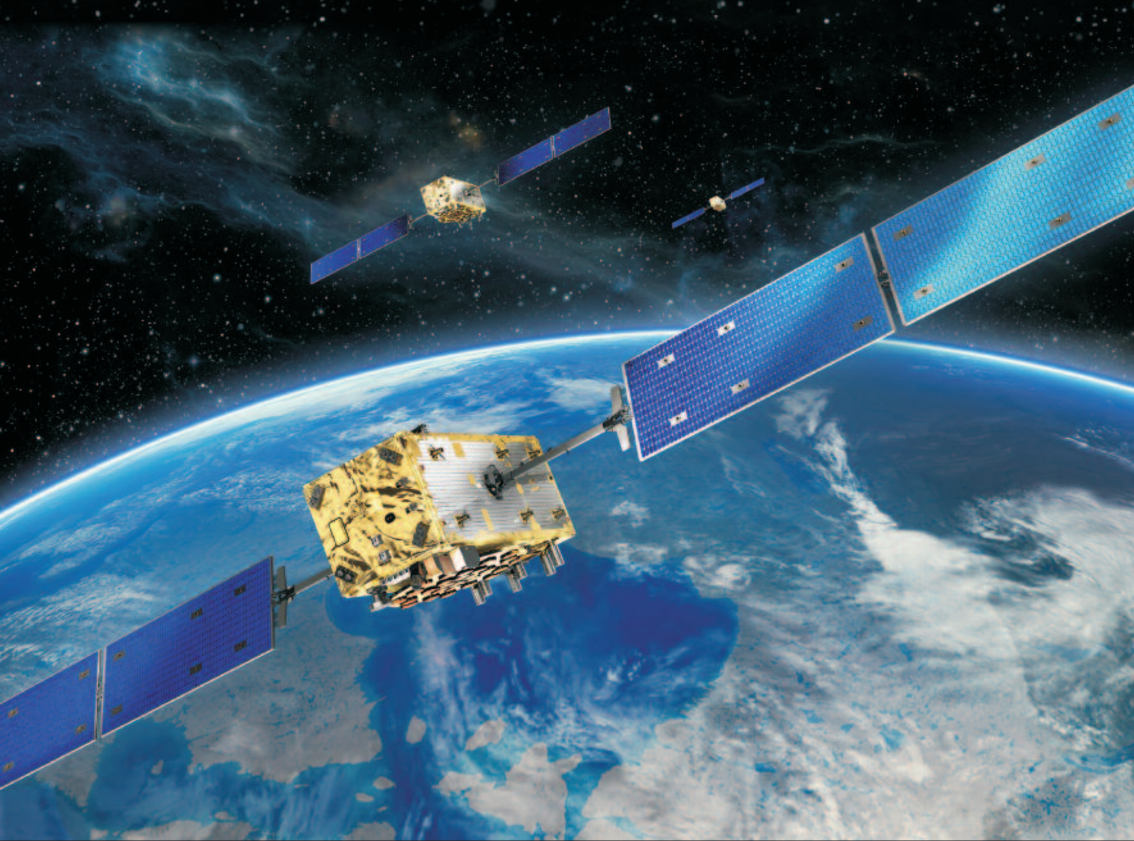
2015 CANADA - UK COLLOQUIUM

SPACE:
Obstacles and Opportunities



Rapporteur's Report

Professor Alan Smith

Library and Archives Canada Cataloguing in Publication

Smith, Alan, 1952-, author
Space: obstacles and opportunities: 2015 Canada-UK Colloquium : rapporteur's report / Alan Smith.

Colloquium held at The University of Strathclyde, Technology and Innovation Centre, Glasgow, Scotland, November 19-21, 2015.
Issued in print and electronic formats.
Co-published by: Canada-United Kingdom Council.
ISBN 978-1-55339-361-0 (paperback)

1. Outer space--Congresses. I. Queen's University (Kingston, Ont.). School of Policy Studies, issuing body II. Canada-United Kingdom Council, issuing body III. Canada/UK Colloquium (2015: Glasgow, Scotland) IV. Title.

QB495.S65 2016 500.5 C2016-901539-4
C2016-901540-8

COVER IMAGE

Galileo Full Operational Capability Satellite, Built by Surrey Satellite Technology Ltd (UK) and OHB System (Germany). The Galileo Constellation will provide satellite navigation and timing services to Europe.

Credit: OHB System AG

SPACE:
Obstacles and Opportunities

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Alan Smith

Canada-UK Colloquium, 19-21 November 2015

The University of Strathclyde,

Technology and Innovation Centre

Glasgow

Canada-UK Council

School of Policy Studies, Queen's University

ABOUT THE AUTHOR

Professor Alan Smith

Alan Smith was awarded a PhD at Leicester University in 1978 based on his X-ray study of supernova remnants. His work involved the payload development and flight of a Skylark sounding rocket from Woomera, South Australia. Between 1984-1990 he worked for the European Space Agency at its technology centre in the Netherlands as both an astrophysicist and as an instrument scientist. His early career involved a combination of technology development (space flight hardware on European, and Russian satellites), project management and astrophysics. In 1990 he joined University College London's Mullard Space Science Laboratory, initially as Head of Detector Physics, eventually becoming Director and Head of Department (2005). In 1998 he was made a Professor of Detector Physics. While at UCL he has been Director of UCL's Centre for Advanced Instrumentation Systems (1995-2005), a Co-Director of the Smart Optics Faraday Partnership (2002-2005) and is presently founding Director of the Centre for Systems Engineering (from 1998). Alan was appointed Vice-Dean for Enterprise for the faculty of Mathematical and Physical Sciences in 2007, helped set up UCL's Centre for Space Medicine in 2011 and is Chair of the UK Space Life and Biomedical Sciences Association. He is a Fellow of the Royal Astronomical Society and of the Association of Project Management. His mission engagements have included Exosat, Mir, BeppoSax, XMM-Newton, Yohkoh, and Hinnode. He is a member of the Plato Council, the European Space Agency extra-solar planet mission in development. His present research interests include systems engineering, project management and future space mission design.

THE CANADA-UK COLLOQUIA

The Canada-UK Colloquia are annual events that aim to promote the advantages of a close and dynamic relationship between Canada and the United Kingdom through the advancement of education in a wider context. These conferences bring together British and Canadian parliamentarians, public officials, academics, business people, journalists and broadcasters, other private sector representatives, graduate students, and others. The organisers focus on issues of immediate relevance and concern to both countries with the aim of exchanging experience and enhancing policy outcomes. One of the main endeavours of the Colloquia is to address these issues through engaging British and Canadian experts in the exchange of knowledge, experience and ideas and the dissemination of their conclusions in a published report. Previous reports can be found at
http://www.queensu.ca/canuk/.

The first Colloquium was held at Cumberland Lodge in Windsor Great Park in 1971 to examine the bilateral relationship. A British steering committee, later to become the Canada-United Kingdom Council, was launched in 1986. The School of Policy Studies at Queen's University assumed responsibility for the Canadian side in 1996, succeeding the Institute for Research on Public Policy.

The Colloquia are supported by Global Affairs Canada and by Foreign and Commonwealth Office in the United Kingdom, as well as by private sector sponsors. As of 2016, the Canadian side is organized by the School of Policy Studies at Queen's University and by the Canada-United Kingdom Council on the British side, from which an executive board, the Council of Management, is elected annually.

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LONDON SW1A 2AA

THE PRIME MINISTER

It is now four years since Stephen Harper and I endorsed the Canada-UK Joint Declaration celebrating the enduring partnership between our countries and dedicating ourselves to getting the most out of it. The annual Colloquium has served as an important vehicle for this work, exploring issues of mutual concern chosen with the support of both Governments.

This year's meeting in Glasgow will look at opportunities in Space, and especially near-earth Space. It will also examine legislative, regulatory and other obstacles that stand in the way of taking full advantage of those opportunities.

Space tends to be associated in the public mind with science fiction. Yet astonishing advances in satellite technology and space observation mean that activity in near earth Space *already* touches all of our lives, on a daily basis.

Britain and Canada have been early participants in these transformative developments. Our work together is an example of the collaboration espoused by the Joint Declaration - helped by Canada's status as the only non-European 'co-operating state' in the European Space Agency. Together, we are well placed to contribute to resolving some of the challenges of Space - from uncertainties over governance to the rapid accumulation of debris. We are also well placed to benefit from the exciting commercial opportunities that are opening up.

So it is with great pleasure that I welcome all participants to the 2015 Canada-UK Colloquium and wish you every success.

Rt Hon Nicola Sturgeon MSP
First Minister of Scotland

St Andrew's House, Regent Road, Edinburgh EH1 3DG
T: 0300 244 4000

The Scottish Government
Riaghaltas na h-Alba

LEGACY 2014
XX COMMONWEALTH GAMES
SCOTLAND

Mr Phillip Peacock
By Email: philipjpeacock@btinternet.com

6 November 2015

Dear Mr Peacock

It is with great pleasure that I welcome the 2015 Canada-United Kingdom Colloquium to Glasgow, and to Scotland.

Scotland enjoys a long and close connection with Canada and this year was not only the bicentenary of the birth in Glasgow of Canada's first Prime Minister, Sir John A. Macdonald, but also the year in which several airlines inaugurated direct flights between Scottish and Canadian airports.

The Scottish government recognises that science, technology and innovation are essential to increase competitiveness and improve economic performance in today's knowledge-based economy. The Space sector therefore provides a perfect opportunity for both Canada and the UK to make the best use of their strengths in this area. The Colloquium's location here in Scotland is especially exciting given the internationally leading universities and companies in Scotland that are working together to advance human exploration and exploitation of Space for the betterment of all of our lives on earth.

I hope as part of your programme you will have the opportunity to see examples of how intensive the Space sector is in Scotland, employing over 5,500 people with employment increasing 16% in the last three years and turnover doubling over the same period.

During these times, where important future directions are being chosen in fields such as climate change, humanitarian relief and enabling legislation, it is vital that our respective governments are wisely counselled. For this reason I am confident the Colloquium will carefully examine the diverse issues that confront this fast moving sector and offer sound advice and guidance.

I would like to take this opportunity to wish the Colloquium every success in its endeavours and look forward to receiving its conclusions and recommendations.

With my very best wishes

Nicola

NICOLA STURGEON

PREFACE

We have great pleasure in presenting our Report on the discussions and conclusions of the 2015 Canada-United Kingdom Colloquium on "Space: Obstacles and Opportunities" which was held in Glasgow in November 2015.

True to its title, the Colloquium demonstrated that while there are many obstacles to the successful exploitation of Space there are opportunities that are being successfully pursued by government, industry, commerce and the academic world. Significantly, new opportunities are emerging that were not possible even a few years ago that have the potential to improve economic life on Earth and the wellbeing of its citizens.

Our discussions highlighted many areas where the UK and Canada stand to benefit from investment in new and developing Space technology, but also underlined the significant risks that required a solution, such as the effect on Earth of Space Weather and Space Debris to name but two. International co-operation will be vital in mitigating these risks and this in turn highlighted the need for a more effective global regulatory environment.

Our acknowledgements this year are many and much deserved. Principal among them is our debt to the Scottish Government, Scottish Enterprise and Highlands and Islands Enterprise for their unstinting support which enabled us to hold the Colloquium at the Technology and Innovation Centre at Strathclyde University. We also received financial support, for which we are most grateful, from the Canadian Space Commerce Association, MDA, Urthecast, Surrey Satellite Technology Ltd, GSI, Inmarsat and, not least, Dadco Group. Our thanks also go to the Universities of Strathclyde and Glasgow for their help and collaboration throughout.

Our regular supporters continued to support our endeavours and thanks are due in this respect to the Foreign & Commonwealth Office, Global Affairs Canada, Queen's University School of Policy Studies and the Canada-United Kingdom Council in the UK.

We were delighted to receive letters of support from Prime Minister David Cameron and First Minister Nicola Sturgeon and are grateful to all our hosts in Scotland, in particular the University of Glasgow, Glasgow City Council and Clyde Space. We also enjoyed the contributions of Minister Fiona Hyslop MSP in opening the proceedings, and of Chris Ashton of Inmarsat and Stuart Patrick of Glasgow Chamber of Commerce for their keynote addresses.

Much credit goes to the author of our Report, Professor Alan Smith of UCL for his in-depth analysis of our discussions and for articulating the detailed recommendations we make, which are to be found at the end of this Report. Professor Smith also acted as the UK adviser for the Colloquium and Mac Evans, former President of the Canadian Space Agency acted as the adviser to the Canadian team, both of whom provided invaluable help in planning the Colloquium.

The Colloquium was chaired by Lord (David) Willetts and its success is due in large measure to the experience and knowledge of Space that he brought to the task of chairing the proceedings and skilfully steering us through an engrossing event.

Planning for a Colloquium takes longer than one might expert and sincere thanks this year are due for the largely unseen work of the two organisers, Maureen Bartram in Canada and George Edmonds-Brown in the UK. We should add that this is likely to be George's last Colloquium, having been in harness for 16 years. We wish him a long and fruitful rest from his labours which have been much appreciated over the years.

Philip J Peacock
Chairman
Canada—United Kingdom Council

Kim Richard Nossal
Centre for International and Defence Policy
Queen's University, Kingston

EXECUTIVE SUMMARY

The 2015 Canada UK Council Colloquium took Space as its subject and brought together individuals from the two nations with expertise in diverse areas of endeavour including government, commerce, industry, law and space science. The meeting proved to be characterised by cooperation and the appreciation of various, sometimes conflicting, viewpoints. Indeed the atmosphere of the Colloquium was a microcosm of the Space sector itself. In times of tension the strong international relations built up in the Space sector continue to demonstrate that nations can work effectively together for common benefit.

The vital importance of the 1967 UN Space Treaty was very evident from the presentations and discussion. While in many respects the 1967 Treaty urgently needs updating to include aspects not imagined 50 years ago, nevertheless its principles have stood the test of time. We need to find a way to keep treaties and legislation relevant – a huge challenge. The pace of technological growth and human inventiveness is outstripping that of international treaty negotiation and so we have to expect nations to take pre-emptive action, to be sorted out in the expert groups at international fora in due course. The removal of space debris and asteroid mining are two current examples of where the 1967 Treaty provides an inadequate framework. A strong recommendation of the Colloquium is that a meeting of the signatories of the 1967 Treaty should meet again on its 50th anniversary to seek a way of moving the treaty forward without losing its principles.

Climate change was not covered in the Colloquium, it deserves one of its own, however a number of key issues were explored including: Space Weather (with strong support for a bilateral Space Weather mission to help with both the understanding of the phenomena and in forecasting); Space Debris (noting that while some reduction in the rate of growth of debris in Space has been achieved, more needs to be done and the situation continues to deteriorate); the democratization of Earth Observation data (with EO moving from a large state-driven situation to one that is fundamentally commercial); telecommunications (where regulation needs to keep abreast of such developments as small satellite constellations in low earth orbit); and international cooperation (where national security and the alignment of foreign policy are important issues).

INTRODUCTION

Our understanding of the Universe has grown enormously following the availability of data undistorted by the Earth's atmosphere. For instance, the so called 'Violent Universe' of black holes, active galaxies, and accreting neutron stars would not have been discovered without scientific satellites. The continuing exploration of the solar system that included Gagarin's first flight, the Apollo programme and most recently the Rosetta's robotic landing on a comet has been a source of inspiration to many, including the author. However, this Colloquium was not focussed on science although the technologies, techniques and knowledge that science produces have provided a foundation for the commercial exploitation of Space.

While Environmental Change and Global Warming are of great concern and are informed by satellite measurements, this subject was not covered at this Colloquium. The topic is simply too large and multifaceted to be given justice and warrants a Colloquium of its own.

Space clearly offers huge commercial possibilities but these must be exploited within a robust framework of international agreement and regulation of space-based activities. The Colloquium addressed key and important issues that relate to dependency on Space and the space agencies, industries, government agencies, institutes and legal frameworks that govern, facilitate and deliver space-based services.

Both Canada and the UK have been early participants in the transformative development stemming from scientific exploration and commercial use of near earth space over the past 60 years. Canada has a unique status as the only non-European 'Cooperating State' with the European Space Agency – while there are numerous bilateral space-related activities between the two countries

Here we examine the obstacles to and opportunities for the exploitation of Space, and in particular how we use satellites in Space, for the benefit of mankind. The essential roles of state agencies, industry and academia are reflected in the makeup of the speakers and delegates to the Colloquium.

We make no distinction between 'Space' and 'Outer Space', the latter term is rarely used by the Space community. For our purpose we can adopt the definition by the Fédération Aéronautique Internationale which says that 'Space' begins 100km above the Earth. Other heights have been suggested and the US favour 80km. In fact there is no actual boundary between the atmosphere and the vacuum of space and the effects of atmospheric drag can be seen on satellites far above 100km. More importantly at 100km atmospheric drag is very severe and quickly causes satellites to re-enter and so commercial satellites cannot be operated at such low altitude. Since aircraft and even balloons cannot fly up to 100km this value gives us a clear separation between operational regimes. Altitudes greater than Geostationary Orbit (GEO), also known as Geosynchronous Orbit, at around 36,000 km have little commercial application and are the province of space exploration or space science.

For equipment to work in Space it needs to be able to survive the rigors of launch and a hostile environment. This environment in characterised by a hard vacuum that makes thermal control much more difficult – there is no point having a cooling fan in Space, because of a variety of ionising radiations, that can affect electronics, materials and humans, and a very bright source of power and heat - the Sun. Almost all satellites are not serviceable in Space and so have to be built to be reliable and resilient. Altogether this makes Space hardware expensive compared to commercial products for use on Earth. Nevertheless, Space enables services that are now essential to our way of life, especially telecommunications, navigation, and Earth Observation.

In our modern, information rich, internet linked world we depend upon satellite communications, particularly involving equipment in GEO. Communications link our planet and help integrate even remote, under-developed regions of Earth into a global economy. Our leisure is enhanced through Satellite TV while access to the internet is becoming part of our essential services alongside the mobile phone.

The Global Positioning System (GPS) satellites in Low Earth Orbit create a network that delivers accurate geolocation anywhere on the planet. The location of assets such as vehicles can be tracked, useful when you are waiting for a bus or train. As importantly, satellite GPS provides an easily accessible, universal time standard.

Satellites provide a truly global view of the Earth, useful for weather forecasting, surveillance, security, agriculture, environmental monitoring, disaster management, forestry and much more. Marine activity (legal and otherwise) can be tracked through cloud cover with synthetic aperture radar. Important environmental variables can be routinely measured including air and sea surface temperatures, and the extent and thickness of polar ice caps and sea ice. We are able to predict the track of hurricanes and map features such as flooding, drought and forest fires, especially useful in otherwise inaccessible locations. Perhaps most importantly of all, we are able to create credible models of a global climate.

When one seeks a local weather forecast on a smart phone one is using with a single app all three of the above aspects together with many terrestrial services.

THE BRIEFING DAY

On the day prior to the Colloquium a briefing of delegates took place. This was held in the morning at Merchant's House in Glasgow where presentations were given and displays shown. This was followed by lunch at the University of Glasgow hosted by Professor Muffy Calder, former Chief Scientific Adviser to the Scottish Government. In the afternoon, delegates visited Clyde Space Ltd where a tour followed by a discussion was conducted by its founder, Craig Clark. Overall the day gave an indication of how Scotland is embracing the Space sector, showcasing local industries like Clyde Space (a nanosatellite manufacturer), Star Dundee (the spin-out creators of 'SpaceWire'), Global Surface Intelligence (a British/Canadian company with links to Scotland that specialises in Earth Observation), Com-Dev International (UK) (a global provider of space equipment, and data services) and MDA (a Canadian Telecoms satellite provider with a base in the UK). All of these presentations indicated a growing, innovative sector.

The briefing day also included presentations of UK regional ambitions. Harwell Space Cluster was described with impressive plans for growth – up to 15,000 more jobs by 2030. Already over 200 organisations are represented on the Harwell site in Oxfordshire.

The UK's interest in a local space port has led to a consideration of various sites around the country. Proponents of Prestwick and Campbeltown in Scotland, and Llanbedr in Wales made presentations. While diverse in their nature all three possibilities appeared credible and exciting. It is excellent to see the enthusiasm, and the quality and diversity of choice that the UK has in this area.

The day was completed with a Gala Reception and Dinner at Glasgow City Chambers at which Chris Ashton, Director, Spectrum Engineering, Inmarsat, described his company's contribution to the search for the Malaysian Airliner lost in the Southern Ocean in 2014 – flight MA370.

Overall we were impressed by the warm welcome provided by Glasgow and the Scottish Government and the way it is embracing the exploitation of Space.

THE COLLOQUIUM

The Colloquium was opened by Ms Fiona Hyslop MSP, Cabinet Secretary for Culture, Europe and External Affairs, Scottish Government. Ms Hyslop reflected upon the close and historical relationship between Scotland and Canada noting that 15% of Canadians identify themselves as Scottish Canadians, almost as many people as the entire population of Scotland. It was very fitting that the Colloquium was taking place within the University of Strathclyde Technology and Innovation Centre given that the Space sector is at the vanguard of innovation. Ms Hyslop noted that nothing exemplifies innovation more than the Scottish Space sector. 'The Scottish Government recognises that a truly thriving Scottish economy can only realise its full potential within a thriving global economy'. In retrospect there was a remarkable alignment between Ms Hyslop's recognition of the need for collaboration and cooperation, and the repeated messages from the speakers and participants at the Colloquium.

SESSIONS

Session 1: The Politics and Legal Framework of Space

While this session was originally entitled 'The Politics of Space', the above is a more accurate title. That is not to say that Politics is not in play here and throughout the Colloquium, but rather that the emphasis of this session was more about the legal framework that exists around Space. The development of this framework will be consequential to a global political environment in which the major players, particularly the US, Russia and China, compete and collaborate. Canada and the UK with their links to NASA and ESA, and given their close ties to each other, have the opportunity to facilitate and influence this development.

The session began with presentations by Professor Lesley Jane Smith, Visiting Professor, Strathclyde University; Solicitor and Partner, Weber-Steinhaus & Smith, Bremen and Mr Paul Meyer, former Canadian Ambassador, The Simons Foundation.

Outer Space enjoys a special status, exemplified in the 1967 United Nations Outer Space Treaty as: 'the province of all mankind'; 'the use of which should be for peaceful purposes'; and 'in the interests of all countries'. It was a high point in international cooperation, 'an impressive act of preventative diplomacy that has served the international community for several decades' –Paul Meyer. While there have been four subsequent United Nations space treaties, none has been ratified to the same extent and as ground breaking as the treaty of 1967. The 1967 treaty made no provision for many issues we face today, nor did it create mechanisms to ensure its own, timely evolution. As the non-aggressive military use of Space grows we rely on the self-restraint of nations, which unfortunately was not seen in the China and US anti-satellite weapons tests of 2007 and 2008 respectively.

While groups of nations have brought forward initiatives, fuller international agreement has not followed and established political differences and inevitable self-interest have persisted. Both the EU International Code of Conduct for Outer Space Activities (driven by the need for sustainability and common foreign and security policy interests) and the Sino-Russian Prohibition on Placement of Weapons in Space Treaty have not received general acceptance. Moreover, while recommendations have been forthcoming, such as in the 2013 Russia led UK Group of Governmental Experts on Transparency and Confidence Building Measures (TCBM), there has been no commitment to implement them. While the UN General Assembly continues to pass the 'Prevention of an Arms Race in Outer Space' resolution annually since the 1980s, its proposal 'to establish a working group to negotiate multilateral arms control and disarmament agreements' has not materialised.

More recently the old Soviet doctrine involving a pledge 'not to be the first state' in this case to place weapons in outer Space, has received wide, albeit not universal, support within the UN with a General Assembly resolution receiving 126 votes in 2014. This doctrine did little to prevent the nuclear arms race and does nothing to prevent the development of weapons technologies for Space, merely their 'first' deployment. Once deployed, 'who shot first?' may become a matter for the history books. For instance, the ongoing debate about the legality of the anti-satellite tests will most likely come to nothing as all concerned will seek to save face.

We are in a time of growth and change. Space is important to us in many different ways; from Space science to telecommunication, from defence to disaster relief, from exploration to navigation. Diversity is growing both in the application domains and in the way we collaborate, more often than not globally. Driven by this evolving Space sector there is a need to improve our legal framework and to ensure it is kept up to date. Issues such as space debris and sustainability have become pressing.

2017 will mark the 50th anniversary of the 1967 UN Outer Space Treaty and there was a consensus within the Colloquium for a meeting of the 101 States that were party to the Treaty to be convened, perhaps even adding an amendment that the parties would then meet annually to progress the Treaty and keep it up-to-date. Of course this would have to be handled carefully; we should not risk undermining its underlying principles, principles that remain valid today and that have been instrumental in dampening our political differences over the last 50 years.

While the 1967 Treaty and its successors provide a common denominator, practice varies across jurisdictions. Space is a data-rich domain and while the concept of 'Territoriality' does not apply in Space, the earthly context of this data means that it is nevertheless an issue in its exploitation. Nations have different legal cultures and levels of sophistication within their national legal frameworks as pertaining to Space – the US being the most developed, giving significant advantage to US contractors dealing with Space. In the absence of a normative situation, there is no level playing field. For instance, the US and others, notably France, limit the liability for those who launch and operate Space borne equipment, (e.g. The US Commercial Space Competitiveness Act 2015); Canada is currently engaged in establishing better insurance provisions and the UK has recently made special provision for nanosatellite insurance. We can expect to see competition between States to attract investment through supportive statutes, export guarantees, standards, etc.

'Private commercial space needs government backing through authorisation and monitoring' – Lesley Jane Smith. A nation state 'in charge' is needed that provides a regulatory apparatus through statutes etc. and hence provides a level of legal certainty and so protection for the investor – necessary for economic sustainability. Therefore, States are naturally in competition yet able to collaborate through such entities as the European Space Agency. States, agencies, operators and users all have their role to play, and perhaps should each recognise their limitations.

Nation States have differing alliances, priorities and philosophies on how to manage locally their Space interests. For instance compare the distinct, independent arrangement of the Centre National d'Études Spatiales (CNES) in France to the executive, hands-on approach with the UK Space Agency. Similarly one can hardly overlook the special relationship of Canada and the UK with the US in matters of security.

Some issues, such as space debris (see Working Group 2) can only be addressed by a more integrated approach (e.g. through the Interagency Debris Coordination Committee) rather than each State or company merely taking responsibility for their own contribution to the situation. Some major nations might take the lead in addressing this non-commercial yet growing issue. A moratorium on past space debris indiscretions might be necessary. Where broader 'environmental' issues are at stake we may need to re-assess the appropriateness of European procurement rules and our interpretation of ‘value-for-money’ from competitively bid contracts, to achieve a more sustainable future for Space that is also viable commercially.

Subsidiarity as applied to the Space sector is a term not well defined. Within the EU the principle is one of ‘conferral’ when and where it is deemed more effective for the EU to act rather than its individual member states. This lends itself to the implementation by the EU of mega projects, such as space traffic management. Moreover, the Treaty on the Functioning of the European Union accepts the sovereignty of its member states in matters related to Space law and so restricts its ability to harmonise. While ESA has a natural understanding of Space issues, the EU has much less experience and can bring forward erratic, even irrelevant legislation, such as a proposal for a single market in data distribution despite an extant global market. It is essential that as the EU and ESA move closer together this valuable asset of ESA is not swamped by bureaucracy. In the case of Scotland, although Space is not a devolved power within the UK, nevertheless Scotland could have an important role to play as a facilitator for change, especially in the light of its well-developed legal system.

In a rapidly advancing technological domain it is appropriate to ask whether legislation is falling behind capability. In the 1967 Treaty and subsequent treaties the focus of legislation was on launch and re-entry, damage and liability of States and damage to third parties on the ground. The subject of orbital damage was less well covered and rather given to the ‘rule of fault’. However, fault liability in outer Space is also largely undefined and has not been addressed by the UN Committee on the Peaceful Uses of Outer Space (COPUOS). In turn this hinders sustainability of the outer Space environment, i.e. keeping it ‘clean’. Only France through direct transposition of international law imposes fines on those who fail to meet international obligations on space debris avoidance. The creation of international treaties during the Cold War era has moved into a ‘soft law’ agreement to agree (e.g. Transparency and Confidence-Building Measures (TCBM)) to a not directly enforceable regime.

As we move into a situation of integrated, global enterprises that operate alongside national and international agencies, so our legal culture will need to adapt. Space is becoming so commercially important that major nations will ‘vote with their feet’ to protect their interests rather than wait for the slow wheels of treaty change to take effect. This may be the way to break through the inertia of international treaty negotiation. Precedence will force agreement or at least discussion. Pragmatically, lawyers will continue interpreting existing precedents as best they can.

While the sale of celestial bodies has no legal validity, it is considered rather harmless fun when it involves very small sums of money and a certificate of ownership arriving through the post. In fact, the appropriation of celestial bodies is prohibited by the Outer Space Treaty, a position that is unlikely to change. However, very recent US legislation (National Strategic and Critical Minerals Production Act of 2015) appears to permit the ownership of mined materials that are returned to Earth – an example of a nation 'voting with its feet'. While the Moon Treaty does address mining, it has never been ratified and so is not in force. Other protected environments exist on Earth, notably Antarctica, and may be used as prototypes for a future agreement for Space. It is likely that a legal framework around Space mining will only come into place when mining itself becomes feasible – the power of the imperative.

There is a price to be paid for the relative neglect of the politics and diplomacy of Space security. Is it wise to rely indefinitely on the self-restraint of States without codifying in some fashion norms for responsible State behaviour? The current political-military environment is manifesting negative tendencies that could seriously threaten safe and secure Space operations. There is a need for a countervailing diplomatic dynamic that will look to reinforce the existing cooperative regime for Space security and extend its scope and effectiveness. This is not only a work for diplomats and politicians. It will be crucial for the broader stakeholder community to engage in these issues in order to defend their own interests and those of mankind in general in the vital, but vulnerable Space environment.

"The Peaceful Use of Outer Space", while laudable, is also subject to interpretation and has an impact on dual-use technologies, i.e. technologies that could have application to commercial but also security/defence. The distinction between defence and civil satellite capabilities is now very blurred. A single satellite can support commercial and defence applications. Technologies related to GPS, Earth Observation, and telecommunications, and automated on-orbit satellite servicing can all be seen as dual-use. From a commercial perspective using similar technologies to service defence and non-defence markets makes sense but brings with it national security issues such as the US International Traffic in Arms Regulations (ITAR) which are seen by many to be an obstacle to international cooperation. The Colloquium explored options to address the perceived negative impact of ITAR, suggesting either a loosening of the rules or more controversially through the creation of an ITAR 'Schengen' zone. When considering issues of security and defence a broader than 'weapons of mass destruction' view is needed.

We can expect legislation to continue to play catch-up as new issues evolve. The apparent incompatibility between the timescales of commercial growth in the Space sector and those of Treaty change suggest that pragmatism and precedent setting could be the norm. Nevertheless, the 1967 Treaty is a valuable basis that should not be put at risk. Canada and the UK should cooperate to enable commercial growth of their Space sectors and should use their influence with their partners accordingly.

Session 2: The Commercial Potential of Space

The Space Sector is already an essential part of our lives and many of the services that support us are delivered commercially by the private sector. Telecommunications, the largest element, is almost entirely delivered commercially. For navigation and Earth Observation we see joint, collaborative endeavours with, in the main, satellites being State funded (but commercially built) with the downstream applications often being commercial. The Global Positioning System (GPS) is a gift to the world by the USA, albeit with some caveats, that has sparked innumerable downstream applications. Space offers new and exciting opportunities for commerce and industry. This is recognised in the UK where it is strongly supported, e.g. through its Innovation and Growth Strategy (IGS), an executive Space Agency, Satellite Applications Catapult and a highly productive and respected academic sector. In Canada, Space receives less emphasis and support. Its footprint has faded from the early days when it was closely linked into both NASA and ESA. Today Canada's engagement with ESA is much reduced. Several Canadian delegates during the Colloquium noted this reduction in emphasis and looked across to the UK with more than a little envy.

The session began with presentations by Sir Martin Sweeting, Executive Chairman, Surrey Satellite Technology Ltd (SSTL), Mr Wade Larson, President and COO, Urthecast Corporation and Mr Paul Bush, former VP, Telesat.

Space is a rapidly growing and now essential part of the UK national infrastructure, supporting communications, timing, remote sensing, security and disaster relief – all of which are also relevant on a global scale. Within the UK, Space addresses several key challenges, for instance: telecare supports a growing and ageing population by bringing health monitoring into the home; Skynet 5 is the latest phase of a defence telecommunications infrastructure; Earth Observation supports global security, a sustainable natural environment, and the exploitation of our natural resources; GPS informs our transport sector, improving its efficiency and increasing its capacity. The UK Space sector is a key part of a technically innovative environment. It benefits from and contributes to an increased pace and reach of technology development. It spins-along with ground sectors, sharing and exchanging technologies where appropriate.

Very significantly, Space is a creator of wealth and economic growth, a result of continued ministerial support across recent governments. The UK's Space IGS has the aim of creating an additional 100,000 jobs in the next 20 years and increasing the UK's world market share to 10%. In recent years the Space sector has exceeded by a factor of 4 the average economic growth in the UK. 'Space is a driver of innovation … not just of technology but in applications and in business' – Martin Sweeting. Although the downstream (applications and exploitation) Space sector produces 80% of the economic benefit it is essential that a balance is kept with investment in the enabling upstream activities (manufacturing and operations). The UK Space Applications Catapult links upstream and downstream and stimulates new business, especially in small and medium sized companies. The sector is underpinned by a very strong science base, which validates the underlying science of Space and brings forward new technologies and analysis techniques.

Space is inspirational and we need to use this to grow the next generation of skilled professionals, essential for the growth of the sector. Much is already done that builds upon astronauts such as Chris Hadfield and Tim Peake – indeed Tim provided the Colloquium with a welcoming video prior to his trip to the International Space Station (ISS). Unmanned space exploration and space derived science data captures the imagination of all generations. The majority of those excited by Space will go on to become involved in other sectors, often linked to science, technology, engineering or mathematics. Communicating the message of Space and its ethos is an investment that gives an exponential return nationally.

One manifestation of this innovative climate within the UK has been the emergence of Surrey Satellite Technology Ltd (SSTL) and other small satellite businesses that use commercial, off-the-shelf technologies to provide Earth Observation services. Here the Space sector is taking advantage of the huge investment in innovative technologies that has been made in the area of consumer electronics for instance – 38 successful small satellite launches gives testament to this. SSTL built and operates the highly innovative 6-satellite Disaster Monitoring Constellation (DMC), a new and effective business model that provides rapid response to natural and man-made disasters. Indeed we are seeing a rapid growth in the small satellites market, driven by both communications and Earth Observation needs. In Earth Observation a major driver is the need for fast repeat ground passes that provide high quality yet affordable data. Some situations, such as the effects of a natural disaster, change too quickly to be properly monitored by infrequent observations several days apart.

It is entirely possible to conduct ethical business in the development of third world economies and in disaster response. Just as the tents that are sent to aid disaster victims are manufactured on a commercial basis, so can the data that facilitates the relief of those affected.

When deciding between a small or large satellite for a particular application, it is ‘utility that is key’ – Martin Sweeting, with small satellites offering the possibility of very large constellations. Small, and therefore less expensive, satellites naturally reduce funding requirements. New companies are appearing in the market place. Such are the aspirations of companies such as Google that Space may soon become dominated by non-State players. Nevertheless we must be alert to the possibility of a small-satellite ‘bubble’ reminiscent of the collapse of Iridium and GlobalStar, which ‘turned the financial sector against small satellites for a decade’ – Martin Sweeting.

Large constellations bring vast data sets, ‘Big Data’. Interestingly data itself is not typically seen as a commercial asset. However, this is likely to change. The extraction of useful knowledge from such large data sets, fused with data from other sources, is a huge business opportunity. The maintenance of such large data sets is another – something that States will be looking towards the private sector to do. Privacy and security (e.g. ‘shutter control’) are important issues to be resolved. Reflecting on the previous Session, it will be essential that appropriate national and international legal regimes are set in place to facilitate new business and benefits in these areas.

Key enabling technologies include inter-satellite and satellite to ground optical links, small satellite propulsion to maintain the integrity of constellations, debris removal (albeit with dual-use overtones), and economic small satellite launchers. The latter will be critical for the replenishment of constellations and is an opportunity that the UK is exploring through its interest in spaceports.

While telecommunications and navigation are now largely in the private sector, and space science is likely to remain in the public sector, Earth Observation (EO) is in a transitional phase. The democratisation of Earth Observation services (not to be confused with ‘free data’) will happen when Space becomes an embedded utility such that the user need not know or care about its source. Companies including Skybox Imaging, Planet Labs, Urthecast and BlackSky are leading in this area. Rather than seek maximum EO coverage, Urthecast’s approach is to minimize revisit times at key locations through coordinated satellite observations. Its current constellation of four sensors will be supplemented by a further 16, including optical and Synthetic Aperture Radar (SAR) payloads in partnership with SSTL.

According to Wade Larson, data democratisation involves ‘providing unhindered and near universal access at an affordable price point, and in formats and on platforms that do not require expertise within an Eco-system, that attracts third-party investment and innovation that significantly broaden the utility of the data for the average person/organisation’. Therefore data democratisation will require that two obstacles are overcome: access – data is currently expensive, hard to obtain and scarce; and user capability –a high level of expertise, capital and recurrent investment is needed to understand and manipulate data sets. Democratised services might involve a three tier business model involving business–to–government (B2G) through traditional EO data provisions; business–to–business (B2B) through Big Data services, data analytics, machine learning etc. and business-to-consumers (B2C) through applications. B2C applications of EO remain speculative and somewhat an act of faith. Nevertheless, there is a strong belief that once data is democratised creative and innovative applications will follow.

Despite the benefits afforded by democratisation of data services, the commercialisation of identity, especially as applied to the individual, is becoming a pervasive issue. Private citizens can be subjected to unwanted intrusion into their private lives through disclosure of personal Data which that person expected would remain private and personal. In the case of public figures such cases are commonly justified on the grounds of public interest but, particularly in more prosaic cases, there is ongoing debate about the need to protect a person’s privacy in circumstances where personal or private Data pertaining to that individual is misused. English common law does not fully recognise a general right to privacy, which has led to other ways to establish a privacy law such as by invoking statutory Data Protection laws, contractual obligations of confidentiality and the European Convention on Human Rights, now incorporated within the British Human Rights Act, which provides an explicit right to respect for a private life.

While some areas of the telecoms market appear to be relatively flat (e.g. TV services), others continue to grow, especially mobile internet provision. Many systems depend critically on access to a high speed internet pipe. Telesat is an interesting case study of a leading global satellite operator created and based in Canada. In its formative years it benefited from clear and simple Canadian government mandates – for instance to provide telephone and notational broadcast services to all who lived in Canada regardless of location, or to provide internet services to all schools. While Canada continues to look to the Space sector for communications and for the security of its borders, recently government policy in this area in Canada has been less evident. In comparison with the UK which has benefited from clear policy documents around security and economic benefit, Canada appears to have 'lost its way'.

Demand was seen as the main enabler for innovative growth. While science provides opportunities to create innovative technology and techniques, at the end of the day demand is the key driver. Other essential elements include a rational decision making process, that is free from delusion, and the availability of investment. The latter comes from a demonstrated return on investment and a strong competitive position – a low cost per bit. Smaller satellites provide useful flexibility in this area.

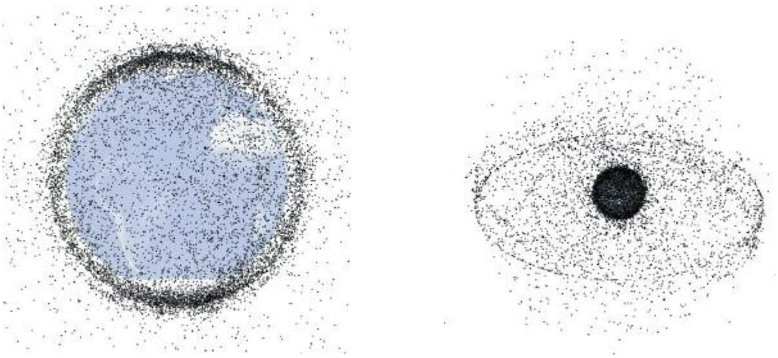
In both the UK and Canada there is a fear that policy will lead to a 'free market' in Space business development with less and less funding coming from government. However, governments have a number of important roles in the creation of a thriving Space economy:

- By ensuring an appropriate regulatory framework that is competitive on the global stage – indeed devolution of this to Canadian provinces or nations within the UK could better stimulate competition and reflect local priorities;
- Through the creation of essential infrastructure. While downstream delivers the return on investment, it is the upstream, in a low return situation, that creates the potential. For example, £16m investment in small satellites by the UK over 30 years has returned 45 to 1 in exports and has been essential to the development of a very strong market position.;
- Through the development of key, enabling technologies and helping them through the 'valley of death' to become commercially available;
- Through the development of the capability by which data is turned into knowledge by the application of underpinning science;
- Through the stimulation and facilitation of downstream markets and the provision/commissioning of common downstream services, e.g. Space Situational Awareness;
- Through acting as an anchor tenant, providing a guaranteed market for satellite services yet giving scope for commercial development and avoiding over-dependence on government business;
- Through the encouragement of a more diverse workforce that better reflects the user community and national aspirations, and also helps meet the very

- demanding human resource requirements for the future in the face of a currently poor age profile;
- Through the coordination of diverse governmental funding streams such that investment in Space does not fall between conflicting priorities.

Session 3: Surveillance and Security

The title of this session relates to the surveillance and security both of and by Space assets. The gap in Space between 100 and 36,000 km around the Earth is shared by the vast majority of operating satellites and other Space objects. To the satellite owner there is the risk of collisions and loss of operation, to those nations that depend critically on the sustainability of this environment the risks are shared and the potential consequences much graver.



Satellite distributions in (left) Low Earth Orbit (LEO) and High Orbit (right) – Courtesy of NASA.

In terms of national security, Space assets provide an important service or a threat, depending upon your viewpoint.

It was evident that there was a natural connection between this session and the discussions earlier in the day, notably the Politics and Legal Framework of Space.

The session began with presentations by Professor Richard Crowther, Chief Engineer, UK Space Agency, and Professor James Fergusson, Centre for Defence and Security Studies, University of Manitoba.

'Space is Congested, Contested, and Competed' – Richard Crowther.

Congestion relates to the physical crowding of Space, particularly in low earth orbit (LEO) and geostationary orbits (GEO). The possibility of collision between satellites and other high speed objects (space debris) poses a real risk to Space assets. Moreover, these regions are relatively unique. While in principle as LEOs become congested, it is feasible to operate at higher and higher altitudes albeit with some loss of performance, this is not possible in GEO where there is a narrow ring around the equator at a fixed altitude at which satellites co-rotate with the surface of the Earth, remaining at a fixed position in the sky as seen by someone on the ground. This is very useful for global communications. Only satellites in these orbits provide continuous communication to static Earth-based antennae such as domestic satellite dishes. Worse still, some GEO longitudes are much more attractive than others, making the population of satellites very bunched and so locally more congested. The relative velocity between objects in LEO is measured in ~10 km per sec and the energies involved are therefore formidable, for instance a £1 coin at 10 km/sec (or 36,000 km/hr) has the same kinetic energy as a minibus travelling at 100 km/hr. It is easy to imagine the potential for damage, even paint flakes can cause serious damage to a spacecraft under these conditions.

Collisions are not a hypothetical concept. For example, the results of minor collisions are visible on the International Space Station, while in 2009 the disused Russian Kosmos-2251 spacecraft collided with the Iridium-33 satellite, increasing the amount of space debris by 10% at a stroke.

Space is contested because it has strategic benefit. Anti-satellite weapon demonstrations by China (Feng Yun) and the USA (USA-193) in 2007 and 2008 respectively are testament to this.

Competition is a natural consequence of the commercial potential of Space. Whether it be associated with the unique geostationary longitude slots or the spectrum needed for communications (both geostationary and, increasingly, lower orbit systems). We have also seen a market created in 'paper satellites' in which the commodity is bandwidth.

The UK government response to the three Cs listed above (Congested, Contested, and Competed) are the three Ss of Safety (in response to congestion), Security (in response to the contesting of space) and Sustainability (in response to the competition). Three UN bodies address these issues. The Committee for the Peaceful Use of Outer Space (COPUOS), the Conference on Disarmament, (CODUN) and the International Telecommunication Union (ITU). CODUN has made little progress in recent years and since Safety, Security and Sustainability are interconnected, COPUOS has taken on a wider remit. The ITU deals with spectrum allocation. The Outer Space Treaty of 1967 was also supplemented by the Rescue Agreement of

1968 (dealing with property rights in Space), the Space Liability Convention of 1972 (dealing with State responsibilities for their actors), and the Registration Convention of 1974 (dealing with notification of States' activities in Space, when, where and why). These treaties implied an obligation for States to implement national legislation. In the UK this manifested itself in 1986 as the UK Outer Space Act, still very much 'Fit-for-Purpose' according to Crowther.

A wide variety and huge number of man-made objects orbit the Earth, and just one, as far as we know, natural object, the Moon. Space objects are classified as follows: operational spacecraft; fragments; mission related objects; rocket bodies; defunct space craft. Only 7% of this material is currently functionally useful while most comes from collisions and breakups. Upper stages of rockets tend to remain in orbit for some time, as do the various interface adaptors etc. that form the class of mission related objects. We seek to 'Protect and Predict'. Satellite protection is afforded by physical shielding (e.g. as used on the Space station to protect astronauts), reduction of on-board stored energy at end of life (to avoid disruption of the satellite if this energy is released), and avoidance (orbital manoeuvres to avoid collisions). To receive a licence from the UK will require that rocket bodies are removed from orbit with their redundant objects attached, and that satellites are also removed from orbit after their useful life. Moreover, licensed operators and their Space assets are monitored to confirm compliance with their obligations. It is perhaps not so clear what the consequences of non-compliance are in reality.

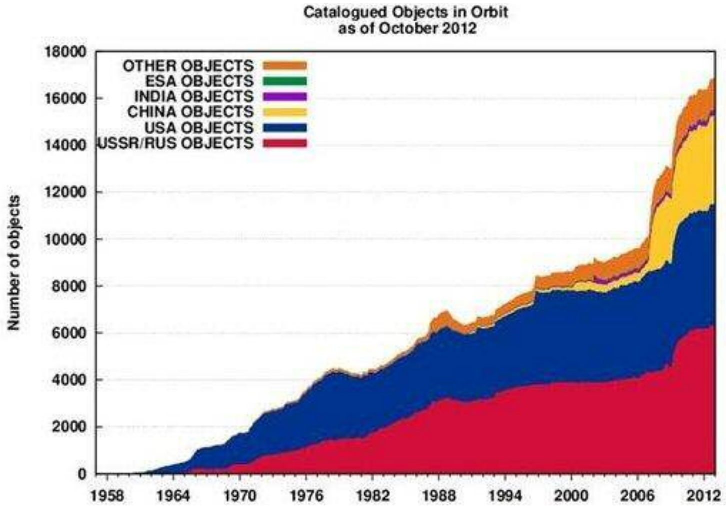
Radar and optical telescopes on the ground can track objects down to 10 cm in size in LEO and down to 1m in GEO. Detection of objects down to 1 cm in LEO is possible. Orbital populations of smaller objects can be deduced from local observations from satellites and the frequency of impacts seen, especially on the space shuttle, the Hubble Space Telescope, and more recently the ISS where inspection and even recovery of 'witness plates' is possible. Altogether this allows us to make good estimates of Space object (space debris) population densities for a wide range of sizes, and to monitor how it is evolving over time. It is clear from such observations that damage and the creation of secondary Space debris from impacts is commonplace in LEO. From these population studies it is evident that the greatest risk to satellites comes from the <1cm population (note the comment about the energy of a £1 coin in orbit above).

The obligation to re-enter objects inevitably leads to an increase in the number of such re-entries, some of which reach the ground! We cannot simply transfer risk from one place to another. The passage through the atmosphere is very arduous for a re-entering object and so only those of a spherical or cylindrical shape (and robustness) make it back to Earth. Such objects tend to spin-up on entry which in turn spreads the heat load and reduces 'burn-up'. Therefore spacecraft design has to include a 'design for destruction during re-entry' aspect along with the many other functional and non-functional requirements.

The UK policy of Predict and Protect is enabled by shielding below 1cm objects and by collision avoidance above 10cm, however in the 1-10cm range we have a problem. For those objects that we cannot track we cannot protect satellites and so we are vulnerable. The lethal population of objects in space in this range is around 400,000!

Orbital collision prediction is not an exact science, and while refinement accuracy of potential collision probabilities can be undertaken, in reality it is still not possible to achieve certainty. Collision possibility predictions can become so commonplace (and of low likelihood) that operators may prefer merely to take the risk rather than disrupt operations through a complex satellite manoeuvre operation – as happened in 2009 between Kosmos and Iridium.

The years 1960 to 1990 saw a growth of about 270 tracked objects per year. The increase is affected both by the number of launches and by the rate of natural re-entry due to atmospheric drag, itself a function of the 11 year solar cycle. By 1990 the number of tracked objects had reached 8000 and some developed nations began to be concerned and to implement legislation (as mentioned above) to reduce this increase. By 1995 the effects of this legislation could be seen and between 1996 and 2004 the increase in tracked objects was reduced to around 90 per year, a reduction by a factor of 3 in the increase, but an increase nevertheless. Unfortunately the Feng Yun anti-satellite test (~3000 extra objects) and the Iridium-Cosmos collision (~ 2000 extra objects) have more than wiped out all the good work achieved through regulation. The number of tracked objects in 2011 was around 16,000.



Evolution of the traced space debris population - Courtesy ESA

The following table gives an estimate of the population density of Space objects by size:

Size	Number	% Mass
>10 cm	>17,000	99.93
1-10 cm	>400,000	0.035
<1cm	>35,000,000	0.035
Total	>35,000,000	>6,000 tonnes

Note the enormous potential for the >10cm objects to create many millions of potentially lethal smaller objects. 'If you want to deal with the space debris problem, you deal with it when the objects are intact rather than try to collect the pieces after the event' – Richard Crowther. Regulators are seeking to maintain the very high percentage of mass in tracked objects, which is much more important than simply the mass of objects in Space. However, the majority of tracked objects are non-operational and so we have no control over them. To remove them as a threat (and the largest threat is their potential to create more threats), we would need to engage directly with these objects, a challenge both practically and legally. Practical solutions include nets, grapplers or even ground based lasers. However, it is essential that the very act of engagement does not itself pose an even greater risk. A system for the removal of a defunct satellite from orbit could also be used as an anti-satellite weapon – a classic case of dual-use.

Perhaps surprisingly, the increase in the number of proposed small satellites and CubeSats is not currently seen as a major increase in risk.

Space Weather (see Working Group 1) and satellite tracking are linked since the density of the thermosphere (where low earth orbiting spacecraft are located) is strongly affected by solar phenomena. A large part of the uncertainty that exists around re-entry locations and timing is due to uncertainties in space weather. The UK Met Office is beginning to provide thermosphere density prediction services, although direct measurement of the density of the Earth's lower thermosphere at around 100 – 200 km is very difficult.

Tracking of Space objects falls within the domain of Space Situational Awareness (SSA) and is dominated by the US. In the immediate wake of 9-11 the US response to the terrorist threat was to slow down very significantly the flow of people and goods across the US-Canada border. Canada sought to remind the US that this would undermine the US economy and in response the US simply noted that 'security trumps trade' – James Fergusson. This is indeed true in the area of Space surveillance and SSA. Space surveillance has been 'securitized', i.e. placed firmly within a security mind-set. There is no commercial case beyond government to undertake Space surveillance. That is not to say that Space operators have no civil or company involvement in Space surveillance/SSA. Satellite companies have an obvious interest in ensuring the safety of their assets against collisions with other spacecraft or space debris. Civil Space companies and Space operators know better where their satellites are than can be determined from ground-based tracking. For instance, the Space Data Association brings together satellite operators that share data which is critical to the safety and integrity of the Space environment, and includes Inmarsat, Intelsat, SES and Eutelsat. Working with such companies/organisations is pragmatic, and the US is looking at this option.

The inter-dependence of Space assets leads to the need for and the manifestation of international agreement and regulation. However, the creation of a global SSA infrastructure is always missing. How is the essential SSA data produced? Where are the assets? How are they governed? How is the data validated? Who pays? In practice, nation States take this on out of their own self-interest, for the public good and in some globally accessible way. This is all done to promote the peaceful use of Space and to inhibit the evolution of unwanted threats. However, given the predominant position of the USA in SSA and given the dominance of national security within the USA, the emergence of a global SSA is unlikely to occur. In the USA Space has a strategic defence significance and highly classified Space programmes exist therein. In the absence of its own national security-related filters, the USA would see a global SSA infrastructure and data service provision as a threat to its national security. A global SSA service would provide potential adversaries with targeting information for instance. 'Indeed, were national SSA services somehow co-ordinated on a global scale, the prevalence of national security agendas would probably lead to a system that is no better than the current US-centric arrangement' – James Fergusson.

Space Situational Awareness (SSA) has its origins in the Cold War and the threat of intercontinental ballistic missiles. It is therefore not surprising that in the US, SSA is a defence mission assigned to the US Strategic Command that is located centrally at the joint Space operational centre at Vandenberg Air Force Base in California. Both Canada and the UK have Memoranda of Understanding with US Strategic Command and a presence at the joint space operational centre. Indeed there are indications that the US is developing a new centre that will include allied surveillance assets. In short access to SSA information depends in part on the willingness of collaborating States to invest relevant assets – club membership requires a contribution.

The predisposition to see accidental happenings as evil intent applies in Space as much as anywhere else. It is fed by lack of transparency that leads to suspicion and pre-emptive/strategic action. Where SSA is concerned all parties operating in Space require a sustainable environment and are affected by the actions of others. Transparency and cooperation are essential ingredients in making Space Safe, Secure and Sustainable.

Within the context of a fundamentally defence sector enabled system, ground based surveillance limitations as mentioned earlier can be overcome with space-based assets, particularly for GEO. Indeed GEO satellites are now an important element of national defence capability, and therefore, so is a nation's ability to understand the 'local' potential threats from other satellites at similar locations. Space-based surveillance in the US began in the 1980s with the Midcourse Space Experiment (MSX), designed to track ballistic missiles in their mid-course phase. 2010 saw the launch of the first 'pathfinder' satellite in the US Space Based Surveillance Satellite (SBSS) programme for operation in low earth orbit. In 2014 the first two Geosynchronous Space Situational Awareness Program (GSSAP) satellites were launched and have since been declassified – an apparent statement to foreign nations that their activities in GEO are now being monitored. The programme also includes a small satellite that can accurately position itself with respect to other satellites – i.e. probably in relation to anti-satellite technologies and noting anti-satellite technology experiments still being undertaken by Russia and China. When it comes to SSA, the elephant in the room is US national security.

Of course, on-orbit servicing for GEO satellites is highly desirable for economic reasons – extending operational lifetimes already typically by 15 years. Is commercial pragmatism set to out manoeuvre security?

Canada's first dedicated military satellite, Sapphire, was launched in 2013 into low earth orbit and tracks objects out to GEO. SSTL provided the satellite bus. It is linked in to NORAD and was commissioned to ensure Canadian engagement in the US SSA programme following an internal US reorganisation of responsibilities.

'No great change in international governance of SSA is foreseen' – James Fergusson. While the US continues to dominate SSA, there is little to drive a change in the current situation. China continues to develop its own SSA capability, employing ship-based sensors to provide more global coverage. Until nations move beyond local, national interests there is unlikely to be a move towards a more global SSA system. However, if and when the US supremacy is challenged, a more globally based collaboration may be forthcoming that will allow the SSA issues and threats of space debris to be addressed in a more effective manner. After all, the original Outer Space Treaty had its origins in a US-USSR bilateral agreement.

Within the UK (and US) Space assets are seen as part of the Critical National Infrastructure (CNI), although this is not true in Canada where repeated attempts to establish this position have failed. Once identified as such and so present on national risk registers, its robustness and risk mitigation schemes can be put in place, such as redundancy or interoperability and complementarity with ground systems. The Colloquium would support a recognition by Canada of Space as a CNI.

Space Debris and Space Weather are areas of relatively greater public interest and so are the subject of media based stories relating their intrinsic threat to mankind or the economy. While the same general story repeats every ~ 5 years: event (whether hypothetical or real); statement of a larger problem; consideration of potential adverse events in the future; and general summary of what is and should be done, little appears to change. This could be because there is some intractable problem, because the individual events are merely someone crying wolf and in reality the risk does not justify a high enough priority, or perhaps because the predicted scenario is both low likelihood (i.e. they do not happen as often as every 5 years) yet dreadful (the adverse impact is very significant). In fact, the problems associated with Space Debris and Space Weather are technically very difficult to solve and while technology and systems improvements may reduce the likelihood or impact (as is the case with the increase in the number of space objects mentioned above), the risk persists and so stories repeat.

It is instructive to compare the conditions for space debris removal with the law of salvage at sea. In Space there is no concept of 'fault' and so an object or its owner cannot be considered in an illegal state merely because the particular property is defunct or poses a potential collision hazard to other spacecraft. To remove space debris currently would require the permission of the owner. Salvage at sea involves the appropriation of discarded or abandoned items (ships). In Space we are in the main talking about destruction through re-entry rather than recovery of material although there is some interest in in-orbit reuse of such spacecraft (e.g. the DARPA Phoenix concept). It was argued at the Colloquium that it will merely take a major nation to begin some form of space debris removal in order to stimulate associated regulation – to force a precedent. It is the case that material that poses a hazard to others could be removed, a situation common to most legal situations on Earth. Of course, the magnitude of a hazard that warrants removal is probably an issue. It was also argued that an important first step would be to build international confidence in space debris removal systems so that they were not seen in themselves as a potential hazard, i.e. to establish and reward best practice. Dual-use issues may not in fact be as onerous as some fear, there has been no reaction from China or Russia for instance to the EU funded UK 'Remove Debris' programme. The UK Space Agency is currently considering how it would deal with applications for space debris removal systems.

With space debris we have two distinct categories: that which currently exists and that which comes about after some agreement is in place regarding obligations and the definition of fault. In the former it is probably best to have an amnesty. In the latter case those States that fail to remove debris or cause debris to be in orbit must expect to suffer some consequence, presumably in the form of fines or restrictions on future licences.

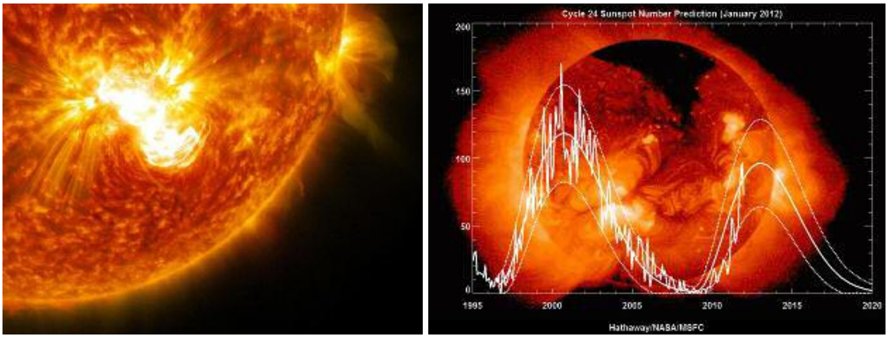
It was generally agreed that the current UN Space treaties do not satisfactorily address space debris – which is not surprising since 50 years ago the concept was not imagined. Voluntary agreements may be useful, but at the end of the day international agreement enshrined in legislation or regulation will probably be necessary. While we have succeeded in reducing the rate of increase of space debris it continues to rise, supplemented by collisions of one sort or another. It is not clear what might be considered an unacceptably high number of Space objects but an increase by a factor of two over 20 years would require around 5-10 satellite collisions, a seemingly high number. A situation could occur in the future where positive feedback creates an out-of-control growth in collisions, the so called Kessler Syndrome, with dreadful consequences to LEO.

Individual satellite operators are concerned with individual risks, either to their assets or of other assets. The former situation stimulates operators to cooperate with satellite collision avoidance initiatives or perhaps to trade the inconvenience and disruption of frequent avoidance manoeuvres with the associated economic risk of losing a spacecraft. The latter is a matter of liability associated with leaving satellites in orbit too long, not currently a problem outside the French licensing system. However, nations and groups of nations are perhaps more concerned about the sustainability of the Space environment and its continued economic viability rather than its status as a CNI. A risk to one spacecraft is then added to the risks to all other satellites, any collision being a problem for everyone, not just the unfortunate satellites involved. For a sustainable future we must account for both perspectives and for this reason we cannot leave it to the narrowly focussed, share-price driven commercial sector.

Four working groups explored a range of relevant topics, picking up on issues raised during the first three sessions. Each was introduced by one or two speakers and feedback was given to a later plenary session.

Working Group 1: Space Weather

While the Sun appears as a benign object in the sky, in fact it has a highly active surface that is racked by magnetic storms and, over an 11 year cycle, creates disturbances and ejections that have manifest impact on and around the Earth. The Earth's magnetic field provides a natural, albeit leaky, shield to much of this material. The scientific disciplines of solar physics and magnetospheric physics combine to underpin our understanding of this Sun-Earth connection. So significant is this connection that the US named its Space Weather research programme 'Living with a Star'. Indeed, it has been the US that has led the field in Space Weather science missions.



Left: Large solar flare erupting forms giant sunspot on 24 October 2014, Right: the 11-year cycle of solar activity – courtesy NASA

This working group was co-chaired by Professor David Jackson, Manager for Space Weather Research, UK Met Office, and Dr Christian Sallaberger, Canadensys Aerospace Corporation.

Space Weather relates to solar driven environmental changes on the Earth. In the main Space Weather comprises solar flares: sudden releases of energy in the form of optical to x-ray radiation; coronal mass ejections (CMEs) that are vast releases of material in the form of a plasma cloud that will take 1 to 4 days to reach the Earth; and radiation storms that originate in active regions typically characterised by sunspots, and cause very energetic particles to reach the Earth in less than an hour.

If magnetically aligned to the Earth's field, CMEs can cause interruption to large scale terrestrial power systems. They may also affect the ionosphere, which in turn affects GPS timing – the essence of GPS, and heat the upper atmosphere which in turn affects atmospheric drag and so Space Situational Awareness (SSA). Solar flares also affect the ionosphere, which in turn affects communications. In the presence of an extreme Space Weather event it is thought that up to 10% of orbiting spacecraft could be affected and that we might lose GPS services for up to four days. Radiation storms can result in an increased radiation dosage for astronauts or frequent air travellers, and/or damage electronics on satellites. The risk to the new constellations of satellites might also be severe. As the events last several hours to days, even the Earth itself might not provide shielding and in the worst case an entire constellation might be compromised since all of the satellites would be equally vulnerable.

Within the UK National Risk Register, Severe Space Weather sits alongside low temperature, heatwaves, and poor air quality events as of moderate impact and medium/high likelihood. Similarly severe Space Weather also appears on the

Canadian federal All Hazards Risk List. The Met Office is the risk owner for Space Weather in the UK and is responsible for providing guidance, monitoring and informing, and to some extent for forecasting and for the notification of alerts, which it does mainly through its recently launched on-line service. Through this service the Met Office provides advance warning of geomagnetic storms, solar flares and radiation storms.

Technical mitigation of Space Weather impact is possible and routinely adopted. This consists of such things as back-ups, resilient designs, and radiation hardened components. Satellites in orbit are designed to survive Space Weather, albeit at some loss of performance and disruption of services.

The current Space assets used to observe emerging and actual Space Weather events comprise science satellites deployed for scientific research rather that Space Weather forecasting. These together with our understanding of the underlying, highly complex physics are not sufficient to provide a highly reliable and robust, low false-alarm rate prediction service. Not that the current Met Office service is unhelpful, only that greater accuracy and a greater warning time would allow companies and astronauts to be better prepared and avoid nugatory effects. Indeed the Met Office is very transparent about the accuracy of individual forecasts, relying on a probabilistic approach (rather than a causal model), and ensuring that subscribers are aware of its limitations. The Canadian government supports an equivalent service through Natural Resources Canada, available at spaceweather.gc.ca.

Our experience with the Soho satellite (located at the first Lagrangian point, L1, 1.5 million km from the Earth in the direction of the Sun) and the two Stereo satellites (which have passed through L4 and L5, points 60 degrees around the Earth's orbit) provide a useful basis for the design of a dedicated Space Weather mission. Both Soho and Stereo are nearing the end of their lives (one of the Stereo satellites has been out of contact for more than a year and it seems unlikely it will be heard again) having greatly exceeded the designed mission durations, and when these are gone our current Space Weather services will be reduced.

As alluded to earlier, any system that is able to forewarn against events that could have humanitarian consequences, including Space Weather through its disruption to power and other services, should be made available to those at risk. This makes it difficult for that information to be the basis of a commercial activity unless the service is commissioned by affected nations or industries. A group in the UK, led by the Met office and including Space industry and major Space science research groups, strongly promotes the use of an observatory satellite to be placed at L5 – the so called 'Carrington' mission named after Richard Carrington, the observer of the famous 1859 solar super-storm. This would be the first operational Space Weather mission and would provide a side-view of CMEs as they move towards the Earth. It is surprising that Canada is not more active in Space Weather missions, given that the greatest vulnerability of power systems is in nations with large east-west extent and that the largest recorded Space Weather incident occurred in Quebec.

To assess accurately the consequences of a CME arrival it is important to understand its magnetic signature since the result of the impact depends upon how well this matches the configuration of the Earth's magnetosphere. To know this a spacecraft at the L1 is needed since this point is on a direct line to the Sun – the US has committed to such a mission. The combination of suitable spacecraft at L1 and L5 would provide a formidable basis for the next generation of Space Weather prediction service and would be a natural collaboration between a US and a UK led consortium.

An improved Space Weather understanding would be beneficial to many countries beyond the UK and Canada, and a mission or set of space missions should be explored that have cost-sharing participation from other countries (Europe/ESA, USA/NASA, Russia/RKA, China/CSA and others). The ESA is currently scoping out an L1/L5 mission but progress is very slow. A national or bi-lateral approach would be faster and less expensive. Speed is a concern given the limited life of existing Space assets.

Within the UN Committee on the Peaceful Use of Outer Space (COPUOS) a series of guidelines is being developed for the long-term stability of Outer Space activities. Space Weather has been extensively discussed. Building on these discussions Canada proposed last year that an expert group on Space Weather be formed. The first session took place in February 2015, with the next planned for February 2016. This is an excellent opportunity for the UK and Canada to work together to identify what collective actions States could take at the political level to address the issues of Space Weather, building on the work of the World Meteorological Organization (WMO) and others. There should be greater standardization of Space Weather warning services and it should be remembered that an Inter-programme Coordination Team for Space Weather exists within the WMO that is looking into this amongst other things.

The impact of a Carrington-type event today has been estimated to have a cost of the order of $billions. The likelihood of such an event in the next decade or two is of order 10%. It would appear that a significant budget is likely to be justified to mitigate against the effects of such an event. This is unlikely to come from the insurance industry, which is not strongly motivated to reduce risk. A socio-economic cost/benefit analysis is needed to justify the financial costs of improved prediction. Such a study is currently under way in the UK funded by the UK Space Agency and is led by the Met Office with support from Imperial College, Mullard Space Science Laboratory and RAL Space.

Working Group 2: Space Debris

This group was co-chaired by Ian Taylor MBE, Chair Lunar Missions Ltd, ex UK Minister of State, and Dan King, Director for Business Development at MDA Robotics & Automation.

The deliberations of this working group built upon much of the material described in the Surveillance and Security session. In particular, it was noted that there are around 23,000 space objects greater in size than a grapefruit, 400,000 larger than a marble, all travelling at a speed of the order of 17,000 miles per hour. These pose a threat to our Space assets, which are valued in the order of a trillion dollars. This threat and the cost of its mitigation, through monitoring and collision avoidance manoeuvres, is a serious issue which leads to a loss of operational effectiveness (productivity) and reduced operational lifetime.

The following conclusions were reached:

- The problem is getting worse, as the amount of space debris and the number of operational satellites increase. While national legislation has reduced the rate of increase of space debris, it remains on an upward trend. It is unclear when this might hit a critical point at which satellite collisions will become increasingly commonplace and lead to a positive feedback. Nevertheless, we do not appear to be facing this problem in the near term.
- There is ‘congestion’ in low earth orbits. 1996 saw the first recorded collision between two artificial objects in space when the French military satellite Cerise collided with space debris from an Ariane rocket. The Iridium-Kosmos collision in 2009 was the most famous incident.
- The problem of congestion has spread to geostationary orbits.
- The number of CubeSats (with dimensions ~10-30cm) is increasing, their missions are increasingly commercial in nature, and many have orbital, but not operational, lifetimes of 25 years. May 2013 saw the first collision of a CubeSat (Ecuador’s NEE-01 Pegasus) with debris from a S14 Soviet rocket

launched in 1985. While not currently a major collision hazard, the growth and governance of CubeSats should be monitored carefully.

- Very large constellations of satellites are being proposed. For instance 'One Web', a mature concept, would provide a network of 720 Ku band communications satellites in low earth orbit. Even larger constellations have been proposed including those of SpaceX and Samsung, the latter involving a 4600 satellite constellation – a far cry from the 66-satellite strong Iridium network. Such constellations would be designed to have an operational lifetime of 30 years with satellites being replaced as they fail.
- The Chinese Anti-satellite weapons test, Feng Yun in 2007 and the satellite-satellite collision of Iridium-Kosmos 2009, have made significant contributions to space debris.
- Remedies to the problems of Space Debris include manipulation, deflection, removal and de-orbiting. Technologies under development or conceptual design include active approaches such as harpoons, nets, clamps, laser cannons, and passive approaches to speed-up de-orbiting through increased atmospheric drag, such as sails.
- ESA's Clean Space initiative includes a Space Debris mitigation dimension. Space Debris research in various forms, including hazard assessment and new technologies, is under way at many sites including Strathclyde and Surrey Universities in the UK. The Space industry is also collaborating in this area, e.g. Airbus, Thales Alenia and OHB System AG.
- The Inter-Agency Space Debris Coordination Committee is an international governmental forum for the worldwide coordination of activities related to the issues of man-made and natural debris in Space. Its primary purpose is to exchange information on space debris research activities between member Space agencies, including Canada, UK, USA, Russia, China, India, Japan and ESA, to facilitate opportunities for cooperation in space debris research, to review the progress of ongoing cooperative activities, and to identify debris mitigation options.
- While the main problem of Space Debris is in low earth orbit, it is geosynchronous orbits that afford the greater wealth creation.
- Questions remain over who pays? Who owns debris? What is appropriate regulation? What are the enforceable penalties for non-compliance? How do we deal with dual-use? – see also the Surveillance and Security session.
- The following proposals were made by the working group:
    a. The UK and Canada should co-sponsor US proposal for the establishment of an expert group on Space Operations within the UN

COPUOS Scientific and Technical Sub-committee. This would be an excellent opportunity for the UK and Canada to work together to identify what collective actions States could take at the political level to address issues of space debris.

b. The UK and Canada are perceived as honest brokers within the international community without the baggage of the USA and US security, but are trusted partners of the USA. Therefore they should position themselves as champions for servicing/active debris removal.
c. As champions of innovation, such as small satellites, the UK and Canada should show leadership in promoting the responsible use of Space, such as more balanced operational/disposal lifetimes, through licensing regimes.
d. Within the UK and Canada academic groups are leaders in both technical and legal frameworks. Their role in coordination should be promoted.
e. The UK and Canada should support and encourage the ESA to deliver on their Clean Space initiative.
f. The value of in-orbit servicing and debris removal capabilities should be recognised with regard to sustainability, e.g. through the extension of space asset lifetimes and consequential reduction in the number of launches.
g. There is a parallel between Space Debris and Global Warming. We should note these parallels and learn lessons appropriately, e.g. Space Debris mitigation benefits both Space and non-Space faring nations. The solutions are likely to comprise many small acts, the enormity of the problem should not prevent small scale mitigations on a piecemeal basis. We should not await a catastrophe before taking decisive action.
h. Existing fora should be used to leverage solutions, such as COPUOS.
i. Envisat, the now defunct ESA Earth Observation Satellite weighing >8000 kg is considered the 8th most serious space debris hazard. It or another high ranking hazard should be used as a case study, in developing debris removal technology. However, it was also noted that this should not be of an experimental nature, i.e. human lives should not be put at risk. Indeed, removal of space debris which will be destroyed on re-entry is a lower-risk place to start.
j. Existing controlling bodies such as the ITU and the insurance industry should be encouraged to provide a framework that mitigates against

the hazards of space debris. However, it was noted that the insurance industry is more interested in resupply and recovery than removal.

Working Group 3: Global Monitoring of Hazards and the Environment

For reasons mentioned earlier Global Warming and Climate Change were not covered in this working group.

The group was co-chaired by Dr Nick Veck, Head CEO Office, Satellite Applications Catapult, Harwell, UK, and Wade Larson, President and COO Urthecast.

Mankind faces many threats that might be foreseen or monitored through observation from orbiting satellites. These include earthquakes, volcanic eruptions (and ash clouds), tsunami, large-scale fires, floods and many more. The list gets even longer when one adds those threats to the environment caused by man.

Currently the approach to hazard warning is somewhat *ad hoc* with some systems already in place, while others are used in a piecemeal fashion. Europe's Copernicus Earth Observation programme provides an opportunity to do better, while new commercial initiatives offer further improvements.

The International Charter on Space and Major Disasters was formed in 2000, Canada joining at that time while the UK joined in 2005, through an innovative use of the SSTL Disaster Monitoring Constellation (DMC). The DMC is a unique international partnership combining national objectives of the DMC members, humanitarian aid and commercial activity. The Charter pools access to Earth Observation data from its members to support humanitarian response to disasters – both for those signatories of the Charter and more widely. For instance, support was provided to Yemen following the effects of a cyclone on 3 November 2015 after the UN Office for the Coordination of Humanitarian Affairs initiated the request for this information.

Left, DMC satellites in preparation at SSTL; Right ESA's Copernicus front page

The disaster risk management cycle comprises three phases: the pre-disaster phase in which the emphasis is on risk assessment, mitigation and prevention, and preparedness; the response phase where warning and evacuation, lifesaving, immediate assistance and damage assessment are key; and the post-disaster phase, which is more long term, providing ongoing assistance, restoration of infrastructure, reconstruction, economic and social recovery, ongoing development and risk assessment, completing the lifecycle. Earth Observation has a role to play in all three phases.

The European Earth Observation Programme, Copernicus, through its Emergency Management Service provides analysis and services across the above phases. Note that the International Charter on Space and Major Disasters only provides imaging data, not its analysis or interpretation. Copernicus offers: Rapid Mapping including reference mapping, impact delineation maps, damage grading maps; and Risk and Recovery mapping, which offers on-demand geospatial information in support of emergency management not related to immediate response.

The working group made the following observations:

1) In the future the private sector has a lot to offer in terms of data/image provision and value adding services. Provision of information through a commercial arrangement is not immoral, especially during the pre- and post-disaster phases. Yet in practice barriers are still very evident with public sector organisations being unable to find the required resources. Within the Charter mentioned earlier this issue is already addressed since the signatory States are supporting their own satellites as anchor tenants or the like. This model might be widened to incorporate a more general commercial sector.
2) Earth Observation should be seen as only part of a disaster response lifecycle and other sources of information from the ground need to be integrated with it for best effect – a holistic approach is often very important.
3) An “X-Prize” approach could generate innovative solutions from the private sector. It would become industry focussed and engaged in the provision of new services.
4) Timeliness of data is an important issue. While the production of data products has speeded up (now only a few hours compared with 2 days for the Boxing Day Tsunami of 2004), this is ultimately limited by the repeat period of the satellite coverage.
5) The interpretation of data requires compatibility between IT systems and in this case a ‘standard’ data structure would be very beneficial.

6) The quality of Earth Observation data continues to be an issue. Higher quality data in terms of spatial and spectral resolution would drive ever improving applications – a point noted by Astrosat for instance when creating new disaster management tools.
7) Copernicus is a great opportunity to show the value of satellite Earth Observation – hopefully leading to a more global, rather than European, solution through GEO/GEOSS. A global organisation would need to take ownership of the problem. The role of the UN (e.g. UN-Office for the Coordination of Human Affairs, World Food Programme, UN Institute for Training and Research, etc.) is important. Director General, European Commission's Humanitarian Aid and Civil Protection Department (ECHO) could become a champion for the technology.
8) The UK and Canada should conduct a capability audit. Each country has a lot to offer, providing various elements of the supply/value chain, for different emergency situations. This could lead to a "catalogue" of services being provided.
9) Three layers of infrastructure were identified: the satellites delivering the data; the processing and value adding platform; and the downstream integration of data into highly informative products.
10) Overall there is a great opportunity for private sector involvement in an area that has historically been dominated by the public sector/space agencies. Indeed, it could build and operate this infrastructure.

The link to data democratization mentioned in session two is apparent. As this happens, engagement by the commercial sector in areas of disaster relief will follow naturally with innovative products appearing in the market place.

Working Group 4: Contention for Spectrum

This group was co-chaired by Professor Jim Norton, Royal Academy of Engineering, Engineering Policy Committee, and Paul Bush, Senior Vice President, Corporate Development Telesat (retired).

The working group explored four important areas and for each made concise recommendations:

1. Major change is anticipated:

- A quantum leap is to be expected in the level of satellite activity driven by both large constellations of LEO Communications Satellites and dramatic new deployments of Earth Sensing Satellites.

- In radio terms, these large numbers of small satellites may be less clean in their out-of-band radio emissions, not least due to the lack of space and weight for traditional filters – a matter of concern.
- The timescales for change are now not compatible with the timescales of missions, especially in the small and micro-satellite domains. While useful progress is being made at the national level both within Canada and the UK, a more global solution is necessary.
- The UK has established a coordination group, the Space Spectrum Advisory Committee that is co-chaired by Ofcom and the UK Space Agency.

Conclusions:

- A review of processes at the ITU should be undertaken to determine whether they remain 'fit for purpose'? A World Radiocommunication Conference (WRC) every 3 or 4 years on its own may no longer be adequate. There should be greater use of task based groups of experts (after the COPUOS model) and expedited processes to implement urgent recommendations.
- That appropriate emission masks be agreed for these new generations of satellite. A Commission of European Post and Telecommunications (CEPT) group could lead this in Europe, and that, as part of pre-flight testing, compliance should be verified prior to launch. This would be consistent with the level of test and verification being applied to even the smallest satellites as part of their build process.

2. Increasing contention at GEO orbit for slot and spectrum resources:

- There is increasing abuse of the existing procedures in terms of 'paper satellites', orbital placeholders and un-agreed changes in transmit and receive frequencies.
- There is a pragmatic need by operators to swap frequency assignments amongst themselves to establish suitable spectrum suites for large, high power, multi-function satellites.

Conclusions:

- An examination should be undertaken as to whether adequate GEO enforcement processes exist and are being applied properly against those gaming the system.
- The pragmatic approach taken by operators is akin to spectrum trading and might usefully be formalized on that basis.

- An examination should be undertaken of the processes used in Aviation Law (1944 Chicago Convention) through regular addenda and codicils to determine whether these might have utility in international spectrum management.
- A full scale change to WRC date priorities is not recommended. Broadcast for International Understanding (BIU) milestones, and general operational conditions of licence should remain as they are. Operators that have filings in place would maintain their date priority and milestone obligations.

3. Increasing contention for spectrum between satellite and terrestrial systems:

- Mobile phone company lobbying is highly robust and the value of the space sector, as evident at this Colloquium, is often underappreciated at governmental levels. The technological dimension of telecommunications can appear impenetrable to those concerned more with applications and implications.
- It is recognized that there will be great pressure for increased spectrum sharing between satellite and terrestrial systems. This is already the case between:
    - Earth Sensing SAR and WiFi (Copernicus at 5GHz).
    - 5G Mobile and Satellite services at 6GHz and above.
    - C Band Satellite and terrestrial broadband mobile services.

Conclusions:

- A full and detailed interference and mitigation analysis should be undertaken in each case, such that sharing decisions can be properly informed.
- The satellite industry and downstream users should build full life economic value cases comparable to those developed by the terrestrial mobile communications community so that decision-making can be fully informed and understood.

4. Earth Observation:

- Within the ITU Earth Observation is seen as an area of science rather than of commercial satellites. However, with the upsurge in Earth Observation’s importance to global issues and its potential for commercial exploitation, this seems inappropriate.

Conclusion:

- The ITU should be encouraged to view Earth Observation as more related to commercial satellite activity than pure science.

Session 4: Space: The One truly International Environment

The final session began with presentations by Dr David Parker, Chief Executive of the UK Space Agency and Dr Mac Evans, Former President, Canadian Space Agency.

Dr Parker gave a prepared speech which is reproduced in full in Annex 1.

It was noted that both Canada and the UK have been Space-faring nations for more than 50 years. Following a US invitation to collaborate on international space missions the UK joined in with Ariel-1 in April 1962, and Canada with Alouette-1 in September that year.

From the first beginnings, UK activities in space blossomed both through national projects and increasingly through cooperation with its European neighbours. The UK was a founding member of the European Space Research Organisation (ESRO) and the European Launcher Development Organisation (ELDO), which merged to form ESA in 1975.

David Parker noted that “Canada has achieved remarkable international recognition for its Space activities through high profile successes like the Canadarm on the Space shuttles and ISS; and projects like Radarsat”.

Even with a number of significant Space achievements the UK breadth and importance of UK Space activity was relatively less well known until recently when a determined effort changed the situation. Policy makers recognised the enormous potential of the downstream sector as well as the substantial upstream activity. At the time the sector was worth about £7bn to the UK economy and a long term action plan (the space IGS) was drawn up to grow it to £40bn by 2030. By 2014, it had already risen to £11.8bn. Most of the 16 original actions in that original plan have now been delivered and it appears that the issue of a National Space Strategy, the last open action, will soon be completed.

First and foremost was the creation of the UK Space Agency itself – fully operational from April 2011 and its new national Civil Space Strategy for 2012-2016. This identified six pathways to growth, and an increased emphasis on exports and inward investment is one of the six. Practical actions included selectively increasing the UK’s investments in the European Space Agency – doubling the contribution to the telecoms programme, for example.

The UK has supported novel projects such as UKube-1, its first national CubeSat, built by Clyde Space which completed its mission in 2015; and SABRE, a radical air breathing rocket that could transform the cost of space access by enabling a reusable launch vehicle.

The role of the UK Space Agency is often to create the right eco-system for the Space sector to thrive. One example is through the representation of the UK at international fora on the sustainability and safe use of Space. Another example is the growing UK Space Gateway at Harwell, Oxford, where a cluster of Space facilities has been created. Rather than a green field site, the Gateway is embedded in a wider science and technology campus with existing world class science facilities. Several international organisations are now on site – not least ESA. 'Think of (the Gateway) as a docking port to the UK Space scene' - Parker.

Meanwhile the UK commercial satellite sector is thriving. Avanti Communications is doing well in Africa while Inmarsat is forging business partnerships with China. SSTL's success in making Space more affordable is now being applied to navigation satellites through Galileo; and to telecommunications for global operator Eutelsat with the Quantum satellite, which the UK is co-funding.

Engagements in global Space science abound with numerous very successful contributions coming from the UK, including the UK led mid-infrared instrument that was the first of the four instruments for James Webb Space Telescope (JWST) to be delivered to NASA; and the Rosetta Spacecraft that took Europe to Comet 67P in August.

International collaboration is part of the UK's Space DNA which is further manifested by its now full participation of the International Space Station. The UK hopes that Tim Peake's Principia mission to the ISS will have the same impact as Chris Hadfield's mission. To grab the interest of the next generation, the UK has created two dozen education projects around Tim's mission, like the AstroPi project with the Raspberry Pi foundation, focused on computer coding. The UK Space ambassador network will be working in 1000 primary schools and progress is good in signing up 5000 secondary schools for the 'Rocket Science' project with the Royal Horticultural Society.

While the ISS is a successfully internationalized endeavour, nevertheless neither China nor India, important nations in the Space sector, are participating. Rather, China has invited nations to join its own programme. There are global tensions and fears around the aspirations and actions of the major space powers and David Parker expressed concern that such tensions will inhibit an international response to global issues such as space debris. Deepening international collaborations in space science and exploration have traditionally helped improve relations and this should be seen as an important outcome of such programmes.

To encourage the factor of four increase in space exports, the UK is looking at services rather than at hardware and in the style of ‘New Space’. In this respect the UK has instigated its International Partnership Space Programme, a programme that is designed to build sustainable relationships with developing space economies. For instance, the UK is working with South Africa and Ghana to improve airline flight safety, and Kenya to improve maternal and child health services. In recent years the UK Space Agency has signed international agreements with new partners including Algeria and Indonesia, as well as old friends such as France. ‘I see great potential for an operational (international) Space weather mission’ David Parker.

Canada is lagging behind is former engagement. ‘As pointed out in the 2012 Emerson Report to the Government of Canada on the Canadian Space Program, there is a strong sense that Canada has lost its way in Space’– Mac Evans. This is a time of re-evaluation. Canadian governmental support and engagement with ESA has fallen while the UK’s has grown, in the UK’s case partly due to a succession of supportive space ministers. The UK has made Space a key element of its growth strategy. Canada could learn lessons from the UK, following its lead.

Canadian experience indicates that at times major space programmes do engender cooperation, such as with the ISS, at others not so (such as Radarsat 1 with the UK). International partners sometimes drop out. The US, a nation rather known for this, calls this dependency on another nation ‘international risk’ and treats it as such.

International supply chains work well when those nations involved have similar foreign policies, but not well when these foreign policies are poorly aligned. For instance, the US defence became concerned about the capability of Radarsat 2 and the Canadian desirability to commercialise. This led to the US pulling out of the programme. Government programmes can engender cooperation and working relations between industries and this works best when industry-to-industry cooperation is an objective of the programme.

Science is fundamental to Space activities and academia has a strong international modus operandi. Moreover, science does not particularly respect international borders, it goes where it must, often with global implications such as in the case of Climate Change. Canada and the UK are essentially international in their space programmes, both preferring international collaboration over national programmes.

Both nations have been highly successful in this regard, after all Ariel 1, a joint US/UK endeavour, was the first international satellite.

In a similar spirit a global market place and applications domain mean that commercial Space activities are inherently international. Companies engaged in Space need to form international relations to deliver the ‘biggest bang per buck’ with a mix of small, medium and large enterprises. Through this approach small, niche companies have the opportunity to join large, international projects. Collaboration in Space can encourage relations between countries that might not otherwise exist, for instance Nigeria, Turkey, Kazakhstan, Spain, China and Algeria have engaged with SSTL’s Disaster Monitoring Constellation.

Space and foreign policy cannot be separated. President Ronald Reagan’s promotion of the ISS was his major foreign policy initiative – indeed the ISS is not essentially a space science programme. From Canada’s view engagement with ESA allowed Canada to reduce its dependence on the US.

At least five types of international cooperation models appear to exist: Multi-national or bi-lateral programmes such as Mars Exploration - expensive programmes where the essential element is not national advantage or commercial opportunity; Joint missions, sometimes known as bi-laterals, where a win-win can be identified; Formal international structures, such as the European Space Agency; Pay to Play models where nations and organisations get what they pay for, such as some aspects of the ISS; and Treaty-based arrangements like the ISS itself – albeit the US being the first among equals in this case. Treaties bring with them management structures and processes, dispute resolution mechanisms etc. that ensure a level playing field for the participants. With such a plethora of options hopefully the most suitable horse for a course can be found.

This diversity of cooperation models is set to grow, for instance when Lunar Mission One launched its funding campaign it received more than 7000 sponsors from over 60 countries – this privately funded programme demonstrates that there is no lack of creativity or appetite for international collaboration in Space. Indeed, we need new models of collaboration to ensure engagement with the emerging Space nations and to make sure that their involvement is mutually beneficial.

Nevertheless, with whatever models we use comes a downside. More international partners leads to more agendas, greater complexity, management challenges, extra expense and a struggle to reach consensus. These are becoming characteristics of ESA which, reluctantly, is forced to turn towards the European Union for a mechanism to cope with them. Technology transfer issues, dual use implications, proprietary technology, intellectual property, non-aligned legal frameworks and funding stability are other important factors that are easier to manage on a national rather than international level. While ESA approves ('adopts') mission to completion, the US re-approves missions on an annual basis. Not least of these obstacles are the natural cultural differences and even language. While Tim Peake's Russian is very good, language remains a barrier to skills mobility and common understanding.

The expanding commercialisation of Space and the competition that it involves inevitably creates obstacles to future international space cooperation. Space is seen as a strategic national asset (at least by many nations including the US and the UK), which affects the relationships within an international supply chain. Export control particularly affects dual-use technologies, and "dual-use" can be interpreted very widely indeed. Protectionism, buy local policies, ESA's Juste Retour, trade agreements – all these inhibit free-trade and international cooperation. Selling to China is a thorny problem, especially for Canada, which is economically and politically tied to the US. However, many would argue that the US ITAR has stimulated technology development across the world creating greater competition for the US. Industry-to-industry cooperation is becoming an important facet of a growing commercial sector while the State domination of Space is beginning to fade.

Nevertheless, Space offers many opportunities. Global issues may be addressed including environment and climate change, disaster management, space debris mitigation, and Space Weather. For the most part, space science and exploration does not benefit from national duplication, and for the most challenging issues they are best dealt with cooperatively. International supply chains create markets and enable industrial development through shared development costs, shared flight demonstration, government-enabled industry-to-industry partnerships. Inseparability between Space and Foreign policy can be turned into an advantage – creating a safer world and providing mechanisms for aid to developing nations. In this regard communications between the Space community and the sustainable development community should be improved since there are opportunities here for mutual benefit.

While Space is 'too big' and multi-faceted for any one country to deal with on its own, it is not so big that it requires every nation to participate in every aspect and we may see, and are seeing, the evolution of large international alliances, particularly China, Russia, ESA and the US with its normal partners. Currently it appears that the former will lead lunar exploration and the next generation of the space station, possibly even Mars human exploration. Canada and the UK have feet in both camps and these nations should seek to reduce tensions that may arise through competition of one form or another.

Space has been a huge success story in international collaboration, but is the atmosphere becoming more sceptic as the stakes rise? The opportunity to engage with China is real, but there are some very formidable challenges to overcome – it is currently ‘impossible’ to launch a European satellite on a Chinese rocket. Nevertheless there are important markets in China that are demanding applications and services based on Space assets. There is good business to be done with China, but we are going to have to work hard to enable a conducive playing field. While China publicly declares a desire to cooperate in space programmes, their actual engagement in international forums is less evident – there does not appear to be a grass-roots desire to cooperate. Work on this playing field will be needed on both sides. Perhaps the largest stumbling block with Canadian and UK collaboration with China is IP protection. Rather curiously in 2022 we may well have a Chinese space station operating alongside the ISS!

While China continues to be problematic, it is interesting to note that the foreign policy and legal framework of India aligns much more readily with the US, Canada and the UK. Increased international collaboration with India is likely to be less fraught, with the benefits of access to its vast Indian market a particular incentive. Although India is the world’s largest democracy, it turns more to Russia than the West for engagement with its Space programme.

There is great merit in Canada – UK cooperation. Both countries have a common interest in industrial development, science, exploration, foreign policy, aiding developing countries and disaster management. There are increasing industrial partnerships with Canadian companies including COMDEV, MDA and URTHECAST developing strong links in the UK. Opportunities for the future cooperation between the UK and Canada include joint R&D programmes and flight demonstrations, environmental science programmes, enhanced disaster management cooperation, space weather and space debris risk management. Canada and the UK should take the leadership in internationalising Space Weather and Space Debris risk mitigation. This is an opportunity that would be generally beneficial, inculcate international cooperation, create jobs and demonstrate leadership. More generally Canada and the UK are well placed to take a leading role within the UN on the reform of Space matters.

It is proposed that Space should be the subject for an annual multi-stakeholder consultation between Canada and the UK, which could provide a forum for exploring partnerships, to consult on the worrying signs and coordinate the positions of these two countries on these global challenges.

Indeed it would be beneficial for Canada, through its links with ESA and with UK support, to seek to join the European Inter Parliamentary Space Conference (EISC).

Space captures the interest and imagination of the public. NASA dominates in this field, overshadowing the efforts of other nations. Within Canada more is known by the public about the US Space programme than the Canadian Space programme, a disappointing situation. In the UK there has been a very significant improvement in Space communications in recent years. NASA sees outreach as an integral part of its programme, something envisaged from the outset and built-in. In Canada and the UK it remains something of an afterthought, something to be exploited when it happens. However neither Canada nor the UK can hope to rival NASA's public communications, NASA's education programme is $100m per year, and so Canada and the UK should remain focussed on specific sectors and opportunities including schools (where there is a huge appetite and potential), manned space flight and national engagements in space programmes generally.

SUMMARY AND CONCLUSIONS

The most impressive and perhaps remarkable characteristic of the Colloquium was that the benefits from Space arise through collaborative working between a wide range of disciplines and between States. Not only is Space truly international, it is not the sole province of any sector or profession. To make progress we need to work together, just as we did in this Colloquium. Our recommendations reflect this need.

Moreover, it is clear that our engagement with Space is changing. The domination by States is fading fast with commercial organisations leading the delivery of services in telecommunications, navigation, and soon, Earth Observation. Opportunities are growing, upstream and downstream. The more data that is available to applications developers, the more applications are developed and the more innovative ways of benefiting society ensue.

Our engagement with Space is a great asset in itself, inspiring and encouraging take-up in science and technology, essential skills, education and training – vital for the future prosperity of our nations.

Canada and the UK appear to be on different trajectories. While UK space policy appears mature, well developed and well integrated into a national context, in recent years there has been a sense that Canadian Space policy has not kept pace with developments, and appears less well integrated with the national context than it once was.

The conclusions of the Colloquium are summarised below with the main points highlighted and its recommendations given:

Basis for Recommendation 1

- It was evident from the presentations and discussion that Space is in a period of rapid change and development. While we need changes to treaties, legislation and regulation, our ability to adapt these is slower than change demands. We appear to be moving towards a period of work-arounds, national precedents and reactive pragmatism. We therefore need to create alternative mechanisms to facilitate progress. International communication and cooperation will be key. Industry will seek to cooperate and self-regulate rather than rely on deterministic legal frameworks. Working groups will be needed to deal with specific issues. Some States or groups of States may have to take precipitate or precedent setting actions to force the issue. We should not wait for a disaster to trigger change.
- While Space law is founded on the 1967 Outer Space Treaty, it has progressed at a slower, more erratic pace than the associated technology, applications and commercial aspirations. Much remains unratified or even undefined ('Space', 'fault', 'debris', 'weaponisation').
- Where the need for change is identified, it must be well-articulated and with a sound case, whether economic, humanitarian, political, etc.
- Celestial bodies cannot be appropriated – but the US appears to be taking a unilateral position through the National Strategic and Critical Minerals Production Act, 2015. This may open the door to asteroid mining in the future and probably lead to a more international agreement in time.
- Non-aggressive military use of Space has grown significantly. While sometimes 'regrettable' this has generally not been in direct violation of the 1967 Treaty, a treaty that has actually served us very well. National 'positions' are not always the same as behaviours.
- Self-regulation of GEO by the Space industry seems to be working, this is an example of industry working together pragmatically.

- The roles or States, Space agencies and commercial operators are evolving. Space law should facilitate not obstruct. States need to provide an effective regulatory framework, targeted funding and acting as anchor tenants where appropriate.

Recommendation 1: A meeting of the 1967 Space Treaty signatories should be called at the 50th anniversary of its creation at which the principles of the Treaty could be reaffirmed and, mechanism for their evolution established.

Basis for Recommendation 2

- The concept of "Informed Consent" for space tourism may be challenged.
- The current liability cap is a problem and makes no sense for nanosatellite manufacturers.
- Space is an essential part of our lives which we increasingly take for granted.
- While most of the financial return comes from the downstream sector, investment in the enabling upstream sector is essential, especially in Earth Observation, tourism and deep space exploration. The enabling role of Space science and exploration as a source of technical innovation must not be underestimated.
- The dependence of applications on Space data acquisition, analysis and dissemination should be better appreciated.
- Space is becoming increasingly transparent – that is, end users care little from where the data arises and application providers will integrate Space and ground-based data as necessary to meet their needs. To meet the anticipated growth of the Space sector we must blur the distinction between Space and terrestrial data sources.
- In the UK and elsewhere Space is an acknowledged part of the Critical National Infrastructure, this is not the case in Canada.

Recommendation 2: Canada should recognise Space as a component in its Critical National Infrastructure.

Basis for Recommendation 3

- Constellations of small satellites are becoming an integral part of our Space infrastructure. We need to recognise the implication of such constellations and the market opportunities (upstream and downstream) that they provide, and their associated risks.

- As constellations of small satellites become more commonplace, Nanosatellites/CubeSats will transition from being mainly educational tools to become part of our economic and even scientific infrastructure. Nevertheless we need to be cognoscent of Iridium and GlobalStar – there has to be a market for the service provided by any constellation.
- In Earth Observation increased temporal persistence and higher spatial resolution are drivers. As these improve so will the inventiveness of industry to provide innovative services. Business opportunities come from information extraction from otherwise free data (e.g. Copernicus), or by providing early release data sets to subscribers.
- The inability to access and difficulty to interpret Earth Observation data without expensive tools are barriers to democratisation. Nevertheless Earth Observation data democratisation will have profound implications as we move towards a Big-Data environment. However, as democratisation becomes endemic, it will force fuller consideration of privacy issues.

Recommendation 3: Privacy issues associated with data democratisation should be proactively addressed.

<u>Basis for Recommendation 4</u>

- Dual-Use technologies are now so common-place that a better distinction is needed. Since Dual-Use can be applied very widely and given the sharing of military and commercial assets and data, the term Dual-Use is now largely redundant and should be abandoned.
- While an ITAR Schengen area appears attractive, we should be cautious. Rather than create additional regulations, we should better encourage a gentle relaxation of existing US restrictions.
- Growth in the Space sector demands a skilled workforce.

Recommendation 4: The Space sector should do more to address the apparent lack of diversity in its workforce – a workforce that must grow rapidly to meet our expectations.

<u>Basis for Recommendation 5</u>

- Significant leverage from government investment is possible. However, funding reductions both in terms of direct support and agency manpower will limit these opportunities.

- The role of States as anchor tenants is evolving. Even in the defence sector, spare capacity is being made available to commercial enterprises. As this role evolves consideration will need to be given to the pre-emption by government to reassure commercial endeavours that they will have secure access to resources.
- Although rather in the future, asteroid mining will require a legal framework. The recent steps by the USA have taken the subject forward, but ultimately national consensus will be necessary. Only when such commercial endeavours become practically possible will we see significant legal progress internationally.
- Satellites have huge potential to enable enterprise in the third world.

Recommendation 5: We should better link the Space sector with those interested in third world development and sustainability.

<u>Basis for Recommendation 6</u>

- Space Debris is not yet under control. While recent measures have significantly reduced the rate of increase of space debris, future aspirations, particularly the growth in LEO and GEO assets, will continue to create an upward pressure. Barriers to space debris removal must be overcome while greater incentives are needed to prevent its occurrence. An amnesty should be declared such that the 'sins of the past' are written off and no longer pursued. Any such attempt at recrimination will delay a resolution of the problem. Rather, we should cooperate internationally, pooling resources to solve the problem.
- We should not ignore our huge dependence on US debris tracking services, noting the underlying military agenda, and develop more independent, comprehensive and cooperative approaches, including the engagement of spacecraft operators. For the future, greater incentives are needed to reduce the creation of space debris, including punitive measures and public exposure.
- We should recognise that the motivations for collision avoidance by satellite operators are quite different from those of Space-faring states and that the largest risk comes from objects we cannot track.
- A balance needs to be found between prediction/avoidance and protection/resilience. This balance may appear quite different for satellite operators and nation states.
- Adopting the maritime concept of 'salvage' appears attractive but is practically and legally difficult. For instance, there is no legal concept of

abandonment in space. While space debris is not an illegal state of affairs, general principles of law that allow one to act to protect one's property might provide a way forward. To deal with the legalities of space debris it may be necessary to call an amnesty on the current situation and be more punitive with future offenders. One nation may take the lead merely by beginning to remove debris, setting a precedent that would trigger international discussion and, eventually, consensus.

- Space situational awareness is dominated by the US and by securitisation (which wins over commercialisation). Space debris is an international issue. National self-interest will not lead to a solution, international cooperation is essential.
- Although congestion is currently more of a problem for LEO, it is GEO telecommunications satellites that generate the most income. The ITU should provide incentives for sustainable practices in GEO.
- Nanosatellites or CubeSats may become an issue if the numbers continue to increase strongly. Per kilogramme nanosatellites represent a greater risk.

Recommendation 6: Space Debris continues to be an urgent and growing issue. The UK and Canada should:

6.1 Use their strengths as honest brokers to champion action on active Space debris removal.

6.2 Co-sponsor the US proposal for the establishment of an expert group on Space Operations within the UN COPUS Scientific and Technical Sub-committee.

6.3 Champion the case for more sophisticated disposal of defunct spacecraft in Low Earth Orbit, linked to the time since last operation, plus altitude and inclination.

<u>Basis for Recommendation 7</u>

- Space Weather represents a serious threat. It is the class of threat that is low likelihood but high impact and so lacks the imperative that leads to action. While it is recognised that any investment in a predictive system is likely to be expensive and that its justification would need to be compelling, it is important to act decisively where the case is made. We endorse the need for the current UK cost-benefit analysis.
- In a few years there will be a gap in our current space weather monitoring system as current assets fail or go off-line.

- The current predictive services in Canada and the UK are valuable and should be maintained.

Recommendation 7: The UK and Canada should work together to support a Space Weather mission given a compelling financial case. Serious consideration should be given to a 'Carrington' mission aligned with the US commitment to place a satellite at L1.

Basis for Recommendation 8

- Copernicus provides an excellent, holistic service. EO data should be seen as an integral part of the disaster response lifecycle.
- The democratisation of Earth Observation data will trigger commercial opportunity and global benefit. While privacy and security considerations will be an issue to be resolved, the public sector role is now well developed and we should expect a transition from a state/agency managed Earth Observation capability to a much more commercial situation with States acting more and more as anchor tenants.
- Even where data is being used for humanitarian purposes, there is a potential role for the private sector.
- Timeliness and quality are drivers for EO and, as improved, will stimulate downstream innovation and growth.

Recommendation 8: The UK and Canada should conduct an EO capability audit.

Recommendation 9: Access to spectrum of appropriate characteristics and quality represents a significant and growing challenge for the Space sector. The UK and Canada should take the initiative to:

9.1 Work together to promote a review of the current ITU spectrum allocation process, considering whether task based groups of experts (after the COPUOS model) with expedited processes to implement urgent recommendations, might usefully complement the existing WRC structure. The processes already used in Aviation Law (1944 Chicago Convention) through regular addenda and codicils might offer significant utility.

9.2 Develop, potentially through a European Conference of Postal and Telecommunications Administrations (CEPT) group, emission masks for the new generations of LEO Communications and EO satellites, ensuring that compliance verification is properly integrated into the existing pre-flight test and verification regimes.

9.3 Assess whether existing terrestrial spectrum trading methods might usefully be extended to the Space segment and whether existing GEO enforcement processes remain fit for purpose.

Recommendation 10: Increased spectrum sharing, including between Space and terrestrial systems, is an essential fact of life in the 21st Century. The UK and Canada should promote rigorous, engineering based approaches to maximise mutual utility and minimise interference. In particular the UK and Canada should:

10.1 Ensure that the satellite industry and downstream users build full life economic value cases directly comparable to those already in use by the terrestrial mobile industry such that economic and social decision making can be fully informed.
10.2 Encourage the ITU to view Earth Observation as more closely related to commercial satellite activity than to pure science.
10.3 Mandate that full and detailed interference and mitigation analysis informs each sharing decision.

<u>Basis for Recommendation 11</u>

- International collaboration is intrinsic both to nation States and to Space, but works better when foreign policies align. This leads to difficulties with China but is an opportunity for India.

Recommendation 11: Canada and the UK should seek to strengthen their relations with international partners that align politically and that offer large market opportunities, especially India.

<u>Basis for Recommendation 12</u>

- As the commercial importance of Space increases and as more and more innovative approaches emerge, increasing international tensions could be amplified. We should be vigilant and continue to use Space to engender good international relations.
- There is a potential tension between Canada's alignment with the US and the UK's alignment with ESA (and potentially its links with Russia and China). Canada and the UK should use their bilateral relationship to lessen this tension.
- Industry to industry international cooperation will be increasingly important, including shared technology development.
- Global initiatives present an opportunity for collaboration and commercial benefit

Recommendation 12: The Canadian and UK Space Agencies should convene an annual stakeholder collaboration forum to explore further engagement.

Recommendation 13: Canada and the UK should engage with the US to seed a level of strategic alignment

Communication with the public, including schools, is vital. It enables one of the primary benefits of Space, to encourage greater interest in Science, Technology, Engineering and Mathematics, and also an interest in the World as a global, precious entity. Chris Hadfield and Tim Peake are excellent ambassadors for Space. Greater emphasis should be placed on the communication of our engagement with Space, building upon the already excellent work carried out. This investment should not seek to compete with NASA but rather reflect national engagement, interests and agendas.

Within the Space sector there is an enormous inter-relationship between business, academia and government agencies. This has been evident in the makeup and discussions of this Colloquium. A common understanding and cooperative spirit will be important to our future prosperity.

Professor Alan Smith
University College London

Annex 1: Speech by Dr David Parker, Chief Executive, UK Space Agency

You all know that both countries gained their space 'wings' over 50 years ago when the US proposed to its allies to carry out international space missions, somewhat in reaction to the shock of Sputnik. Both Canada and the UK responded, leading to the UK's Ariel 1 launched in April 1962 and Alouette 1 in September 1962. Ariel 1 involved several UK experiments launched aboard a US rocket, and the data was eagerly received by UK scientists.

Sadly, a few months later, Ariel 1 was killed off by a US high altitude nuclear test – project Starfish. So, our cousins south of your border got us our first toe hold in space – and then blew it away. Our chair David Willetts memorably referred to this as a prime example of what we Brits are pleased to call 'the special relationship '!

Anyhow, from the first beginnings, UK activities in space blossomed both through national projects and increasingly through cooperation with our European neighbours. The UK was a founding member of ESRO, ELDO and then ESA, in 1975.

The similarities and differences with Canada's priorities in Space are quite interesting. It is fair to say that Canada has achieved remarkable international recognition for its Space activities through high profile successes like the Canadarm on the space shuttles and ISS; and projects like Radarsat.

Although the UK built Europe's first telecom satellites under licence from the US in the 70s; the Halley's comet interceptor satellite Giotto in the 80s; and led the way with practical applications such as maritime communications, it is fair to say that - a few years ago - the breadth and importance of UK space activities were much less well known, but as a result of concerted action by the whole community, the outlook has brightened.

The key insight for policy makers was to value not just the spacecraft hardware built in the UK – the so-called upstream sector - but also the rapidly growing downstream sector and the spill over benefits to the wider economy. At the time the sector was worth about £7B to the UK economy and a long-term action plan (the space IGS) was drawn up to grow it to £40B by 2030. By 2014, we had got to £11.8B.

Most of the 16 original actions in that original plan have now been delivered and I am hoping that the last one – the issue of the National Space Policy - is not far off.

First and foremost was the creation of the UK Space Agency itself – fully operational from April 2011 and its new national Civil Space Strategy for 2012-2016. This identified six pathways to growth, and an increased emphasis on exports and inward investment – in other words, internationalism, is one of the six. Practical actions included selectively increasing our investments in the European Space Agency – so doubling our contribution to the telecoms programme, for example.

There has also been support for novel projects such as UKube-1, our first national CubeSat which finished its mission earlier this year and built by ClydeSpace; and SABRE, a radical air breathing rocket that could transform the cost of space access by enabling a reusable launch vehicle.

Oftentimes, our role can be about creating the right eco-system for the space sector to thrive. One example is our duty to represent the UK at international fora on the sustainability and safe use of Space. You have heard from Richard Crowther yesterday.

Hopefully, you know about the new eco-system called the UK Space Gateway at Harwell Oxford, where a cluster of space facilities have been created to match our goals. Rather than a green field site, the Gateway is embedded in a wider science and technology campus with existing world class science facilities. Several international organisations are now on site – not least ESA. The Gateway name is trying to express an idea of openness and connectedness – think of it as a docking port to the UK space scene.

Meanwhile the commercial satellite sector is thriving. Avanti Communications is doing well in Africa while Inmarsat is forging business partnerships with China. SSTL's success in making space more affordable is now being applied to navigation satellites through Galileo; and to telecommunications for global operator Eutelsat with the Quantum satellite, which we are co-funding.

Engagements in global space science abound –the UK led mid-infrared instrument was the first of the four instruments for JWST to be delivered to NASA. MIRI will look back in time to image the first star and planetary systems forming at the dawn of the Universe.

The spacecraft that successfully took Europe to Comet 67P in August 2015 after a four billion km voyage was built in the UK, and the UK has built the extraordinary space physics laboratory called LISA Pathfinder, which launches on 2 December 2015. I could reel off a list of future projects too.

All of these projects are international – as international collaboration is in our DNA. Nothing shows that more that the International Space Station in which the UK is now a full participant and starting to reap scientific rewards. We are all looking forward to Tim Peake's Principia mission to the ISS which launches on 15 December 2015 – we will see if he has the same impact as Chris Hadfield.

But to grab the interest of the next generation, we have created two dozen education projects around Tim's mission, like the AstroPi project with the Raspberry Pi foundation, focused on computer coding. The UK space ambassador network will be working in 1000 primary schools and we are well on the way to signing up 5000 secondary schools for the 'Rocket Science' project with the Royal Horticultural Society.

For those in Scotland, I hope you can participate in one of the four national events on 15 December 2015 (in Edinburgh it is at the Dynamic Earth Centre) or join one of the 'Destination Space' events happening at 17 more science and discovery centres around the UK.

Now, the ISS is international space cooperation 'classic mode'. Its success in bridging the nations involved is obvious. But equally obvious is the absence on the ISS of other spacefaring powers such as China and India. China has now very openly invited other countries to join its space station programme. But global tensions and fears around the aspirations and actions of the major space powers is a reality.

My concern is that this impedes a common response to some of the collective challenges, such as the question of space traffic management; and dealing with the growing orbital debris problem. Deepening collaboration in the civil domain – as ESA is doing with Russia on ExoMars and tentatively with China on human spaceflight is a pragmatic response, but what else? Maybe this is something we could debate shortly.

But, in contrast, I also wanted to say something about achieving global reach 'new space' style. If the UK sector is to meet its growth targets, a quadrupling of UK space sector exports is needed, mostly in export of services rather than hardware.

Our response is our International Partnership Space Programme. This is building sustainable relationships with developing space economies.

So we have a project working with South Africa and Ghana to demonstrate the use of satellite navigation technology to improve airline flight safety. Today, Africa has 3% of global air travel but roughly 20% of air accidents. We want to tackle this.

We also want to tackle social challenges such as creating inclusive digital economies. So we are working with the Equity Bank of Kenya and the Mobile Alliance for Maternal Action (MAMA), to bring maternal and child health services to 50 physically and technologically disconnected communities using satellite broadband.

Other projects involve Chile, Vietnam, Malawi, Mexico, Indonesia and Kazakhstan.

In the past few years, the UK Space Agency signed international agreements with new partners such as Algeria; and Indonesia; and old ones such as France. The latter case involves two Earth observations projects. One is the novel mission to measure fresh water stocks and the shape of the ocean surface called SWOT (for which the UK arm of COMDEV will provide key payload electronics). Of course, the CSA is involved in SWOT with NASA, so the four nations are now working together on one project – speaking some combination of English and French, I suppose.

For the future, we should explore new possibilities.

Expressing a personal view, I see great potential for an operational space weather mission – we have raised this with European partners but maybe a transatlantic link-up is another approach. This is important because an extreme Space Weather event is now recognised on the UK's critical national risks. Work in active debris removal is another possibility.

So to try and summarise all I have said:

Space is indeed borderless and limitless in its potential. But there are challenges as well as opportunities.

UK space policy is re-energised, to deliver value down here on Earth as well as the exploration of the beyond – head in the clouds and feet on the ground.

We have a laser focus on enabling success by working locally, nationally, in Europe and vitally - through international partnerships, with friends old and new.

Annex 2: PROGRAMME

19 NOVEMBER

Briefing Day in Glasgow

9.00 am The Merchants House of Glasgow, 7 West George Street, Glasgow G21BA

Commercial Presentations,

Refreshments and displays

Presentations by Spaceport bidders

12.30 pm Lunch and Presentations, The Senate Room, University of Glasgow G12 8QQ

Host: Professor Muffy Calder OBE, Former Chief Scientific Adviser to the Scottish Government.

2.30 pm Visit to Clyde Space (including presentation from Spire)

Mr Craig Clark MBE, Chief Executive Officer, Clyde Space

7.00 pm Civic Reception City Chambers

7.30 pm Gala Dinner

Keynote Speaker - Mr Chris Ashton, Director, Spectrum Engineering, Inmarsat

THE 2015 CANADA-UK COLLOQUIUM

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SPACE: OBSTACLES AND OPPORTUNITIES

The Strathclyde University Technology & Innovation Centre, Glasgow G1 1XQ

Chairman: The Rt. Hon. Lord Willetts

Rapporteur: Professor Alan Smith

20 NOVEMBER

8.30 am Introductory Remarks: CUKC British Chairman and the Canadian Co-organiser

8.40 am Opening of the 2015 Canada-UK Colloquium

Ms Fiona Hyslop MSP, Cabinet Secretary for Culture, Europe and External Affairs

8.50 am Video Message from Tim Peake

8.55 am Remarks by the 2015 Colloquium Chairman

9.00 am Session 1: The Politics of Space

UK: Prof Lesley Jane Smith; Visiting Professor, Strathclyde University; Solicitor and Partner, Weber-Steinhaus & Smith, Bremen

Canada: Mr Paul Meyer, former Canadian Ambassador, The Simons Foundation

10.30 am *Coffee/Tea*

10.45 am **Session 2: The Commercial Potential of Space**

UK: Professor Sir Martin Sweeting OBE FRS, Executive Chairman Surrey Satellite Technology Ltd

Canada: Mr Wade Larson, President and COO, Urthecast Corporation and Mr Paul Bush, former VP, Telesat

12.15 pm *Lunch*

1.30 pm **Session 3: Surveillance and Security**

UK: Prof. Richard Crowther; Chief Engineer, UK Space Agency

Canada: Prof. James Fergusson, Centre for Defence and Security Studies, University of Manitoba

3.00 pm *Coffee/Tea*

3.15 pm **Session 4: Working Groups**

Group 1: Space Weather

UK Co-Chair: Professor David Jackson, Met Office

Canadian Co-Chair: Dr Christian Sallaberger, Canadensys Aerospace Corporation

Group 2: Space Debris

UK Co-Chair: Mr Ian Taylor MBE, former MP and Co-Chair of Parliamentary Space Committee

Canadian Co-Chair: Mr Dan King, MDA Inc.

Group 3: Global Monitoring of Hazards and the Environment

UK Co-Chair: Dr Nick Veck, Head CEO Office, Satellite Applications Catapult

Canadian Co-Chair: Mr Wade Larson, President and COO UrtheCast

Group 4: Contention for Spectrum

UK Co-Chair: Professor Jim Norton, Royal Academy of Engineering, Engineering Policy Committee

Canadian Co-Chair: Mr Paul Bush, Senior Vice President Corporate Development Telesat (retired)

6.15 pm **Whisky Tasting**

7.45 pm **Colloquium Dinner, Millennium Hotel**

Keynote speaker – Mr Stuart Patrick, Chief Executive, Glasgow Chamber of Commerce

21 NOVEMBER

9.00 am **Royal Anniversary Trust video**

9.10 am **Session 5: Reports from Breakout Groups**

10.30 am *Coffee/Tea*

10.45 am **Session 6: Space: The One Truly International Environment**

UK: Dr David Parker, Chief Executive UK Space Agency

Canada: Dr Mac Evans, former president, Canadian Space Agency

12.15 pm *Lunch*

1.30 pm **Rapporteur's Report and Concluding Discussion**

Rapporteur: Professor Alan Smith, University College London

2.30 pm **Closing Remarks by Colloquium Chairman**

Annex 3: LIST OF PARTICIPANTS

CHAIRMAN
The Rt. Hon. Lord Willetts

RAPPORTEUR AND UK ADVISER TO THE 2015 COLLOQUIUM
Professor Alan Smith, University College London

OPENING THE 2015 COLLOQUIUM

Ms Fiona Hyslop MSP, Cabinet Secretary for Culture, Europe and External Affairs

DINNER 19 NOVEMBER: KEYNOTE SPEAKER

Mr Chris Ashton, Director, Spectrum Engineering, Inmarsat

DINNER 20 NOVEMBER: KEYNOTE SPEAKER

Mr Stuart Patrick, Chief Executive, Glasgow Chamber of Commerce

BRITISH PARTICIPANTS

Dr Hina Bacai, Business Development Manager, Scottish Centre of Excellence in Satellite Applications

Mr Thomas Barry, British Deputy High Commissioner, Ottawa

Mr David Beadle, Head of Canada Team, Foreign & Commonwealth Office

Ms Frances Brown, Space Policy journal

Mr Anthony Cary CMG, Hon President Canada-UK Council

Mr Craig Clark MBE, CEO Clyde Space

Professor David Cope, Council Member Canada-UK Council

Professor Richard Crowther, Chief Engineer, UK Space Agency

Professor Colin Cunningham, Science and Technology Facilities Council, UK Astronomy Technology Centre

Miss Georgina Dean, Stevenson Astrosat Ltd./University College London

Mr Nigel Douglas, CEO - Global Surface Intelligence Ltd

Mr George Edmonds-Brown, Executive Secretary Canada-UK Council

Ms Caitlin Egen, Qinetiq

Mr Gerry Ford, Snr International Executive, Scottish Development International

Ms Kate Arkless Gray, Freelance Journalist - @SpaceKate

Mr Peter Hulsroj, Director European Space Policy Institute (ESPI)

Dr Patrick Harkness, University of Glasgow

Professor David Jackson, Met Office

Mr Michael Koetsier, Head of Inward Investment, Highlands & Islands Enterprise

Eur Ing Dr Malcolm Macdonald FRAeS, Director, Scottish Centre of Excellence in Satellite Applications, Strathclyde University

Mr Nicolas Maclean CMG, Council Member Canada-UK Council

Ms Lesley McNeil, Senior Policy Executive for Manufacturing, The Scottish Government

Professor Colin McInnes MBE, FREng, FRSE, James Watt Chair, Professor of Engineering Science, University of Glasgow

Dr Callum Norrie, Space Network Scotland

Professor Jim Norton FREng, Royal Academy of Engineering – Engineering Policy Committee

Dr David Parker, Chief Executive UK Space Agency

Professor Steve Parks, Managing Director, Star Dundee

Mr Philip Peacock, Chairman Canada-UK Council

Dr Lesley Jane Smith, Visiting Professor, Strathclyde University; Solicitor and Partner, Weber-Steinhaus & Smith, Bremen

Ms Elisabeth Stark, Head of Industries, Scottish Government

Professor Sir Martin Sweeting FRS, Executive Chairman, Surrey Satellite Technology Ltd; Chairman Surrey Space Centre

Mr Ian Taylor, Chair, Lunar Missions Ltd.

Professor Nicholas Veck, Head of the CEO Office, Satellite Applications Catapult

Mr Alan Webb, Project Manager, Commercial Space Technologies Ltd.

CANADIAN ADVISER TO THE 2015 COLLOQUIUM

Dr William (Mac) Evans, W. MacDonald Evans Consulting Inc., Former President, Canadian Space Agency

CANADIAN PARTICIPANTS

Ms Maureen Bartram, Canadian Coordinator, Centre for International and Defence Policy, Queens' University

Colonel Marc Bigaouette CD, MSC, Canadian Air Adviser to the United Kingdom

Mr Marc Boucher, Executive Director, Canadian Space Commerce Association, Toronto

Mr Paul Bush, Senior Vice President Corporate Development Telesat (retired)

Professor Mel Cappe OC, University of Toronto, Chairman of the Canadian Advisory Committee, Former Canadian High Commissioner to the UK

Dr James Fergusson, Director, Centre for Defence and Security Studies

Mr David Kenyon, Managing Director, MDA UK

Mr Dan King, MDA Inc.

Mr Eric Laliberté, Director General Space Utilization, Canadian Space Agency

Mr Wade Larson, President and COO UrtheCast

Ms Maria Lucas-Rhimbassen, Institut d'Entrepreneuriat, HEC Montréal

Dr Christie Maddock, University of Strathclyde

Professor Charles Thomas (Tom) McElroy, NESRC Industrial Research Chair, York University

Dr Caroline Martin, Trade Commissioner (Science and Innovation), Canadian High Commission, London

Mr Paul Meyer, Simon Fraser University / The Simons Foundation

Professor Kim Richard Nossal, Queen's University, Canadian Coordinator

Mr Douglas Scott Proudfoot, Minister- Councillor (Political and Public Affairs) Canadian High Commission, London

Dr Yaroslav Pustovyi, President, Canadian Space Commerce Association

Dr Christian Sallaberger, Canadensys Aerospace Corporation

Mr Ivan Semeniuk, Science journalist, The Globe and Mail

Dr Lucy Stojak, Directrice, MOSAIC, HEC Montréal

Mr John Stuart, Vice-President, COMDEV

Mr André Vigneault, A/Director, Policy Development, Canadian Space Agency

The Scottish Government
Riaghaltas na h-Alba

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HIE
Highlands and Islands Enterprise
Iomairt na Gàidhealtachd 's nan Eilean

Scottish Enterprise

SCOTTISH
DEVELOPMENT INTERNATIONAL

DADCO

Foreign & Commonwealth Office

SURREY
SATELLITE TECHNOLOGY LTD

MDA

urthecast

GSi
Global Surface Intelligence

Foreign Affairs, Trade and Development Canada
Affaires étrangères, Commerce et Développement Canada

CSCA Canadian Space Commerce Association
CSCA Association Canadienne du Commerce Spatial

Canada-United Kingdom Council

inmarsat
The mobile satellite company

Centre for International and Defence Policy • Queen's University

School of Policy Studies
Queen's University