perchlorate used in the Space Shuttle Orbiter's solid rocket motors, or liquid, like the hydrogen used by the Orbiter's main engines. While ammonium perchlorate is a powerful rocket propellant and was responsible for providing more than 80% of the total lift-off thrust for the Space Shuttle, it is also toxic. Hydrogen, on the other hand, produces steam, water vapour, as it burns with liquid oxygen (also carried by the Shuttle). Unfortunately, for most deep space applications, relatively toxic propellants like hydrazine and nitrogen tetroxide are frequently used, posing storage and handling risks for all directly involved. There are efforts to develop and demonstrate less-toxic 'green' propellants, but these are not yet in wide use.

Nuclear rockets use the heat of a nuclear fission reaction to heat propellant and expel it as exhaust rather than using the heat generated via chemical combustion. The advantage with this approach is that the propellant can be heated to much higher temperatures, and the atomic weight of the propellant can be optimized to provide the maximum thrust for the least mass. In nuclear rockets, the optimal propellant happens to be hydrogen. The US last tested nuclear thermal rockets in the 1960's and 1970's under Project NERVA (Nuclear Engine for Rocket Vehicle Application) before the project was cancelled due to the ending of Project Apollo, and the subsequent lack of defined missions for it. Since then, studies consistently show that such rockets are among the best for sending a mass into deep space efficiently, such as would be required for a human mission to Mars.

While there is currently no full-scale nuclear rocket program, engineers at NASA are testing system elements using low-cost, simulated nuclear reactors to avoid the safety, cost and complexity issues associated



Future missions to Mars could involve TransHub modules driven by nuclear thermal rockets.

with nuclear testing to develop fuels that offer superior performance over what was available nearly a half-century ago. The reactor technology for nuclear rockets is not much different from that used in today's nuclear power plants. Both use the fissioning of uranium to generate heat, but space nuclear reactors will be much smaller than their ground-based analogues. It is important to note that any nuclear rocket would not be engaged until the spacecraft is well out of the Earth's atmosphere, posing little or no risk to our environment should there be an accident.

Solar electric rockets are the most efficient rockets known today and, for propulsion in deep space where distances are vast, efficiency is king. Rockets that provide the most thrust for the least mass are the ones that have the highest payoff in this type of exploration. Using technologies originally developed for nuclear physics research, particle accelerators, and adapting them for spaceflight has led to a method of space propulsion that is about ten times more efficient (per kilogram of fuel) than any chemical rocket. Powered by sunlight, these electric rocket engines use electric and magnetic fields to accelerate ionized propellant to very high exhaust velocities, providing a small but continuous thrust that enables very large changes in spacecraft velocity.

The noble gases are the best propellants for these engines. Argon, xenon and krypton are generally nonreactive, fairly easily ionized, and can be accelerated to very high exhaust velocities resulting in a relatively high momentum exchange between the propellant and the spacecraft. To date, electric propulsion systems have flown on several space missions, most of which are commercial communications satellites in Earth orbit. Larger and more capable systems are planned for use in deep space. For example, NASA's recently announced Asteroid Redirect Mission (ARM) is currently planning to use high-power solar electric propulsion to alter the trajectory of an about 400t asteroid and place it on a safe trajectory into lunar orbit.

The problem with rockets, both chemical and electric, is that they all-too-soon run out of fuel. Most people are unaware that when a robotic mission is launched to Mars, nearly all of the acceleration of the payload occurs within the first few minutes of flight before the chemical propulsion system onboard the spacecraft shuts down due to lack of fuel. The rocket and its payload then coast for the next several months at a constant velocity until the spacecraft uses another rocket to place the ship into orbit or to target its planetary entry for landing. Electric propulsion systems are more efficient in using propellant and about ten times more efficient in changing spacecraft velocity, but their performance is still limited by the amount of fuel they can carry onboard. And many destinations of interest for scientists require propulsive manoeuvres beyond what either type of rocket can provide.

Star Sailors

A possible solution to the fuel burn out can be provided by 'propellantless' propulsion systems like solar sails and electrodynamic tethers. Though their fundamental physics of operation are very different from each other, they have in common a lack of need for propellant because neither of them expel any sort of rocket exhaust in order to derive thrust and hence movement. All of these systems also take advantage of the space environment itself for propulsion, making them perhaps the ultimate in 'green' propulsion for space.

A possible solution to the fuel burn out can be provided by 'propellantless' propulsion systems like solar sails and electrodynamic tethers.

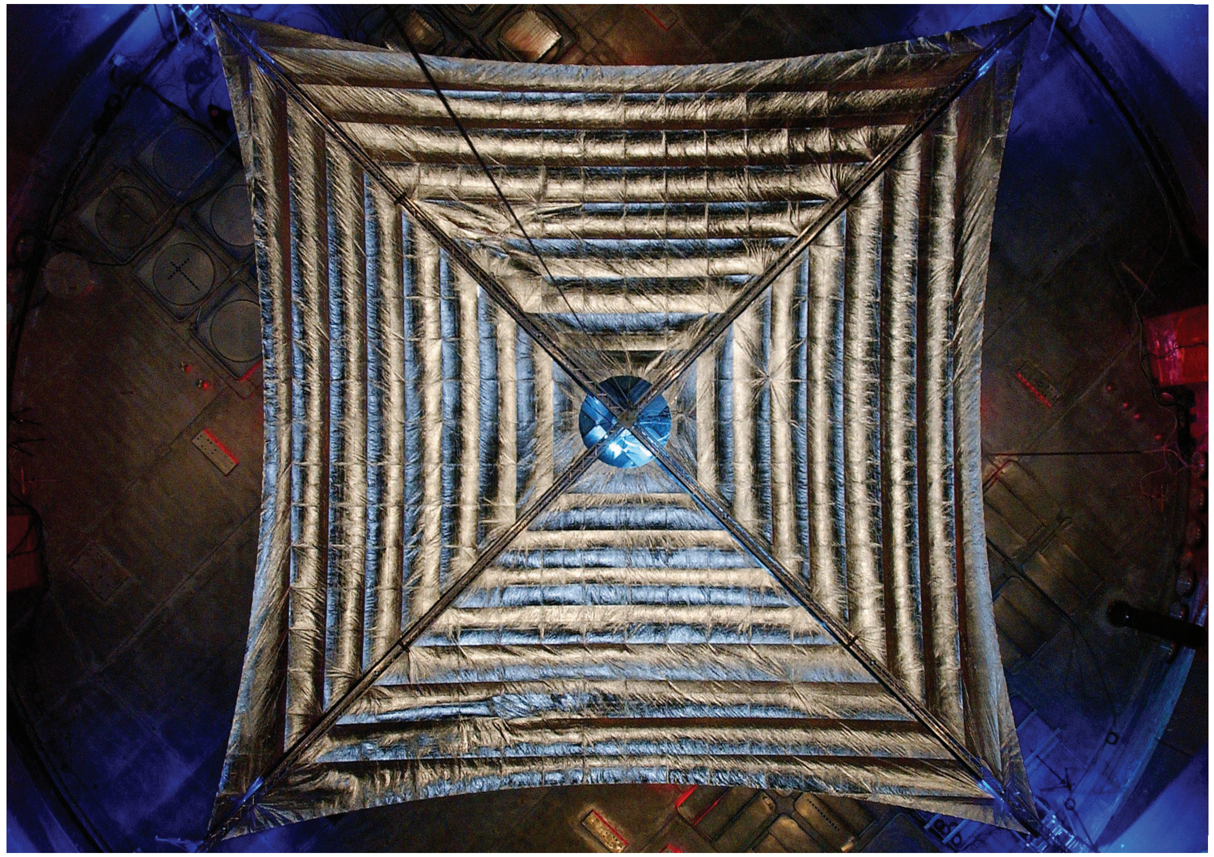
Solar sails use reflected sunlight to propel vehicles through space. Incident light reflects from a mirror-like sail made of a lightweight, highly reflective material and imparts momentum to the sail in the process. Although light has no rest mass, it does possess momentum and as long as sun shines on the sail, it will move. This continuous thrust allows solar sails to perform a wide range of missions, many of which are simply impossible using chemical propulsion – the rocket will run out of gas before the mission is complete. In the near-term, solar sails will be used to study the Sun and the Earth from unique vantage points. Eventually, a solar sail propulsion system could propel a spacecraft to reach tremendous speeds – potentially allowing us to send a spacecraft to visit another star or solar system.

Solar sails are conceptually simple and have been discussed as a theoretical possibility for nearly a hundred years. However, they have only been practical in the last few decades due to recent advances in highly-reflective, lightweight and high strength-to-weight materials. Studies and tests of polymide film-based materials, such as LaRCT-CP1, developed by NASA's Langley Research Centre and fabricated by DuPont, show that sails can be made to be very robust, to withstand a very wide range of temperatures and to be unsusceptible to damage from solar wind, micrometeors, or solar ultraviolet radiation exposure.

Japan has been flying the world's first solar sail, called IKAROS (Interplanetary Kite-craft Accelerated by Radiation of the Sun), since 2010. In 2014, NASA will launch its first deep space solar sail, the Sunjammer, on a demonstration mission that will take it toward the Sun. Sunjammer is over 1,200 square meters in area and uses inflatable booms, similar to balloons one might find at a fair, only much more sophisticated, to support the sail. Beginning in 2014, Europe has planned a series of small solar sail flights that will incrementally increase in size and capability.

Electrodynamic tethers use the force exerted by a magnetic field, such as Earth's, on a current-carrying wire (the Lorentz Force), and represent an interesting alternative to conventional rocket engines for missions in Earth orbit. When this force acts on a current carrying wire attached to a spacecraft, it will either accelerate or decelerate the spacecraft in its orbit, lowering or raising its orbital altitude – using no propellant in the process. Only sunlight converted to electrical power is required. Tethers, which may need to be many kilometers in length for operational systems, need to be resistant to damage from micrometeors and orbital debris. Tethers may one day be used to transfer working satellites to new orbits, remove dead satellites from orbit at the end of their life, keep space stations and space hotels in orbit, and even provide propulsion and power for vessels orbiting the other planet in the solar system with a large magnetosphere: Jupiter.

The fundamental physics of electrodynamic tethers have been proven in space on numerous test flights, including the 2010 flight of the suborbital JAXA T-Rex mission. The T-Rex was launched from Japan on a sounding rocket and demonstrated that a long (400 m) conductive tape can be deployed in space and collect ampere-level currents – a critical step toward developing a tether-based propulsion system. The next step, which has not yet been funded, is a demonstration of the tether's ability to actually boost and de-boost a functioning satellite in a controlled fashion.



NASA's solar sail demonstration mission, dubbed 'Sunjammer' in honour of Arthur Clarke's sci-fi short story, could provide an economic alternative for the removal of space debris.

To Infinity and Beyond

The future of deep space exploration using conventional chemical rockets is far from certain, yet it is expected that they will remain the mainstay of space exploration for many years to come. However, in the very near future they will no longer be humanity's only means of travel within our solar system.

For example, solar sails will enable spacecraft to remain directly above the Earth's polar regions, balancing solar pressure on the sail against the pull of Earth's gravity and preventing the sail from either falling to the ground or flying off into space. Electrodynamic tethers may enable spacecraft to fly at very low altitudes in the ionosphere, using their inherent propulsive capability to prevent them from re-entering the Earth's atmosphere due to the very high atmospheric drag at those altitudes. Solar electric propulsion will be used to launch more payload mass, in some cases more than twice the mass that can be sent by chemical propulsion, to destinations all over the solar system.

In general, these new technologies are much simpler and less expensive to build and operate than today's state-of-the-art chemical propulsion systems. Hence, although overall funding for developing new space technologies is scarce, these technologies and others are mature enough to be considered real alternatives to chemical propulsion in the near term and are receiving varied amounts of research and development funding from NASA, ESA (European Space Agency) and other space-related organizations all over the world.

As many of these new propulsion technologies become viable alternatives, they will enable exploration of regions of deep space simply inaccessible with conventional technology.

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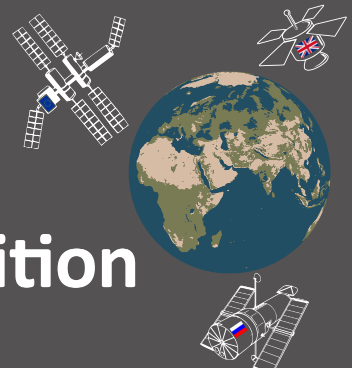
Space:

A Place for International Cooperation and Competition



Dr. Emily Baldwin, EJR-Quartz (ESA)

Space exploration was sparked by an intense rivalry between the US and the Soviet Union in the 1950s and 60s to be the first to land a manned mission on the Moon. Several decades later, the U.S, Russia, Japan, Canada and Europe now work together on the International Space Station, a research post in low-Earth orbit. Hundreds of experiments have been conducted on the station, benefiting a range of scientific disciplines including the biological, physical and materials sciences. Beyond Earth orbit, the world's space agencies have a fleet of robotic satellites exploring all corners of the Solar System, within both independent and collaborative missions.

The desire to step foot on another world has been romanticized in literature, poetry and art for centuries, and fills the daydreams of many, but it has its roots buried firmly in the harsh reality of war. As World War Two ended the Cold War began, and a fierce competition ensued between the U.S and Soviet Union with the aim of developing systems capable of delivering long-range missiles with trajectories around the planet.

Countries are still competing for supremacy in space exploration

The Soviet Union announced their capabilities to the world by launching the very first space satellite, Sputnik, in 1957. In 1961 the Soviet Union defeated the US again, this time by launching the first human into space, Yuri Gagarin. Just three weeks later, Alan Shepard would become the first American in space. To regain lost national pride, US President Kennedy announced the ambitious goal of landing a man on the Moon before the end of the decade. The space race was well and truly on, and was only settled in July 1969 when the late Neil Armstrong and fellow astronaut Buzz Aldrin stepped onto lunar soil and planted the American flag. It would be something that that to this day, no other nation would ever achieve. Six more manned lunar missions followed but, as funds and public interest waned, the last footprint on the Moon was made in 1972.

While the US and Soviet Union stole the limelight for the great race to the Moon other countries were busy establishing their own space programs and launching rockets. During the 1960s the foundations were laid for the formal creation of the European Space Agency in 1975. Meanwhile Japan and China both independently launched their own first satellites in 1970, with India following in 1975. Even today, countries are still competing for supremacy in space exploration. This is especially important for developing countries where it carries the symbol of technological superiority and contributes to national pride.

In 2003 China became – and still is – only the third nation to independently launch a human into space. The country has also demonstrated success in launching and docking its own space station modules, including two short-stay manned missions. The last, which concluded in June 2013, saw three Chinese astronauts spend 15 days in space, testing technology and conducting scientific research. Having achieved this milestone, China is now looking ahead to its next spacelab for which it will begin launching modules in 2015.

Meanwhile, the International Space Station (ISS) takes centre stage. Orbiting the Earth at an altitude of around 330-430 km, this habitable research station is the most ambitious global space project in history, but comes with a hefty price tag of over 100 billion euros. Five space agencies worked together to conceive, plan, construct and now operate the working space laboratory – a collaboration far removed from the tensions that existed during the Cold War era. Working together, the United States, Russia, Japan, Canada and Europe are represented by the National Aeronautics and Space Administration (NASA), Russia's space agency Roscosmos (RSA), the Japan Aerospace Exploration Agency (JAXA), the Canadian Space Agency (CSA) and the European Space Agency (ESA) respectively. From ESA's 20 member states, 10 contribute to the ISS including Germany, France, Italy, Belgium, Switzerland, Spain, Denmark, The Netherlands, Norway and Sweden. The first space station module was deployed in 1998, and the entire station is approximately the size of a football pitch. This orbiting outpost serves a range of functions, including living quarters, science laboratories and storage facilities. It has been occupied continually since November 2000, typically with between three and six astronauts living on board in six monthly cycles.

International Science in Space

Some 700 experiments have been conducted onboard in the last decade, covering biological sciences, physical sciences, materials sciences, technology and nanotechnology, and astronomy, space and Earth sciences. Many of these experiments have direct implications for future long-term space exploration, particularly concerning the human body's reaction to long-term exposure to micro-gravity, and to an environment with greater levels of radiation. Studies have already found that, despite daily exercise, bone mass is reduced by 1-2 percent for every month spent in space – a finding which, for example, has significant implications for possible year-long or longer missions to Mars.

SpaceX made history in 2012 when it became the first commercial company to deliver cargo to the ISS

The microgravity environment of the ISS has also allowed unique discoveries to be made in the medical field, such as spaceflight increasing the virulence of some bacteria, providing a new route into vaccine development for viruses including salmonella, pneumonia, meningitis and MRSA. Stem cells also respond differently in space, reducing an astronaut's immune system defences and wound-healing abilities. This research has also opened new doors into the study of traumatic wound-healing from military injuries. Other areas of scientific research such as light technology – used to support plant growth on the ISS – have been developed into a novel method in the treatment of paediatric brain tumours.

There are also numerous space technology spin-off applications, such as an astronauts' handheld pressure altitude warning system that is now also being used in aviation, scuba diving, mountaineering and meteorology. Similarly, technology used by astronauts to recycle their urine, sweat and respiration into drinking water has had applications in water purification for areas of contaminated water on Earth.

The ISS also acts as a powerful tool for education. Onboard astronauts regularly engage in educational activities by inviting schools to communicate with them via amateur radio. On some occasions students have participated in research being conducted in space, typically by comparing the results of simple experiments performed in the classroom with the same experiment carried out by an astronaut on the space station. In this way, space can be used as a means to encourage school children to pursue careers in science and engineering topics.

Furthermore, the presence of European astronauts on board the ISS opens up a link between space and the general public in their country of origin. In 2015, the UK's Timothy Peake will spend a six-month sojourn on board the station. Peake is the first official, government-backed UK astronaut; previous UK-born astronauts, such as the recently retired Michael Foale, have had to become American citizens and have flown as NASA astronauts, while Helen Sharman won a Russian competition to get her ticket into space.

British space activity received a boost earlier this year when ESA inaugurated its first technical base in the UK, in Oxfordshire, following Britain's increase in its subscription to ESA last year. While a significant proportion of the subscription is dedicated to telecommunications, it is imagined that Peake's upcoming mission may boost the UK's desire to increase its participation in human spaceflight. Britain recently became a member of ESA's European Life and Physical Sciences in Space programme, which focuses on research conducted on the ISS, and will inevitably see Peake working on microgravity experiments during his mission. Furthermore, while British companies already play a key role in space technologies – Reaction Engines Ltd. Skylon spaceplane concept, for example – it is anticipated that Peake's mission will provide an economic boost to the growth and development of the space sector, thus providing British school pupils with a greater exposure to possible career paths in the fields of science and technology.

Space Station Supply Ships

Peake will depart for the ISS on a Russian Soyuz. Since NASA retired its space shuttle in July 2011, the ISS's human occupants have relied exclusively on the Russian Soyuz spacecraft to make the journey. Commercial companies are currently taking steps to fill the gap in this niche market. SpaceX made history in 2012 when it became the first commercial company to deliver cargo to the ISS in its unmanned Dragon capsule, and safely return cargo back to Earth; the company is working towards the first manned test flight.

Meanwhile, the ISS continues to support the docking of a mixed fleet of supply ships to deliver experiments, provisions and spare parts to the space station. ESA has visited the station four times with its Automated Transfer Vehicle (ATV), which can deliver up to 8 tonnes of cargo as well as bring back waste at the end of its mission – it safely burns up in the Earth's atmosphere on the return journey. The latest ATV 4 docked with the station in June and will depart in late October of this year.

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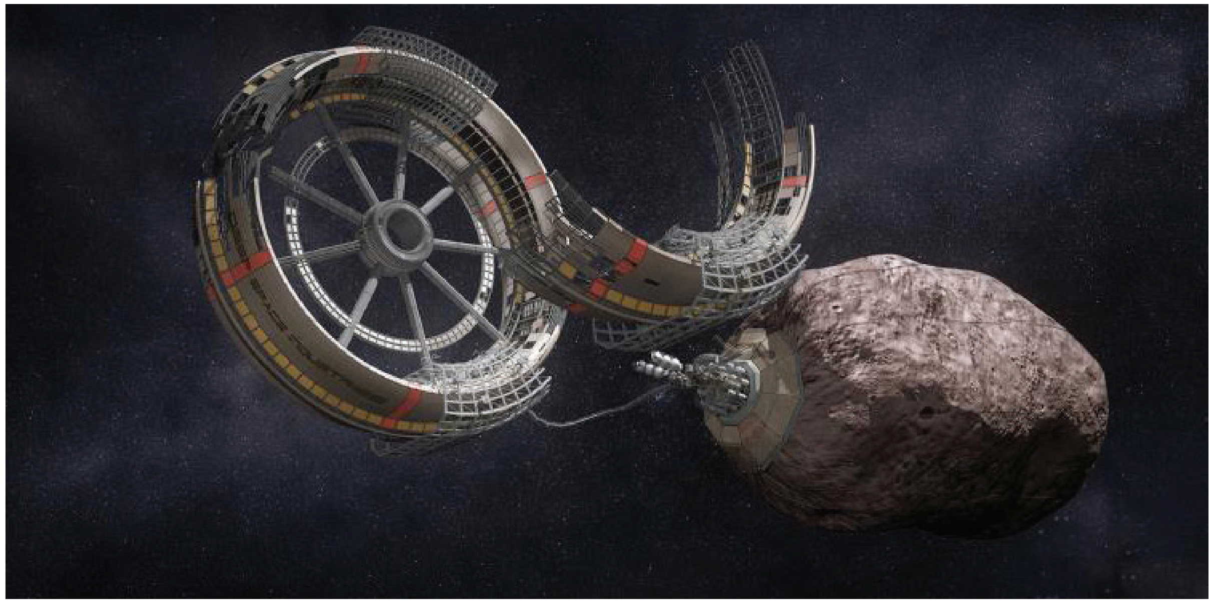


Private companies, such as Deep Space Industries based in US, are planning missions to exploit resources from asteroids from 2016.

Japan has also sent four supply ships to the space station; its most recent H-2 Transfer Vehicle docked on 9 August 2013 to deliver 3.6 tonnes of food, water and clothing, as well as technical equipment including a freezer to store experiment samples, oxygen tanks for spacesuits, and life science experiments. Russia's expendable Progress spacecraft also ferries supplies to the ISS – the latest ship docked at the end of July.

Earth from Above

Orbiting the Earth once every 90 minutes, ISS astronauts have an ever-changing view of their home planet. But there is also an armada of dedicated Earth observation satellites looking down on us from altitudes of up to 36,000 km, recording aspects of daily life from weather and climate trends, to land use, natural disasters, and resource management. Satellites are also in place to facilitate communications, for example your daily mobile phone calls, acquiring GPS (Global Positioning Service) locations for your car's satellite navigation, and for relaying TV broadcasts.

Although providing telecommunication and positioning services are typically peaceful activities, there has been a move in recent years for both well-established space agencies and developing nations to provide independent services, with a somewhat more sinister undertone. While many GPS systems are true to their name of being globally accessible ultimately, they are run by individual countries. The US operates the primary GPS service, but Russia recently completed its GLONASS fleet of satellites that offer the same level of precision as GPS. China and Europe are both on their way to developing their own systems, and India recently launched the first satellite for its new fleet too.

Navigation and positioning services are vital during military conflicts – to provide accurate data for ground and air manoeuvres, for missile guidance, and for emergency services. But the use of foreign GPS systems may not necessarily be guaranteed during these situations because their operators can deliberately reduce the accuracy of signals. The ability to operate independently therefore provides additional security for military operations, and with many nations taking this step forward there are some similarities to the political undertones that drove the Cold War of the last century.

Beyond Earth Orbit

Elsewhere in the Solar System, far beyond Earth orbit, the world's space agencies also have a fleet of international robotic satellites exploring our cosmic neighbourhood for peaceful purposes such as learning more about the Universe in which we live. NASA and ESA missions have drawn much of the attention so far this year: NASA's Curiosity rover is currently exploring the surface of Mars and returning new images of the Red Planet on a near-daily basis, while ESA's Planck mission recently unveiled the most detailed picture of relic radiation from the big bang yet seen.

But rising space powers, notably Japan, China, Russia and India are also exploring beyond Earth orbit with an armada of robotic satellites, boosting prestige and driving socio-economic uplift of the country. Like the US, Russia and Europe, China, Japan and India have all led orbiting missions to the Moon. NASA, Russia and ESA have also demonstrated successes on Mars, but in November of this year, India plans to launch its own Mars satellite in its most ambitious mission yet. The orbiter will primarily demonstrate the technological capabilities of the nation, but it is also tasked with scientific research,

SPACE: INTERNATIONAL COOPERATION AND COMPETITION

in particular the detection of methane. This is also the goal of the upcoming joint ESA-Roscosmos ExoMars mission. Detecting methane and identifying its source will lay to rest one of the key questions in Mars research; on Earth methane is produced primarily by biological activity and, to a lesser extent, volcanic activity. Detecting it on Mars could therefore imply that living organisms may be present on the Red Planet.

Before the first ExoMars mission launches – the orbiting mission is planned for 2016, while a follow-up rover mission will launch in 2018 – ESA has two big milestones in space science ahead. The first is the launch of the Gaia mission, anticipated for autumn 2013. Over five years Gaia will map the precise locations of over a billion stars, allowing scientists to create a 3D map of the Milky Way, and to learn more about the origin, evolution and future of our home Galaxy.

The commercial mining company Planetary Resources announced its goal to prospect near-Earth asteroids for water and minerals

In 2014, ESA will attempt the first landing on a comet. The Rosetta mission, which launched in 2004, will be woken up from deep space hibernation in January, a few months ahead of its rendezvous with Comet Churyumov-Gerasimenko. It will then follow the comet as it loops around the Sun, studying the effects of solar heating on a comet from close quarters – also for the first time. Then in November 2014 it will deploy its Philae lander to the surface. Comets are thought to have played a role in seeding the Earth with ingredients for life – by directly analysing the surface of such a primitive body, scientists will get one step closer to unlocking what could be the 'Rosetta stone' of the Solar System.

Meanwhile NASA has designs on capturing an asteroid a few metres wide and bringing it to a safe distance from Earth for further study by astronauts in a quest to learn more about the threats that these rocky objects pose to the Earth should they be on a collision course with our planet. The initiative would also accelerate technology development in areas such as solar-electric propulsion.

Space Solutions

Asteroids are also the subject of another debate, that is, the role they could play in solving the problem of the growing shortage of strategic mineral resources on Earth. In April 2012 the commercial mining company Planetary Resources – founded by American entrepreneurs Eric Anderson and Peter Diamandis – announced its goal to prospect near-Earth asteroids for water and minerals, including rare earth elements such as platinum, which are typically found in higher concentration on asteroids than on Earth.

Planetary Resources' vision is to bring the natural resources of space that are bound up in asteroids within humanity's economic sphere of influence. The advantages of prospecting asteroids include their small fields of gravity rendering them easy to approach and leave. In addition, their heaviest metals, such as iron and nickel, are distributed throughout rather than closer to a central core facilitating their extraction process.

Planetary Resources first plan to launch low cost commercial robotic spacecraft to determine the best asteroid candidates, taking into account their location and the accessibility of mineral resources. Eventually, mining outposts would be set up, and the precious metals returned to Earth, in theory increasing the global GDP. Even further into the future the company envisions the utilization of extracted water for rocket fuel, and fuelling stations could be built in space to open up space exploration to more distant destinations within the Solar System. Technology and engineering is continually pushed to its limits to allow us to explore the Solar System and beyond, uncovering a bounty of scientific discoveries, while simultaneously driving industry back on Earth.

Space exploration has certainly come a long way since the Space Race of the 1960s, even though humans have not ventured further than the Moon since 1972. But with plenty of new and exciting missions being launched before the end of this decade, there is plenty for the next generation of scientists and engineers to draw inspiration from. In the meantime, there is also a new space race unfolding, with an underlying sense of competition between developing nations; China, Japan and India in particular are continually stepping up their efforts to reach the same technological achievements in space as leading organisations such as NASA, ESA and Roscosmos. While in the 21st century the International Space Station, along with countless space exploration missions, demonstrated the benefits of peaceful scientific collaboration, there has been a turn towards developing independent navigation and location satellites. Will this result in new conflicts or will international collaborations continue to lead the way?

Dr. Emily Baldwin is the Space Science Editor at EJR-Quartz, with the primary role of writing content for the European Space Agency's web portal (www.esa.int). She also contributes reports to the Geopolitical Information Service, and has previously worked as Website Editor and Deputy Editor for the UK's Astronomy Now magazine. She has a PhD and MSci in Planetary Science from University College London.

Liquid Democracy

New Politics in a Connected World

Dr. Marc Rea, Imperial College London

Over the past five years we have seen several examples of people engaging in mass protests under the auspices of social justice. Demonstrations such as those in Egypt, Brazil and Syria have clearly expressed a large-scale dissatisfaction with current government, and illustrated the huge potential power of digital, internet-based communication.

Leading to some parallels with the global socio-political revolution seen during the Sixties, the digital technology available to today's youth provides both a means to co-ordinate action, but also a non-violent means of protest and a platform to drive social change.

What forms the technological basis of this emerging form of liquid democracy, and how might it be used to bring about a new political revolution?

The ancient Greeks played a key role in developing the form of government which we refer to as 'democracy' today. The word itself originates from the Greek term *demokratia*, consisting of the two words *demos* (people) and *kratos* (power), meaning 'power of the people'. The founding principles of Greek civilisation were such that in each city, or region, men of a certain age would gather to raise issues and vote on resolutions. This system was seen as the fairest way to set policies which affected all, and was successful in its time. A system such as this is known today as a 'pure democracy', where each person receives one vote and the majority prevails.

Over the ages, as societies and economies have become more complex and individuals have specialised in particular fields, the most common form of democracy that has emerged is referred to as a 'representative democracy'. In this case, individual voters elect politicians to govern for periods normally lasting 4-5 years. However, this system, which many of us consider as the only truly democratic approach, has failed at various times due to a combination of factors.

One such factor is the lack of feedback or sustained communication between politicians and voters in certain parts of the world. In these cases the media is often state-controlled and is hence distrusted by voters. Italy is a prime example of media failure in terms of democracy, with MP (and former prime minister) Silvio Berlusconi owning, either directly or indirectly, five out of the six most influential TV channels (and a number of newspapers) in the region.

> *In response to [...] media oppression, armed with weapons of mass communication, emerging groups are proposing to re-introduce aspects of pure democracy into the political spectrum*

In response to such media oppression, armed with weapons of mass communication, emerging groups are proposing to re-introduce aspects of pure democracy into the political spectrum, aiming to level the field of democratic expression. They hope to provide new meaning to the process of political participation and change the rules for legitimacy, accountability and transparency.

The Power of Decentralisation

The internet provides us with a decentralised, accessible meeting point where information can be distributed, arguments can be presented, and most importantly votes can be counted, all in a highly customisable environment. Exploiting these features to rethink the way democracy operates, it is possible to move political processes online. In this manner policy proposals are available to be considered and analysed by all, and evidence can be presented in an open framework that enables extensive discussion and voting.

Moreover, many alternative ways of counting votes can be devised. One favoured implementation uses the concept of liquid democracy, a hybrid system which retains the individual power of a pure democracy, but uses representation to remove the necessity for constant participation. This is the system used by free2vote, a recently formed non-profit organisation based in London which is focusing initially on the UK general elections to be held in 2015.

The idea of a practical e-democracy is still in its infancy, though it has already garnered support in Northern Europe, particularly in Sweden, The Netherlands, and in Germany, where in the last general election candidates of the Pirate Party (who propose a direct e-democracy) collected 2% of the vote. While not enough to get a seat in parliament, this vote was largely obtained from young voters. Shifting demographics mean this early result could signal the possibility of more mainstream support for direct democracy in the future.

> *Despite some opposition, the voice of the people is becoming louder than before*

In Italy, the political movement M5S (Movimento 5 Stelle) is another example of an attempt to construct a coherent political movement based on 'pure' democracy through the internet. Launched in 2009, the movement has consistently grown, obtaining an impressive 25.55% of the vote in the 2013 Italian general elections. An alternative approach has been to use social media, such as was demonstrated recently in Brazil, to both influence and measure public opinion in real time. By-passing the traditional sampling strategies of data and media organisations, it was possible to gauge the 'pulse of the nation' as events changed on the ground, and provide a direct line of communication between protesters and the world-at-large.

Design Hurdles

Arguably, the technological basis for implementing this form of democracy already exists. Various websites, some of which are open source, have sprung up to handle and compile or assimilate opinion data. Most systems, on a fundamental level, consist of databases containing current Polls, Opinions and Votes which may be filled in by users. However, similar to issues surrounding the management of online forums, some curation will be required in the long run to deal with issues such as the simultaneous creation of an unmanageable number of closely overlapping poll topics – thus raising inevitable issues of wider representation.

Security issues are also paramount since they are understandably a major worry of most people, and it is accepted that major attacks would have an adverse effect on public perception. There is a growing movement towards login systems incorporating face-recognition and other advanced methods of identification.

Several other important issues remain, such as how to design the process of curating accurate information, and how to encourage the expression of a representative spectrum of opinions required to produce a balanced vote. Research into these areas will likely have to proceed on a trial and error basis.

Power and Influence

Politics is about power and governance, and often those who have power set the rules to govern. It is only through open, and independent, traditional and new forms of media that emerging models of democracy can hope to gain exposure and support. While some politicians have been quick to see the potential of social media to garner a youth following, some have been slow to realise its power and others outright hostile. For example, the embattled Prime Minister of Turkey, Mayor Erdoğan, reacted angrily to online pressure during the occupation of Taksin Square in Istanbul by citizens protesting against government action: "There is now a menace which is called Twitter. The best example of lies can be found there. To me, social media is the worst menace to society".

However, despite some opposition, the voice of the people is becoming louder than before, and public opinion can be influenced and gauged in new ways such as through social media. If groups like free2vote can make use of this fact, by tying the power of public opinion to individuals who are committed to act only upon the consensus at the expense of their own judgements, then public opinion may take a seat in Parliament (similar to what is actually happening in Italy with the M5S movement). This new approach may be called a 'digital democracy', and aims to take the people to Westminster.

Dr. Marc Rea is an MRI Physicist working at Imperial on Interventional MR Systems. He is the joint founder of free2vote and a proud new dad.

Co-founder of the Italian Five Star Movement (M5S) which advocates a form of 'pure' democracy, Beppe Grillo is a comedian and political activist

Digital Platforms and E-Bureaucracy in Participative Democracy

Prisca Merz, Imperial College London

In times of access to high speed internet and social media virtually everywhere, one would expect that it is easy to reach out to millions of people and encourage them to participate in direct democracy – but experience so far has proven the contrary. When the European Citizens' Initiative (ECI) first started in 2012 it was hailed as a great means to foster citizen participation and increase the democratic legitimacy of the European Union. However, while people do 'like' and share pictures or videos online, it appears to be very difficult to translate this interaction into participation in democracy. More than one year into its existence, the experience of both proposers and users alike has been mainly one of disappointment. The process is cumbersome, with many people concerned about the amount of data required for a digital signature, and the system is not user-friendly. Another case of EU over-regulation, or an example of innovative technology taking a while to get on its feet?

The European Citizens' Initiative (ECI) is a means of direct democracy allowing citizens from at least 7 EU countries to propose legislation. When one million EU citizens support a certain proposal, it has to be considered at EU level.

This instrument was originally designed to allow citizens to participate in EU policy-making in the same way as governments or members of legislative houses such as the UK Parliament do. In this manner citizens can call on the European Commission, which has the sole power to propose legislation, to bring legislation to both the European Parliament and Council who, in most cases, jointly vote on its implementation. However, implementation of this low-budget initiative, run entirely by volunteers, has resulted in a large number of hurdles for proposers and signatories alike, which has ultimately hampered the potential impact of this effort to promote direct democracy among EU citizens.

Traditional Media

The Right2Water initiative launched by the European Federation of Public Service Unions (EPSU) against the privatisation of water has been the first ECI to achieve over 1 million votes. While it has had a great online presence, its success resulted from the combination of three main factors:

- The European Commission was at that time discussing the concessions directive, that aimed to facilitate competition and public-private partnerships within the water industry, which gave the organisers a window of opportunity
- German TV discussed the privatisation of water in December 2012, and
- A famous German comedian discussed the ECI directly on his comedy show (Erwin Pelzig, 13th Jan 2013).

This led to a big jump in signatures, with over 900,000 German signatures within only a few weeks, followed by another feature on German TV directly dedicated to Right2Water[1]. Germany is still the leading country with almost 1.3 million signatures, or well over three quarters of the total.

'End Ecocide' in Europe, a European citizens initiative which started in 2012 aiming at criminalising severe cases of environmental destruction, shared a similar experience as Right2Water. When it was first mentioned on French TV, internet traffic reached over 150 clicks per second, with intense activity on Facebook (one post reached over 50,000 people) and YouTube. However, only a very small percentage of those sharing the Facebook picture or watching the YouTube video actually voted for the petition.

Moreover, not all of the clicks on 'vote now' actually translate into valid votes. While the figures vary by country, overall more than 50% of the votes are lost due to the voting system. Specifically, only when a citizen receives a signature ID, his or her vote has been counted. This problem indicates that there are clarity issues with the online form, or that the voting procedure is too cumbersome for today's instant communicators. The on-going collection of signatures for 'End Ecocide' in Europe has so far achieved the support of over 47,000 Europeans, a long way to go for the million.

A possible explanation of this partial failure of the initiative, as explored further below, is that citizens might decide not to support the initiative after reading the data requirements, or coming across issues of voter eligibility. In fact, differing national data requirements actually exclude some from voting. Another reason could be a failure in communicating a successful vote, with citizens being unaware that only once they receive a signature ID the vote is counted. Of course a third explanation simply lies in a lack of interest from the citizens in supporting the initiative. A major problem in the ECI platform, though, is the absence of useful software and statistics to track visitors' behaviour, so it is very difficult to come up with a reliable explanation of an eventual unsuccessful outcome.

A Burgeoning e-Bureaucracy
Contrary to traditional petition platforms such as change.org, the European Commission requires a substantial amount of data from signatories. It does not allow either the simple collection of email addresses or sharing buttons for social media. The format of the signature form is not very clear with lots of small print, obliging the user to go through a tedious process within the voting system.

Data requirements are probably the most obstructive aspect of this process. While some information is, of course, needed in order to check the identity of a signatory and ensure people sign only once, the process is further complicated by the fact that EU member states do not agree on uniform requirements. For example, Irish citizens have to provide different information, in different format, from Spanish citizens, for example. But even worse, there are some citizens who are completely excluded from voting due to the difference in requirements between their country of residence and origin. For example, the UK requires signatories to be residents, but Austria or Portugal require them to be nationals – with the result that UK citizens living in some other member states cannot vote. This bureaucratic norm clearly does not help to promote the democratic principle of universal suffrage.

A major problem in the ECI platform [...] is the absence of useful software and statistics to track visitors' behaviour

A closed-box software is provided to the promoters of initiatives, which cannot be customised as long as their ECI is hosted on the Commission servers. On the other hand, hosting an initiative on a different server is only possible for ECIs with a substantial budget, which usually is not available to the promoters. Such restrictions and complicated requirements within the EU digital platform constitute a sort of e-bureaucracy, which hampers the efficient promotion of policy-making initiatives.

Window of Opportunity
The ECI platform has great potential to become a tool for a more direct and participatory democracy within the EU, but there are major caveats in its implementation that need to be overcome. It's almost impossible to achieve the 1 million targeted number of votes without a proper organisation and budget for any initiative – which contradicts its purpose to facilitate citizen participation, but rather transforms it into a tool used by strong lobby groups to further advance their agendas.

In addition, it is still unclear whether a digital platform alone is enough for the successful promotion of a political campaign – recent experiences suggest that a traditional offline presence is still needed to reach a large enough audience. Experience also shows that it is only when the promoters of an initiative can place the campaign's issue on the agenda of mainstream players that it is possible to achieve an audience large enough to spread the word to at least 100 million citizens, assuming that one in hundred votes.

[1] Georg Restle (2013) Wasserprivatisierung Marsch! Wie EU und Bundesregierung Politik für Großkonzerne betreiben [online] Available at: http://www.wdr.de/tv/monitor/sendungen/2013/0314/wasser.php5

Social media such as Twitter, Facebook and internet platforms such as YouTube can serve as stepping stones for promoting campaigns, but traditional channels of communication are still needed for the ultimate success of such initiatives. The single most important determining factor here appears to be linked to the 'window of opportunity' available to the campaign, such as news stories falling within current topics as occurred for the Right2Water initiative. Within this short window, the interest of citizens is sparked and digital platforms can play their role in efficiently and rapidly spreading the initiative.

Social media [...] and internet platforms [...] can serve as stepping stones for promoting campaigns, but traditional channels of communication are still needed for the ultimate success of these initiatives.

It took decades to establish the democratic foundations of the ECI for EU citizens, but new norms and a simplified bureaucratic model need to be established in order to ensure that efficient and democratic participation of EU citizens in policy-making takes place. The technical caveats must be fixed, but beyond that policy-makers at a European level must recognise the ECI as an important tool (many members of the European Commission are not even aware of the ECI). Ultimately, one million votes is only the first step in wider policy participation – how to involve people in a continuous discussion surrounding new laws and their implementation is a future problem which must be tackled.

Nevertheless, this first step already demonstrates that only through a simplified e-bureaucracy, which facilitates the use of a digital platform among the citizens from all EU Member States in equal way, can the ECI function efficiently. In this manner the European Commission can benefit from the wide participation of citizens in policy-making on important socio-political issues, which can ultimately pave the way towards a more direct and participative form of democracy within the EU.

Prisca Merz is heading a team of over 200 volunteers who are organising End Ecocide in Europe. One million votes are needed by January 2014. Vote now at: www.endecocide.eu

Assistive Technology and Audiovisual Translation:

A key combination for Access Services in Online Education

Emmanouela Patiniotaki, Imperial College London

Online education has become a reality in many universities worldwide, either as complementary educational material in support for conventional courses or as a standalone online information. The web can also offer great support to disabled people who use it for purposes of entertainment, education and communication. With standards emerging in web accessibility, developers are looking into ways to make online material as accessible as possible. Within this context, Audiovisual Translation (AVT) and Assistive Technology (AST) have the potential to create new channels in the provision of university-level educational material on the web for people with sensory impairments such as blindness and deafness.

Digital literacy and accessibility, in a broad sense, is included in the availability of products, services and places to people with all sorts of disabilities – physical, cognitive, mental, sensory, emotional, and developmental – as mandated by the European Union. Accessible education on the web is composed of two major aspects: (a) accessible audiovisual material (i.e. videos) and (b) accessible functional context (i.e. design, navigation, assistive tools, etc.). Accessibility in online education can be achieved through access services and assistive tools, which are respectively the outcomes of Audiovisual Translation (AVT) and Assistive Technology (AST).

Improvements in web accessibility have played a crucial role in shifting from "Web for some" to a more democratic "Web for all"

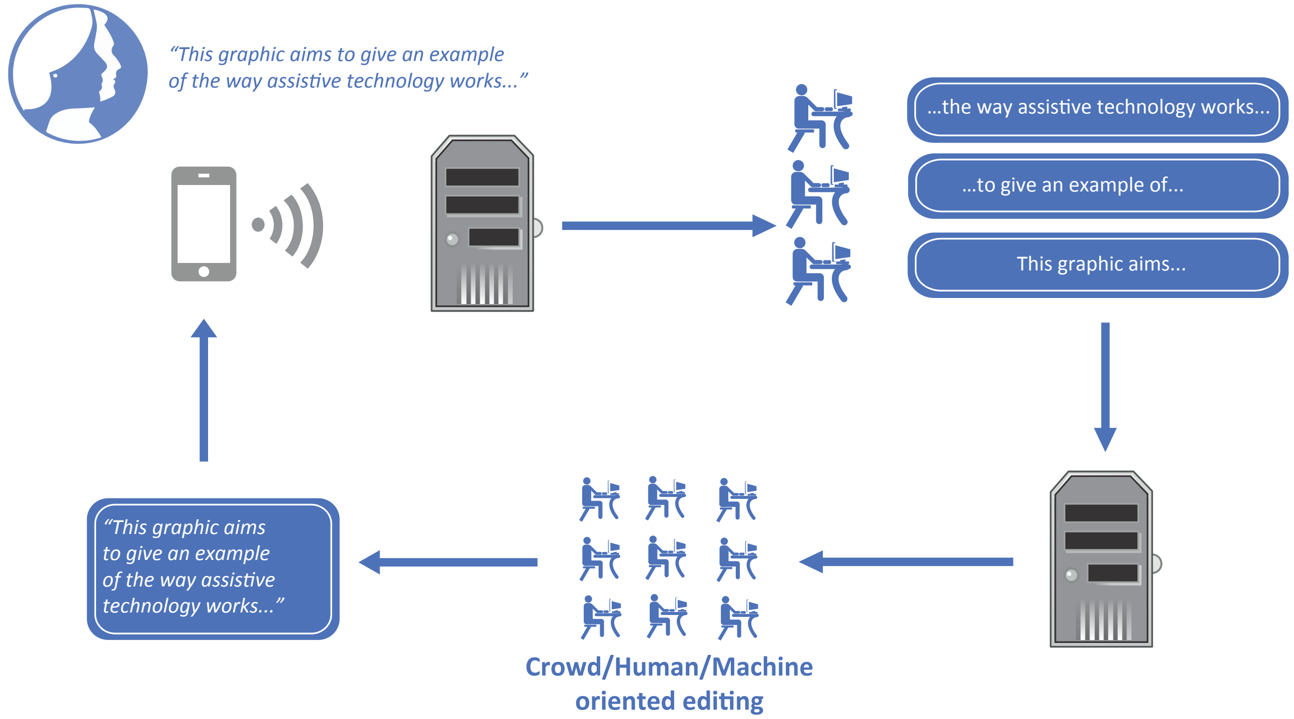
Audiovisual Translation and Assistive Technology

AVT services consist of software, such as subtitling for deaf and hard-of-hearing (SDH) and audio description (AD) for blind and partially sighted audiences. AST tools, such as speech recognition, screen reading and magnification of content, are implemented in websites and online platforms, but are also used offline to assist students with several applications. SDH and AD are two services that were born within the field of AVT and today they are established access services used mainly in television and theatrical performances.

SDH, in particular, includes audiovisual material broadcasted or watched in any form of distribution, and can be both intra-lingual (performed within the same language) and inter-lingual (between one or more different languages). AD is a process that "provides a narration of the visual elements – action, costumes, settings – in theatre, television/film, museums exhibitions, and other events" and it "allows patrons who are blind or have low-vision the opportunity to experience arts events more completely – the visual made verbal"[1]. SDH is greatly valued as a service that advances learners' reading and writing skills in the same way that AD enhances speaking and listening skills.

Within the educational sphere, the two services have been mainly focused on facilitating learning for students with sensory impairments, but they have been also used for learning languages. These technologies might also be used to increase ease of use for online interaction, and for accessibility of applications such as video games.

Within AST, for web and computer-based educational content, available tools consist mainly of software and hardware that make services and content available to disabled people on specific devices. Software



Assistive technology such as audio and video captioning and crowd services integrated with e-learning software can help sight and hearing impaired people in education.

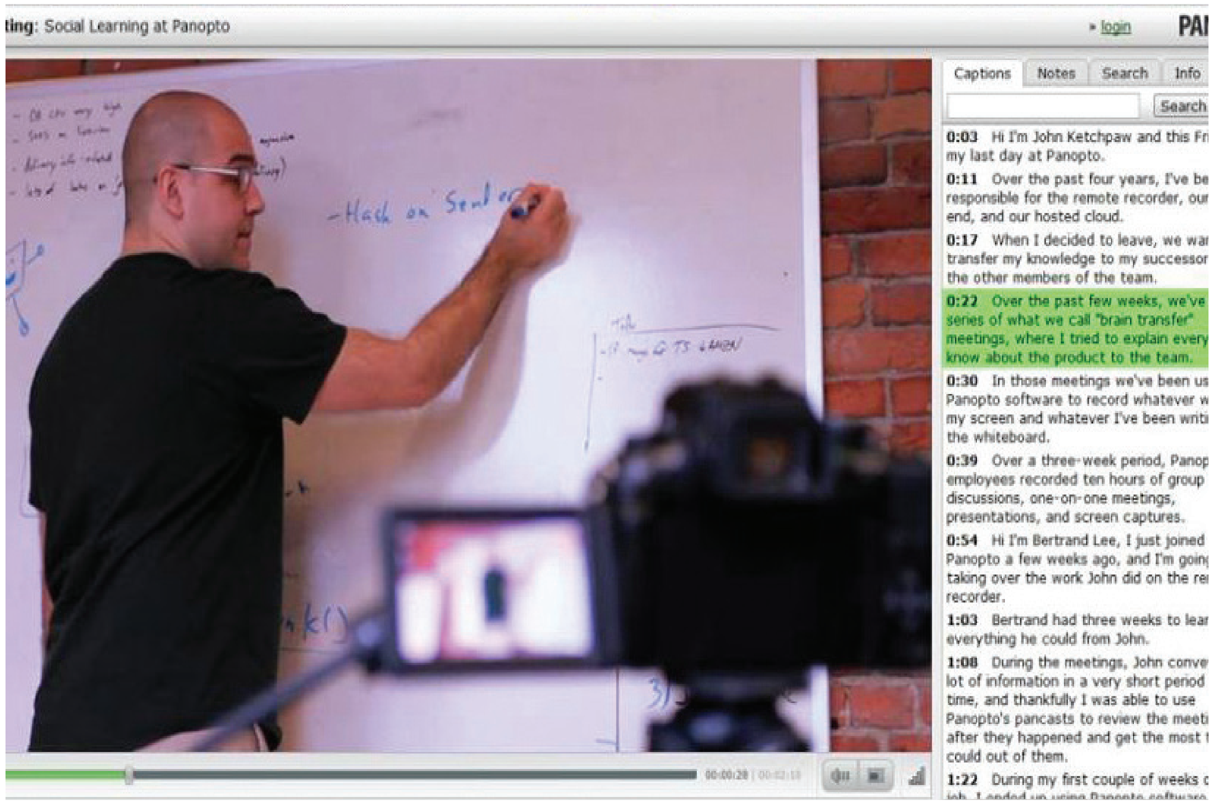
developments, such as screen readers, are gradually substituting hardware since they have proved to be affordable, more practical and multifunctional. People with sensory impairments use assistive technologies in their everyday life through commonly used devices, including iPads and smartphones, while several applications are implemented by specific hosts or providers to make life easier for people visiting online websites.

Creating a Web for All

The web is gradually evolving into a sphere with vast potential for people with disabilities. As mandated by regulatory bodies such as the European Union, and via Web Content Accessibility Guidelines (WCAG) of the World Wide Web Consortium (W3C), alongside navigation options for blind and partially sighted users, developers are often required to provide alternative tools for audiovisual material on their websites. This can take the form of pre-recorded audio-only and video-only media, captions, audio description for pre-recorded media, as well as live captions for live audio content in synchronised media.

Initially SDH and AD were mostly available on the web either in the form of amateur services provided by AVT enthusiasts, or as a component of pre-recorded material published on the web. Today, website development language HTML5 facilitates developers in including other forms of SDH and AD. For example, it supports direct embedding of supporting material for multi-media content, e.g. video content, without the need for third party plug-ins. It is safe to say that this development has allowed AVT to enter the world of online accessibility which was until recently restricted only to AST applications, with providers focusing on alternative texts for images and readable content. These improvements in web accessibility have played a crucial role in shifting from "Web for some" to a more democratic "Web for all".

Nevertheless, some web developers have been generating products for online education which do not integrate functional and contextual developments from one field to the other, therefore limiting the benefits to specific



Software for audiovisual translation, such as Panopto, is a complementary tool for video capturing which can help sight and hearing impaired people involved in distance learning.

disabilities. Ideally the accessibility to AVT and AST technologies should be more flexible and global, and should encompass technical, social, educational and linguistic dimensions.

Access services are beginning to flourish both online and offline within the academic environment

Crowd-Sourced Solutions?

New AVT services have been gradually used by several institutions for educational purposes. For example, in the field of synthesized speech and voice recognition, new tools such as Synthesized AD, speech-to-text narration, video description and annotation, attempt to substitute audience-targeted and humanly produced SDH and AD. Subtitling and crowd-sourcing have also lately improved their accessibility through more sophisticated means. Open source software and platforms hosting audiovisual material, which includes MAGpie, YouTube and Amara (Universal Subtitles) offer users a simple working environment in order to create captions for their videos or to acquire captions that have been produced through machine translation and speech recognition.

At the same time, networks of crowd-sourced and cloud-based subtitling are being built in an attempt to produce fast real-time captioning with minimum latency and maximum precision with hybrid contributors, rather than just humans. An indicative example of crowd-sourced subtitling is Legion:Scribe, a system that, as claimed by the company, "captions speech on-demand and with less than 3 seconds latency by automatically merging the simultaneous input of multiple crowd workers".

A number of products in the field of AST have also emerged to provide more inclusive solutions for online education. Most of them, including ClassInFocus (2009), DELE (2012), SSTAT (2012), MVP (2011) and the Photonote system (2007) focus on

[1] Snyder, Joel. (2011) Fundamentals of Audio Description. Teaching Audio Description: An On-Line Approach. Imperial College 4th International Conference Media for All 4.

[2] Cornford J. and Pollock N. (2003) Putting the University Online: Information, Technology and Organizational Change. Buckingham: SRHE and Open University Press.

assisting either deaf and hard-of-hearing or blind and partially sighted students. Most of the research in AST conducted by universities worldwide focuses on captioning for deaf students. Among the most prominent commercial solutions are systems such as Panopto, Tegrity, MediaSite and Echo306, which form learning environments that capture video, audio and screen activity. They support captions, whether these are produced by people or machines (speech-to-text technologies), and offer users the opportunity to edit videos, make video annotations and provide access to further educational material i.e. PowerPoint presentations. Other open-source solutions for AD and captioning include Amara (captioning), YouTube (captioning), MAGpie (AD), CapScribe (AD) and LiveDescribe (AD). These are proper tools rather than learning solutions, which can satisfy the needs of both blind and deaf students.

Networks of crowd-sourced and cloud-based subtitling are being built in an attempt to produce fast real-time captioning with minimum latency and maximum precision

AVT and AST in the Classroom

An increasing number of universities have Disability Advisory Centres and Accessibility Units, which offer advice and solutions to disabled students in order to minimize the hurdles to be overcome to attend courses. At Imperial College, besides the well-established Advisory Centre, a new organization – the Assistive Technology Steering Group – was set up in 2012 with the aim of examining issues and providing solutions for access to educational materials by disabled students.

The main purpose of the organization is to assist departments in developing new ideas for accessing educational material on the IC website and on on-site computers. The team is now looking into ways to provide lectures online as well as solutions for a more accessible IC website. Moreover, a new European project called ClipFlair (2011) aims to develop an online social network to provide material for learning languages through a series of access services (including captioning and re-voicing) and lesson plans which allow learners to practise their speaking, listening, reading and writing skills.

An important limit of all the aforementioned tools is the lack of holistic solutions for all students with sensory impairments. In most of the cases, users are provided with rather limited applications, i.e. video input, and also when lectures/videos are accompanied by other material, such as presentations, these are only intended for the deaf and hard-of-hearing. Moreover, AVT and AST tools and services are rarely combined in educational contexts, i.e., a screen reading tool smoothly connected to an AD time-coded script.

Another urgent issue is that of quality of access services. Crowd-sourced or transcript captions are not as efficient as SDH. The latter is produced to serve deaf and hard-of-hearing audiences through the use of several techniques such as the preparation of a new script read by a human voice instead of speech synthesis. More importantly, what is missing is a functional approach that allows students to enter learning environments as self-serviced individuals, an idea introduced by Cornford and Pollock in 2003[2]. Other solutions should be critically evaluated in place of inappropriate educational tools such as synthetic and machine-oriented solutions. The present guidelines may often make demands for accessible AV material, but still do not specify the production process and do not openly explain which approaches should be followed by educational institutions in using the relevant material. AST tools and access services should be combined in such a way that they can bridge the gap between the several disciplines.

It is clear that access services are beginning to flourish both online and offline within the academic environment. The key action to be taken in order to guarantee the widest and most efficient accessibility in online education is through the creation of a holistic accessible environment for disabled students incorporating and integrating both AST and AVT technology. This approach will guarantee several benefits such as flexibility and compatibility for different countries while offering social inclusion and interaction throughout the web.

Emmanouela Patiniotaki is a researcher at Imperial College in the field of Online Accessibility for disabled students. She is an active volunteer in Access Services and a member of the IC Assistive Technology Steering Group and the Hellenic Association for Assistive Technology.

Imperialism 2.0:
Do We Really Want to Save the Poor?

Prof. Steve Fuller, University of Warwick

For nearly the last half-century, we have heard that a shift of 1-2% of GDP from the developed to the developing world would raise as many as 1.5 billion people to a level that would assure the benefactors that the beneficiaries are on their way to lives much like the benefactors' own. However, this widely advertised claim is best taken as 'inspirational bookkeeping', a phrase that should be understood not simply as a euphemism for 'false' or 'delusional'. Nevertheless, a hard-headed economist would say that the stated figure ignores 'transaction costs' – that is, the costs of providing the background conditions that would allow the stipulated 1-2% transfer of income to work the desired magic. In what follows, these hidden costs are discussed in light of the recent eye-opening work, Poor Economics by two MIT economists, Abhijit Banerjee and Esther Duflo.

Inspirational bookkeeping gets its political legs from an unexamined mythology about the rich and the poor as suffering from complementary liabilities. On the one hand, the rich are presumed to be less productive per unit of wealth than the poor; on the other, the poor are presumed to be appropriately productive with whatever unit of wealth they receive. That the global gap between the rich and poor remains wide is then explained by saying that the rich buy politicians who let them sit on their wealth (e.g. via preferential tax rates), while the poor are stymied by overlords who divert or squander whatever aid comes their way. In both cases, politics is the fall guy. But at a deeper level, there is also a question of living up to one's potential. Neither the rich nor the poor do this, but for opposed reasons, reflecting how they differ in relation to the sources of power in their societies. The rich expend considerable energy to avoid having to live up to their potential, whereas the potential of the poor is quashed by rulers worried about their own fate, should the poor acquire a sufficiently decent standard of living to participate in politics.

What makes this mythology attractive is that the rich and powerful are portrayed as corrupt, while the poor appear as blameless victims waiting to be liberated. The underlying assumption is that there is a sense of human potential – or 'human capital', if you will – that is common to rich and poor people. As economists would put the matter, the two groups are fundamentally similar in disposition but operating under radically different resource constraints – the rich having too much money and power, the poor too little. If we make that assumption, then income redistribution looks like a win-win strategy for releasing human potential to its fullest. However, the reality on the ground presents a subtler picture, one that increasingly suggests that if our inspirational bookkeeping is to be made real, we shall need to engage in a new and quite possibly more entrenched round of Imperialism. The question then becomes more one of political will than economic resources.

> *'Poorer' regions use the new technology more to extend than to transform their current lifestyles*

The main obstacle is that the evidence is at best patchy that the global poor see themselves as 'poor' in our morally degrading sense. Even more striking than the fact that mobile phone penetration in, say, India is greater than in the United States is that 'poorer' regions use new technology more to extend than to transform their current lifestyles. Of course, there are cases in which mobile phones have enabled the creation of new economic infrastructures that permanently transform living conditions. But typically without the sustaining presence of some development agency, there are no guarantees of what might happen in the long term. Those who still cling to Abraham Maslow's hierarchy of needs, according to which clean water and safe housing must be secured before the sense of self-transcendence permitted by the internet is fostered, have cause for concern.

The End of Poverty & Poor Economics

The debate about international aid to countries with people living in extreme conditions of poverty has been polarized between two positions: on one side Jeffrey Sachs in his book The End of Poverty argues that it is poverty itself which keeps people being poor and that only international aid without repayment can free the poor from the poverty trap. On the other side, William Easterly, in his book The White Man's Burden argues that the real problem is not the poverty trap, but aid itself, which ends up harming the poor, creating a dependency culture and preventing them to find their own solutions within the free market.

Abhijit V. Banerjee and Esther Duflo have worked with the poor in dozens of countries around the world, trying to understand the specific problems related to poverty and the attempts to find solutions. In their book Poor Economics they present a careful analysis, including hundreds of randomized control trials to estimate the effectiveness of the international policies in finding a solution for poverty. They found that several attempts of aid, such as free or subsidized mosquito nets or water chlorination tablets, schooling or contraception, were not ultimately used by the beneficiaries; even microcredit turned out to be less revolutionary than previously thought. Poor did not make use of the technology provided and continued borrowing in order to save, missing out free life-saving immunizations while paying for unnecessary drugs and starting businesses which do not grow. But the book also shows that when aid is designed in such a way that can permeate the specific socio-cultural aspects of the lives of the beneficiaries, it does help them to emancipate from poverty.

The book criticises anti-poverty policy to have failed over the years because of inadequate understanding the problems behind poverty. Crucial factors are the socio-psychological aspects involved with poverty, with particular emphasis on what the authors call "time of inconsistency". This is when many decisions that people think to implement and stick to fade away in the moment people have to commit to them, as they change their mind. It is an inconsistency between the "yourself in repose" and "yourself in action" among the poor, which is underestimated by aid programs when thinking that the poor will always follow the most sensible, convenient and practical action.

The book does not support any of the aforementioned views in the debate about solutions to end poverty, and it concludes that there is no Big Idea or golden bullet, but it still believes in the value of aid in "promoting and digging deep into something, and committing to generate innovations".
More information is available at: www.pooreconomics.com

Poor Economics and Cultural Relativism

Would-be global developers are faced with a problem, which might be seen as the revenge of cultural relativism. Whether 'rich' or 'poor' from the standpoint of GDP per capita, the meaning of people's lives is tied to whatever they take to be normal. It follows that if you deem the conditions under which a culture normally survives as 'impoverished', you run the risk of disliking the people themselves – or at least wishing that they were people other than who they really are. This worry simmers just below the surface of the generally positive vision advanced in Banerjee and Duflo's Poor Economics, perhaps the best book on development published in recent years.

Although Poor Economics has been rightly feted for its success stories of grassroots development projects in Africa, at a deeper level the book points to obstacles in the way of generalising from those stories. In one very general sense, we fail to take seriously just how alike the rich and the poor are. Both envisage their lives as having a certain texture, reflecting the various challenges they expect to face, which in turn play into larger narratives that illuminate how their societies are maintained over time. To see how this applies very close to home,

Mobile phone penetration in the Indian market is even higher than in the US, and plays an important role in the lives of many such as providing mobile banking and access to regional markets.

consider the havoc that the steady rise in life expectancy in the developed countries over the 20th century has wreaked on state welfare systems.

When Bismarck set up the first national insurance scheme as a bulwark of German solidarity over a century ago, people were expected to benefit from the system for only a few years after having paid into it throughout their working lives. However, as people now routinely live twenty or more years after their formal retirement from the labour force, crises have arisen on many fronts at once, including: (1) the sheer fiscal maintenance of the welfare system; (2) intergenerational conflict as the young are either blocked from career advancement or channelled into caring for the elderly; (3) general cultural confusion concerning the boundaries between 'young' and 'old' (4) more downstream ecological effects, as a greater number of healthier and wealthier people consume more resources.

The West has been sold on the Enlightenment promise that the promotion of science and technology will deliver indefinite human progress

The Cost of Scientific Progress

While it is easy to blame particular politicians and policies for landing us in this predicament, at a deeper historical level it is simply the long-term unintended consequence of the amelioration of the human condition through science and technology. For at least a quarter-millennium now, the West has been sold on the Enlightenment promise that the promotion of science and technology will deliver indefinite human progress. Thus, whatever crises we now face reflect the efforts of, say, seven or eight successive generations trying to make good on this promise.

Make no mistake: this author still backs the Enlightenment as necessary to take humanity to the next stage, what Julian Huxley originally called 'transhumanism', whereby we aim to make all of reality conducive to the realization of human ends. Nevertheless, anyone with cross-cultural consciousness must concede that this project is indigenously 'Western', which is to say, difficult to justify unless one sees science and technology as delivering on the promises of the Abrahamic religions, with their distinctive focus on humanity's godlike dominion over the Earth. Indeed, our sense of identity as Westerners is largely defined by our perseverance with this project (the so-called 'civilising mission') in the face of enormous pushback – not only from the four previously mentioned problems at home, but also the massive collateral damage to other cultures that has resulted from the attempt to impose competing versions of this world-view across the globe in the 20th century.

This immediately raises the question: Suppose you do not naturally define yourself as a 'Westerner'. To what extent should you be drawn into this project? The question is rarely asked so explicitly because Western analysts – abetted by Marxist notions of false consciousness – tend to believe that residents of developing countries are beset in ways that compromise their ability to deliberate rationally about their own self-interest. But why should these self-avowed liberals, perhaps even egalitarians, adopt such a patronising attitude? After all, residents of developing countries often inhabit a world where the average life expectancy is just over half of that which is being promised by Westerners. Is it not more rational, then, to stick to the devil you know than to sup with the devil you don't know? Not only would those of the developing world have to trust the Western development agencies to deliver on their promises but they would also have to be willing to absorb all the consequences – both positive and negative – of realizing the Western dream on their own soil.

A Question of Identity

Readers who continue to have difficulty understanding the source of suspicion towards Western development agencies should consider their own attitudes towards the 'transhumanist' initiatives most closely associated with Aubrey de Grey, which would extend current scientific research to halt or even reverse the ageing process, so that we live many times longer than we currently do. Here too there is both scepticism that it could happen and horror that it might – the latter exacerbated by the long-standing crisis of the welfare state: what would we do with the extra time – and who would pay for it?

Implied in this analogy are complementary challenges: the developers must be resolved to make the necessary changes in the target environments, while the targeted beneficiaries must be resolved to lead radically different yet still meaningful lives in the wake of these changes. There is reason for doubt on both scores, if only on grounds of risk aversion. Thus, the developers may not sufficiently invest, and the developing may not sufficiently exploit the investment and the fear of loss trumps the hope for gain.

Not surprisingly, to make their development projects work, Banerjee and Duflo have had recourse to Western-trained native collaborators who can explain that long-term strategic thinking is not simply an exotic Western fantasy but something that ultimately results in concrete benefits. But among those 'benefits' is a major change in your sense of identity, such that you are effectively 'Westernized'. In this context, Banerjee and Duflo stress the importance of what behavioural economists call 'time preference' (or 'discounting'), the strikingly fashionable – and neutral – way of capturing the disciplined fervour behind first Imperialism and then Leninism, as they fearlessly pushed their agenda on those who may have started from a point of indifference or hostility.

The poor get richer only if the rich get richer too, suggesting that greater inequalities are the cost for the improvement of everyone's fortunes

So who is this new person that denizens of the developing world are being asked, if not forced, to become? In brief, this person treats the future as her friend, with longer time horizons suggestive of opportunities for potential to be realized. She does not insist on assurances that all the fruits of her efforts be borne in the short term. The sociologist Max Weber famously argued that Protestantism, with its proactive commitment to building a 'Heaven on Earth' in hope of divine approval, enabled the strong future-orientation of the Christian salvation narrative to morph into the capitalist practice of re-investing rather than simply consuming company profits. This tendency was ratcheted up a level with the advent of Imperialism, with its claim that the full benefits of capitalism would not be realized until the entire world was made into a free trade zone that allowed everyone to maximise their productivity. This then licensed an expansionist geopolitical strategy, which Lenin, armed with Marx's account of socialism as capitalism's heir apparent, adapted to launch Communism as a worldwide movement that would not rest until every nation had been converted.

The inspirational bookkeeping cited at the start of this article, so characteristic of United Nations and such relatively innocuous contemporary figures as the philosopher Peter Singer, the economist Jeffrey Sachs and U2's front man Bono Vox, is the natural, albeit less grandiose and violent, descendant of this general line of thought. Indeed, it may even be its death rattle. However, Banerjee and Duflo offer one last throw of the dice by using Western-trained natives to mediate the transition of the developing world into one in which, as the economists gingerly say, 'does not discount the future so heavily'.

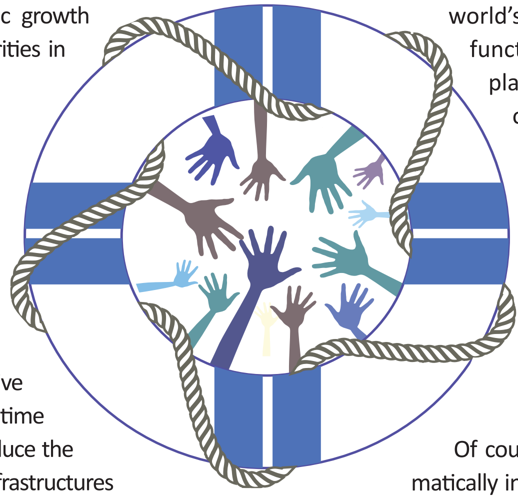
Helping the Rich Get Richer?

The question then is the cost of generalising from the successful social experiments documented in Poor Economics. In the first instance, it would mean the systematic recruitment of natives of the developing world for a Western education, after which they would be parachuted back into their societies. The recruitment process alone would incur all the social disruption that comes from evaluating people in terms of an externally imposed standard. Scaled-up, the proposal is no less than Imperialism 2.0, an unprecedented infiltration of the mindsets and lifestyles of perhaps a fifth of all humanity. Pursued long and successfully enough, this project is bound to transform massively if not outright destroy existing cultures. But the world on the other side of the change may be one in which Homo sapiens will have reached new milestones in liberty, productivity and rationality – at least as their would-be benefactors understand those concepts.

In this scenario, a shift can be detected in what it means to 'release human potential'. It is not simply a matter of taking the lid off an already boiling pot, which is very much an Enlightenment image: If only the obstructive tyrant were gone, the people would be free to self-legislate! This image lay behind the optimism of the theorists of the 1789 French Revolution, as well as the American neo-conservatives who believed in 2003 that a short 'shock and awe' military strategy would liberate Iraq, whose natives would then form a liberal democracy. On the contrary, the task ahead may be more like the riskier strategy of 'fracking', the deep rock drilling for oil and gas that nowadays generates so much controversy because of its possibly long-term destabilising effects on the environment. Eventually the rocks do yield the desired resource – but perhaps much else as well: are we prepared to deal with the collateral damage? By analogy, then, the problem may be less that the natives provide resistance to accepting a longer-term life horizon than that the developers lack the perseverance to make their efforts sustainable.

It is worth noting that most of the billion people who have been taken out of extreme poverty over the past generation have not been beneficiaries of the global income redistribution scheme proposed by our inspirational bookkeepers. In fact, more than half of these people have been in China, an

authoritarian state that has imposed markets to stimulate growth. The strategy has worked by providing incentives for those with disposable capital to employ the services of those lacking it. The lesson here seems to be that the poor get richer only if the rich get richer too, suggesting that greater inequalities are the cost for the improvement of everyone's fortunes, a situation, to be sure, that egalitarians find both unpalatable and unnecessary. The challenge for them, then, is to set aside knee-jerk feelings of resentment and provide an alternative economic growth strategy that also reduces disparities in wealth.



Imperialism 2.0

On 1 June 2013, an editorial in *The Economist* celebrated the above achievement as a victory for capitalism, while shrewdly observing that the remaining billion or so still mired in poverty are perhaps not so attractive for capital investment. Longer time horizons will be needed to introduce the requisite mental and material infrastructures both to turn a decent profit for investors and to deliver promises of a new world order to natives. To describe the task simply in terms of redistributing global GDP by 1-2% is to ignore transaction costs. Rather, it is a job for Imperialism 2.0. This time, instead of Christian missionaries, social scientists following the example set in Poor Economics would pave the way for capital development by engaging in social experiments designed to convert the natives to the idea of an extended and open future, notwithstanding any short-term hardship and disorientation they might experience.

The economic historian Niall Ferguson is perhaps the most outspoken and clever defender of 'Imperialism 2.0' today – certainly the person who would most happily embrace the moniker. He diagnoses the decidedly mixed balance sheet of Imperialism 1.0 in terms of lack of political will on the part of the imperial powers to realize their global vision. They ultimately recoiled at the magnitude of the task, despite ample evidence that their strategy was largely working. But in addition, Ferguson is notorious for arguing that the United States – not the United Nations – should be the driver of Imperialism 2.0. It is easy to assume that his case is purely ideological. However, his best argument rests on the moral debt that the US incurred by becoming the world's banker – that is, once the dollar became the global monetary standard, in terms of which the values of other currencies are set.

The US, through its influence in the International Monetary Fund and the World Bank, has determined the economic and political fate of nations. But what exactly does the US do in return? The most obvious answer is that, through its 'hard' and 'soft' power, the US maintains sufficient stability across the globe to enable market transactions to flow smoothly. But if one truly believes that capitalism can bring prosperity to all, does the US not have a further obligation to develop the world's capacities so that every region can function optimally in the global marketplace? To be sure, the US has taken this obligation seriously in the past, especially during the Cold War, when the Soviet Union offered a serious alternative in the global development sweepstakes. But once the US lost its market competitor, it interpreted its moral commitments to the world in more narrowly strategic terms.

Of course, all of this may change quite dramatically in the next few years. The dollar standard is already under attack, especially from China, which sees capitalism more as an instrument for national self-improvement than as a full-blown global ideology. No doubt, many Americans – both on the right and the left – would welcome losing the ideological baggage associated with being the world's banker. Yet, it is equally clear that Ferguson's appeal to imperial history – or for that matter the more general Western legacy recounted here – is unlikely to shift China's policy horizons. In this respect, cultural relativism may be vindicated, but perhaps not as its advocates would have wished: real bookkeeping suggests that less overall suffering would result simply from respecting the poor as they are and dealing with them on those terms. At least, they suffer for a shorter period and without the disappointment of broken promises. In short, taking seriously the agenda of Poor Economics as a global proposition makes rational sense only as a long-term ideal for which we would be willing to have both them and us suffer a fair bit in the meanwhile.

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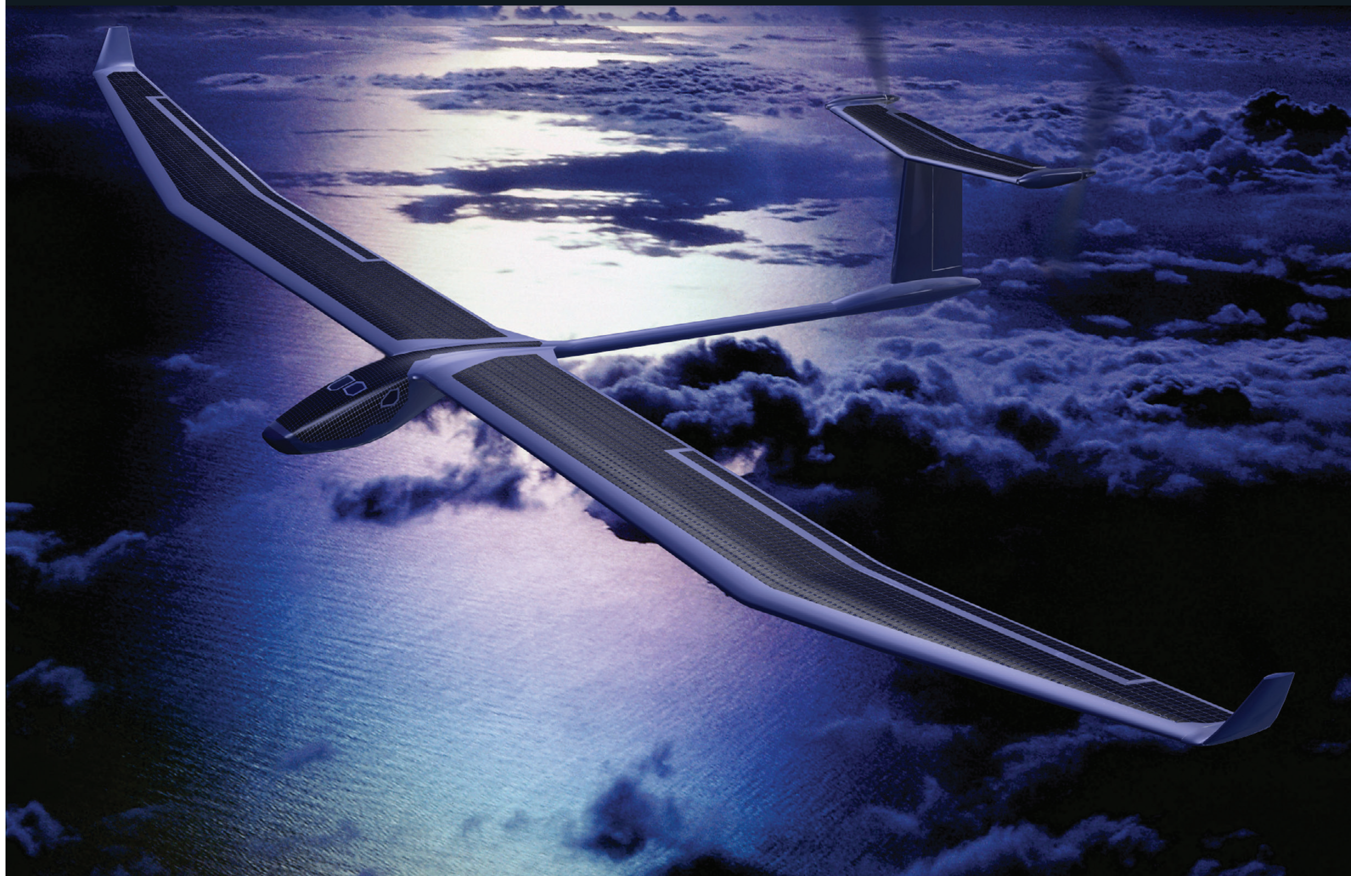
A Global Village

WHERE POLICY AND POLITICS MEET SCIENCE AND ENGINEERING



Submissions for the January Issue

A Global Village focuses on key areas where politics and policy meet science and engineering from global health to climate change and energy, food security and development. Article lengths should be within the range 1000-2500 words.

deadline:

October 30

first draft

Topics: The Virtual Citizen, Drug Delivery Systems, 21st Century Jetsetting