SPACE SERVING HUMANITY: CELEBRATING SIXTY YEARS IN SPACE
& FIFTY YEARS OF LAWFUL AND PEACEFUL USE

A Joint Seminar of ISPL and UCL Space Domain
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ISPL
LONDON INSTITUTE OF SPACE POLICY AND LAW

UCL

REPORT[1]

This seminar is the first in a series exploring the legacy of the 1967 Outer Space Treaty ("OST"). The principles enshrined in the Treaty may be said to have established a climate of cooperation, internationalisation and peaceful use. This has led to the development of space assets and capabilities that are essential to our way of life, and enrich our understanding of the universe.

Topics of relevance at this first seminar were outlined by specialists in the relevant fields and discussed by invited delegates from all sectors of space operation and regulation under Chatham House Rules.

The contributions at this seminar underline the enormous potential of space to deal with world problems and to improve life on Earth through Earth observation and space monitoring. The OST has served us well, but we must ensure that space is used well and responsibly to ensure its long-term sustainability.

WELCOME AND INTRODUCTION

Professor Sa'id Mosteshar, Director Of ISPL, and Professor Alan Smith, Director Of UCL Space Domain

Engagement with space began with our interest in intercontinental ballistic missiles, and early drivers of the space sector were nuclear weapons on warheads. The OST marked the appearance of common sense and stopped the proliferation of weapons into orbit. Without the Treaty, space would be a much more reactive place. We are now completely dependent on space in our daily lives, with, for example, many participants using satellite navigation to get to this seminar. It is now 50 years since the signing of the OST, and Star Trek started a year before that.

[1] This report was compiled with the sterling assistance of the Rapporteurs, ISPL Associate Researcher Jemma Queenborough and PhD Candidate and ISPL Researcher Valentino Quaggiato. Errors and omissions are entirely the responsibility of ISPL. The opinions expressed are not necessarily those of ISPL, UCL or the organisations represented by the speakers.

THE LEGACY OF THE OST[2]

Gérard Brachet, Founder of Spot Image and ISPL Adviser; Former Director-General of CNES; Former Chairman of UNCOPUOS

There were deep motivations for the OST. During the Cold War, both the USA and the Soviet Union considered outer space to be a strategic high ground. There was a strong link between nuclear deterrence and space capability, in terms of surveillance and targeting. The priority was to prevent a surprise attack by knowing what other states were doing.

A very large number of satellites were launched in the early years for observation purposes only. A huge number of observation satellites were launched by the Soviet Union between 1960 and 1980. The reason for this was that observation satellites did not last long. Some were carrying cameras with old style film, rather than broadcasting data to a ground station, so capacity for observation was limited. A large number of observation satellites continued to be launched by the Soviet Union (then Russia) between 1980 and 2000, although to a lesser extent as data became digital and transmitted by digital techniques.

Looking at equivalent statistical data for the USA between 1960 and 1980, the number of launches was also high, although not as high as the Soviet Union. The USA launched a high number of keyhole spy satellites carrying photographic film. As for the Soviet Union/Russia, once data was transmitted digitally from the 1980s onwards, a smaller number of satellites were launched.

Early warning satellites were also launched, a large number by the US and Soviet Union/Russia. These satellites were launched mainly into geo orbit to watch launches by other states.

The two super powers had a vested interest in keeping outer space free of restrictions that might limit its use. In addition, the international scientific community pushed for a wide access to outer space as a base for exploration. As a result, the OST's basic principles included a ban on national appropriation, equal access for all nations, freedom of circulation, freedom of data collection, no deployment of weapons of mass destruction and military activities forbidden on the Moon and other celestial bodies, and, perhaps most importantly, States' responsibility for activities in outer space conducted by their nationals, whether governmental or not. It is also noteworthy that the Treaty does not prohibit military activities in space generally, just on the Moon or other celestial bodies.

The principles of the OST have been successfully supported over the years by all space-faring nations, and 105 States have ratified the Treaty. One country that has signed but not ratified the OST is Columbia, whose constitution says they own the orbit directly above Columbian territory, which is in contradiction to the OST. As of 2017, 60 countries own and operate (although may not have launched) at least one satellite in orbit, 9 countries and one regional grouping have orbital launch capability, and 6 countries launch spacecraft regularly: China, Europe (European Space Agency (ESA)), India, Japan, Russia and the USA. In addition, many private launch operators are now in the market, and will probably extend this list in the near future.

Fifty years after the OST, there are several satellite launch bases and capability across the globe, and both civil and military satellites are in operation. Some launch bases have been closed or are not in operation: Australia's base and the French base in the Sahara are now closed; Brazil's base which never launched a satellite; and the San Marco base off the coast of Kenya which was used in 1960s and 1970s but is no longer used. There is a strong presence of military satellites from Russia and the USA.

[2] http://www.space-institute.org/app/uploads/1518018901_ISPL_UCL_SD_Seminar_13Dec2017_Brachet_Legacy_of_OST.pptx

Let us look at the space budgets in Purchasing Power Parities (PPP) and per capita of space-faring nations as reported by the OECD in 2013. The largest budget in PPP in USD millions is the USA at 39,332.2 followed by China at 10,774.6 and Russia at 8,691.6. These budgets, especially that of the USA, are likely to be much higher today. Although it is remarkable how the OECD has managed to discover the Chinese space budget, which is notoriously elusive, China's space budget is notably significant. It is also notable that the USA's budget per capita (USD millions) is large at 123.2, while China's and Russia's are much lower at 7.9 and 61 respectively.

The OECD's reported space budget as a share of GDP also provides interesting data, showing that although between 2008 and 2013 Russia's has more than doubled, the USA's and China's have decreased. However, the USA continues to dominate the space sector, and is the only country to have taken a manned mission to the Moon. It is also clear from the OECD data that the USA's space expenditure is by far the largest, not only in its civilian NASA-led programme, but also in its extensive military space programme, which represents probably more than half of the world's expenditure in military space. In 2010 it was reported that the space budget was very large, at 7% of the USA's defence budget, and it is stated that the USA accounts for more than 60% of world space spending.

During the Cold War, the USA and Russia were competing at the same level. However, that is no longer the case. Russia is trying hard to rebuild its space capability in order to become a great player again, building on its industrial base, vast experience and achievements. The Russian government is prioritising its military space capability and leaving its civilian programme unsupported, and they are struggling to modernise at a rate to compete with the USA and China.

China is very active and has publicly aired its ambition to become a world player. Looking at launch data between 1970 and 2012, China's missions were mainly unmanned. Its manned space action is ambitious but cautious, as it does not want to experience failures. China publishes an official space policy paper every 5 years, but it is written in a style that is difficult to understand or to read between the lines. Lack of transparency remains a major problem.

India has a very active and dynamic programme, mainly for civilian purposes, and has been a very active space power for a long time, far longer than, for example, China. After being very application-oriented for many years, India's space activities have recently extended to include space exploration. India operates its own very reliable polar orbiting launch capability (Polar Satellite Launch Vehicle, PSLV) mainly for outside customers, and sells launch services on the world market. India successfully launched 100 nano-satellites earlier this year.

Japan is also a major space actor, with a very strong science community and successful space science projects. Japan has some ambitions in the commercial launch sector and has its own very reliable launcher (H2B), but has found it difficult to commercialise it on the world market due to difficulty finding customers. Japan has a small military activity presence, managed by the PM's office rather than its space agency JAXA. Japan's military space assets, Intelligence Gathering Satellites (IGS), have also developed significantly over the last 10 years in reaction to the political situation in East Asia.

In Europe, space activities started in the 1960s, mostly at a national level, and developed nicely in the 1970s within the ESA cooperative framework. Launch services were a signifier of the success of ESA's space programme, and Meteosat (part of the Eumetsat fleet of satellites) was another successful venture.

Today, ESA faces the complex situation of the EU trying to take over the traditional role played by ESA and control its strategy for civilian space programs. Despite investing in the Galileo and Copernicus missions, the EU has not been entirely successful in taking over ESA's activities and missions – these remain managed by ESA as Members States are happy with way ESA functions. It is understood that the UK will continue to be a part of ESA after Brexit, which is a good indication that the UK is also satisfied with how ESA works. ESA stands as a positive mechanism and successful role model for coordinated regional space activities, which still surprises many people outside Europe.

Thanks to the principles of the OST, many other emerging and developing countries have become active space nations, mostly via the deployment of their own micro- or mini- satellites, such as Thailand, South Korea, Indonesia, Malaysia, Singapore, Vietnam, Kazakhstan, UAE, Egypt, Algeria, Morocco, Nigeria, South Africa, Brazil, Argentina, Colombia, Chile, Peru and others. The list is increasing daily as new spacecraft are being launched. For example, two days ago China launched a satellite for Algeria, funded by Chinese development aid.

All this was possible because the OST and the other Conventions provided an adequate international legal framework.

The urge to go beyond the horizon and explore the solar system with manned missions remains a strong motivation. The OST acknowledges this by repeatedly referring to the "exploration and use of outer space", although the UN Committee for the Peaceful Uses of Outer Space (COPUOS), created in 1959, does not include the word "exploration".[3]

The OST also declares astronauts as envoys of mankind in outer space who deserve special protection. Manned space programmes were mostly driven by strategic considerations during the last fifty years, such as political demonstration of technical capabilities during the Apollo program or more recently with China flying manned spacecraft to demonstrate their strength to the rest of Asia. The International Space Station (ISS) has been a major investment in manned space over the last 30 years, mainly for the US taxpayer. Today, there is some disappointment with the limited spin-offs from the ISS, but manned space exploration will continue to inspire. It is not clear what will come next, however we will await the outcome of President Trump's directive two days ago for the US to go back to the Moon.

There are some negative consequences of space exploration, like increased crowding in Low Earth Orbit (LEO) and the region around the geostationary ring, which creates new risks for interference and physical collisions. Proliferation of space debris on and around certain orbits is a major concern. Another negative consequence is that the ITU's managing of the limited orbital and radio spectrum resources is becoming a real challenge.

There have been 5,340 successful launches between 1957 and 2016, and 240 in-orbit break-ups. There are about 1,200 operational satellites, of which 500 are on the GEO ring. This activity has created space debris, generated by launch, end of life and upper stage rockets, which either remain in space or generate their own debris when they explode.

Over 20,000 objects are being tracked and catalogued by the US Space Surveillance Network: 22% are satellites, 12% are rocket bodies, 10% are mission-related objects, and 56% are fragments (up from 41% before the China ASAT test of 11 January 2007, and the Iridium-Cosmos collision in February 2009).

The risk of collisions between operational satellites in high inclination low Earth orbits is increasing. Close approaches at less than 15 km (or 'conjunctions') between NASA Terra, Cloudsat and Aura Earth observation satellites, and China's Shijian series of satellites, occur every month. Very strict procedures have been set in place to minimize the risk of collision. Perhaps a congestion charge will be introduced in space as it has been in London.

There is also the risk of outer space becoming a battlefield. Deployment of weapons in outer space has (apparently) not taken place, but it is not possible to know for sure. Ground-based weapons can be used against spacecraft in Low Earth Orbit, and have been used by some countries. Also of concern,

[3] The title of the Committee does not include the word *exploration*, but General Assembly Resolution 1472 (XIV) creating the Committee refers both to exploration and exploitation.

several highly mobile "inspection" satellites have been launched and tested in orbit during the last few years by the USA, Russia and China. The legacy of the OST is extremely positive, but new international mechanisms are needed to ensure a safe and sustainable use of outer space.

CURRENT STATUS OF THE OST[4]

Professor Sa'id Mosteshar, Director of ISPL

What is necessary is a set of procedures to make space safe and sustainable for use on a continuing basis.

The OST is a set of principles by which space activities are governed. Member States that have ratified it by and large abide by those rules, although there are some areas where they do not. The OST provides a sound foundation for activities in and peaceful uses of outer space. It is often said that space treaties are somehow inhibiting commercial or private activity in outer space, but that is not the case. Technology has enormously improved and reduced the costs of space activities. Today there are many more participants in the space sector. The OST provides that member States must supervise and authorise private activities, so activities by non-governmental entities were foreseen, and it was intended that nationals of those countries were also to be bound by the OST. There are a growing number of countries ratifying the OST: of the 195 UN recognised states, 105 states have already ratified it and more are doing so.

Gérard Brachet mentioned that the OST does not stand on its own: it sets out principles, with details added by other conventions and treaties. For example, the OST provides the principle of liability that makes states liable for any damage caused by space objects. The Liability Convention expands on this principle to provide detail of how that occurs. That is not to say that the OST is perfect – there are some things that could be a little better. For example, although we have mentioned 'space' dozens of times in this seminar already, nobody actually knows where 'space' is because there is no agreed legal definition of space, or where the boundary line is between air space and outer space. This has been on the agenda of the UN legal sub-committee since the 1960s but no conclusion has been reached.

This lack of legal delimitation has some consequences because liability provisions are different in the two areas. In particular, recent ambitions to provide space tourism raise the question of how far out a spacecraft would need to go to be in 'space'.

The OST distinguishes between the way liabilities and obligations attach to States. Under the OST, States are responsible for their national space activities. States must therefore decide what is their "national activity", and then authorise and licence it. States have jurisdiction and control over a space object if it is an object that the State has registered. But there can be a number of countries that could register an object, as each Launching State has a right to register it.[5] Generally, if there are more than one Launching States, they will agree between them who registers the object.

Although this slight difficulty can be overcome, it does make things a bit complicated when there is a change of ownership of a satellite or space object between different nations. Once in orbit, ownership can be transferred to a national of a State that had nothing to do with the launch. As part of this process intergovernmental agreements about how change of ownership happens must be in place.

By and large the OST provides a sound basis for space activities. Additional progress is being made, mainly through best practice and non-binding guidelines on the OST developed by the Committee on Peaceful Uses of Outer Space.

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[4] http://www.space-institute.org/app/uploads/1518784084_ISPL_UCL_SD_Seminar_13Dec2017_Mosteshar_Current_State_of_OST.pdf

[5] A Launching State is one that launches or procures the launch of a space object, or a State from whose territory or facility a space object is launched. OST Article VII, Liability Convention Article I.

A FORWARD LOOK[6]

Professor Serge Plattard, Deputy Director Of UCL Space Domain

Space is pervasive through society. We depend more and more on space and, because of this, we are vulnerable to threats on space objects and services. Although a debatable figure, it is said that 7% of EU GDP depends on, or is tied to, space. We could carry out an experiment to confirm this by turning off satellites for an hour or a week and see how life changes. The OST is fundamental as, thanks to it, we have been able to develop all the space activities and technology that we enjoy today. Yet the situation is changing. Space is congested, contested, competitive and complex. This is not a new situation – it has been an evolving situation since the 1990s – but is a fact. We are no longer in the time when there were two rulers of space and new people like the Europeans and Japanese were coming in.

Space is congested. There are 460 active satellites in orbit, plus 23,000 pieces of debris larger than 10cm, and 750,000 pieces of debris larger than 1 cm. Because of this space debris, we need to manage satellite operations carefully. The situation will continuously develop, especially regarding low earth orbit constellations. There is also congestion regarding the frequency band that many satellites are using. The allocation of frequency is complicated and will get more so as the flood of new small and nano-satellites require a frequency allocation.

Space is contested in all orbits. Some countries have capabilities to deny, deceive, degrade, disrupt, and destroy space assets. This is demonstrated by the USA, China and Russia, to name a few. We must cope with threat. Again, radio frequencies are also contested.

Space is competitive. There is a lot of competition in the geo and low earth orbits. There is also competition between satellite companies and between launch operators, such as between the EU, USA (SpaceX and BlueOrigin) and India (PSLV). There is also a new class of space actor developing – private competitors with mini launchers – although whether this is a new market is debatable.

Space is complex. Because of the advent of new platforms in low earth orbit and probably in the future around the Moon, the situation will change and become more complex. Spacecraft and satellites will not travel in lines but from one orbit to another, and to and from platforms. The new dimension is coming slowly but surely. Russia was exploring this years ago – they were planning a platform and seeking EU cooperation, but the EU did not respond.

To face these challenges, there have been many initiatives since the early 2000s through add-ons and guidelines to the OST. We need properly defined rules of the road. So far, all initiatives have failed except two technical initiatives. For example, the 2008 Chinese-Russian initiative preventing weapons in space and use of threats against space objects has not been effective, and the 2008 EU International Code of Conduct has so far failed. Government experts coordinated by the UN laid down transparency rules but, despite being endorsed by UNGA, they have not been put into practice. Also, although 12 guidelines were adopted as a result of a COPUOS initiative, difficult aspects of the guidelines were not laid out, so the initiative came short of its aim.

The two successful initiatives have been the UNGA 2007 guidelines for debris mitigation, regarding conditions to remove objects from orbit, and the USA initiative that by 2025 it will have the capability via 'Space Fence' to catalogue or follow 150-200,000 space objects. This is achievable and feasible, and, being 10 times the number we can catalogue or follow today, this will greatly enhance space asset security.

[6] Professor Plattard did not present slides.

Looking at the magnitude of new challenges, we must definitely rely on the OST. To try to renegotiate it would be to open Pandora's box. We need to stick with the Treaty and make it workable for modern challenges through additional guidelines, so that we can exploit space assets in a sustainable, secure and safe way.

SECURITY OF SPACE ASSETS[7]

Mark Roberts CBE, Business Development Director Of International Defence, Security And Space, Atkins

In terms of the threat, space has 5 components: orbiting assets, ground stations, command and control, users, and information. Users are the most-missed target irrespective of the sector. Information is a key target as it is more and more accessible, and there is a drive to make it so.

In terms of security threats, they can be physical (namely infrastructure and hard facilities), cyber or debris related. Reliance on security of cyber space is important, especially in the space domain.

Cyber crime is defined as "any identified effort directed toward access to, exfiltration of, manipulation of, or impairment to the integrity, confidentiality, security or availability of data, an application, or a federal system, without lawful authority."[8] Space debris is defined as "all the inactive, manmade objects, including fragments, that are orbiting Earth or re-entering the atmosphere".[9]

To imagine a cyber threat, we need adopt a tool from the military world - imagine a day without space. This would lead to degradation, disruption or denial of transportation, banking, power, telecommunications (including mobiles and the Internet), news services, air, sea and land navigation, distress detection, blue light services, GPS/timing: the ability to do business and our way of life in general. If this occurred, we would be returned very rapidly to the 1960's way of life and we would not be able to cope with it. Space is pervasive and we are utterly dependant on space technologies.

Equally, space destruction could lead to the Kessler syndrome, a concept that the debris produced from a collision of objects causes a chain reaction and could destroy an orbital sphere. This is becoming increasingly possible with the increase in space objects and debris in orbit. There have been a number of space incidents:

- the US-German ROSAT satellite was disabled in 1998;
- Telstar 12 was jammed in 2003;
- two telecommunications satellites were jammed in 2005;
- there was a successful ASAT test in 2007;
- homemade equipment was used to 'hijack' UHF frequencies in 2009;
- satellite broadcasts were jammed in 2010;
- Terra EOS & Landsat 7 experienced cyber interference when 'hackers "achieved all steps required" to assume control of the spacecraft' in c. 2011;
- IntelsatONE identified 300,000 denial-of-service attacks in 2011; and
- US National Oceanographic and Atmospheric Information was denied for 48 hours in 2014.

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[7] http://www.space-institute.org/app/uploads/1518019712_ISPL_UCL_SD_Seminar_13Dec2017_Roberts_Security_Space_Assets.pptx

[8] Cybercrime – US Department of Homeland Security, March 2010.

[9] ESA Space Debris Brochure, 2017.

The ability for hackers to take over space objects could lead to collisions and damage caused by debris due to the Kessler syndrome. The weapons are not technology or systems, but knowledge and skills. There is more and more information online about what you need to do to carry out a cyber-attack, and the drawing of red lines does not work, as a certain government recently found out.

The cyber threat to space is not new. It has been talked about for over 10 years, and longer in the military, but the issue still seems inexplicably new. Although we are putting more and more objects into space each day, and there remains the problem of legacy equipment still in space, the cyber threat is not being properly addressed.

A key problem is the rapid speed of attacks, which raises questions and legal problems about the rules of engagement and whether automated responses or pre-authorisations should be used. There is likely to always be a human in the 'war loop', however s/he may now be a programmer. The legal implications of programming need to be addressed.
To secure the future, we also need to secure spaceports and make them cyber resilient. Spaceports will become critical infrastructure, as opposed to sites of 'commercial activity' as they are currently deemed. Once in orbit, we need to look a long way forward, which is difficult to do because of Moore's law. It is difficult to recommend a solution for 5 years ahead, let alone 25 or 30 years ahead, but an approach is needed – we can have vulnerability but we need an overall secure system. We must be as forward looking as possible, testing 'what if' scenarios and understanding the threats and risks. More can be done with self-healing technology in new equipment, although not with old equipment. Hardening the infrastructure is vital, and is starting to happen. We should also, as we are starting to, consider reversionary modes of operation.

There is a staggering amount of space debris. There have been about 5,250 rocket launches since the start of the space age in 1957, which have placed about 7,500 satellites into Earth orbit. About 4,300 satellites are still in space and about 1,200 are functioning. It is estimated by statistical models that there are debris objects in orbit: 29,000 objects over 10cm; 750,000 objects between 1 cm and 10 cm; and 166 million objects between 1 mm and 1 cm. We are on the verge of discovering that these figures are correct. About 23,000 debris objects are regularly tracked by the US Space Surveillance Network and maintained in their catalogue. It is estimated that there have been a more than 290 break-ups, explosions and collision events resulting in fragmentation, and the total mass of all space objects in Earth orbit is estimated to be about 7,500 tonnes. This amount of debris leads to frequent near misses and sometimes collisions. The ISS manoeuvres relatively regularly for seen objects, but is still hit by unseen objects, which is a real problem.

There are a number of solutions proposed for debris removal including tug satellites, electro dynamic tethers, laser brooms, solar sails, space nets and collectors. ESA is leading on a few of these solutions. However, all solutions – whether to push away, divert path or bring closer – are effectively weapons, or at least will be viewed as such by the USA, Russia and China. Broad disclosure of launches and space activity is needed, including by private/commercial actors, beyond the disclosure in small communities that has occurred to date. For example, Spaceport1 will not rely on any government launches, only commercial small satellites up to 500kg in low Earth orbit.

In terms of space debris prevention, limiting launches in order to limit debris would be farcical, as all actors are pushing for more launches. The OST has articles related to cyber and debris prevention but they are not working. The International Code of Conduct may work, as there are signatories who will seek to make it function, however it will be a big problem for the USA. An answer may be to follow the European 2017 Principles approach. These have real potential, however it is always difficult to get national and international interests to balance. It is a long game, and the aim has to be to get space faring nations to lead by example. All states must behave responsibly or all will lose. All states must meet the need to de-orbit at the end of missions and to fund clean-up. States should fund the clean-up activities as, being expensive and technically demanding, there isn't a good business case for the private sector doing so.

Policy and treaties need to define responsibility for achieving and verifying cyber survivability, and responsibility for the threat mitigation or response. The current law is not perfect but we must keep going and try to make it work.

BIG DATA AND PRIVACY[10]

Dr Sandra Leaton Gray, Senior Lecturer In Education, UCL Institute Of Education

Big data, privacy in space and space science raise three very big questions. First, how necessary or desirable is ownership? Second, is narcissism or egocentrism an intrinsic problem in technology development? And third, what do we consider to be surveillance?

In answer to the first question, we are all familiar with territorial privacy in physical space, which is often linked to ownership rights, but it might not be in our interests to view space in the same way. Do we want private companies and/or the state collecting data about us? Is the state becoming redundant? Even if we can analyse and deploy all satellite data moving forward, who is deciding which data matters? What should be privileged, what is allowed or not allowed? How do we avoid biases, and small groups or parts of the world being disadvantaged as big players or certain states make decisions about what data is interesting for forming policy? A small disadvantaged percentage may actually be a very large number of people. We need an understanding of the impact of analysis algorithms. It is complicated, and a time of uncertainty and imbalance in privacy. Maybe we do need to hand ourselves over to Facebook? Maybe we need to think of new forms of democracy to handle these kinds of data and privacy issues, and then decide how to avoid disadvantage.

In answer to the second question, the development of new technology is applauded for doing the possible: monetising and leveraging investment, and having an impact. But it is a 'do first, think of ethics later' attitude, borne out of a desire to control, which disregards the social damage caused. An example of this is artificial intelligence and algorithm problems on the back of them, and predatory venture capitalism. We must think about big data in this context and discipline our thinking. Mistakes become enormous, and damage is wide-reaching, as all technology is scaled to an unimaginably large volume. Controlling other people's data and lives can be made privacy-friendly, but it is not the normal starting point.

In answer to the third question, simple monitoring can be genuinely interesting or it may not. Working out where the line is – what is legitimate and what is nosy – is fraught in the privacy world. Some issues may not be as consequential, like finding out what music you like, but other issues are, like tracking people just because it can be done. Space assets can bring about security, enabling evacuation before natural disasters or improving emergency service provision by monitoring ambulance routes in Africa. But how do we define security – when does it become unwelcome surveillance or even oppression?

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[10] http://www.space-institute.org/app/uploads/1518019329_ISPL_UCL_SD_Seminar_13Dec2017_Leaton_Gray_Space_Big_Data_and_Privacy.pptx

We need a 'naughty government check' to avoid undesirable government population surveillance. Deciding what form that takes is very difficult. The International Association of Privacy Professionals has a useful checklist for monitoring that could be applied to space monitoring – it asks if it is necessary, legitimate, proportionate and transparent. When applied to space-based collection of data, the checklist raises a number of issues. Who decides the objective – the client State or the corporation involved? Should organisations be in place to ensure the other criteria are met – the national state through international law, or existing or new supranational bodies? How do we provide transparency to people who are being observed by satellite? Privacy is a difficult thing to work through in this context. We're balancing competing rights. These are questions of privacy versus security, privacy versus freedom of expression and information, individual rights versus collective rights, and benefits to society and profits to corporations versus intrusion into personal space and lives.
It's not a new problem. The OECD 1980 privacy guidelines[11] recognised that new forms of international cooperation would be necessary. We find some things embedded that link to the three big questions.

- It covers collection limitation. In space monitoring, who sets the limits and defines proportionate use of surveillance?
- It covers data privacy and personal data. Who defines data quality?
- It covers purpose specification. Who can check if surveillance is properly specified or the specified purpose is followed?
- It covers use limitation. How is use controlled? We need cooperative international treaties.
- It covers security safeguards. Will state actors always be the major players in hacking and how do we enforce this?
- It covers openness. How can transparency be enforced when the satellite is far above Earth and people don't know it is there?
- It covers individual participation. How can data subjects' rights be ensured when people don't know who controls it?
- It covers accountability. Is there a regulatory authority to hold organisations to account?

In the big data age, the balances are hugely complex. There is a new dichotomy of state actors versus multinational corporations and organisations. If companies are beyond reach, can international law and enforcement mechanisms be sufficient, given they primarily rely on the nation state? As the technology of space and capability of big data increase in speed and reach, can legislative and sociological counterbalances keep pace? There is no magic bullet, no single answer about how we balance these rights and interests. But the real question is not the balance of rights, but who judges the balance and checks that it is right.

FOOD SECURITY

Dr Conor Walsh, Natural Resources Institute, University Of Greenwich
Mark Jarman, Head Of Earth Observation and Agri-Tech Lead, Satellite Applications Catapult

FOOD SECURITY AND THE POTENTIAL ROLE FOR SPACE SCIENCE : SOME THOUGHTS FROM A WORRIED OBSERVER[12]

Dr Conor Walsh

This topic raises three areas to consider: current trends in food security, likely future stresses, and the role of space science in food security.

[11] https://www.oecd.org/internet/ieconomy/oecdguidelinesontheprotectionofprivacyandtransborderflowsofpersonaldata.htm
[12] http://www.space-institute.org/app/uploads/1518019853_ISPL_UCL_SD_Seminar_13Dec2017_Walsh_Food_Security.pptx

Looking at current trends and taking cereals as an example, cereal production has actually grown at a faster rate than the population. However, the global population is predicted by the UN to increase to 9 – 10 billion people by 2050, 80% in developing regions, with per capita rise in demand for food, meaning the global crop production must increase by 70-100%. This will lead to growing intensification of production, placing greater demand on surface and ground water, and increased demand on nitrogen-fertiliser-grown crops.

In terms of food security, it is useful again to consider import and export of cereals, and import dependency shown by these statistics. The situation is complex. Looking at FAO[13] statistics for grain imports and exports in 1975 and 2013 in major countries, it can be seen that certain countries are very reliant on imports, such as China since 2007 and Egypt, however Russia has increased capacity to export since the early 2000s.

It can also be seen[14] that there is a ratio between imports and domestic consumptive demand as many big producers are also big consumers, such as in the USA. As such, it may not be possible to rely on major producers for exports of cereal to other countries in the future.

Looking at global statistics, we can see that in 2013 we were more reliant on a smaller group of exporter countries than we were in 1975. Dependency on large producers may not be sustainable in the future.

Looking then at likely future stresses, as climate change takes effect and the temperature increases by four degrees by the end of the century, there is likely to be a reduction in yields in many states, especially those in the southern hemisphere. However, some suggest that areas might actually see increased yields, as land suitability is enhanced by increased temperature. Overall, however, the distribution of imports and exports is likely to change. Some states will become entirely dependent on imports, with consequences for food security, and new states will become global producers.

Focusing on Egypt, for example, if this temperature increase occurs, Egyptian yields are likely to decrease 20% by 2050 while consumption will increase as the population also increases, leading to a 30% increase in import dependency, to 80% dependency. This has consequences for social cohesion, as seen recently. Equally, Africa, for example, is likely to become a key producing region, although historically it has been unable to irrigate land and increase yield.

Considering the role of space science, we will become increasingly reliant on "magic" technology, such as space observation data, bioenergy and bio mass CCS[15] pathway, where biofuel captures carbon in a form that can be sequestered. We will need to find places that are less constrained by competition for land and resources, however this will raise its own challenges, such as degradation. Space observation data will prove vital while the world adapts to climate change in understanding the impact of climate change, the extent of vulnerabilities to climate change, and potential for expansion of productivity in food, water, energy and land across the globe. In particular, satellite data will be able to verify models of climate change impact and level of adaptation, or to demonstrate stress over time, and to identify trends in resource demands.

[13] Food and Agriculture Organisation of the UN
[14] See the author's powerpoint slides for details.
http://www.space-institute.org/app/uploads/1518019853_ISPL_UCL_SD_Seminar_13Dec2017_Walsh_Food_Security.pptx
[15] Carbon Capture and Storage, or Carbon Capture and Sequestration.

FOOD SECURITY AND THE POTENTIAL ROLE FOR SPACE SCIENCE
Mark Jarman[16]

Everyone knows the challenge for every farmer is to grow more with less – it is known to farmers all over the world – and farmers love new technology to help them achieve this. However, the challenge is difficult for farmers as it changes every year, and farmers are traditionally reactive rather than proactive. Farmers have access to information but they need to know how to use it most appropriately, and they need the tools to enable them to think proactively.

Space science is vital in this challenge, enabling sound agronomy and crop science, public policies, and innovative agricultural technologies leading to a more connected world. Within space science, satellites are crucial in enabling and enhancing agricultural applications in many different ways. They provide positioning information, deliver wide-scale observation on a frequent, regular basis eliciting vital knowledge when analysed, and facilitate communication.

These tools are useful across countless issues in farming, including:

Variability Mapping;
Growth Stage Monitoring;
Irrigation Management;
Seed density optimisation;
Soil mapping;
Crop re-growth monitoring;
Fertilizer application;
Crop health management;
Crop damage assessment;
Invasive species monitoring;
Weather forecasting;
Crop yield estimation;
Harvest forecasting and management;
Agri-environmental assessment;
Land Use and change;
Management planning;
Field boundary management;
Illicit crop management;
Compliance and certification; and
Crop identification.

To give a few examples, a joint initiative between Catapult, Agri-EPI Centre and Cranfield University has used satellite Earth observation (EO), weather and field data alongside other emerging technologies to improve grassland nutrition and support precision grazing management. Catapult and the Rice Federation (Fedearroz) in Colombia used satellite data to monitor field conditions and crop development stages through the growing season. This enabled growers to quickly identify fields displaying variability indicative of crop stress (drought, disease and pest damage) to help target field investigations and enable intervention, and highlighted variations in levels of rice vigour to inform field visits. Finally, Catapult and Australian sugar cane mills used satellite data to assess the sugar

[16] http://www.space-institute.org/app/uploads/1518019214_ISPL_UCL_SD_Seminar_13Dec2017_Jarman_Satellites_and_Food_Security.pptx

cane growth stage, aid harvest date estimation and support logistics planning, where previously they used visual observation from a dedicated train moving through the plantations.

More can be done to share big data and boost production globally. When data related to agriculture and food is made open or shared more easily, more can be done by scientists, governments, industry, NGOs and farmers to improve agricultural outcomes. There are many global initiatives now aiming to utilise space science for the benefit of agriculture and farming, including:

the International Partnership Programme (IPP), UK Space Agency;
the UN's Sustainable Development Goals;
GBDX[17] for Sustainability Challenge;
the GEO Global Agricultural Monitoring;
Global Open Data for Agriculture and Nutrition;
the Consumer Goods Forum;
the Smart Agriculture Conclave;
the Department for Biotechnology in the Ministry for Science and Technology; and
Catapult Satellite Applications.

Technology must be combined with the economical push to solve the Food Security issue – technology must be put in the right place.

EXPLORATION & EXPLOITATION – WHY, HOW, HOW FAR HAVE WE GOT?[18]

Professor Andrew Coates, Deputy Director (Solar Systems), MSSL, UCL

The Mullard Space Science Laboratory is 50 years old this year, and has its origins going back to 1953, before the space age had started. With the anniversary also of the OST, it is a good time to ask why, how, and how far we have got in our exploration and exploitation of space.

Considering the OST, the most relevant provisions for exploration and exploitation are that the exploration and use of outer space shall be carried out for the benefit and in the interests of all countries and shall be the province of all mankind; outer space shall be free for exploration and use by all States; outer space is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means; the Moon and other celestial bodies shall be used exclusively for peaceful purposes; and astronauts shall be regarded as the envoys of mankind.

EXPLORATION

When considering why we explore space, it is to understand how the solar system formed, why Earth is so special and our place in the Universe, and more about the Universe. We also explore to put the Earth in context with the other planets, and to examine the Sun's and other influences on the environment of the planets. We do this by unmanned missions like ExoMars, JUICE, Cassini, Cluster, Solar Orbiter, JWST and Euclid, and by manned missions like Apollo, Mir, ISS and the proposed Deep Space Gateway. The key threat or limitation on space exploration is space weather.

So how far have we got in exploring space? There has been initial exploration of many objects in the solar system with non-crewed missions, and manned crewed missions like the Apollo and low Earth orbit missions. Non-governmental exploration has emerged in the last few years, including the Google

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[17] DigitalGlobe's geospatial big data platform.
[18] http://www.space-institute.org/app/uploads/1518019091_ISPL_UCL_SD_Seminar_13Dec2017_Coates_Exploration_and_Exploitation.pptx

Lunar X prize, which has a mission completion deadline of 31 March 2018,[19] and the SpaceX projects.

We have looked for life elsewhere. We now know from volcano craters visible on the surface of Mars that there was water on the surface and a thick atmosphere 3.8 billion years ago; and from the crust on the planet surface that there was a magnetic field. We also know that Mars's magnetic field was lost after a collision, leaving it unprotected and gradually losing its atmosphere. Mars today has extinct volcanoes, remnant regions but no large-scale magnetic field, and a thin atmosphere that is cold and dry, 7 mbar and CO2 rich. Could life have started on Mars 3.8 billion years ago? The requirements for life – liquid water, essential elements, source of heat, and time – appear to have been present. Future missions to Mars are planned to investigate further: ESA-Russia's Trace gas orbiter (2016) (which is currently aero breaking around Mars and will be looking at methane around Mars) and ExoMars rover (2020), NASA's InSight (2018) and Mars 2020 (2020), UAE's Orbiter (2020), China's Orbiter rover (2020), and other commercial missions like Space X. The ExoMars Rover's 2 metre drill will look for signs of life and get below the UV and radiation environment.

Other planets show good potential for life. Europa has an icy crust with a subsurface ocean and a sandy seabed. Ganymede has the same protective properties against radioactivity as Earth, and will be explored by JUICE in 2022. Titan has prebiotic chemistry. Enceladus has plumes, sodium indicating a salty ocean, silicates indicating subsurface hydrothermal vents, hydrogen needed for habitability, and water in a subsurface ocean. Pluto, Charon and Titan all have tholins[20] (evidenced by red surface material). Titan in particular has heavy neutral and positive ions, and unexpected heavy negative ions. Enceladus, Europa and Mars are the current leading hopes for life. We have a scientific imperative to gain answers to the question about whether life exists beyond Earth before sending potentially contaminating (i.e. human carrying) missions.

Planetary exploration is also planned for other planets including Mercury (ESA BepiColombo landing in 2025), Jupiter (ESA JUICE and NASA Europa Clipper), the Sun and solar wind (ESA Solar Orbiter, and NASA Parker Solar Probe), the Moon (Chandrayaan-2 and the Deep Space Gateway) and Extra-solar planets (ESA's Plato and CHEOPS and NASA's TESS). Missions are also scheduled to explore other objects and areas including the Magnetosphere (ESA-China's SMILE), comets (New Horizons Kuiper Belt Object 2014 MU69), asteroids (NASA's Dawn, Osiris-REX, Psyche, and Lucy missions, and Japan's Hayabusa 2), and astrophysics (ESA's Euclid and Athena, NASA-ESA's JWST and NASA's WFIRST). Although there have been missions to Venus in the past including a lander, no exploration is currently planned for Venus, or for Saturn, Uranus, Neptune, or Pluto. Following the Cassini in mid-September 2017, there are proposed future missions to Saturn, however none have been selected yet. The community will want to explore Uranus to complete the solar system exploration.

EXPLOITATION

Turning to exploitation, why and how are we exploiting? As for the why, it must be for global coverage and business opportunities. As for the how, we are doing so through technology development, meteorology, remote sensing of Earth, telecommunications, navigation, military, manned exploration, mining and space debris removal. How far have we got with exploitation? We

[19] https://www.space.com/37813-google-lunar-x-prize-deadline-extended-march-2018.html
[20] A tholin has been defined as an abiotic complex organic solid formed by chemistry from energy input into simple, cosmically relevant gases or solids. It is often described by words like 'tar', but see http://www.planetary.org/blogs/guest-blogs/2015/0722-what-in-the-worlds-are-tholins.html, where an analogy of 'salad' is also proposed.

have weather satellites, land use and climate change *applications,* lucrative communications markets, GPS and Galileo, surveillance and arms monitoring, the Moon missions of 1969-1972 and LEO. Luxembourg recently expressed a mining interest, and the RemoveDEBRIS mission in 2018 will test active debris removal (ADR) methods.

There are exciting times to come in both exploration and exploitation.

PANEL DISCUSSION
Chaired By Professor Sa'id Mosteshar, Director Of ISPL

- A lot of data is being collected by satellite but most is not analysed. Most States' laws require consent of the person whose personal information is being collected. It is not possible to know what personal information is included. How can collectors know if they have collected personal information, and what they have? How can they analyse data for that specific personal information, and is that inability to comply with the law a concern?

    Big data is a haystack and no one can analyse all the data gathered. Efforts have been made to develop an algorithm to be selective, however this creates problems as biases are created. It is greedy to think we need all this data, and we are too competitive about data. We are not disciplined enough. It's a problem that won't go away.

- Does the democratisation of data, especially within Europe through free access to data collections, have cyber consequences? Could data be manipulated with severe consequences?

    We need to protect against the cyber risk. The obligation is on data owners to protect it, but it is becoming more difficult. However, if there is the will and enough money, there is a way. Are we at the point where we can stop worrying about data being protected? Governments are protecting data that is really important but, for other data, enormous money and effort can be spent protecting it without much point. We need to analyse what we have and what is really important – that may be personal, or security. Data is out there and if it is collected, it is vulnerable to access.

- Is there a policy approach that can ameliorate this problem?

    [There were a number of comments from the panellists.]

    The same image will be analysed in different ways depending on what is being looked for, meaning that different sets of knowledge are generated from the same data. Lots of work is taking place on information coming from a huge set of data/imagery over the same area, which allows extraction of information you would not be able to extract from a smaller set of images. It is a big data approach. Although challenging as the format for preserving data changes over time, we must properly archive all data so it can be kept for future years. Some countries have guidelines. The US for example has an archive for Landsat data at USGS, but it isn't known if they can still read data from 1972.

    It is possible to gather lots of new data from space, such as Google's street pictures and the regularly updated images by Planet from small satellites to create a "life view" of the planet. This raises many questions, like who is buying the images, how are they distributed, can citizens subscribe to have images of particular area like their home area, what do we do with raw data updated every few hours, and how do we disseminate it? Who is the authority to decide the balance?

People don't want images, they want the intelligence or information gained from those images. How do you create business models allowing the user to query information? Lots of companies offer intelligence and we need to think about how to monetise dissemination of data.

Privacy is cyclical – peoples' views on privacy change over time – and it must be the same with data. In our current model we are mindful of databases that determined whether you lived or died, and Cold War surveillance concerns. However, this was not always the model.

We face the vicious circle that using the benefits of additional information may actually increase our vulnerability. We bequeath a certain amount of our resilience for utility in the same way as we used to be reliant on fossil fuels despite the negative consequences.

- Should neuroscientists be involved, to help sifting big data in order to spot advantageous information, as the brain does when it sifts information it receives.

This may be supportable; there is also the possibility of using AI in big data. Clients now don't want to know the source of the information – be it drone, space, manned aircraft, theodolite – they just want the information blended together to provide the best information set for their purposes.

- With the current focus being on encouraging private space activities, is there an impact on pure science missions?

[There were a number of individual responses.]

We are seeing a big change. New private entities are exploring space and could pose a new threat to space. However, States are required to ensure the OST requirements apply to private entities and individuals and that they will have to adhere to its principles in exploration of space. They must ensure they are not taking contamination to planets. There is a history of private entities helping NASA with its exploration. SpaceX is now launching cargo for the ISS, and has ambitions to colonise Mars and use Titan as filling station for space travel. We need to be careful and use planetary ethics to protect the space environment.

Under the OST, States must ensure that private entities do that.

NASA is talking about private partnerships and acknowledging that they must work with them otherwise their efforts could be compromised.

We need a business model.

Donald Trump's initiative to go back to the Moon was mentioned.

Public-private partnerships are fuelling this.

The world is changing. Trump's initiative opens the door to the combination of public-private entities in space exploration. If the Deep Space Gateway is put into orbit, it will probably not be a fully NASA mission, and it is not inconceivable that some elements could be private and have non-US collaborations.

- In the UK and ESA there is a collision between maintaining ethics and member state agreement on the one hand, and space exploration on the other, which is impeding progress. Did the panel agree that the UK is dragging its feet in the space sector?

  [There were several individual responses.]

  In disagreement with this viewpoint, it was commented that Catapult has government investment, and that the UK is pushing development through the Harwell as well as being a big contributor to ESA.

  The situation is improving and ESA is a force for good. ESA brings together the industry and academic sectors - the ExoMars rover, for example, had academic and industry building parts – and the UK now has a space agency. Bringing the industry and academic sectors under the same roof has had a positive effect for the UK.

  Another panellist agreed entirely that the UK is dragging its feet, and commented on the struggle to get government support for a spaceport project. It is a mixed picture.

CONCLUDING REMARKS
Professor Alan Smith, Director of UCL Space Domain

Professor Smith summarised the presentations and concluded the seminar.

Further joint seminars will be held by ISPL and UCL Space Domain as developments occur. Those interested to participate are encouraged to contact ISPL at Events@space-institute.org.

If you would like to follow up on the issues raised in this report please contact:

London Institute of Space Policy and Law
Charles Clore House
17 Russell Square
London
WC1B 5DR
+44 (0)20 7175 7677
Events@space-institute.org
www.ispl.org

Professor Alan Smith
Director, UCL Space Domain
Mullard Space Science Laboratory
University College London
Holmbury St Mary
Dorking
Surrey
RH5 6NT
+44 (0)1483 204 100
Alan.Smith@ucl.ac.uk &