



UCL

The 2016 UCL Space Policy Workshop

Workshop Report

Event held

10th May 2016

University College London

Gower Street, WC1E 6BT

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The 2016 UCL Space Policy Workshop

New approaches for achieving benefit in a changing world

Introduction

This workshop was designed to provide an environment for key thinkers and policy makers, from the UK and overseas including space agencies, research organisations, academics and international bodies, to challenge current approaches and consider alternatives to future space policy related development.

The essence of the workshop was to challenge current approaches to Space, take note of trends and to consider alternatives. While there is a natural disposition to defend current practice, much of which is justified by circumstance and custom, the workshop sought to explore beyond the conventional. Is 'New Space' a response to a conventional space sector that has become too conservative?

The event takes the premise that thinking in relation to space strategy may have fallen into a number of furrows that carries the risk of missing new innovative opportunities. The following four potential 'furrows' had been identified in advance of the workshop and provided a flexible backdrop to the discussions:

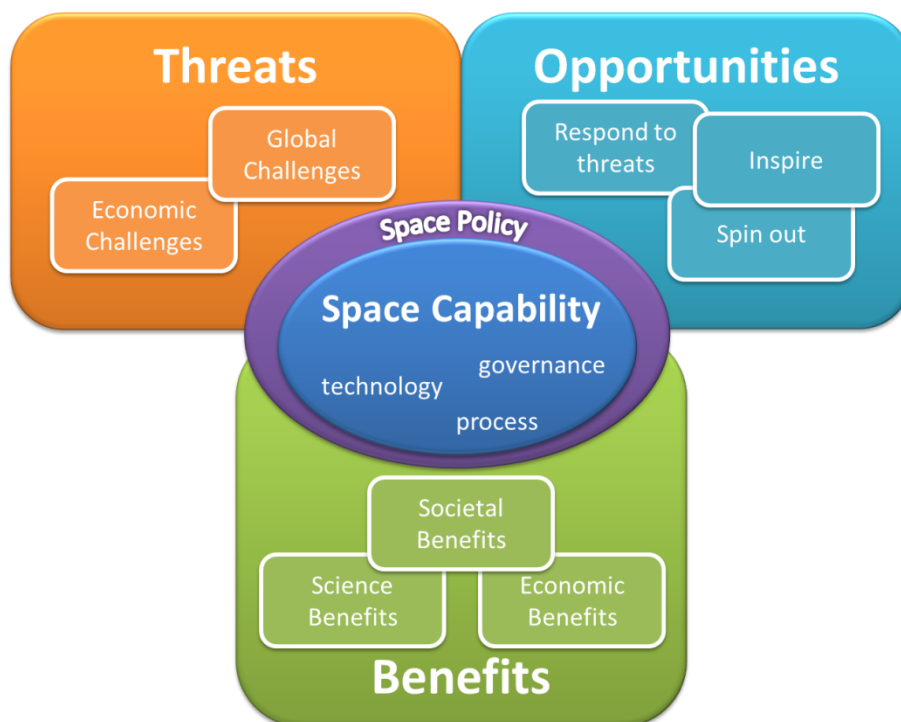
The focus on technology planning: To manage risk in a highly technological domain, technology planning and the use of technology readiness levels is becoming commonplace. Ground-rules are created (and obviated) which dictate minimum TRL levels at various stages in technology development. The valley of death between TRL 3 and TRL 5 shows how awkwardly technology planning maps against the actual lifecycle from idea to product and its manifestation in organisations. While highly effective in managing risk (and overspend?), is there a danger that it is inhibiting innovation?

Fixed goals: Nationally or even internationally agreed goals can unite and focus a community. However, when do they become a millstone? The political and economic climate of Apollo was very different from that of today yet 'A man on the Moon' and 'A man on Mars' seem to have similar, focussing intentions. There are plenty of roadmaps available, how useful are they? Is there room for just exploring without this huge burden of conforming to some community consensus? Is a track record of success a better measure of quality than a project plan that meets agreed objectives?

Economic impact: If we only chose to support initiatives that had guaranteed (or highly probable) economic impact we risk drifting into a time of incremental technological improvement. We cherish entrepreneurship yet often make it difficult for the innovative entrepreneur. We say that it is OK to 'fail' yet demand strong business cases, and favour the predictable over the speculative.

Waiting for the accident to happen: It is sadly true that to justify funding of traffic calming measures by local authorities in the UK, a serious accident must first occur. This ensures that resources are targeted in areas where there is evident need yet at what cost? A Health and Safety viewpoint would be to risk assess situations and proactively take action but this can

be taken too far as numerous incidents of ‘health and safety gone mad’ can attest. What should we do about low probability, high impact risks such as Space Weather, multiple satellite collisions or asteroid impact?



Many of the attendees met for dinner on the previous evening at which Ian Taylor, ex Minister of Science and Technology 1994-97, gave a talk. Ian is currently Chairman of Living PlanIT and Lunar Mission One Trustees.

The workshop itself comprised 5 sessions each dedicated to a specific topic with one or two introductory speakers followed by plenary discussion.

The Workshop was held at University College London on the 10th May 2016 and is set to be the first in a series of UCL hosted events that address issues of Space Policy.

Workshop Chairperson

Martin Barstow, Professor of Astrophysics and Space Science and Pro-Vice-Chancellor, Strategic Science Projects, University of Leicester; Director, Leicester Institute of Space and Earth Observation, President of the Royal Astronomical Society.

Conclusions

From the session presentations and plenary discussions, captured in the following sections, a number of key themes emerge that should be explored further. Central to these was a recognition that any policy development needs to tackle funding, governance, security, risk and dependability.

C1: Capture experience from the past – Identify the characteristics and practices that enabled rapid and successful development and deployment of innovative instruments and technologies, whilst recognising the risks of such approaches.

C2: Identify modes of working with public funding bodies that provide a risk and benefits approach, and encourages innovation whilst satisfying the requirements of public spending.

C3: Identify the means to provide guidance to policy makers and funders on what is an appropriately balanced portfolio of 'safe' and 'speculative' investment for space technologies and services.

C4: Identify the barriers and means to improving communication to government and the public on the benefits of the space sector.

C5: Develop policy guidance for 'New Space'. What is an appropriate policy landscape for a sector that will be increasingly dominated by non-state players such as Google?

C6: Recognising that national approaches to innovation can vary fundamentally, can the relationship between these approaches be understood so as to develop guidance for maximising benefits?

C7: Characterise the stewardship of technology between public and private sector actors and develop policy guidance regarding appropriate innovation model.

Session 1: The bigger picture

Presentation summary

Session Speaker: Chris Rapley, Professor of Climate Physics, University College London

We face a world that is changing rapidly. An aging population, increasing urbanisation, and climate change are just three of the issues that may have profound impact on our way of life. Climate Change will exacerbate existing tensions related to, for instance, the competition for resources and mass migration – a global risk recognised by the World Economic forum.

The 2015 Paris Agreement on Climate Change commits governments to come together every 5 years to set more ambitious emission reduction targets, to report progress towards their own targets, and so be transparent and accountable. It is not enough to merely monitor global temperatures, rather we must monitor those vital signs as indicated from our climate models including: Surface temperature; atmospheric CO₂; ocean (Earth system) heat content; sea level/ sea level rise; arctic sea ice extent/concentration; stratospheric ozone; the number of extreme climate events per year; Ice sheet/glacial extent; and solar irradiance. Some of these are relatively straightforward to monitor, others are more difficult.

Human carbon emission over the last decade or so shows a continuing rise in giga-tonnage per year from around 22 in 1990 to ~35 in 2012. Based on current national commitments a peak at 40 Gt/year in 2030 can be predicted, but only if those commitments are met – a doubtful premise. To meet the goal to limit global temperature rise to 2°C an impossibly steep decline in emissions from 2030 would be required. Significant progress is vital within the next 5 to 10 years.

The Stockholm Convention identifies Climate Change as one of 9 ‘Planetary Boundaries’ in a ‘Safe Operating Space for Humanity’. Of the nine two are already violated (Biosphere integrity and Bio-geochemical flows) while others (Land-systems change and Climate change) are of great concern.

At the time of its publication the book ‘Limits to Growth’ by Donella H. Meadows was vilified by those upset by its implications, yet it made predictions that have proved surprisingly accurate (e.g. non-renewable resource remaining, food per capita, services per capita, industrial output per capita, global pollution and population). Unsettlingly it predicts population collapse in 2030! The world economic forum envisaged three future (dystopian) scenarios in 2030: ‘Walled cities’, ‘Strong regions’ and ‘War and peace’. While these are gloomy scenarios indeed they are not those of scaremongers but rather of thoughtful individuals. Over the next 15 years we could be faced with extraordinary changes.

A period of rapid change forced by the factors mentioned above seems inevitable. However, humanity has responded to such imperatives in the past often as the result of external military aggression. Lockheed ‘Skunk Works’ is just one example where very effective progress can be made when there is both the imperative that demands action and the will to act quickly, challenging established norms of behaviour. These highly effective, rapid response initiatives can be characterised by: strong, authority-empowered leadership;

laboratory-based experimentation; small tight-knit teams of scientists and engineers; vertical integration (rather than contract management); dedicated and competent personnel; reduced paperwork which is often more to protect from criticism than to benefit the project; demanding and uncompromising deadlines; rapid turn around and team continuity between projects; and being prepared to take risks. In short much like the situation in experimental space science in the UK in the 1970s and presently seen in companies like Space X.

The practices of the past have great relevance to the future. Therefore we might assemble scientists and engineers with experience of UK space programme in 70s era (whilst they are still available) together with those with experience of contemporary analogues. This group would identify the characteristics of practices that enabled rapid and successful development and deployment of innovative instruments and technologies. Shortcomings, pitfalls and risks of this approach would also be recognised and an improved code of practice based on these principles could then be disseminated and implemented in a virtuous circle. “As long as you are not violating the laws of physics, but only the laws of technology, anything is possible if you work at it” – Chris Rapley

Plenary discussion

The cost-effectiveness of the approach would need to be addressed but the need to respond quickly could be paramount. While failure might be more common, given a broad spectrum of initiatives, enough might succeed to make this worthwhile.

The reluctance of public funders to accept risk would need to be addressed. The private sector, with an entrepreneurial spirit might be better placed – e.g. Space X. Public-Private Partnerships, governments acting as anchor tenants, governments seeing themselves as enablers through legislation etc. may be the way forward. The new Catapult initiatives in the UK appear to be embracing some of this. However, we must caution against upscaling that increases bureaucracy.

Current ‘fixed price’ contracting together with the excessive dependence on large volumes of paperwork approach adopted by the EU and ESA consumes a great deal of time and effort. SR 71 Blackbird took just 22 months development – something not imaginable under these regimes. A reconsideration of the merits of ‘cost plus’ contracts with thorough auditing is merited. In this coming period of potentially rapid change the current practices may have to be swept aside in favour of those that can be more responsive.

The principle that only ‘Small is beautiful’ should be challenged. Larger organisations can be responsive if they are appropriately organized and motivated. Competition is a great motivator yet there has been a tendency to eliminate duplication within the research environment in favour of supporting the maximum breadth of activity.

Can we rely on governments or major agencies to make timely decisions when things are changing so rapidly? The increase in mobile phone usage and the evolving big-data applications are testament to this rapid change. UKSA and ESA must catch-up to these trends if they are to remain relevant.

If governments wish to see their nations participate effectively in these new opportunities they must move away from narrowly based cost benefit analysis. There needs to be a trust-

based component where track record, ambition and unspecific potential are the discriminators.

Recall the largely defunct MoD initiative of SMART procurement that dominated defence procurement thinking in the 90's. Also reflect upon NASA's Faster, Better, Cheaper initiative of the same era. Both had their merits but failed to impress their masters. We should learn the lessons of these initiatives and push forward with such innovative approaches.

Do large projects really need very large teams linked through complex documentation and process models? Can we create projects from small teams in the same way that we create systems from simpler subsystems?

Session 2: Existing approaches viewed in a new light

Presentation summary

Session Speaker: Stuart Martin, CEO Satellite Applications Catapult, Harwell

The space sector came into existence in the 1950s and has passed through three ‘ages’: The first Space age was associated with the cold war, it was a time dominated by the USSR and USA and by their national programmes; The second space age was one of science and exploration, and early commercialisation. While it saw the emergence of communication giants such as Inmarsat and Intelsat, it was/is a period of governmental domination and vision; The Third space age is now dawning and it will bring democratization of its data products. Organisations outside of government are taking control of the vision. The Economic downturn in 2007 meant that NASA could step back and cut back – enabling a new wave of entrepreneurs. Government became a user of space services. A wave of supporting services appeared allowing better access and facilitation.

We are moving from satellite programmes that involve a few large satellites to those of many small satellites, from expensive to low cost data. Data volumes have entered into the realm of ‘big data’, with the equivalent of all the data ever taken from space up to 2010 now being collected every day.

Space is a global technology and the services it delivers are more effective when they are delivered globally. Europe, with a population of 507 million, is ideally placed to benefit from such global provision.

However the services are not always delivered globally. National policies may target local services. Uber.com, the world’s most successful satellite application grew out of San Francisco. It seems unlikely that such an organisation could grow so quickly in Europe due to regulatory issues. The local regulative environment has a large impact on commercial services development.

On a 2030 timeframe the UN has identified 17 global goals for Sustainable Development. These include: No poverty; zero hunger; good health and well-being; quality education; gender equality; clean water and sanitation; affordable and clean energy; decent work and economic growth; Industry; innovation and infrastructure; reduced inequalities; sustainable cities and communities; responsible consumption and production; climate action, life below water; life on land, peace and justice; and strong institutions. To achieve these goals will require global, disruptive change. Just the sort of change Space can facilitate. However, currently we see mainly incremental delivery of these challenges. Space needs to demonstrate its relevance to these global challenges – to act globally and deliver globally. Otherwise we will miss a great opportunity.

We need amazing solutions and find new ways of long term sustainable services. To achieve this we must bring technology developers together across government, industry and academia.

The Space community faces the following challenges:

- How can policy create a more receptive environment for genuine disruption?

- How can policy facilitate access to markets demanding disruption?
- How do we ensure policy remains relevant during periods of change?
- How do we engage with policy outside of Space to encourage broader take up of satellite derived solutions? (How do we get people think about space?).

Plenary discussion

The private sector is stepping up to this challenge, guided and enabled by governments. For instance the International Partnership Space Programme has been successful. Government must stimulate but not distort the market or make it unsustainable.

Third world populations will need to embrace space more, engaging with space-facilitated services. We should seek to convince populations that space facilities are part of the infrastructure of society providing essential services in communications and navigations. In parallel we must promote scientific activities, essential for the progress of society and to stimulate innovation, and highly affordable (in Europe this amounts to just 1 euro per person per year).

The cost of delivering excellent science is coming down with smaller missions now providing a real alternative to major projects and can be delivered within the lifetime of a Ph.D.

‘Catch-up’ can turn into ‘Leap-frog’. In the late 80s it was expected that eastern European countries would take 20 years to catch up in communications, but instead they developed and invested in a wireless infrastructure and now Eastern Europe is at the forefront of wireless technologies.

It is noted that smaller nations entering the space market as users of services tend to naturally focus on local issues. For instance in Nigeria space policy is focused on indigenous capability growth rather than global engagement. In Australia Space is seen mainly as an opportunity to create locally useful services rather than as the engine for a future, global export market. We need to engage locally for global impact and invest in long-term relationships. It will be necessary to build local human capital through improved education.

There is a low appetite for risk in government procurement. Public investment follows demonstrated track records and sound business cases. There are plenty of examples of how genuinely disruptive technologies would not have come about through this route. To change this we need champions and visionaries within government.

We should not take a too utilitarian approach to space, but rather take advantage of the inspiration from manned space flight, exploration of the solar system and space science – to find the right balance between safe and speculative investment

While we need to accept the risk of commercial failure in some of our entrepreneurial endeavours, nevertheless we should take prudent measures to prevent them. Lessons should be learned – for instance we should avoid a situation in which ambition triumphs over the realistic market potential, such as was the case with Iridium. The failure of the Iridium programme effectively closed down investment in satellite constellations for 20years.

Within the UK there is a sense that there is some governmental and public prejudice against Space which is seen as remote and really about the Earth and its monitoring. The Space

community needs to do more to inform the public and government about the merits of its activities and its potential.

Currently it appears that the US is leading innovation in Space, Europe needs to catch up. The US regulatory system appears to be more focused on 'yes we can' compared with Europe and the UK which is more 'why you can't'.

Session 3: Global threats as stimulation

Presentation Summary

Session Speaker: G. David Price, Professor of Mineral Physics and Vice_Provost (Research) University College London.

Our world is in a uniquely vulnerable stage because of the challenges of population growth, anthropogenically driven climate change, and interfaith interactions. As a society how are we going to get to the 22nd century?

Global threats include: Water and food security; Climate change; Growing populations; and Inequality. All are complex, systemic, interconnected and urgent to an unprecedented degree. Each pose a threat to health, security, freedom and justice, together they threaten the continuity of humanity.

Extinction is a natural process and humanity should not consider itself immune from it. While we may not expect complete extinction, 'civilization as we know it' is under threat. Indeed, civilizations do, periodically, collapse. In the past civilizations have been isolated and their collapses have occurred on different timescales. Today we have a global civilization and if it collapses it will collapse on a global scale.

"Those of us who are privileged to be alive during this extraordinary period of time have the opportunity to make an impact on the future of human civilisation, to affect what fraction of the species with which we share this plane will survive this extinction spasm that is brought about by the activities that now need to be changed." – Al Gore.

No one disciple will provide the solution to this threat and for UCL's part, it is working on five Grand Challenges: Human wellbeing; Intercultural Interaction; Sustainable cities; and Global Health. Two further Challenges are planned: Justice and Equality; and Transformative Technology. By bringing together UCL's breadth of expertise along with external partners we enable a global perspective – after all, it is not Climate Change itself that is the main issue, it is the societal impact of Climate Change. A multi-disciplinary approach is important since within a single discipline an abstracted view is taken with a focus on what you know rather than what you don't know.

While Space has an important role to play there is a sense that the Space community is not getting its message across. Perhaps the community is too inward looking and needs to become more inclusive as it moves towards Space 4.0.

Universities are about making an impact, scholarly, pedagogical, commercial, societal, public policy. To be successful in having beneficial impact it is important for academia to be informed by the perspectives of others rather than to push from their own perspective. Trust in academic expertise will only come about if this appreciation is explicit and overt.

Technology changes society and societal need drives technological innovation. Space is no exception to this rule and a great deal of novel technology has come about due to the needs of space science and Earth observation. But we should not silo space science, it needs to work within a much broader landscape, benefiting from and giving input to many other sectors.

Space science is responding to global threats in the following areas:

- Telemedicine, education and commercial communications
- Efficient use of transport, energy
- Monitoring of pollution
- International collaborations as a source of common understanding
- Disaster prediction and monitoring
- Self-actualization

Plenary discussion

It was noted that DIFFID Overseas Development Aid (ODA) funding was transferred to UKSA BIS/RCUK within the Global Challenge Fund. And while science implementation in an ODA context is immature in UK, it has potential for developing nations

The private sector is getting to grips with transformative technologies. In a particular situation the introduction of a Space contribution can add significant value. The private sector looks to government to identify high priority, national or international issues and to challenge them to find solutions. However, a speculative element to research is essential if we are to find disruptive technologies whose applications cannot yet be imagined.

10 years ago PPARC articulated the need for impact. The Catapult Centres are about creating impact, solving real world problems. But are the Catapults reaching out enough to academia?

While the academic community focusses on the most likely outcomes of global change, strategists want to know what is the worst that can happen? While we can hope for the best, we must prepare for the worst.

For Space to have impact public policy must accommodate it. Export controls often fail to enable this impact, especially in some parts of the world.

In the area of global warming, space provides a good source of evidence that is less prone to local bias but may be affected by the way the data is brought together. Academia is not really set up to provide key evidence in the Climate Change debate. Perhaps a body in the private sector might be more appropriate. However, the private sector probably sees no commercial opportunity.

Is the climate research community fit for purpose given societal need? Of the five roles: do, explain, communicate warning, communicate as an honest broker, advocate, academia is set up mainly to handle the first one. Governments need to be well informed (lobbied) so that they can exert influence.

However there is a disconnect in timescales, technology development and international treaty negotiations. A time is coming when international law will have to give way to national precedence.

Session 4: New goals

Presentation Summary

Session Speaker: Sir Martin Sweeting, Executive Chairman of Surrey Satellite Technology Ltd.

We all agree that space is important, that its use is expanding and that it is essential to our well-being and security. 25 years ago due to prohibitive costs, access to space and its exploitation was restricted and the preserve of superpowers. Now, the relentless miniaturization of electronics (and associated economies) has allowed Small and Medium-sized Enterprises (SMEs) to enter and even lead in areas of space exploitation.

Small satellites that use industrial and consumer market technologies has changed the economic model for Space, providing access to a growing community both within and beyond academia. This revolution we call 'New Space.'

Serious and credible proposals exist for mega constellations of small satellites comprising 100s to 1000s of units. In the near term we can expect: Ubiquitous and persistent Earth Observation; Shutter control or other approached dealing with privacy; LASER optical communications (to transfer huge amounts of data); Constellation management; Big Data technologies applied within the Space sector; and Space debris control. We cannot foresee all future applications.

Nevertheless we must caution against over ambitious initiatives that are not based on sound business plans that payback in short timescales.

Currently, cost of launch is constraining innovation. While SpaceX has made some remarkable advances, we need something more revolutionary in launch vehicles, such as Sabre-like engines (supported by the UK and ESA). A significant reduction in the cost of access to space afforded by such changes will transform the overall economics of Space. In fact Space is becoming increasingly dominated by non-state players such as Google, and power will be substantial in their hands. Are our governmental policies aligned to this change?

Science provides the basis for engineering and engineering provides the basis for economic success. While science timescales can be long, timescales in engineering and its rollout to products is shorter. These two areas need to be joined up. Science needs long-term stable funding/investment and stability of policy. Space must be seen to be a-political (the UK Innovation and Growth Strategy for Space has been welcomed from both major political parties) so that initiatives may cross political administrations without disruption. Regulation and export policy needs to keep up with technological advancement and so becomes a barrier to economic growth.

We should expect some initiatives to fail if we are to develop disruptive technologies. The rewards for this ambition could be very great.

Patrick Besha, Senior Policy Advisor, NASA

Scientific advance in Space is enabled in part through political and economic institutions. For instance nations rallying around democratic principles gave rise to the international space

station and other major scientific missions. The long term trajectory of space programmes will depend upon whether these institutions are divergent or convergent. Within the democratic nations we are seeing a shift towards greater private sector leadership, especially in the areas of Earth Observation, Launcher services, and even human space flight, planetary exploration and weather. In the US emerging space companies have received significant government support, e.g. ISS cargo flights and the model is being adopted elsewhere. 'New Space' appears to be evolving into a new status quo.

Democratic countries appear to have a fundamentally different approach to innovation. Different levels of venture capital and risk capital are available, and there is greater availability of primary funding sources such as government programmes, private resources, venture capital and private equity. Moreover, these countries tend to have a cultural preference towards entrepreneurship. Some countries prefer a central industrial policy which then leads to a divergence of opinion about how the commercialisation of space will proceed.

The US has seen revolutionary improvements in technology by utilizing funding from NASA as well as other sources, e.g. re-usable rockets by Space-X and Blue Origin. These technologies are having impact on NASA programmes including science payloads. The timescale of these developments is shortening and is becoming faster than the decadal review/survey process. The US is seeing spin-in from non-space domains such as image recognition technology from Google and Facebook being used in astrophysics and planetary science.

NASA is able to use emerging space companies to take on high risk activities that it cannot take on themselves because of the relatively high failure rate. Innovation is being encouraged through competitions, grand challenges and otherwise tapping into public ingenuity. In smaller organisations speed to market can be traded against capability or performance more easily. However, a balance has to be found between the dynamism of small enterprises and the stability of larger organisations.

Innovation is not confined to technology, sometimes it is in the concept (such as small satellite constellation) or a novel application.

NASA has to be able to choose which technologies it should take ownership for and which it should leave to the public sector. NASA's focus is more on fundamental science but it has an obligation to support commercial space and seeks to lever innovation when it can. A balance between science and economic drivers has to be found. Private sector missions to Mars and the Moon are under consideration. NASA's general policy of free and open access to scientific data is not always compatible with those of other nations or of commercial interests. The latter is especially true in the Earth Observation sector.

NASA believes that human spaceflight has a variety of benefits: technological and commercial impact; national security and defence; national stature and international relations; education and inspiration; scientific exploration, ...

The question remains as to whether the shift to private sector space is sustainable. How do we influence 'New Space' to ensure it meets our national needs? Can it be extended into the more general exploration of the solar system?

Plenary discussion

The dual use of information is an issue but not only for the Space sector. Terrestrial technologies have similar issues of data security and privacy.

Public acceptance of space is high at the moment and its support to human space flight is strong. However, it also has a disproportionate attitude to risk and danger. Space tourism will be very sensitive to the perceived level of risk involved. Humans living in space have dangers that the public perhaps does not appreciate, however much riskier endeavours exist. After all Tim Peake considered his time on the ISS to be a relatively low risk activity.

We are entering a new period and a transition phase from a traditional role of the agencies into something much more commercial. Agencies should focus on the very difficult and challenging activities, especially related to solar system exploration. Let commerce have a free hand to follow their interests, to raise the money and invest accordingly and to buy support from the Space Agencies as they need it. Total autonomy (except human space flight) for the commercial space sector is surely inevitable.

Session 5: Enablers

Presentation Summary

Session Speaker: Serge Plattard, Resident Fellow at the European Space Policy Institute, Honorary Professor at University College London

Space now pervades our lives. We are becoming increasingly dependent on the security of space assets and are at risk due to their vulnerability. Space assets form part of national critical infrastructures. Space has become indispensable to billions of lay end users, to defence and to disaster relief.

The number of space nations has reached ~60 with now many private sector space actors. Space debris has become a serious issue, and set to become more of an issue as the very large low earth orbit satellite constellations become a reality. The security of our space infrastructure is a complex and increasing concern.

The 1967 Outer Space Treaty and its various successors (often not wholly ratified) has provided a legal framework for space and set down some important principles. But many of these are now more than 40 years old and space is moving on at a pace far greater than that of international treaty agreement.

A UN Governmental Group of Experts on Transparency and Confidence Building Measures (TCBM) in outer space activities has been set up. This body will seek to set the stage for future agreement. A working group of the Committee on the Peaceful Use of Outer Space (COPUOS) on Long Term Sustainability of Outer Space Activities (LTSSA) is looking at policy, regulatory mechanisms, international cooperation, and management issues. However its recommendations are still under discussion at COPUOS and a tug of war has developed between Russia and the US. The EU has drafted and revised an International Code of Conduct (ICoC) for outer space activities. However this has stalled since July 2015. Non-EU nations are reluctant to participate in this non UN initiative. While progress is slow, we must persist.

Moreover, attempts to limit the armament of Space have stalled. PAROS (preventing an Arms Race in Outer Space) on the agenda since the early 80s but is currently in deadlock. PPWT (Treaty on Prevention of the Placement of Weapons in Outer Space and of the Threat or Use of Force against Outer Space Objects) first proposed in 2008 by Moscow and Beijing is making no progress. We will have to live with this lack of agreement.

Both the physical environment (e.g. management of space debris) and the communications environment (data security and bandwidth) have to be sustainable. While the International Telecommunications Union oversees issues of frequency allocation (and arbitrates between Space and Terrestrial demands) data security is a concern.

Session Speaker: Sa'id Mosteshar, Professor of International Space Policy and Law, Director of the London Institute of Space Policy and Law

Civilizations have failed in the past due to the 'tragedy of the commons' – individual exploitation of a common infrastructure. Are we in danger of doing the same with Space. We see space as a way of sustaining humanities long term survival yet we pollute space with

debris due to short term, narrowly focussed expedience. Debris has become very much in the public consciousness. Space Law has become a recognised topic and it is related to Space Debris in the public eye. It's been talked about since the 70's.

We already have a fairly well articulated and established set of rules regarding our Space-related activities, if only we played by them. The Outer Space Treaty (OST) article 9 says that states should conduct activities in outer space with due regard to the interests of other states, i.e. don't do things in space that harm or limit the access to space of others. Leaving debris in space is very much in breach of that provision.

The OST goes on to say that if you suspect or are aware that your activities may or do interfere with others you should invite consultation with other states so that you can design your activity accordingly and not interfere with them. Conversely if a state becomes aware of an activity that interferes with their activity then they can ask that the other state enters into consultation with them. While these provisions of the OST were not specifically about space debris they do deal with it.

Ownership of a space asset doesn't change merely because it has become inoperative, therefore you would need the consent of the owner before removing it. There is no concept of abandonment in Space. Issues of this kind are a legal barrier to active debris removal

One suggestion is to recognise who has the greatest interest in the continuing access to LEO. Those countries might then form an international, intergovernmental organisation (like INTELSAT), that would share the costs and collectively retrieve, or commission the retrieval of items of debris.

Plenary discussion

There is a strong policy sensitivity since there is a fine line between active debris removal and dual use. However, the definition and application of the term 'dual use' is now problematic since almost any technology can be given that epithet.

Recent US legislation opens the route to exclusive use of Outer Space in the area of mining. If the US is granting property rights over space resources (defined as in situ, i.e. while it is still there, extending its jurisdiction into Outer Space) other countries may feel this is the first step to colonisation.

Today, according to the treaties, nations can launch anything into space other than weapons of mass destructions. You have to register what is launched and the general nature of the mission but you do not have to give much more detail. In fact registration of satellites is one of the least observed requirements of the Space treaties. In space traffic management it is not known what objects are actually doing. In the future the precise use of satellites may have to be disclosed. For instance should inspection of one satellite by another be allowed? The shadow of a satellite has been seen on the solar panel of a geostationary satellite!

Within the telecommunications sector Space security is an issue. Commercial satellites carry military traffic. Drones operate on the Ku band. Access to professional satellite equipment is becoming easier because it's cheaper and so satellites are more vulnerable. Ground stations to enable cyber security are being introduced, and there is anti-jamming capability on-board satellites. Piracy is also an issue, with illegal operators getting a free ride. The Quantum

satellite will have geolocation capability to identify sources of unwanted signals and then to frequency notch them out.

The radiation environment is another aspect of Space that needs to be sustainable.

An analogy can be drawn with Antarctica and the associated treaties. Like space the Antarctica is successful because the major nations assembled outside the UN an international governance mechanism enshrined in international law that works well and others have signed up to – Antarctica for peace and science. However, Space is not learning from this, perhaps because there is a lot more interest in exploiting space than the Antarctic. It is perhaps the strategic nature of space and its strategic potential that is the issue. Given the uncertain future use of space, nations are reluctant to close off avenues of potential national interest. However this is likely to be counterproductive because all would benefit from a more normalised environment. It was noted that the Antarctic treaty is in the form of a moratorium rather than the governance of a resource. One could look to the Seabed Authority which manages a resource.

Session 6: Plenary

Chaired by: Gérard Brachet, Space Affairs Consultant, former founder and CEO of Spotimage, and later Director General, CNES; ex Chairman of United Nations Committee on the Peaceful Use of Outer Space.

While the workshop has covered a lot of ground, some areas have not been addressed, in particular military applications which are a driving factor, space surveillance and satellite tracking. There are objects in GEO orbit that are looking in detail at our assets. We're trying to track them and monitor their capability but they are a threat.

In the face of very serious threats as discussed in the first session we need to be more proactive. Rapid development cycles are practical for small satellites and should be deployed dynamically to monitor climate aspects (for instance) as necessary. Larger satellites will demand a more strategic approach.

Europe is not well suited to adopt disruptive technologies. While over the last 30 years we have seen very significant advances in launchers and Earth Observation (for instance) today's European market is fragmented, regulations vary from nation to nation, and internal barriers persist. Nevertheless, there is a substantial world market.

While satellite response to local issues has at times been effective, e.g. through the use of satellite altimetry, our response to global threats has been more disappointing. There remains plenty of scope and enthusiasm for innovative technology development.

The stewardship of technology by the private sector is now becoming evident. Its ability to create ever more efficient designs is demonstrated. The private sector has the potential to offer services at a fraction of the cost of governments but would like the opportunity to engage. For instance presently weather satellites are a governmental facility, but could be operated more efficiently by the private sector. Climate monitoring is another possibility in the future.

ITAR remains a disabler despite hopes that it may become simpler. While ITAR free satellites have been produced by Thales-Alenia they have brought an adverse political reaction.

There is untapped synergy between the technologies used in space science and planetary exploration, and climate monitoring.

Space science continues to be a driver of technology although international collaboration is essential. Currently international collaboration is fragmented and subject to many agendas and instabilities, we need to improve.

Rapporteur's summary: Professor Alan Smith, Director Mullard Space Science Laboratory, University College London.

We see a rapid change in the landscape of Space, from a world dominated by governments to one increasingly dominated by the private sector.

Dystopian futures should not be thought of as something only in science fiction. Space is surely a player in their avoidance but the rate of change is very great and 'conventional' governance routes are not dynamic enough to avoid being a barrier

rather than an enabler.

The European Space Agency's programme is characterised by the cost of its missions, the time taken for their gestation and development, and their political complexity. While commercial space is characterised more by its innovation, rapid turn-around and diverse funding routes.

Although these two domains differ they are not necessarily incompatible. Neither should seek to dominate the core domain of the other, they are not designed for that. Both ESA and NASA recognise the potential for technical innovation in both public and private sectors.

Space is naturally global and its benefit to mankind is best afforded by international collaboration and global structures.

Space debris and other space situational awareness issues are growing threats. As man's engagement with Space grows so does our dependence upon it and its potential for disruption. Meanwhile, legislation is playing catch-up.

Space science is an enabler, driver of innovation, and remains as relevant now as in the earliest days of Space exploration.

Attendees

Local Organising Committee

Alan Smith, Rapporteur, Professor of Detector Physics, Director of the Mullard Space Science Laboratory, University College London

Ian Raper, Teaching Fellow, Centre for Systems Engineering, University College London

Len Culhane, Emeritus Professor, Mullard Space Science Laboratory, University College London

Serge Plattard, Resident Fellow at the European Space Policy Institute, Honorary Professor at University College London

Speakers and workshop leaders

Prof. Martin Barstow	University of Leicester - Chair
Prof. Chris Rapley	University College London - Speaker session 1
Stuart Martin	Satellite Applications Catapult - Speaker session 2
Prof. David Price	University College London - Speaker session 3
Sir Martin Sweeting	SSTL - Speaker session 4
Dr. Patrick Besha	NASA - Speaker session 4
Prof. Serge Plattard	European Space Policy Institute - Speaker session 5
Prof. Sa'id Mosteshar session 5	London Institute of Space Policy and Law - Speaker session 5
Gerard Brachet	Independent consultant - Plenary
Prof. Alan Smith	UCL Mullard Space Science Laboratory - Rapporteur

Invited guests

Dr. Chris Chaloner	Trym Systems Ltd & UKspace SSEC
Matt Child	Eutelsat
Prof. Richard Crowther	UKSA
Phil Davies	Deimos Space UK
Cyrille van Effenterre	French Embassy
Paz García Calvo	Embassy of Argentina
Andy Green	UKSpace
Kanae Kariyasu Kurata	Embassy of Japan
Prof. Lucie Greene	UCL MSSL
Doug Liddle	In-Space Missions Limited

Prof. Keith Mason

Independent consultant

Dr. J. Miguel Mas-Hesse

National Institute of Aerospace Technology, Spain

Andrius Nikitinas

Embassy of Lithuania

Pat Norris

CGI & UKspace SSEC

Matt Perren

Airbus D&S

Mahvash Siddiqui

US Embassy

Ian Taylor

Fentiman Consultants Limited

Speaker Biographies

Professor Chris Rapley

Prof Christopher Graham Rapley is Professor of Climate Science at University College London. Previously he was Director of the Science Museum, Director of the British Antarctic Survey and Director of the International Geosphere-Biosphere Programme. In 2008 he was awarded the Edinburgh Science Medal – “For professional achievements judged to have made a significant contribution to the understanding and well-being of humanity” Since January 2014 Chris has been the Chair of European Space Agency (ESA), Director General's High Level Science Policy Advisory Committee.

Stuart Martin

In January 2013, Stuart was appointed CEO of the Satellite Applications Catapult, one of seven independent research and development centres established by the Technology Strategy Board to stimulate growth in the UK economy by accelerating the development and take up of emerging technologies. His leadership of the Satellite Applications Catapult, places the commercial exploitation of space right at the heart of the UK growth agenda, and the ambition established by the Space Innovation and Growth Strategy of 2010 to create 100,000 new jobs in the sector by 2030.

Prior to this recent appointment, Stuart was a partner at Logica (now CGI), a large European business technology company. There he was responsible for the worldwide space business, turning over more than £50M annually and employing over 300 staff, a position he had held since 2006.

During his time at Logica, which he joined in 1989, Stuart performed a range of engineering and management functions, mainly in the fields of satellite navigation and meteorological processing, before moving onto more strategic business roles in 2003. More recently, Stuart held the position of Vice Chair of UKSpace, the UK trade association for space business, he was a member of the council of Eurospace (the European equivalent), and was three-time chair of UK judges for the annual European Satellite Navigation Competition, also known as the Galileo Masters. He was also responsible for establishing Logica as a founder member of ISIC, the International Space Innovation Centre which is now part of the Satellite Applications Catapult, and for Logica joining Galileo Services, the industry association focussed on promoting investment and collaborative innovation in the satellite navigation sector.

Stuart holds a BSc in Physics (first class) from Imperial College and, in 2013, was elected a Fellow of the Royal Aeronautical Society, and the Institute of Physics.

Professor G. David Price

Professor David Price is UCL Vice-Provost (Research) and Professor of Mineral Physics.

David has an undergraduate degree and a PhD from the University of Cambridge. He was a Fulbright-Hayes Scholar and Research Associate at the University of Chicago and a Research Fellow at Clare College Cambridge, before coming to UCL in 1983 as a Royal Society University Research Fellow.

He was one of the first to establish the now major field of computational mineral physics, and has published more than 240 research papers. He was awarded the Schlumberger Medal of the Mineralogical Society of Great Britain in 1999, the Murchison Medal of the Geological Society of London in 2002 and in 2006 he was awarded the Louis Néel Medal of the European Geosciences Union for “establishing the importance of computational mineral physics in Earth sciences and for outstanding contributions to the physics of the Earth's core”.

David is a Member of the Academia Europaea and an Elected Fellow of the American Geophysical Union and of the Mineralogical Society of America. He has been an editor of Elsevier's Earth and Planetary Science Letters, was President of the Mineralogical Society of Great Britain and Ireland and was a Trustee of the Royal Institution. He was a member of the UK's HEFCE RAE2008 sub-panel on Earth and Environmental Sciences, and will chair the REF2014 sub-panel in this area.

He is Chair of Governors of the UCL Academy School, Camden, and a Member of the Science & Technology Facilities Council.

Sir Martin Sweeting OBE, FRS, FREng, FIET

Sir Martin has a BSc in electronics and PhD in radio engineering from the University of Surrey (UK) and is the founder and Executive Chairman of Surrey Satellite Technology Ltd. (SSTL). Following two experimental ‘microsatellites’ built by his research team at the University of Surrey and launched in 1981 & 1984, he pioneered rapid-response, low-cost and highly-capable small satellites utilising modern consumer electronics to ‘change the economics of space’ and has established the UK at the forefront of this new field.

In 1985 he formed a spin-off University company (SSTL) that has since has grown to 550 staff with annual revenues exceeding £100M and exports of over £0.5Bn. SSTL has built and launched 48 small satellites – including the international Disaster Monitoring Constellation (DMC) and the first Galileo navigation satellite (GIOVE-A) for ESA – and currently has 13 new small satellites under construction, including the Company's first geostationary telecommunications satellite for EutelsAT, alongside building the 22 satellite navigation payloads for the European Galileo constellation. In 2015, SSTL launched a constellation of three high-resolution (1-metre) Earth Observation mini-satellites and is preparing a low-cost medium-resolution SAR minisatellite (NovaSAR) for launch in 2016. SSTL has developed a highly successful satellite know-how transfer and training programme with long-term collaborative partnerships with 18 countries – particularly enabling emerging space nations achieve their first space missions and thus to access space directly to benefit their environment and economies.

Sir Martin also chairs the Surrey Space Centre comprising around 100 researchers investigating advanced small satellite concepts and techniques and which acts as the research laboratory for SSTL – an exemplar of real academic-commercial synergy. The SSC collaborated with SSTL on the world's first ‘smartphone’ nanosatellite, STRaND-1, launched in February 2013 and launched a research nano-satellite for orbital debris mitigation in 2015.

Sir Martin has been appointed OBE and knighted by HM The Queen, elected a Fellow of the

Royal Society and a Fellow of the Royal Academy of Engineering and received the prestigious von Karman Wings Award from CalTech/JPL. He is a member of the UK Space Agency Leadership Council and, in 2014, was identified by The Sunday Times as one of the UK's 20 most influential engineers and received the Chinese Academy of Sciences/COSPAR Jeoujang Jaw Award recognising his contribution to international space development.

Professor Serge Plattard

Serge Plattard is Resident Fellow at the European Space Policy Institute (ESPI) in Vienna, Austria, since 2012, working on space governance, dynamics of exploration of the solar system, and space security. He is also Honorary Professor of University College London (UCL) since 1993 where he lectures in two Master's courses.

After earning a doctorate in nuclear physics (Université d'Orsay, 1973), he worked in low energy nuclear physics at the French Atomic Energy Commission (CEA) and in two American national laboratories. He then moved to S&T policy matters at the policy planning staff of the French Ministry of External Relations (1981-83), and back to CEA (Directorate for Planning and Programmes, 1983-87). Starting a career in science diplomacy, appointed deputy counsellor/counsellor science & technology in several French Embassies (1987-98) respectively in India, Japan, and the USA, serving one year as assistant director for science and technology cooperation of the French Ministry of Foreign Affairs (1990). He became Director for international relations of CNES (1998-2003), CNES Deputy Director for Planning, Strategy, Programmes and International Relations (2003-2004). Plattard served as the first secretary general / CEO of ESPI (2004-07), and was appointed Science & Technology counsellor to the French Embassy in London (2008-12).

He was a French delegate to ESO (European Southern Observatory) Council (1990-1991), Vice-Chair of the Committee for International Relations of the European Space Agency (2003-04), and chairs the International Astronautical Federation (IAF) Space Security Committee since October 2015.

He is an alumnus of the French Institute for Higher Defence Studies (IHEDN), 56th national session, 2003-04.

Dr Plattard is also life member of the American Physical Society, founding member of Euroscience, member of the International Academy of Astronautics. He is author/co-author of more than 50 publications/communications and a book "Nucléaire, merveille ou menace?" (1984).

He lectured on nuclear physics (1976-1986) at Université d'Orsay, economy of research and innovation (1984-85) at Université Paris-Dauphine, technology management and industrial innovation (1999-2002) at the French business school ESSEC.

Plattard holds the Golden Rays in the Order of the Sacred Treasure (Japanese distinction, 1994), and is Knight in the Order of the Légion d'Honneur (1998).

Professor Sa'id Mosteshar

Prof Sa'id Mosteshar, is the Director of the London Institute of Space Policy and Law and its

Professor of International Space Policy and Law. A Barrister and California Attorney, he has advised governments, international agencies and major space corporations on legal and policy issues for over twenty-five years. Among his degrees he holds a bachelor's degree in physics.

Sa'id is a member of the Space Leadership Council, and of the UK delegation to the UN Committee on Peaceful Uses of Outer Space. He is a member of the International Institute of Space Law and a past Chairman of the Outer Space Law Committee of the International Bar Association.

Gérard Brachet

Gérard Brachet completed an engineering degree at the Ecole Nationale Supérieure d'Aéronautique in 1967 and a MSc in Aeronautics and Astronautics from the University of Washington in 1968. He began his professional career at the Centre National d'Etudes Spatiales (CNES) in France, and from 1972 to 1982 was successively Head of the Orbit Determination and Spacecraft Dynamics Department, the Scientific Programmes Division and the Application Programs Division.

Brachet was directly involved in defining and developing the French SPOT satellite programme in 1978 and led the set-up of the SPOT IMAGE company to market their earth observation images. In 1982 Brachet was appointed Chairman and Chief Executive Officer of SPOT IMAGE and remained in this position until 1994. At the same time he was an advisor on space matters to the European Commission, and in 1991-2 he helped formulate space policy for the European Union.

Brachet returned to CNES in 1994 where he was successively the Director for Programs, Planning and Industrial Policy and Director General from July 1997 to September 2002. He chaired in 1997 the international Committee on Earth Observation Satellites (CEOS), which brings together 20 space agencies and 7 international organisations with the objective of coordinating Earth observation satellite programmes.

Since January 2004 he has been a highly respected aerospace consultant. He chaired the United Nations Committee for the Peaceful Uses of Outer Space (UNCOPUOS) from 2006 to 2008. He was in 2012-2013 the French expert in the Group of Governmental Experts (GGE) set up by the United Nations Secretary General to develop Transparency and Confidence-building Measures (TCBMs) in Outer Space.

Brachet is a member of the International Academy of Astronautics (IAA) and a member of the Air and Space Academy/Académie de l'Air et de l'Espace, which he chaired from 2009 to 2012. He is also Honorary Secretary of the International Astronautical Federation (IAF).

Brachet received many international awards, including the "Brock Gold Medal Award" of the International Society for Photogrammetry and Remote Sensing in 1992, the Gold Medal of the British Remote Sensing Society in 1994 and the "Social Sciences Award" of the International Academy of Astronautics in 2007.

Brachet is « Officier de l'Ordre national du Mérite » (1997) and « Officier de la Légion d'Honneur » (2001).

Ian Taylor MBE

Ian served as Minister for Science and Technology 1994 to 1997.

During this time he dealt with a wide variety of issues, including providing support for the next phase of the Large Hadron Collider at CERN, increasing awareness of the importance of access to the early internet revolution and co-ordinating Government support for the Roslin Institute which led to the Cloning of Dolly the Sheep and the creation of the Human Genetics Advisory Commission in February 1997.

He was Chairman of the Conservative Policy Task-force on Science, Technology, Engineering and Mathematics 2005-2009.

He chaired the all-Party Parliamentary and Scientific Committee (the oldest all-party committee), which includes the Parliamentary Engineering Group.

He was also an officer of several all-party Parliamentary committees, including the Office of Science & Technology, the Information Society Alliance (EURIM), PITCOM (Information Technology Committee) and the Corporate Social Responsibility Group.

In 2008, Ian Taylor gained the (Sir) Arthur C. Clarke Award for Individual Achievement in Promoting Space and Science.

He was co-chair of the Parliamentary Space Committee and in 2009 he chaired the European Inter-Parliamentary Space Conference.

Professor Martin Barstow

Prof Martin Barstow received his undergraduate degree in physics from the University of York (UK) in 1979. From there, he became a member of the X-ray Astronomy group in the Department of Physics and Astronomy at the University of Leicester, receiving his PhD in 1983.

He was head of the Physics and Astronomy department from 2005 to 2009 and is currently Pro-Vice Chancellor and founding Head of the College of Science and Engineering.

During the past few years, Prof Barstow has played an increasingly important role in scientific funding and advisory structures, becoming a member of Science and Technology Facilities Council in 2009. He has also been appointed to membership of the ESA Astronomy Working Group and Space Programme Advisory Committee of the United Kingdom Space Agency. He has served on the Council of the Royal Astronomical Society since 2005, as Councillor and then Astronomy Secretary. He is currently the President of the Royal Astronomical Society.

Professor Alan Smith

Professor Alan Smith has a background of Astrophysics, Instrumentation, Space Research and Systems Engineering. He has been involved in sounding rocket and satellite programmes for almost 30 years, 8 of which were spent at the European Space Agency.

Alan is currently Director of the Mullard Space Science Laboratory and Head of its host Department, the Department of Space and Climate Physics (the largest University based space research organisation in the UK); and Director of UCL's Centre for Systems

Engineering (UCLse).

His experiences working with all the major space agencies in highly structured programmes has allowed him to appreciate and contribute to the systems engineering process. As Director UCLse he delivers on the its MSc programmes in Systems Engineering Management and Technology Management, supervises postgraduate students, and undertakes a research programme. He provides consultancy support and workshops in systems engineering to industry. Alan teaches Project Management widely within UCL including Association of Project Management accredited courses through UCL's School of Management.