Memorial lecture by The Lord Rees

14 December 2015 at the Embassy of Japan in the UK

Your Excellency, Ladies and Gentlemen

I offer sincerest thanks for the undeserved compliments paid to me – and for this honour. It's a huge privilege to be standing here – and it gives me an opportunity to pay tribute to Japanese science, and to say why close collaboration between our two nations is so beneficial. I'll also, before I conclude these remarks, venture some broader comments on what the global challenges will be between now and 2050, and how science can help to confront them.

Our two nations have much in common. We're both densely populated, we both lack natural resources. But we both have an outstanding tradition in science and high-tech. It's imperative for us both to promote and exploit this strength. The mantra 'If we don't get smarter, we'll get poorer' applies to the UK and Japan alike.

And both have long histories. I'll start with a flashback to the 19th century.

I was here at the Embassy two years ago – along with some of my friends in today's audience -- to commemorate an important event in Anglo/Japanese relations. The 150th anniversary of the arrival in England of the 'Choshu Five'

These five young men, from the Choshu clan in western Japan came here to study at University College London. After returning to Japan, they all contributed in major ways to the modernisation of their country. Indeed one of them, Hirobumi Ito, became Japan's first Prime Minister. A second became the first Foreign Minister. Others became prominent engineers. And the pioneering five were followed by 19 more.

Indeed the arrival in the UK of the 'Choshu Five' has been cited as a springboard for the emergence of modern Japan. It certainly marked the beginning of wide-ranging interchange between the UK and Japan and of 150 years of productive and mutually-beneficial academic interaction. So it's something to celebrate – and an occasion to envision how contacts can be expanded and deepened.

Japan today is a real technological powerhouse. It spends more on R and D than the UK, France and Germany combined. It has the second highest spend per capita of any country -- over 3 percent of GDP. That's largely because a lot comes from the private sector. Japan's top 10 companies spend more on R&D than the whole of the UK public and private sector combined. Key industrial sectors are energy, automotive, ICT, electronics and pharmaceuticals; it's a goal of the Abe government that Japan should become the world's No1 innovator within 5 years.

Japan's leading universities -- Tokyo, Kyoto, Osaka etc-- are significant global centres of research, and there are many other more specialised centres of excellence. The Okinawa Institute, an international centre for scientific research and graduate studies is an imaginative initiative that I'm privileged to have been associated with.

So it's very much in our interests in the UK, to expand our cooperation with a country that offers so many exciting opportunities. The links are already quite strong. Several UK universities now have

offices there. We rank fourth among Japan's international partners for research collaboration (after US, China and Germany).

Japanese authors have published hundreds of articles in Royal Society journals. That's not as many as from China, but I'm told that far more Chinese papers are rejected- - it's quality that counts.

I'm delighted that Julie Maxton, the Society's Executive Director, is here this evening along with some of her colleagues. And that reminds me that the Royal Society has other long-standing links with Japan.

Emperor Akihito was the first recipient of the Society's King Charles II Medal for heads of state or government who've contributed to science.

The Society participated in the UN Disaster Risk Reduction meeting, Sendai, February this year. And when Japan hosts the G7 next year – the Society and the other G7 academies will be producing statements to feed into the discussion.

There are strong government-to-government links too. There's close policy engagement on science-linked themes such as nuclear safety, cybersecurity, regenerative medicine, open innovation, emergencies and contingency planning. In May 2014, prime ministers Cameron and Abe made a joint statement highlighting the importance of science and technology to the UK-Japan relationship.

Japanese research strengths, as I've already emphasized, are spread across many fields including : medical sciences (regenerative medicine, cancer research, infectious disease, neuroscience), basic biology (genomics, synbio, plant science), robotics and nano-technology.

But I'll focus on astronomy, physics and space. These are my own special interests –moreover they're fields where the Japanese effort has been very strong – and exceptionally cost-effective. I'm sure I speak for all the astronomers here today in expressing admiration for Japanese achievements in our field, and in testifying to the value we place on collaboration with Japanese colleagues.

But before mentioning this – a quick flashback, to another anniversary that we recently celebrated: this was a 400th anniversary. In 1611 The Clove, a ship of the East India Company left England in a small convoy. After stopovers in several Asian ports, it reached the island of Hirado, in south-west Japan in 1613. The ship's captain, John Saris, had official letters and presents from King James I, intended for the Shogun. These gifts included a small telescope – the first to reach Japan (and indeed one of the first ever made – the invention of the simple two-lens telescope is normally dated around 1610). In return, the ruler presented Saris with two suits of armour for King James – these are still in the Tower of London. The telescope is long lost, but to mark the 400th anniversary of the gift, a modern replica was made and presented for display in a Japanese museum.

Let's fast forward to the present – and to a very different telescope. One of the flagships of Japanese science today is the huge Subaru telescope on Mauna Kea in .Hawaii. It's one of the dozen or so 8-meter class telescopes in the world, and it would be acknowledged as the one with the most elaborate instrumentation – it can, for instance, take spectra of 2400 galaxies simultaneously, via an optical fibre system.

It can take pictures of the sky so deep that even a field of view a few arc-minutes across reveals thousands of remote galaxies, each containing tens of billions of stars. And many of those stars have planetary systems around them. There are probably a billion billion earth-like planets in range of this

telescope. How many will have life – even intelligent life -- on them? Perhaps billions – perhaps none. That's one of the challenges for the coming decades.

We humans have evolved in a rather quiescent region of an ordinary galaxy. But we've learnt that the cosmos is a violent place. It manifests a whole zoo of phenomena –black holes, jets, and vast explosions, which involve extreme conditions, and unusual physics. These emit very energetic radiation – X-rays and gamma-rays – rather than visible light. And this radiation doesn't penetrate our atmosphere, so can only be studied from space.

And the Japanese space programme has achieved a lot in x-ray astronomy. And it's been extraordinarily cost-effective – because (especially in the early days) a lot of the work was done in universities, and because of the quality of the people involved. And I'd like to pay tribute to two great pioneers of ths programme who I was privileged to know – Satio Hayakawa and Minoru Oda.

These distinguished and dedicated men have both sadly passed away, but they established a tradition of excellence carried on by the present generation.

They'd have been specially excited about a major spacecraft, Astro H, due to be launched on 12 February next year – the latest in a series of telescopes to study cosmic X-rays. There are four focusing telescopes – but the main advances will come from the soft x-ray spectrometer. That's because it will offer higher resolution than we've had up till now, and will be able to reveal the Doppler effect from the swirling motions of gas in clusters of galaxes, and in jets squirting from the environs of black holes

My colleague Professor Andrew Fabian has been involved in this project right from its conception. And I recall with special pleasure a meeting that he hosted at our Institute in Cambridge, where there were about 40 Japanese scientists. We have regular exchanges but it was special to have a large phalanx.

Astro-H is just one in a range of Japanese space projects – aimed at exploring the cosmos from the planets of our Solar System to the remotest galaxies. And we had good news just last week that the probe sent to Venus, which initially didn't get on the right trajectory, is now firmly in orbit around that planet and will soon be sending back exciting data.

Some great science is done not in space, but by burrowing underground. We should surely acclaim the world-leading Kamiokande facility, built to detect and study the elusive particles called neutrinos. The researchers use rowing boats on a large underground tank to check the thousands of photomultipliers. Kamiokande has led to two Nobel Prizes. It's made perhaps the most surprising discoveries in particle physics in the last 40 years – that there are three types of neutrinos, with different masses, and the different types turn into each other while they travel. .

Neutrinos are about the most elusive messengers from space – but not quite. That distinction belongs to gravitational waves. They're one of the crucial predictions of Einstein's general relativity. They're tiny ripples in the fabric of space itself, emitted when stars collapse or collide.

They haven't yet been detected, but a Japanese detector. KATRA, involving cryogenically cooled equipment and tunnels 3 km long, is being built and is now joining this even more challenging quest. It's also deep underground –indeed under the same mountain as Super-Kamiokande). This venture is timely as this year is the centenary of Einstein's general relativity.

Einstein is the archetype academic scientist. But it's worth mentioning that even this recondite theory has a technical application. The GPS satellite system, crucial for navigation, and linked to our sat-navs and smartphones, depends on very accurate clocks. And it wouldn't work if allowance weren't made for the tiny change that the Earth's gravity induces the clock rates, according to general relativity.

And of course we all know that science is the basis of our modern world. That's why science education is crucial in all advanced countries – especially those like ours that depend on getting a lead in the high-tech economy. Moreover, science isn't just for would-be scientists who will need it for their careers. It impinges on everyone.

Today's young people – all of them – will live in a world, ever more dependent on technology, and ever more vulnerable to its failures or misdirection. Even if they don't have scientific careers, they need a 'feel' for science if they are to be responsible citizens and voters.

These are the reasons why politicians prioritise scientific education. But let us not forget an extra reason, which Einstein would have impressed on us: science is part of our culture, valuable for its own sake as much as art and music.

More than that, it's special in being the culture that's most truly global – protons, proteins and Pythagoras are the same everywhere. Science transcends all barriers of nationality and faith.

That universality is especially true of astronomy – the night sky is the part of our environment that's been gazed at and wondered at ever since the dawn of human history.

It's a real intellectual deprivation not to understand the principles that govern the biosphere and climate. And to be blind to the marvellous vision offered by Darwinism and by modern cosmology -- the chain of emergent complexity leading from a 'big bang' to galaxiesm stars, planets, biospheres --- and human brains able to ponder the wonder and the mystery of it all.

And that's in itself a justification for teaching the principles of science to everyone.

Astronomers bring a cosmic perspective. They realize that the Earth is a pale blue dot in a vast cosmos. And it has existed for 45 million centuries. But this century is special: it's the first when we've had this awareness of our planet's place in the cosmos.

But I want to use my final few minutes to move away from 'pure' science, and emphasise that this century is special for another reason – and a more disquieting one. It's the first century when one species, ours, has the planet's future in its hands. That's because there are more of us – world population is rising. And through advancing technology we're more empowered to transform the world, and even to reach worlds beyond ours. We've entered an era that some call the 'anthropocene'.

What kind of world will today's young people be living in by mid-century? One of the few things we can predict is that they'll be in a more crowded world. Fifty years ago, world population was below 3 billion. It now exceeds 7 billion. And by 2050 it's projected to be between 8.5 and 10 billion. And, importantly for Japan the world's intellectual and physical capital will shift to Asia -- the end of 400 years of hegemony by Europe and North America.

Someone who has addressed these issues, with far more authority than I can muster, is John Beddington, former chief scientific advisor to our government. It's good to see him here, and gratifying that he has already been invested with the Order of the Rising Sun. He's far more deserving

of this honour than me, and had an especially close involvement with Japan, especially in the aftermath of the tsunami disaster.

John has written about the ‘perfect storm’ that we may confront in coming decades – pressures on food, water and energy from a growing and more demanding population.

But the message from experts like him isn’t a despairing one. Modern agriculture – low-till, water-conserving, and perhaps involving GM crops – together with better engineering to reduce waste, improve irrigation, and so forth, could sustainably feed the world, And other advances, especially in healthcare and information technology, offer grounds for hope .

Admittedly, 9 billion people can’t live as profligately as present-day Americans – they can’t use as much energy or eat as much beef. Nonetheless, with energy efficiency, renewables, advanced food production, and so forth, there’s no technical reason why all shouldn’t enjoy a lifestyle better than we have today.

As well as being more crowded, the world will have a changed climate and that will add to the pressures. It’s; specially welcome that the Paris conference offers hope of progress on one of the most intractable of all global problems – intractable for two reasons. It involves thinking long-term: the worst downsides of CO2 emission lie decades in the future. And it involves thinking globally too -- the effects of emission in the UK have as much effects in Japan as here, and vice versa.

And climate change would aggravate other pressures on the global environment. If humanitie collective activities push too hard against so-called ‘planetary boundaries’, the resultant ‘ecological shock’ could irreversibly impoverish our biosphere. Extinction rates are rising – we’re destroying the book of life before we’ve read it.

How much does this matter? Biodiversity is a crucial component of human wellbeing. We're clearly harmed if fish stocks dwindle to extinction; there are plants in the rain forest whose gene pool might be useful to us. But for many environmentalists these 'instrumental' - and anthropocentric - arguments aren't the only compelling ones. For them, preserving the richness of our biosphere has value in its own right, over and above what it means to us humans To quote the great ecologist E O Wilson ‘mass extinction is the sin that future generations will least forgive us for’.

So we can predict a more crowded, warmer and ecologically vulnerable world. And we can predict something else too. Our everyday lives will be hugely transformed. Smartphones would have seemed magic 20 years ago, so by mid-century our lives may be dominated by technologies that now seem science fiction – in genetics, in robotics and in IT. These could offer huge benefits, but they’ll have a dark side. They will open up new threats and poses new ethical dilemmas. There’ll be a growing gap between what science allows us to do, and what it’s prudent or ethical actually to do. For instance:

How will lengthening life-spans affect society? Should we build nuclear power stations - or solar farms - to keep the lights on? Should the law allow 'designer babies' or cognition enhancing drugs? What happens if the robots take over? Will we link up with computers to become ‘cyborgs’?

Navigating these issues will demand dialogue between scientists, technologists, ethicists and politicians. And in this context I’d like to acclaim an important Japanese initiative -- the STS Forum (STS stands for science Technology and Society). This was started by the eminent politician Mr Koji Omi. Each year the Forum gathers in Kyoto an impressive international mix of scientists, business leaders and politicians. The Royal Society has been very supportive, and has encouraged attendance

from the UK. It addresses all the issues where science impinges on policy – and the future trends I've just mentioned.

And it addresses them in a global context. That's essential, because the world is getting more interconnected. We depend on elaborate networks: electric power grids, air traffic control, international finance, just-in-time delivery and so forth. Unless these are highly resilient, their manifest benefits could be outweighed by catastrophic (albeit rare) breakdowns cascading through the system. Pandemics could spread at the speed of jet aircraft, causing maximal havoc in the shambolic but burgeoning megacities of the developing world. Social media could spread psychic contagion – rumours and panic – literally at the speed of light.

Reducing the downsides of these is the agenda of the STS forum.

Coping with potential shortage of food, water, resources -- and transitioning to low carbon energy --- can't be solved by each nation separately. Nor can threat reduction. For instance, whether or not a pandemic gets global grip may hinge on how quickly a Vietnamese poultry farmer can report any strange sickness. Warning of an approaching tsunami requires an international network. So does dealing with cyber-attacks.

Indeed a key issue is whether nations need to give up more sovereignty to new organizations along the lines of the IAEA, WHO, etc.

More of the important issues facing the world -- energy and climate change, for instance -- are global and long term. In contrast, politicians look to their own voters – and the next election. Stockholders expect a pay-off in the short run. We downplay what's happening even now in far-away countries – even the moral imperative to improve the lot of today's 'bottom billion'. And we discount too heavily the problems we'll leave for new generations

That's why organizations like the STS forum are so valuable – they widen horizons in space and time – they raise consciousness of issues that may not seem urgent but which are crucial for civilisation's survival.

"Space-ship Earth" is hurtling through the void. Its passengers are anxious and fractious. Their life-support system faces disruption and break-downs - but there is too little planning, too little horizon-scanning. Without a broader perspective – without realizing that we're all on this crowded world together – governments won't properly prioritise projects that are long-term in a political perspectives, even if a mere instant in the history of our planet.

We need a change in priorities and perspective -- and soon – if we are to navigate the 21st century safely: to share the benefits of globalization, to prioritise clean energy, and sustainable agriculture; and to handle the Promethian challenge posed by ever more powerful technology. Let's hope that Britain and Japan can be enlightened pathfinders in this global enterprise –and show the way to a brighter future.

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